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COMMENTS ON NEC 705.13 FOR THE 2023 CODE CYCLE

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INTRODUCTION

The last two decades has seen the dramatic growth of distributed energy resources (DERs) across the US grid, and this growth is only projected to continue in the years to come. DERs increase the complexity of grid operations, and involve a larger number of active market participants than the traditional model of monopoly utilities who provide power to accounts at the grid-edge from large, centralized plants. Because of this, there is increasing need for control systems that can coordinate both generation and load across discrete busses and circuits from transmission systems down to premises wiring. The adoption of 705.13 in the National Electric Code (NEC or Code) 2020 cycle was a vital recognition of this changing reality. However, this new article, as first adopted, does not adequately reflect the composition, variability, behavior or full capabilities of control systems, and their necessary role in the deployment of DERs.

Control systems can manage all different kinds of equipment, not just electrical equipment; in the electricity sector, they are active at all levels of the electric grid. They can do everything from controlling current in a residential PV system to improving power factor at a high voltage substation. Functionally, we can contemplate the locus of control systems' activity according to the interfaces between major systems in the grid: a) at substations among transmission networks or between transmission and distribution networks; b) at the service point between utility circuits and the premises wiring; and c) at busses or circuits connecting equipment across the premises wiring. Because we are addressing the function of and requirements for control systems as specified in NEC 705.13, our concern will be for the latter, c). However, it should be noted that many of the core considerations discussed here apply equally among distribution and transmission networks, and at the connection of NEC-compliant systems to these networks.

Control systems can manage a wide array of applications, and, indeed, are often central to their design. These applications can operate: a) in time; b) in coordination between different pieces of equipment; c) in reaction to specific monitored conditions; and d) in reaction to signals sent from a higher point of coordination. Electrical equipment can be controlled: a) as a current source; b) as a voltage source; c) if it's an AC system, for its power factor; and/or d) if it's an AC system, for the quality of its power signal against an idealized sine curve. 705.13 specifically deals with limiting current to the busbars or conductors of premises wiring on the basis of monitored conditions for the purpose of protecting this equipment from current overload. This current-limiting function is just one application among many that control systems may be asked to superintend; for example, the same control system which may be limiting current from an energy storage system (ESS) inverter to a sub-panel in a building may also be using the inverter to correct the premises wiring power factor output to the grid across its service point to reduce imaginary power. It is important that the rules and standards required by the NEC are able to grade between this particular application and the broadest set of other control functions, without compromising 705.13's intended safety benefits.

It is not appropriate to think of control systems exclusively as a single, definite type or piece of equipment. Controls can either be ***regulatory***, where they are incorporated into the design and operation of a single

device, or ***supervisory***, where they comprise a computing device and its signaling mechanism to one or more other pieces of equipment with the aim of governing their operations, *together*, as a whole system. In the former, the "control system" is a subordinated feature of a piece of equipment with a specific function, listing requirements, and particularized applicability to different NEC articles. In the latter, the "control system" may have its "brains" associated with a computing device, but it is effectively a set of virtual functions for a *system* embodied by signals coordinating among its constituent parts to govern the behavior of heterogeneous pieces of equipment.

SCENARIOS FOR LIMITING THE CURRENT OF DERS

The current-limiting function authorized, alternately, by 705.11, 705.12 and 705.13 can be realized in three different basic scenarios.

SCENARIO #1. A fuse, breaker, or other switching device can be installed at the point of connection for a single circuit, and will trip automatically when the current at that point exceeds some pre-determined, unchangeable limit. This principle is iterative across the premises wiring and can apply to a circuit feeding a single piece of equipment or a circuit serving an enclosure, such as a sub-panel, that combines other circuits for multiple pieces of equipment. This automatic switching operation can happen in milliseconds, if necessary, or longer.

SCENARIO #2. A power source or an energy storage system can be designed and listed to self-limit or modulate its output or intake of power under the governance of its own regulatory controls at pre-defined, but manually changeable, set-points. Alternately, a load control device can limit or modulate current across a single circuit by reacting to a signal under a pre-defined, but manually changeable, function. The input condition, in both cases, could be a current value registered at one or more circuit anywhere across the premises wiring system, or it could be a function of some other measurable value, like time or power factor (though this is unlikely). The modulating action of regulatory controls for many devices can be designed to activate within milliseconds, or longer, as required.

SCENARIO #3. A supervisory control system can orchestrate the output of one or more source, as well as demand from controllable loads, by interfacing with different devices, acquiring relevant real-time information and giving instructions through communication signals. These sources and loads won't necessarily be installed at the same time or be sourced from the "ecosystem" of a single manufacturer. Supervisory controls depend on components that have changeable set-points or alterable functional behavior and that can receive its signals -- similar to those described in Scenario #2. The difference in Scenario #3 is that these inputs to regulatory controls can change dynamically under the guidance of the supervisory controls, and different devices can be coordinated with respect to one another. The supervisory controls, in turn, could be governed by a person, by an algorithm or by machine learning. Supervisory controls are as adaptable and scalable as they need to be. They usually operate, at their fastest, in a second or two, but may be closer to a ten or fifteen second threshold for certain kinds of equipment configurations.

705.11 and 705.12 are both exclusively concerned with Scenario #1. The connections these two articles describe, on both sides of the service point, can only be served by some combination of switch and overcurrent protection device. Scenario #1 is of no particular interest to 705.13, but, as currently written, 705.13 could theoretically apply both to Scenario #2 and Scenario #3.

The requirements that were included in the introduction of 705.13 to the NEC, in the 2020 Code cycle, entail a few items that are germane to its application in Scenario #2 or Scenario #3:

* The text starts by stating: "A power control system (PCS) shall be listed and evaluated to control the output of one or more power production sources, energy storage system (ESS) and other equipment." So the "PCS" must be specifically listed for its control function.

* This sentence also specifically calls for the "PCS" to limit the current from *sources*, but it leaves the door open for loads to be limited as well. "Other equipment" could mean loads, and ESSs are listed as a separate item here because they can behave as loads; also we could interpret the consumption

of power by a piece of equipment under normal operating conditions to be its "output" or at least part of its "output." Current on a bus or a circuit, therefore, can be limited either by curtailing production, or by curtailing load, or both.

* According to 705.13 (A), the "power control system" has to monitor the current of all controlled equipment or circuits, and may monitor uncontrolled equipment or circuits that feed affected busbars or conductors. In most cases, this monitoring function will require an external, automated signal to which the controls must react.

* The text states in 705.13 (C): "The PCS shall provide overcurrent protection either by overcurrent devices or by the PCS including the functionality as an overcurrent device in the product listing." So the whole scheme of affected busses or circuits must react to current fault conditions that produce an overload condition, not just the switching and curtailment under normal operating conditions enabled by the "PCS" -- whether this be handled by the "PCS" or independently by other devices.

* 705.13 (E) specifies that access to the settings in the controls should be limited to qualified personnel.

Scenario #2 involves equipment whose regulatory controls operate with pre-defined, but manually changeable, set-points. Such equipment can react to a condition on a bus or circuit where the current from multiple sources or to multiple loads exceeds some pre-defined current limit.

Here is a canonical example: let's say in a small commercial building in a strip mall there is a 10 kW inverter for a nominal 12.5 kW DC PV system and it is interconnected at a 200 A main panel with a 200 A main breaker at the service point; if the service and inverter output are single phase, 240 V, the inverter can produce up to ~41.7 A and will need to be protected by a 60 A breaker -- 20 A more than is allowable for this 200 A panel under 705.12 (B) (3) (2) or (4). If the inverter's regulatory controls are able to monitor all of the loads on the main panel, the inverter could proportionally curtail its output when its output and the loads, together, exceed 200 A; under this scheme the PV inverter could still be connected with a 60 A breaker and no modifications would need to be made to the main panel. Presumably, the monitoring scheme would involve devices manufactured by the inverter company and listed for narrow variations of this scenario.

While it is expected that the monitored input signal to these regulatory controls would come from more than one piece of other equipment, there will always be a strong preference to limit the complexity of information meant to serve as input. In other words, Scenario #2 for 705.13 will typically involve measuring simple current values at a single busbar or conductor with power inputs and outputs connected at that point from a manageable number of circuits or pieces of equipment; it is unlikely (though possible) that most regulatory controls would be capable of reacting to situations at more than one busbar or conductor, or under input from some other variable, like time (if equipment utilization is strictly scheduled, for example).

Scenario #3 imagines a "power control system" where the currents of multiple components have to be *coordinated*. Regulatory controls are intrinsic to a single piece of equipment and only will process *input* signals from external (and probably lab tested) devices. In order for a control system to govern more than one piece of equipment, external communication connections are necessary and signals have to be sent, received and acted upon by some equipment that is *extrinsic* to the controls; input signals, moreover, may come from a wide range of sources. Supervisory controls are usually the only option for complex configurations: system with variable inputs, multiple outputs, dynamic information processing. It also may be the only option for certain retrofit projects or where components are sourced from different manufacturers.

In the most straightforward versions of Scenario #3, there will be a computer on site that is connected to different equipment and monitoring devices, and this computer will be the central dispatch for all controlled devices. The computer could be housed in a piece of equipment with some other function, like an inverter, but it is more likely to stand alone as a controller unit. Theoretically, the computing device for the supervisory controls may not necessarily be located on site: supervisory controls could be a software

program stored in a remote server or in the cloud, and could retrieve data and issue instructions to equipment over an internet connection or some other secure network connection.

Here is a distinct Scenario #3 example: in the building next door to our previous example, there is a system with a single phase, 240 V service, a 400 A Eaton panel with smart, load control breakers and a 400 A main breaker, a just-installed 500 kWH Li-ion battery ESS with a Sinexcel inverter that outputs up to 100 A, a PV system installed 5 years ago with an SMA inverter that outputs up to 80 A, and an automatic transfer switch that, when the power goes down, connects to a 20 kW Generac generator, installed 10 years ago. The loads from the building, if everything is running all at once could reach as high as 490 A, but curtailment of a Tesla electric vehicle (EV) charger, which draws up to 100 A, should always bring the total possible load drawn from the main panel below 400 A. The PV and ESS systems together output 100 A too much for the size of the main service panel to which they are connected under the limits from 705.12 (B) (3) (2) or (4). Let's say the building is drawing its maximum load and the PV and ESS systems can output their full capacity; the supervisory control system now has several options: it can a) curtail the PV system; b) make sure the ESS isn't charging or discharging; c) curtail the 100 A EV charger; d) curtail several other loads; e) curtail input current from the 400 A main breaker; or f) do more than one of these things at the same time. All six options will accomplish the same safety aim, but the building owner may want to implement a complex scheme for which option is chosen under different conditions. For example, the EV charger might have priority in the evening and morning when the building owner is charging a company car after a day's use so that it has a full battery next morning, while the PV and/or ESS system are prioritized during the afternoon when the building has a high time-of-use electricity rate and would prefer not to consume energy. Furthermore, in a power outage, supervisory controls could manage the loads to match the capabilities of the backup generator, PV system and ESS system (which would vary over time) without electricians needing to segregate only a small bundle of loads in a protected loads panel. This site configuration could only be managed by a supervisory controls system, and there is no practical way to list a single piece of equipment to do all of these things. Nevertheless, this is not an especially challenging control system for an experienced controls engineer to design and implement.

PROBLEMS WITH 705.13 AS CURRENTLY WRITTEN

1. Incoherence of Treatment in the NEC. The NEC deals with control systems in various ways, largely in chapters 4 and 7; the responsibility for these articles is scattered among the code-making panels, and it shows. Viewed at some remove, the approach is not very coherent. Here is a summary of articles that deal substantively with control systems that govern electrical equipment; a number of other articles have provisions for the electrical installation of control systems that govern non-electrical equipment, and these aren't our main focus.

Article 100, Definitions: This article has several definitions for control components.

Article 430, Motors, Motor Circuits & Controllers: This article deals with motors and motor controllers. 430.32, 430.39 and Parts VI, VII and VIII all address some aspects of motor controllers and their use for protecting motor function against overload and failure.

Article 708, Critical Operation Power Systems (COPS): This article covers requirements for backup power systems deemed "critical." The article has a definition for supervisory controls ("SCADA"), but controls functions are only discussed, briefly, in 708.22 (B). The defined term, SCADA, isn't used anywhere else in the text of 708. Its presence here points to Informative Annex G.

Informative Annex G, Supervisory Control & Data Acquisition (SCADA): This is a short informational annotation at the end of the Code which gives some suggested design parameters for the deployment of SCADA in COPS. This Informative Annex is written, syntactically, as though it were a set of Code requirements, but it is explicitly not part of the Code, and its rules are not obligatory.

Article 725, Class 1, 2 & 3 Remote-Control, Signaling & Power-Limited Circuits: This article details requirements for control circuits that are part of a supervisory controls system or that are necessary for, but auxiliary to, a regulatory controls system.

Article 750, Energy Management Systems: This article gives requirements for "energy management systems," which it defines as: "A system consisting of any of the following: *[sic]* a monitor(s), communications equipment, a controller(s), a timer(s), or other device(s) that monitors and/or controls an electrical load or a power production or storage source." The intent of this article, basically, is to list systems, such as fire alarms, that should *not* be interfered with by a control system that fits this definition.

There doesn't appear to be a uniform approach to dealing with the design of control systems and their components across the NEC. If a new concept of "power control systems", along with a new set of requirements, are being introduced in article 705, they need to be reconciled to the functions of and stipulations upon control systems elsewhere in the Code.

2. Terminology and Definitions. This incoherence is particularly noticeable in defined terms found in articles that touch about upon control systems. Here are some controls-oriented terms and definitions sprinkled across the NEC; note that "general scope" as used here means that the definition is indicated to apply throughout the Code, while "article specific scope" means that the definition is indicated to only apply to that article:

Term	Article	Scope
controller	100	General
controller	430	Article Specific
controller, motion	620	Article Specific
controller, motor	620	Article Specific
controller, operation	620	Article Specific
diversion load controller	694	Article Specific
diversion charge controller	706	Article Specific
control circuit	100	General
remote control circuit	100	General
signaling circuit	100	General
electronically actuated fuse	100	General
motor control center	100	General
industrial control panel	100	General
supervisory control & data acquisition (SCADA)	708	General
control	750	Article Specific
energy management system	750	General
control system	620	Article Specific
monitor	750	Article Specific

This terminology, even taken together, is not comprehensive of control systems' components or their modalities as they apply to electrical installations. In some cases, it isn't even consistent. Note, for instance, the redundancy of "controller" in articles 100 and 430, as well as the presence of specific controller types in article 620 that aren't congruent with the basic definition in article 100.

Article 705.13 also doesn't formally define "power control system," nor is any such definition provided elsewhere in article 705 or in article 100. . Even worse, the definition for an "energy management system" in article 750 (which is noted to apply throughout the Code) is functionally indistinguishable from the

undefined concept of a "power control system" as 705.13 seems to use it.

The problems with defined terms and their definitions allow the requirements adopted in the 2020 cycle to elide some of the complexities discussed here. This is a recipe for confusion.

3. Supervisory and Regulatory Controls. There is no acknowledgement in 705.13 of the difference between regulatory and supervisory controls, or between Scenario #2 and Scenario #3. As discussed, this distinction can have substantial implications for the capabilities, reliability and responsiveness of control systems. It stems not only from a difference in the components, but in the conception of what *constitutes* a "control system." A regulatory control system is part of some discrete piece of equipment that has been engineered, evaluated and listed under a standard, and, when applicable, it is transparently regulated by specialized articles of the NEC. Supervisory controls consist in the virtual functions of a system whose components are governed by these functions to achieve some coordinated, emergent outcome. The variability possible under supervisory controls can be managed in a straightforward way by engineering, but is more difficult to regulate from on high, so to speak. Requirements in 705.13 for "power control systems" have to apply themselves, in one fashion or another, to this particular difference.

4. Load and source. The text of 705.13 should be more explicit that both sources AND loads can be controlled to limit current on busbars and conductors. For example, let's say the bus in a sub-panel is rated for 100 A. If there is only 100 A or less of source power on the bus, from the point of view of the bus, there is no safety problem, regardless of potential loads; similarly, if there is only 100 A or less of load on the bus, there is no safety problem, regardless of source potential. It is only when there is more than 100 A possible of BOTH source power AND load that there can be an overload. A controls system can manipulate the sources OR the loads OR both to curtail the total current on a bus or a circuit. Article 705 was written primarily with the idea of controlling DERs as power sources in premises wiring where the overcurrent protection devices on feeders constrain an effectively infinite grid source. As we see more load control devices and ESSs on the market, the ability, and the need, to control loads and sources on equal footing will become more common, and 705.13 should be more explicit about the means by which it can achieve its ends.

To pursue this line of reasoning further, the amount of possible current on a busbar or conductor is determined by the *lowest* possible current value in EITHER the source OR the load. If there is 100 A of source power from a PV inverter and 100 A available from the feeder breaker, again, on a 100 A sub-panel bus, but only 50 A of breakers for loads, the sub-panel will never see more than 100 A of current. The presence of ESSs complicates this picture further, because they can behave either as a source or as a load; in calculating the worst case of maximum current, each ESS presents two different scenarios, one where it behaves as a source and should be counted with other sources, and one where it behaves as a load and should be counted with other loads. In fact, where we have on-site, interconnected power generation, the service of a premises wiring, or circuits connecting back to the service, *also* can behave as a current source or as a load.

The best systematic method for determining the maximum possible current on a busbar or conductor is to enumerate each possible configuration of sources and loads, noting the *lowest* possible current value between source and load in each scenario, and then to choose the *highest* current value among them. Here is an example: there is a 7.6 kW inverter for a 10 kW DC PV system, a second 3.8 kW inverter for a 25 kWH Li-ion battery ESS, and load control breakers on all of the circuits connected to the main panel. The PV inverter has a 40 A breaker connection and the ESS a 20 A breaker connection. The building has a single phase, 240 V service with a 200 A main breaker in a 200 A main panel. The loads from the building, if everything were running all at once, could reach as high as 250 A. Both the ESS and the main breaker can be sources or loads, while the breakers in the panel are always loads and the PV inverter is always a source. From this we get four different scenarios (where L=load and S=source):

	1	2	3	4
Building loads	L	L	L	L

PV inverter	S	S	S	S
Main breaker	S	S	L	L
ESS	S	L	S	L

Based on our set up we can assign a maximum current value to each category of equipment based on its overcurrent protection device(s) (the numbers represent amps):

	1	2	3	4
Building loads	(L) 250	(L) 250	(L) 250	(L) 250
PV inverter	(S) 40	(S) 40	(S) 40	(S) 40
Main breaker	(S) 200	(S) 200	(L) 200	(L) 200
ESS	(S) 20	(L) 20	(S) 20	(L) 20

Next we can determine the maximum possible current on the bus, in each case, by the lowest possible current value between source and load:

S = 260	**S = 240**	**S = 60**	**S = 40**
L = 250	L = 270	L = 450	L = 470

The lowest value in each scenario is bolded; only the first and second iterations are above 200 A, with #1 being the highest at 250 A. Clearly the bus is undersized for this system. However, under the common method of 705.12 (B) (3) (2) or (4), we would have assumed that the PV and ESS systems would have overloaded by the bus by up to 60 A, whereas, in fact, the overload where both systems acted as sources would only have been 50 A, and no higher in any other scenario. With this method we can more accurately determine the magnitude of potential overload and what devices it may be associated with.

It has to be mentioned here that neither 705.11 nor 705.12 do a great job of dealing with situations where multiple devices can behave as both source and load. The additions in past cycles of 705.12 (B) (3) (1) & (3) (or their equivalent) were a perfectly adequate means of resolving this conundrum when it was expected, mostly, that only service-facing breakers or feeders would behave as both source and load, but with the growth of ESSs and control systems as regular features in premises wiring in all site types, the NEC needs to adopt more sophisticated rules around this issue.

5. Signaling. All control systems rely on signaling to accomplish their ends. Typically, regulatory controls have the advantage of being compact and more testable in their functionality through a standardized listing process. Nevertheless, for most applications of 705.13, they will rely on external signals from CTs or other monitoring devices.

Supervisory controls rely extensively on signals among multiple pieces of equipment integrated in the field in unique configurations. This may involve multiple regulatory control systems and equipment with different functions. These systems are likely to include equipment produced by different manufacturers. Communications protocols may not be identical among this equipment, and communications signals may have to travel relatively long distances. Wireless or power-line communication devices are an option where hardwiring poses practical installation difficulties. Communication can even be mediated through the internet or another network where some key component (probably the supervisory computing device) could be located off-site.

Because 705.13 is fundamentally a set of safety requirements, it should include some rules on the deployment of signaling systems to ensure their reliability. For example, internet connections are notoriously prone to periodic cutting out, and probably shouldn't be relied upon. Other communications equipment, like some on-site wireless systems or power-line transmitters, may also be less reliable than desired. UL 1741 does disallow off-site connections in the listing of regulatory controls in inverters, but the issue is complicated enough that the NEC should outline some basic parameters for what is allowable, as it does for numerous other engineering issues.

6. Listing requirements. In 2018, UL released a Certification Requirement Decision (CRD) adjunct to the 1741 standard. Among other things, it deals with controllers and DERs. This standard gives us a means of testing and listing regulatory controls under Scenario #2 in our descriptions of control systems. Unfortunately, it does not give us a clear standard for Scenario #3 or engineering guidelines for the wide functionality of supervisory controls. Supervisory controls are often in charge of equipment: a) from different manufacturers: b) that may have been installed at different times under different Code requirements; c) at different distances; d) with signaling systems that require different physical wire and connections (or even wireless signals) and different communications protocols; e) under applications with different response time horizons; and f) under applications with different functional outputs (i.e., current, voltage, power factor, etc.). UL and other standards are written to evaluate the behavior and the safety risks of either: a) individual pieces of manufactured equipment; or b) a limited number of self-contained pieces of equipment that can be tested together in the lab, and that generally operate in the "ecosystem" of the same manufacturer. However, supervisory controls are not a component of a single piece of equipment, nor are they necessarily derived from the limited configurations of a single manufacturer's "ecosystem." They are a set of virtual functions for a multi-component system. They can serve all different kinds of equipment for the special requirements of each site and each system. Their prime virtue is their adaptability and scalability.

If the standards and the Code are written such that only equipment within a single listed "ecosystem," installed together as a project, are acceptable, then there will be little opportunity for retrofit projects or for competitive product development to integrate the many possible configurations of various DERs. As efforts to modernize the grid proceed apace, with considerable economic and environmental consequences, this is not an insignificant consideration.

The proper venue for evaluating supervisory control behavior is electrical engineering for field applications in the construction sector. Compliance should fall under the purview of state-approved professional electrical engineers, with basic requirements articulated in the NEC and adopted by local AHJs. Listing standards are intended to govern the manufacturing of products, not all the details of their on-site installation, the advances represented in the UL 1741 CRD notwithstanding.

There are multiple precedents for this approach. Elsewhere in the construction industry, field engineering is standard for the kind of engineering problems that supervisory controls pose. Consider structural engineering. In order to build a structure or modify a building structurally, contractors don't typically contact an equipment manufacturer and determine that the modification is approved under a listing standard for a manufactured product ("manufactured homes" are a small minority of the building stock in the US, and even then modifications aren't necessarily within the purview of the manufacturer). Instead, they approach a structural engineer who can evaluate the new structure or a modification *in situ* under his or her professional training and relevant parameters of the local building code.

There are also closely related precedents in the NEC itself. Selective coordination, as defined in article 100, is the arrangement of overcurrent protection devices to limit current in different scenarios to busbars and conductors. In articles 620.62, 645.27, 695.3 (C) (3), 700.32, 701.32, and 708.54, a licensed professional must sign off on and document the selective coordination of overcurrent protection devices among relevant circuits. There is no expectation that equipment listing would be the appropriate mode of engineering for limiting current flow. Closer to home, 705.12 (B) (3) (5) allows for configurations that would otherwise violate the rules of 705.12 (B) (3) if a professional engineer has reviewed the particular configuration of equipment in detail and will sign off on it. Similar allowances are certainly possible for control systems to accomplish the same end.

The current policy in 705.13 to push engineering oversight of control systems onto the listing process, rather than professional engineering under local codes, is not a matter of safety: it's a matter of convenience for regulators and well-capitalized manufacturers.

7. Response time frames. For the purposes of 705.13, a crucial safety feature of control systems is how quickly they respond to overload conditions of different magnitudes. All switching and overcurrent protection devices are intended to *react* to specific conditions, and so, necessarily, there is a delay between

the onset of those conditions and the reaction. With breakers and fuses, this can be very, very fast, if necessary, although many overcurrent protection devices are designed to allow for temporary overloads at certain current levels, on the order of seconds, depending on the magnitude and application. Control systems, both regulatory and supervisory, because they rely on external signals, can be designed to meet certain response time thresholds for their reaction to current overload conditions; these response time thresholds have to be indexed for the magnitude of overload, the application (particularly for motors), and the difference between overloads due to faults and those due to excessive, but predictable loads. Where a listing standard, such as the UL 1741 CRD, is applicable, this information can be addressed in the standard, but where a listing standard does not apply, the NEC should articulate some thresholds, indexed, again, according to these variables.

RECOMMENDATIONS

Recommendation #1: The material from article 750 should be re-located to 705.13 or an adjacent number within article 705. Under the definition of "energy management systems" from 750, there isn't a coherent argument as to how these systems differ from the "power control systems" referenced in 705.13; it's a distinction without a difference. The intent of Article 750 is very limited -- it restricts what equipment can be controlled by "energy management systems." In fact, it might benefit 705.13 to explicitly restrict what load functions can be manipulated to limit current.

There is a bit of conceptual problem with this shift in that article 705 is labeled, "Interconnected Electric Power Production Sources." "Energy management systems" are focused on load control. However, as we've discussed, with the proliferation of ESSs and load control devices that can do demand response, loads and sources are both of concern when engineering against current overload. 705 should evolve towards addressing both power production and load control on equal terms. The fundamental interest of this article is the safe engineering of power *flow* and power *balancing*. So article 705 probably could be renamed to something like "Power Balancing Across the Premises Wiring."

Recommendation #2: The terminology and definitions for control systems needs a through-going overhaul that reaches across multiple articles. As described earlier, there are definitions relevant to 705.13 scattered in different parts of the Code, as well as other items we've discussed that are not defined or even conceptualized. The term "power control system" should be jettisoned for the specific context of 705.13 and the terminology used in 705.13 should be congruent with material covering control systems elsewhere in the NEC.

Control systems have a number of possible constituent parts; furthermore, supervisory control systems can be recursive in having regulatory controls or subordinate supervisory controls embedded within them. Here is a list of possible control system components:

* Supervisory computing devices
* Communications wiring and connections
* Communications signals and their protocols
* Software that gives instructions under some set of programmed functions
* An operator or technician
* The interface for that person which allows him or her to manipulate the controls.
* Regulatory controls in equipment or subordinate supervisory control systems

Additionally, the conceptual difference between regulatory and supervisory controls should be clearly drawn.

Here are some suggestions for definitions dealing with control systems. It is recommended that most of these be deployed in article 100, for a general scope of use, rather than article 705 or elsewhere. The content here is tentative, and the list by no means exhaustive; the code-making panels are encouraged to contemplate additional terms and alternate wordings in consultation with each other and other stakeholders.

control system — "A system comprised of components designed to control one or more pieces of equipment. These components could include controllers, other control systems, wires, wireless signaling devices, receivers, monitoring devices, software, and the signals routed along this system to relay information or give instructions. Control systems can have many different functions, only some of which are directly regulated by this Code. A control system does not itself include the equipment that it controls."

The definitions for "control system" in article 620, "control" in article 750, and "energy management system" in article 750 are not necessary if there is a general definition of "control system" in article 100. If the code-making panels feel that control systems governing different functional outputs need to be distinguished, then these could be treated as sub-types. For example, a control system that governs power output in an inverter, ESS or generator could be a "Control System, Power" ("Power Control System"), whereas the control system governing motion in a motor (as the term is used in article 620) could be a "Control System, Motor" or a "Control System, Motion" ("Motor Control System" or "Motion Control System").

controlled equipment — "Equipment which is governed by a control system. Components of controlled equipment, like receivers or regulatory control systems, may be part of a control system, but, as a whole, each piece of controlled equipment is not considered to be part of the control system governing it."

This definition would allow the Code to distinguish between that can and cannot be governed by a given control system. It also makes clear that control systems, as *systems*, ONLY include the mechanisms of control, not their object.

regulatory control system — "A type of control system which is incorporated within a single piece of equipment, which is integral to the design and function of this equipment, and which only governs the behavior of this equipment. Regulatory control systems may utilize information or may respond to instructions from an external signal to carry out its controls; they also may be part of a larger SCADA system."

This definition should be included in article 100.

SCADA system — "A Supervisory Controls And Data Acquisition (SCADA) system is a type of control system which independently coordinates the behavior of one or more piece of controlled equipment. SCADA systems can incorporate other SCADA or regulatory control systems which, in turn, control some subset of equipment within the governance of the larger SCADA system. SCADA systems receive information from different devices and send instructions to controlled equipment."

The presence of SCADA as a definition in article 708 is somewhat strange, given that the term is never actually used in that article, but only referenced in a non-binding Informative Annex at the end of the book. Granted, the Annex does just address the use of SCADA systems in COPS, but the whole arrangement comes across as kind of self-defeating jiu-jitsu. It would make more sense for SCADA systems not to be defined narrowly in terms of COPS and to be placed in article 100 *vis à vis* regulatory control systems. And given the rules articulated in the Informative Annex, perhaps they need their own article with a more general scope (and some specific rules pertaining to COPS SCADA functions)?

controller — "A computing device within a control system that receives data and sends instructions, either according to self-contained functions or according to signals originating from an external device.

The definition in article 100 limits "controller" to only devices that govern the electric power of controlled electrical equipment. The scope of the definition should be expanded to include any kind of functional output, and then the article specific definition from 430 can be eliminated. Specific

types of controllers, such as those defined in articles 620, 694 and 706, can remain in those articles and be article specific in scope.

signaling system — "A system for sending information between components in a control system."

The definition of "control circuit" can stay, if it's useful. A "signaling system" would include not only the control *circuits*, but the signals themselves. It's not clear why there needs to be a definition of "control circuit" *and* "signaling circuit" in article 100. Both definitions describe the same thing -- though they appear to be the provenance of different code-making panels.

monitoring device — "A device that generates information of a specific type, like temperature data or current flow, and reports this information to some other device, either continuously or periodically."

"Monitor" is a definition that only applies to article 750. It should be deleted and a more general term and definition, such as what is suggested here, put in its place in article 100. Note that 705.13 refers to monitoring without defining a "monitor" or "monitoring device."

control interface — "The interface containing set-points and other features of a control system that can be manipulated by qualified personnel."

Having a definition of a control interface makes the locus of 705.13 (E) more concrete and specific.

off-site — "Not located on the same physical property as other equipment associated with a control system and controlled equipment."

This definition would be used if the recommendation of this comment is accepted to restrict signaling systems; it could be article specific in scope to 705.

Recommendation #3: UL and similar standards are designed to test and certify manufactured pieces of equipment, if not strictly alone in their functionality, then with respect to a highly select number of commonly paired components. These standards can insist on *some* limits to the manner of integration for a given piece of equipment, but manufacturing standards are not able to anticipate every possible situation in which listed equipment can be installed and utilized. Critically, for our purpose, they are not meant to evaluate a heterogeneous multi-component system, considered as a gestalt, under a nearly unlimited range of field conditions -- as we have discussed with SCADA systems. Field integration, moreover, is a valid mode of engineering; in fact, it is the whole, entire purpose of the National Electric Code. If too much oversight over equipment behavior is vested in the manufacturing process, the final result isn't necessarily going to enhance safety, but it will hamper innovation and produce anti-competitive product markets.

The testing process within, and, indeed, the inherent purpose of, UL-type standards is not appropriate for evaluating many SCADA systems. The evaluation requirement for control systems in 705.13 should be broken into two separate stipulations:

For the purposes of controlling current in one or more pieces of equipment to prevent overload across a bus or circuit:

A) Regulatory control systems shall be listed for this function;

B) SCADA systems either shall be listed for this function, or they shall be evaluated and approved by a professional electrical engineer or other professional recognized by the AHJ.

Realistically, the company that builds and implements a SCADA system isn't necessarily going to be the company that does the electrical design, and chooses wire sizing, conduit sizing, grounding methods, etc. Controls engineering is a specialized discipline and so it should be allowable that the engineer who signs off on the SCADA system may not be the same engineer or electrician who signs off on the rest of the electrical design, as submitted to the AHJ. Therefore, it would be helpful if an Informational Note were added to stipulation B):

Information Note: The engineer who signs off on the SCADA system may not be the same engineer

who signs off on other aspects of the system electrical design and integration, nor will they necessarily be employed by the same company.

Recommendation #4: Without signaling reliability, most control systems will not be guaranteed to provide the safety protections that are the sole purpose of 705.13. In general, the efficacy and dependability of a signaling system should be something for which an electrical engineer can vouch, having evaluated its performance in the lab, and, if necessary, in the field. The approvals stipulated in Recommendation #2 should include signaling reliability as one of its benchmarks.

However, it is also recommended that the NEC include an additional requirement which cannot be bypassed by an engineer: no off-site control component can be used to implement the safety requirements of the NEC with respect to current overload. An Information Note could be added to clarify this requirement: off-site control components can be used to change set-points and manage equipment function for a variety of purposes, but any *reaction* to an overcurrent condition necessitated in article 705 or elsewhere in the NEC should never rely on off-site components. The code-making panel may also want to better understand the reliability of on-site wireless and power-line technologies for signaling.

Recommendation #5: Where supervisory controls are engineered by a professional and not specifically listed by the manufacturer for compliance with 705.13, the NEC should indicate minimum acceptable response times in which control systems should react. These response times should vary by magnitude (in terms of potential current), by application and by fault condition, and be organized in a table. To illustrate the need for these indices: a fault of 10,000 A over the rating of a conductor or busbar should clear much faster than a controlled overload of 1 A; the peak in-rush current of a motor is intrinsically limited in time in a way that a continuous load is not; a fault can generate near infinite current instantaneously for systems connect to the grid, whereas overload from too many loads will only exceed a predictable value. This comment is not proposing any specific time values, except to note that supervisory controls' signaling typically operates in the range of 1 second to 15 seconds.

Recommendation #6: At the moment, the NEC does not articulate a clear, principled conception of how multiple loads and sources can be balanced within the ampacity limits of busbars and conductors, particularly with equipment that can function, at different times, as either loads or sources. Traditionally, utilities controlled all power generation, so power would flow in one direction from the service point down a hierarchically arranged series of busses, feeders and branch circuits, and the existing rules have worked well where one or two DER sources might intrude on this configuration. However, in the not-too-distant future, there will be not just thousands, but *millions* of DERs and load-control devices connected at the grid edge, often in close proximity and performing many different functions, and so it is imperative that the NEC adopt a view of power balancing that appropriately accounts for this new paradigm.

In an earlier section of this article, we described a method for calculating possible current on a bus or conductor based on a worst balance of load and source. The NEC should adopt some version of this method in determining threshold current values when evaluating possible current overload on busbars or conductors for 705.11, 705.12 and 705.13. It would offer AHJs, engineers and electricians a more accurate assessment of potential overloads than current methods.

Statement of Problem and Substantiation for Public Input

The version of 705.13 adopted in the 2020 cycle was an important advance in incorporating DERs to the NEC, but its stipulations do not adequately address the composition and capabilities of control systems. This comment gives a background on control systems, critiques some aspects of 705.13 and related issues, and offers some recommendations for code-make panel #4 as they decide how to update the NEC for the next cycle.

Submitter Information Verification

Submitter Full Name: Jeffrey Quackenbush

Organization: Integrated Storage Technologies
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 10 11:41:21 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: This public input (PI) was submitted as a global input when it is recommending changes specifically to 705.13. The PI does not follow the requirements for submitting a PI as it is not submitted with specific changes to the text. This PI could be forwarded to the Alternative Energy Task Group for the 2026 code cycle in case there is material within the PI that could be applied to the NEC.

Public Input No. 4685-NFPA 70-2020 [Global Input]

Align the on-site energy sources into a series of articles as follows:

689 On-Site Energy Sources

690 Solar Photovoltaic (PV) Systems

691 Large-Scale Photovoltaic (PV) Systems

692 Fuel Cell Systems

693 Generators

694 Wind Electric Systems

695 Energy Storage Systems

696 Storage Batteries

Public inputs were made by this task group to accommodate the following:

1. **Move Article 445 to 693**
2. **Move Article 480 to 696**
3. **Move Article 695 to 703 (This is to make room for 706 Energy Storage Systems)**
4. **Move Article 706 to 695**

In addition, ARticle 705 should be renumbered to Article 689.

Statement of Problem and Substantiation for Public Input

This global input accommodates the work of the Alternative Energy Taskgroup appointed by the corrrelating committee and consisting of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

These actions impact multiple Code Making Panels. Public inputs were made for all of these actions except for the renumbering of ARticle 705. This task group is asking the correlating committee to coordinate these actions to ensure changes align with the new numbering and location of these articles. This will help ensure correlation between eachother and establish their true closer relationship. This task group is not asking that CMP ownership be changed for any of these Articles.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3006-NFPA 70-2020 [Article 706]	
Public Input No. 2984-NFPA 70-2020 [Article 445]	
Public Input No. 2985-NFPA 70-2020 [Article 480]	
Public Input No. 2692-NFPA 70-2020 [Article 705]	

Submitter Information Verification

Submitter Full Name: Thomas Domitrovich
Organization: Eaton Corporation
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City:
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Submittal Date: Thu Sep 10 16:46:36 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: The CMP-4 generally supports the concept of consolidating power sources and locating them for easier access within the Code. There is need to clarify that ESS are power sources as well as loads. Reorganization is a correlating committee issue and the panel encourages actions by the correlating committee that supports clarity and usability of this Code.

Public Input No. 4318-NFPA 70-2020 [Chapter 0 [Title Only]]

THIS IS A GLOBAL INPUT

THE TERRAVIEW SOFTWARE WOULD NOT ALLOW THE SUBMISSION OF A GLOBAL INPUT.

PROPOSED GLOBAL INPUT.

Mandate that all alternative energy sources referenced throughout this code comply with the requirements of 230.82(6).

Statement of Problem and Substantiation for Public Input

This global input is written to address a very serious safety issue that exists abundantly in the NEC. CMP-10 has purview over services and mandates that PV, fuel cells, wind systems, energy storage systems and interconnected power production sources connected on the supply side of the service disconnecting means be done so only with a disconnecting means and overcorrect protection as required for service conductors in Article 230.
The problem here is that 90.3 provides committees dealing with alternative energy sources the ability to completely ignore 230.82(6). They simply claim that "their conductors are output conductors, not service conductors."
Any conductor that taps into or splices to service conductors is a service conductor.
This issue must be dealt with immediately by the NEC Correlating Committee. While this global input may not result in first revisions to correct this very serious safety concern, this concept now exists and is not new in the second draft stage.
We can no longer ignore this issue.

Submitter Information Verification

Submitter Full Name: James Dollard
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City:
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Zip:
Submittal Date: Thu Sep 10 10:00:36 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9380-NFPA 70-2021

Statement: The title of Section 705.11 is changed to clarify that it refers to any connection to a service. The initial paragraph introducing Section 705.11 adds the phrase, “connection is permitted to a service as permitted in 230.2(A)(5)” to clarify that a supply-side source connection is an additional service.

Section 705.11(A) is moved to 705.11(A)(1) and modified for clarity.

The revision to 705.11(B) becomes (A) and covers the maximum size of power sources based on service conductor size. It also specifically addresses the conductors from the point of connection to service conductors to the power source disconnecting means. The conductor requirements for power source output conductors are organized into a list to

better comply with the NEC Style Manual.

Section 705.11(B) moves the section that used to be 705.11(D) Connections to (B) and splits the requirements into a list to better comply with the style manual. The reference to Section 110.14 is removed as unnecessary and the references to Sections 230.33 and 230.46 are added to clarify how splices and taps are made.

The new section 705.11(C) is added for the power source disconnecting means. The new section provides proper reference to the location sections of Article 230. It also clarifies that additional disconnecting means are permitted by Section 230.40 Exception 5.

The new section 705.11(D) is added for bonding and grounding. This language uses the balloted First Draft language of Section 705.11 of the 2020 NEC as it clearly addresses how metal parts are to be bonded and grounded.

The revision to the overcurrent protection section of 705.11 changes the first sentence to call out the exact run of conductors addressed in this section. The reference is changed from 705.30 to Part VII of Article 230. Since 230.95 is in Part VII, the ground-fault protection requirements are clarified as to what equipment requires ground-fault protection. This eliminates the need for a separate section on ground-fault protection so Section 705.11(E) is deleted.

A related FR to 705.32 clarifies that power sources are permitted to be connected to the load side in this instance as there is no other way to make this connection. Listings of this type of ground-fault protection equipment are certified for power flows in either direction.

Public Input No. 2182-NFPA 70-2020 [New Article after 100]

Health Care Microgrid

A group of interconnected loads and distributed energy resources within clearly defined boundaries that acts as a single controllable entity with respect to the utility.

Statement of Problem and Substantiation for Public Input

NFPA 99 has included the concept for a Health Care Microgrid, including its definition. We are submitting a series of PIs to NFPA 70 to correlate with NFPA 99.

This comment is being made by a committee comprised of members of NFPA 99 ELS, NFPA 70 CMP15, and NFPA 110 who has worked over the summer to create a series of proposals to help correlate better with NFPA 99.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2173-NFPA 70-2020 [New Section after 517.30(B)]	

Submitter Information Verification

Submitter Full Name: Walter Vernon
Organization: Mazzetti
Affiliation: NFPA 99 ELS
Street Address:
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Zip:
Submittal Date: Thu Aug 06 17:15:27 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: The proposed definition does not differentiate between a standard microgrid and a health care microgrid, and so would serve no purpose. The proposed definition should not apply throughout the Code.

Public Input No. 1993-NFPA 70-2020 [Definition: Generating Capacity, Inverter.]

Generating Capacity, Inverter.

The sum of parallel-connected inverter maximum continuous output power at 40°C in ~~watts or kilowatts~~ volt-ampere or kilovolt-ampere . (CMP-4)

Statement of Problem and Substantiation for Public Input

Problem: Many inverters are available with kVA ratings that are greater than their kW ratings. Example, the CPS SCH100/125KTL-DO/US-600 which is rated as 125kW and 132kVA AC output.
Solution: Since the generating capacity should represent the maximum capacity of the system it would be correct to use the higher volt-ampere rating of the inverter as the maximum output. Where inverter output is rated only in watts the volt-ampere will be equal to the watt rating and the volt-ampere unit is still the correct unit to use.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 1995-NFPA 70-2020 [Section No. 690.7(A)]	Paired change
Public Input No. 1996-NFPA 70-2020 [Section No. 690.8(A)(1)]	Paired change
Public Input No. 1995-NFPA 70-2020 [Section No. 690.7(A)]	
Public Input No. 1996-NFPA 70-2020 [Section No. 690.8(A)(1)]	

Submitter Information Verification

Submitter Full Name: Marvin Hamon
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Street Address:
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Submittal Date: Fri Jul 24 11:35:51 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9345-NFPA 70-2021
Statement: New interconnection standards require that inverters have the ability to control reactive power (kVA). Because of this, some inverters are rated in kVA and do not have a kW rating. This change addresses these devices. The defined term was added to the title per NEC Style Manual Section 2.2.2.3.1 to facilitate digital searches.

Public Input No. 2683-NFPA 70-2020 [Definition: Hybrid System.]

~~**Hybrid System.**~~

~~A system comprised of multiple power sources. These power sources could include photovoltaic, wind, micro-hydro generators, engine-driven generators, and others, but do not include electric power production and distribution network systems. Energy storage systems such as batteries, flywheels, or superconducting magnetic storage equipment do not constitute a power source for the purpose of this definition. The energy regenerated by an overhauling (descending) elevator does not constitute a power source for the purpose of this definition. (CMP-4)~~

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

This definition is being deleted as it is not used in any alternative energy article and since a similar term exists in Chapter 8 its presence here could cause confusion.

Submitter Information Verification

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Submittal Date: Fri Aug 28 13:57:47 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9346-NFPA 70-2021
Statement: This definition is deleted. It is not used in any advanced energy article. A similar term exists in Chapter 8 and so this definition could cause confusion.

Public Input No. 2684-NFPA 70-2020 [Definition: Interactive System.]

Interactive ~~System~~ Mode .

~~An electric~~ The operational mode for power production ~~system~~ equipment that is operating in parallel with and capable of delivering energy to an electric power production and distribuution network or other primary source ~~supply system~~ . (CMP-4)

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

Replaced “system” in this term with “mode” since the term “interactive” is more often used without “system” and can be applied to a specific piece of equipment, not a system as a whole. With related changes to “microgrid system” and “stand-alone system” the term interactive mode should apply to a power source, such as an interactive inverter, not a system as a whole. Will need additional PIs or a global PI to ensure where the term interactive system or just interactive is used, the term mode is replaced or added.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2538-NFPA 70-2020 [Section No. 705.32]	
Public Input No. 2978-NFPA 70-2020 [Definition: Electric Power Production and Distribution Netw...]	
Public Input No. 2979-NFPA 70-2020 [Section No. 690.13(C)]	
Public Input No. 2980-NFPA 70-2020 [Section No. 694.24]	
Public Input No. 2981-NFPA 70-2020 [Section No. 694.50]	

Submitter Information Verification

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Submittal Date: Fri Aug 28 14:01:51 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9347-NFPA 70-2021

Statement: This revision replaces “system” with “mode” since the term “interactive” is more often used without “system” and is typically applied to a specific piece of equipment, not a system as a whole. With related changes to “microgrid system” and “stand-alone system” the term interactive mode will apply to a power source, such as an interactive inverter, not a system.

Public Input No. 2686-NFPA 70-2020 [Definition: Inverter, Multimode.]

Inverter, Multimode.

~~Equipment~~ Inverter equipment having the capabilities ~~of~~ to operate in both ~~the~~ interactive ~~inverter and the stand-alone inverter~~ mode and island mode . (CMP-4)

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

These changes reflect more accuratelywhat a multimode inverter is and aligns with how this term is being used in the alternative energy articles.

Submitter Information Verification

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Submittal Date: Fri Aug 28 14:07:14 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9348-NFPA 70-2021
Statement: These changes better reflect the definition of a multimode inverter usage in the advanced energy articles. The defined term was added to the title per NEC Style Manual Section 2.2.2.3.1 to facilitate digital searches.

Public Input No. 2685-NFPA 70-2020 [Definition: Island Mode.]

Island Mode.

The operational mode for ~~stand-alone~~ power production equipment ~~or an isolated microgrid, or for a multimode inverter or an interconnected microgrid~~ that is disconnected from an electric power production and distribution network or other primary power source and capable of delivering energy to loads . (CMP-4)

~~Informational Note: Isolated microgrids are distinguished from interconnected microgrids, which are addressed in Article 705 .~~

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

Deleted undefined term and unnecessary terms to better restrict the application of this definition with the other defined terms of “stand-alone system” and “microgrid system” (in 705).

Submitter Information Verification

Submitter Full Name: Thomas Domitrovich
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Street Address:
City:
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Submittal Date: Fri Aug 28 14:04:39 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9349-NFPA 70-2021
Statement: This change better aligns with revised definitions of stand-alone and microgrid systems. The informational note was deleted as the terms isolated and interconnected microgrids are not used in the Code.

Public Input No. 3666-NFPA 70-2020 [Definition: Island Mode.]

Island Mode.

The operational mode for stand-alone power production equipment or an isolated microgrid, or for a multimode inverter or an interconnected microgrid that is disconnected from an electric power production and distribution network or other primary power source. (CMP-4)

Informational Note: Isolated microgrids are distinguished from interconnected microgrids, ~~which are addressed in Article~~ see 705. 1 .

Statement of Problem and Substantiation for Public Input

Section 4.1.4 of the 2020 NEC(r) Style Manual prohibits reference to an entire article, other than Article 100. As such, it is proposed that you instead refer folks to the scope of the relevant article.

Submitter Information Verification

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Submittal Date: Wed Sep 09 10:28:08 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9349-NFPA 70-2021
Statement: This change better aligns with revised definitions of stand-alone and microgrid systems. The informational note was deleted as the terms isolated and interconnected microgrids are not used in the Code.

Public Input No. 2199-NFPA 70-2020 [Definition: Stand-Alone System.]

Stand-Alone System.

A system that is capable of supplying power independent, with no connection, of an electric utility power production and distribution network.(CMP-4)

Statement of Problem and Substantiation for Public Input

The parameters the Stand Alone Definition must be clearly established as to what is and what is not a connection with serving utility. A part of this definition appears in Article 712 and there is clarification that must be established for installations of Generators, P V. ESS and Wind. Neither of these systems are a Stand Alone System anytime there is a serving Utility connection.

The 4-Pole Transfer Switch of a Separately Derived System could be the only system closely near consideration for a Stand Alone System since the Grounded Conductor is actually Switched there by disconnecting the serving utility from the Premise Wiring. An Automatic Transfer Switch that complies with UL 1008 is the only Listed equipment that creates a Separately Derived System.

A device being installed currently is not evaluated to UL 1008, is not a 3-Pole or 4 Pole application and there is not a Separately Derived System terminated as Another Power Source.

This must be applied in Article 710.1 for clarification for Contractors and AHJ's.

Submitter Information Verification

Submitter Full Name: James Hathorn
Organization: City Of Irving
Street Address:
City:
State:
Zip:
Submittal Date: Sat Aug 08 21:46:00 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9350-NFPA 70-2021
Statement: This revision clarifies that a stand-alone system is one that is not connected to a utility. The definition is modified to complement the definition of a microgrid system.

Public Input No. 2688-NFPA 70-2020 [Definition: Stand-Alone System.]

Stand-Alone System.

A premises wiring system that is ~~capable of supplying power independent of~~ not interconnected to an electric power production and distribution network or other primary source that has any combination of generation and energy storage capable of operating in island mode .(CMP-4)

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

Clarifies that a Stand-Alone system is one that is not connected to a utility. Definition is modified to align more closely (as a mirror image) with a microgrid system (as defined and modified in a related PI within 705.2).

Submitter Information Verification

Submitter Full Name: Thomas Domitrovich
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Submittal Date: Fri Aug 28 14:13:37 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9350-NFPA 70-2021
Statement: This revision clarifies that a stand-alone system is one that is not connected to a utility. The definition is modified to complement the definition of a microgrid system.

Public Input No. 588-NFPA 70-2020 [Definition: Stand-Alone System.]

Stand-Alone System.

A system that ~~is capable of supplying power~~ supplies power independent of an electric power production and distribution network.(CMP-4)

Statement of Problem and Substantiation for Public Input

As currently written, any piece of equipment that is capable of creating electrical energy falls under this definition. I apologize that I don't have a better suggestion, but perhaps some mention of transfer equipment should be added? Without that clarification an emergency generator is a stand-alone system.

Submitter Information Verification

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Submittal Date: Mon Mar 02 17:00:21 EST 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9350-NFPA 70-2021
Statement: This revision clarifies that a stand-alone system is one that is not connected to a utility. The definition is modified to complement the definition of a microgrid system.

Public Input No. 2792-NFPA 70-2020 [New Definition after Definition: Battery System.]

TITLE OF NEW CONTENT

Building Integrated Photovoltaic (BIPV) system . Building-integrated photovoltaics are photovoltaic materials that are used to replace conventional building materials in parts of the building envelope such as the roof, skylights, or facades.

Statement of Problem and Substantiation for Public Input

This is related to public input 2791-NFPA 70-2020. We need a definition listed for this new content.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2791-NFPA 70-2020 [New Section after 690.51]	Definition

Submitter Information Verification

Submitter Full Name: Todd Fries
Organization: HellermannTyton
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 01 10:17:09 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: The proposed revision was required for PI 2791 which was resolved. BIPV is not used elsewhere in the Code.

Public Input No. 1882-NFPA 70-2020 [New Definition after Definition: Conductor, Insulated.]

Conductor, System

Circuit conductors that are on the supply side of the main disconnect or transfer switch in systems where the supply source is not considered a service.

Statement of Problem and Substantiation for Public Input

The term "System Conductor" is used 12 times in the 2020 NEC and the usage is confined to Articles 100 and 250. In each instance of usage, it is describing a grounded conductor and in 11 of the 12 instances it is part of the term "Grounded System Conductor". The term "Circuit Conductor" is used 81 times throughout the 2020 NEC. The term "Grounded Circuit Conductor" is used 43 times throughout the 2020 NEC and 10 times in Article 250.

In Articles 100 and 250, it is not clear that there is a difference between a "Grounded System Conductor" and a "Grounded Circuit Conductor", these terms appear to be used interchangeably.

If it is not the intent that these terms be used interchangeably:

- Definitions should be provided as proposed in PIs 1881-NFPA 70-2020 and 1882-NFPA 70-2020 to delineate the unique features of a "System Conductor" versus those of a "Circuit Conductor“

- PIs 1883-NFPA 70-2020 , 1906-NFPA 70-2020 , 1892-NFPA 70-2020 , 1893-NFPA 70-2020 , 1904-NFPA 70-2020 , and 1905-NFPA 70-2020 should be disregarded

If it is the intent that the two terms are to be used interchangeably:

- All instances of "System Conductor" should be changed to "Circuit Conductor“

- PIs 1883-NFPA 70-2020 , 1906-NFPA 70-2020 , 1892-NFPA 70-2020 , 1893-NFPA 70-2020 , 1904-NFPA 70-2020 , and 1905-NFPA 70-2020 should be accepted to change instances of “system conductor” to “circuit conductor”

- PI 1881-NFPA 70-2020 may be helpful in this scenario to clarify the meaning of the term ”Circuit Conductor”

- Replacing all instances of "Circuit Conductor“ with "System Conductor" and defining the term "System Conductor" would accomplish the same goal. "Circuit Conductor“ is presently more used throughout the NEC, so the proposal above requires a smaller number of revisions.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 1881-NFPA 70-2020 [New Definition after Definition: Conductor, Bare.]	
Public Input No. 1906-NFPA 70-2020 [Section No. 250.36(B)]	
Public Input No. 1893-NFPA 70-2020 [Section No. 250.84]	
Public Input No. 1904-NFPA 70-2020 [Section No. 250.187(C)]	
Public Input No. 1905-NFPA 70-2020 [Section No. 250.34(C)]	
Public Input No. 1883-NFPA 70-2020 [Definition: Grounded Conductor.]	
Public Input No. 1892-NFPA 70-2020 [Section No. 250.80]	

Public Input No. 1881-NFPA 70-2020 [New Definition after Definition: Conductor, Bare.]

Public Input No. 1883-NFPA 70-2020 [Definition: Grounded Conductor.]

Public Input No. 1892-NFPA 70-2020 [Section No. 250.80]

Public Input No. 1893-NFPA 70-2020 [Section No. 250.84]

Public Input No. 1904-NFPA 70-2020 [Section No. 250.187(C)]

Public Input No. 1905-NFPA 70-2020 [Section No. 250.34(C)]

Public Input No. 1906-NFPA 70-2020 [Section No. 250.36(B)]

Submitter Information Verification

Submitter Full Name: John Cowans
Organization: Siemens
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City:
State:
Zip:
Submittal Date: Mon Jul 13 15:41:04 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: There is no need for a general definition for a system conductor. The term “system” is used throughout the NEC and is not limited to a power system.

Public Input No. 2682-NFPA 70-2020 [New Definition after Definition: Grounded, Solidly.]

Grounded, Functionally.

A system that has an electrical ground reference for operational purposes that is not solidly grounded.

Informational Note: A functionally grounded system is often connected to ground through an electronic means internal to an inverter or charge controller that provides ground-fault protection. Examples of operational purposes for functionally grounded systems include ground-fault detection and performance-related issues for some power sources.

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

This definition is being moved to Article 100 as part of an effort of the alternative energy task group which is expanding the usage of this term in various areas of the NEC associated with alternative energy.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2681-NFPA 70-2020 [Definition: Grounded, Functionally.]	Moved from 690
Public Input No. 2681-NFPA 70-2020 [Definition: Grounded, Functionally.]	

Submitter Information Verification

Submitter Full Name: Thomas Domitrovich
Organization: Eaton Corporation
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Submittal Date: Fri Aug 28 13:37:30 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9324-NFPA 70-2021

Statement: This revision moves all definitions previously in Section 2 of Articles 690, 692, 694 and 705 to Article 100.

The NEC Style Manual also requires that for definitions that apply in only one article, the article number in parentheses shall follow the definition.

CMP-4 identified the following definitions that apply to only one article:

690: AC Module System, AC Module, Array, Direct-Current Combiner, Module, Monopole Circuit, PV Output Circuit, PV Source Circuit, PV System DC Circuit.

692: Fuel Cell Output Circuit

694: Maximum Output Power, Maximum Voltage, Nacelle, Rated Power, Tower, Wind Turbine Output Circuit.

These have been moved to Article 100 with the relevant article number appended. All other definitions have been moved with no article number identified.

All definitions were moved with the annotation (CMP-4) appended to indicate the code panel responsible for the definition in accordance with NEC Style Manual Section 2.2.2.3.3.

Public Input No. 2699-NFPA 70-2020 [New Definition after Definition: Inverter.]

Inverter , Stand-alone.

Inverter equipment having the capabilities to operate only in island mode. (CMP-4)

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

New term to address all three flavors of inverter that could be used in these systems.

Submitter Information Verification

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Submittal Date: Fri Aug 28 16:18:59 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9352-NFPA 70-2021
Statement: This new definition completes the set of inverter type definitions: stand-alone, interactive and multi-mode. The defined term was added to the title per NEC Style Manual Section 2.2.2.3.1 to facilitate digital searches.

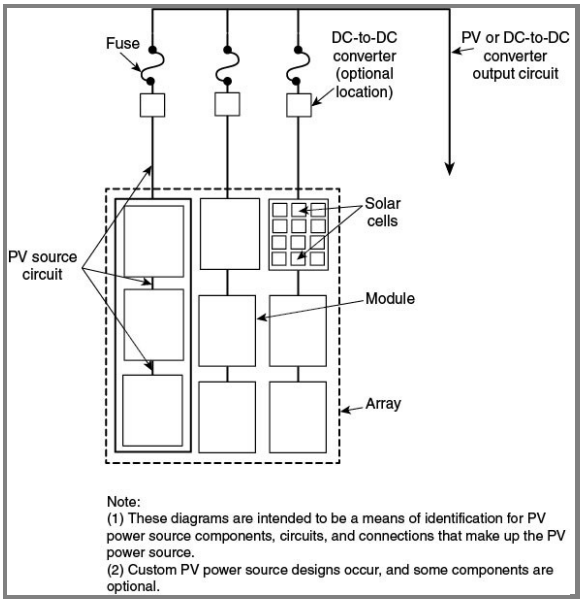
Public Input No. 4418-NFPA 70-2020 [Section No. 690.1]

690.1 Scope.

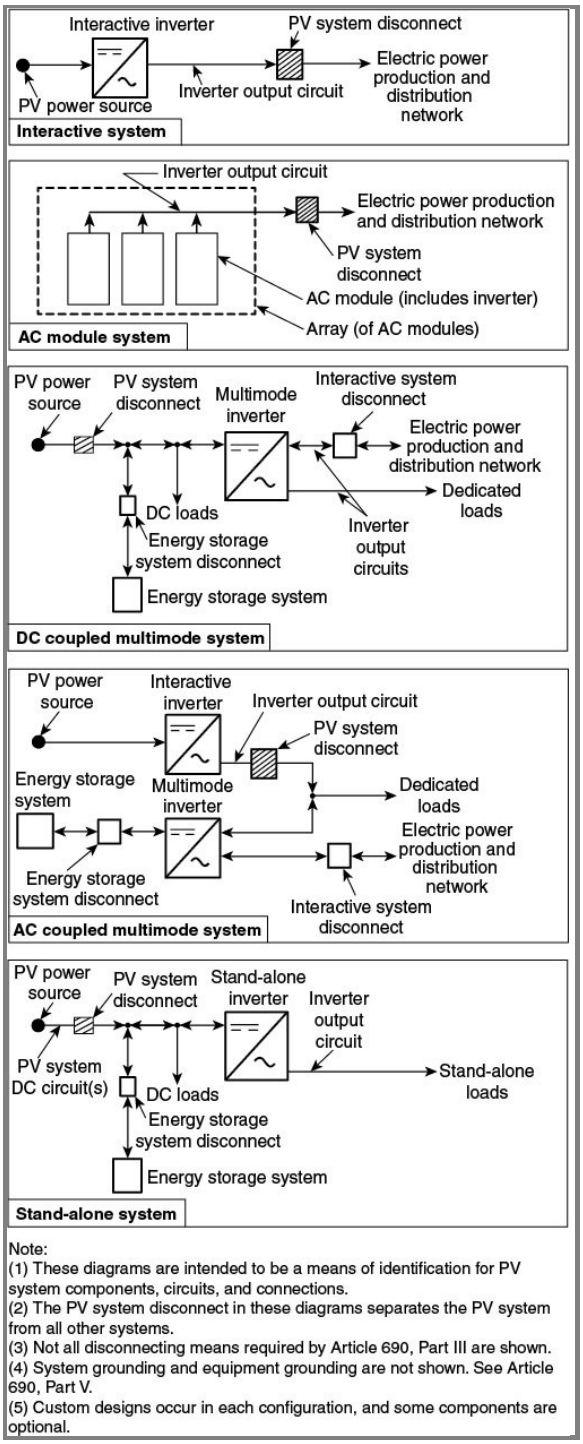
This article applies to solar PV systems, other than those covered by Article 691, including the array circuit(s), inverter(s), and controller(s) for such systems. The systems covered by this article include those interactive with other electric power production sources or stand-alone, or both. These PV systems may have ac or dc output for utilization.

Informational Note ~~No. 1~~ : ~~See~~ ~~Informational Note Figure 690.1(a)~~ ~~and~~ ~~Informational Note Figure 690.1(b)~~ . ~~Informational Note No. 2:~~ Article 691 covers the installation of large-scale PV electric supply stations.

~~Figure Informational~~ Informational Note Figure 690.1(a) Identification of PV ~~Power Source~~ DC Circuits and Common Components.



~~Figure Informational Note Figure 690.1(b) Identification of PV System Components in Common Configurations.~~



Note:
(1) These diagrams are intended to be a means of identification for PV system components, circuits, and connections.
(2) The PV system disconnect in these diagrams separates the PV system from all other systems.
(3) Not all disconnecting means required by Article 690, Part III are shown.
(4) System grounding and equipment grounding are not shown. See Article 690, Part V.
(5) Custom designs occur in each configuration, and some components are optional.

(replace with new figure and notes as shown in attachment)

Additional Proposed Changes

File Name	Description	Approved
690_1_IN_Figure_1a_correct.pdf	New figure 690.1a	

Statement of Problem and Substantiation for Public Input

As PV system typologies and designs proliferate, this Informational Note Figure has become increasingly problematic. Confusion about whether every component should be installed in every system, and what equipment is required where (such as fuses or dc-to-dc converters) has been expressed by enforcement and installers. Splitting the diagram into 3 more digestible sections, and simplifying each, will help better illustrate defined terms such as source circuit and dc-to-dc converter circuit while lessening confusion regarding design variations. This action is linked to related PIs to update this language to harmonize with the deletion of the PV Output Circuit definition and changes to the DC-to-DC Converter Source and Output Circuit definitions.

The deletion of IN Figure 1b is recommended, along with a suggested move to Article 705. PV Power Source is not a defined term in 690, and the use of this term on the diagram generates confusion. Article 705 uses the term “Power Source” to refer to the AC output of a power system, while this diagram currently uses the term to point to the DC side of a PV system. Substituting a term that is defined, PV System DC Circuit(s) improves the usability of these diagrams. In addition, swapping the “electric power production and distribution network” label for a more succinct and generalized term “Other Power Sources” will lessen confusion. Additionally, making these diagrams more generic (not PV system specific) and moving them to 705 will allow them to be referenced for any type of power production source operating in parallel with a primary source.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF’s effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI’s as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI’s submitted.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain, P.E., SEIA; Bill Brooks, PVICC; John Berdner, PVICC, Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing, Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower; Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

Related Public Inputs for This Document

Related Input	Relationship

Public Input No. 3705-NFPA 70-2020 [Definition: PV System DC Circuit.]

Submitter Information Verification

Submitter Full Name: Evelyn Butler
Organization: Solar Energy Industries Assn
Affiliation: PV Industry Forum (PVIF)
Street Address:
City:
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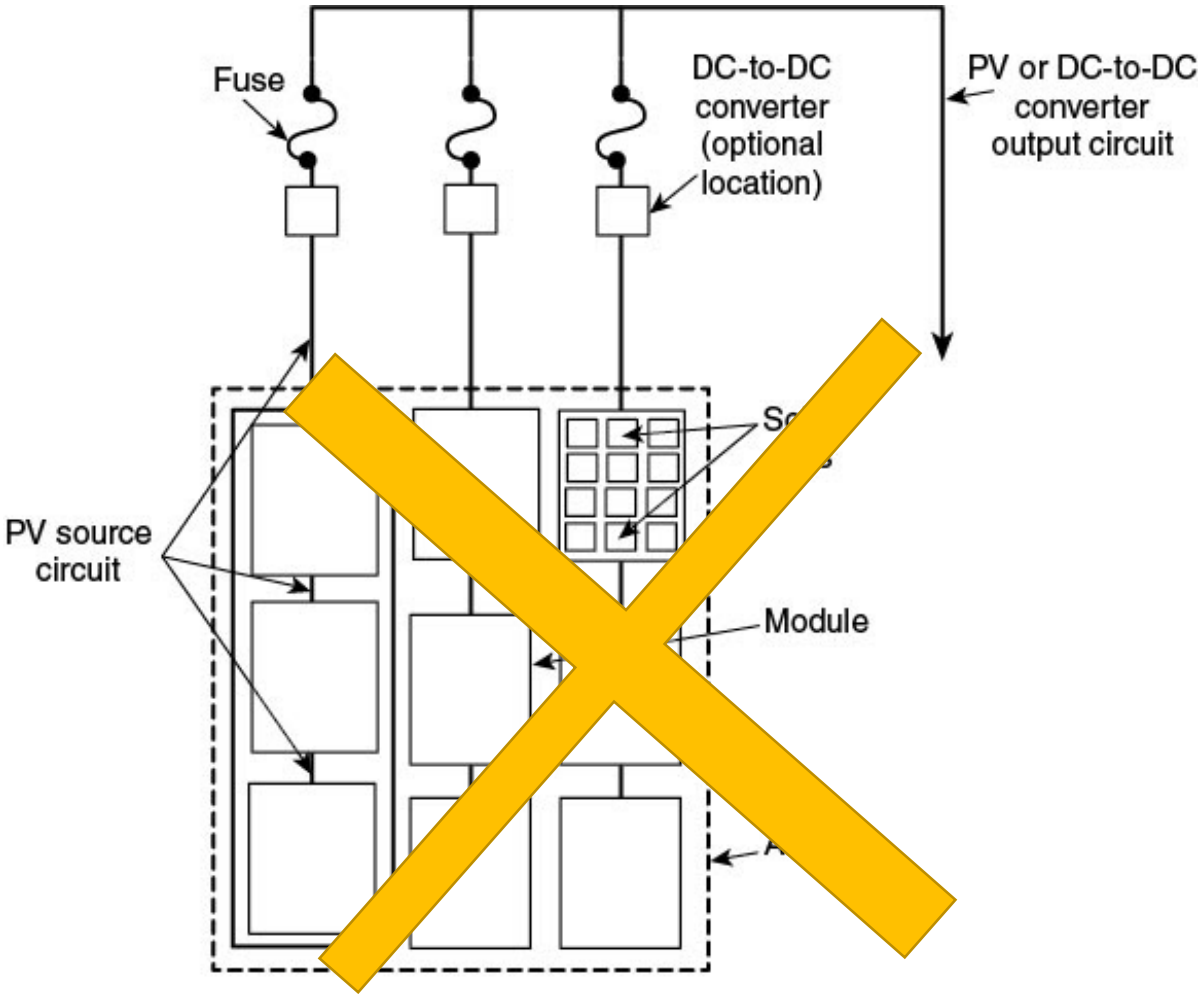
Zip:
Submittal Date: Thu Sep 10 12:40:54 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9476-NFPA 70-2021
Statement: Changes are made to align with the deletion of the term PV output circuits. The references to the existing PV source circuit term and new PV string circuit terms are clarified in several common configurations to aid users of this Code. The deletion of IN Figure 1b is made recognizing the addition of similar figures into Article 705, where they are more appropriate since they address multiple sources.

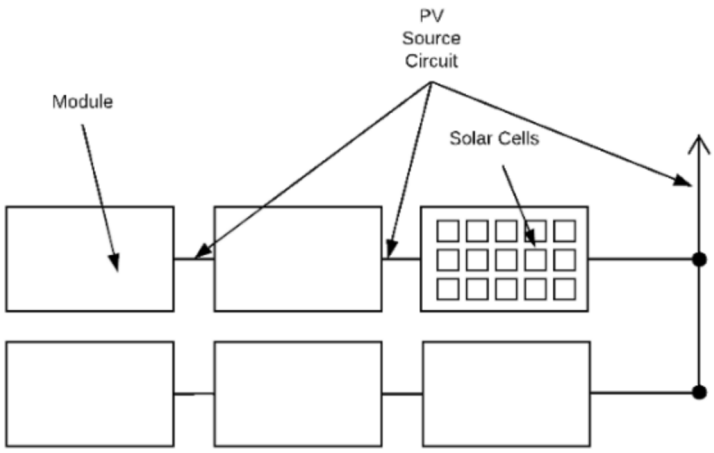
Informational Note Figure 690.1(a) Identification of PV DC Circuits and Common Components ~~Power Source Components~~.

(Cross out drawing and image notes immediately below it and replace with new)

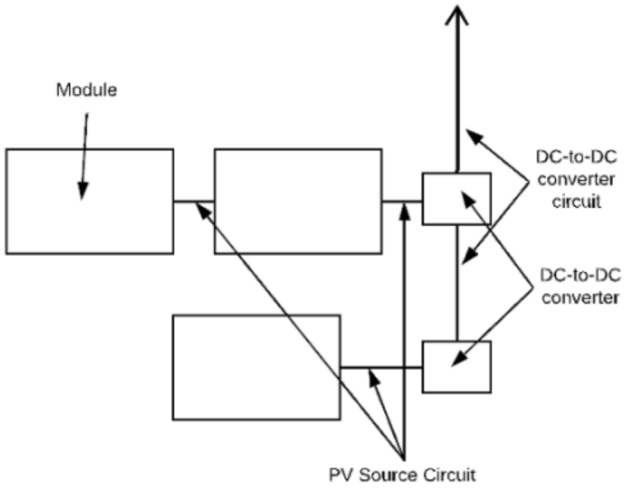


Note:
(1) These diagrams are intended to be a means of identification for PV power source components, circuits, and connections that make up the PV power source.
(2) Custom PV power source designs occur, and some components are optional.

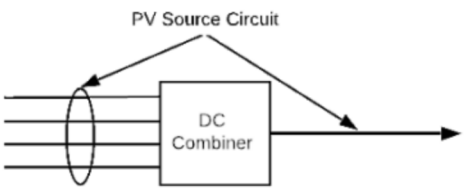
Identification of PV System DC Circuits and Common Components
Informational Note Figure 690.1(a)(1)



Informational Note Figure 690.1(a)(2)



Informational Note Figure 690.1(a)(3)



Note:

1. These diagrams are intended to be a means of identification for PV system dc circuits and common components.
2. Overcurrent protection and disconnects are not shown; custom configurations will occur.

Public Input No. 3892-NFPA 70-2020 [Section No. 690.2]

(Relocate all definitions in the 690. 2 to Article 100, arrange them in alphabetical order and without any subdivisions.)

690. 2 Definitions.

The definitions in this section shall apply only within this article.

AC Module System.

An assembly of ac modules, wiring methods, materials, and subassemblies that are evaluated, identified, and defined as a system.

Alternating-Current (ac) Module (Alternating-Current Photovoltaic Module).

A complete, environmentally protected unit consisting of solar cells, inverter, and other components, designed to produce ac power.

Array.

A mechanically and electrically integrated grouping of modules with support structure, including any attached system components such as inverter(s) or dc-to-dc converter(s) and attached associated wiring.

Bipolar Circuit.

A dc circuit that is comprised of two monopole circuits, each having an opposite polarity connected to a common reference point.

DC-to-DC Converter Output Circuit.

The dc circuit conductors connected to the output of a dc combiner for dc-to-dc converter source circuits.

DC-to-DC Converter Source Circuit.

Circuits between dc-to-dc converters and from dc-to-dc converters to the common connection point(s) of the dc system.

Direct-Current (dc) Combiner.

An enclosure that includes devices used to connect two or more PV system dc circuits in parallel.

Electronic Power Converter.

A device that uses power electronics to convert one form of electrical power into another form of electrical power.

> Informational Note: Examples of electronic power converters include, but are not limited to, inverters, dc-to-dc converters, and electronic charge controllers. These devices have limited current capabilities based on the device ratings at continuous rated power.

Grounded, Functionally.

A system that has an electrical ground reference for operational purposes that is not solidly grounded.

> Informational Note: A functionally grounded system is often connected to ground through an electronic means internal to an inverter or charge controller that provides ground-fault protection. Examples of operational purposes for functionally grounded systems include ground-fault detection and performance-related issues for some power sources.

Module.

A complete, environmentally protected unit consisting of solar cells and other components designed to produce dc power.

Monopole Circuit.

An electrical subset of a PV system that has two conductors in the output circuit, one positive (+) and one negative (−).

PV Output Circuit.

The dc circuit conductors from two or more connected PV source circuits to their point of termination.

PV Source Circuit.

The dc circuit conductors between modules and from modules to dc combiners, electronic power converters, or a dc PV system disconnecting means.

PV System DC Circuit.

Any dc conductor in PV source circuits, PV output circuits, dc-to-dc converter source circuits, and dc-to-dc converter output circuits.

Solar Cell.

The basic PV device that generates electricity when exposed to light.

Statement of Problem and Substantiation for Public Input

"The National Electrical Code has definitions in multiple parts in Article 100 and many definitions scattered through out the code many of them in the .2 section of the articles.
Most of the other standards under NFPA have their definitions in one location and this will allow the NEC the same requirement. The revisions to the NEC Style Manual require all the definitions to be relocated to Article 100. "

Submitter Information Verification

Submitter Full Name: David Williams
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Zip:
Submittal Date: Wed Sep 09 14:57:58 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9324-NFPA 70-2021
Statement: This revision moves all definitions previously in Section 2 of Articles 690, 692, 694 and 705 to Article 100.

The NEC Style Manual also requires that for definitions that apply in only one article, the article number in parentheses shall follow the definition.

CMP-4 identified the following definitions that apply to only one article:

690: AC Module System, AC Module, Array, Direct-Current Combiner, Module, Monopole Circuit, PV Output Circuit, PV Source Circuit, PV System DC Circuit.

692: Fuel Cell Output Circuit

694: Maximum Output Power, Maximum Voltage, Nacelle, Rated Power, Tower, Wind Turbine Output Circuit.

These have been moved to Article 100 with the relevant article number appended. All other definitions have been moved with no article number identified.

All definitions were moved with the annotation (CMP-4) appended to indicate the code panel responsible for the definition in accordance with NEC Style Manual Section 2.2.2.3.3.

Public Input No. 3680-NFPA 70-2020 [Definition: Alternating-Current (ac) Module (Alternating-Cu...]

~~Alternating-Current (ac) Module (Alternating-Current Photovoltaic Module)~~ AC Module .

A complete, environmentally protected unit consisting of solar cells, inverter, and other components, designed to produce ac power.

Statement of Problem and Substantiation for Public Input

This change aligns the defined term with the way the term is actually used in the text of Article 690. The language that would be deleted is never used anywhere else in the text of Article 690.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain, P.E., SEIA; Bill Brooks, Brooks Engineering/PVICC; Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing, Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower; Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Ben Chamberlain, Olivewood Energy; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

Submitter Information Verification

Submitter Full Name: Evelyn Butler
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Submittal Date: Wed Sep 09 10:42:30 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9353-NFPA 70-2021
Statement: The title was changed to reflect primary and alternate terms now allowed by the NEC Style Manual.

Public Input No. 3714-NFPA 70-2020 [Definition: DC-to-DC Converter Output Circuit.]

PV DC-to-DC Converter ~~Output~~ Circuit.

The dc circuit conductors connected to the output of ~~a~~ dc ~~combiner for dc~~ -to-dc ~~converter source circuits~~ converters .

Statement of Problem and Substantiation for Public Input

There are two definitions related to dc-to-dc converters that can create a source of confusion among inspectors, installers, and system designers. The seeming overlap and lack of clarity make interpretation and enforcement subjective as both refer to circuits on the output of dc-to-dc converters.
Much like the previous distinction between PV source and PV output circuits, there are no significant, separate, or differentiating requirements for current calculations, overcurrent protection, or material installation methods in Article 690 that distinguish between dc-to-dc converter source and output circuits - with a single exception in 690.11 related to arc-fault circuit requirements which is addressed in the related PI.
For enforcement officials and system designers, correctly determining the circuit current and voltage is far more important than trying to distinguish between various circuits all on the output side of dc-to-dc converters, especially as changing system architectures and equipment options have rendered the current two definitions unclear and unnecessary.
Combining these two terms into a single definition will benefit both enforcement and system installers and help improve readability of the NEC.

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This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate.
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Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3724-NFPA 70-2020 [Definition: DC-to-DC Converter Source Circuit.]	

Submitter Information Verification

Submitter Full Name: Evelyn Butler
Organization: Solar Energy Industries Assn
Affiliation: PV Industry Forum (PVIF)
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 09 11:15:58 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9354-NFPA 70-2021 The letters PV were not added to the title to allow general use.

Statement: This change generalizes the defined term so that it can be used in other contexts such as ESS. The word “output” was deleted from the title to match the use of the term throughout the NEC.

Public Input No. 3724-NFPA 70-2020 [Definition: DC-to-DC Converter Source Circuit.]

~~**DC-to-DC Converter Source Circuit.**~~

~~Circuits between dc-to-dc converters and from dc-to-dc converters to the common connection point(s) of the dc system.~~

Statement of Problem and Substantiation for Public Input

There are two definitions related to dc-to-dc converters that can create a source of confusion among inspectors, installers, and system designers. The seeming overlap and lack of clarity make interpretation and enforcement subjective as both refer to circuits on the output of dc-to-dc converters.
Much like the previous distinction between PV source and PV output circuits, there are no significant, separate, or differentiating requirements for current calculations, overcurrent protection, or material installation methods in Article 690 that distinguish between dc-to-dc converter source and output circuits - with a single exception in 690.11 related to arc-fault circuit requirements which is addressed in the related PI.
For enforcement officials and system designers, correctly determining the circuit current and voltage is far more important than trying to distinguish between various circuits all on the output side of dc-to-dc converters, especially as changing system architectures and equipment options have rendered the current two definitions unclear and unnecessary.
Combining these two terms into a single definition will benefit both enforcement and system installers and help improve readability of the NEC.

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This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
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Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3714-NFPA 70-2020 [Definition: DC-to-DC Converter Output Circuit.]	the new combined definition

Submitter Information Verification

Submitter Full Name: Evelyn Butler
Organization: Solar Energy Industries Assn
Affiliation: PV Industry Forum (PVIF)
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 09 11:25:10 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9355-NFPA 70-2021

Statement: This definition is deleted as, while a dc-dc output circuit can be clearly identified and is used for ampacity calculations, the input to a dc-dc converter may have many other functions (such as a PV source circuit), and is generally not used for ampacity calculations.

Public Input No. 3675-NFPA 70-2020 [Definition: Electronic Power Converter.]

Electronic Power Converter. - Move to article 100

A device that uses power electronics to convert one form of electrical power into another form of electrical power.

Informational Note: Examples of electronic power converters include, but are not limited to, inverters, dc-to-dc converters, and electronic charge controllers. These devices have limited current capabilities based on the device ratings at continuous rated power.

Statement of Problem and Substantiation for Public Input

This term Electronic Power Converter applies both within Article 690 and throughout the Code, therefore it should be moved to Article 100. The defined term is used in multiple Articles, and is foundational in usage in Articles 690 and 705, requiring that it remain under the purview of CMP-4.

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Submitter Information Verification

Submitter Full Name: Evelyn Butler
Organization: Solar Energy Industries Assn
Affiliation: PV Industry Forum (PVIF)
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 09 10:38:49 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9324-NFPA 70-2021

Statement: This revision moves all definitions previously in Section 2 of Articles 690, 692, 694 and 705 to Article 100.

The NEC Style Manual also requires that for definitions that apply in only one article, the article number in parentheses shall follow the definition.

CMP-4 identified the following definitions that apply to only one article:

690: AC Module System, AC Module, Array, Direct-Current Combiner, Module, Monopole Circuit, PV Output Circuit, PV Source Circuit, PV System DC Circuit.

692: Fuel Cell Output Circuit

694: Maximum Output Power, Maximum Voltage, Nacelle, Rated Power, Tower, Wind Turbine Output Circuit.

These have been moved to Article 100 with the relevant article number appended. All other definitions have been moved with no article number identified.

All definitions were moved with the annotation (CMP-4) appended to indicate the code panel responsible for the definition in accordance with NEC Style Manual Section 2.2.2.3.3.

Public Input No. 2681-NFPA 70-2020 [Definition: Grounded, Functionally.]

~~**Grounded, Functionally.**~~

~~A system that has an electrical ground reference for operational purposes that is not solidly grounded.~~

~~Informational Note: A functionally grounded system is often connected to ground through an electronic means internal to an inverter or charge controller that provides ground-fault protection. Examples of operational purposes for functionally grounded systems include ground-fault detection and performance-related issues for some power sources.~~

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

This definition is being moved to Article 100 as part of an effort of the alternative energy task group which is expanding the usage of this term in various areas of the NEC associated with alternative energy.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2682-NFPA 70-2020 [New Definition after Definition: Grounded, Solidly.]	Destination in Article 100
Public Input No. 2682-NFPA 70-2020 [New Definition after Definition: Grounded, Solidly.]	

Submitter Information Verification

Submitter Full Name: Thomas Domitrovich
Organization: Eaton Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Fri Aug 28 13:36:41 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9324-NFPA 70-2021
Statement: This revision moves all definitions previously in Section 2 of Articles 690, 692, 694 and 705 to Article 100.

The NEC Style Manual also requires that for definitions that apply in only one article, the article number in parentheses shall follow the definition.

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These have been moved to Article 100 with the relevant article number appended. All other definitions have been moved with no article number identified.

All definitions were moved with the annotation (CMP-4) appended to indicate the code panel responsible for the definition in accordance with NEC Style Manual Section 2.2.2.3.3.

Public Input No. 3343-NFPA 70-2020 [Definition: Grounded, Functionally.]

This definition shall be relocated to Article 100. This identical definition is also found in Article 712. The revised Style Manual requires panel action to only have one definition.

Grounded, Functionally.

A system that has an electrical ground reference for operational purposes that is not solidly grounded.

Informational Note: A functionally grounded system is often connected to ground through an electronic means internal to an inverter or charge controller that provides ground-fault protection. Examples of operational purposes for functionally grounded systems include ground-fault detection and performance-related issues for some power sources.

Statement of Problem and Substantiation for Public Input

The identical definition for "Grounded, Functionally" is also used in Article 712.
This term may not be used elsewhere in the code and could apply for the entire document.
Review the Style Manual revisions for definitions and acronyms. 2.2.2.4 Terms with Multiple Definitions.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 08:43:46 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9324-NFPA 70-2021

Statement: This revision moves all definitions previously in Section 2 of Articles 690, 692, 694 and 705 to Article 100.

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CMP-4 identified the following definitions that apply to only one article:

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692: Fuel Cell Output Circuit

694: Maximum Output Power, Maximum Voltage, Nacelle, Rated Power, Tower, Wind Turbine Output Circuit.

These have been moved to Article 100 with the relevant article number appended. All other definitions have been moved with no article number identified.

All definitions were moved with the annotation (CMP-4) appended to indicate the code panel responsible for the definition in accordance with NEC Style Manual Section 2.2.2.3.3.

Public Input No. 3677-NFPA 70-2020 [Definition: Grounded, Functionally.]

Grounded, Functionally. - Move to 100

A system that has an electrical ground reference for operational purposes that is not solidly grounded.

Informational Note: A functionally grounded system is often connected to ground through an electronic means internal to an inverter or charge controller that provides ground-fault protection. Examples of operational purposes for functionally grounded systems include ground-fault detection and performance-related issues for some power sources.

Statement of Problem and Substantiation for Public Input

This term Functionally Grounded applies both within Article 690 and throughout the Code, therefore it should be moved to Article 100. The defined term is used in multiple Articles, and is foundational in usage in Articles 690 and 705, requiring that it remain under the purview of CMP-4.

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Submitter Information Verification

Submitter Full Name: Evelyn Butler
Organization: Solar Energy Industries Assn
Affiliation: PV Industry Forum (PVIF)
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 09 10:40:51 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9324-NFPA 70-2021

Statement: This revision moves all definitions previously in Section 2 of Articles 690, 692, 694 and 705 to Article 100.

The NEC Style Manual also requires that for definitions that apply in only one article, the article number in parentheses shall follow the definition.

CMP-4 identified the following definitions that apply to only one article:

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692: Fuel Cell Output Circuit

694: Maximum Output Power, Maximum Voltage, Nacelle, Rated Power, Tower, Wind Turbine Output Circuit.

These have been moved to Article 100 with the relevant article number appended. All other definitions have been moved with no article number identified.

All definitions were moved with the annotation (CMP-4) appended to indicate the code panel responsible for the definition in accordance with NEC Style Manual Section 2.2.2.3.3.

Public Input No. 4548-NFPA 70-2020 [Definition: Grounded, Functionally.]

Grounded, Functionally.

A system that has an electrical ground reference for operational purposes that is not solidly grounded.

Informational Note: A functionally grounded system is often connected to ground through an electronic means internal to an inverter or charge controller that provides ground-fault protection. Examples of operational purposes for functionally grounded systems include ground-fault detection and performance-related issues for some power sources.

Additional Proposed Changes

File Name	Description	Approved
Functional_Ground_Dwg.pdf	A Visual representation showing what a functionally grounded system might look like	

Statement of Problem and Substantiation for Public Input

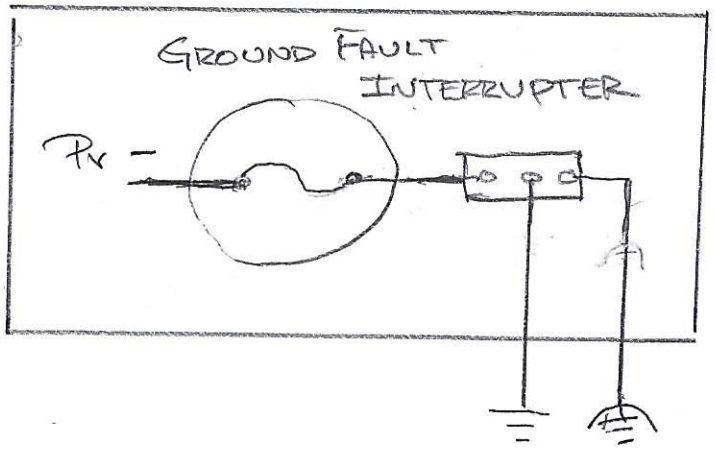
The term functionally grounded is not well defined and there are no readily available drawings depicting what or how it is installed or used. The NEC is used primarily by installers and a visual representation of how this grounding method is installed is necessary for proper installation of the system.

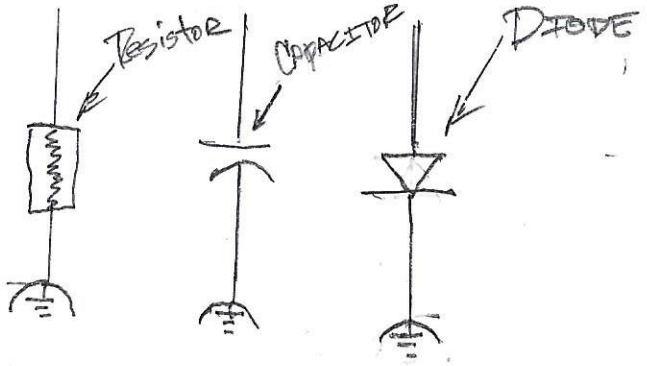
Submitter Information Verification

Submitter Full Name: Wendell Whistler
Organization: IBEW Local 280
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 10 14:57:59 EDT 2020
Committee: NEC-P04

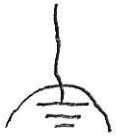
Committee Statement

Resolution: The figure is not added to the definition as it is too involved for Article 100.

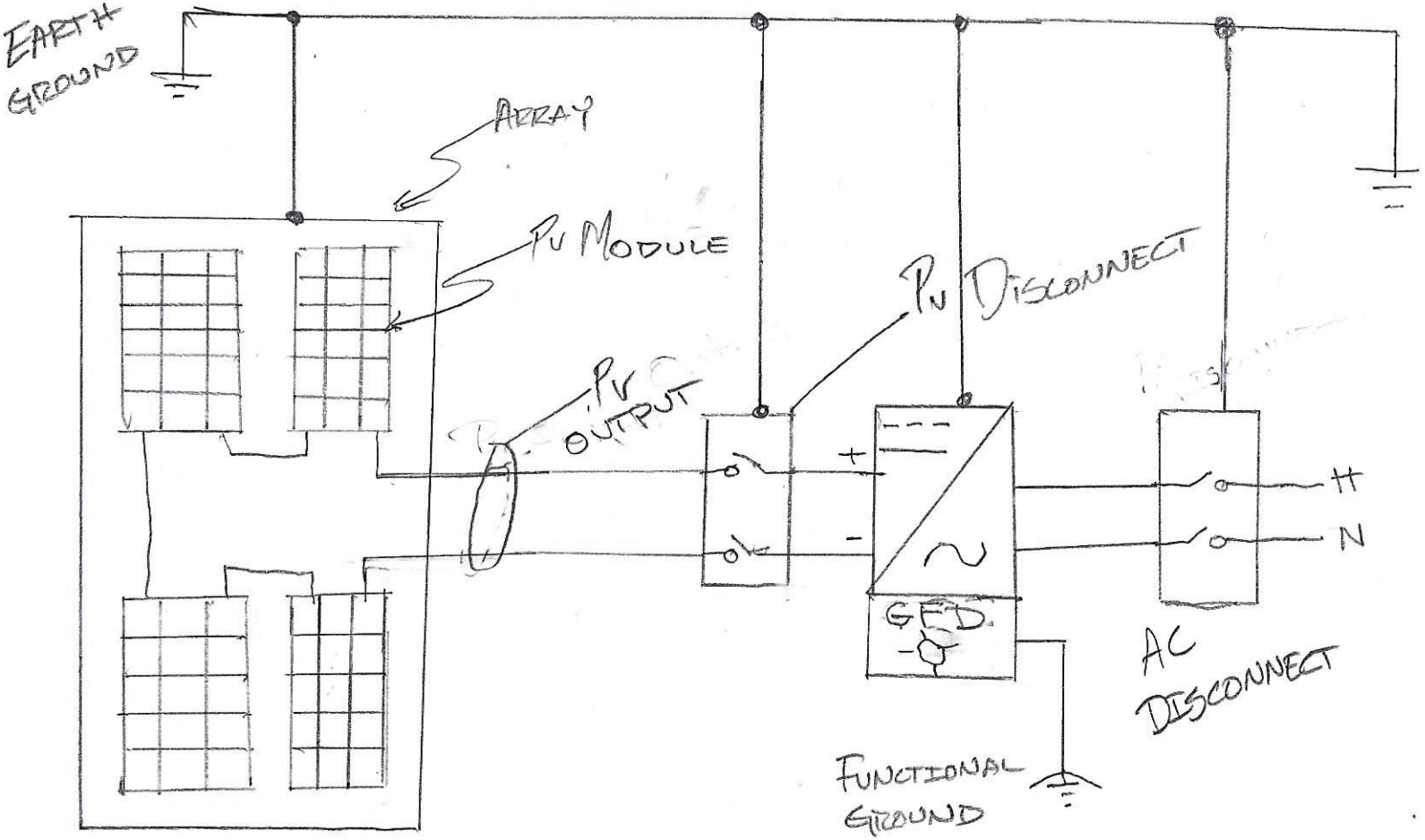




FUNCTIONAL
GROUND CONFIGURATIONS



FUNCTIONAL
GROUND
SYMBOL



Public Input No. 3701-NFPA 70-2020 [Definition: PV Output Circuit.]

~~**PV Output Circuit.**~~

~~The dc circuit conductors from two or more connected PV source circuits to their point of termination.~~

Statement of Problem and Substantiation for Public Input

The definition of PV output circuit as compared to that of PV source circuit has caused confusion among inspectors, installers, and system designers for years. This creation of a separate category for PV output circuits suffers from a lack of clear logic in regards to where source circuits end and an output circuit begins. There are no significant, separate, or differentiating requirements for current calculations, overcurrent protection, or material installation methods in Article 690 that distinguish between PV source and output circuits. Furthermore, the use of the word “output” creates confusion with regards to whether these are dc or ac conductors as Article 705 consistently uses “output” to denote the AC output of a power system.

Historically the term output circuit was used to distinguish between a single PV source circuit and some number of them in parallel, as the output circuit would have a higher maximum circuit current than a single PV source circuit.

However, as system architecture has evolved, there are numerous points where DC PV circuits may be connected in parallel; and sometimes it occurs at multiple locations, with single circuits paralleled, and then the output of these parallel circuits further paralleled; a common example is source circuits paralleled in wiring harnesses, then the output of the harness paralleled with others in a combiner box, then the output of the combiner box is paralleled with other combiner box outputs. In this case, the term “PV output circuit” could be applied to multiple circuits, and this adds no clarity because all these circuits would have different levels of current. In this case, the need to even distinguish between any of the circuits becomes questionable: what is fundamental is knowing the current level in a circuit, and sizing conductors and overcurrent appropriately. Calling different dc PV circuits different names, but in some cases the same name, does not add any functional benefit - it is far better to understand them all as PV source circuits, and base sizing on their specified currents.

Additionally, a PV system, under the current terminology, can have dc PV output circuits, but it doesn’t have to - it may only consist of PV source circuits. If it does have PV output circuits, it does, by current definition, have PV source circuits. It follows that all PV systems have PV source circuits. But those with only PV source circuits don’t have an “output”? This unnecessary confusion evaporates when all of these circuits are simply recognized as circuits in the PV source, with specific currents and voltages that the system designer must determine and use as the basis for conductor and overcurrent device calculations.

With one exception (noted below with associated PI), there are no differentiating requirements for current calculations, overcurrent protection, or material installation methods in Article 690 that distinguish between PV source and output circuits. It follows that this is an unnecessary distinction that does nothing to improve system safety, but instead just increases complexity and confusion when applying the Code. Therefore, PV output circuit should be deleted as a referenced term, reducing confusion and enhancing usability through brevity.

The only instance where this is not the case is the Exception to Section 690.11 regarding dc arc-fault protection. As such, this PI is submitted in conjunction and coordination with the related PI to update the Exception language and clarify where it applies.

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This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
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Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3705-NFPA 70-2020 [Definition: PV System DC Circuit.]	
Public Input No. 3774-NFPA 70-2020 [Section No. 690.7(C)]	
Public Input No. 4203-NFPA 70-2020 [Section No. 690.31(A)]	

Submitter Information Verification

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Submittal Date: Wed Sep 09 11:06:34 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9428-NFPA 70-2021

Statement: There is no longer any need for this definition so it is deleted. PV source circuits, and the requirements for those, are adequate to describe the dc circuits energized by PV cells. A new definition for PV string circuits has been added for clarity where some unique conditions and requirements exist. Requirements are simplified if all PV module-connected wiring is considered to be a source circuit.

Public Input No. 3705-NFPA 70-2020 [Definition: PV System DC Circuit.]

PV System DC Circuit.

Any dc conductor in PV source ~~circuits,~~ circuits and PV ~~output circuits,~~ dc-to-dc converter ~~source~~ circuits~~, and dc-to-dc converter output circuits~~ .

Statement of Problem and Substantiation for Public Input

This PI is submitted in conjunction with related PIs to update this language to harmonize with the deletion of the PV Output Circuit definition and changes to the DC-to-DC Converter Source and Output Circuit definitions.

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Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3701-NFPA 70-2020 [Definition: PV Output Circuit.]	Deletion of old definition

Public Input No. 4418-NFPA 70-2020 [Section No. 690.1]

Public Input No. 3785-NFPA 70-2020 [Section No. 690.9(C)]

Submitter Information Verification

Submitter Full Name: Evelyn Butler
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Submittal Date: Wed Sep 09 11:09:07 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9429-NFPA 70-2021

Statement: This change supports the simplification of PV circuit types through the removal of the previous PV output circuit term. Since the new PV string circuit is included in the definition of PV source circuits, these two circuits are the only ones needed within this general term. The existing term is modified to better align with the related terms that are sub-parts of this general definition per Section 2.2.2.3 of the NEC Style Manual. Other uses of the term are added in parenthesis per Section 2.2.2.5 of the NEC Style Manual.

Public Input No. 3641-NFPA 70-2020 [New Section after 690.4]

TITLE OF NEW CONTENT

690.4(G) PV Equipment and Systems Installed Over Water

PV equipment and PV systems installed over bodies of water shall be listed for the purpose.

Exception- PV equipment and PV systems on mounted onto fixed structures, including trackers that may occasionally have water under them as the result of heavy rains or flood waters, shall not be required to be listed for installation over bodies of water.

Informational Note: PV equipment and systems intended for installation over bodies of water are evaluated for the increased levels of humidity and mechanical and structural stresses associated with this type of installation.

Statement of Problem and Substantiation for Public Input

Substantiation – It is becoming more common for PV equipment and PV systems to be located within the jurisdiction of the NEC, including locations where additional hazards associated with bodies of water should be evaluated. Requiring these systems to be listed for the specific application ensure these hazards are taken into consideration and facilitate inspection by the local AHJs.

Submitter Information Verification

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Submittal Date: Wed Sep 09 10:02:07 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9199-NFPA 70-2021
Statement: Like all electrical equipment, PV equipment installed on floating structures are likely to be exposed to unique environmental and mechanical conditions. Though there is no single product safety standard in use today for these installations, these projects have been constructed successfully using specialized equipment with ratings matching the environmental conditions and engineering considering the unique application. This new section provides some minimum requirements for designers, installers, and enforcers when considering these applications. All other requirements in this article would still apply, including equipment listings, etc. Since this equipment will often involve wiring that is subjected to movement during normal use, language similar to that addressing unattached rooftop systems found in 690.31(F) has also been added. An informational note is included to highlight unique conditions often found in these systems, and similar to the informational

note in 690.31(F), that a common method to determine expected movement is in the structural design.

Public Input No. 3653-NFPA 70-2020 [New Section after 690.4]

TITLE OF NEW CONTENT

690.4 (H) Interoperability.

Multiple pieces of PV equipment protecting the same PV source circuit(s) shall be listed and rated for compatibility.

Informational Note: Some combinations of PV AFCI and PVRS equipment are incompatible and can reduce or prevent the level of protection each device is required to provide. The equipment instruction manuals identify compatible equipment that has been evaluated as a system to provide the required GFDI, PVRSS and AFCI functionality.

Statement of Problem and Substantiation for Public Input

Substantiation – It has been identified that some PVRS equipment can filter PV Arc Fault signals/signatures, reducing the effectiveness of PVAFCI protection. Some PVRS, PV DC to DC converters and optimizers can generate electrical noise that can mask a PV arc fault signal/signature and reduce the effectiveness of the PVAFCI protection. Some PV Ground fault protection equipment has been found to be ineffective or less effective when paired with some DC to DC converter and optimizer devices.

UL1741 requirements for rapid shutdown equipment require that PVRS equipment and systems that include PVAFCI protection be evaluated as a system to verify compliance with both sets of requirements. UL1699B includes evaluation and testing of PVAFCI equipment with electronics in the PV source circuits. It is important that the combination of these different protective equipment components are evaluated and rated for use together to prevent unintended consequences that can interfere with the protection these devices are required to provide. The equipment instruction manuals should identify the specific compatible equipment that have been evaluated to interoperate properly and provide the required GFDI, PVRSS and AFCI protection.

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Submittal Date: Wed Sep 09 10:09:04 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: This issue is addressed in the listing of PV equipment as is required in Section 690.4(B). The standard governing the listing of equipment should address any interoperability issues. Enforcement relies on the installation instructions included in this listing to enforce the compatibility of products to each other.

Public Input No. 3311-NFPA 70-2020 [Section No. 690.4(B)]

(B) Equipment.

Inverters, electronic power converters, motor generators, PV modules, ac modules and ac module systems, dc combiners, dc-to-dc converters, rapid shutdown equipment, dc circuit controllers, and charge controllers intended for use in PV systems shall be listed or be evaluated for the application and have a field label applied.

Statement of Problem and Substantiation for Public Input

690.2 in the 2020 NEC added the definition of Electronic Power Converter to the list of definitions. Electronic Power Converters are also periodically referenced throughout Article 690. Since the NEC now specifically references Electric Power Converter equipment, such should be added to the list of equipment required to be listed (found under NEC 690.4(B)).

Submitter Information Verification

Submitter Full Name: Doug Smith
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Submittal Date: Mon Sep 07 16:57:15 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9204-NFPA 70-2021 RESPONSE TO PI 3311: The language previously located in 690.51 is not included here as it is duplicative in the listing requirements. RESPONSE TO PI 3044: Adequate substantiation was not provided to justify the proposed requirement in Article 690. CMP-4 requires additional case evidence of the issues in order to further consider a mandatory requirement for SPDs in this section of the code.

Statement: The new definition of electronic power converters allows for the removal of all the items on the list that are covered directly by the definition. Items related PV hazard control are added.

Public Input No. 3684-NFPA 70-2020 [Section No. 690.4(B)]

(B) Equipment.

Inverters, motor generators, PV modules, ac modules and ac module systems, dc combiners, dc-to-dc converters, rapid shutdown equipment, ~~dc~~ PV hazard control equipment, PV hazard control systems, dc circuit controllers, and charge controllers intended for use in PV systems shall be listed or be evaluated for the application and have a field label applied. Modules and ac modules shall be marked in accordance with their listing.

Statement of Problem and Substantiation for Public Input

To increase usability of the NEC, the enforcement requirements for marking of modules and ac modules should be found in one section, and 690.4 generally covers equipment listing requirements for PV systems, including ac modules. Previously, these related requirements for ac modules were found in both Sections 690.4 and 690.51.
This change is part of a larger initiative to group applicable but dispersed information into fewer, but more comprehensive, sections.

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Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3686-NFPA 70-2020 [Section No. 690.51]	Source of module language
Public Input No. 3686-NFPA 70-2020 [Section No. 690.51]	

Submitter Information Verification

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Submittal Date: Wed Sep 09 10:48:15 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9204-NFPA 70-2021 RESPONSE TO PI 3311: The language previously located in 690.51 is not included here as it is duplicative in the listing requirements. RESPONSE TO PI 3044: Adequate substantiation was not provided to justify the proposed requirement in Article 690. CMP-4 requires additional case evidence of the issues in order to further consider a mandatory requirement for SPDs in this section of the code.

Statement: The new definition of electronic power converters allows for the removal of all the items on the list that are covered directly by the definition. Items related PV hazard control are added.

Public Input No. 476-NFPA 70-2020 [Section No. 690.4(C)]

(C) Qualified Personnel.

The installation and maintenance of equipment and all associated wiring and interconnections shall be performed only by qualified persons.

Informational Note: See Article 100 for the definition of *qualified person*.

Statement of Problem and Substantiation for Public Input

The code needs to provide clarity that PV systems not only have to be installed by qualified persons, but the PV system needs to be maintained throughout the equipment's life cycle by qualified persons as well.

Submitter Information Verification

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Submittal Date: Tue Feb 18 11:50:06 EST 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9209-NFPA 70-2021
Statement: These changes align with the definition of qualified persons and includes maintenance as part of any operations.

Public Input No. 3682-NFPA 70-2020 [Section No. 690.4(F)]

(F) Electronic Power Converters Mounted in Not Readily Accessible Locations.

Electronic power converters and their associated devices shall be permitted to be mounted on roofs or other ~~exterior~~ areas that are not readily accessible. Disconnecting means shall be installed in accordance with 690.15.

Statement of Problem and Substantiation for Public Input

A non-readily accessible location can be either inside or outside of a building. Existing disconnecting means requirements for PV system equipment (690.15), PV systems (690.13), and sources (705.20) makes it irrelevant whether an electronic power converter is located inside or outside. Regardless, this allowance has historically also been applied to electronic power converters located inside that are not readily accessible, such as in high bays or other elevated locations, provided the installation meets the other relevant requirements. Deleting “exterior will clarify this and allow this accepted practice to continue.

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Submittal Date: Wed Sep 09 10:45:31 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9210-NFPA 70-2021
Statement: Deleting “exterior” clarifies that inverters may be installed in non-readily accessible areas in indoor locations as well as outdoor locations.

Public Input No. 1995-NFPA 70-2020 [Section No. 690.7(A)]

(A) Photovoltaic Source and Output Circuits.

In a dc PV source circuit or output circuit, the maximum PV system voltage for that circuit shall be calculated in accordance with one of the following methods:

(1) The sum of the PV module–rated open-circuit voltage of the series-connected modules corrected for the lowest expected ambient temperature using the open-circuit voltage temperature coefficients in accordance with the instructions included in the listing or labeling of the module

(2) For crystalline and multicrystalline silicon modules, the sum of the PV module–rated open-circuit voltage of the series-connected modules corrected for the lowest expected ambient temperature using the correction factors provided in Table 690.7(A)

(3) For PV systems with an inverter generating capacity of ~~100 kW~~ 100 kVA or greater, a documented and stamped PV system design, using an industry standard method maximum voltage calculation provided by a licensed professional electrical engineer

Informational Note No. 1: One source for lowest-expected, ambient temperature design data for various locations is the chapter titled “Extreme Annual Mean Minimum Design Dry Bulb Temperature” found in the *ASHRAE Handbook — Fundamentals,* 2017. These temperature data can be used to calculate maximum voltage.

Informational Note No. 2: One industry standard method for calculating maximum voltage of a PV system is published by Sandia National Laboratories, reference SAND 2004-3535, *Photovoltaic Array Performance Model*.

Table 690.7(A) Voltage Correction Factors for Crystalline and Multicrystalline Silicon Modules

Correction Factors for Ambient Temperatures Below 25°C (77°F). (Multiply the rated open-circuit voltage by the appropriate correction factor shown below.)		
Ambient Temperature (°C)	Factor	Ambient Temperature (°F)
24 to 20	1.02	76 to 68
19 to 15	1.04	67 to 59
14 to 10	1.06	58 to 50
9 to 5	1.08	49 to 41
4 to 0	1.10	40 to 32
–1 to –5	1.12	31 to 23
–6 to –10	1.14	22 to 14
–11 to –15	1.16	13 to 5
–16 to –20	1.18	4 to –4
–21 to –25	1.20	–5 to –13
–26 to –30	1.21	–14 to –22
–31 to –35	1.23	–23 to –31
–36 to –40	1.25	–32 to –40

Statement of Problem and Substantiation for Public Input

Problem: Many inverters are available with kVA ratings that are greater than their kW ratings. Example, the CPS SCH100/125KTL-DO/US-600 which is rated as 125kW and 132kVA AC output.
Solution: Since the generating capacity should represent the maximum capacity of the system it would be

correct to use the higher volt-ampere rating of the inverter as the maximum output. Where inverter output is rated only in watts the volt-ampere will be equal to the watt rating and the volt-ampere unit is still the correct unit to use.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 1993-NFPA 70-2020 [Definition: Generating Capacity, Inverter.]	Paired change
Public Input No. 1996-NFPA 70-2020 [Section No. 690.8(A)(1)]	Paired change
Public Input No. 1993-NFPA 70-2020 [Definition: Generating Capacity, Inverter.]	
Public Input No. 1996-NFPA 70-2020 [Section No. 690.8(A)(1)]	

Submitter Information Verification

Submitter Full Name: Marvin Hamon
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Submittal Date: Fri Jul 24 12:02:19 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: The proposed revision would not add clarity to this section. The conventional method of specifying generating capacity is power in watts. A safety issue with the current language was not identified.

Public Input No. 3729-NFPA 70-2020 [Section No. 690.7(A)]

(A) Photovoltaic Source ~~and Output~~ Circuits.

In a dc PV source circuit ~~or output circuit,~~ the maximum PV system voltage for that circuit shall be calculated in accordance with one of the following methods:

(1) The sum of the PV module–rated open-circuit voltage of the series-connected modules corrected for the lowest expected ambient temperature using the open-circuit voltage temperature coefficients in accordance with the instructions included in the listing or labeling of the module

(2) For crystalline and multicrystalline silicon modules, the sum of the PV module–rated open-circuit voltage of the series-connected modules corrected for the lowest expected ambient temperature using the correction factors provided in Table 690.7(A)

(3) For PV systems with an inverter generating capacity of 100 kW or greater, a documented and stamped PV system design, using an industry standard method maximum voltage calculation provided by a licensed professional electrical engineer

Informational Note No. 1: One source for lowest-expected, ambient temperature design data for various locations is the chapter titled “Extreme Annual Mean Minimum Design Dry Bulb Temperature” found in the *ASHRAE Handbook — Fundamentals,* 2017. These temperature data can be used to calculate maximum voltage.

Informational Note No. 2: One industry standard method for calculating maximum voltage of a PV system is published by Sandia National Laboratories, reference SAND 2004-3535, *Photovoltaic Array Performance Model*.

Table 690.7(A) Voltage Correction Factors for Crystalline and Multicrystalline Silicon Modules

Correction Factors for Ambient Temperatures Below 25°C (77°F). (Multiply the rated open-circuit voltage by the appropriate correction factor shown below.)		
Ambient Temperature (°C)	Factor	Ambient Temperature (°F)
24 to 20	1.02	76 to 68
19 to 15	1.04	67 to 59
14 to 10	1.06	58 to 50
9 to 5	1.08	49 to 41
4 to 0	1.10	40 to 32
–1 to –5	1.12	31 to 23
–6 to –10	1.14	22 to 14
–11 to –15	1.16	13 to 5
–16 to –20	1.18	4 to –4
–21 to –25	1.20	–5 to –13
–26 to –30	1.21	–14 to –22
–31 to –35	1.23	–23 to –31
–36 to –40	1.25	–32 to –40

Statement of Problem and Substantiation for Public Input

This PI is submitted in conjunction with the related PIs to update this language to harmonize with the deletion of the PV Output Circuit definition.

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Committee: NEC-P04

Committee Statement

Resolution: FR-9433-NFPA 70-2021
Statement: This change updates this section language to recognize the deletion of the PV Output Circuit definition and the addition of the new defined term PV String Circuit. Additional changes are made to improve readability.

Public Input No. 3770-NFPA 70-2020 [Section No. 690.7(B)]

(B) DC-to-DC Converter ~~Source and Output~~ Circuits.

In a PV dc-to-dc converter ~~source and output circuit~~ circuits , the maximum voltage shall be calculated in accordance with 690.7(B)(1) or (B)(2).

(1) Single DC-to-DC Converter.

For circuits connected to the output of a single dc-to-dc converter, the maximum voltage shall be determined in accordance with the instructions included in the listing or labeling of the dc-to-dc converter. If the instructions do not provide a method to determine the maximum voltage, the maximum voltage shall be the maximum rated voltage output of the dc-to-dc converter.

(2) Two or More Series-Connected DC-to-DC Converters.

For circuits connected to the output of two or more series-connected dc-to-dc converters, the maximum voltage shall be determined in accordance with the instructions included in the listing or labeling of the dc-to-dc converter. If the instructions do not provide a method to determine the maximum voltage, the maximum voltage shall be the sum of the maximum rated voltage output of the dc-to-dc converters in series.

Statement of Problem and Substantiation for Public Input

This PI is submitted in conjunction with the related PIs, to update this language to harmonize with the changes to the DC-to-DC Converter Source and Output Circuit definitions

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
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Committee: NEC-P04

Committee Statement

Resolution: FR-9434-NFPA 70-2021
Statement: This action updates the language in this section to harmonize with the changes to the previous DC-to-DC Converter Source and Output Circuit definitions. The single DC-to-DC Converter Circuit applies to all cases addressed in this section.

Public Input No. 3774-NFPA 70-2020 [Section No. 690.7(C)]

(C) Bipolar Source ~~and Output~~ Circuits.

For monopole subarrays in bipolar systems, the maximum voltage shall be the highest voltage between the monopole subarray circuit conductors where one conductor of the monopole subarray circuit is connected to the functionally grounded reference. To prevent overvoltage in the event of a ground fault or arc fault, the monopole subarray circuits shall be isolated from ground.

Statement of Problem and Substantiation for Public Input

Following on the same logic as the related PI, the need to distinguish between bipolar source and output circuits is both unnecessary, and impractical to apply due to variations in system architecture, including where single or multiple points of parallel occur on the dc side of a PV system. Having clear circuit current values for sizing conductors and overcurrent protection is critical to system safety, not trying to decide if a circuit is a source or output circuit, when in some circumstances it could be called either.

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Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3701-NFPA 70-2020 [Definition: PV Output Circuit.]	deletion of old term

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Committee: NEC-P04

Committee Statement

Resolution: FR-9436-NFPA 70-2021

Statement: Changes are made here to align with the deletion of the term PV output circuits. The single term PV source circuit is adequate to describe these circuits. The word subarray is removed in several locations since it is not included in the defined term “monopole circuit”.

Public Input No. 3622-NFPA 70-2020 [Section No. 690.7 [Excluding any Sub-Sections]]

The maximum voltage of PV system dc circuits shall be the highest voltage between any two conductors of a circuit or any conductor and ground. The maximum voltage shall be used to determine the voltage and voltage to ground of circuits in the application of this Code . Maximum voltage shall be used for conductors, cables, equipment, working space, and other applications where voltage limits and ratings are used.

PV system dc circuits within or originating from arrays located on or

~~in buildings shall be permitted to~~

attached to buildings, and PV system dc circuits inside buildings, shall have a maximum voltage no greater than 1000 volts. PV system dc circuits on or in one- and two-family dwellings shall

~~be permitted to~~

have a maximum voltage no greater than 600 volts.

~~Where not located on or in buildings, listed dc PV equipment, rated at~~

. PV system dc circuits with a maximum voltage

~~no~~

greater than

~~1500 volts, shall not be required to comply with Parts II and III of Article 490.~~

1000 volts shall comply with 690.31(G).

Additional Proposed Changes

File Name	Description	Approved
690_max_voltage_correct_text.pdf	690.7 revised text as it should be shown	

Statement of Problem and Substantiation for Public Input

This text modifies the phrase “on or in buildings” to clarify requirements of ground-mounted arrays interfacing with buildings.
Maximum System Voltage requirements have intended to differentiate the nature of risks between one- and two-family dwellings, commercial/ industrial buildings, and ground mounted PV arrays. With PV arrays mounted on buildings and dc wires within a building there are unique concerns over electrical shock risks since the conductors may be concealed. Ground-mounted PV arrays and equipment do not have the same risks since the circuits are not concealed behind building surface finishes, etc.
Ground-mounted PV arrays with a maximum system voltage of 1500 Vdc are becoming more common in commercial and industrial (C&I) applications. Often these arrays are located near commercial and industrial buildings, such as a PV array carport structure in a parking lot. It should be permitted to attach some equipment (e.g. inverters) on the outside wall of a building when there are area limitations, or necessary equipment clearances, or where constructing a concrete pad to support the equipment is not possible. The industry trend of 1500 Vdc ground-mounted arrays located near buildings creates a need to clarify Code language around ground-mounted arrays interfacing with buildings.
Currently, it is permitted to install >1000 Vdc equipment mere inches from a building, but it is not permitted to install this equipment on the exterior wall of a building. Providing an allowance to locate these circuits outside but attached to buildings, but never within buildings, provides the clarity needed to apply the voltage restrictions in this section. This allowance would not apply to one- or two- family dwellings. PV arrays installed on a rooftop or integrated in a building and any PV system dc circuits inside a building would remain limited to 600Vdc for one- or two- family dwellings and 1000 Vdc for other buildings.

The language on listed dc PV equipment up to 1500 Vdc not requiring compliance with Article 490 is proposed to be moved to a new subsection 690.31(G). As 690.31 concerns wiring methods and equipment requirements, it is a more relevant section for specifications of equipment over 1000 volts, similar to Article 490. Furthermore, the new subsection 690.31(G) covers the limitations stated above for dc circuits >1000 Vdc mounted on the outside wall of a building. Specific limitations are included there that the conductors be installed within a limited distance above grade to prevent this allowance be used for overhead conductors; inaccessibility of equipment to unqualified persons (referencing 110.31); and limiting the extent of wiring and equipment that can be attached to the outside of the building.

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Committee: NEC-P04

Committee Statement

Resolution: FR-9213-NFPA 70-2021

Statement: This revision modifies the language for clarity and deletes the requirements for systems over 1000 volts which are now included in wiring methods.

690.7 Maximum Voltage.
The maximum voltage of PV system dc circuits shall be the highest voltage between any two conductors of a circuit or any conductor and ground. The maximum voltage shall be used to determine the voltage and voltage to ground of circuits in the application of this Code. Maximum voltage shall be used for conductors, cables, equipment, working space, and other applications where voltage limits and ratings are used.

PV system dc circuits within or originating from arrays located on or ~~in~~ attached to buildings and PV system dc circuits inside buildings shall ~~be permitted to~~ have a maximum voltage no greater than 1000 volts. PV system dc circuits on or in one- and two-family dwellings shall ~~be permitted to~~ have a maximum voltage no greater than 600 volts. ~~Where not located on or in buildings, listed dc PV equipment, rated at a maximum voltage no greater than 1500 volts, shall not be required to comply with Parts II and III of Article 490.~~ PV system dc circuits with a maximum voltage greater than 1000 volts shall comply with 690.31(G).

Public Input No. 202-NFPA 70-2019 [Section No. 690.8]

690.8 Circuit Sizing and Current.

(A) Calculation of Maximum Circuit Current.

The maximum current for the specific circuit shall be calculated in accordance with one of the methods in 690.8(A)(1) or (A)(2). Currents calculated as part of 690.8 shall be considered continuous loads for the purposes of sizing of conductors and selection of overcurrent protective devices.

(1) PV System Circuits.

The maximum current shall be calculated in accordance with 690.8(A)(1)(a) through (A)(1)(e).

(a) *Photovoltaic Source Circuit Currents* The maximum current shall be as calculated in either of the following:

(2) The maximum current shall be the sum of the short-circuit current ratings of the PV modules connected in parallel multiplied by 125 percent.

(3) For PV systems with an inverter generating capacity of 100 kW or greater, a documented and stamped PV system design, using an industry standard method maximum current calculation provided by a licensed professional electrical engineer, shall be permitted. The calculated maximum current value shall be based on the highest 3-hour current average resulting from the simulated local irradiance on the PV array accounting for elevation and orientation. The current value used by this method shall not be less than 70 percent of the value calculated using 690.8(A)(1) (a)(1).

Informational Note: One industry standard method for calculating maximum current of a PV system is available from Sandia National Laboratories, reference SAND 2004-3535, *Photovoltaic Array Performance Model*. This model is used by the System Advisor Model simulation program provided by the National Renewable Energy Laboratory.

(d) *Photovoltaic Output Circuit Currents.* The maximum current shall be the sum of parallel source circuit maximum currents as calculated in 690.8(A)(1)(a).

(e) *DC-to-DC Converter Source Circuit Current.* The maximum current shall be the dc-to-dc converter continuous output current rating.

(f) *DC-to-DC Converter Output Circuit Current.* The maximum current shall be the sum of parallel connected dc-to-dc converter source circuit currents as calculated in 690.8(A)(1)(c).

(g) *Inverter Output Circuit Current.* The maximum current shall be the inverter continuous output current rating.

(2) Circuits Connected to the Input of Electronic Power Converters.

Where a circuit is protected with an overcurrent device not exceeding the conductor ampacity, the maximum current shall be permitted to be the rated input current of the electronic power converter input to which it is connected.

(B) Conductor Ampacity.

Circuit conductors shall be sized ~~to carry not less than the larger ampacity calculated~~ in accordance with ~~690.8(B)(1) or (B)(2).~~

~~**(1)** Without Adjustment and Correction Factors.~~

~~The maximum currents calculated in 690.8(A) multiplied by 125 percent without adjustment or correction factors.~~

~~*Exception: Circuits containing an assembly, together with its overcurrent device(s), that is listed for continuous operation at 100 percent of its rating shall be permitted to be used at 100 percent of its rating.*~~

~~**(2)** With Adjustment and Correction Factors.~~

~~The maximum currents calculated in 690.8(A) with adjustment and correction factors.~~

~~(~~

210.19 or 215.2.

(C) Systems with Multiple Direct-Current Voltages.

For a PV power source that has multiple output circuit voltages and employs a common-return conductor, the ampacity of the common-return conductor shall not be less than the sum of the ampere ratings of the overcurrent devices of the individual output circuits.

(D) Sizing of Module Interconnection Conductors.

Where a single overcurrent device is used to protect a set of two or more parallel-connected module circuits, the ampacity of each of the module interconnection conductors shall not be less than the sum of the rating of the single overcurrent device plus 125 percent of the short-circuit current from the other parallel-connected modules.

Statement of Problem and Substantiation for Public Input

The public input is not intended as a technical change but rather meant to better align these requirements with Chapters 1 through 4. Ampacity calculations are addressed in Article 210 for branch circuits and 215 for feeders. The only difference between earlier chapters and these article 705 requirements are found in how we calculate maximum currents as found in 690.8(A). The change in 690.8(A) makes it clear that these currents are to be considered as continuous load currents facilitating the application of 210.19 and 215.2.

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Committee: NEC-P04

Committee Statement

Resolution: There is no need to restate of the general ampacity requirements for conductors.

Public Input No. 1996-NFPA 70-2020 [Section No. 690.8(A)(1)]

(1) PV System Circuits.

The maximum current shall be calculated in accordance with 690.8(A)(1)(a) through (A)(1)(e).

(a) *Photovoltaic Source Circuit Currents* The maximum current shall be as calculated in either of the following:

(2) The maximum current shall be the sum of the short-circuit current ratings of the PV modules connected in parallel multiplied by 125 percent.

(3) For PV systems with an inverter generating capacity of

~~100 kW~~

(1) 100 kVA or greater, a documented and stamped PV system design, using an industry standard method maximum current calculation provided by a licensed professional electrical engineer, shall be permitted. The calculated maximum current value shall be based on the highest 3-hour current average resulting from the simulated local irradiance on the PV array accounting for elevation and orientation. The current value used by this method shall not be less than 70 percent of the value calculated using 690.8(A)(1) (a)(1).

Informational Note: One industry standard method for calculating maximum current of a PV system is available from Sandia National Laboratories, reference SAND 2004-3535, *Photovoltaic Array Performance Model*. This model is used by the System Advisor Model simulation program provided by the National Renewable Energy Laboratory.

(d) *Photovoltaic Output Circuit Currents.* The maximum current shall be the sum of parallel source circuit maximum currents as calculated in 690.8(A)(1)(a).

(e) *DC-to-DC Converter Source Circuit Current.* The maximum current shall be the dc-to-dc converter continuous output current rating.

(f) *DC-to-DC Converter Output Circuit Current.* The maximum current shall be the sum of parallel connected dc-to-dc converter source circuit currents as calculated in 690.8(A)(1)(c).

(g) *Inverter Output Circuit Current.* The maximum current shall be the inverter continuous output current rating.

Additional Proposed Changes

File Name	Description	Approved
690.8_1_Proposal.docx	Correct markup of proposal	

Statement of Problem and Substantiation for Public Input

TerraView is not showing the correct markup of the proposal, see attached Word file for correct markup.
Problem: Many inverters are available with kVA ratings that are greater than their kW ratings. Example, the CPS SCH100/125KTL-DO/US-600 which is rated as 125kW and 132kVA AC output.
Solution: Since the generating capacity should represent the maximum capacity of the system it would be correct to use the higher volt-ampere rating of the inverter as the maximum output. Where inverter output is rated only in watts the volt-ampere will be equal to the watt rating and the volt-ampere unit is still the correct unit to use.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 1993-NFPA 70-2020 [Definition: Generating Capacity, Inverter.]	Paired change
Public Input No. 1995-NFPA 70-2020 [Section No. 690.7(A)]	Paired change
Public Input No. 1993-NFPA 70-2020 [Definition: Generating Capacity, Inverter.]	
Public Input No. 1995-NFPA 70-2020 [Section No. 690.7(A)]	

Submitter Information Verification

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Organization: Pure Power Engineering
Street Address:
City:
State:
Zip:
Submittal Date: Fri Jul 24 12:10:02 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: The proposed revision would not add clarity to this section. The conventional method of specifying generating capacity is power in watts. A safety issue with the current language was not identified.

(1) PV System Circuits.
The maximum current shall be calculated in accordance with 690.8(A)(1)(a) through (A)(1)(e).

1. *Photovoltaic Source Circuit Currents* The maximum current shall be as calculated in either of the following:
    1. The maximum current shall be the sum of the short-circuit current ratings of the PV modules connected in parallel multiplied by 125 percent.
    2. For PV systems with an inverter generating capacity of 100 ~~kW~~ kVA or greater, a documented and stamped PV system design, using an industry standard method maximum current calculation provided by a licensed professional electrical engineer, shall be permitted. The calculated maximum current value shall be based on the highest 3-hour current average resulting from the simulated local irradiance on the PV array accounting for elevation and orientation. The current value used by this method shall not be less than 70 percent of the value calculated using 690.8(A)(1)(a)(1).

    Informational Note: One industry standard method for calculating maximum current of a PV system is available from Sandia National Laboratories, reference SAND 2004-3535, *Photovoltaic Array Performance Model*. This model is used by the System Advisor Model simulation program provided by the National Renewable Energy Laboratory.

2. *Photovoltaic Output Circuit Currents.* The maximum current shall be the sum of parallel source circuit maximum currents as calculated in 690.8(A)(1)(a).
3. *DC-to-DC Converter Source Circuit Current.* The maximum current shall be the dc-to-dc converter continuous output current rating.
4. *DC-to-DC Converter Output Circuit Current.* The maximum current shall be the sum of parallel connected dc-to-dc converter source circuit currents as calculated in 690.8(A)(1)(c).
5. *Inverter Output Circuit Current.* The maximum current shall be the inverter continuous output current rating.

Public Input No. 2411-NFPA 70-2020 [Section No. 690.8(A)(1)]

(1) PV System Circuits.

The maximum current shall be calculated in accordance with 690.8(A)(1)(a) through (A)(1)(e).

(a) *Photovoltaic Source Circuit Currents* The maximum current shall be as calculated in either of the following:

(2) The maximum current shall be the sum of the short-circuit current ratings of the PV modules connected in parallel multiplied by 125 percent.

(3) For PV systems with an inverter generating capacity of 100 kW or greater,

~~a documented and stamped PV system design, using~~

(1) using an industry standard method maximum current calculation shall be permitted if provided by a licensed professional electrical engineer,

~~shall be permitted~~

(1) documented and stamped . The calculated maximum current value shall be based on the highest 3-hour current average resulting from the simulated local irradiance on the PV array accounting for elevation and orientation. The current value used by this method shall not be less than 70 percent of the value calculated using 690.8(A)(1) (a)(1).

Informational Note: One industry standard method for calculating maximum current of a PV system is available from Sandia National Laboratories, reference SAND 2004-3535, *Photovoltaic Array Performance Model*. This model is used by the System Advisor Model simulation program provided by the National Renewable Energy Laboratory.

(d) *Photovoltaic Output Circuit Currents.* The maximum current shall be the sum of parallel source circuit maximum currents as calculated in 690.8(A)(1)(a).

(e) *DC-to-DC Converter Source Circuit Current.* The maximum current shall be the dc-to-dc converter continuous output current rating.

(f) *DC-to-DC Converter Output Circuit Current.* The maximum current shall be the sum of parallel connected dc-to-dc converter source circuit currents as calculated in 690.8(A)(1)(c).

(g) *Inverter Output Circuit Current.* The maximum current shall be the inverter continuous output current rating.

Statement of Problem and Substantiation for Public Input

To say that an engineered design with sealed design documentation "is permitted" is not actually stating that anything is required. It appears that a requirement intent needs to be stated more clearly.

Submitter Information Verification

Submitter Full Name: John Blissett
Organization: Bernhard TME
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State:

Zip:
Submittal Date: Wed Aug 19 17:28:21 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: The proposed revision would not add clarity to this section or additional safety.

Public Input No. 3645-NFPA 70-2020 [Section No. 690.8(A)(1)]

(1) PV System Circuits.

The maximum current shall be calculated in accordance with 690.8(A)(1)(a) through (A)(1)(~~e~~ c).

(a) *Photovoltaic Source Circuit Currents* The maximum current shall be as calculated in either of the following:

(2) The maximum current shall be the sum of the short-circuit current ratings of the PV modules connected in parallel multiplied by 125 percent.

(3) For PV systems with an inverter generating capacity of 100 kW or greater, a documented and stamped PV system design, using an industry standard method maximum current calculation provided by a licensed professional electrical engineer, shall be permitted. The calculated maximum current value shall be based on the highest 3-hour current average resulting from the simulated local irradiance on the PV array accounting for elevation and orientation. The current value used by this method shall not be less than 70 percent of the value calculated using 690.8(A)(1) (a)(1).

Informational Note: One industry standard method for calculating maximum current of a PV system is available from Sandia National Laboratories, reference SAND 2004-3535, *Photovoltaic Array Performance Model*. This model is used by the System Advisor Model simulation program provided by the National Renewable Energy Laboratory.

(d) ~~*Photovoltaic Output Circuit Currents.* The maximum current shall be the sum of parallel source circuit maximum currents as calculated in 690.8(A)(1) (a).~~

(e) *PV DC-to-DC Converter* ~~Source~~

(f) *Circuit Current.* The maximum current shall be the ~~dc-to-dc converter continuous output current rating.~~

(g) ~~*DC-to-DC Converter Output Circuit Current.* The maximum current shall be the~~ sum of parallel connected dc-to-dc converter ~~source circuit currents as calculated in 690.8(A)(1) (c).~~ continuous output current ratings.

(h) *Inverter Output Circuit Current.* The maximum current shall be the inverter continuous output current ~~rating. ratings.~~

Informational Note: Modules that can produce electricity when exposed to light on multiple surfaces are labeled with applicable short-circuit currents. Additional guidance is provided in the instructions included with the listing.

Additional Proposed Changes

File Name	Description	Approved
690_8_A_1_correct_text.pdf	Correct text changes.	

Statement of Problem and Substantiation for Public Input

Note that the formatting shown in the legislative text is not accurate, no changes are being proposed to the existing text in (a). This input deletes a couple of items since the definitions for those circuits are deleted in related PIs plus it seeks to add a new informational note. Please see attached file for correct text.
This PI is submitted in conjunction with the related PIs, to update this language to harmonize with the

deletion of the PV Output Circuit definition and changes to the DC-to-DC Converter Source and Output Circuit definitions.

Making it clear that current needs to be considered for each circuit in a system is the best way to ensure adequate conductor and overcurrent protection device sizes, rather than trying to distinguish between circuit terminology that may not be clear for a large number of systems.

Regarding the IN, modules that can produce electricity when exposed to light on multiple surfaces may have higher short-circuit current ratings relative to ratings that are based solely on front-side illumination. Such modules will be labeled with appropriate short-circuit current ratings as required by the applicable safety standard (UL 61730), and the manual that is relied upon for the listing will contain additional guidance to guide designers.
Modules that can produce electricity when exposed to light on multiple surfaces may be installed in a manner that prevents light to reaching any surface other than the front, such as modules mounted flush to and in close proximity to a supporting surface. In such cases, the short-circuit current rating as it is traditionally measured based on illuminating only the front of the module is appropriate.
This new IN seeks to guide users of this Code to refer to the instructions included with the module listing for guidance on applying this section.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain, P.E., SEIA; Bill Brooks, Brooks Engineering/PVICC; Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing, Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower; Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Ben Chamberlain, Olivewood Energy; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

Submitter Information Verification

Submitter Full Name: Evelyn Butler

Organization: Solar Energy Industries Assn

Affiliation: PV Industry Forum (PVIF)
Street Address:
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Submittal Date: Wed Sep 09 10:04:47 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9437-NFPA 70-2021

Statement: This change deletes list items for circuit definitions that are deleted in other sections of Article 690. A new informational note is added to recognize modules that can produce electricity when exposed to light on multiple surfaces. Since these modules may have higher short-circuit current ratings relative to ratings that are based solely on front-side illumination, this note is to inform users of this Code that those modules will be labeled with appropriate short-circuit current ratings as required by the applicable safety standard. This new IN seeks to guide users of this Code to refer to the instructions included with the module listing for guidance on applying this section.

Text Changes:

690.8(A)(1) PV System Circuits.
The maximum current shall be calculated in accordance with 690.8(A)(1)(a) through (A)(1)(~~e~~c).

a. *Photovoltaic Source Circuit Currents.* The maximum current shall be as calculated in either of the following:
   1. The maximum current shall be the sum of the short-circuit current ratings of the PV modules connected in parallel multiplied by 125 percent.
   2. For PV systems with an inverter generating capacity of 100 kW or greater, a documented and stamped PV system design, using an industry standard method maximum current calculation provided by a licensed professional electrical engineer, shall be permitted. The calculated maximum current value shall be based on the highest 3-hour current average resulting from the simulated local irradiance on the PV array accounting for elevation and orientation. The current value used by this method shall not be less than 70 percent of the value calculated using 690.8(A)(1)(a)(1).

Informational Note: One industry standard method for calculating maximum current of a PV system is available from Sandia National Laboratories, reference SAND 2004-3535, *Photovoltaic Array Performance Model*. This model is used by the System Advisor Model simulation program provided by the National Renewable Energy Laboratory.

~~(b) *Photovoltaic Output Circuit Currents.* The maximum current shall be the sum of parallel source circuit maximum currents as calculated in 690.8(A)(1)(a).~~

~~(cb) *DC-to-DC Converter Source Circuit Current.* The maximum current shall be the dc-to-dc converter continuous output current rating.~~

(~~d~~b) PV *DC-to-DC Converter ~~Output~~ Circuit Current.* The maximum current shall be the sum of parallel connected dc-to-dc converter continuous output current ratings ~~source circuit currents as calculated in 690.8(A)(1)(cb)~~.

(~~e~~c) *Inverter Output Circuit Current.* The maximum current shall be the sum of the continuous output current ratings of inverters connected in parallel to a single set of circuit conductors.

Informational Note: Modules that can produce electricity when exposed to light on multiple surfaces are labeled with applicable short-circuit currents. Additional guidance is provided in the instructions included with the listing.

Clean Text:

690.8(A)(1) PV System Circuits.
The maximum current shall be calculated in accordance with 690.8(A)(1)(a) through (A)(1)(c).
(a) Photovoltaic Source Circuit Currents. The maximum current shall be as calculated in either of the following:
1. The maximum current shall be the sum of the short-circuit current ratings of the PV modules connected in parallel multiplied by 125 percent.
2. For PV systems with an inverter generating capacity of 100 kW or greater, a documented and stamped PV system design, using an industry standard method maximum current calculation provided by a licensed professional electrical engineer, shall be permitted. The calculated maximum current value shall be based on the highest 3-hour current average resulting from the simulated local irradiance on the PV array accounting for elevation and orientation. The current value used by this method shall not be less than 70 percent of the value calculated using 690.8(A)(1)(a)(1).

Informational Note: One industry standard method for calculating maximum current of a PV system is available from Sandia National Laboratories, reference SAND 2004-3535, Photovoltaic Array Performance Model. This model is used by the System Advisor Model simulation program provided by the National Renewable Energy Laboratory.

(b) PV DC-to-DC Converter Circuit Current. The maximum current shall be the sum of parallel connected dc-to-dc converter continuous output current ratings.
(c) Inverter Output Circuit Current. The maximum current shall be the inverter continuous output current rating.

Informational Note: Modules that can produce electricity when exposed to light on multiple surfaces are labeled with applicable short-circuit currents. Additional guidance is provided in the instructions included with the listing.

Public Input No. 200-NFPA 70-2019 [Section No. 690.8(B)]

(B) Conductor Ampacity.

Circuit conductors shall ~~be sized to carry~~ have an ampacity not less than the larger ~~ampacity calculated in accordance with~~ of 690.8(B)(1) or (B)(2) and comply with 110 .14(C) for equipment terminations.

(1) Without Adjustment and Correction Factors.

The minimum conductor size with an ampacity not less than the maximum currents calculated in 690.8(A) multiplied by 125 percent

~~without adjustment or~~

.

(2) With Adjustment and Correction Factors.

The minimum conductor size with an ampacity not less than the maximum currents calculated in 690.8(A) with adjustment and correction factors.

Exception No. 1 to (1) : Circuits containing an assembly, together with its overcurrent device(s), that is listed for continuous operation at 100 percent of its rating shall be permitted to be used at 100 percent of its rating.

Exception No. 2 to (

~~2) With Adjustment and Correction Factors.~~

~~The~~

~~1) and (2): Where a portion of a branch circuit is connected at both its supply and load ends to separately installed pressure connections as covered in 110.14(C)(2), it shall be permitted to have an allowable ampacity, in accordance with 310.15, not less than the maximum currents calculated in 690.8(A)~~

~~with adjustment and correction factors.~~

~~. No portion of a branch circuit installed under this exception shall extend into an enclosure containing either the branch-circuit supply or the branch-circuit load terminations.~~

Statement of Problem and Substantiation for Public Input

This public input does not seek to make a technical change to this section but provide better language for useability. The langauge being proposed better alighns with language found in other areas of the NEC such as Articles 210 for branch circuits and 215 for feeders.

Submitter Information Verification

Submitter Full Name: Thomas Domitrovich
Organization: Eaton Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Sun Dec 22 17:05:24 EST 2019
Committee: NEC-P04

Committee Statement

Resolution: FR-9217-NFPA 70-2021
Statement: The revised language better aligns with ampacity language found in Chapter 2.

Public Input No. 208-NFPA 70-2019 [Section No. 690.9(B)]

(B) Device Ratings.

Overcurrent devices used in PV system dc circuits shall be listed for use in PV systems. Electronic devices that are listed to prevent backfeed current in PV system dc circuits shall be permitted to prevent overcurrent of conductors on the PV array side of the device. ~~Overcurrent devices, where required, shall be rated in accordance with one of the following and permitted to be rounded up to the next higher standard size in accordance with 240.4(B) :~~

- ~~Not less than 125 percent of the maximum currents calculated in 690.8(A) .~~
- ~~An assembly, together with its overcurrent device(s), that is listed for continuous operation at 100 percent of its rating shall be permitted to be used at 100 percent of its rating.~~

Informational Note: Some electronic devices prevent backfeed current, which in some cases is the only source of overcurrent in PV system dc circuits.

Statement of Problem and Substantiation for Public Input

Proper selection of an overcurrent protective device is addressed in Article 240. Conductors must be protected at their ampacity.

Submitter Information Verification

Submitter Full Name: Thomas Domitrovich
Organization: Eaton Corporation
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City:
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Submittal Date: Thu Dec 26 21:15:58 EST 2019
Committee: NEC-P04

Committee Statement

Resolution: Existing NEC language provides clarity and usability for proper application of the code.

Public Input No. 3812-NFPA 70-2020 [Section No. 690.9(B)]

(B) Device Ratings.

Overcurrent devices used in PV ~~system dc circuits~~ source circuits shall be listed for use in PV systems. Electronic devices that are listed to prevent backfeed current in PV system dc circuits shall be permitted to prevent overcurrent of conductors on the PV array side of the device. Overcurrent devices, where required, shall be rated in accordance with one of the following and permitted to be rounded up to the next higher standard size in accordance with 240.4(B):

(1) Not less than 125 percent of the maximum currents calculated in 690.8(A).

(2) An assembly, together with its overcurrent device(s), that is listed for continuous operation at 100 percent of its rating shall be permitted to be used at 100 percent of its rating.

Informational Note: Some electronic devices prevent backfeed current, which in some cases is the only source of overcurrent in PV system dc circuits.

Statement of Problem and Substantiation for Public Input

This PI constrains the requirement of PV-rated overcurrent devices to PV source circuits. This excludes dc-to-dc converter circuits that do not have the same characteristics as PV source circuits. The PV Industry Forum is recommending the removal of the term PV output circuits to reduce confusion. This Code should be clear on the application of these special PV-rated devices. Also, the Panel should consider removing this sentence altogether and including this listing requirement in the existing list in 690.4(B).

Submitter Information Verification

Submitter Full Name: William Brooks
Organization: Brooks Engineering
Street Address:
City:
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Submittal Date: Wed Sep 09 13:23:35 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9441-NFPA 70-2021

Statement: This change constrains the requirement of PV-rated overcurrent devices in a PV system to PV source circuits. Since a specific PV rating as applied to overcurrent devices is unique for circuits directly connected to PV cells, this change excludes dc-to-dc converter circuits that do not have the same characteristics as PV source circuits.

Public Input No. 4045-NFPA 70-2020 [New Section after 690.9(C)]

TITLE OF NEW CONTENT

Type your content here ..

690.9(C). Exception. Ungrounded PV DC source and DC output circuits connected to non-isolated utility-interactive inverters which have ground-fault detector/interrupter systems that detect array ground faults only before startup and not during operation, shall have overcurrent protective devices at the inverter input in both polarities of the input conductors.

Statement of Problem and Substantiation for Public Input

Non-isolated utility-interactive inverters used with ungrounded PV arrays and connected to grounded ac services are subject to backfeed currents from the ac service into the dc source and output circuits when ground faults occur in the dc array circuits. Some, but not all ground fault detection and interruption circuits built into the inverters should stop any damage from these ground fault currents. However, at least one major inverter manufacturer (SMA Technologies AG) has the ground fault detection system check for ground faults only before inverter start up. With this ground fault detection and interruption system, ground faults that occur in the daytime during normal inverter operation will not be detected and large backfeed currents may flow from the utility into the either polarity of the dc circuit conductors depending on which conductor has faulted to ground. The instruction manual for these, and possibly other similar inverters, states that any damage (internal to the inverter or external) caused by daytime ground faults will not be covered under warranty. And, due to solar heating and operating currents heating and possibly softening conductor insulation and higher circuit-to-ground voltages during the daytime, ground faults during the day are at least as likely as ground faults occurring at night and possibly more likely. This Section 690.9(C) permits only one conductor to be protected from overcurrents. Obviously, these backflowing ground fault currents may flow in either conductor and therefore both circuit conductors should be protected from back flowing ground fault currents originating from the utility service. A proposal has been made to change UL Standard 1741 to test the ground fault system on all inverters for proper operation during normal daytime inverter operation.

Submitter Information Verification

Submitter Full Name:	John Wiles
Organization:	Southwest Technology Development Institute, New Mexico State University
Street Address:	
City:	
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Submittal Date:	Wed Sep 09 19:02:03 EDT 2020
Committee:	NEC-P04

Committee Statement

Resolution: The proposed language belongs in the product listing standard and is un-enforceable by AHJ.

Public Input No. 3314-NFPA 70-2020 [Section No. 690.9(C)]

(C)– **PV** Source and PV Output Circuits.

A single overcurrent protective device, where required, shall be permitted to protect the PV modules, dc-to-dc converters, and conductors of each PV source circuit or the conductors of each PV output circuit. Where single overcurrent protection devices are used to protect PV source or PV output circuits, all overcurrent devices shall be placed in the same polarity for all circuits within a PV system. The overcurrent devices shall be accessible but shall not be required to be readily accessible.

Informational Note: Due to improved ground-fault protection required in PV systems by 690.41(B), a single overcurrent protective device in either the positive or negative conductors of a PV system in combination with this ground-fault protection provides adequate overcurrent protection.

Statement of Problem and Substantiation for Public Input

The current wording of 690.9(C) uses phrases such as "Source" and "Output" circuits. However, such do not have definitions found under 690.2. The correct wording to use would be "PV Source" and "PV Output" circuits, which definitions are found in 690.2. Also, it would be problematic to leave the phrase "Output Circuits" as currently written in the text since individuals could misinterpret that such is referring to AC output circuits of inverters, which is not correct.

Submitter Information Verification

Submitter Full Name: Doug Smith
Organization: West Coast Code Consultants (WC3)
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Submittal Date: Mon Sep 07 17:10:06 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: It is not necessary to re-state PV as this is in Article 690. The requirement is for more than just PV source circuits. It includes DC-to-DC converter source circuits

Public Input No. 3785-NFPA 70-2020 [Section No. 690.9(C)]

(C) ~~Source and Output~~ PV System DC Circuits .

A single overcurrent protective device, where required, shall be permitted to protect the PV modules, dc-to-dc converters, and conductors of each ~~source~~ circuit ~~or the conductors of each output circuit~~ . Where single overcurrent protection devices are used to protect ~~source or output~~ circuits, all overcurrent devices shall be placed in the same polarity for all circuits within a PV system. The overcurrent devices shall be accessible but shall not be required to be readily accessible.

Informational Note: Due to improved ground-fault protection required in PV systems by 690.41(B), a single overcurrent protective device in either the positive or negative conductors of a PV system in combination with this ground-fault protection provides adequate overcurrent protection.

Statement of Problem and Substantiation for Public Input

This PI is submitted in conjunction with the related PIs to update this language to harmonize with the deletion of the PV Output Circuit definition.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain, P.E., SEIA; Bill Brooks, Brooks Engineering/PVICC; Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing, Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower; Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Ben Chamberlain, Olivewood Energy; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar;

Jason Smolko, Copperweld;

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3705-NFPA 70-2020 [Definition: PV System DC Circuit.]	

Submitter Information Verification

Submitter Full Name: Evelyn Butler
Organization: Solar Energy Industries Assn
Affiliation: PV Industry Forum (PVIF)
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City:
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Zip:
Submittal Date: Wed Sep 09 12:41:18 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9442-NFPA 70-2021
Statement: This revision updates language in this section to harmonize these requirements among all dc circuit conductors in a PV system. These changes were made necessary through the deletion of related terms.

Public Input No. 3408-NFPA 70-2020 [Section No. 690.9(D)]

~~(D)~~ ~~Power Transformers.~~

~~Overcurrent protection for a transformer with a source(s) on each side shall be provided in accordance with~~ ~~450.3~~ ~~by considering first one side of the transformer, then the other side of the transformer, as the primary.~~

~~*Exception:* *A power transformer with a current rating on the side connected toward the interactive inverter output, not less than the rated continuous output current of the inverter, shall be permitted without overcurrent protection from the inverter.*~~

Statement of Problem and Substantiation for Public Input

The current language at 690.9(D) was established in the 1984 NEC with the following substantiation:

This requirement is necessary to ensure that proper overcurrent protection is provided for power transformers where sources of supply are connected to both sides.

705.30 (C) addresses the requirements for transformers used with interconnected electric power production sources.

The primary and secondary windings of a transformer are required to be identified by the manufacturer through the UL product standard XQNX - Power and General-purpose Transformers, Dry Type. Step-up and step-down transformers are available and some manufacturers permit transformers to be reverse connected within certain operational limitations in accordance with installation instructions.

The current language requires “one side, then the other side” of the transformer to be considered the primary for application of 450.3 (primary over-current protection). The secondary over-current protection rules of 450.3(B) are not addressed. Nor are the transformer secondary feeder conductor over-current protection requirements of NEC 240.21(C). 690.9(D) does not modify or eliminate 240.21(C). If we are to consider each side of the transformer as the primary are we also to consider the opposite side as the secondary and therefore apply 240.21 (C) to each side in turn?

Deletion of the current language from 690 combined with the revised transformer requirements for 705.30 (see companion PI) would increase clarity and aid in enforcement for the inspection community.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3409-NFPA 70-2020 [Section No. 705.30(C)]	
Public Input No. 3409-NFPA 70-2020 [Section No. 705.30(C)]	

Submitter Information Verification

Submitter Full Name: Rudolph Garza
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Submittal Date: Tue Sep 08 14:04:08 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9219-NFPA 70-2021
Statement: Section 705.30(C) addresses the requirements for transformers and is applicable to connections where there are multiple sources.

Public Input No. 1864-NFPA 70-2020 [Section No. 690.10]

690.10 Stand-Alone Systems.

The wiring system ~~connected to a~~ for stand-alone ~~system.~~ systems shall be installed in accordance with Article 710. ~~15.~~

Statement of Problem and Substantiation for Public Input

This rule as written is way too 'specific.'

Submitter Information Verification

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City:
State:
Zip:
Submittal Date: Sat Jul 11 19:12:11 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9220-NFPA 70-2021
Statement: The section is deleted as Article 710 applies to these systems without the need to refer to it.

Public Input No. 2652-NFPA 70-2020 [Section No. 690.11]

690.11 Arc-Fault Circuit Protection (Direct Current).

Photovoltaic systems with PV system dc circuits operating at 80 volts dc or greater between any two conductors shall be protected by a listed PV arc-fault circuit interrupter or other system components listed to provide equivalent protection. The system shall detect and interrupt arcing faults resulting from a failure in the intended continuity of a conductor, connection, module, or other system component in the PV system dc circuits.

Informational Note: Annex A includes the reference for the *Photovoltaic DC Arc-Fault Circuit Protection* product standard.

Exception: For PV systems not installed on or in buildings, PV output circuits and dc-to-dc converter output circuits that are installed in metallic raceways or metal-clad cables, or installed ~~in enclosed metallic~~ in metallic cable trays, or are underground shall be permitted without arc-fault circuit protection. Detached structures whose sole purpose is to house PV system equipment shall not be considered buildings according to this exception.

Statement of Problem and Substantiation for Public Input

The term "enclosed" is problematic and not practical to accomplish. There is no way to completely enclose a cable tray when using string harnesses to combine multiple strings of modules (more prevalent with thin film type modules) ahead of a combiner box or inverter. There is no way to completely enclose the cable at the back of the modules where the module whips would enter it and for many inverters there is no way to enclose it at the input to the inverter. Also by totally enclosing a cable tray, the module/harness connectors and any inline fusing ends up being in an enclosure that does not allow proper heat dissipation and could lead to overheating and fire hazards related to those components and perpetuate fault problems rather than containing a potential arc flash as was intended. With new requirements for PV connectors required to be mated UL listed connectors, there is less likelihood of there being a risk of arc flash at those connectors, also as with other wiring systems that utilize standard metallic cable tray systems, the grounded cable tray would provide a path for any arc flash to conduct to causing a ground fault and allowing those elements at the inverters to function and also allow for fuses for the individual strings to clear and remove the arcing fault from the system like an arc fault detection system would. If there is still a concern on the spacing of rungs/support members being too far apart to allow for an arc to conduct to, maybe the exception that allows for the cable tray could limit rung/member spacing gaps for ladder, ventilated, and wire basket tray to limit any gaps to maybe 3" or 4" to insure an arc would be close enough to arc over to the grounded metal but also allow for ventilation of the cables, connectors, and inline fuses.

Submitter Information Verification

Submitter Full Name: Douglas Mutcher
Organization: Westwood Professional Services
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Zip:
Submittal Date: Thu Aug 27 12:40:22 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: Enclosed cable tray provides adequate protection when not using arc fault protection

Public Input No. 2824-NFPA 70-2020 [Section No. 690.11]

690.11 Arc-Fault Circuit Protection (Direct Current).

Photovoltaic systems with PV system dc circuits operating at 80 volts dc or greater between any two conductors shall be protected by a listed PV arc-fault circuit interrupter or other system components listed to provide equivalent protection. The system shall detect and interrupt arcing faults resulting from a failure in the intended continuity of a conductor, connection, module, or other system component in the PV system dc circuits.

Informational Note: Annex A includes the reference for the *Photovoltaic DC Arc-Fault Circuit Protection* product standard.

Exception: For PV systems not installed on or in buildings ~~, PV~~ and having PV output circuits and dc-to-dc converter output circuits that are installed in metallic raceways or metal-clad cables, or installed in enclosed metallic cable trays, or are underground shall be permitted without arc-fault circuit protection. Detached structures whose sole purpose is to house PV system equipment shall not be considered buildings according to this exception.

Statement of Problem and Substantiation for Public Input

A significant number of people are misinterpreting the exception to mean that all PV systems not on or in buildings are exempted from needing AFCI. People are not interpreting that the first clause of "not on or in a building" then needs to have one of the following conductor installation methods to be exempted. The addition of the words "and having" after the first cause will clarify the combination of requirements needed. Since a significant number of ground mount PV is installed in California and we now have a 5th season called "fire" I would like to see the chance of PV caused wildfires reduced by proper application of AFCI.

Submitter Information Verification

Submitter Full Name: Marvin Hamon
Organization:
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 01 17:22:25 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9222-NFPA 70-2021

Statement: The revision generalizes the exception to all PV system dc circuits not installed on buildings and in metal wiring methods.

The word “metallic “ was changed to “metal” to comply with the NEC Style Manual.

Since ground-mounted systems generally use significant amounts of single-conductor cables and multiconductor cables, that may include custom harnesses (some with fuses), there is a need to focus this exception not on the circuit’s name, but rather on the wiring protection provided. The modification to replace the term “house” with “support or contain” provides more clarity to the intention of the exception.

Public Input No. 3359-NFPA 70-2020 [Section No. 690.11]

690.11 Arc-Fault Circuit Protection (Direct Current).

Photovoltaic systems with PV system dc circuits operating at 80 volts dc or greater ~~between~~ up to and including 1,000 volts dc between any two conductors shall be protected by a listed PV arc-fault circuit interrupter or other system components listed to provide equivalent protection. The system shall detect and interrupt arcing faults resulting from a failure in the intended continuity of a conductor, connection, module, or other system component in the PV system dc circuits.

Informational Note: Annex A includes the reference for the *Photovoltaic DC Arc-Fault Circuit Protection* product standard.

Exception: For PV systems not installed on or in buildings, PV output circuits and dc-to-dc converter output circuits that are installed in metallic raceways or metal-clad cables, or installed in enclosed metallic cable trays, or are underground shall be permitted without arc-fault circuit protection. Detached structures whose sole purpose is to house PV system equipment shall not be considered buildings according to this exception.

Statement of Problem and Substantiation for Public Input

The requirement for arc-fault protection for PV dc circuits over 1,000V has been in the NEC since 2014. During that time no inverter manufacturer has made a 1,500V arc-fault protection product available for the US market. Only one DC combiner manufacturer has made 1,500V arc-fault protection equipment available in the US and due to lack of demand is discontinuing that product. This has left both contractors and AHJs having to invoke NEC 90.4 for every PV array over 1,000V and not covered by 691 to allow for the lack of arc-fault protection equipment. Since the lack of demand has resulted in the only available equipment no longer being produced and no other manufacturers have indicated that a product is likely to be put on the market in the future it appears that keeping the requirement for arc-fault protection on dc circuits over 1,000V is not useful and is just going to continue requiring the use of 90.4 when it is required. To acknowledge this fact the section should be revised to limit arc-fault protection to systems where equipment is available. While most of the time putting a requirement in the NEC does encourage manufactures to produce equipment satisfying that requirement there is a point at which we have to accept that it is not working in every instance. Three code cycles is more than long enough to say that it's just not working here.

Submitter Information Verification

Submitter Full Name: Marvin Hamon
Organization: Pure Power Engineering
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City:
State:
Zip:
Submittal Date: Tue Sep 08 10:34:39 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: The proposed revision would create additional safety issues for PV systems operating above 1000 volts. The availability of arc-fault protection for these higher voltage systems is not a reason to remove the safety requirements. Section 90.4 addresses the situation where listed equipment is not readily available

Public Input No. 3442-NFPA 70-2020 [Section No. 690.11]

690.11 Arc-Fault Circuit Protection (Direct Current).

Photovoltaic systems with PV system dc ~~circuits operating at 80 volts dc or greater between any two conductors shall~~ circuits shall be protected by a listed PV arc-fault circuit interrupter or other system components listed to provide equivalent protection. The system shall detect and interrupt arcing faults resulting from a failure in the intended continuity of a conductor, connection, module, or other system component in the PV system dc circuits.

Informational Note: Annex A includes the reference for the *Photovoltaic DC Arc-Fault Circuit Protection* product standard.

Exception: For PV systems not installed on or in buildings, PV output circuits and dc-to-dc converter output circuits that are installed in metallic raceways or metal-clad cables, or installed in enclosed metallic cable trays, or are underground shall be permitted without arc-fault circuit protection. Detached structures whose sole purpose is to house PV system equipment shall not be considered buildings according to this exception.

Statement of Problem and Substantiation for Public Input

Voltage of a single 60 cell module can be enough for an arc. Modules themselves should be made more intelligent in their junction boxes. Adding additional equipment to the roof cannot change that modules, especially high wattage modules, are getting more potential for causing disasters.

Submitter Information Verification

Submitter Full Name: Jason Eiseman
Organization: Wellspring Components
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City:
State:
Zip:
Submittal Date: Tue Sep 08 15:05:55 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: The 80 volt threshold is retained. The substantiation did not provide documentation of arc-fault issues in the field below 80 volts.

Public Input No. 3655-NFPA 70-2020 [Section No. 690.11]

690.11 Arc-Fault Circuit Protection (Direct Current).

Photovoltaic systems with PV system dc circuits operating at 80 volts dc or greater between any two conductors shall be protected by a listed PV arc-fault circuit interrupter or other system components listed to provide equivalent protection. The system shall detect and interrupt arcing faults resulting from a failure in the intended continuity of a conductor, connection, module, or other system component in the PV system dc circuits.

Informational Note: Annex A includes the reference for the *Photovoltaic DC Arc-Fault Circuit Protection* product standard.

Exception: For PV systems not installed on or in buildings, PV ~~output circuits and dc-to-dc converter output~~ system dc circuits that are installed in metallic raceways or metal-clad cables, or installed in enclosed metallic cable trays, or are underground shall be permitted without arc-fault circuit protection. Detached structures whose sole purpose is to ~~house~~ support or contain PV system equipment shall not be considered buildings according to this exception.

Statement of Problem and Substantiation for Public Input

This proposed change addresses and aligns with the related PVIF proposal to remove the terms “PV output circuits” and “dc to dc converter output circuits” from Article 690. These terms have created significant confusion without clear logic for their distinction from other PV dc circuits, particularly in ground mount systems.
Since ground-mounted systems generally use significant amounts of single-conductor cables and multi-conductor cables, that may include custom harnesses (some with fuses), there is a need to focus this exception not on the circuit’s name, but rather on the wiring protection provided. The exception as proposed applies to the more generic “PV system dc circuits” term, but as before is only applicable to those conductors not installed on or in buildings, and installed in metallic raceways, enclosed metallic cable trays, or underground. As such, in practice AFCI protection will still be needed in string inverters, combiner boxes, or the input wiring to other converters to protect any exposed module to module and string conductors and cables. Where an installation does use the physical protection methods identified in this exception to protect any system wiring from damage, those methods will provide the same level of fire protection regardless of their location in the circuit, or the term used to identify the circuit.
The modification to replace the term “house” with “support or contain” is simply to provide more clarity to the intention of the exception. This is necessary since the distinction between what is a “structure” and what is a “building” lacks clarity in this Code.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF’s effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI’s as they deem appropriate.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain,

P.E., SEIA; Bill Brooks, Brooks Engineering/PVICC; Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing, Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower; Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Ben Chamberlain, Olivewood Energy; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

Submitter Information Verification

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State:
Zip:
Submittal Date: Wed Sep 09 10:10:33 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9222-NFPA 70-2021

Statement: The revision generalizes the exception to all PV system dc circuits not installed on buildings and in metal wiring methods.

The word “metallic “ was changed to “metal” to comply with the NEC Style Manual.

Since ground-mounted systems generally use significant amounts of single-conductor cables and multiconductor cables, that may include custom harnesses (some with fuses), there is a need to focus this exception not on the circuit’s name, but rather on the wiring protection provided. The modification to replace the term “house” with “support or contain” provides more clarity to the intention of the exception.

Public Input No. 4113-NFPA 70-2020 [Section No. 690.11]

690.11 Arc-Fault Circuit Protection (Direct Current).

Photovoltaic systems with PV system dc ~~circuits operating at 80 volts dc or greater between any two conductors shall~~ circuits shall be protected by a listed PV arc-fault circuit interrupter or other system components listed to provide equivalent protection. The system shall detect and interrupt arcing faults resulting from a failure in the intended continuity of a conductor, connection, module, or other system component in the PV system dc circuits.

Informational Note: Annex A includes the reference for the *Photovoltaic DC Arc-Fault Circuit Protection* product standard.

Exception: For PV systems not installed on or in buildings, PV output circuits and dc-to-dc converter output circuits that are installed in metallic raceways or metal-clad cables, or installed in enclosed metallic cable trays, or are underground shall be permitted without arc-fault circuit protection. Detached structures whose sole purpose is to house PV system equipment shall not be considered buildings according to this exception.

Additional Proposed Changes

File Name	Description	Approved
Electric_arc_ignition_below_80_volts.JPG	Electrical Arc possibilities voltage/amperage	
2018-06-14_PV_Fire_Safety_Fire_Guideline_Translation_V04_20180614_FINAL.pdf	Original Document, page 40 for the image	
ArcGen.pdf	Fronius recreation of the test using MC4 connectors	

Statement of Problem and Substantiation for Public Input

Test have shown that only a single module can cause arcs and therefore it's necessary to decrease the voltage from 80 volts to 0 volts. Attached is a graphic from TUV Rheinland indicating the arc threshold coming from the attached article found on page 40. We have recreated the tests and found that 1x40 VOC module can create a substantial sustained arc for longer than a minute. We also have numerous videos of this test which we re-created and can provide as well.

Submitter Information Verification

Submitter Full Name: Chris Connell
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City:
State:
Zip:
Submittal Date: Wed Sep 09 21:05:13 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: The 80 volt threshold is retained. The substantiation did not provide documentation of arc-fault issues in the field below 80 volts.

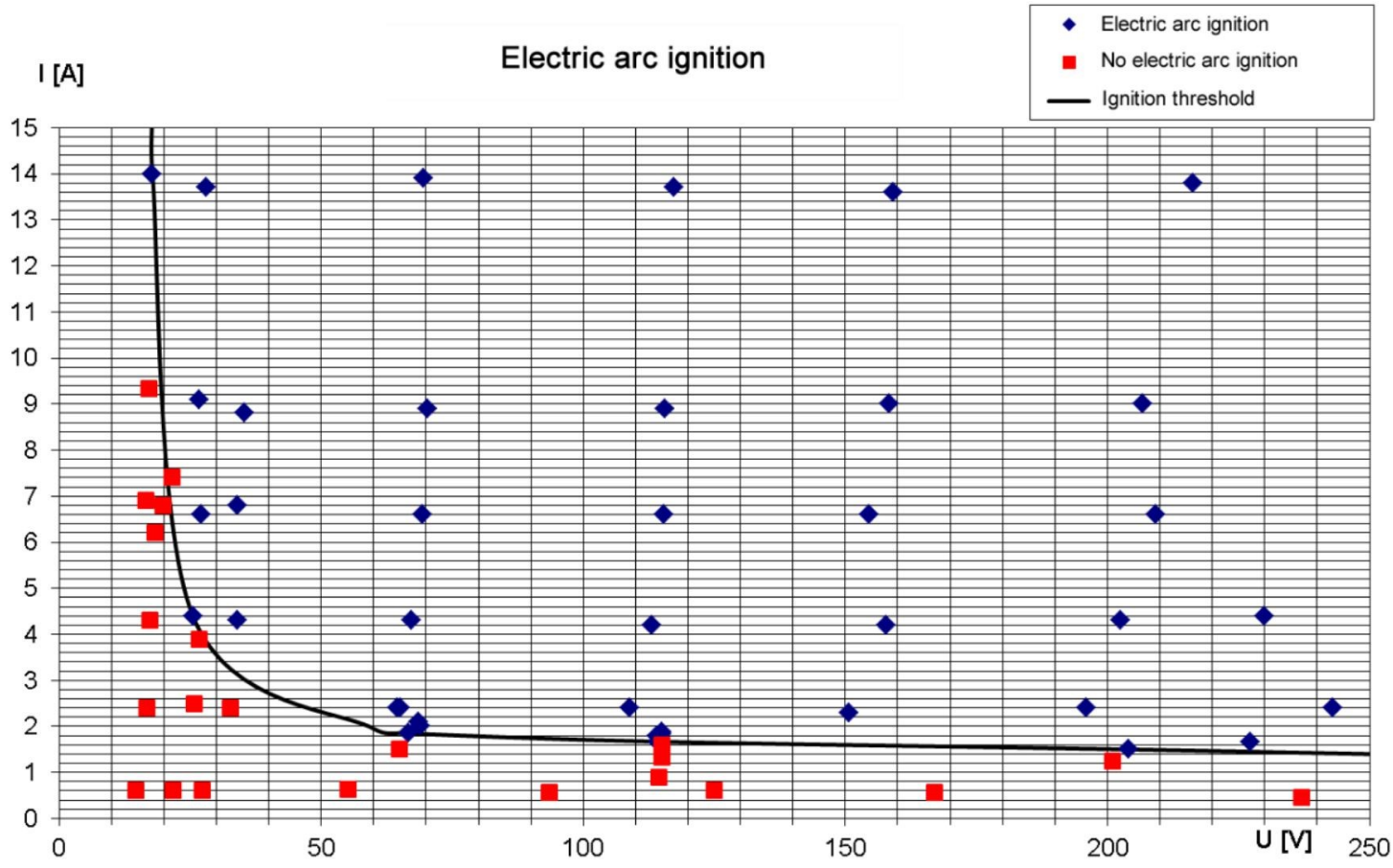

Figure 2-2: Electric arc ignition limit determined on the basis of copper electrodes, source: TÜV Rheinland

GUIDELINE

Assessing Fire Risks in Photovoltaic Systems and Developing Safety Concepts for Risk Minimization

Project Sponsor

Dr.-Ing. Klaus Prume, Project Sponsor Jülich
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Denver, June 2018

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The Project Team especially thanks project sponsor Jülich (PTJ) for support of the research project. The dedicated work by the responsible persons of the PTJ, Mr. Jochen Viehweg and Dr. Klaus Prume, enabled the comprehensive work on fire risks and fire safety in PV systems, with the summary of this work and findings being presented in the form of the present Guideline.

The Project Team is also grateful to the colleagues from the companies or institutions of the affiliated partners and to the representatives of the German solar energy industry for the expertise they provided through professional exchanges, as well as to the German Solar Energy Society (DGS) and the German Solar Industry Association for their multifarious activities in connection with the research project.

Heartfelt thanks are also due to our students, who acquired solid professional knowledge through their dedication and who supported our series of experiments with many good ideas and diligence during their practical semesters and work on their bachelor theses.

Personnel and professional support in particular from Munich Fire Department as well as personnel and equipment from the Cologne Professional Fire Department, the Cologne Volunteer Fire Department, the Porz-Langel Fire Brigade and the Siegburg section of the THW made possible the series of elaborate and realistic experiments. We expressly thank them again.

Special thanks are also due to the following companies for providing equipment and materials on loan: Clausen OHG – Treble-Light Special-Lighting, SETOLITE Lichttechnik GmbH, Schmidt-Strahl GmbH, Karl Meister GmbH, Hella Fahrzeugteile Austria GmbH, Dönges GmbH & Co. KG.

We also thank the participants in our online survey, whose information and detailed knowledge about past occurrences of fire damage involving PV systems gave us an overview of the incidents, including the affected components. In this regard we wish to single out the professional fire departments in Germany, who conducted a survey among their own ranks. We are also especially grateful to Mannheimer Versicherung, which significantly supported us with statistical data on their insurance cases related to PV systems.

Last but not least, we wish to express our heartfelt thanks to the participants in our three workshops in Cologne and Freiburg, whose professional interest, expertise and own experiences repeatedly gave us a fresh impetus and strengthened our resolve.

Willi Vaaßen, TÜV Rheinland and Heribert Schmidt, Fraunhofer ISE

and on behalf of the Project Team

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Introduction

The Act on the Sale of Electricity to the Grid (StrEG) and the Renewable Energy Sources Act (EEG) led to a boom in the installation of photovoltaic (PV) systems in Germany particularly in the years 2005 through 2012. The installed power output of solar power plants grew by more than 60% annually in the years 2007 to 2010. The great demand for PV modules and inverters brought about a rapid increase in the number of manufacturers of photovoltaic components worldwide. Installation companies were able to meet the demand for installing PV systems only through the massive support from auxiliary personnel. By the year's end, bottlenecks in installing and connecting the systems arose because of the EEG deadline regulation. As a result, the quality of the system installation unfortunately often fell by the wayside.

In 2006, individual cases of electric arcs and their extension to roof constructions could already be observed. In 2008 and 2009, reports on PV component fires increased in frequency.

In June 2009, larger fire damage originating from what was then the world's most powerful PV roof system in Bürstadt (Hesse) caught great public attention and became a "hot topic" in the order of business.

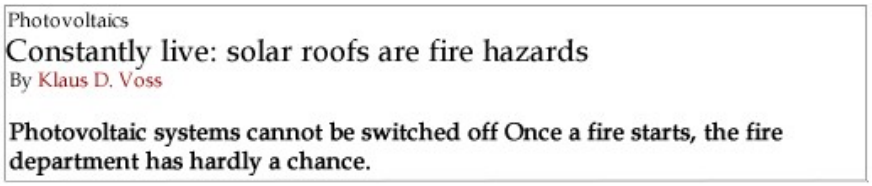
Long-term studies of PV systems found burn and overheating marks on various PV system components. The flaws discovered in inspections of the systems, such as damaged or discolored modules, weathered cables, local fusion in junction boxes and improper installations, as well as fire incidents of various degrees of severity, have led to a drastically increased awareness of the safety aspect of PV systems, especially roof-mounted systems and building-integrated PVs (BIPVs). In addition to economic and environmental considerations, this aspect plays a fundamental role in the acceptance and further spread of photovoltaics.

PV systems are almost always energized, even in overcast weather. The trend towards increasingly larger systems has led to the realization of DC voltages of 1,000 V and soon 1,500 V. Contact protection and especially protection against electric arcs are accordingly becoming more important.

Another aspect is the safety of emergency personnel and firefighters in particular. Here there has prevailed widespread uncertainty, which in part led to drastically exaggerated or even false reports in some media and consequently to public qualms about the safety of roof-mounted PV systems.

Here are just a few representative headlines from 2010 and 2011:

> Firefighters let houses with solar roofs burn down
>
> For fear of powerful electric shock, firefighters often cannot extinguish fires at homes with solar installations on their roofs.

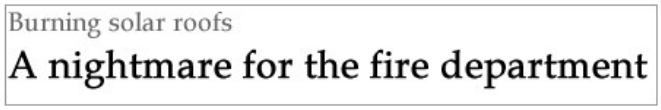


Photovoltaics

Constantly live: solar roofs are fire hazards

By Klaus D. Voss

Photovoltaic systems cannot be switched off Once a fire starts, the fire department has hardly a chance.



Burning solar roofs

A nightmare for the fire department

SOLAR ENERGY

Fire on the roof

Solar modules can be surprisingly dangerous

For the risk analysis and derivation of recommendations for action for emergency personnel, various series of experiments were performed with the participation of the fire departments and the German Federal Agency for Technical Relief (THW) for assessing the electrical hazards from PV facilities and fire-related emissions from PV modules (including thin-film modules).

Reviews and systematic causal analyses of known incidents of damage on the one hand and fundamental, scientifically substantiated studies of PV modules on the other hand made possible a realistic assessment of electric arc hazards as part of this research project. Support in this regard was provided by the feedback from PV experts, fire departments and operators of PV facilities in an initiated online survey on fire and overheating damage to PV systems. A significant share of the derived findings was provided by a generally recognized procedure for risk assessment (FMEA), employed by an expert committee for system analysis covering all components of a PV system including installation and system operation.

On the basis of the identified risk potential, studies on the component and system levels regarding the possibilities of risk reduction yielded concrete recommendations for action for the component manufacturers as well as for planners and installers of photovoltaic systems. In addition, significant results concerning risk minimization were taken up by the PV standardization committees.

In the course of the project, the three public, well attended workshops in Cologne and Freiburg afforded ample opportunities for technical discussions in addition to the presentation of the work results. In addition to the project's homepage at http://www.pv-brandsicherheit.de, numerous publications on the subject of preventive fire protection in cooperation with the industrial associations DGS and BSW and with the Munich Fire Department made the obtained findings available to the general public and in particular to emergency services.

Particular issues were or are being pursued in separate, advanced research projects such as fire tests on BIPV modules, switches and disconnectors for photovoltaic systems, inspection of electric arc detectors and risk assessments for PV systems with storage solutions (accumulators).

1 Status of PV system designs and requirements

1.1 PV system design

A photovoltaic (PV) system converts solar energy directly into electrical energy by means of several solar modules (a string) electrically connected in series. In the case of a grid-connected PV system, inverters aid in converting the direct current produced in the solar modules to alternating current, which may then be fed into the grid via transformers.

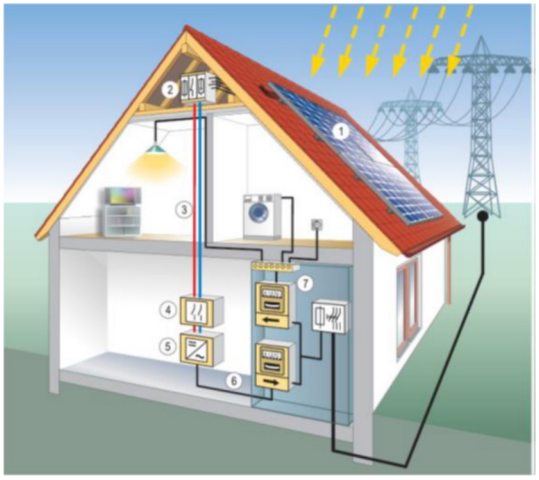


Figure 1-1: Grid-connected PV system with direct feed

The diagram shows the schematic layout of a grid-connected photovoltaic system, consisting basically of the following main components:

(1) PV generator (several PV modules connected in series and in parallel with mounting frame)
(2) Generator junction box (with protective technology)
(3) Direct current wiring
(4) DC main switch
(5) Inverter
(6) Alternating current wiring
(7) Meter cabinet with sub-circuit distribution, consumption and feed meters and house connection

Single-family homes often employ only module strings, so that the strings can be directly connected to the inverter and the aforementioned generator junction box omitted.

In cases of larger systems, generator junction boxes (GJBs) are used for the parallel connection of the strings. Very large systems and systems with many separate inverters employ DC coupling boxes interconnecting multiple GJB outgoing lines.

The generator junction box contains connecting terminals and disconnection points as well as possibly string fuses and string diodes. Often the generator junction boxes contain integrated surge arresters for diverting overvoltage to the ground. The potential equalization or grounding conductors therefore lead into the generator junction boxes.

The selection of DC switches should make sure that they have the appropriate switching capacity for direct current (at least DC 22B switching capacity).

Lines are differentiated into module lines, string lines, direct current main line and alternating current connecting line. The electrical connecting lines between the individual modules of a solar energy generator and to the generator junction box are referred to as module lines or string lines. These lines are used outdoors. To ensure ground-leakage-proof and short-circuit-proof routing, double-insulated single-core cables are used. Solar energy lines as per EN 50 618 or VDE-AR-E 2283-4 (designation: PV1-F) have become standard in outdoor use. The standard version of the double-insulated rubber hose line of type H07 RN-F often used outdoors is approved only for operating temperatures of up to 60°C and is not UV-resistant. This line should therefore not be used as a solar line. Aging of these lines or use of other unsuitable lines can result in insulation flaws and electric arcs.

1.2 Categorization of different PV systems

Generally PV systems can be divided into *open-space systems* and *building systems*. Building systems can in turn be classified as *roof-parallel elevated systems* on pitched roofs, *elevated systems* on flat roofs or (seldom) on pitched roofs, *roof-integrated systems*, *PV curtain walls* and *facade-integrated systems*. The roof-parallel systems often comprise the largest interconnected module fields and under certain circumstances may hinder firefighting more. Generally the integrity of the fire compartments must be maintained. Construction over fire compartments is not permitted.

Table 1-1: Categories of PV systems

Open-space facility, Source: Krug Immobilien GmbH	Pitched roof: roof-parallel system, source: www.photovoltaik.org	BIPV: roof-integrated PV system, source: Photovoltaik Buero
Flat roof: elevated PV system, source: Solaranlagen-Portal	BIPV: facade-integrated system, source: Solarfabrik GmbH	Oldenburg PV wall curtain, source: Colt Int. GmbH

In line with the electrical circuitry concept, we can distinguish between PV systems with central inverters and those with decentralized inverters. Systems with central inverters rarely occur with small voltages (up to 120 V), but typically with higher DC voltages (up to 1,000 V, in the future also 1,500 V). Large systems occasionally employ master-slave devices or even inverters with assigned medium-voltage transformers.

Decentralized systems are implemented with multiple string or subgenerator inverters, with module inverters or with module-oriented direct current converters (power optimization).

1.3 Status of the requirements on components, systems and installation

Studies on the causes of fire incidents involving PV systems have shown that to a rough approximation 1/3 of the damage cases are due to component defects, 1/3 to deficient planning and 1/3 to faulty installation (see section 3.3.2, Statistical damage analyses)

This section lists the current standards and requirements from the German Renewable Energies Act (EEG) for the most important PV system components. One reason – among many others –for installation errors is that the manufacturer's documentation often contains insufficient or even no information on possible danger sources. An overview will show what types of information are typically provided by manufacturers and which types would also be desirable to have. In addition, we list guidelines and special connection conditions from the energy industry.

1.3.1 Standards, regulations and guidelines

Regarding photovoltaic systems we must distinguish between standards that are applicable generally and therefore to PV systems in particular and standards specially devised for PV systems. The most important series of standards for low-voltage systems in general is the DIN VDE 0100, based on the European Low-Voltage Directive. Most standards pertaining to PV systems are compiled in the DIN VDE 0126 series.

Besides these standards, we also have the more detailed application guidelines of the VDE, the guidelines of the BDEW, in particular the medium-voltage guidelines, and the accident prevention regulations of the workers' compensation boards (Berufsgenossenschaften).

The Deutsches Institut für Bautechnik (DIBt) has published a set of instructions for assembling and installing PV systems and defined construction regulations in the building regulation list with relevance to PV modules and their application (download link in Appendix II, p. 253).

For the building rules and building standards the Deutsches Institut für Bautechnik (DIBt) regularly publishes the building regulation list and interprets the European Construction Products Regulation (EU-CPR) for Germany. This also yields requirements for PV systems and their components. The requirements (mechanical strength, structural stability, fire protection, etc.) are given in the bulletin 'Hinweise für die Herstellung, Planung und Ausführung von Solaranlagen' (Information on the Manufacture, Planning and Implementation of Solar Energy Systems), published in November 2012. The industry association BSW and the professional association DGS are also working on the development of professional rules and on standardization in the field of solar energy. Examples are professional rules for the planning, installation and maintenance of PV systems in accordance with fire protection (download link in Appendix II, p. 253).

The lists given here present an overview only of the most important standards and series of standards in reference to photovoltaics and make no claim to completeness.

1.3.1.1 Requirements on PV system configuration

General requirements on low-voltage systems up to 1,500 V DC system voltage, which also include PV systems, are formulated in the international series of standards DIN IEC 60364 *Low-Voltage Electrical Installations*, listed in the VDE as DIN VDE 0100. The series contains, among other things, safety regulations, terminological definitions and instructions on selecting, designing and assembling operating equipment, and defines the required resistance of the system to external factors. DIN VDE 0100-712, *Requirements for Special Installations or Locations – Photovoltaic (PV) Power Supply Systems*, refers in particular to PV systems. It explains the basic design of the systems, in particular its connection to necessary switchgear, and requires protective measures against fault currents, overcurrents and surges and contact with live components as well as against environmental factors, but only superficially treats these subjects. They are discussed in further depth in the respective generally applicable standards on these subjects, namely DIN EN 62305-3 on *Protection against Lightning and Overvoltage*, DIN EN 61140 on *Protection against Electric Shock* and DIN EN 61439-1 on *Low-Voltage Switchgear and Controlgear Assemblies*.

In addition, on some subjects there also exist standards on generating systems in general and on PV systems in particular. DIN EN 61173 on *Overvoltage Protection for Photovoltaic (PV) Power Generating Systems* explains measures for avoiding surge damage, in particular potential equalization, grounding and shielding. Supplement 5 to DIN EN 62305-3 contains similar information on lightning protection. The necessary switchgear and grid interface of a PV system are described in VDE AR 4105 and DIN EN 61727.

Limits for grid perturbations are also defined. Guideline VdS 3145 formulated by the VDE and GDV contains a compilation of specifications on PV system safety. They include safety recommendations for planning and operating the systems, both on the system level and for individual components. Particular focus lies on the avoidance and limitation of fires as well as on the resistance of the system to environmental factors, also in view of state building regulations.

Some special cases of PV applications are also treated by standards and guidelines: DIN EN 61194 states the parameters of the different components of a *PV stand-alone system* and states the requirements on its documentation.

DIN EN 62124 (VDE 0126-20) contains requirements on the design qualification of storage systems operated in conjunction with PV systems. Charge controllers for such PV accumulators are treated in DIN EN 62509.

To ensure the safety of emergency services in the event of a fire, application guideline VDE-AR-E 2100-712 specifies measures for preventing contact with live components. Especially highlighted are the installation requirements on the DC lines and the labeling of the cable routing in a schematic accessible to firefighters. The following table summarizes the currently available standards on the configuration of photovoltaic systems.

Table 1-2: Important standards and series of standards pertaining to the configuration of PV systems

System configuration	
Designation	**Content**
DIN EN 61277 *Terrestrial photovoltaic (PV) power generating systems – General and guide*	General information on PV systems
DIN IEC 60364 DIN VDE 0100 *Erection of low-voltage installations*	Design, connection and components of low-voltage systems, protective measures
DIN VDE 0100-712 *Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems*	PV-specific part of DIN VDE 0100. Covers design of PV systems and necessary protective measures
DIN EN 61140 *Protection against electric shock*	Contains measures for preventing injuries from electric shock
DIN EN 61439 *Low-voltage switchgear and controlgear assemblies*	Regulates the combination of switchgear units in a building unit
DIN VDE 0126-1-1 *Automatic disconnection device between a generator and the public low-voltage grid*	States requirements and disconnection parameters for an automatic switch at the grid interface (obsolete, superseded by VDE AR-N 4105)
DIN EN 61727 *Photovoltaic (PV) systems – Characteristics of the utility interface*	Defines requirements on the grid interface of a PV system and lays down limits for grid perturbations
DIN EN 62305-3 Bbl 5 VDE 0185-305-3 Bbl 5 *Lightning and overvoltage protection for photovoltaic power supply systems*	Contains information on lightning and overvoltage protection for PV systems (no standardized specifications)
DIN EN 61173 *Overvoltage protection for photovoltaic (PV) power generating systems*	States measures against overvoltage damage to PV systems
DIN EN 62124 VDE 0126-20 *Balance-of-system components for photovoltaic systems – Design qualification for natural environment*	Contains criteria for the design suitability of balance-of-system components, mainly accumulators
DIN EN 61194 *Characteristic parameters of stand-alone photovoltaic (PV) systems*	States parameters of various components of a stand-alone PV system

System configuration	
Designation	**Content**
VDE-AR-E 2100-712 *Measures for the DC range of a PV installation for the maintenance of safety in the case of firefighting or technical assistance*	States measures for avoiding contact with live components in case of fire
VDE-AR-N 4105 *Generators connected to the low-voltage distribution network – Technical requirements for the connection to and parallel operation with low-voltage distribution networks*	States requirements on the technical connection conditions of the distribution grid operators

1.3.2 Requirements on PV modules

PV modules generally undergo design testing prior to use or marketing. The requirements on design suitability are laid down in DIN EN IEC 61215 for crystalline and DIN EN IEC 61646 for thin-film modules, and contain comprehensive aging and stress tests. Besides resistance to temperature fluctuations, UV radiation, moisture, wind and other mechanical influences, electrical characteristics of the modules are also examined.

Safety aspects are tested irrespective of the cell technology as per DIN EN 61730-1 and DIN EN 61730-2. Part 1 describes the design and material requirements. Part 2 describes the tests on modules pre-aged as per DIN EN IEC 61215 or DIN EN IEC 61646. These additional stress tests include mechanical stress, fire tests and intensified insulation resistance measurements. Design certification as per DIN EN 61730 forms the basis of CE marking of PV modules for the European market. Modules meeting class A requirements as per DIN EN 61730-1:2004 apply as protection class II operating equipment as per DIN EN 61140.

The quality seal as per RAL GZ 966 is issued if the RAL quality and test requirements for solar energy systems are met. This set of quality marks and quality criteria defines the target requirements for the manufacture of high-quality components as well as for the proper conception and professional execution, servicing and operation of solar energy (photovoltaic and solar heat) systems. The RAL-Gütegemeinschaft für Solarenergieanlagen e.V. is one of 130 independent quality associations specifying and monitoring the RAL quality and test requirements of their respective industrial and service sectors (*RAL since 1980: Deutsches Institut für Gütesicherung und Kennzeichnung e. V.*)

DIN EN 50380 regulates the data sheets issued by the manufacturers for each module series as well as the mandatory data on the model plates. DIN EN IEC 60904-1 also defines the standard test conditions (STC) for determining electrical parameters of modules. DIN EN 50548 formulates requirements on module junction boxes. The international version of this standard, IEC 62790, will supersede this European standard in the future. Methods for testing the conformity with these requirements are also laid down. Requirements on PV plug connections are described in IEC 62852 (or DIN EN 50521). For PV lines there exists a draft standard, prEN 50618, based on the applicable TÜV Rheinland internal test specification 2PfG 1169.

For the special application of building-integrated photovoltaics, modules must comply with the special demands of DIN 18008 (formerly (e.g. Technical Guidelines for Linearly Supported Glazing (TRLV)). DIN VDE 0126-21 defines different types of modules for building-integrated use, states application-

specific demands and refers to other requirements, such as design certification as per DIN EN IEC 61215 or DIN EN IEC 61646 and DIN EN 61730-1/-2.

Besides the particular requirements on building-integrated modules, there exist other standards for particular areas of application and for particular designs, plus further standards are under development. Some examples are modules for maritime or near-coastal applications, modules in noxious gas environments, modules operating under concentrated sunlight and modules with integrated electronics (such as AC modules).

Table 1-3: Important standards for photovoltaic modules

Modules	
Designation	**Content**
DIN EN IEC 61215 *"Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval"*	Type approval for crystalline modules according to aging characteristics
DIN EN IEC 61646 *"Terrestrial thin-film photovoltaic (PV) modules – Design qualification and type approval"*	Type approval for thin-film modules according to aging characteristics
DIN EN 61730 *"Photovoltaic (PV) modules – Safety qualification –* *Part 1: Requirements for construction* *Part 2: Requirements for testing"*	Safety qualification of PV modules
DIN EN 50548 (IEC 62790) DIN VDE 0126-5 *"Junction boxes for photovoltaic modules"*	Requirements and test procedures for junction boxes for use on PV modules
DIN EN 50521 (IEC 62852) *"Connectors for photovoltaic systems"*	Requirements and test procedures for junction boxes for use on PV connectors
DIN VDE 0126-21 *"Photovoltaics in construction"*	Requirements on building-integrated PV modules
DIN EN 50380 *"Datasheet and nameplate information for photovoltaic modules"*	Provides information that must be contained in PV module datasheets and nameplates
DIN EN 60904-1 VDE 0126-4-1 *"Measurement of photovoltaic current-voltage characteristics"*	Defines test procedures and standard test conditions (STC) for creating module characteristic curves

Modules	
Designation	**Content**
DIN EN 13501-1 *"Fire classification of construction products and building elements"*	Fire classifications according to fire behavior, for the classification of modules
DIN 4102-1 *"Fire behaviour of building materials and building components"*	Fire classifications according to flammability, for the classification of modules

1.3.2.1 Requirements on PV inverters

Safety standards for PV inverters are laid down in DIN IEC 62109. Covered are risks from mechanical and electrical stress as well as from fire. Also treated is the correct design of the inverter. The electrical AC requirements are determined by the technical connection conditions of the distribution grid operator, the VDE-AR-N 4105 and the DIN EN 61000 series on *"Electromagnetic Compatibility (EMC)"*. The latter concerns the compatibility of grid parameters with connected systems and defines limits for grid perturbations and fluctuations.

DIN EN 50524 governs the content of datasheets and labels for inverters, in particular voltage and current parameters at input and output, as well as efficiency, which is specified as a weighted European efficiency level. Its measurement is laid down by DIN EN 50530, which also stipulates the test conditions and measurement circuits.

In the event of collapse of the grid voltage, the inverter must automatically disconnect from the grid. Tests as per DIN EN 62116 must be performed to check the suitability of measures that are to fulfill this requirement. However, no conditions are therein formulated requiring the inverter to be disconnected from the grid, since such conditions depend on local factors, in particular the requirements of the distribution grid operators (technical connection conditions, German abbreviation: TAB).

Table 1-4: Important standards and series of standards for PV inverters

Inverter	
Designation	**Content**
DIN IEC 62109 VDE 0126-14 *Safety of power converters for use in photovoltaic power systems*	Defines mechanical and electrical safety requirements on PV inverters
EN 61000 *Electromagnetic compatibility (EMC)*	Electromagnetic compatibility of grid and connected systems and equipment
DIN EN 50530 VDE 0126-12 *Overall efficiency of grid-connected photovoltaic inverters*	Defines test procedures for determining the efficiency of PV inverters
DIN EN 50524 VDE 0126-13 *Datasheet and nameplate information for photovoltaic inverters*	Provides information that must be contained in PV inverter datasheets and nameplates
DIN EN 62116 VDE 0126-2 *Utility-interconnected photovoltaic inverters – Test procedure of islanding prevention measures*	Defines procedures for testing the suitability of measures for disconnecting PV inverters with abnormal grid voltages

1.3.2.2 Requirements on mounting systems

At present no special standardizations exist for mounting systems for photovoltaic systems. To be applied are instead the general standards for steel and aluminum structures from the European codes, namely EN 1990, EN 1993 and EN 1999. They govern the planning, measurements and design of support structures.

DIN EN 1090-1 governs the proof of conformity with European standards and regulations, which is a prerequisite for use of the CE mark, for steel and aluminum structures.

Designing for local environmental influences is performed as per DIN 1055. Besides wind and snow loads, temperature effects and effects of earthquakes are also considered here.

Table 1-5: Important standards and series of standards for PV mounting systems

Mounting systems	
Designation	**Content**
DIN 1055 *Actions on structures*	Specifies load assumptions for different environmental influences, in particular wind and snow loads
DIN EN 1993 *Design of steel structures*	Contains information and regulations on the design of steel structures
DIN EN 1999 *Design of aluminium structures*	Contains information and regulations on the design of aluminum structures
DIN EN 1090 *Execution of steel structures and aluminium structures*	Governs the proof of conformity (CE mark) for steel and aluminum structures

1.3.2.3 Requirements on DC components and solar energy storage systems

The DC components include DC cable, connector and DC circuit breaker. Cable layouts and circuit breakers are treated in DIN VDE 0100-712 (see 2.3.2.1 “Requirements on PV System Configuration”). PV plug connections are governed by a separate standard, DIN VDE 0126-3. Besides requirements on mechanical and electrical strength, it also contains requirements on shape for protection against polarity reversal, relockability and labeling. In addition, test procedures for complying with these specifications and aging tests are presented.

PV-specific specifications on wiring are given in the application guideline VDE-AR-E 2100-712. It stipulates routing the lines in at least fire-inhibiting material, if occurring within the building. General requirements on cable routing appear in the VDE series VDE 0604.

The original standard for solar energy storage systems is DIN EN 62093. It formulates criteria for the design qualification of all components of a storage system, including charge controllers and batteries, as well as test procedures. The focus lies on stress from environmental influences, i.e. mechanical and thermal stress as well as moisture.

Only lead and nickel-cadmium batteries are considered, however. It is supplemented by DIN EN 62509 and DIN EN 61427-1.

DIN EN 62509 presents requirements on the power parameters and charge management of PV battery charge controllers, to allow maximum possible battery lifetimes. The standard pertains only to lead batteries. DIN EN 61427-1 defines operating conditions for solar energy accumulators and contains requirements on mechanical stressability, safety and documentation. Test procedures for capacity, charge retention, efficiency and service life are also laid down. While the standard covers all common cell technologies, including Li ion cells, it refers only to off-grid applications.

A standard for grind-counted storage systems is in preparation under the designation DIN EN 61427-2 (as of July 2015).

Table 1-6: Important standards for DC components or storage systems

DC components and solar energy storage systems	
Designation	**Content**
DIN EN 50521 DIN VDE 0126-3 *Connectors for photovoltaic systems – Safety requirements and tests*	Contains requirements on the mechanical and electrical strength of PV connections and defines test procedures for approval
DIN EN 62093 VDE 0126-20 *Balance-of-system components for photovoltaic systems – Design qualification for natural environment*	Contains requirements on the design qualification of solar batteries and their charge controllers; geared to lead batteries
DIN EN 61427-1 VDE 0510-40 *Secondary cells and batteries for renewable energy storage – General requirements and methods of test*	Requirements on solar energy batteries in off-grid applications irrespective of the cell technology
DIN EN 62509 VDE 0126-15 *Battery charge controllers for photovoltaic systems*	Contains electrical requirements on PV battery charge controllers, geared to lead batteries

1.3.3 Manufacturers' installation instructions

The manufacturers of the system components publish the requirements on the installation and initial start-up of their products in the form of installation instructions (Table 1-7). Besides technical product information and assembly instructions, they also include references to relevant standards and provisions as well as warranty and guarantee terms.

Major differences found between the manufacturers in the scope and descriptive detail of the installation instructions show that the latter alone often do not suffice for the technically correct installation of a PV system.

1.3.3.1 PV modules

Considered were selected manufacturers from Germany, China, Japan and the United States who cover all market segments and common cell technologies. The module series to which the instructions refer date to the years 2008 to 2012. Since the manufacturers were chosen arbitrarily, this listing makes no claim to completeness. A complete list of module manufacturers, from which these manufacturers were selected, was published in the journal PHOTON Profi [source: Market overview of solar modules in: PHOTON Profi, 2/2010 issue].

Table 1-7: Typical contents of installation instructions for PV modules

	Manufacturer 1	Manufacturer 2	Manufacturer 3	Manufacturer 4	Manufacturer 5	Manufacturer 6	Manufacturer 7	Manufacturer 8	Manufacturer 9
Installation									
Instructions on handling	X	X	X	X	X	X	X	X	X
Installation by suitable specialist	X	X	X	X	X		X	X	X
Work safety regulations	X	X		X	X	X	X		
Antifall guard for installer	X			X	X	X			
Inspection for mechanical integrity prior to installation	X				X				X
Mechanical requirements									
Instructions on installation location and orientation	X	X	X	X	X	X	X	X	X
Static strength	X	X	X	X	X	X	X	X	X
Ventilation of the module rear side	X	X	X	X	X	X	X	X	
Protection against moisture	X	X			X	X	X	X	X

Restriction on modifications	X	X			X	X		X	X
Avoidance of flammable materials	X	X		X		X		X	X
UV protection for cables and junction box	X	X	X			X	X	X	
Mounting on fire-resistant supporting surface	X	X		X		X			X
Lightning protection	X				X	X	X		
Corrosion protection	X	X			X				
Strain relief of connecting cable	X						X		
Instructions on overhead glazing		X					X		
Electrical requirements									
Instructions on circuitry	X			X	X	X	X	X	X
Potential equalization	X	X	X	X		X	X	X	X
Designing for 1.25 UOC and ISC	X	X		X		X	X	X	X
Disconnection before work	X			X					X
Notes on further regulations									
References to standards	X	X		X	X	X	X	X	X
References to guidelines	X	X	X		X	X	X	X	X
Reference to technical connection conditions (TAB)	X								

All installation instructions for modules formulate mechanical and electrical requirements on the system and specify procedures for their installation. Besides instructions on work safety, they also include instructions on handling the modules to prevent damage during installation, such as glass or cell breakage and delamination.

The mechanical criteria demanded by a majority of the manufacturers mainly include an installation location free from mechanical stress at any temperature, the use of a suitable mounting system and attention to the maximum snow load. In addition, some manufacturers also prohibit modifications to the module frame, the module surface or the junction box.

Other instructions refer to topics relevant to fire protection, such as the presence of flammable materials in the vicinity of the modules, fire and surge protection and the proper handling and installation of the wiring.

Most installation instructions also give a detailed treatment of the electrical requirements on PV systems, in particular the assembly of strings in compliance with limits on voltages and short-circuit currents. Some manufacturers also recommend certain cable cross sections for DC and ground cables.

Besides the manufacturers' requirements, all installation instructions also refer to standards or other provisions and guidelines (VDE, VDEW, TAB), in particular DIN 1055 on load assumptions and IEC test standard 61730.

Altogether noteworthy is that German module manufacturers provide more comprehensive installation instructions than their international competitors, especially when it comes to safety and protective measures. Manufacturer 1, a well-known German company, covers every recorded subject in its instructions.

Besides the installation instructions, module manufacturers also publish compilations of technical information in the form of datasheets. While standardized as per DIN EN 50380, they show small discrepancies in scope among the manufacturers.

Conclusion

As with the datasheet standard, standardization of installation instructions must be demanded.

1.3.3.2 Inverters

Installation instructions from European, US and Chinese inverter manufacturers were evaluated.

Table 1-8 shows an excerpt of the market overview representative of the current market from the journal *PHOTON* (source: Market overview of inverters, PDF version, [1])

Table 1-8: Typical contents of installation instructions for inverters

	Manufacturer A	Manufacturer B	Manufacturer C	Manufacturer D	Manufacturer E	Manufacturer F	Manufacturer G	Manufacturer H	Manufacturer J	Manufacturer K
Installation										
Instructions on handling				X	X		X	X	X	
Installation by suitable specialist	X	X	X	X	X	X	X			X
Work safety regulations	X					X				X
Inspection for mechanical integrity prior to installation		X	X			X				X
Mechanical requirements										
Restriction on modifications	X	X	X	X	X	X	X			X

	Manufacturer A	Manufacturer B	Manufacturer C	Manufacturer D	Manufacturer E	Manufacturer F	Manufacturer G	Manufacturer H	Manufacturer J	Manufacturer K
Instructions on installation location	X	X	X	X	X	X	X	X	X	X
- Safety distances	X	X	X	X		X	X	X	X	X
- Mounting on flame-retardant material	X	X	X	X		X	X	X		
- Protection against UV radiation	X	X	X	X	X	X	X	X		X
- Air feed	X	X	X	X	X	X	X		X	X
- Ambient temperature	X	X	X	X	X	X	X	X		X
- Protection against wet		X	X	X		X	X	X		
Instructions on DC connection	X	X		X				X		X
Instructions on AC connection	X				X		X		X	
AC cable routing	X	X	X	X	X	X	X	X	X	
Strain relief					X				X	
Electrical requirements										
Limits on input voltage and power	X	X	X	X	X	X	X	X	X	X
Residual-current circuit breakers	X	X	X	X	X		X	X	X	
AC interconnection	X	X		X	X			X	X	
Grounding at inverter	X	X	X	X		X	X	X	X	X
Grounding of generator terminal	X	X	X	X	X	X	X		X	
Notes on further regulations										
References to standards	X	X	X	X	X	X				
References to guidelines	X		X		X				X	
Reference to technical connection conditions (TAB)		X	X					X		

The installation instructions for inverters are considerably more comprehensive than for other components. Besides instructions on installation, they also cover operation and maintenance topics as well as contain information on the peripherals of the inverter, such as the residual-current circuit breaker and AC cables.

Nearly all manufacturers require installation on a flame-retardant or non-flammable surface, specify safety distances and recommend measures for sufficient heat dissipation at the inverter. Usually they

also treat the potential equalization at the generator or grounding at the inverter itself. References to more detailed standards and guidelines are contained in all installation instructions to varying degrees.

Work safety issues are given relatively little attention. While individual protective measures such as disconnection before working on the inverter and the consideration of the discharge times of the capacitors precede the particular operational steps, references to work safety guidelines, protective equipment and to the use of the corresponding tools are usually lacking. Strain relief and fastening the connecting cables are also seldom addressed. The various manufacturers treat the subject of connection in very different ways. While some instructions provide extensive information or at least some notes on connection, others fully neglect the subject.

1.3.3.3 DC cables and connectors

Some large manufacturers of solar cell connection systems provide special instructions for the user, while others limit themselves to brief guides. Mostly Installation instructions and product information are found (

Table 1-9). Installation instructions for modules also contain in part information on the connecting lines and connectors.

Table 1-9: Typical contents of installation instructions for DC components

	Manufacturer a	Manufacturer b	Manufacturer c	Manufacturer d
Installation				
Installation by suitable specialist	**X**	**X**		
Work safety regulations	**X**			
Use of suitable tool	**X**	**X**	**X**	**X**
Inspection for mechanical integrity prior to installation				**X**
Mechanical requirements				
Restriction on modifications	**X**	**X**		**X**
Inspection of the plug connection		**X**		**X**
Compatibility	**X**	**X**		
Protection against dirt	**X**	**X**	**X**	
Protection against moisture	**X**	**X**		
UV protection		**X**		
Strain relief	**X**			

	Manufacturer a	Manufacturer b	Manufacturer c	Manufacturer d
Fastening	X			
Notes on crimping	X	X	X	
Bending radii	X	X		
Notes on further regulations				
References to standards		X	X	
Reference to work safety guidelines	X			
References to general provisions		X		

Generally the manufacturers allow only trained personnel to handle their system components. The products may be neither modified nor combined with other makes. In particular, established manufacturers reject combinations with connectors from other manufacturers.

No connections may be established with dirty or wet connectors. In the cable routing, cables and plugs must not lie in water or be exposed to sunlight over long periods of time, junction boxes and plug connections must not be stressed and bending radii must be maintained.

Especially extensive are the instructions for establishing crimp connections. Major manufacturers provide detailed and illustrated instructions in this regard, covering, among other things, the use of suitable crimping tools from the respective manufacturers.

The scope of the instructions varies more for cables and connectors than for other system components. Documentation from various manufacturers also contains in part contradictory information on the compatibility of different systems. In particular, many smaller companies claim compatibility of their systems with wide-spread connector systems, while manufacturers of the latter categorically advise against combinations with other systems.

1.3.3.4 Mounting systems

The assembly instructions for mounting systems are comparatively extensive, but geared more to the assembly than to the design and static strength of the system (

Table 1-10). Accordingly, they contain only few specifications on the condition of the completed installation. Generally all manufacturers demand a static inspection of the construction by appropriately trained personnel. Local snow and wind loads in particular are to be observed. Some instructions contain recommendations for avoiding damage from lightning and overvoltage by means of adapted cable routing and grounding of the subframe.

All manufacturers provide more or less detailed information on work safety during the installation and most refer to legal work safety regulations and guidelines of the professional associations. They also

specify suitable tools, either generally or also in specific cases. Only one manufacturer recommends checking the condition of materials before the start of assembly.

Table 1-10: Typical contents of installation instructions for mounting systems

	Manufacturer I	Manufacturer II	Manufacturer III	Manufacturer IV	Manufacturer V	Manufacturer VI	Manufacturer VII	Manufacturer VIII	Manufacturer IX
Assembly									
Installation by suitable specialist	X	X	X	X	X				X
Work safety	X	X	X	X	X	X	X		X
Antifall guard for installer			X	X	X	X	X		X
Use of suitable tool	X			X		X	X		
Check of screwed connections	X	X	X	X	X				
Requirements for installation conditions (weather condition - no moisture)		X							
Inspection for mechanical integrity prior to installation	X								
Mechanical requirements									
Static inspection	X	X	X	X	X	X	X	X	X
Snow loads	X	X			X	X	X	X	X
Wind loads	X	X	X		X	X	X	X	
Lightning and surge protection		X	X	X	X	X		X	
Water drainage	X		X					X	
Notes on further regulations									
References to standards	X	X	X	X	X	X		X	
Reference to work safety guidelines	X	X	X	X		X	X		
References to general provisions	X	X	X	X	X				

The assembly instructions for mounting systems differ only slightly in scope; only one manufacturer provides additional information on requirements for module orientation and cable routing. Nearly all instructions refer to standards on the layout of the mounting technology. Often mentioned are DIN 1055 on “Actions on structures,” DIN 4113 on aluminum constructions, DIN 18800 on measuring steel

structures and DIN 4102 on fire characteristics of construction materials. In addition, some assembly instructions also mention national construction regulations (regional building codes).

1.3.4 Installation requirements of the distribution grid operators

The installation requirements of the distribution grid operators (VNB) for connecting PV systems to low-voltage and medium-voltage grids are formulated in the Technical Connection Conditions (TAB), which as per § 19 of the German Energy Industry Act must be made publicly accessible. The TABs refer to the connection of domestic and industrial consumers, in addition to generation systems operated in parallel with the grid. They define limits on grid perturbations pertaining to system safety and stability, prescribe protective and monitoring equipment and regulate the properties of the fed-in electrical power.

While the distribution grid operators of the major energy utilities (such as On-edis, Westnetz) issue their own TABs, the smaller distribution grid operators employ the guidelines created by the Federal Association of the German Energy and Water Industries, which contain no regulations on generating systems, but refer to the VDE application guideline on “Generators Connected to the Low-Voltage Distribution Network,” VDE-AR-N 4105:2011-08, or to the “Technical Guideline on Power Generating Systems at the Medium-Voltage Power Grid”. Besides the technical connection parameters, the TABs also regulate organizational procedures for registration, commissioning and maintenance of the connection.

1.3.4.1 Grid connection

The system is connected to the distribution network via the grid connection or node. For systems > 30 kW this will generally be the previous connecting point of the property. A meter connection column as per VDE-AR-N 4102 is then to be set up as a switching and disconnecting point, to which the TABs require unrestricted access for the distribution grid operators, unless an automatic disconnection device was installed. Like the rest of the system, the connection may be set up only by qualified specialist companies.

In addition, the distribution of the power input over the phases of the grid connection is regulated. The asymmetry between the external conductors with feed-in to the low-voltage grid must not exceed 4.6 kVA; from 5 kWp a system generally requires a three-phase connection. Up to 30 kWp the three-phase connection can also be established by using multiple single-phase connections to the phases of distributed inverters, if the maximum permissible asymmetry is not exceeded.

1.3.4.2 Measurement technology

The electricity meters documenting the consumed or produced energy must be designed according to the level of the connection power. The TABs stipulate load profile meters from 100,000 kWh of consumed energy per year or 100 kW of fed-in power. The TABs also organize the provision, installation, operation and readout of the measuring equipment. The meter cabinet with connection and mounting equipment is provided by the customer. Depending on the distribution grid operator, a remote readout accompanies operation of the load profile meters, either by radio signal or by telephone line. With regular operating currents > 60 A the electricity meter has the form of a measuring transformer. In the event that the customer opts for comparative measurements, the TABs arrange for shared use of the transformer.

1.3.4.3 Switch and remote control technology

For galvanic isolation as per DIN VDE 0105 part 100, a switch device with load switch capacity is specified at the AC end. For systems ≤ 30 kWp this can be an automatic disconnection device with two parallel grid monitoring units, each coupled in series with a load disconnect switch or power switch. The switch device is triggered if the voltage or frequency limits defined in the TABs are exceeded or the connection to the local power transformer is broken and must be designed for the maximum short-circuit current. Following a power outage in the distribution network, the system may switch back on at the earliest after 3 minutes (low voltage) or 15 minutes (medium voltage).

Besides the automatic disconnection the TABs require for PV systems the installation of a ripple control receiver for limiting the maximum feed-in power. The signal is transmitted via the phone connection, by radio or through audio frequencies in the grid, depending on the network operator. Power generation is reduced in the increments 60%, 30% and 0% of the maximum feed-in power and is converted by relay. Systems ≤ 30 kWp require no ripple control receiver, if the feed-in is permanently throttled to 70% rated generator power.

1.3.4.4 Reactive power compensation

The TABs obligate the operator of a power generator to provide a certain share as reactive power. Its power factor cos φ is specified by the distribution grid operator, is graduated according to system size, operating point and rate period of the feed-in and lies in the range of 0.9 (underexcited) to 1. Consumed or fed-in reactive power exceeding the tolerances is charged to the system operator according to the conditions stated in the TABs. Capacitors installed for the reactive power compensation must always cut in and shut off together with the generator, in order to avoid capacitive reactive power.

1.3.4.5 Grid perturbations

Generally other grid components and connections must not be perturbed by operation of the generator. In specifying limits for disturbance variables, some TABs refer to DIN EN 61000-2-2, while others define their own limits. Conformity with the grid operator's requirements comes with the manufacturer's declaration or the operator's own calculations.

The individual disturbance variables defined for the limits are:

Voltage pulses from cutting in or shutdown of the generators or major consumers, flickering at the grid connection point, harmonic currents and voltage asymmetries between the external conductors. In addition, some TABs also contain limits for impairment of intra-grid audio frequencies for ripple control receivers.

For avoiding grid perturbations, the system is disconnected from the grid if the maximum registered feed-in is exceeded.

1.4 Maintenance status and quality assurance

1.4.1 Manufacturer’s warranty and guarantee conditions

Most components of a PV system come with a manufacturer's guarantee in addition to the legally required product warranty. The manufacturer’s guarantee is tied to the particular manufacturer’s guarantee conditions, which demand measures for maintenance and servicing in addition to proper installation. The specifications of the guarantee conditions are generally implemented, since failure to do so would void the manufacturer's guarantee.

Besides the manufacturer’s guarantees, there is also the installer’s warranty, which depending on the type of contract holds for two (purchase agreement), four (construction contract) or five (contract for services) years. In addition, many installers also provide further services for promoting sales.

The terms “warranty” and “guarantee” are used in various ways in this regard, and sometimes incorrectly. For example, a manufacturer will use the term “Leistungsgewährleistung” (performance warranty) in the German translation of the guarantee conditions for the manufacturer’s products.

The following discusses in more detail the guarantee conditions for the individual components. We exclude DC components, since they are covered only by the two-year legal warranty. Our lists of manufacturers make no claim to completeness, but represent a comprehensive cross section of the market.

1.4.1.1 PV modules

The manufacturer’s obligations over the module service life break down into three different warranty and guarantee claims.

The legal warranty applies for 24 months from delivery of the module and comprises functionality and appearance.

In addition, all module manufacturers provide a product warranty or guarantee that is valid for 5 to 10 years. It covers production as well as material defects and for some manufacturers also includes aging beyond usual extent.

The performance guarantee goes into effect in case of reduced power by the module. This guarantee stipulates linear or graduated degression rates for the product service time below which a replacement must be provided.

Common are periods of 10 years for a performance guarantee over 90% of the module power and over 20 years for 80% of the power. Manufacturers are increasingly providing performance guarantees of up to 30 years, with a linearly expected annual loss in power of 0.5 to 0.7%. [2]

Regarding performance guarantees, it must be kept in mind that power tolerances (module datasheet) are always used in solar module calculations. Added are measurement tolerances making verification of the claim for the performance guarantee difficult. In case of a specified module power tolerance of ±3% and a measurement tolerance of ±3% as well, a power reduction greater than 10% can be verified only if the measurement value is less than the rated power by more than 16%. Table 1-11 contains an overview of warranty and guarantee conditions from different manufacturers.

All three forms of warranty provide compensation by exchanging or repairing the module in question, or financially in the form of reimbursement of the residual value or payment for revenue lost because of

the reduced performance. Some manufacturers also assume the costs incurred from replacement and transport of the modules.

Table 1-11: Criteria in module manufacturers' warranty and guarantee conditions

	Manufacturer 1	Manufacturer 2	Manufacturer 3	Manufacturer 4	Manufacturer 5	Manufacturer 6	Manufacturer 7	Manufacturer 8
Types of warranty and periods [years]								
Legal warranty	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Product guarantee/warranty	**10**	**12**	**5**	**5**	**10**	**10**	**10**	**10**
Performance warranty	**25**	**25**	**25**	**20**	**30**	**25**	**25**	**25**
Warrantee								
End customer	**X**	**X**			**X**		**X**	
First purchaser		**X**	**X**	**X**	**X**	**X**		**X**
Damage								
Material and workmanship flaws	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Reduced performance	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Visual flaws		**X**				**X**		
Services								
Exchange of product	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Repair	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Acceptance of replacement costs	**X**	**X**	**X**	**(X)**		**X**		
Reimbursement of residual value	**X**			**X**	**X**	**X**		**X**
Compensation for loss of revenue from reduced performance	**X**							**X**
Conditions								
Installation as per installation instructions	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Proper assembly	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Normal use	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Regular maintenance	**X**		**X**		**X**	**X**		
Use in original system	**X**			**X**	**X**		**X**	**X**

	Manufacturer 1	Manufacturer 2	Manufacturer 3	Manufacturer 4	Manufacturer 5	Manufacturer 6	Manufacturer 7	Manufacturer 8
Exclusion of liability for:								
Stand-alone systems	X	X	X	X	X	X	X	X
Force majeure	X	X	X	X	X	X	X	X
Vandalism	X	X	X	X	X	X	X	X
Combination with other module types	X	X	X	X	X	X	X	X
Overvoltage, grid perturbations		X				X	X	X

A precondition for warranty claims is proper use of the module as intended, in particular compliance with the installation instructions (see 2.3.1 Manufacturers' Installation Instructions). Ascertained infringements of the installation instructions or generally recognized codes of practice void all warranty claims against the manufacturer and revert to the constructor of the system if the latter is still liable.

About half of the module manufacturers require appropriate maintenance of the system for continuation of liability. Hardly any of the manufacturers state this requirement in terms of maintenance intervals or scope of the measures, however. Merely one set of installation instructions recommends an annual visual inspection of the wiring and mounting system.

1.4.1.2 Inverters

Unlike modules, inverters do not come with any separate performance guarantee. Reduced performance is instead covered by the manufacturer's guarantee, which applies alongside the two-year legal warranty and runs for two to seven years.

In addition, some of the manufacturers offer an incremental extension of the product guarantee for up to 25 years, at an extra charge. In a warranty case, the defective device is generally repaired or replaced by the manufacturer. Financial compensation is not provided for.

Table 1-12: Criteria in warranty and guarantee conditions for inverters

	Manufacturer A	Manufacturer B	Manufacturer C	Manufacturer D	Manufacturer E	Manufacturer F	Manufacturer G	Manufacturer H	Manufacturer J
Forms/max. period [years]									
Warranty	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Factory product guarantee	**5**	**7**	**2**	**5.5**	**5**	**5**	**12**	**2.5***	**5**
Product guarantee subject to extra charge	**20**	**25**	**20**	**-**	**-**	**20**	**-**	**-**	**-**
Warrantee									
End customer	**X**	**X**	**X**		**X**	**X**	**X**	**X**	
First purchaser				**X**					**X**
Damage									
Material and workmanship flaws	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Reduced performance	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Visual flaws			**X**	**X**					
Services									
Exchange of product	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Repair	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	
Acceptance of replacement costs	**(X)**	**X**	**X**	**X**	**(X)**		**(X)**	**(X)**	**X**
Reimbursement of residual value							**X**		
Compensation for loss of revenue from reduced performance				**X**					
Conditions									
Installation as per installation instructions	**X**			**X**	**X**	**X**	**X**	**X**	**X**
Proper assembly	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Normal use	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Regular maintenance	**X**			**X***	**X**	**X**	**X**		
Exclusion of liability for:									
Force majeure	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Overvoltage, grid perturbations	**X**	**X**	**X**	**X**	**X**	**X**		**X**	**X**
Infringements of common regulations		**X**	**X**	**X**	**X**	**X**	**X**		**X**

*Only for some product series

Asserting a claim under the guarantee presupposes that the inverter has been properly mounted and operated. Not all manufacturers refer to the installation instructions, however, but instead refer to common regulations, mainly those from the VDE. No liability exists for damage caused by force majeure or overvoltages. Exempted from the guarantee are usually also wear parts like filters and varistors.

Manufacturers differ greatly in the requirements on maintenance. While some of them state no express conditions at all, others require merely “proper operation” of the inverter. Still others even mention specific measures, such as cleaning the air filters or a visual inspection of the connection terminals, and specify maintenance intervals.

1.4.1.3 Mounting systems

For mounting systems, a ten-year factory product warranty in addition to the legal warranty is common. Only the larger manufacturers publish comprehensive warranty conditions, however. Usually details on the guarantee are published in the datasheets of the particular system or in a brief guarantee certificate. The factory guarantee covers defects related to material flaws and production errors and or a product exchange or factory repair in case of damage. Assumption of transport costs is not common.

Table 1-13: Criteria in warranty and guarantee conditions for mounting systems

	Manufacturer I	Manufacturer II	Manufacturer III	Manufacturer IV	Manufacturer V
Forms/max. period [years]					
Warranty	**2**	**2**	**2**	**2**	**2**
Factory product guarantee	**10**	**10**	**10**	**15**	**10**
Warrantee					
End customer	**X**		**X**		**X**
First purchaser		**X**		**X**	
Damage					
Material and workmanship flaws	**X**	**X**	**X**	**X**	**X**
Visual flaws					
Services					
Exchange of product	**X**	**X**	**X**	**X**	**X**
Repair		**X**			**X**
Acceptance of replacement costs		**X**			**X**
Reimbursement of residual value	**X**				**X**

	Manufacturer I	Manufacturer II	Manufacturer III	Manufacturer IV	Manufacturer V
Compensation for loss of revenue from reduced performance					
Conditions					
Installation as per installation instructions	**X**	**X**	**X**	**X**	**X**
Proper assembly	**X**	**X**	**X**	**X**	**X**
Normal use	**X**	**X**	**X**	**X**	**X**
Regular maintenance	**X**	**X**			
Use in original system					**X**
Exclusion of liability for:					
Force majeure	**X**	**X**	**X**	**X**	**X**
Infringements of common regulations	**X**		**X**	**X**	**X**

Warranty claims can be accepted only if assembly was performed in compliance with the installation instructions by a qualified handicraft business. In addition, the static design must comply with the conditions in the particular application. Some guarantee conditions refer here to DIN 1055 (see 2.3.2 Standards, Regulations and Guidelines). Disassembly of the mounting system or parts thereof for use in a different system is not expressly precluded, if the static requirements are met. Most manufacturers require regular maintenance of the system as a precondition for continuation of the warranty. They do not specify maintenance intervals or specific measures, however.

1.4.2 Facilities for quality assurance and maintenance

Besides the manufacturers of PV components, there exists a series of other institutions and facilities for ensuring the quality of PV systems. On the one hand, there exist normative specifications by the manufacturers, dealers and installers. On the other hand, industrial and professional associations as well as independent test centers offer further voluntary certifications and documentation templates.

1.4.2.1 Quality assurance for the components

The first step in quality assurance lies in the manufacturer's quality checks during production. The corresponding normative specifications include ISO 2859 on "Sampling procedures for inspection by attributes" and ISO 3951 on "Sampling procedures for inspection by variables". The first refers to inspection characteristics that have the character of attributes, while the second focuses on constant product properties.

Both describe procedures for continual quality control in production and at goods issue, and state sampling sizes and scope. On the basis of these standards, intermediate dealers have developed their own processes for quality assurance.

Compliance with quality standards can be monitored on a voluntary basis by independent test centers. For example, TÜV Rheinland offers “power-controlled” certification for module manufacturers. A precondition for the issue of a certificate is a high standard of quality assurance with particular attention to compliance with performance tolerances for modules. Several prominent module manufacturers both in and outside of Germany are availing themselves of this offer.

Other institutes undertaking independent quality inspections for components are (in Germany) the Fraunhofer ISE, the VDE, PI Berlin and (internationally) Ispra, UL and JET, for example.

For the further improvement of quality assurance for PV modules and the assessment of PV modules in solar parks, a research project is being jointly conducted between 2013 and 2017 by Sunnyside upP, ISC of Constance, RWTH Aachen, the Solarfabrik and TÜV Rheinland. The project is being supported with funding from the Federal Ministry for Economic Affairs and Energy (BMWi) on the basis of a resolution of the Bundestag with reference number 0325588D.

1.4.2.2 Quality assurance for assembly and acceptance inspection

At least as important as the quality of the employed components is the correct performance of assembly by the installer. Complaints by end customers pertain as much to improperly performed work as to defective components. This is equally true of damage-causing events, including fire, as will become clear in section 3.3 Damage and fire event analysis of PV systems.

Damage from installation flaws noticed in due time are covered by the installer’s warranty. If this warranty has already expired, the end customer must pay for the damage themselves.

For detecting defects in the system even prior to acceptance and for the best possibility of reacting to subsequent damage, DIN 62446 (VDE 0126-23) contains specifications on commissioning inspections, documentation and maintenance (see section 5.5). This standard expressly does not apply to systems with integrated power storage systems, however. The documentation is produced by the constructor of the system and provided to the end customer at commissioning. It contains a wiring diagram, product data sheets of all employed components and instructions on operation and maintenance.

The wiring diagram consists of a sketch of the overall system up to the grid connection point and information on the individual components, such as manufacturer, component description, string size, rated current and voltage, position and accessibility. As instructions for further operation of the system, the owner is provided information in case of a system malfunction or emergency shutdown as well as information on the system condition and existing warranty claims. At this point the installer also has the possibility of leaving behind maintenance instructions.

Regarding the commissioning inspection, DIN EN 62446 supplements IEC 60364-6, “Low-voltage electrical installations – Part 6: Verification” (German implementation of DIN VDE 0100-600), dividing the inspection into viewing, measuring and testing. The visit comprises a visual inspection of the system according to criteria determined by the standard as well as a check of conformity of all components with common safety regulations. Testing and measurements contain every additional inspection of functional availability and safety of the system, in particular the application of measuring procedures described in the standard. DIN EN 62446 makes these general specifications for the case of a PV system and expands the test criteria of IEC 60364-6 along these lines.

As an orientation aid for the system documentation, several associations have issued standardized preprinted forms to ensure the quality of the documentation, such as the “PV passport”; see section 2.4.3.

Another tool for ensuring quality are the RAL quality and test requirements for PV systems (RAL GZ-966) compiling the common technical rules for installing and operating PV systems and serving as a template for technical terms of delivery. They contain a list of requirements on the production of components as well as on the planning, installation and maintenance of entire systems. In doing so, they capture at least the status of current standardization, while tightening the latter in a few points. The use of RAL GZ-966 in supply agreements is subject to a charge for the contractor and presupposes certification by the RAL Quality Association. To obtain this certification, the company must undergo an initial inspection and thereafter repeat inspections at intervals of at most two years, during which its capability for complying with RAL GZ-966 will be assessed.

For PV power plants qualification services are provided by various institutes, test facilities and experts. The advantage is quality assurance parallel to construction, with a quality check by an independent third party at the acceptance inspection of the system.

In addition, services that are focused on the certification of installation specialist companies (for example, by TÜV Rheinland) or on PV experts (for example, by the VDS (Association of German experts)) can ensure a high installation quality.

1.4.2.3 Maintenance

Instructions for the maintenance of low-voltage systems in general appear in DIN VDE 0105-100 “Operation of electrical installations – Part 100: General requirements”. Repeat inspections of the system must occur at appropriate intervals, so that any deterioration of safety conditions will be detected before damage to people or property occurs.

As in the commissioning inspection, different measures for viewing, testing and measuring are provided for, which are not mandatory, however, but are to be implemented so as to exclude any detriment to system safety. The repeat inspections of PV systems are regulated in DIN EN 62446, which treats the commissioning inspection as a standard for the scope of the repeat inspections. The recommendations on maintenance and cleaning contained in the system documentation must also be followed. However, specific time intervals between the repeat inspections are not specified here either. To close this gap, DIN VDE 0100-712 is currently undergoing expansion, and will possibly recommend *maintenance intervals between two and three years*.

A few guarantee conditions, in particular for inverters, also state measures for maintenance (see section 2.4.1: “Manufacturer’s Warranty and Guarantee Conditions”).

While other countries, such as Switzerland, stipulate maintenance intervals for electrical energy producing plants (including PV systems) by law, Germany merely offers recommendations from insurance companies via standards and guidelines. Exceptions are individual cases of binding agreements between investors and operators, for example.

Regular maintenance measures are the precondition for undisrupted and safe operation of the system. Faulty components or installations, environmental effects and general aging processes can lead to local overheating over the course of the operating period and in the worst case cause electric arcs.

1.4.3 Requirements by law and by institutions (VDS, GDV, BSW)

The specifications of the particular regional building code with the corresponding requirements must be heeded. This applies also and especially to roof accessibility for fire extinguishing purposes and to the structural fire protection requirements. The system is commissioned and connected to the grid as per VDE AR 4105 and the general supply conditions (AVBEltV).

Together with the Verband der Sachversicherer (VdS) (Registered Association of Property Insurers), the Gesamtverband der Deutschen Versicherungswirtschaft e.V. (GdV) (Registered Association of German Insurers) formulates guidelines for systems and products. These VdS guidelines basically comprise measures on personal, property and building protection for the purpose of damage prevention. The Technical Guideline for Photovoltaic Systems, VdS 3145, dated 07/2011, offers information from the insurers' perspective on selecting, planning, installing and operating grid-connected PV systems with the aim of avoiding or minimizing operational disruptions, fires and damage. Guideline VdS 2010 on "Risk-Oriented Lightning and Surge Protection" authoritatively specifies the risk and protection classes for lightning and surge protection. Guideline VdS 2025 provides information on planning, designing, installing and operating cable and electrical line systems.

Together with the German Electrical and Electronic Manufacturers' Association (ZVEH), the German Solar Industry Association (BSW) has developed the "PV passport *www.photovoltaik-anlagenpass.de*. It basically consists of a multi-page form and inspection log for a professional inspection and documentation and specifies the guidelines to be followed in planning and installing the PV system (see also 8 Supplement, IX Appendices, c).

2 Electric arcs: Physical background and DC issues

Electric arcs are plasma currents and perceivable as searing light that is arc-shaped from a certain length, with typical crackling noises. The temperatures of an electric arc can reach several thousand degrees.

While AC electric arcs have self-extinguishing properties owing to the voltage and zero-current crossings, DC electric arcs can generally burn with stability, which poses a considerable risk of fire.

All electric arcs are accompanied by a high-frequency, electrical noise that can be registered in the conductor as well as through detection of the electromagnetic waves. The characteristics of a DC electric arc, for example, the way it can appear in the PV generator field, differ from those of an electric arc in the AC circuit. This will be explained in detail in the following.

2.1 Definition and properties of an electric arc

An electric arc is a gas discharge occurring between two electrodes in which an electrical potential difference causes an impact ionization, which in turn allows a continual flow of current.

Above a certain temperature a conductive plasma is formed from the nitrogen in the air. This state can occur if contacts through which an electric current is flowing are pulled apart, for example. As the contact pressure of the contacts decreases, the transition resistance increases. Fusion will occur at points, followed by boiling of the contact material. The remaining metallic bridge finally explodes. An initial metallic vapor electric arc can become a stable gas discharge electric arc if the current and voltage are sufficiently high [3].

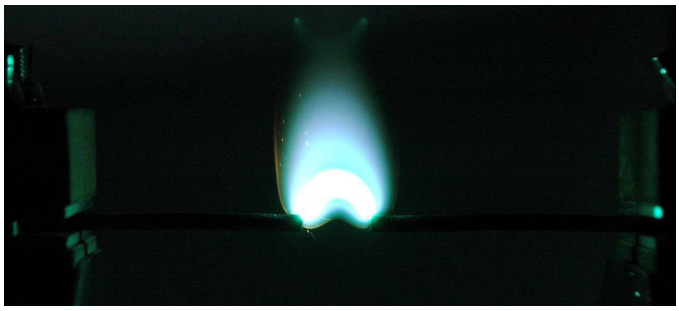


Figure 2-1: Stable DC electric arc between copper electrodes, photo: TÜV Rheinland

For a stable, freely burning electric arc to occur, sufficient voltage must be available to the electric arc. This electric arc voltage consists of the cathode drop, the anode drop and the column drop linearly dependent on the length of the electric arc. The minimum voltage for an (extremely short) electric arc thus consists of an anode drop and a cathode drop; no electric arcs are possible with a lower voltage.

Both the minimum voltage and the minimum current of an electric arc depend on the material. In the case of copper, they are 13 V and 0.4 A, respectively, according to the literature [4]. Series of measurements performed at TÜV Rheinland have confirmed these magnitudes [5]:

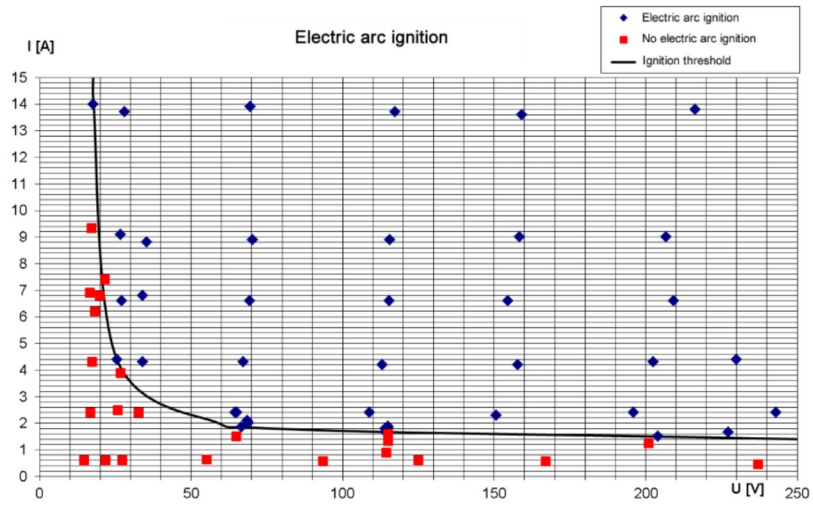


Figure 2-2: Electric arc ignition limit determined on the basis of copper electrodes, source: TÜV Rheinland

An electric arc emits very bright light in both the visible and UV light ranges and can cause eye damage. The electric arc itself is distinguished by extremely high temperatures of 10,000 K and higher [6], so that the resulting fire can easily spread to surrounding components.

A powerful voltage flashover produces a very loud noise, comparable to a thunder clap, caused by the air escaping at ultrasonic speed from the discharge channel. In addition, the explosion-like spread of the hot air creates a pressure wave. In contrast, an arc flash of just a few amperes produces only a soft crackling and no perceptible difference in pressure.

The electric arc emits electromagnetic radiation of frequencies up to the MHz range through cables as well as through the air. Unfortunately, no spectrum characteristic of all types of electric arc exists that would enable reliable identification of an electric arc in a PV system under any circumstances. Identification is possible based on certain shared properties of these spectra, however. The procedure is described in section 5.3.5 Electric arc detection.

2.2 Arc quenching

The purpose of an arc quenching device is to increase the energy beyond what is necessary for maintaining an electric arc in the stable range and thereby to rupture the arc path.

Generally this rupture is brought about by increasing the required arc voltage. The following measures are used with conventional switch elements:

- Lengthening the electric arc column
- Cooling the electric arc
- Pressure on the electric arc
- Segmentation of the electric arc

Figure 2-3 shows schematically how these measures can be implemented in an arc quenching device.

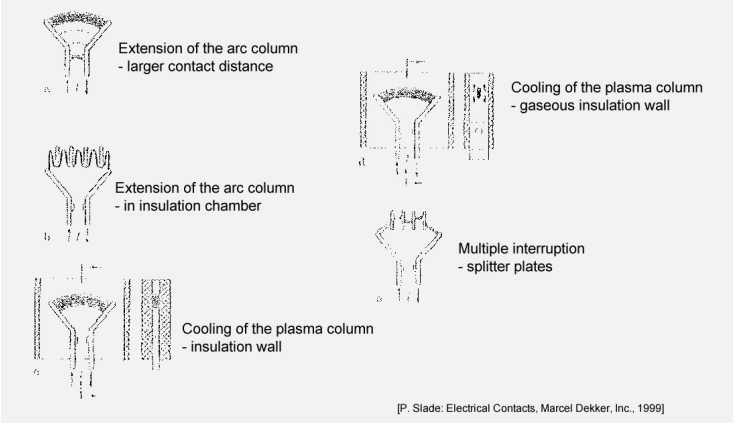


Figure 2-3: Different possibilities of electric arc quenching **[4]**

2.2.1 Arc flashes in AC and DC systems

Transmission and distribution of electrical energy occurs mainly in AC systems. Alternating current is distinguished by the periodic reversal of the current flow, which has a positive effect on the arc safety of electrical systems.

As an AC voltage or alternating current approaches its zero-point crossing in the case of an existing electric arc, the current and voltage levels required for maintaining the arc are exceeded, which quenches the arc.

A repeated voltage increase will often not cause re-ignition, since this would require a much higher voltage than that needed to maintain an electric arc.

Since the arc path is still partially ionized and heated by the pre-existing electric arc and leakage currents can occur along damaged insulation segments, a new flashover is still possible in unfavorable cases. In these cases, an intermittent electric arc occurs that is briefly extinguished twice per current period, in order to re-ignite again at sufficient voltage.

The situation is different with a DC system, as is present in PV modules, the module wiring and the string distribution of a PV system up to the inverter. Here there is no zero-point crossing. Electric arcs persist and burn with stability as long as the voltage and current suffice for maintaining them. This can certainly be the case for longer periods of time (up to some ten minutes).

Since DC electric arcs are not intermittent, but constant, their radiation has a different characteristic than that of AC arcs. For this reason DC and AC arcs cannot always be detected by the same method.

2.2.2 Electric arc characteristics with different DC sources

If an electric arc is supplied by an energy source, the U/I characteristics of the generator and the arc ignition boundary (see Figure 2-2) intersect. Figure 2-4 shows the arc ignition boundary for a fixed electrode spacing with the characteristics of a PV generator and an active linear two-terminal circuit (voltage source with an internal resistor) with identical no-load voltage and identical short-circuit current. We can clearly see that the PV generator characteristic intersects the electric arc ignition boundary. If on the other hand we compare the characteristic of the active linear two-terminal circuit with the electric arc ignition boundary, we find that no intersection occurs. The electrode spacing is too great to maintain the voltage of the arc at a given resistance.

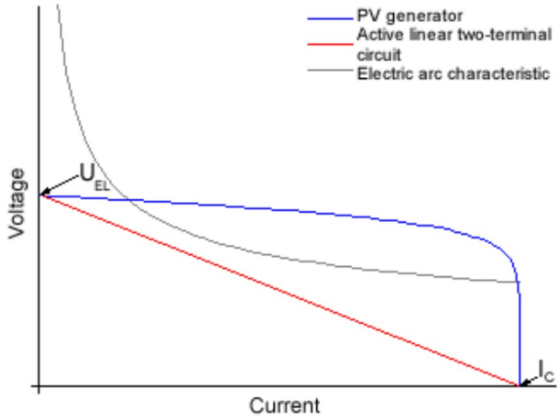


Figure 2-4: U/I characteristic of an active linear two-terminal circuit and of a PV generator and the electric arc ignition threshold with fixed contact spacing (schematic).

As a consequence, electric arcs in PV systems can already remain stable longer with smaller contact spacing than in conventional DC systems, owing to the current source-like properties of the solar generator. In addition, switchgear designed for conventional DC sources cannot necessarily shut down a PV generator with the same parameters (I_{SC}, U_{OC}).

Summary

An electric arc is a gas discharge (plasma) between two electrodes caused by impact ionization that allows a flow current depending on the material and the presence of minimum levels of current and voltage. In DC systems this current is not self-extinguishing.

Because of their particular PV generator characteristic, PV systems support electric arcs in case of a fault. The electric arc issue therefore deserves special attention in reference to fire risks.

3 Safety and quality in photovoltaics – risks and errors

Besides structural properties (such as spacing), the material properties of the participating components are crucial in the development and spread of a fire. Here different factors like fire resistance, sustained combustion or smoldering or the possible dripping of burning parts determine the spread and ultimately the effects of a fire. Since polymer materials make up a significant share of a PV module, their properties in particular greatly influence fire behavior.

The research project investigated two different scenarios of PV fire emergence.

(1) Fires in or at the building and spreading to the installed PV system.
(2) PV system as cause of fire given overheating with scorching or production of an electric arc at defective contact points in the module (or other components), corresponding to the damage analysis in section 3.3

The assessment and requirements of the material properties differ in part among these scenarios. Finally, the materials should meet all requirements as much as possible.

While section 3.1 considers the properties of a PV module regarding resistance to fire from an external source, section 3.2 analyzes the risks of arcing in a PV system and section 3.3 presents the results of a detailed damage analysis of actual events of overheating and PV fires in recent years in Germany.

The requirements and approaches to preventing fire emergence within the PV system especially due to arcing are described in sections 3.5 and 3.6.

3.1 Fire behavior of modules

Different components of a photovoltaic system are combustible because of their polymer content. Section 4.6 describes in particular the composition of PV modules as they are mostly installed in existing PV systems in Germany. The polymer content of crystalline glass thick-film modules (c-Si) is 5 – 10% [7], [8], [9], or about 600 – 1,200 g/m². This content largely pertains to the embedding material (EVA embedding film) and the backing (PET/PVF). In addition, various adhesives and sealants are used, along with insulation materials in junction boxes, connecting cables and connectors.

Given an assumed module area of 50 m² (approx. 38 standard modules, approx. 9 kW_p), up to 60 kg of polymer materials thus come from the modules alone. Other polymers occur in string cables, junction boxes and inverters.

Polymers generally produce a high combustion heat amounting to about the level from heating oil, according to a VDS publication [10], as in the case of polyethylene, for example (PE: 46 MJ/kg > heating oil: 43 MJ/kg), as illustrated in the following figure.

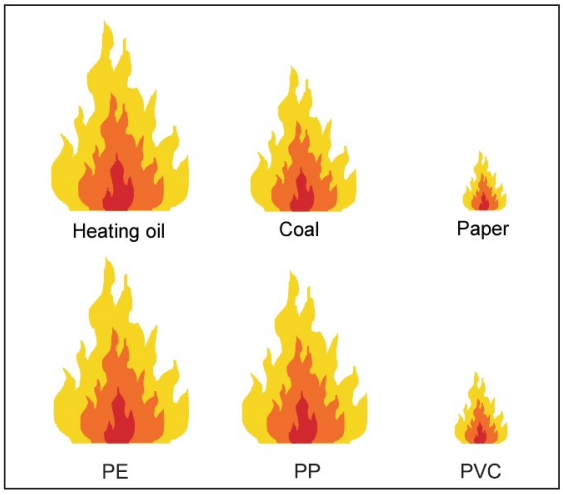


Figure 3-1: Combustion heat of different polymers compared with conventional heating substances **[10]**

In the event of a fire involving a PV system, the fire behavior of the employed polymers and their mass in the components play an important role in fire development and spread.

3.1.1 Fire tests (resistance to flying sparks and heat)

PV modules forming part of a roof (building-integrated PV modules (BIPV)), are tested as roof coverings in Germany. Generally roofs must be sufficiently resistant to fire from external sources and to heat radiation. PV modules as roof components must meet these requirements. There are different test procedures for assessing the fire behavior of roofs with respect to external and internal sources. DIN VDE 0126-21 on “Photovoltaics in Building” declares the special requirements on BIPV modules. In addition, in its bulletin from 2012 the DIBt refers to the necessity of a general building authority test certificate (abP) with inspection as per EN 13501-5 (ENV 1187-1) or DIN 4102-7 for roof-mounted PV modules.

On the other hand, PV modules of an elevated solar system are located outside the building envelope on roofs (“hard roof coverings”) and are not subject to any particular requirements of the building authority approval for fire protection in reference to resistance to flying sparks and heat, but they are regarding inflammability with min. *normal flammability* through DIN EN ISO 11925-2 and EN 13501-1, class E, as per requirements of the state building codes.

Section 1.3.2 lists all the normative requirements on PV modules. A detailed description of the fire tests of PV modules including pass criteria provided for in Germany and internationally appears in a research report of the BAM from 2014 [11]. The research investigated fire behavior including emissions from PV modules in laboratories.

Three of the most common types of modules were also studied in the fire lab. The identified fire behavior is described below, while pollutant emissions are discussed in detail in section 4.6.

3.1.2 Flammability and fire spreading

A market review by Photon from 2012 (see section 4.6.3) revealed that the market share of crystalline modules as the clearly leading technology has remained relatively constant at 80% to 90%, while the share of all thin-film technologies in total lies between 10% and 20% (with a declining tendency in recent years). The Currenta fire laboratory conducted three series of experiments with the following technologies:

- c-Si (crystalline thick-film module, glass film laminate)
- CIS (thin-film module based on cesium indium selenium semi-conductors, glass film laminate)
- CdTe (thin-film module based on cadmium telluride semi-conductors, glass-glass laminate)

(see also section 4.6.6).

An elevated solar system parallel to the roof and in a pitched position (23° incline) was emulated, with the fire spreading from the underside of the module (fire emergence scenario: influence of a roof timber fire). The experimental setup and performance of the experiment are described in detail in 4.6.6.1, the results can be found in IX Appendices in the Supplement.

The experiments were performed underneath an exhaust hood based on ISO 9705, with an exhaust flow rate of about 1 m³/s. The following variables were measured for describing the fire behavior:

- Heat release rate
- Smoke production rate
- Temperatures on front and back of the module
- Mass loss of the modules and mass of the fire residue
- Destroyed module surface

Two different burner outputs of 25 kW and 150 kW simulated different levels of fire stress.

In the 25 kW burner output experiments, only locally limited, otherwise primarily surface, damage occurred on all three module types.

Figure 3-2: Damage from stress with 25 kW burner output, left: c-Si, center: CIS (transversely placed), right: CdTe (transversely placed)

At 150 kW burner output, on the other hand, all module types were destroyed over wide areas:

Figure 3-3: Damage from stress with 150 kW burner output, left: c-Si, center: CIS (transversely placed), right: CdTe (transversely placed)

Glass film modules (c-Si, CIS)

The results of the lab tests can be summarized as follows: burning material already fell from test samples within about 1.5 – 4 minutes; after 2 – 4 minutes the backsheet became detached and a full-scale fire started after 6 – 8 minutes. The upper glass plate burst after 7 – 10 minutes. After about 12 minutes most of the combustible parts had already disintegrated.

Glass-glass module (CdTe)

This test sample already began dripping burning material after 2.5 minutes; the glass (rear side) fractured after about 4 minutes, and fire penetration occurred 30 minutes later.

As long as combustible material was still present after the end of the flame impingement, all 3 test types subjected to the 150 kW burner continued burning for 2 – 3 minutes. In the tests with merely 25 KW burner output no significant after-burning was determined.

In other words, under relatively low stress, e.g. with a smaller electric arc turned off by an arc detector, no independent spread of fire occurred on these specimens.

On the other hand, once a full-scale fire develops in a PV module, it can continue burning and thereby spread the fire to other elements. This is also the case with glass-glass modules.

If we consider the heat release rate in these tests, we see that the fire develops primarily between approximately 4 minutes and about 12 minutes after the start of flame impingement, after which time it decreases relatively fast. Below we show this in the case of the c-Si module. The other two module types showed similar developments over time; merely the values differ.

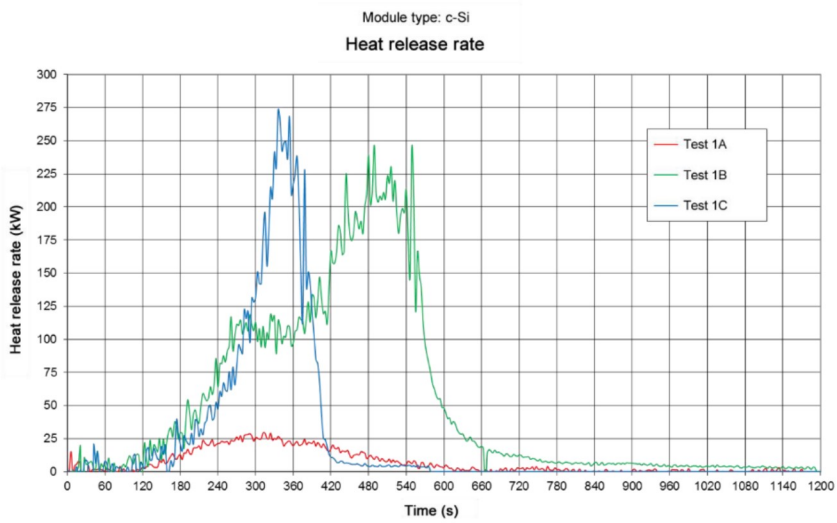


Figure 3-4: Heat release rate of the c-Si module during the tests (red – 25 kW, green –150 kW burner, (blue – the fire was extinguished after 7 minutes, so not relevant here)

The fire tests conducted by experts from the Bundesanstalt für Materialforschung und -prüfung (Federal Institute for Materials Research and Testing, BAM) in a research project [12] on the fire behavior of PV modules contained several different series of tests, including a series with stress analogous to the test series described here, with a gas flame impinging from below. The burner output was merely 30 kW with a compact flame (spot stress as opposed to wide-area application in the tests performed in this project).

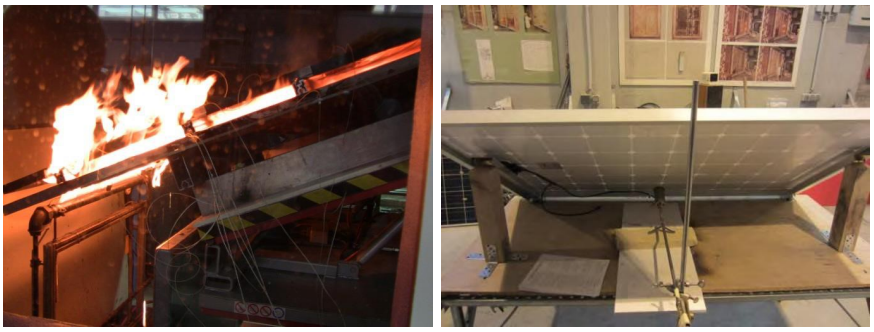


Figure 3-5: Left: TÜV/Currenta test setup with surface burner, photo: TÜV Rheinland, right: BAM with point-like gas burner centrally positioned, photo: BAM **[12]**

As results BAM found that:

- Damage from flame impingement from below was significantly greater than in the standard fire tests with flame impingement from above (burning brand tests), for both crystalline thick-film modules (glass-film) and thin-film modules (glass-glass).
- No flame penetration occurred in the crystalline modules, although the modules themselves were damaged over large surface areas.
- Thin-film modules suffered flame penetration already after 2 minutes with only low surface damage.

By comparison, significant differences were found in the results for the fire behavior of PV modules. The statements on the time of burn-through, extent of destruction, detachment of burning parts and fire propagation vary depending on the flame intensity and impinged module area.

Specific statements on fire behavior accordingly apply only to the examined test samples in the particular test constellation. No generalizations can be made!

General statements from previous fire tests on modules or module samples agree with one another.

Conclusion

PV modules are combustible irrespective of their technology and design, and can independently continue burning in the event of a full-scale fire.

Within a few minutes, burning materials (films, fused glass) can begin dripping. Depending on the flame impingement, glass plates can also burst after a few minutes.

Glass-glass modules develop less combustion heat and smoke gas because of their lower polymer content.

3.2 Assessment of the electric arc risk in PV systems

Like any electrical system, a PV system can release large amounts of heat in spots in case of a malfunction, and thereby become a fire source. Section 3.3.2 contains an analysis of how often this case actually occurs (see also [13]).

Even if fires caused by PV systems are fortunately rare, fire incidents often pose severe risks for people and property.

To develop effective strategies for avoiding fires or reducing their propagation, we must know the effects triggering and promoting fire.

The largest danger potential within a PV system comes from electric arcs. An enormous amount of heat, measuring several thousand degrees, develops that can destroy the surrounding materials and lead to a fire.

If electric current is flowing, heat is generated by the electrical resistance of the conductor. In case of a malfunction, increasing heat can also come from local elevations in resistance, as at aging contact points. This sets in motion a dangerous spiral with forced aging at increased temperatures, at the end of which scorching or, in the worst case, an electric arc can occur depending on the given materials and structural design.

Contacts and therefore potential risk points exist in large numbers in any PV system. A single module alone contains hundreds of contacts between the individual cells and strings.

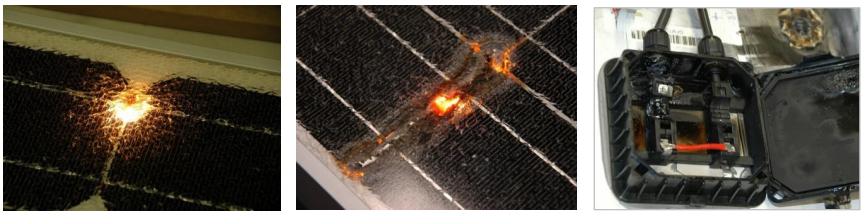


Figure 3-6: Electric arcs in PV modules, photos: TÜV Rheinland

If a terminal of the solar generator is grounded, damaged insulation can allow short-circuiting to ground by the other terminal and thereby ignite an electric arc. Since the overwhelming majority of systems in Germany do not have grounded solar generators as in the US, this danger is low here (Germany), however.

Another possible source of risk is a short circuit between the terminals of the system or simultaneous short circuits of both terminals to ground (so-called parallel electric arcing). Since in such cases the entire system voltage is available for ignition and for maintaining the electric arc, even smaller currents will suffice for a stable electric arc, as shown in figure 3-2. On the other hand, such scenarios are fortunately quite unlikely, since cables in PV systems are double-insulated. In addition, a genuine parallel electric arc requires simultaneous damage to two main cable strings immediately adjacent to one another as well as an initial contact for the electric arc ignition. A double short circuit to ground is in turn hardly possible in contemporary inverters, since their insulation monitoring will already detect the first short-circuit to ground and shut down the system.

Much more likely is the occurrence of a serial electric arc. A typical PV system contains countless serial points of connection – for example, in the module between the individual cells, at the string connectors and in the module junction box, outside the module in junction boxes or connectors and inside the inverter. If one of these connections is faulty or deteriorates in the course of the operating period, resulting in an elevated transition resistance, this area will become overheated from the current flow. The heat development can cause other contact material to diffuse or even melt down until at some time the connection fully breaks. In this case, an electric arc can form over the (initially very small) air gap. Serial electric arcs are typically lower in energy compared with parallel electric arcs, since a large part of the voltage drops via the inverter and these arcs often occur only in one of several parallel strings. This also makes them more difficult to notice, however, since the system seems to continue running normally. Figure 3-7 schematically illustrates different points of risk.

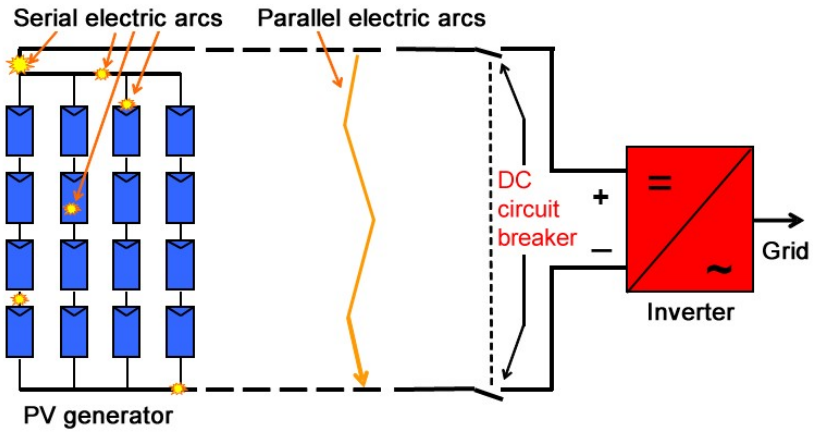


Figure 3-7: Possible propagation of serial and parallel electric arcs in a PV system [source: **[14]**]

3.3 Damage and fire event analysis of PV systems

3.3.1 Introduction

The project specifically researched cases of fire and overheating in PV systems in order to identify possible weak points and derive potential for improvement. Since the point was to find weak points, overheating and fire incidents were considered together, thus neglecting the influence of the surroundings of the damaged component on the level of damage.

The following sources of information were analyzed:

- Internet and media reports
- Operational reports from fire departments
- Assessor reports and statements
- Damage reports from Mannheimer Versicherung
- Internet-based survey

The recorded information was checked as to plausibility and if necessary followed up and evaluated. In many cases only incomplete details were available, so that only partially plausible estimates about the origin of damage were possible or the ultimate cause of fault could not be identified. If a damage appraisal was available, the conclusions from this report were adopted.

The analyses presented in the following reflect the status of January 2013. At this point in time, Germany had approximately 1.3 million PV systems with a total output of over 30 GWp. Individual fire incidents in 2013 entered into the analysis.

The following incidents of damage from overheating or fire involving PV systems in Germany were researched or reported:

- approximately 430 cases of fire or overheating in PV systems,
- about 220 cases thereof with external causes of fire
- about 210 cases with the cause of fire lying in the PV system

While far from recording all incidents, the analysis is probably the most comprehensive published compilation to date.

In 2013 and 2014, a series of further fire events was found whose causes and effects correspond to the statistics of section 3.3.2, so that a representative data stock may be assumed.

Two known fire cases 2013 and 2014 illustrate the point:

1. Fire incident in Walldorf: fire in a photovoltaic system on a warehouse roof

Foto: PR Video

Figure 3-8: Incinerated PV modules on a flat roof, substructure here with plastic trays(!)

In June 2014 PV modules in the system in question caught fire on a flat roof owing to a technical defect, resulting in property damage amounting to several thousand euros. Firefighters were able to promptly extinguish the fire, without it spreading to the building. As can be seen on the photo, the elevation was provided by plastic trays. These plastic trays are generally *normally flammable* (class E as per EN13501-.1). When selecting installation materials, especially for roof-mounted systems, attention must be given to the significant **potential for ignition and propagation of fire** if plastic is to be used.

2. Fire incident on Norderney: In August 2013, a fire started here in a workshop with adjoining vehicle depot. The fire spread rapidly, the roof structure and entire PV system collapsed, and the damage amounted to several million euros.

Figure 3-9: After a fire in a workshop with warehouse and depot (photo: Norderney Fire Department)

These examples demonstrate the scenarios basically to be distinguished among fire incidents at buildings with PV installations: on the one hand, the origin of the fire lying in the PV system itself, and on the other hand the “collateral fire” at a PV system caused by an external source (in this case, a building fire).

3.3.2 Statistical damage analyses

The approximately 210 damage incidents with causes lying inside the PV system were further analyzed. Table 3-1 breaks down these cases according to level of damage. Figure 3-10 explains these figures.

Table 3-1: Extent of damage in approx. 210 cases

Component damaged	59
PV system damaged	75
Building damaged	67
Building burned down	12

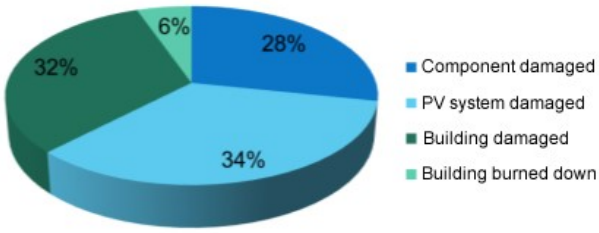


Figure 3-10: Overview of damage levels in the examined cases

These cases were further analyzed, depending on the available information. Despite uncertainties about the exact development of the damage in individual cases, the totality of the cases allows some robust conclusions to be drawn. The following aspects are of interest:

- Cause of fault
- Component causing the fire
- Age of system
- Type of system
- Severity of damage, impact on surroundings

The following presents these results in the form of analytical graphs.

A general observation reveals that the destructive force of an electric arc greatly increases if a serial arc develops into a parallel arc, as in the case of the electric arc from a string reaching a bundle of string lines. The Lorentz force gives the parallel electric arc the tendency to move away from the PV modules and thereby shift the fire hazard in the direction of the inverter.

3.3.2.1 Influence of the system type on damage frequency

The following graph shows how often the different types of system suffer damage.

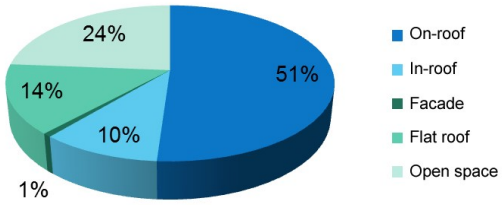


Figure 3-11: Breakdown of damage according to system type (based on 139 incidents of damage)

The ascertained distribution roughly corresponds to the market shares estimated by the German Solar Industry Association (BSW), with around 70% capacity on buildings and about 30% in open space. Less than one percent of the capacity has the form of building-integrated (in-roof) systems. Systems with building-integrated modules make up around 10% of the damage statistics, however.

Among all cases with building damage, building-integrated systems are more prominent. Figure 3-12 shows the distribution of cases where a building was damaged or destroyed and where information on the PV generator mounting type was available.

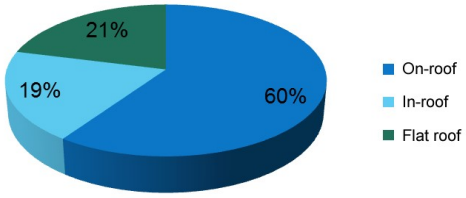


Figure 3-12: Damage distribution in cases with damage to buildings. “In-roof” also includes facade-integrated systems (based on 57 damage incidents).

Given an estimated BIPV share of 1% of the installed PV capacity, the share of PV-caused fires with damage to buildings among BIPV systems is around 20%!

This can be explained by the absence of the protective effect of the “hard roof covering” in tiled roofs. Should overheating or an electric arc occur in the PV system, the ignition source in the case of in-roof systems already lies within the building!

Conversely, particular care must be taken when planning and installing roof-integrated systems.

3.3.2.2 Cause of damage

Figure 3-13 shows the distribution of causes of damage for 103 cases, corresponding to the outside numbers. Installation errors and product flaws greatly predominate over external factors as the cause. The share of malfunctions involving aluminum lines in the particular category are already captured as installation or planning errors and for the sake of clarity appear as the shaded areas and are described by the inside numbers.

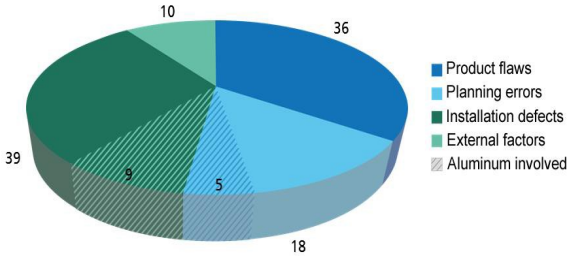


Figure 3-13: Number of causes of damage for more than 100 cases

The following explains the causes in more detail.

“Product flaws” concern especially modules and inverters. In the past, several module manufacturers were affected by serial defects. This led in part to recall and exchange campaigns. Some series of inverters also appear to be consistently defective in design or manufacturing.

“Planning errors” concern on the one hand the mechanical design with errors like:

- Modules jammed together, causing them to fracture and electric arcs to be ignited
- Shear forces acting on module junction boxes from mounting rails placed too closely together damaged the boxes and led to electric arcs
- Unprotected installation of generator junction boxes and inverters outdoors with subsequent stress from temperatures and condensation resulted in fires at these components
- Firewalls missing at the introduction of DC lines into the building, so that a fire can be directly conducted into the building

The electrical layout also has numerous defects, such as

- Unsuitable inverters outdoors
- Unsuitably placed inverters (direct insolation, corrosive gases)

- Undersized cables and lines
- Undersized DC main switch
- Wrong types of fuses at the DC end
- Heat loss from fuses neglected
- DC lines in generator junction boxes rubbing against metallic edges
- Unsuitable terminals at aluminum lines
- Subsequent PV generator expansion without checking the load capacity of the operating equipment

Planning errors can have a large influence on the possible consequences of a fire. If the inverter is suspended on a concrete wall, an electric arc at the DC connection can cause only a soot mark. If it is suspended from a beam or stands on a wooden base, the building can catch fire. The surroundings of the inverter have an equally great influence. Should burning material fall onto a stone floor, nothing will happen, but if it falls into stored hay a major fire can ensue.

Several experts describe construction situations in [15], [16] and [17], for example, where requirements on electrical installations in fire-hazardous locations [18] were grossly neglected, as shown here in the agricultural installation sector:

Figure 3-14: Non-fire-protected installation of inverters on wood, also with difficult accessibility for maintenance; photos: W. Schröder, PV expert, 2014

"Installation defects" are the most frequent causes of faults. In part these flaws may be due to the difficult installation conditions under great time pressure during the winter. Some of these flaws are so massive, however, that inadequate expertise on the part of the installers must be assumed.

Here is a list with defects that have caused fires:

- DC connector poorly plugged in
- Plug poorly (or not at all) crimped
- Screw terminal not tightened
- Inadequate insulation of lines with clamping of the conductor insulation
- Improper workmanship of the aluminum lines (wrong terminals, no torque monitoring)
- No strain relief at cables (leads to mechanical stress on the terminals)

"External factors" are primarily animal bites, individual strikes by lightning and in one case a workman who struck the covered DC cable bundle with a screw that was too long.

"Aluminum line": These defects are already included in the above defects. We list them here separately in order to underscore their significance.

3.3.2.3 Components causing faults

Past discussions on fire hazards from PV systems have focused on the supposedly more critical DC currents. Owing to the numerous electrical connections, the many components exposed to weather and the self-stabilization of any electric arcs given the current source characteristic of the solar cells, the risk of fire emergence in the PV generator sector is estimated to be significantly higher than in the AC part.

Figure 3-15 shows that defects are also more frequent in the AC PV system part, however. This is surprising, since in the AC part the number of components is less than in the DC part by at least a factor of 10, proven operating equipment with long lead times are available, AC installations usually occur in weather-protected spaces and electricians are generally well trained for AC installations.

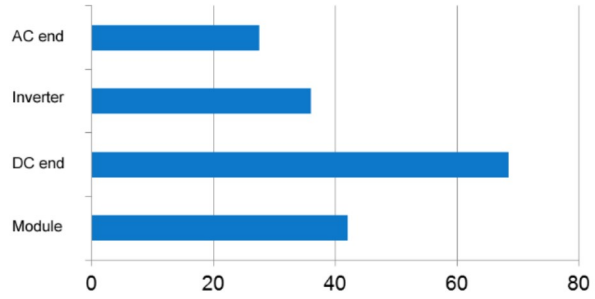


Figure 3-15: Rough distribution of the system parts where defects occurred (for altogether 17,174 defects)

If we assign the defects to the components in as detailed a way as possible, we can see how often single components were found to be affected (Figure 3-16).

Note: The components destroyed in the event of damage (fire damage) are not always the causal components of the event.

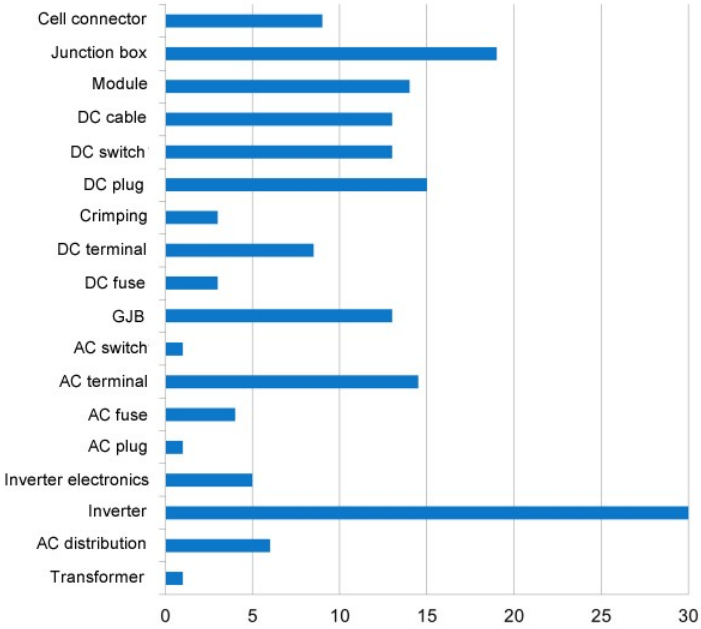


Figure 3-16: Number of defects per component (total number of defects: 174).

"Junction box" stands for module junction box, "crimping" for crimp contacts of DC plugs, "GJB" for generator junction box, "IN" for inverter, and "Transformer" for the grid transformer of the feed-in station.

Specified are the defect sites that could be determined with the possible cause in each individual case. That is, if module damage was reported, it falls under "module" and if damage to the module junction box was reported, it falls under "junction box". The total number of defects in (e.g.) modules is obtained by adding together the numbers of defects under "Modules," "Junction boxes" and "Cell connectors".

Most defects occur in modules and inverters. This result is not very surprising: the module is a prominent component quantitatively speaking, and the inverter the most complex component, of a PV system.

At the DC end, most system components have about the same frequency of defects. If we count together "DC plugs" and "Crimping," "DC plugs" with the number 18 are the second most frequently defective components, following the modules.

In the AC sector, the "AC terminal" is the most common location of defects, following the inverter. Here installation errors become especially evident.

Defect locations in the generator junction box, at the inverter and in the AC distribution often cannot be identified more precisely. It is supposed, however, that in many cases poor connection points were the cause.

Reports in the online survey and statements from experts indicate that in particular screw terminals have a greater risk of causing overheating compared with other connecting technologies.

3.3.2.4 Age of the systems

Figure 3-17 shows the distribution of system age at the onset of damage. We find a significant accumulation of damage during the first year of operation.

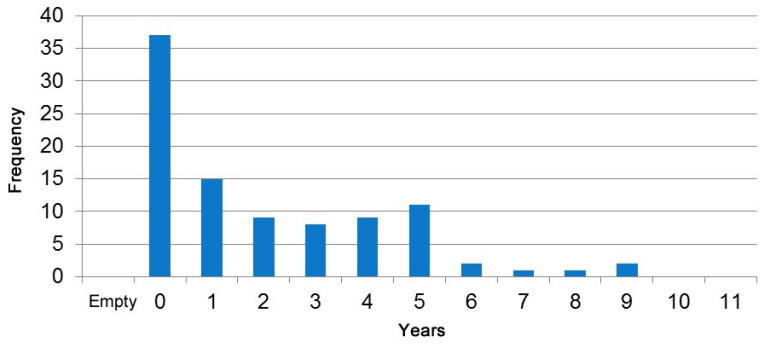


Figure 3-17: System age at time of damage (99 cases)

Some of the damage already occurred during construction. In the authors' view, the high number of early occurrences of damage reflects on the one hand production defects especially with inverters and on the other hand the numerous installation flaws that led to fires even after a few weeks at full load.

The high number of installation flaws may in part be due to the poor working conditions. In 2011, for example, around 40% of the newly installed capacity was installed in December [19], under enormous time pressure and adverse working conditions. The cause is known to be related to the cut-off date at that time for a massive compensation reduction according to the Renewable Energy Sources Act.

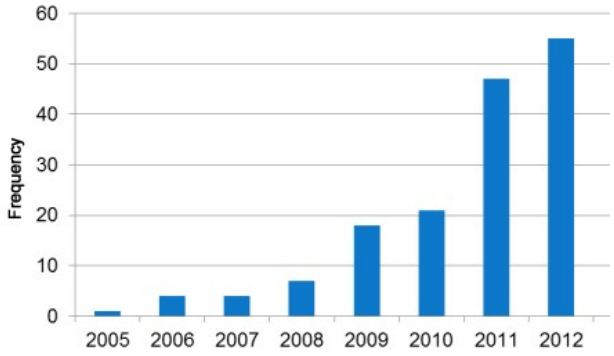


Figure 3-18: Damage incidents according to year of occurrence. The damage frequency also increases with the addition rate (data for altogether 157 cases).

Figure 3-18 shows the number of damage incidents found per year. We see a sharp increase in the years 2011 – 2012, reflecting, with something of a delay, the numerous expansions of the 2010 – 2012 of around 7 GWp each.

From the capacity of around 25 GWp installed by the end of 2011 and the 65 damage cases in 2012 we can roughly estimate a frequency of potentially fire-inducing cases of 0.3% per MWp and year – most likely a conservative estimate, insofar as it includes the installation flaws during the construction boom of December 2011. The number of installation flaws should be significantly less in “normal” years.

3.3.2.5 Time of the malfunction

The following two graphs will aid an understanding of the mechanisms that can lead to a fire. They show the dependence of malfunction frequency on the month and time of day.

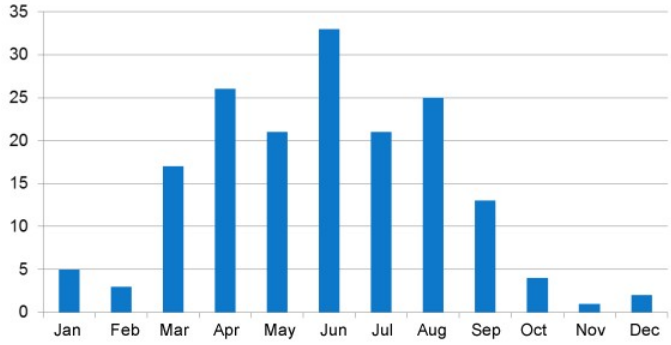


Figure 3-19: Number of damage cases per month (total: 171).

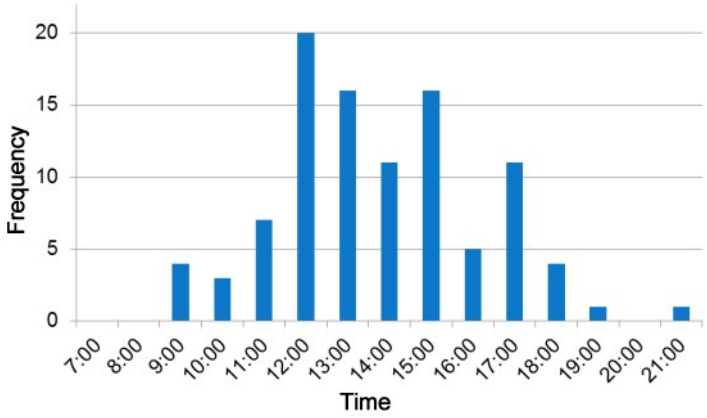


Figure 3-20: Number of damage incidents as a function of the time of day (here 99 – for many cases no time could be specified)

Both graphs show a strong dependence of malfunction frequency on the available solar energy. The malfunction frequency increases with the irradiation power.

This indicates that most malfunctions are current-related, i.e. due to the failure of connections or contacts and to overloading of the operating equipment. Insulation flaws accordingly play only a minor role.

3.3.2.6 Conclusions from the damage analysis

Modules and inverters are relatively conspicuous components, as expected. Defects were surprisingly often found in the following components/aspects:

- DC plugs
- in the AC distribution with all components and especially with the terminal connections
- improper workmanship of aluminum lines

Summary

The main causes of fires are “installation flaws” and inverter product defects.

All connections provided by the customer are potentially critical.

The defects causing fires are by far connection flaws in the main current path, or “serial defects”. Short circuits and insulation flaws are comparatively less frequent.

3.3.3 Damage patterns of particular malfunctions

To illustrate the above observations, we present in the following some damage cases in more detail.

3.3.3.1 DC plug connectors

DC plug connectors emerge as frequently affected components in the malfunction statistics of figure 6. Identified causes of faults in this component are:

- Poor crimping – e.g. with combination pliers,
- Poor insertion – i.e. connectors not fully inserted,
- Improper assembly of the plug – a contact piece slips back unnoticeably when inserted
- Cross-pairing (combination of plug and socket from different manufacturers)

Plug incorrectly inserted

A roof-integrated PV system caught fire in the middle of the afternoon. The fire encompassed and destroyed the entire roof structure. In the debris the fire expert found remnants of various connectors (Figure 3-21). The right plug pin was fully preserved, the left one was vaporized by an electric arc.

Figure 3-21: The remains of two connectors from the debris of a house [9] (photo: Institut für Schadenverhütung und Schadenforschung (IFS))

The appraiser came to the conclusion that “the cause of damage was the damaged plug connection, or its improper assembly.” [16]

In terms of risk, an installation or product flaw and an “in-roof” PV system came together with a proximate, high fire load.

Cross-pairing of connectors

Some manufacturers of connectors advertise their products by claiming their “compatibility” with the products from other manufacturers.

Tests at TÜV Rheinland [20] and at Multi-Contact [21] show that these claims are untenable. Even if good contact connection exists at the time of installation, we may not assume that pairs of contacts from different manufacturers will attain a service life of 25 years. Accelerated aging tests of such “cross-pairs” showed greatly elevated contact resistance in some cases. This cross-pairing leads to overheating of the plug connection and in the long term can lead to contact interruption with ignition of an electric arc.

Multi-Contact consequently rejects any warranty claim in the event of cross-pairing.

3.3.3.2 DC switches

DC main switches were found to be the source of malfunction in 13 cases. The damage cases do not unequivocally show whether the issue was general product weaknesses or overloading of the components due to poor planning and disregard of the permissible temperature range or rated current of the switches. Both complexes of causes are indicated.

The IFS published the following report on a fire in a 1 MWp system on an industrial roof (Figure 3-22):

“…An IFS appraiser found in the investigation that overheating had occurred at the DC main switch in the precollector housing. Switches of identical design were present in each of the nearly 130 precollectors. An inspection revealed that several switches had already suffered damage from scorching …” [22].

Figure 3-22: Fire at a generator junction box. The center of the photo shows a box of the same design. It has no protective roof. (Source: Bühl Volunteer Fire Department)

The appraiser found the following note in a catalog from Santon (with no year of publication):

"Operate the switches, which are seldom used, several times (10x) at least once a year in order to clean the contacts" [23].

The appraiser then found the cause of fire to lie in the failure to perform maintenance of the switches. A study of the other generator junction boxes found other switches with heat marks. Altogether about 10% of the boxes were affected. Incidentally, the note on maintenance appeared in fine print on the final page of the catalog.

At least two other manufacturers of such switches also had problems with flat connectors at similar switches and changed the type of contact connection. These flat plugs probably also caused overheating.

The switches from the above fire incident were installed in generator junction boxes mounted without protection on the roof (Figure 3-23). Elevated temperatures accordingly developed in the distribution boxes – estimated to be above 60°C. This accelerated the contact degradation.

The corresponding product standard for switches, DIN IEC 60947-3, presupposes a maximum ambient temperature of briefly 40°C [24]. The switches were therefore probably operated outside their permissible temperature range.

Elevated ambient temperatures

The above example showed that elevated ambient temperatures increase the susceptibility of operating equipment. The following example further supports this hypothesis. It also indicates the difficulties in exactly determining the cause of fire damage. Last but not least, the example also clarifies the system planner's responsibility to take into account the expected operating conditions of all parts of the system. In particular, the planner must allow for stress from high summerly temperatures.

In the following case, the summerly heat stress on the operating equipment was evidently underestimated. A fire broke out in the engineering room of a PV system aged about six years, containing several subsystems of the same type (Figure 3-23)

Figure 3-23: Engineering room of a PV system following a fire

The appraiser engaged by the plant insurer identified an overloaded DC main switch as the cause of fire.

The switch with 16 A rated current sufficed for a generator rated current (I_MPP) of 14.0 A, without a reserve for *overcurrents caused by excessive irradiation and elevated ambient temperatures*.

Like the other 14 switches of the system, the switch was subjected to significantly increased heat stress.

- The inverters were mounted more closely together than as specified in the assembly instructions.
- The DC main switches were mounted tightly between the inverters.
- The roof above the operation room was only poorly insulated. During mid-summer air temperatures of over 40°C regularly prevail here.
- The PV inverters added up to 5 kW of dissipated heat.

The maximum permissible operating temperature of the switch was 40°C! We must therefore assume that the switch's permissible temperature range was regularly significantly exceeded.

Six of the switches survived the fire practically unscathed. Two of these switches showed preliminary damage in the form of incipient carbonization at the flat connectors (Figure 3-24).

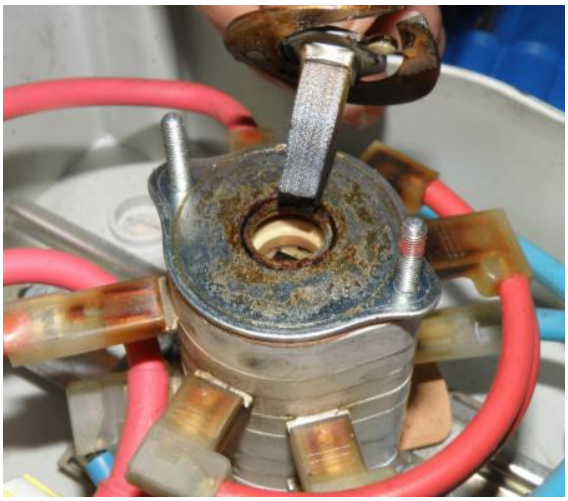


Figure 3-24: Significant marks of overheating at connections and inside a “surviving” switch

Disassembly of the above switch also revealed considerable overheating marks inside the switch. Insulation material, isolating disks and the axle were charred. The heat evidently came from the switch contacts and not as originally conjectured from the weakened flat connectors. The switch axle had shrunken in diameter from the heat stress and fractured in the middle. Most likely it fractured right at the moment when the switch was needed – when the fire department wanted to disconnect the system while extinguishing the fire.

Noteworthy is that inverters and switches were mounted on a brick wall, so that the fire did not spread further.

Test of switch contact resistance

It is well known that sufficiently long “non-operation” of the DC switches due to oxidation of the contact surfaces and friction corrosion from temperature-related changes in length (so-called “fretting”) result in increasingly higher contact resistance. As the resistance increases, so does of course the dissipation loss, increasing the contact temperature and thereby accelerating oxidation. Self-excitation occurs. Ultimately, a temperature may occur that is high enough to scorch the switch or set it on fire.

The increase in contact resistance can be undone through regular switch operation. For this reason, one of the numerous switch manufacturers requires that its switches be operated ten times once a year.

To test the effect of the maintenance recommendation, surviving switches from the damaged PV system described above were removed and their contact resistance measured in the lab. The switches had most likely not been operated for about six years. Figure 3-25 shows the results of the test.

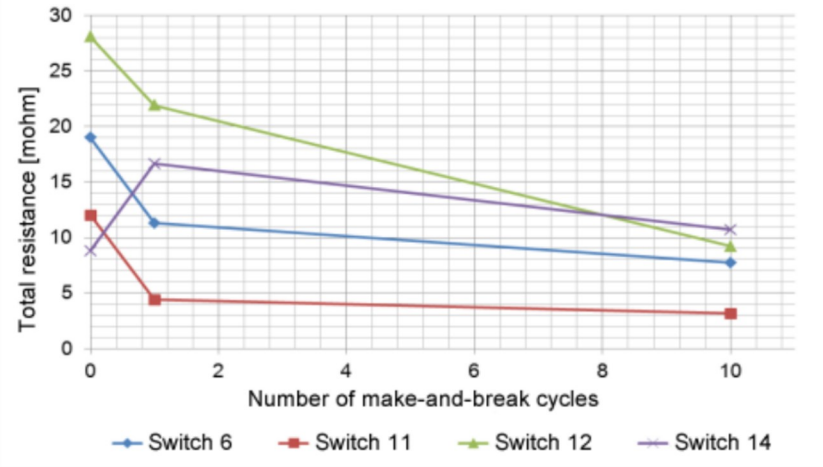


Figure 3-25: Total resistance of four switches as a function of the number of make-and-break cycles. Switches 6, 11 and 12 are of the same type; switch 114 is a different type.

The contact resistance decreases at three out of four switches – on the average about 1/3 of the initial value. The ohmic losses also decrease accordingly. At the worst-case switch, this loss is initially about 17 W under rated current load and drops to about 6 W.

Switches with contact rockers show the same behavior (Figure 3-26) as a field test found.

Figure 3-26: Tested DC main switch with contact rocker

Eight switches in an approximately 10-year-old PV system were also tested as to contact resistance. These switches also showed a significant decrease in contact resistance after multiple operations (de-energized state). The resistance dropped on average to nearly a third of the initial value.

These switches must also undergo routine maintenance.

Summary of the switch studies

- Switches react to continually elevated ambient temperatures with accelerated contact degradation.
- Planning should oversize the switches. Like the DC lines, the switches should have a load capacity of at least 125% of the rated current of the system. Switches subject to elevated ambient temperatures must be designed as per the manufacturer's derating specifications.
- All switches should be inspected once a year in order to discover any signs of overheating.
- All switches should undergo maintenance once a year and then be operated ten times (de-energized).

Section 6 contains these important findings.

3.3.3.3 Improper handling of modules

One system operator observed that an installer had misused the connections of a module as a “transport aid” during assembly. This evidently overloaded the strain relief and somewhat pulled apart the contacts of the module junction box. During the following summer, the power output of the corresponding subgenerator dropped. Figure 3-27 shows why: one of the contacts shows signs of an electric arc:

Figure 3-27: Damaged plug contacts in a module junction box

While searching for the cause of diminished performance, the installer found two modules each with a destroyed contact in the module junction box. Because of internal electric arcs the string current was fully interrupted. Fortunately these electric arcs remained confined to the interior of the box.

The photo shows that the left connector slipped slightly downwards relative to the right one. This probably happened because of the aforementioned mechanical “misuse” of the module connecting lines.

3.3.3.4 Loose clamp connection

Because of their cost advantage, aluminum conductors are finding increasing use in PV systems. Since aluminum melts at lower temperatures compared with copper, increased contact resistance will lead faster to disconnection of the conductor and possibly to an electric arc.

Here is an example of where the appraiser found a defective clamp connection that in combination with an aluminum conductor caused a fire. An AC distribution unit had burned out.

Figure 3-28: Burned-out AC connection of a PV system (photo: Uli Motzer, Württembergische Versicherung)

Figure 3-29: The end of an aluminum line (photo: Uli Motzer, Württembergische Versicherung)

The cause of fire was found to lie in a loose contact point. Figure 3-29 shows the conductor end of another cable of the system. The line had also not been correctly connected, as the signs of fusion at the conductor show.

The matter of hot contacts was also observed at the fuses; see Figure 3-30. Screwed contacts were involved in this case. A high transition resistance occurred at the screw contact.

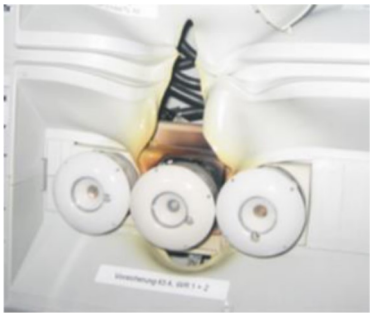


Figure 3-30: Heated fuse link (photo: H. Godard, Energossa)

3.3.3.5 Fire propagation through cable bundle

The insulation of common lines is combustible and can fuel a fire. Cable bundles often contribute to the spread of a fire. Here an insulation fire and electric arcs between the positive and negative lines in the bundle combined together. The great heat from the electric arc can cause even flame-retardant materials to catch fire.

The propagation can be thermally driven, if namely a fire can spread upwards, or a weaker, electromagnetic propagation of an electric arc at a distance from the current source may occur, as Figure 3-31 shows:

Figure 3-31: Charred lines at an inverter (source: Weyerbusch Fire Department)

Given the damage pattern, this fire probably originated in the vicinity of the DC connections of the inverter. It spread upwards as a cable fire with (parallel) electric arcs in the cable bundle and thus to the roof structure.

A spatial separation of the two polarities at the inverter would have probably interrupted the electric arc at an early stage.

3.3.3.6 Disregard of the requirements on "fire-hazardous operating facilities"

The experience of the Württembergische Versicherung is that PV systems on agricultural buildings – like the buildings themselves – are subject to an increased risk of fire [18]. The probable reason is, among other things, that combustible substances are often stored or dust accumulates in buildings of this kind, with the requirements on the installation of electrical systems in "fire-hazardous operating facilities" [18] being often disregarded

The free brochure of the Association of Property Insurers (VdS) [25] presents these requirements in easily understandable form.

Disregard of these specifications reduces the risk of fire propagation and therefore overall damage.

According to this document, the most important requirement is that PV system operating equipment be installed outside the fire-hazardous area. In the hazardous areas only electrical operating equipment may be used that is "required for the immediate operation in these areas."

In many cases inverters are mounted on wood. This practice is grossly negligent and generally prohibited by the manufacturer's product documentation!

Two examples illustrate this:

In the first case, inverters and lines were mounted on OSB boards; see Figure 3-32. A fire damaged components in the engineering room of a PV installation. The OSB board used in the installation then also caught fire. Evidently little flammable material was otherwise present, and the fire department arrived quickly, so that the fire could be contained.

Figure 3-32: Installation of inverters on OSB board. Left: site of the fire, photo: Volunteer Fire Department of the Community of Perl, 2011. Right: here things look OK, but the fire protection is inadequate, photo: W. Schröder, PV expert, 2014

In 2009, the Ellwangen Fire Department reported a fire incident that ended mildly, "Smoldering Fire on Agricultural Property". The fire was noticed relatively soon, so no greater damage occurred.

Figure 3-33 shows that a smoldering fire was caused by a cable, probably damaged by an animal bite, belonging to a photovoltaic system in the unused hay storage floor of a barn.

Figure 3-33: Mild fire case (photo: Ellwangen Fire Department)

The course of the fire turned out to be a stroke of luck, since the straw did not catch fire.

In a similar installation situation, wood and straw caught fire, and when the fire department arrived the building was fully engulfed in flames. Total damage occurred [26].

3.3.4 Large-scale fires

Two damage cases are still under investigation at present (2013), in each of which a PV system on an industrial roof supposedly caused a fully developed fire at a building. In one of these cases, the appraiser found evidence that an incorrectly designed fire department switch (!) caused the fire because it couldn't extinguish the switch electric arc.

In both cases the fire quickly spread to the interior of the building. Experiences with similar systems allow us to conjecture that the lines of the PV systems were led through simple roof penetrations into the building and no firewall was used. The cable bundle thus probably provided the electric arc with a direct path into the building.

In another major fire the sanded bitumen roof sheeting caught fire. This normally qualifies as "hard roofing," i.e. as protection against radiant heat and flying sparks. In combination with an installed PV system, this protective effect does not suffice, as a fire caused by a PV system in Goch (April 1, 2012) impressively showed. It quickly engulfed the large roof surface of a warehouse and led to a dripping, burning flow of bitumen (Figure 3-34).

Such roofs should be provided with preventive fire protection measures as described in section 6.1 in order to minimize the risk that a major fire develops from a poor contact.

Figure 3-34: Electric arc event in a roof-mounted elevated PV system. Left: Bitumen roof sheeting burns with heavy smoke development and produces burning droplets. Right: Fortunately the building could be saved, photos: Goch Volunteer Fire Department

3.3.5 Conclusions and recommendations

The number of reported fires per year has greatly increased in recent years (Figure 3-18). This trend is correlated with the sharp increase in number of installed PV systems in recent years.

Appraisers have repeatedly found that a great number of PV systems violated elementary installation requirements.

Summary of fire case analyses

It is foreseeable that in coming years a significant increase in fires caused by PV systems is to be expected. Increased aging of the materials will lead to an increase in insulation faults, contact problems and transition resistance. Under unfavorable conditions these flaws can trigger a fire.

Recommendations on risk reduction

We see remedies to the previously identified faults as lying on three different levels:

- **Installer training** – Professional and quality-conscious installations can avoid most installation flaws.
- **Inspections** (testing) – Solid acceptance inspections help detect initial flaws and repeat inspections help detect hidden installation errors and developing product flaws due to aging or defects related to extraordinary stress (bad weather).
- **Technological development**
  - Avoidance of screwed connections in load current circuits
  - Electric arc detectors can generally turn off an electric arc

Section 0 summarizes detailed recommendations.

3.4 Damage analyses of a solar system supplier

3.4.1 Damage determined at the incoming goods inspection

To ensure its customers constantly high product quality, especially in the case of PV modules, the solar system supplier “Energiebau Solarstromsysteme GmbH” conducts a comprehensive incoming goods inspection. Random samples are taken from incoming deliveries as per DIN ISO 2859 and examined for any production flaws or transport damage according to a comprehensive list of criteria.

First is the visual inspection that checks compliance with the manufacturing tolerances. Recorded are, among other things, the dimensions and workmanship of the frame, the relative positions of the individual cells, the quality of the glazing and lamination as well as the connections between cell pressure, busbars and main busbars. Also inspected are junction boxes and lines, connectors and module labels and markings.

Besides the visual inspection, an electroluminescence (EL) test is conducted. For this purpose the module as a whole is photographed. The resulting images enable easy detection of cell fractures and defective connections at contacts.

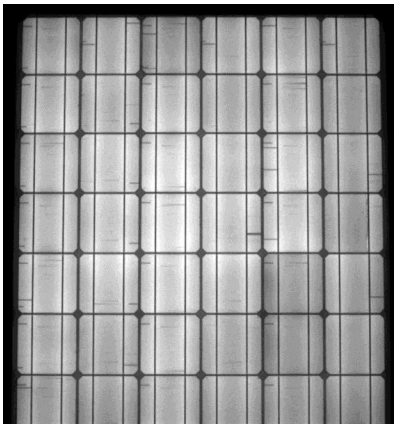


Figure 3-35: EL image of an intact module

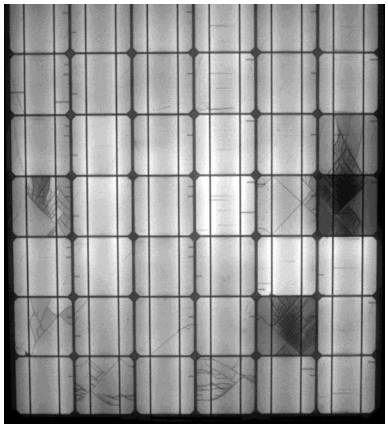


Figure 3-36: EL image of a module with microcracks and cell fractures

Between March 2011 and March 2013, Energiebau inspected nearly 24,000 modules, 20.2% of which showed flaws. *This percentage is not representative of all modules supplied by manufacturers, however.*

The processes at incoming goods are structured in such a way that batches suspected of poorer quality are inspected more intensively than usual. If spot checks of a delivery reveal defects a larger number of modules is examined.

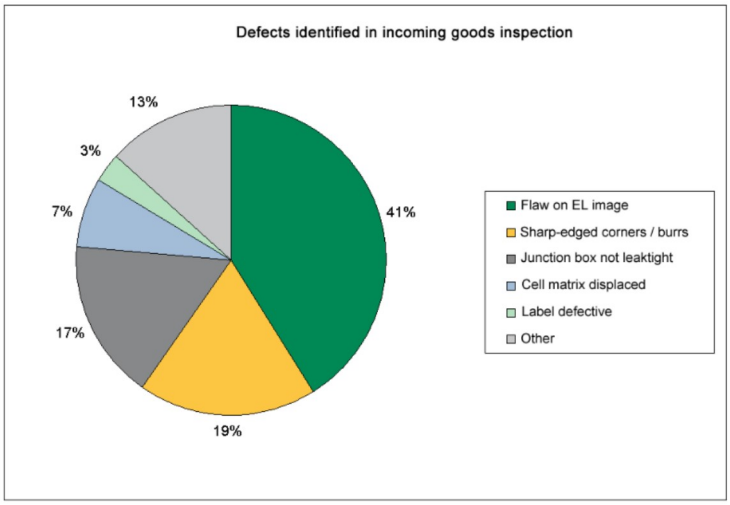


Figure 3-37: Damage frequently found in incoming goods inspections (over 50 units/year)

The most commonly found defects appear as flaws on the EL image. These are predominantly cell fractures, but can also be defective connections at contacts or cell pressures.

Second most common are poorly manufactured frames with burrs or sharp-edged corners, caused by imprecisely manufactured or joined frame parts.

Other defects are imprecisely fabricated lids for junction boxes whose poor seating leads to leakage, shifts in the cells and incorrectly printed or stuck-on nameplates.

Around 13% of damage cases are attributable to other less common defects, among them defective cell pressure, optical damage and delamination (see also Table 3-2).

Table 3-2: Percentages of most common damage patterns relative to total number of damage cases

Defect	Relative frequency in %
Flaw on EL image	41%
Sharp-edged corners / burrs	19%
Junction box not leaktight	17%
Cell matrix displaced	7.2%
Label defective	3.0%
Defective cell pressure	1.7%
Color deviation	1.5%
Scratches	1.4%
Cell connectors moved to side	1.1%
Foreign matter in module	1.1%
Glass flaws	0.8%
Dents in backsheet	0.8%
Deviation from right angle	0.8%
Delamination	0.8%
Deformations / dents	0.6%
Silicone residue	0.6%

3.4.2 Damage in complaints

Despite comprehensive quality controls, time and again defective modules are delivered to customers or damaged during transport. These defects are then recorded as complaints, resulting in a wholly different distribution of the damage patterns for various reasons.

On the one hand, certain defects can already be detected prior to delivery in the incoming goods inspection and complaints can be submitted to the manufacturer. In addition, certain defects become evident only after longer operating periods and can therefore be noticed only at the customer's end. This includes (e.g.) reduced performance from potential-induced degradation (PID).

Finally, damage such as scratches, dents and cell or glass fractures may occur only during transport to the customer or through improper handling on the construction site.

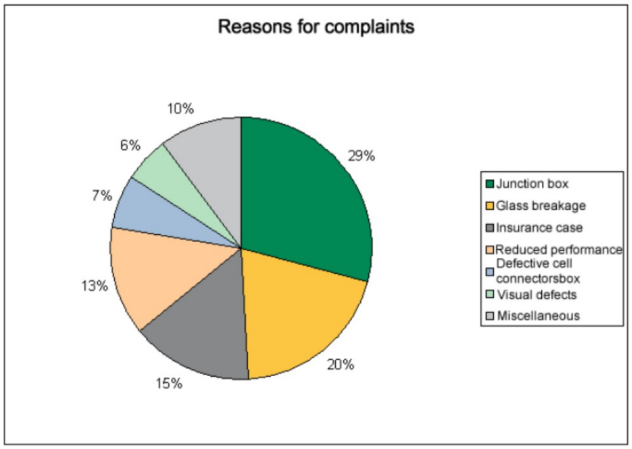


Figure 3-38: Frequencies of defects among modules subject to complaints

The most frequent complaint across all manufacturers concerned defective junction boxes.

Besides housings and housing lids falling off because of poor workmanship, this item also includes defective soldered joints and defective bypass diodes. Owing to the frequency of this flaw, we may assume a particular risk of electric arcing to be posed by defective junction boxes.

Other frequent defects are general insurance cases and glass breakage usually occurring during transport or assembly, but also sometimes caused by overheated cells.

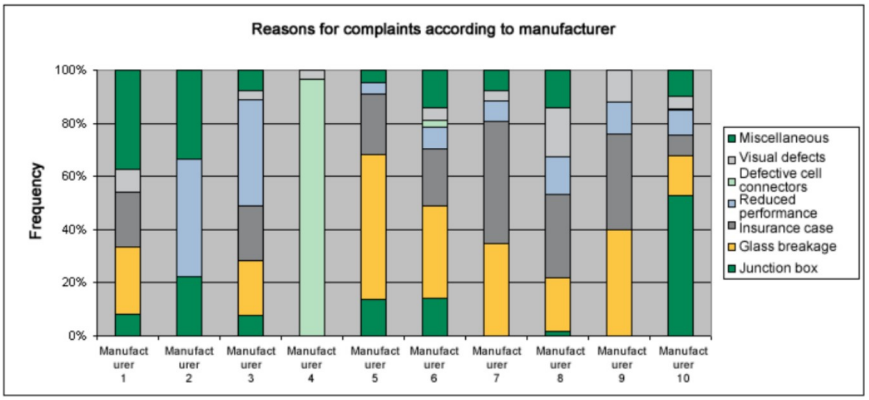


Figure 3-39: Frequency of damage patterns among different manufacturers

Figure 3-39 clearly shows for manufacturer 10 most complaints pertain to a defect in the junction box. The graph also shows that manufacturer 4 has a problem with poor contact connections between the cells.

Altogether we find that for end customers transport-related damage is considerably more of an issue. This indicates that modules are improperly handled at the construction site despite the information provided in the assembly instructions.

In contrast, reduced performance and defective cell connectors are more seldom to be found in completed systems than in the incoming goods inspection. This shows that EL imaging is an effective means for detecting such defects and for filtering out the affected modules.

3.5 Potential electric arc risks in PV systems

3.5.1 Module

3.5.1.1 Cell connectors

Soldered connections are basic weak points regarding the occurrence of an electric arc within a PV module.

Especially many solder joints occur in the connections between the individual solar cells. The busbars of the cells here are interconnected via soldered cell connectors. How many busbars and therefore cell connectors the installed solar cells possess consequently plays a role. Larger cells often contain three busbars to create redundancies and a uniform distribution of the cell currents in the event of failure of individual contact transitions or local temperature elevations – the failure or disconnection of just one busbar will then not suffice to ignite an electric arc [5].

A brief search surveyed the numbers of cell connectors among 50 crystalline PV modules currently on the market. Most of the modules contained two busbars (Figure 3-40).

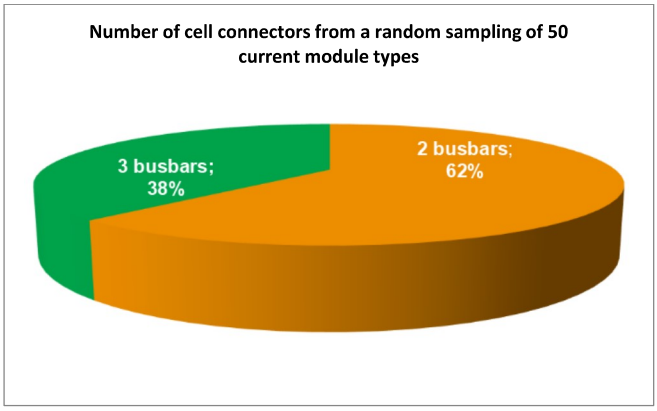


Figure 3-40: Number of cell connectors used in different types of modules

A more detailed analysis of the Cologne solar system supplier “Energiebau” found that only two busbars are used with 5” cells. In the case of 6” cells, both two and three busbars are common.

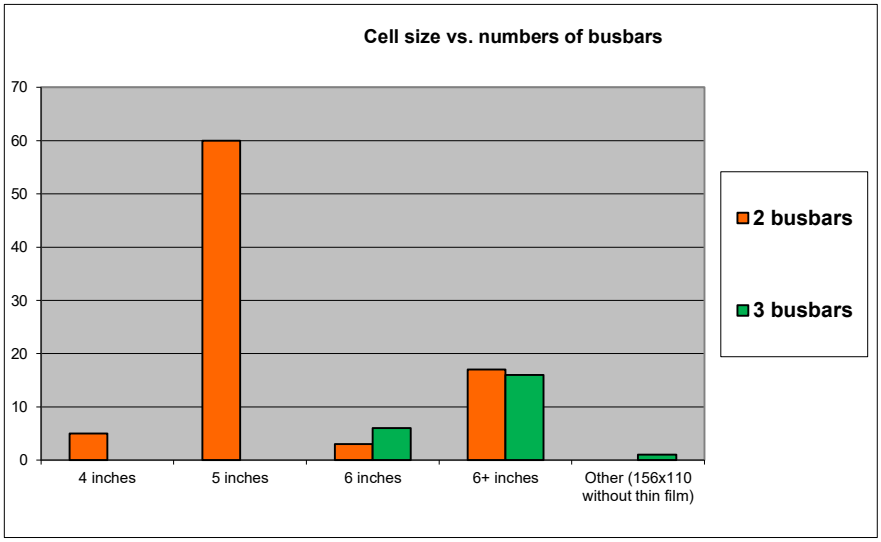


Figure 3-41: Frequency of numbers of busbars as a function of cell size

The overview is based on data on representative modules on the market. Each additional cell connector increases the redundancy. Should defective soldered contacts occur, the current can flow through other busbars.

In the case of three busbars, the occurrence of an electric arc at the cell contacts is therefore less probable. On the other hand, the cell area is slightly reduced that can be actively used for generating electricity.

An electric arc at a cell connector can then occur if only one of the cell connectors still provides a conductive connection and if at this point the metallic contact is also lost.

The latter is to be expected if the contact is already poor and the resulting heat leads to further fusion of the contact material. In addition, the bypass diode belonging to the affected cell string must be interrupted, since the voltage of a single cell string will not suffice for igniting an electric arc. [27] [28]

To emulate this chain of faults, TÜV Rheinland conducted experiments with prepared modules. In one module, both cell connectors between two individual cells were disconnected and the bypass diodes removed from the junction box. Electric arcs were then ignited that generated temperatures far above the melting temperature (600°C) of (e.g.) thermally pre-stressed glass (Figure 3-42). The front glass and the photoactive silicon layers melted and formed burning droplets [29].

Figure 3-42: Effects of an induced electric arc through partition of the cell connectors, photos: TÜV Rheinland

The electric arc will continue burning until sufficient voltage for maintaining it is no longer available. This situation can be attained by turning off the voltage or by increasing the distance between the electric arc contacts. If this distance is so large that the available voltage no longer suffices, the electric arc will extinguish itself. This time can be very long, however (several minutes).

The electric arc burns not only at the direct contacts of the cell, but it can also continue burning between the cells. The electric arc will then move back and forth between the cells. Owing to the large amount of available material, the contacts will burn down only slightly. In the lab experiments the electric arc was always extinguished by turning off the voltage. The electric arc burning the longest was turned off after 16 minutes. During this time the electric arc moved several times from one cell side to the other.

Until the electric arc was extinguished, it emitted a great deal of heat, greatly damaging the surrounding module materials. The latter also burned, but after a period of time extinguished themselves after the electric arc was turned off. Until then, the flames were intensively blazing from the underside of the module, however. In cases of very long-burning electric arcs the temperatures increase until the glass melts (1,000°C to 1,500°C) and liquid silicon drips down from the module.

Causes of electric arcs in the real world can be previous hot spots that can usually occur at soldered cell connectors but also at the soldering between cell connectors and at busbars inside the modules.

3.5.1.2 Module junction box

Recent studies have found that the connection between contact terminals and connecting lines in the module junction box require particular attention. The design here provides sufficient contact material to keep an electric arc continually stable. In addition, the junction box, generally made of plastic, provides combustible material in the close vicinity. The possible spread of the electric arc to the surroundings must be taken into account and the risk classified as high.

Figure 3-43: Junction box after electric arc between connecting line and connection terminal **[5]**

The red line between the two terminals in Figure 3-43 serves to bypass the module already defective from earlier tests. The electric arc occurred with the cable on the left.

The effects of a fire in a module junction box can thus be considerable. Whether a fire can occur in the first place depends on several factors:

(1) Stability of the connections (and the strain relief)
(2) Corrosion protection (leaktightness)
(3) Heat dissipation in the junction box (bypass diodes)
(4) Fire-relevant material properties
(5) Lightning and surge protection

For estimating the actual risk of fire, at this point we now give an overview of the typical designs and materials available on the market.

Re 1. Stability of the connections

Current developments at junction box manufacturers are based on the premise of automation capacity and process reliability (e.g. Spelsberg, Phoenix Contact, Conergy) for ensuring a constantly high level of quality in production (reducing risk of dirt, long-term stability of adhesive leaktightness).

Generally there are 3 types of line connections (Figure 3-44):

- Soldered connections
- Clamp connections
- Screw connections

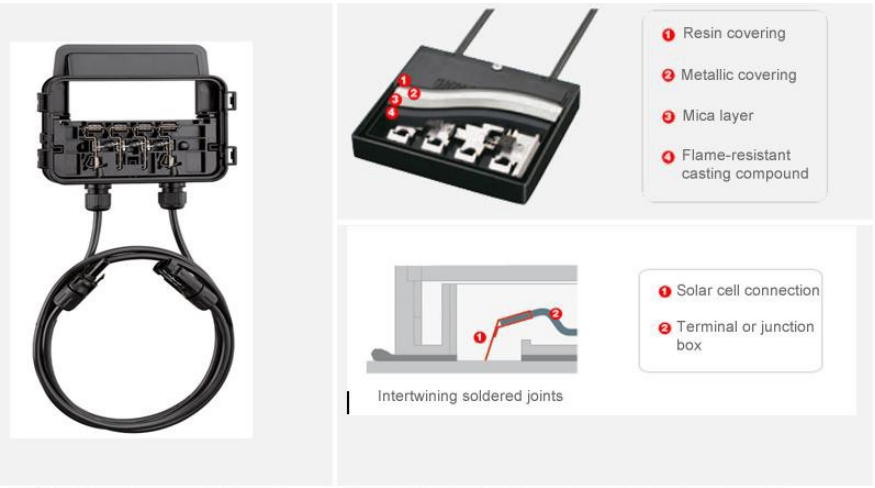


Photo: Günther Spelsberg, terminals

Photo: Mitsubishi Electric Corporation, soldered contacts

Figure 3-44: Contact variants

Clamp connections are not very susceptible to faults. Use of unsprung screw connections is not recommended nowadays, since they provide reliable contact only given optimal assembly, and this contact can progressively deteriorate while the clamp connection automatically adjusts itself.

But even soldered connections can fail if assembly is not performed properly. This risk tends to be greatest with manual soldering processes. At present all three joining technologies are available on the market (Figure 3-44), with clamp connections of a variety of kinds and quality being primarily used.

In addition, solid and reliable strain relief plays a great role, since tensile forces can occur in both the short term (e.g. during transport and installation) and long term (e.g. from the weight of the cables). It must be ensured that these forces cannot affect the quality of the connection.

Re 2. Corrosion protection

Junction boxes are indicated as belonging to the high protection class IP65.

Uncast junction boxes can have disadvantages compared with cast junction boxes as the result of temperature changes and moisture effects. The risk of moisture penetrating the box and corroding the contact point is therefore greater. In addition, in the event of an electric arc, a greater oxygen feed occurs, which helps maintain the electric arc and therefore promotes fire emergence.

A casting compound affords several advantages: leaktightness, electrical insulation and fire inhibition [30]. However, a disadvantage is the low ease of maintenance. Defective bypass diodes cannot be replaced if necessary. It must be kept in mind that some clamp connections should not be cast, because casting would greatly hinder readjustment and overheating or even an electric arc could result.

Re 3. Heat dissipation in the junction box

Junction boxes are also subject to elevated temperatures in normal operation. In the case of a fault, the temperature in the box can climb to over 200°C; in case of an electric arc, temperatures of several

1,000°C are attained. Besides the corresponding material selection, quick dissipation of the created heat is therefore very important.

Figure 3-45 shows various solutions, such as a spacer for the module (Huber & Suhner, HA3 and RH3 product families), metallic plates with cooling fins (aluminum, FPE Fischer, Solon), sheathing with heat-conductive silicon and heat-conductive connections to the aluminum frame (Spelsberg). The preconditions for protection class 2 must be maintained, however.

Photo: Huber & Suhner, junction box with spacer

Photo: FPE Fischer, aluminum junction box with cooling fins

Figure 3-45: Heat dissipation

Re 4. Fire-relevant material properties

Current junction boxes are nearly all made exclusively of plastic. These materials must meet the following requirements:

- Temperature resistance
- Non-inflammability and absence of halogen
- Strength
- Weather resistance
- Cold shock resistance.

A series of technical plastics, such as Ultramid®-A3XZG5 (PA) from BASF and RYNITE® PET plastics (PES) from DuPont are available for this purpose. They are thermoplastically and minerally reinforced by glass fiber content, for example.

Since 2007, aluminum junction boxes have also been on the market, from FPE Fischer (currently FPEAL008 Intersolar 2011, for example ([31]). These junction boxes also contain a plastic box inside for accommodating the electrical connections. According to the manufacturer, the aluminum version of the outer skin guarantees extremely long durability outdoors and is non-critical with overheating – that is, long-lived, safe, low in maintenance and stable in performance.

The aluminum box is used by (e.g.) Solar Energy, SOLAR MODUL ISE 175M/B and Sunworxs GmbH, SUNWORX SW 240P.

Tin-plated copper wire is used as a conductor material in solar cables (DC lines). Regulations require that the cables withstand an operating temperature of 120°C. The temperature in case of a longer persisting short circuit lies even at around 250°C. This temperature must be withstood by the plastic materials.

Re 5. Lightning and surge protection

A PV system generally does not increase the likelihood of a lightning strike. There is no general requirement on installing lightning protection for PV systems. If a building already has a lightning protection system, a retrofitted PV system must be integrated in the existing concept. On public buildings a lightning protection system must be installed for PV systems.

Section 1.3.1.1 lists the applicable standards and guidelines to be followed regarding lightning and surge protection.

The effects of a direct or indirect lightning strike must be considered separately.

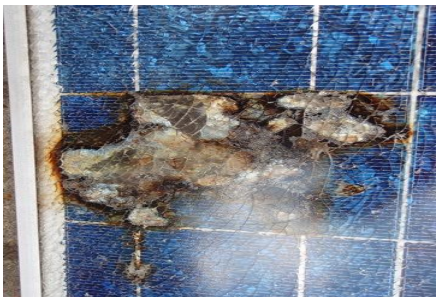


Figure 3-46: Direct lightning damage to a 10-year-old system (source: Photovoltaik-Büro Ternus&Diehl GBR)

In the rare event of a direct lightning strike at the solar generator, considerable damage to the modules must be expected (see Figure 3-46). Fire emergence from the heat effects of the lightning current cannot be ruled out. The bypass diode is most likely broken down and if lightning current capable surge arresters are installed, the inverter is probably defective.

Much more common are indirect or near-strikes, where a partial lightning current flows through a nearby part of a lightning protection system or through the electrical installation, or an overvoltage is induced there.

In these cases, graduated surge protection at the PV generator or at a grid feed point can greatly reduce the risk of damage to the bypass diodes and the inverter (internal lightning protection). Schottky bypass diodes remain greatly threatened, however; see following section.

Especially in the case of frameless modules with lightning protection systems at small distances (less than about 1 – 2 m) from the modules, partial lightning currents can also already induce voltages in the wire loops inside the modules so high as to cause damage to the corresponding bypass diodes.

Framed modules are somewhat less sensitive, but here too very small distances of less than 40 – 80 cm can be critical [32].

Surge protection is also receiving much attention given the recently observed trend in multiple electronic protective devices within the module junction box (intelligent junction box).

Conclusions

The risks at the junction box must be considered high as to the effects of electric arcs and the development of fires compared with other components. That's why a good joining technology is especially important in order to prevent overheating and electric arcs as much as possible.

In addition, favorable corrosion, heat dissipation, material and overvoltage properties are important factors in designing a low-fire-risk module junction box.

3.5.1.3 Bypass diode

To protect solar cells against impermissibly high block voltages due to inactive (e.g. shaded) cells, bypass diodes are commonly used. They are usually integrated in the junction box and ensure that the current generated by the other modules is conducted through the diodes and past the shaded solar cells.

Where previously P/N diodes were mainly used, Schottky diodes that develop less heat loss are now being used. The breakdown voltage in the blocking direction is considerably less with these diodes, however, so that they can be damaged from singular overvoltage events (e.g. surge voltage from proximate lightning strikes).

Schottky diodes also have the property of significant cutoff currents at high temperatures, possibly resulting in thermal instability (thermal runaway).

Three possible fault cases can occur:

The diodes are permanently conductive (imperfect short circuit), partially conductive (significantly higher leakage current/heating) or interrupted, which underscores the original protective character.

Bypass diodes present the problem that they greatly heat up from the power output they attain if they carry high currents over longer periods of time. This heating can ultimately lead to overheating and in the worst case trigger a fire.

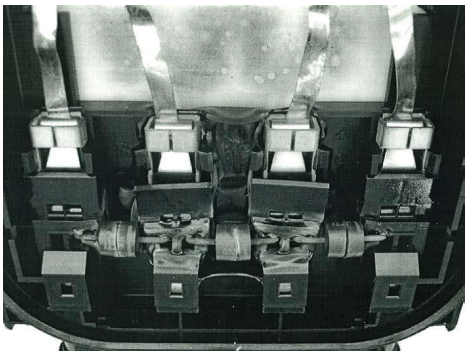


Figure 3-47: Module junction boxes with defective bypass diodes as the result of coupled lightning currents

A module junction box must permanently withstand the heat emitted by the current-carrying bypass diodes. Apart from this, heat development always poses the risk that in the long term contact connections will corrode or even melt.

Should a contact at a bypass diode slowly deteriorate, a continued load on the diode will increase the release heat produced in the contact. In the final stage, this will lead to very intense overheating with scorching or an electric arc.

In case of defective contacts or destruction of the diode (from overheating, for example), the diode is "open," i.e. it no longer performs its protective function. In this case, shading or contact flaws can create hot spots in the module that will damage the module and in unfavorable circumstances cause a fire.

Following surges (e.g. lightning strike) a bypass diode will typically fail because of an (imperfect) short circuit or increased reverse current (partially conductive). This will result in a yield loss, while the protective function need not necessarily be affected. On the other hand, a persistently high current flow through the diode can accelerate aging and thereby increase the electric arc risk at the contact points.

The risk from bypass diodes evidently often lies in the long-term stress. Regular and persistent shading increases heat development of the diodes with correspondingly accelerated aging mechanisms. While Schottky diodes reduce heat development, they are more sensitive to surge events.

Innovative, diodeless protective circuits (so-called "active bypass diodes" or "smart bypass diodes") can significantly mitigate this problem. These products replace the diode by a MOSFET that when actuated has a contact resistance of only a few milliohms, so that the voltage drop via the MOSFET at a current of (e.g.) 10 A is only a few 10 millivolts compared with around 400 … 600 mV with conventional diodes. This also reduces the heat development by a factor of 5… 10, so that the aforementioned problems no longer occur. In addition, active bypass diodes come with integrated surge protection and are therefore many times more resistant to induced overvoltages.

The energy for actuating the MOSFET is obtained through a special control circuit from the only slight voltage drop at the MOSFET, so that the component has only two connections and – without an additional power supply – can be used like a conventional bypass diode.

Active bypass diodes are offered by MICROSEMI (LX2400) [31], for example, with an innovative ultra-thin version (LX2410) being suitable even for lamination into the module. Other manufacturers include STmicroelectronics (e.g. SPV1001) and Texas Instruments (e.g. SM 74611).

3.5.2 Plug connections and wiring

3.5.2.1 Connectors

A photovoltaic system typically contains a large number of plug connections. Each individual module as well as the inverters is usually connected via plug connectors. Owing to their large number, a considerable potential exists here for the occurrence of serial electric arcs.

Progressive professionalization in component development has led to commercially available plug connectors whose inadvertent detachment and contact corrosion can be prevented quite reliably.

The greatest risks lie in the pairing of connectors of different makes and in the crimping of connectors onto cables in the field [33]. The former should always be avoided, for even if the plugs from two different manufacturers mechanically fit together, the electrical transition resistance may significantly increase, resulting in intense heating of the component (Figure 3-48). Even knock-offs of brand-name connector models have occasionally come to light. The quality of such products is dubious, and if a fake is suspected the connector should never be used.

Figure 3-48: Result of pairing connectors from different manufacturers **[33]**

If connectors must be crimped onto cables in the field in order to enable the connection, crimping tongs designated by the manufacturer of the plug must always be used, and with the precisely defined contact pressure. Only then can a gastight, permanent connection point be guaranteed (Figure 3-49).

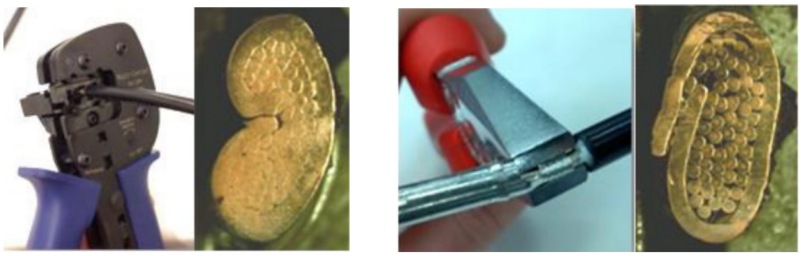


Figure 3-49: Comparison: correct and incorrect crimping in the field **[33]**

3.5.2.2 Lines and line routing

While serial electric arcs occur mainly at contact and connection points, a damaged cable can lead to a very high-energy parallel electric arc if it can form a conductive connection between the positive and negative terminals (or, in the case of a grounded solar generator, between the ungrounded terminal and an object at ground potential). This can mainly occur if the cable insulation is damaged.

Ground and short-circuit-proof line routing is a measure for avoiding parallel electric arcs. That is, both the positive and negative lines are double-insulated or their insulation is reinforced or, in the case of single insulation, routed in separate cable routing systems. An electric arc is highly improbable given *four insulation layers* between positive and negative conductors.

So that only minimal hazardous surges will be induced by a lightning strike, the size of the loop formed by the wiring should be kept as small as possible. At the same time, however, the risk of a parallel electric arc, i.e. contact between two conducts of opposite polarity, must be kept as low as possible. Both requirements are met by laying double-insulated cables next to one another or, even better, with *separate routing* of the two main lines in directly adjacent cable conduits.

The cable routing should also stress the cable insulation as little as possible. That is, the routing should not expose the cables to any direct sunlight, place them continually under water or run them over sharp edges.

The cables should be fastened so that no movement can be caused by wind, with subsequent friction damage to the insulation. Permitted bending radii should be complied with and not exceeded.

3.5.3 Fuses

In the early years of photovoltaics (1985 – 1995), string fuses were often used. It was found, however, that they often failed, causing local overheating or even switch cabinet fires.

The applicable VDE 0100, part 712, accordingly requires them only if the current-carrying capacity of a line could be exceeded. They are therefore installed only in very few PV systems.

For approximately two yearsspecial PV fuses have been available that are designed so as not to trip accidentally, given the correct dimensions, and so that they can interrupt an overcurrent even in a system with high voltages (typically up to 1,000 V_{DC}). At approximately €10 a piece they are quite expensive, however.

Detailed studies have shown that string fuses are helpful at all only with a very limited class of possible faults in a PV system. In all other cases, a string fuse is of no use, and constitutes an additional cost factor as well as several further contact points that present the corresponding electric arc risk potential.

The only scenario in which string fuses can provide protection concerns reverse currents, which can drive parallel strings into a string with partially short-circuited bypass diodes. The permissible reverse current for PV modules is usually twice the maximum short-circuit current. Only if more than 10% of the bypass diodes are short-circuited can a reverse current exceeding this threshold value flow under full insolation [34]. This fault is very improbable, however.

We therefore propose that string fuses be required only for PV systems in which PV modules are installed in a combustible environment.

Since at most (n-1) x the short-circuit current of a string can flow through a short-circuited string of a solar generator consisting of n parallel strings, protection against such faults in the solar generator with fuses is possible in practice only from 3 to 4 parallel strings [35].

During the current international revision of VDE 0100, part 712, intense discussion occurred on whether string fuses for the protection of PV modules and cables against a reverse current should be mandatory again from 3 or some other number (to be calculated) of parallel strings. Given the international claim by standard IEC 60364-9-1: “Low-voltage electrical installations – Part 9-1: installation, design and safety requirements for photovoltaic systems (PV),” we must assume that fuses are required, since in the US and Australia the European concepts of protective insulation and ground-leakage-proof and short-circuit-proof routing are not widespread and therefore parallel electric arcs are to be expected more than is the case in Europe.

Recommendation for standardization:

For Germany, we propose a national addition to the international standard requiring string fuses only for systems with the PV modules installed in a combustible environment.

3.5.4 Isolators and disconnection points

Figure 3-50 shows the schematic design of a PV system with DC switch points as often used in practice in installations at the DC end. The German installation standard for photovoltaic systems [36] specifies a load-break switch (also called a DC isolator) at the DC end of the inverter.

Since this switch must safely disconnect an inverter from the solar generator even under rated load or in the event of an inverter short circuit at the input end, the switch must have the correct dimensions. The use of a DC switch designed for the conditions of a DC power source without consideration of the properties of a PV generator (current source characteristic) can lead to a switch arc that can no longer be extinguished!

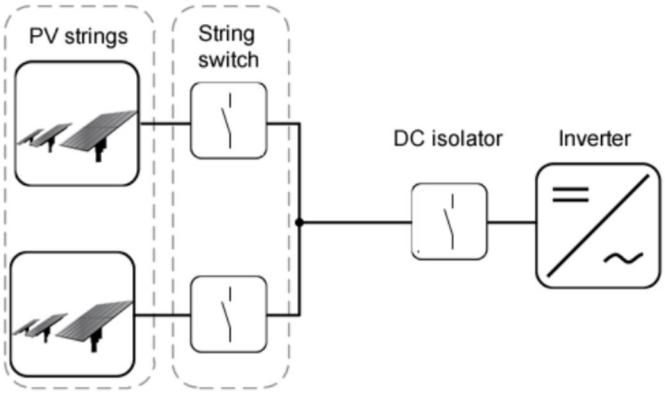


Figure 3-50: Block diagram of a PV system with switch points

Especially larger PV systems employ switching devices to shut down individual strings. For cost reasons circuit breakers are often used here. Circuit breakers must not switch off the circuit when live. They may only be operated if the circuit was previously interrupted by a load disconnecting element [37].

Regarding the occurrence of fault arcs in circuit breakers, the switches must be designed for the operating measurement currents.

Alternatively, DC circuit breakers specially developed for the requirements in PV systems are available on the market.

Some PV systems employ DC contactors. They are designed for remote-controlled switching on and off under load as well as for conducting currents, but may not be used as short-circuit breakers or isolators [37].

Generally each piece of electrical equipment bringing a new contact connection into the system poses the risk of an electric arc. Only proper dimensioning and installation can keep this factor small.

3.5.5 Generator junction boxes

Several PV strings are compiled in the generator junction box. The string cables, the DC main cable and if necessary the potential equalization cable are connected.

The generator junction box contains connecting terminals and disconnection points as well as possibly string fuses and string diodes. Often the generator junction boxes contain integrated surge arresters for diverting overvoltages to the ground. The potential equalization or grounding conductors therefore lead into the generator junction boxes.

DC main switches or line safety switches are sometimes accommodated in the generator junction box. String monitoring elements are finding increasing use in larger systems. These elements report any string malfunction to the data monitoring system, so that troubleshooting can be initiated.

The generator junction box should comply with protection class II and have a clear separation between the positive and negative ends inside.

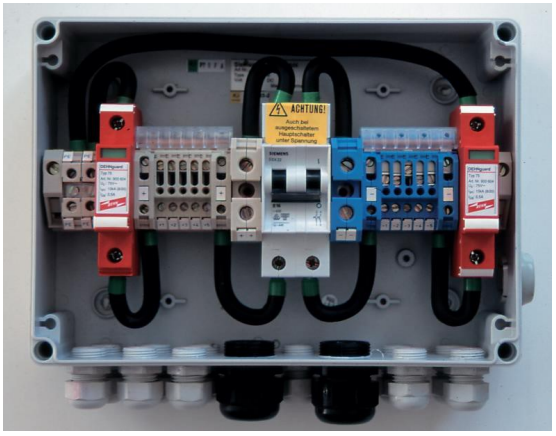


Figure 3-51: Generator junction box [source: DGS-Berlin]

Since the generator junction box is located outdoors, it should have at least protection level IP 54 and be weather and UV resistant. In addition, we recommend selecting installation site so that the junction box is protected against rain and insolation. Accessibility of the junction box should be ensured because of possible, later maintenance work.

In junction boxes with screw terminals the exact connection is important, since a faulty connection can cause the entire string to fail. Junction boxes with spring-type terminals or other suitable terminal systems require no core end sleeves and are easy to handle.

The design of the generator junction box must comply with VDE 0660-600-1 (EN 61439-1). For constructing the circuitry, terminal blocks may be used that are fastened to the top-hat rails. The positive and negative ends must be consistently separated and be both ground-leakage-proof and short-circuit-proof.

String diodes for uncoupling the individual strings were originally used in strongly shaded systems with central inverters. Their usefulness is very questionable, however. If string diodes are nevertheless used, they must have a voltage strength as per VDE 0100-712 corresponding to the doubled generator off-load voltage at STC.

The string fuses protect the cables against overload in case of a fault. They must be designed for DC operation. Unsuitable DC fuses have been used as string fuses. Since the current may fluctuate because of cloud movement, an electric arc may occur in a normal DC fuse, but not suffice to melt the insulation granulate. The result is non-tripping of the fuse and slow heating that can lead to a fire in the fuse box.

Some manufacturers have in the meantime developed suitable PV fuses. To date there exists only one draft standard, IEC 60269-6 FDIS 09/2010, which takes into account the specific use conditions of fuses in PV systems.

Some manufacturers offer suitable PV fuses with DC switch-off capability and full-range characteristic as per this draft standard with the designation gR or gPV (see Figure 3-52**)**. The selection and dimensioning of the fuses and fuse holders must absolutely comply with the following reduction factors for the fuse rated current In (= rated current):

1. for the elevated operating temperatures (e.g. for 60°C. e.g. 0.84)
2. for the accumulation, i.e. multiple fuse holders too densely arranged

3. reduction factor for plastic sheathing of fuse link
4. load cycle factor (considers aging; usually 0.9).

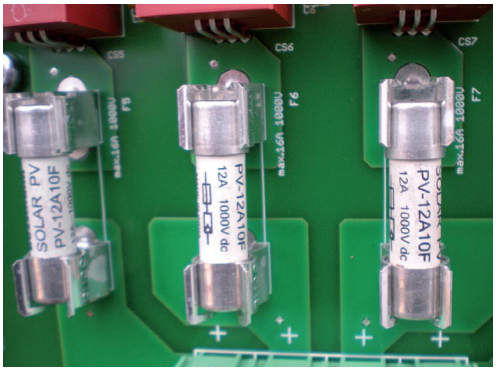


Figure 3-52: PV fuse as per standard [source: SIBA]

3.5.6 Inverters

The inverter is the most complex individual component of a photovoltaic system. All components listed in the preceding sections, like plugs, clamp connectors, switches and cables, occur inside an inverter, along with passive, electronic and power-electronic components. Depending on the equipment features of an inverter, up to several hundred single parts may be assembled together.

Individual serial defects have been encountered in the past that are attributable to inadequate dimensioning of components or even conductor tracks, in part also to production flaws of the PCBs themselves (interlay connections) or even to the poor quality of the soldered joints (cold soldered joints).

These are not solar-specific defects, however, but can occur in any piece of electronic equipment. These defects were accordingly rectified, and according to the above statement the inverters may be said to have a high level of reliability and pose a “normal” fire risk.

Figure 3-53 and Figure 3-54 show the typical single parts of a string inverter:

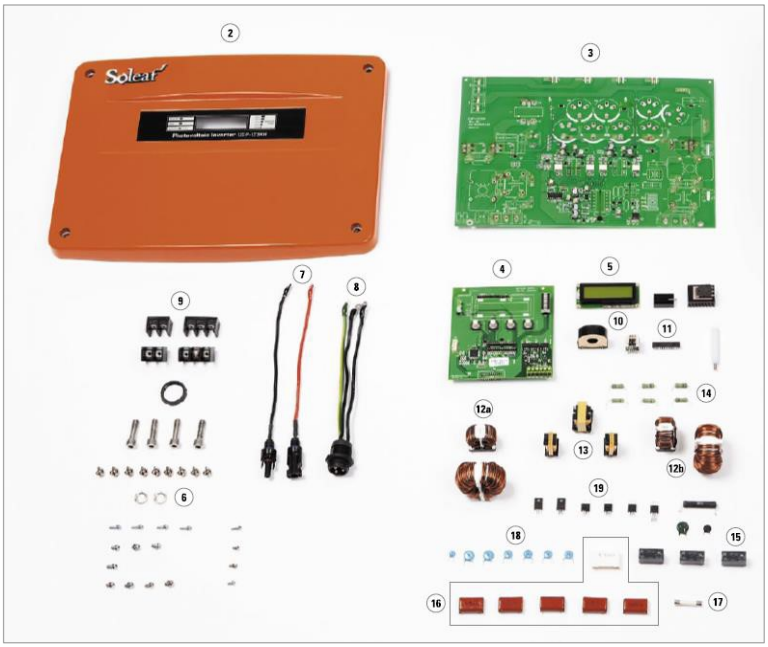


Figure 3-53: Single parts of a string inverter **[38]**

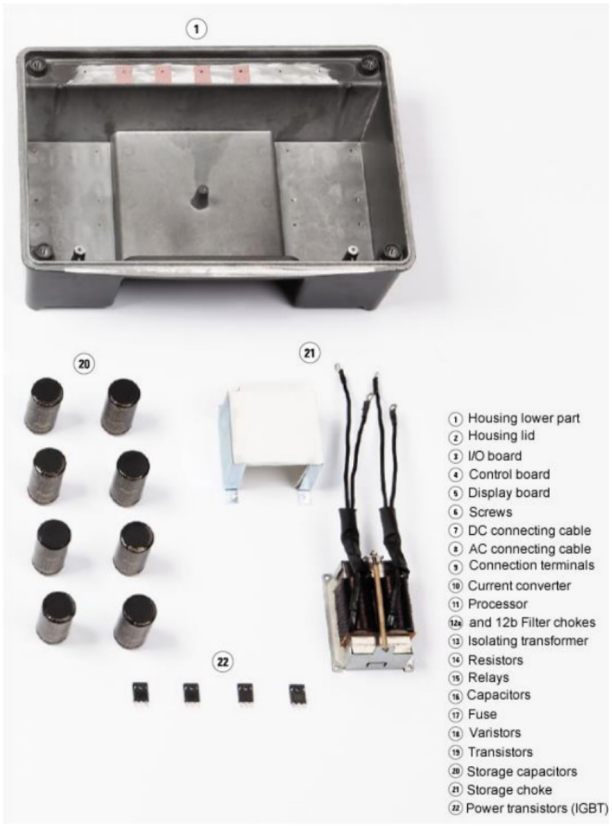


Figure 3-54: Single parts of a string inverter **[38]**

Figure 3-55: Example of a central inverter in a switch cabinet

From experience with numerous inverters we can identify certain potential sources of faults that should be given particular attention during the design phase:

PCBs

In the case of inverters with an output of up to some 10 kW, attempts are made for manufacturing reasons to accommodate all components if possible on one or a few PCBs. Merely the usually heavy and voluminous inductive components (restrictors, possibly transformers) are separately accommodated in the housing, some in their own chambers of the housing. They are connected to the main PCB via cables and clamps. In the case of inverters in the power range of 100 kW and more, the construction occurs in a switch cabinet – subassemblies like buffer capacitors, power semiconductors and inductivities are interconnected via power rails or plates with high-power capability; the actuation as well as the control and regulation technology are compiled on PCBs.

The PCB design must maintain the necessary conductor cross sections, which usually occurs anyway given the requirement of low resistance or high efficiency. Thermographs of inverters show that no problems with excess temperatures occur here.

Interlay connections (vias) with power PCBs constitute a potential weak point – here there is a solution consisting of numerous small parallel-operating vias or the general insertion of a component to such an interlayer connecting point.

The normatively stipulated distances between the conductor tracks must be maintained given the occurring voltage and expected degree of dirt on the PCB.

Connectors / clamps

Today's string inverters are usually fully connected by plug connectors. At the DC end, the same insertion systems are used as in solar modules. At the AC end commercially available or modified multipole AC or three-phase connectors are used. The current carrying capacity of these connectors must be sufficient.

Critical at this point is that usually no prefabricated connecting cables can be used here, rather the installer must manually install the plugs at the connecting cables on site. This always poses the risk of insufficient quality of crimp connections or of the strain relief, a risk that can be minimized only by conscientious work.

According to the findings of the damage analysis within the research project, fire-relevant faults often also occur along the familiar, conventional AC wiring!

In the device itself, the connections sometimes employ clamps on the PCB. Here spring-type terminals are preferable, since they ensure a continually constant contact pressure of the conductors.

In designing the PCB and mounting it on the device, it must be kept in mind that in part unpredictable and considerable forces can occur during transport and assembly, possibly leading to damage to the conductor tracks with possible consequences later on.

As shown above, it is advantageous to accommodate all components on one PCB or on as few PCBs as possible. This will minimize the number of connections between the PCBs / subassemblies, thereby increasing reliability. At the same time, costs will be saved and sources of faults during manufacture of the devices diminished. Here the market continues to have negative examples of numerous individual PCBs and a correspondingly high number of connectors.

Switches

In Germany, a load-break switch is normatively required at the DC end of an inverter. This switch is usually integrated in the device, but can also be added on externally as an extra component. The switch must be suitable for DC and be designed for the special current-voltage curve of a PV system.

Capacitors

Capacitors are used at many places in an inverter. Critical to fire protection are the X and Y capacitors, attached both at the DC end and at the AC end for suppressing EMC interference. Since they electrically occur directly behind the input terminals, they are subject to high voltage spikes and must be correspondingly sturdy – only the pertinent, permitted capacitors may be used here.

The higher-capacity electrolyte capacitors used as input buffer capacitors are not critical components according to present experience. Advantageous for the service life of the devices is the selection of a high temperature class, such as 105°C.

Surge arresters / varistors

At the input and output ends inverters usually contain lightning fine protection in the form of varistors or a combination of varistors and gas arresters. Varistors are potentially jeopardized components, since their response voltage diminishes because of small but quite frequent surges, until finally a noticeable leakage current already flows through them at the normal operating voltage. This leads to overheating and sometimes also to the varistors burning away – a fault that is often to be found in inverters.

To reduce this risk, the varistors with their response voltage must be selected with sufficient distance from the normal operating voltage. Also used are temperature-monitored varistors in which a switch element suppresses the current flow through the varistor once the latter exceeds a temperature threshold.

Since it also suppresses the actual surge protection function, this condition should be indicated. Another solution is the series connection of a varistor with a spark gap.

Housing

Among string inverters, both devices with metallic housing and ones with plastic housing are to be found on the market. Among large devices, metallic switch cabinets are generally used.

For fire protection reasons metallic housing is advantageous, since they inhibit the spread of any possible fire within the device itself. A high IP class (e.g. IP65) is also an advantage, since the very thick housing seal usually occurring in this case will inhibit the oxygen supply to the internal source of fire.

Fans

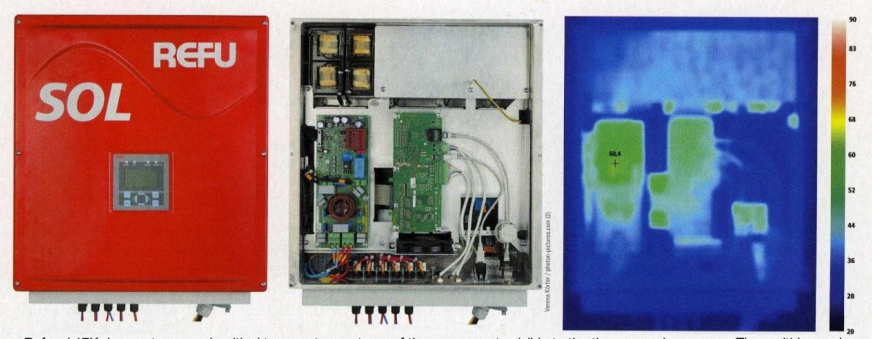
At present both inverters with active cooling by one or more fans and inverters without fans are commercially available.

The advantage of devices with fans is that the total work performed by a small cooling unit with one fan is less compared with a fanless device with a correspondingly large cooling unit. A disadvantage is that the fan is generally a wear part, but more important is the argument pertaining to dirt on the fan and in the cooling duct from forced ventilation.

Of course, even a fanless device can develop a hot spot from dirt or from being covered and present a fire hazard. Crucial to both concepts is therefore monitoring of the cooling unit temperature combined with a corresponding power limitation and if necessary signaling of the fault condition.

Some devices also have fans inside the housing in order to prevent hot spots. Here there is no danger of dirt, although the operating period of the fans must be kept in mind.

Well-designed devices optimized for high efficiency also attain temperature levels of some 10°C above the ambient temperature under continual load. As an example, we show here a device from REFUsol (Figure 3-56):



▲Refusol 17K does not approach critical temperatures at any of the components visible to the thermography camera. The multi-layered design blocks the view of the power section, however.

Figure 3-56: Design and thermography of a highly efficient PV inverter. Maximum measured temperature: 60.4°C **[38]**

3.5.7 AC installation

Unexpectedly many cases of fire damage originate at the AC end of PV systems. In many such cases, inferior quality of workmanship was identified as the cause. The following defects have been observed:

- Cables were undersized
- Screw terminals were not tightened
- Cable insulation was also clamped or cable ends were not fully inserted in the terminal, making the contact surface too small.
- Sizing rules for fuses and LS switches were disregarded insofar as the increased heat stress related to accumulation, coincidence and elevated ambient temperatures was disregarded.
- Grid stations designed for “power utility loads” and with a coincidence factor of 0.7 were used in PV systems. There the coincidence factor is at least 0.85.

All these defects can lead to an increased temperature stress of the affected operating equipment and thereby create an increased degradation risk for the contact points. In the long term, this degradation can cause overheating of the contact up to the point of fire.

There are also indications that the typical load cycles in photovoltaic systems cause particular stress on contacts. Daily changes between no-load operation and rated load and long-term operation under rated load together with the corresponding temperature cycles seems to accelerate aging among many types of contacts. This concerns at least terminal blocks, screw terminals at operating equipment, busbar connections and blade contacts of NH fuses.

This cyclical load may not be sufficiently considered in current product standards.

Given the possibilities of faults and failure, the condition of the connection points should be regularly checked.

3.6 Risk analysis

3.6.1 Methodology

Photovoltaic systems are complex electro-technical systems with numerous individual components. A total of more than 30 GW installed in Germany as of 2013 corresponds to about 150 million modules, approximately 450 million bypass diodes, approximately 10 billion solar cells (3 Wp) and approximately 50 billion soldered joints. Added are cables, distributors, string diodes, DC fuses, DC switches, inverters, AC fuses, IT interfaces, etc., as well as mechanical components like elevating supports and even tracking systems.

As in any technical system, there is a risk of damage from a malfunction in the system. For insurance companies as well as for the installers and operators of PV systems it is therefore necessary to assess this risk.

Pertinent methods are known in the insurance industry; see [39] for an overview.

An approach to identifying and if possible eliminating any sources of faults already during the development phase of a product or a system is provided by the so-called **FMEA** (Failure Mode and Effects Analysis, or also “Effects Analysis” for short) [40].

A research project applied this method to a complete grid-connected PV system (without accumulator). The procedure and results are presented in the following.

FMEA is a method formally required (DIN EN 60812, “Failure Mode and Effects Analysis”) and established in the industry, especially among manufacturers of mass products like motor vehicles, for identifying and assessing possible sources of faults and designating remedial measures already during the development phase of a product. Added is a team of about 10 experts from the widest possible variety of departments that under the management of a moderator considers in detail the components of an overall system or even just a single component.

The risk assessment is based on a combination of years of experience and factual knowledge, but also on “gut feelings”. Controversial assessments are thoroughly discussed, for ultimately the team must agree on a level of risk.

The risk is assessed according to three criteria: A, B and E. Each of these criteria is rated from 1 to 10 on an integral scale according to a specific list, with 10 corresponding to the highest risk in each case (Table 3-3).

“A” describes the probability (**A**uftrittswahrscheinlichkeit) of a fault occurring
“B” describes the significance (**B**edeutung) of a fault, i.e. its consequences.

“E” describes the probability of detection (**E**ntdeckungswahrscheinlichkeit) or, better, the “probability of non-detection,” so that the factor 10 is assigned to a fault that cannot be detected.

Table 3-3: Specific assessment list for PV system analysis

Probability of occurrence		Probability of initiating a fire (at the component)		Probability of detection	
1	Negligible Theoretically conceivable, practically impossible	1	Negligible Fire emergence is theoretically possible, practically never observed	1	Very high E.g. failure of the system, very reliable system monitoring, etc.
2		2		2	
3	Remotely conceivable Has already been observed, but considered the exception	3	Remotely conceivable Fire emergence is theoretically possible given certain conditions	3	High Fault detection exists, but can occasionally fail under certain conditions
4		4		4	
5	Low, seldom Seldom observed, occurs rather sporadically	5	Low, seldom Fire emergence is possible, but seldom occurs	5	Occasional Fault characteristics are easy to detect, e.g. visible, but are not systematically captured
6	Occasional Occurs at regular intervals	6	Occasional Fire emergence is possible, occurs occasionally	6	Low, seldom Fault can be detected by control measures or from its effects
7		7		7	
8	High Has been often observed	8	High Occurrence of the fault has already caused a fire in the past	8	Remotely conceivable Fault can be identified through precisely defined tests
9		9		9	
10	Very high It is practically certain that the fault will occur in the foreseeable future	10	Very high Occurrence of fault very often causes a fire	10	Negligible Hidden malfunction, characteristic cannot be tested

Multiplying together the three individual criteria yields the so-called risk priority number RPN, which can lie between 1 and 1,000.

Further analysis of the RPN can vary in nature – one possibility is to specify a limit value above which the risk is regarded as critical and countermeasures, such as design modifications, become necessary.

The FMEA conducted here specified an RPN of 150 as the threshold value. Rating all three criteria a “5” would therefore yield a non-critical RPN of 125.

This purely formal procedure is controversial and should always be supplemented by “common sense” and the results of the team discussion (see section 4.5.2).

3.6.2 Assessment of the risk points in PV systems

An FMEA can be conducted for a single component, such as a module junction box, or, as in this case, for a complete system; the level of detail will then vary accordingly.

Since within a PV system individual functions or technologies, such as soldered connections, were used at multiple points, the latter were compiled as much as possible and assessed.

The following groups were considered:

- Connectors (module, DC main cable, inverter at AC end)
- Terminals (field distributors, inverters at DC and AC ends)
- Soldered connections (cells/strings, junction box, inverter)
- Diodes (bypass diodes, string diodes)
- Modules (cells, glass, backsheet, connection technology)
- Fuses (DC end, AC end)
- Cables (DC end, AC end)
- Switches (DC end)
- Inverters
- Planning and installation

The moderator formulated altogether 39 questions, yielding approximately 140 assessments, including any necessary iteration, for reducing the RPN.

Table 3-4 shows an example of the assessments according to three criteria given a scorched DC plug related to incomplete insertion.

The “probability of occurrence” at 4 was regarded as relatively low. On the other hand, the “fire-inducing probability,” i.e. the probability that the plug would become scorched, was assigned a “7,” and therefore regarded as quite probable.

The “fire-inducing probability” always refers only to the considered component, since a spread of the fire to other components or to the building depends on many boundary conditions that cannot be estimated here.

A high fire-inducing probability therefore does not necessarily mean that the building will catch fire. An example could be a scorched connector between two modules above a hard roof covering (roof tiles), a situation that generally would not cause a fire.

The third criterion, namely that the fault (defective plug insertion) be already detected prior to the occurrence of scorching, was rather improbable, and thus an “8”. Altogether, multiplication yields an RPN of 224 – significantly above the selected RPN limit of 150!

Table 3-4: Example of assessment of an incompletely inserted DC plug

			Actual status			
Component involved / location	Potential faults	Potential causes	Probability of occurrence	Probability of fire emergence	Probability of fire emergence	RPN
DC plug						
DC plug connector	Plug connector scorched	Plug not fully inserted	4	7	8	224

According to Figure 3-57, of the 39 groups considered, 21 attained an RPN above the limit of 150; Figure 3-58 lists the other 18 below the threshold.

The group of experts regarded the (impermissible!) combination of connectors from different manufacturers as especially critical, assigning an RPN of approximately 450.

Besides faults in component manufacture, primarily installation flaws and planning errors emerge as critical.

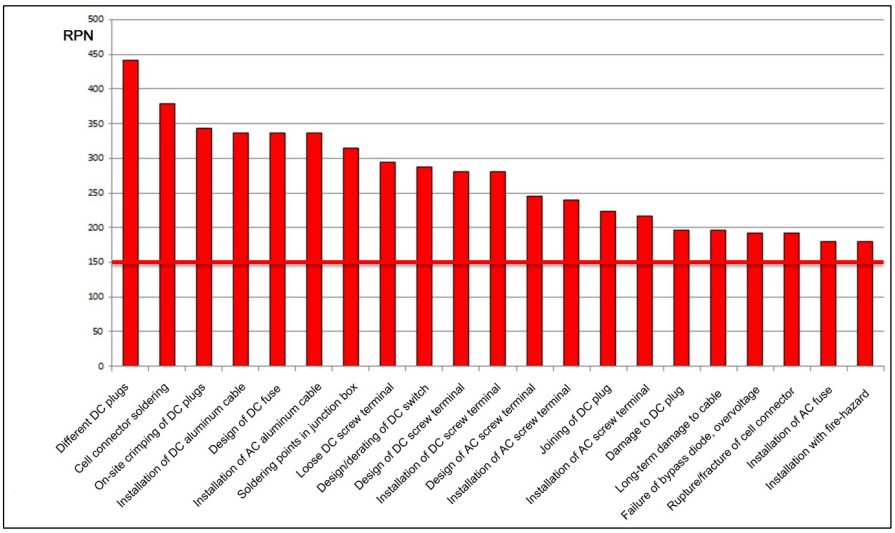


Figure 3-57: Subassemblies/functions with an RPN > 150

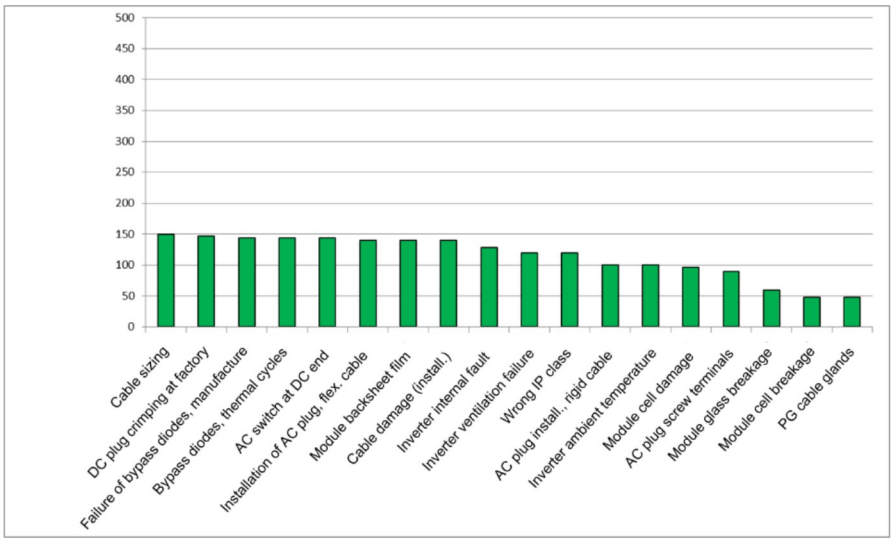


Figure 3-58: Subassemblies/functions with an RPN <= 150

The following table shows a typical assessment of various improvement measures with an incompletely inserted DC plug, alongside the comments from the FMEA team.

Table 3-5: Typical assessment of different improvement measures

Improved status					
Possible remedial measures	Probability of occurrence	Probability of fire emergence	Probability of detection	RPN	Comments:
Initial status	4	7	8	224	
Training of the installers	3	7	8	168	Time and cost pressure
Plug design: Snap tabs, touch & feel, color ring, etc.	2	7	7	98	
Acceptance inspection (DIN 0126-23)	4	7	7	196	Not sufficient!
Acceptance inspection (expanded methods, e.g. IR)	4	7	6	168	If necessary, new measuring methods
Regular repeat inspection (DIN 0126-23)	4	7	7	196	Not sufficient!
Regular repeat inspection (expanded method, e.g. IR)	4	7	5	140	If necessary, new measuring methods
Electric arc detector	4	4	7	112	If reliable!

Training or raising the awareness of the installers can improve the quality of the installation, thereby improving the criterion rating for “occurrence probability”.

The FMEA team viewed the improvement potential as insufficient given the time and cost pressure during the installation, however.

Purposive could be improvements at the plug itself (snap tabs, touch & feel, conspicuous color ring in case of wrong insertion, etc.), also regular repeat inspections with expanded methods (infrared camera) or also an electric arc detector, if the latter can also detect such problems (scorching, but no electric arcs) at an early stage and reliably.

Fortunately, according to Figure 3-59 practical proposals could be found for all groups and functions with an RPN greater than 150, by means of which the RPN could be brought below the critical limit.

The complete results of the FMEA can be viewed in the Appendix (IX Appendixes).

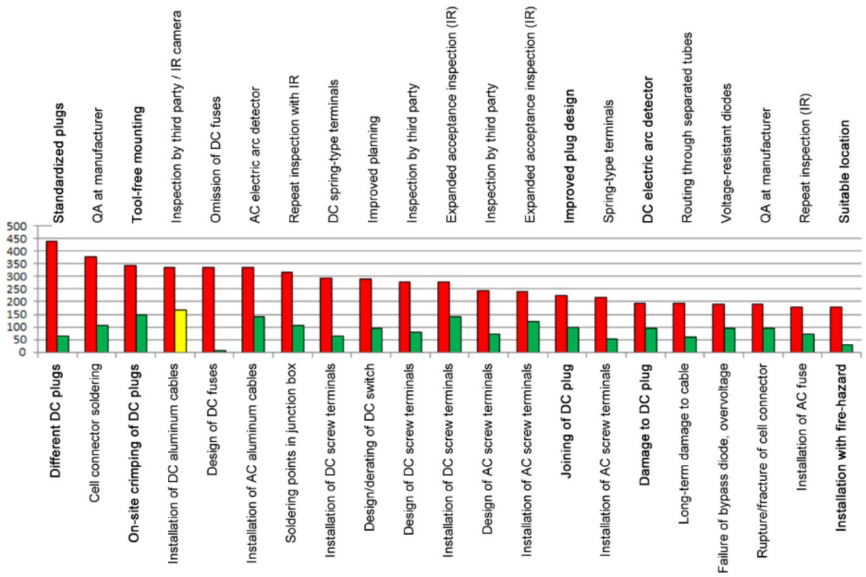


Figure 3-59: Subassemblies/functions with an RPN > 150 and proposals with lowest RPN in each case

3.6.3 Conclusions

Taking together the improvement measures shown in the above graphics and primarily mentioned in the discussions during the FMEA, we arrive at the following ranking:

(1) Compliance with the existing standards and regulations
(2) Acceptance and repeat inspections by independent third party
(3) Expanded acceptance and repeat inspections (IR camera, EL, new methods) by independent third party
(4) Training of planners and installers
(5) Quality assurance at component manufacturer
(6) Spring-type terminals instead of screw terminals
(7) Worldwide standardization of components (especially DC plug connectors)
(8) Electric arc detector and automatic shutdown
(see notes from section 5.3.5)
(9) Design improvements at connectors, for example
(10) "Sleek" system design (omission of superfluous components)
(11) Structural measures (e.g. protected routing of lines)
(12) Many other, for the most part already familiar, detailed solutions)

Conclusion

As a main source of faults we unfortunately had to recognize the "human factor". The proposed improvement measures therefore lie mainly in the realm of quality assurance pertaining to the components as well as to the planning and construction of the systems.

Regular inspections by independent third parties were considered very useful, however the financial cost must stand in a reasonable relationship to the revenue from the system.

Additional safety components can further reduce the risk, but were mentioned only in second place, following professional planning and construction of the systems with high-quality components.

Altogether, the participants considered the FMEA to be very useful, for it was comparable to brainstorming – numerous fault scenarios were addressed and analyzed.

4 Endangerment of emergency services in damage incidents

4.1 Risk analysis for rescue workers

Possible hazards for emergency services attending to PV systems are assigned to nine possible categories according to the hazard scheme routinely used by German fire departments (AAAACEEEE rule):

1. **A**temgifte (respiratory poisons)
2. **A**nxiety attacks
3. **A**usbreitung (propagation)
4. **A**tomic radiation
5. **C**hemical substances
6. **E**rkrankung / Verletzung (illness / injury)
7. **E**xplosion
8. **E**lectricity
9. **E**insturz (collapse)

For analyzing the hazard to rescue workers, the scenarios must be identified that in operations at PV systems could lead to possible injuries or health impairment:

1. Respiratory poisons – yes, PV modules are combustible and contain, besides glass and aluminum (frames), also a great variety of plastics as well as, depending on the technology, toxic heavy metals. Smoke gases and soot particles can be hazardous.
2. Anxiety attacks – no, PV fires generally do not present an increased risk of explosion nor do they involve fast mechanical motions or present otherwise threatening scenarios.
3. Propagation – yes, a fire can spread due to the compact design and cables between the components.
4. Atomic radiation – no, does not apply.
5. Chemical substances – yes, primarily in the form of respiratory poisons (covered by 1.).
6. Illness/injury – yes, but the illness risk is already covered by 1.; a risk of injury exists from (e.g.) electric shock and falling because of a shocked reaction or from falling system parts; since this is covered by 8. and 9., we do not consider the point separately.
7. Explosion – in the strict sense, no, apart from PV systems with accumulators and flooded basements – these systems are investigated in a subsequent study and are not separately considered here. Explosion-like effects can occur, however, if a roof timber fire spreads to the PV system and causes the module glass panes to burst. Reports are known according to which glass fragments were found up to a radius of 20 to 30 meters. Wafer fragments detached by the heat effects of large-scale fires were thermally lifted to great heights and transported several hundred meters.
8. Electricity – yes, in particular the live DC end poses hazards in case of damage, with danger of contact and hazards during extinguishing operations.
9. Collapse – yes, the heat can impair the bearing capacity of a steel structure. In the case of a wood structure, the bearing capacity is reduced by the burning with a decrease in cross section. These effects apply analogously to bearing base frames of the PV modules.

Table 4-1: Fire department hazard matrix for operations at PV systems

Which hazards are detected?									
Hazards	Respiratory poisons	Anxiety reaction	Propagation	Atomic radiation	Chemical substances	Illness / injury	Explosion	Electricity	Collapse
Which hazards must we combat?									
People	x		x				(x)	x	x
Animals	x		x				(x)	x	x
Environment	x		x						
Property			x						
Against which hazards must we protect ourselves against?									
Team							(x)	x	x
Equipment									x

The fire department operational scenarios can generally also be classified according to firefighting and technical assistance types of operations. There are also events that fit into both categories, however. The greatest possible hazardous area, namely “Electric shock,” was subdivided into the three subareas “General scenarios,” “Firefighting” and “Technical assistance.”

Risk assessments classify the different scenarios by means of the **parameters extent of damage** and **probability of occurrence**.

These parameters are employed as per the guideline created in 2012 for preparing hazard assessments in the Fire Service of the German Social Accident Insurance (DGUV).

The **probability of occurrence (P)** breaks down into five categories:

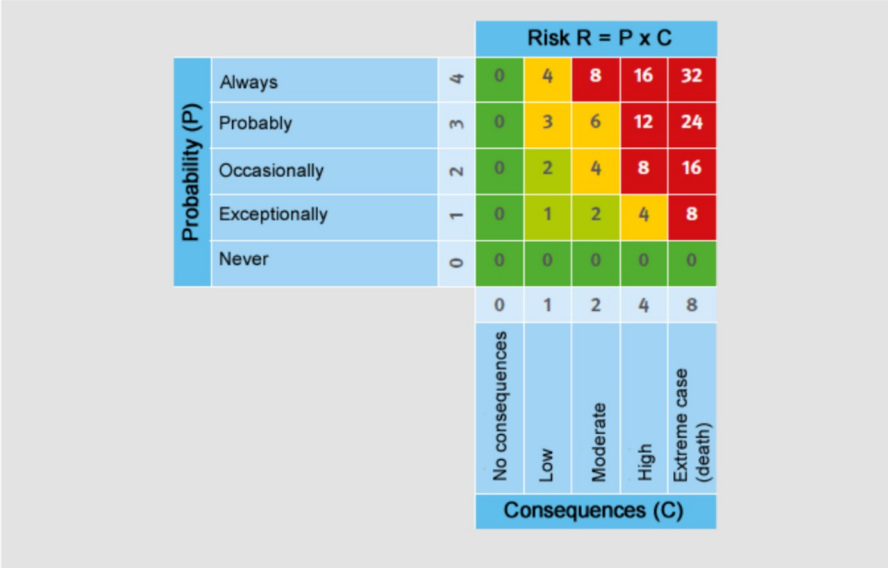
- **0** Never (absolutely no possibility of encountering the hazard)
- **1** Exceptionally
- **2** Occasionally
- **3** Probably
- **4** Always

The possible **health consequences (C)** also break down into five categories:

- **0** No consequences
- **1** Minor, light and reversible injuries, such as minor cut wounds, scrapes, sprains
- **2** Moderately severe injuries, such as bone fractures, 2nd degree burns
- **4** Highly life-threatening injuries; severe, permanent damage to health, such as paraplegia, blindness, etc.
- **8** Extreme case (death)

The risk matrix (Table 4-2) shows the risk assessment (R) based on the probability of occurrence (P) and the expected health consequences (C). Source: Deutsche Gesetzliche Unfallversicherung (DGUV) [1]

Table 4-2: Risk matrix of the fire department



The risk group 0 1-2 3-6 8-32 can be directly read off the intersection of probability of occurrence (P) and consequences C in the matrix.

Table 4-3 shows the identified *risk groups* and the resulting need for action by specifying the urgency and scope of the required measures. Possible technical or organizational measures are described in section 6.

Table 4-3: Risk groups and need for action

Risk group	Risk	Measures
8 - 32	Large	Measures with increased protective effects are urgently required
3 - 6	Moderate	Measures with increased protective effects are urgently required
1 - 2	Low	Organizational and personal measures suffice
0	-	No additional measures necessary

4.2 Electrical hazard for rescue workers

Hazards from electric shock during firefighting operations at PV systems must be considered in various scenarios and appropriate measures taken to protect teams and equipment as well as any other persons, animals and the environment from electrical hazards.

Not only insolation at the PV modules can generate electrical voltage. In individual cases hazardous voltages can occur even with the use of artificial lighting, as in the illumination of the scene of a fire. Scientific studies have shown that in particular the use of halogen spotlights can generate a significant amount of energy under unfavorable conditions. This danger can be countered by maintaining a sufficient distance of the illuminants from the modules (see distance formula according to the study conducted in the research project, section 4.5.2). That's why the individual results do not distinguish between natural and artificial lighting.

4.2.1 General scenarios

The category of "General scenarios" considers all events that are not specifically assignable to firefighting or to technical assistance.

The contact safety of PV systems is extremely important on roofs. Injuries from electric shock are very dangerous especially on roofs, since besides injuries from electric currents they can also lead to severe secondary injuries (falling from the roof).

Figure 4-1: Firefighting operation at a PV fire on a residential building (here 2008 in Bremen), photo: www.feuerwehr.de

4.2.1.1 Exposure of live cables

The effects of a fire, but also mechanical causes, such as a storm, can damage the electrical lines of the PV systems, irrespective of the type of installation or system (e.g. roof or wall-mounted, open-space system).

Hazard: contact with live cables by rescue workers

Protective goal: avoidance of electric shock for rescue workers

Risk measure: 16

Assessment: Owing to the severity of injury (possible fatality), the assessment leads to a high risk.

4.2.1.2 Damage to PV modules (e.g. from the aerial ladder basket)

The use of different (electrically conductive) work equipment can damage PV modules and consequently lead to indirect contact with live parts.

Hazard: electric shock

Risk measure: 4

Protective goal: avoidance of voltage transfer or indirect contact

Assessment: While the rescue workers are at risk of an electric shock (if at all) only if the system is grounded, a precondition for the shock occurring is that they first build up voltage by touching two different potential points (e.g. step voltage).

4.2.1.3 Accessing the roof

The roof surface may have to be accessed during firefighting operations and technical assistance, for example, in order to remove snow from statically endangered roofs. Here it is also possible that module surfaces have to be trod upon. Pre-damaged modules or modules damaged after being trod upon can lead to contact with parts carrying voltage directly or indirectly.

Hazard: electric shock

Risk measure: 8

Protective goal: avoidance of contact with parts carrying voltage directly or indirectly.

Assessment: Modules are not designed for being trod upon. Treading on the modules can damage them and thereby endanger rescue workers. While the probability of coming into contact with voltage is classified as rather low, a considerable degree of injury is possible.

4.2.1.4 Occurrence of electric arcs

Damage due to fire or mechanical effects can cause electric arcs. The high amount of released energy with electric arc temperatures of several thousand degrees can cause burns or temporary eye damage (flash).

Hazard: burns, physiological blindness with eye damage

Risk measure: 2

Protective goal: avoidance of contact with the electric arc or looking into the electric arc

Assessment: In contrast to the usual electrical hazards not perceptible to the human senses, electric arcs are easily discernible owing to their visual and acoustic form of appearance. The probability of occurrence may therefore be assumed to be rather low.

4.2.1.5 Flooding

Flooding of components of the PV system from (e.g.) flood water, quench water or fire extinguishing foam can lead to contact between live parts and water. Carryover of voltage to the immediate surroundings of the affected system parts is then possible.

Hazard: electric shock

Risk measure: 24

Protective goal: avoidance of indirect contact from water contact

Assessment: Especially in extended or angled buildings or with poor visibility from smoke gases it will not be clear whether live system parts are affected by the flooding. The risk of electrical current flowing through the body from the flooded areas must be heeded.

4.2.2 Firefighting

4.2.2.1 Water pressurization

Water (or other extinguishing agents) striking damaged system parts can lead to voltage transfer irrespective of the type of installation (roof or wall mounted, open-space system).

Hazard: Electric shock

Risk measure: 4

Protective goal: Avoidance of voltage transfer

Assessment: Owing to the low conductivity of the water stream (see section 4.5.1), voltage transfer occurs only with the coincidence of several unfavorable parameters (unsuitable extinguishing agent, puddle formation, extinguishing distance not

maintained). For this reason, the probability of occurrence is rather low. On the other hand, the resulting injuries can be considerable.

4.2.2.2 Opening the roof cladding

In individual cases, fire extinguishing operations may necessitate opening the roof for tactical reasons. Contact with live parts from damaged PV systems may then occur.

Hazard: electric shock

Risk measure: 16

Protective goal: avoidance of direct or indirect contact

Assessment: Opening the roof cladding first leads to the exposure of live parts. The probability of occurrence is moderate. The injuries can be considerable owing to the voltage of the still intact PV modules.

4.2.2.3 Fire at an open-space PV system

Fires at open-space PV systems can cause hazardous damage to inverter or transformer stations and (rather seldom) to feed-in stations. At these “medium voltage stations” voltages of up to 20 kV can generally occur.

Hazard: electric shock (high voltage)

Risk measure: 8

Protective goal: avoidance of direct or indirect contact

Assessment: The system parts at the high-voltage end are generally labeled and secured against unauthorized entry. The probability of occurrence can therefore be set very low; because of the high voltages in the systems, extensive injuries must be expected, however.

4.2.3 Technical assistance

Technical assistance operations in connection with photovoltaic systems can involve different scenarios:

- Building and system damage from storms
- Flood water effects
- Accidents (explosions), traffic accidents with removal of objects, vehicles and debris.

We do not separately consider the rescue of people here, since the possible hazards are those encountered by firefighting operations and are described in this section.

4.2.3.1 Building damage or system damage with still functional or partially functional PV systems

The collapse of buildings or parts of buildings as well as other types of mechanical damage to systems or their parts can lead to voltage transfers or exposed live parts at the scene of a fire. Such damage can also be caused by unusually strong winds or stress going beyond general traffic loads (e.g. snow, ice).

Hazard: electric shock

Risk measure: 16

Protective goal: avoidance of direct or indirect contact with live parts

Assessment: Exposed live parts can considerably injure rescue workers through the high voltages. A higher probability of occurrence must also be expected because of the complexity of the destroyed surroundings.

4.2.3.2 Removal of objects, vehicles and debris

Traffic accidents or other incidents pose the risk that objects of varying size and conductivity damage system parts and present an electrical hazard.

Hazard: electric shock

Risk measure: 12

Protective goal: avoidance of direct or indirect contact with live parts when removing objects

Assessment: The accident mechanism in these scenarios is such that we must assume that areas of the system are damaged and that live parts are exposed. The high voltages can considerably injure rescue workers. Directly working on these components can also lead to a high risk of touching live parts.

4.3 Mechanical hazards for rescue workers

4.3.1 Collapse of building parts or system parts

Fires or other technical operations can cause the building and/or system statics to fail. The collapsing building parts or falling modules can endanger rescue workers.

Hazard: injury from falling parts

Risk measure: 8

Protective goal: avoidance of injury from falling parts

Assessment: Falling system parts can cause considerable injuries to rescue workers; subframes of PV systems cannot withstand temperatures of up to 1,000°C at fires (aluminum melting point is 660°C).

The “debris zone” is the hazardous area in which falling debris can land. In damage incidents (fires, earthquakes, floods, washouts, etc.) there is danger to life in debris zones. Presence there is advisable only for the purpose of immediate rescue of people or for propping up or demolishing debris. For example, gable walls can easily topple if the remaining building structure is weakened or no longer exists.

4.3.2 Falling rescue workers

Operations may require treading on the roof and even the modules. Especially the smooth surfaces of the modules pose an increased risk of slipping or falling. The modules are generally not designed for the stress of being trod upon. The modules can also brake through partially damaged roof structures.

Hazard: falling rescue worker

Risk measure: 12

Protective goal: avoidance of falling

Remark: We must assume that roof surfaces without additional safety measures pose a risk of falling. The properties of PV modules increase this risk. The severity of injury must also be rated as high, since the fall will usually result in serious injuries.

4.3.3 Thermal voltages in the module

In case of fire, the thermal stress from (e.g.) fire penetration through the module or from cold quench water can give rise to extreme stress in the module glass, which can subsequently lead to explosion-like bursting and splintering of the glass, with a danger of injury. Mechanical stress in the glass from motion and tilting can also cause splintering during the removal of debris.

Hazard: cut injuries from glass splinters

Protective goal: avoidance of splintering or prevention of cut injuries

Risk measure: 4

Assessment: The effects depend on the given thermal propagation or the mechanical stress of the modules and will cause more serious injuries only with a low probability.

4.3.4 Explosion

Flooding of parts of the PV system (e.g. inverter or accumulator located in the basement) from flood water or quench water can cause electrolysis in the event of simultaneous DC voltage between the positive and negative terminals of the system. Hydrogen then forms that poses a danger of explosion in a closed or poorly ventilated space (electrolytic gas).

With Li ion accumulators under extreme conditions (overheating, short circuit), the danger of "thermal runaway" with a chemical chain reaction at increasing heat build-up cannot be ruled out. This can cause a fire at the battery itself, possibly explosion-like. In the event of destruction of the battery, the escape of toxic and caustic chemicals must be expected (HF). The particular hazards from accumulator batteries are being studied in a separate research project. A risk assessment cannot be made here.

Another hazard comes from the glass bursting from the heat. Glass splinters and wafer splinters can be "shot" in all directions.

Hazard: explosion

Risk measure: **4**

Protective goal: avoidance of explosive gas formation or formation of an ignitable mixture, as well as avoidance of ignition sources

Remark: Many factors must combine to create an explosive atmosphere with hydrogen. The probability of occurrence must be regarded as low. The severity of injuries from a hydrogen explosion must be specified as the maximum value for rescue workers, however.

4.4 Respiratory poisons

4.4.1 Solar module fires

Photovoltaic systems are combustible because of their polymer content (see section 3.1). 4.6 describes in detail the possible toxic emissions from PV system fires. In fires involving a PV system, the release of respiratory poisons, also in concentrations exceeding limits (maximum exposure tolerance levels) must be expected. Depending on the plastics being used, highly toxic and caustic parts (e.g. hydrofluoric acids (HF)) may occur.

Hazard: poisoning, chemical burns

Risk measure: **4**

Protective goal: dilution of the concentrations of harmful substances, prevention of inhalation and skin contact (protective clothing and respiratory protection)

Remark: Building fires without PV also produce toxic fire effluents. PV components on fire contribute additionally. The effects are here regarded as merely minor, since we assume that rescue workers wear PPE.

4.4.2 Mechanical damage from electrical accumulators

Mechanical damage to accumulator cells can on the one hand lead to the escape of liquid chemicals and on the other hand, in the case of lithium ion batteries, pose the risk of thermal runaway of the accumulator. Besides a large heat build-up with an explosive flame or even explosion, toxic and caustic substances are expelled into the environment.

This is especially important in the case of the frequently occurring basement installation situations, where sufficient ventilation must be provided.

An assessment by means of a risk measure will not be provided here. The particular risks in case of damage from electrical accumulators will be analyzed in a further research project under the management of TÜV Rheinland, whose full title runs: *"Safety and reliability of photovoltaic systems with accumulator systems in particular consideration of fire risks and fire extinguishing strategies"*.

Remark:

In December 2014, the Bergische Universität Wuppertal and the Bundesverband Solarwirtschaft (BSW) published a bulletin on the use of stationary lithium ion accumulators which contained information on firefighting and technical assistance. [41] The BSW has made this bulletin available for downloading (see Appendix II, page 253).

4.5 Test series on electrical hazards in rescue operations

4.5.1 Electrical conductivity during extinguishing processes

4.5.1.1 General

Given past public discussions on the risks in firefighting at burning PV systems, this project has developed a series of tests for studying the hazardous situations in fighting fires at electrical systems with ordinary PV DC voltages.

Altogether three series of tests were performed:

1. Measurement of leakage currents at steel tubing in reference to guideline values of VDE 0132
2. Measurement of protective effectiveness of operational clothing (boots, gloves)
3. Determination of hazards from flooded spaces

The general danger in firefighting at electrical systems comes from the risk of flashovers from electrically conductive system parts or from the passage of the electrical current through water, and in particular from the quench water stream.

Guideline distances normatively apply to live electrical systems in reference both to proximities and to extinguishing measures for ruling out the danger of electric shock. By definition, PV systems belong to the low-voltage systems as per VDE 0132 (AC<1,000 V, DC<1,500 V).

Initial results from practical extinguishing spray tests in 2010 by PV consultant Dr. Bendel [42] yielded non-critical current levels primarily in the single-digit mA range. Other study results from conductivity measurements for practical verification of the normative distance recommendations for DC systems were not available to the Project Team at the time of testing, 2011. In the meantime, further series of tests have been conducted by the Oberhessische Versorgungsbetriebe AG (OVAG) in 2012 and as part of a cooperative project of the OVAG and by the Vereinigung zur Förderung des deutschen Brandschutzes e.V. (*vfdb*) in 2014, whose measurement results similarly yielded only very small values in part outside the measuring range of 0.1 mA. These measurements were considered in the assessment of the test results.

PV systems are currently designed for maximum system voltages of 1,000 V DC. Under discussion is an increase of the maximum to 1,500 V DC. The actual voltage value for a PV system depends on the string length and the performance data of the employed PV modules. In cases of small and medium-sized PV systems, as usually installed on buildings, system voltages significantly < 1,000 V are generally to be expected. For the purpose of obtaining generally valid results, 1,000 V was set as the currently maximum possible value for the performed tests.

The risk to people comes not directly from the voltage but from the electric current, however, which flows through the body because of the potential difference. This current can have physiological, physical and chemical effects, depending on the **current path through the body, the current intensity, the period of action and also the type of current**.

4.5.1.2 Normative background to assessing the current effects on humans

4.5.1.3 Current intensity and duration of action

A description of the effects and a determination of levels for the assessment of the hazards of electricity to the body as a function of current intensity and duration appears in DIN IEC/TS 60479-1 (VDE V 0140-479-1): 2007-5 – Effects of current on human beings and livestock. The limit curves given in Figure 4-2 for direct current and in Figure 4-3 for alternating current apply to the current path from the left hand to both feet for an assumed normal health condition of the person.

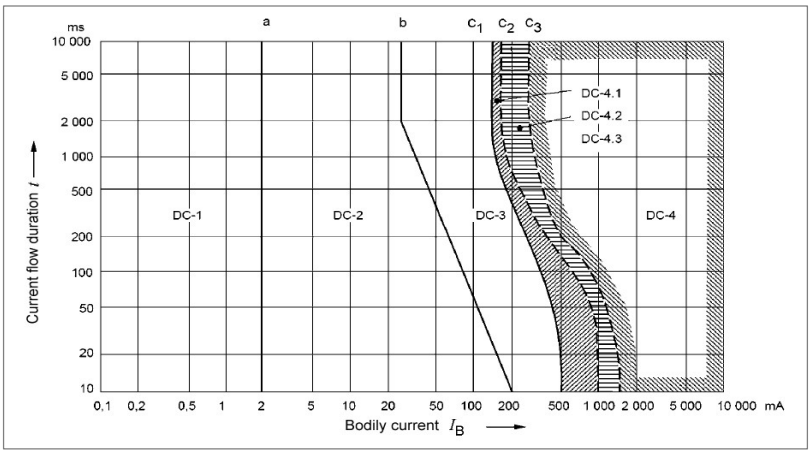


Figure 4-2: Time/current intensity sectors with effects of direct currents on humans with longitudinal current flow *(source: DIN IEC/TS 60479-1 (VDE V 0140-479-1): 2007-5)*

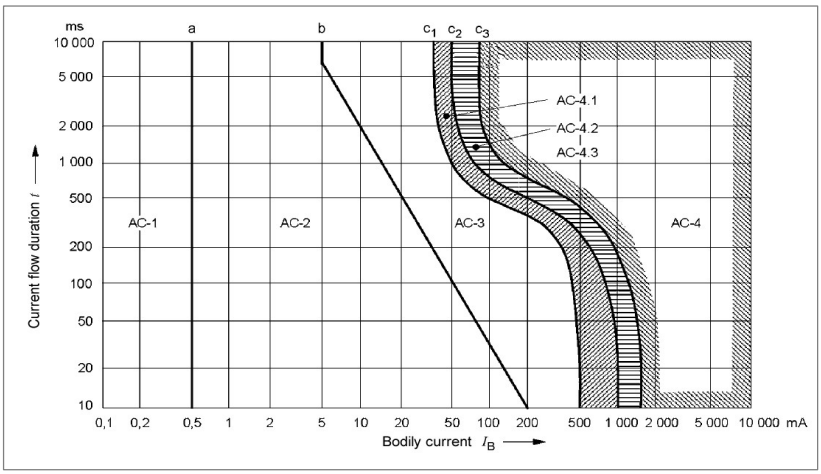


Figure 4-3: Time/current intensity sectors with effects of alternating currents (15 – 100 Hz) on humans with longitudinal current flow *(source: DIN IEC/TS 60479-1 (VDE V 0140-479-1): 2007-5)*

1. **Sector DC-1 / AC-1:** Perception is already possible, but no startle response is to be expected.
2. **Sector DC-2 / AC-2:** No damaging physiological effects are to be expected. Perception and involuntary muscular contractions are possible.
3. **Sector DC-3 / AC-3:** In this sector, severe involuntary muscular contractions are to be expected. In addition, breathing difficulties, reversible cardiac arrhythmia and muscular cramps may occur.
4. **Sector DC-41…4 / AC-4.1...4:** Pathophysiological effects like cardiac arrest, apnea and cell damage are to be expected. The probability of ventricular fibrillation increases with the current intensity and duration.

A comparison of these two graphs shows that alternating current leads at significantly lower values to more critical effects compared with direct current. The reason for this difference is that in the case of alternating current, each change in polarity will stimulate the neural and muscular structures, including the heart. The greatest hazard lies in the frequency range of 50 Hz to 60 Hz. With direct current, about four to five times the given alternating current limit value may be assumed, as Table 4-4 shows.

Table 4-4: Limit values for longer current load

Limit values for continuous electrical currents		IEC 60479-1		UL
		AC	DC	DC
Sector 1	Safe	< 0,5 mA	< 2 mA	0 - 2 mA
Sector 2	Perception	0,5 - 5 mA	2 - 25 mA	2,1 - 40 mA
Sector 3	Lock On	5 - 35 mA	25 - 150 mA	40,1 - 240 mA
Sector 4	Electrocution	> 35 mA	> 150 mA	> 240 mA

Sector 1: Possibly noticeable, no bodily reaction
Sector 2: Muscle contractions possible
Sector 3: Severe involuntary muscular reactions possible
Sector 4: Ventricular fibrillation possible

The threshold of perception for direct current lies at 2 mA. In contrast to alternating current, only the start and interruption of the current are perceptible; heat development is noticeable only with currents above 100 mA. A release threshold is not defined for direct current. The life-threatening range with direct current begins from a current of 150 mA and current flow duration of about 1 second. At such high levels even direct current poses the risk of ventricular fibrillation.

For assessing the hazard, the measurements performed considered a maximum current strength of 25 mA (DC) as the limit (sector 2).

4.5.1.4 Bodily resistance

The body impedance depends on numerous factors, in particular the current path, the contact voltage, the current flow duration, the frequency, the dampness of the skin, the size of the contact area, the applied pressure and the temperature.

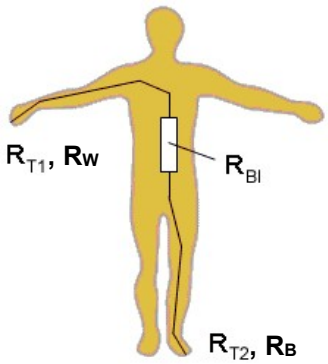
As the voltage increases, the body impedance decreases asymptotically; the skin resistance can already be penetrated at voltages > 200 V. Table 4-5 shows some statistically determined impedance values for the hand-to-hand current path.

Table 4-5: Selected values of the body impedance for current flow from hand to hand as a function of the contact voltage (*DIN IEC/TS 60479-1 (VDE V 0140-479-1):2007*-05)

Contact voltage	**Values of the total bodily resistance RT (Ω) that is not exceeded by**		
(V)	**5% of the population**	**50% of the population**	**95% of the population**
100	990	1,725	3,125
200	800	1,275	2,050
400	700	950	1,275
700	575	775	1,050
1,000	575	775	1,050

The measurements found the total impedance for the current path from a hand to a foot to lie somewhat lower (10 – 30%).

In addition to the bodily internal resistance, transitional resistance arises from clothing and the resistance of any tools present:



Total bodily resistance:

$$R_B = R_{T1} + R_{BI} + R_{T2} + R_B + R_W$$

R_B Total bodily resistance

R_{BI} Bodily internal resistance

R_{T1}, R_{T2} Transition resistance (skin)

R_B Clothing resistance

R_W Tool resistance

Figure 4-4: Total bodily resistance *(source: Brieselang.NET photo)*

For making a general statement about the hazardous situation, the experiments underlying this work assumed a very low total bodily resistance of 550 Ω.

4.5.1.5 Firefighting in the vicinity of electrical systems

To prevent hazardous currents flowing through the water stream and into rescue workers' bodies while they are extinguishing live system parts, DIN VDE 0132 – Firefighting and technical assistance in or near electrical installations – defines the recommended distances between the extinguishing agent outlet and the live system parts.

Table 4-6 shows the minimum distances during firefighting operations at electrical installations in the low-voltage range, i.e. up to 1,000 V with alternating current (AC) or up to 1,500 V with direct current (DC). [DIN VDE 0132 (VDE 0132):2008-08]

Table 4-6: Guideline values for minimum distances in the low-voltage range

Nozzle DIN 14365-CM	Low voltage (L) ≤ AC 1 kV oder ≤ DC 1,5 kV	High voltage (H) > AC 1 kV oder > DC 1,5 KV
Spray jet	1 m	5 m
Full jet	5 m	10 m
Code	N-1-5	H-5-10

These distances basically refer to standardized C-multipurpose nozzles as per DIN 14365-CM with a nosepiece diameter of 9 mm and 5 bar flow pressure. The guideline values also apply to larger water extinguishing devices, however, if their nozzles comply with DIN 14365-2 as to electrical safety. The instructions on use and warnings on the extinguishing equipment must be complied with. If CM nozzles without nosepieces or other multipurpose nozzles are used, the distances must be enlarged as per VDE 0132, e.g. in the case of BM multipurpose nozzles to the minimum distance of 5 m.

To understand these normative restrictions, we consider the structure of the full jet. A full jet contains three zones (Figure 4-5). The zone of the compact water stream directly after exit of the extinguishing agent is known as the rod zone. In the following, development, zone the stream breaks up into tiny droplets. When the stream attains the quality of electrically separated, individual droplets, we speak of the spray zone (which still appears compact to the human eye)).

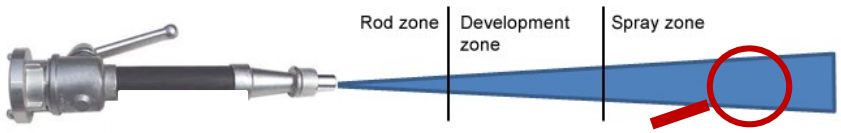


Figure 4-5: Schematic spray jet structure of a multipurpose nozzle

The guideline values for the stream pipe distances were selected so that during extinguishing operations the live electrical system parts would be struck only by the spray zone and therefore the droplet formation

would prevent any continuous track. Rescue workers are therefore not exposed to any risk from hazardous leakage currents.

The length of the described development zone and the extinguishing distances to be maintained vary depending on the technical design of the nozzle.

The test procedure of standard DIN 14365 describes the test setup for measuring the voltage drops of various resistance levels in the leakage current of a nozzle with the application of an extinguishing agent to a live steel grid. Since no critical limit values are listed here, the values from Table 4-4 were used as the basis for the tests from the AP5.3.

Besides DIN 14365, EN 15182 describes a product standard that unfortunately does not address the determination of leakage currents. Merely a recommendation is made to the effect that up to 1,000 V a distance of at least 1 m be maintained at a spray jet angle of at least 30°. The new standard requires manufacturers of new types of nozzles that were not tested as to electrical safety as per the old DIN 14365, part 2, to present proof of suitability for firefighting at electrical installations. Should the manufacturer not be in a position to provide information about electrical safety, these nozzles may be used only in voltage-free electrical systems.

4.5.1.6 Test 1: Measurement of leakage currents via the quench water stream

This test includes measurement of the leakage currents of a fire department spray jet in simulated operation at a live electrical installation. Measurements with DC voltages of 1,000 V and extinguishing distances of 1 m and 5 m were performed as per standard VDE 0132 *"Firefighting and technical assistance in or near electrical installations"*. As described, the currents measured in the test are assessed as to a possible hazard to rescue workers in extinguishing operations at photovoltaic systems.

Extinguishing equipment and extinguishing agents

Water with an electrical conductivity of 630 µS/cm (20°C) was used as an extinguishing agent.

As is well known, extinguishing foam increases the electrical conductivity of water and may not be used for fires in live institutions. To demonstrate the practical effects, measurements with use of a foam extinguishing agent (*class A foam)* were also performed.

Nozzle types generally common in Germany, namely a C multipurpose nozzle (CM; Figure 4-6) and a C hollow jet nozzle (Figure 4-7) were used in the tests. The CM nozzle is standardized as per DIN EN 15182-3 (replaces the old DIN 14365). At 5 bar flow pressure with an attached nosepiece 9 mm in diameter, a water flow rate of approximately 120 l/min is attained. The nozzle has one setting for *full jet* (F) and one for *spray jet* (S) at 15° spray angle. The flow rate does not change. The trajectory range at full jet is approximately 15 m (figure 6).

The C hollow jet nozzle complies with nozzle standard DIN EN 15182-2. At 5 bar flow pressure the flow rate can be adjusted to 55, 120 and 215 l/min by a rotating swivel. By turning the nozzle head, *full jet* (0°) *spray jet (60°)* or *flash-over position (120°)* can be selected for the stream shape. Hollow jet nozzles differ in technical version and shape according to type and manufacturer, with the spray patterns possibly varying as well.

Figure 4-6: CM multipurpose nozzle

Figure 4-7: C hollow jet nozzle (source: Munich Volunteer Fire Department)

Performance of test

This test series (test setup as per Figure 4-8 and Figure 4-9) measured the leakage currents via the water stream when spraying live metallic electrodes (perforated plate). A current resistance of 555 Ω simulated the (smallest) bodily resistance in the worst assumable case with an adult person (rescue worker with soaked protective clothing).

Figure 4-8: Test setup with simulated PV module (perforated plate electrode) and hollow jet nozzle at a distance of 1 meter

Figure 4-9: Test setup with simulated bodily resistance for measuring the leakage currents via the extinguishing stream

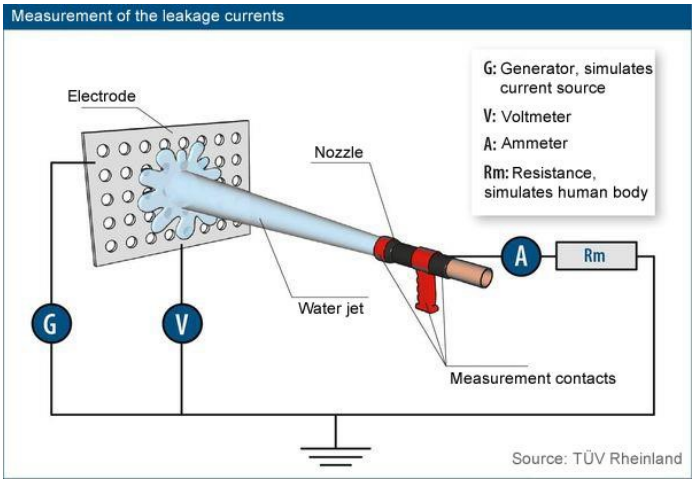


Figure 4-10: Measurement of leakage currents via the water stream: Schematic diagram (graphics: Solarpraxis AG (Harald Schütt))

The given electrical resistance in the circuit is compounded from the resistance of the extinguishing agent, the bodily resistance, the total transition resistance and any (high impedance) resistance in fault circuits and thus determines the level of a possible leakage current running through the human body.

The resistance of the extinguishing agent stream depends on the distance to the live electrode, the conductivity of the extinguishing agent and the properties of the extinguishing stream (Figure 4-10).

Measurement series with a commonly used CM multipurpose nozzle and a C hollow jet nozzle were performed. The tests were performed with different jet settings, in each case with water. For the purpose of comparison, a further series was performed with foam.

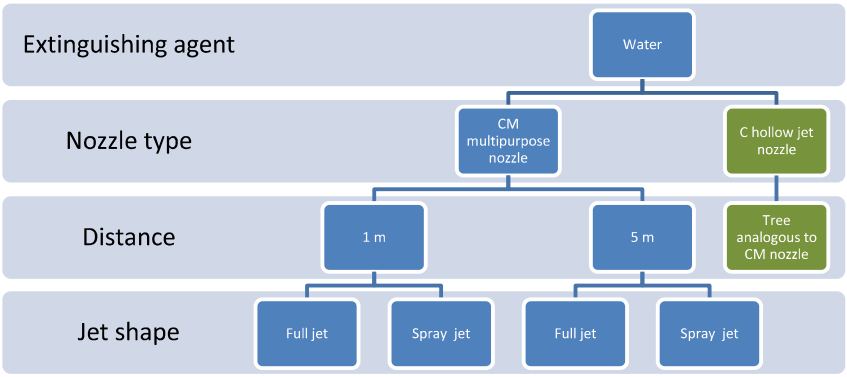


Figure 4-11: Test path for conductivity measurement with water as extinguishing agent

The level of the leakage current via the water jet depends on the voltage of the sprayed installation parts, the human bodily resistance (including transition resistance) and other types of resistance in the circuit, the conductivity of the extinguishing agent and the properties of the spray jet (Figure 4-5). The greater the distance of the electrode, the greater is the fanning of the extinguishing agent jet and the lower its electrical conductivity. The distances as per DIN VDE 0132 are such that no hazardous currents can be transmitted via the extinguishing agent jet.

Expected results

For all measurement values of the leakage current, non-critical values were expected from general experience with electrical installations.

The expectation value for full jet and 1 m distance was comparatively the highest. With increasing distance (5 m) and/or fanning (spray jet position), the leakage currents should be lower, if measurable in the first place.

Multipurpose nozzle

Figure 4-12 shows the measured leakage currents when the CM multipurpose nozzle is used with a nosepiece. The most important result of the measurements: all measured leakage currents that could flow hand-to-foot through the C body of the firefighter in the worst case lie in the non-critical range < 25 mA (Table 4-5).

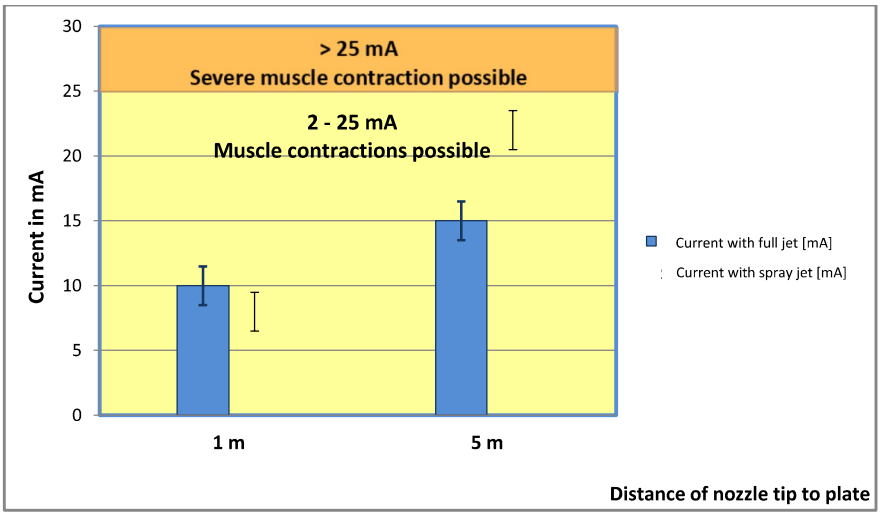


Figure 4-12: Leakage currents with C hollow jet nozzle (water)

As expected, at 1 m distance the currents at the spray jet setting (15° spray angle, striped bar) were somewhat lower than at the full jet setting (solid bar). Unexpected, on the other hand, were the larger currents measured for both stream types at a distance of 5 m compared with 1 m. At 5 m distance, the measurement values for the spray jet setting exceed the values of the full jet setting. Even given the fluctuation in measured values during the tests in the ± 2 mA range (the water stream is not a constant electrical conductor), the measured differences are significant (see discussion of the results).

Hollow jet nozzle

Figure 4-13 shows the measured leakage currents when the C hollow jet nozzle is used with a nosepiece. Here again are the most important results of the measurements: all measured leakage currents that could flow hand-to-foot through the body of the firefighter in the worst case lie in the non-critical range < 25 mA (see Table 4-5).

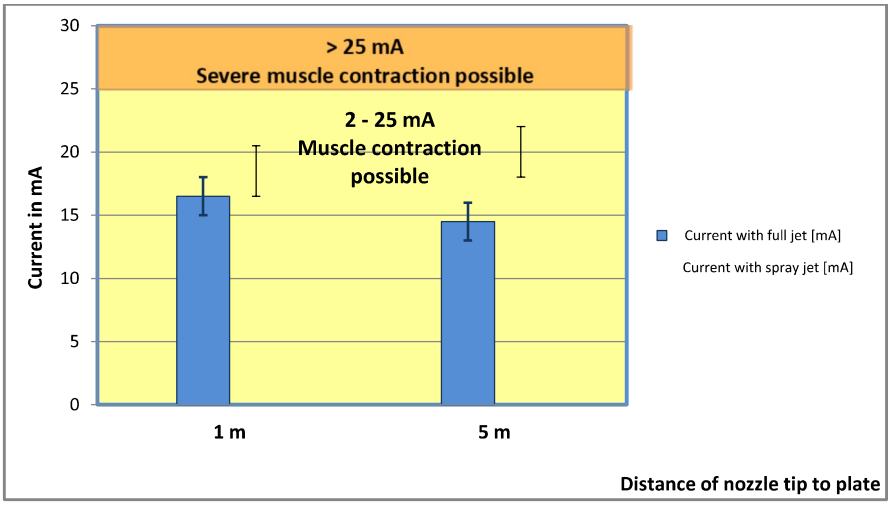


Figure 4-13: Leakage currents with C hollow jet nozzle (water)

At the full jet setting, the measured values here at a 5 m distance were, as expected, lower than at a distance of 1 m, even if quantitatively low. Surprisingly, the measurements at spray jet setting (60° spray angle, striped bar) at both distances showed in each case higher leakage currents than at the full jet setting. At a distance of 5 m the measured value for the spray jet is greater than at 1 m distance.

As expected, the comparative measurements with the use of a foaming agent showed somewhat higher currents than with water.

Discussion of the results

At the greater distance of 5 m to the live electrode, both nozzles yielded in part significantly greater measured values for the leakage currents than expected. Most likely, fault currents related to the practical test setup occurred and were also measured. Possible sources of faults (bypass function) therefore received particular attention:

1. As the test period progressed, a continuous sheet of water from the quench water run-off formed on the ground (asphalt).
2. Increasingly severe rainfall during the measurements also soaked the entire test setup, so that the desired insulated installation of the electrode and nozzle could no longer be ensured.
3. Spraying the electrode (perforated plate) caused partial run-off of the quench water at the plate along the ground, so that a low-impedance connection could be formed here under certain circumstances.
4. The greater the spray angle, i.e. the more widely the water stream fanned over the perforated plate electrode, the more conductive water tracks formed.

Figure 4-14: Run-off water forming conductive tracks to the wet ground – here full jet

Figure 4-15: Run-off water forming conductive tracks to the wet ground **–** here spray jet

We must therefore assume that fault circuits existed between the electrode and nozzle that decreased in impedance independently of the specific spray shape as the duration of the test progressed.

We further assume that these fault currents add to the actually occurring leakage currents and are measured along with them. Figure 4-16 shows this schematically.

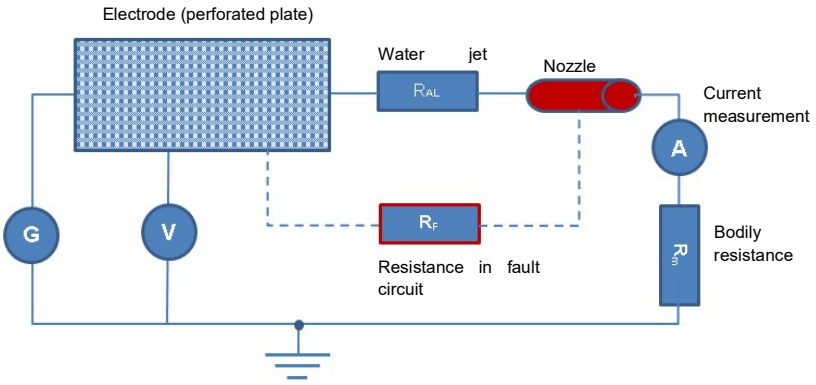


Figure 4-16: Circuit and fault circuit

Since the total resistance with a parallel connection of resistors is less than both individual resistors, the resistance R_F in the fault circuit will act more on the measured total current the lower its impedance. The effective parallel resistance between electrode and nozzle decreases and the current flow therefore becomes greater. The greater currents measured during the course of the test can thus be explained by comparison with the expected values.

Additional contributing factors are also effective, such as actually significantly greater bodily resistance and additional transition resistance from protective clothing like gloves and boots. The actual leakage currents that could flow through a firefighter must therefore be assumed to be less than the measured values generated in the present test setup, which represent a worst case scenario. In actual operations a conductive floor covering can also form with a “bypass potential,” a case (involuntarily) covered by the performed tests. The results consequently lie on the safe side.

Series of tests conducted at later times (2012, 2014) by other institutions yielded significantly smaller leakage currents in the range of approximately 1 mA or less (cooperative project by OVAG and vfdb).

Another electrode type – metallic grid – and greater distance of the electrode from the ground allowed significantly less quench water to run directly onto the ground (in this case, a lawn). This test arrangement evidently allowed significantly lower fault currents to develop. Before and after each test, these currents were measured separately, which however predominantly fell below the measurement value threshold in the µA range. As a qualification, it must be noted that the possibly conductive water streaks form only directly during the test itself. In the left photo the measurement is performed with water at a spray setting of 45° – no water streaks form. The situation is different with the use of foam, for example with a spray setting of 120°, as shown in the photo on the right. Here a conductive covering forms on the ground. Foam sprayed past the electrode and also running off onto the electrode forms possible bypass connections to the spray jet.

Figure 4-17: Measurement leakage currents when extinguishing live electrical installations. Tests conducted on the premises of OVAG in 2014, cooperative project of OVAG and ***vfdb***

Figure 4-18: Measurement of leakage currents, extinguishing with foam under spray setting. Tests conducted on the premises of OVAG in 2014

Conclusion

All currently known measurement series pertaining to this subject yielded very low to non-critical leakage currents via the extinguishing jet in the range below 25 mA.

Given compliance with the recommended extinguishing distances of 5 m at full jet and 1 m with spray jet as per DIN VDE 0132, no leakage currents hazardous to rescue workers occurred when the water was used as the extinguishing agent.

4.5.1.7 Electrical properties of the turn-out gear

This test series investigated the additive protective effect of the turn-out gear against electric shock. Direct contact with a live DC cable was simulated. The employed turn-out gear was tested both dry and wet.

Test setup

A life-sized dummy (75 kg) simulated the human body. The dummy was covered by an electrically conductive aluminum layer and fitted with measuring contacts. The bodily resistance for the different current paths was adjusted with a resistor plate and the dummy then dressed with a complete set of firefighting protective clothing. The dummy stood on a grounded steel plate. Voltage was applied to the surface of the protective clothing by means of metal contacts (**Figure 4-19**).

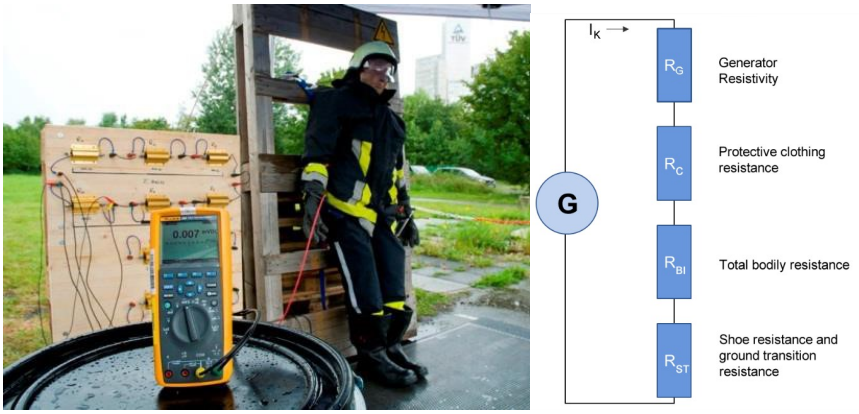


Figure 4-19: Test arrangement with dummy and schematic circuit diagram

The tests measured the currents for three different current paths. The current along the hand-to-hand and hand-to-one-foot current paths was measured at a bodily resistance of 555 Ω. The current for the hand-to-both-feet current path was measured at a bodily resistance of 430 Ω. Two contact points have been specified. The first contact point was located directly at the glove and the second at the sleeve of the protective jacket. To check the protective effect, the gloves and boots were in part left out. A DC voltage of 1,000 V was applied at the contact points.

As the substitute circuit diagram shows, resistances are serially connected here. The individual resistance values sum to a total resistance and limit the current.

In the dry state, very high resistance values are expected, whereas in the wet condition the resistances drastically decrease and the current should therefore increase. The protective boots should yield the highest value among the resistance series, so that omission of the boots would lead to a very sharp increase in the current.

In the dry state of the turn-out gear, all measured values lay in the range of measurement uncertainty. Merely very low currents under 1 µA were measured without protective boots according to the following Table 4-7 and Table 4-8:

Table 4-7: Dry clothing, hand to feet

Parameters	
Protective clothing	Dry
Gloves	On
Boots	Off
Contact point Electrode	Sleeves
Current path	Hand-feet
Bodily resistance	430 Ω
Generator voltage [V]	**Bodily current [µA]**
1000	0,54

Table 4-8: Dry clothing, hand to hand

Parameters	
Protective clothing	Dry
Gloves	On
Boots	Off
Contact point Electrode	Sleeves
Current path	Hand-hand
Bodily resistance	555 Ω
Generator voltage [V]	**Bodily current [µA]**
1000	0,45

When the turn-out gear was wet, considerable currents were measured in part depending on the current path and contact point. While the current from one hand to one foot lay in the noticeable but non-critical range, life-threatening high currents in the ampere range were measured in a hand-to-hand current path, as the following tables (Table 4-9, Table 4-10 and Table 4-11) show.

Table 4-9: Wet clothing, hand to foot

Parameters	
Protective clothing	Wet
Gloves	On
Boots	On
Contact point Electrode	Gloves
Current path	Hand-foot
Bodily resistance	555 Ω
Generator voltage [V]	**Bodily current [µA]**
1000	3,66

Table 4-10: Wet clothing, hand to hand

Parameters	
Protective clothing	Wet
Gloves	On
Boots	On
Contact point Electrode	Gloves
Current path	Hand-hand
Bodily resistance	555 Ω
Generator voltage [V]	**Bodily current [µA]**
1000	1,50

The drastic difference in resistance values were conjectured to lie in the protective boots. They were therefore removed for a further hand-to-foot measurement. The currents now measured also lay in the life-threatening range:

Table 4-11: Wet clothing without boots

Parameters	
Protective clothing	Wet
Gloves	On
Boots	Off
Contact point Electrode	Gloves
Current path	Hand-foot
Bodily resistence	555 Ω
Generator voltage [V]	Bodily current [A]
500	0,85
700	1,21
800	1,40
900	1,57

The following two photos (see Figure 4-20) show the effects of the currents on the contact surfaces. In a human body current marks would occur at these points due to the high heat build-up at the current entry and exit points. Burn holes from the heat appeared on the gloves.

Figure 4-20: Effects of the current on the contact surfaces, burn hole from action of current

The test results agree with the theoretical expectations. Dry turn-out gear has a very high resistance, whereas soaked clothing affords no protection against electric shock. In a current path running from one

hand to the other hand and given a bodily resistance of 555 Ω, a very low resistance of about 50 Ω exists at the wet glove, where contact with a 1,000 V DC cable can cause a life-threatening current of 1.5 A to run through the human body (see Table 4-10)

The high resistance at the boots and the related protection against electric shock became evident from the tests. Despite wet clothing, hardly noticeable currents were measured with the protective boots on. Without boots, the bodily current drastically increased and at 1,000 V exceeded the hazardous limit.

A linear relationship between current and voltage can be observed. With wet clothing and an assumed bodily resistance of 555 Ω, life-threatening currents over 150 mA can already flow through the human body along a current path from hand to hand or from hand to the feet without boots at 100 V DC (see Table 4-11).

Conclusion

The measurements show that contact with a live DC cable of a photovoltaic system with complete and dry turn-out gear being worn poses no risk of electric shock.

On the other hand, soaked turn-out gear affords practically no protection against hazardous bodily currents if the current path runs from one hand to the other hand.

If the current path runs from both hands to the feet, as typically occurs at the nozzle during extinguishing operations, the high resistance at the protective boots will allow non-critical currents to flow through the human body at a level that is just noticeable.

4.5.1.8 Live cable in water

The test (see Figure 4-21) served the determination of the intensity of possible currents flowing through a human body in the case of a flooded space, given the person's contact with a live cable and simultaneous contact with a grounded part of a building.

The measurements were performed with the aid of a 3 x 2 m water-filled pool and 160 cm tall wooden dummy. Metal plates were attached to the feet and lines routed with copper wires. In the water lay a live cable, with the dummy's shoulder connected to the ground potential.

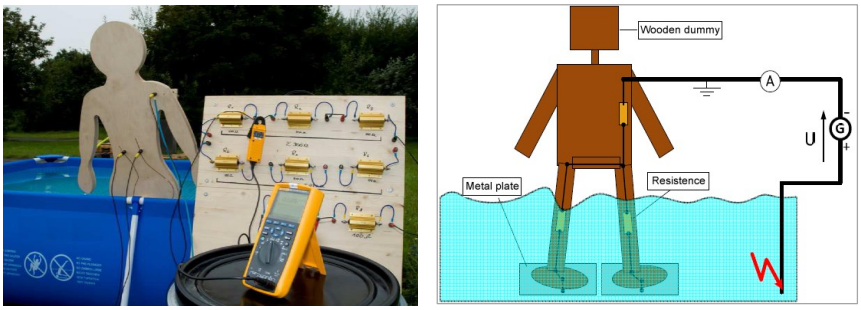


Figure 4-21: Wooden dummy in test pool and schematic test setup

Performance of test

A live cable was immersed in the pool with a water level of 60 cm and a conductivity of 630 Ω *S* / *cm* (at 20 °C). The voltage was adjusted to between 500 V and 900 V (DC). The wooden dummy was placed in the pool and the bodily current measured at three different distances of 0.5 m, 1 m and 2 m from the live cable. Owing to the high conductivity of the water, we expected a relatively high current flow in this experiment. Increasing the distance from the live cable should have reduced the current.

Table 4-12: Results of test 3

Water properties	
Counductivity	630 µS/cm
Temperature	20 °C
Water level	60 cm

Distance to electrode	0,5 m

$U_{Gen,\,nominal}$ [V]	$U_{Gen,\,actual}$ [V]	Bodily current [A]
500	500	1,02
800	800,87	1,64
850	851,87	1,74

Distance to electrode	1 m

500	500,33	1,02
800	801,04	1,62
850	851,54	1,72

Distance to electrode	2 m

500	499,98	0,99
800	801,12	1,57
850	851,54	1,67
900	901,67	1,77

The test results show that all measured bodily currents lie in the ampere range and therefore in the life-threatening range. As expected, the dummy experiment showed a linear relationship between current

and voltage, which only roughly reflects reality, given the voltage-dependence of human bodily resistance (Table 4-5). The given experimental arrangement with the given resistance values already attained the hazardous range as of a voltage of 75 V.

Increasing the distance from the live cable led only to a slight drop in current. At 800 V, the difference in current between the values at a distance of 0.5 m and at a distance of 2 m was merely 70 mA, or about 3%.

Important for the assessment is that this test considered the worst case. The ground conductor lies outside the water, so that here the entire current flows to the ground through the wooden dummy. Otherwise, only partial amounts would still flow through the human body. Given the level of the measured values even at distances of several meters, an all-clear is not possible.

Conclusion

For rescue workers in flooded basements there is a serious risk of electric shock from damaged DC cables hanging down!

Hazardous currents may flow through the body even at low voltages of around 100 V.

4.5.1.9 Concluding discussion

The studies on conductivity and possible leakage currents through nozzles have shown that when extinguishing fires near photovoltaic systems rescue workers are exposed to no serious danger from the leakage currents via the quench water exist at 1,000 V DC, if the safety distances as per *DIN VDE 0132* are maintained.

The employed nozzles had different spray patterns and accordingly different electrical properties as well. Especially different technical versions and designs of high-jet nozzles can produce significant differences in the formation of the water stream. The new standard, *DIN EN 15182*, no longer provides for electrical testing of the nozzles. For characterizing the hollow jet nozzles in terms of their electrical properties individual verifications are necessary.

The employed turn-out gear is a good insulator when dry and protects rescue workers against dangerous electric shocks. Soaked clothing no longer provides protection, so that at high voltages and a hand-to-hand current path life-threatening currents can flow through the human body. This would be the case if both terminals of the DC lines were touched at the same time. Since fire departments are required to always maintain a safety distance of at least one meter from live installation parts, this scenario is improbable, but nevertheless quite possible in practice under conditions of poor visibility and smoke.

Flooded basements pose a potentially considerable danger for rescue workers. Sagging and damaged cables from a PV system, or any other electrical home installation, can cause current to flow through

the water if grounded systems are touched simultaneously. Given the high conductivity of the water, life-threatening currents in the ampere range can thus occur even at distances of several meters.

The described series of tests always considered the worst case. In real-life cases, the resistance values of the people will be significantly higher, especially given clothing or protective clothing and shoes, reducing the risk of dangerous electric shock.

4.5.1.10 Relevance for standardization

- The test series findings regarding safety and nozzle distances confirm the specifications of VDE 132. A brief summary of the test series has been forwarded to the working group of the DKE K 213 on “Firefighting at electrical installations.” In the future, other practical tests are to be extended to a voltage range of up to 1500 V DC, since this voltage limit in the module and PV system sector could be of greater interest.
- Within *DIN EN 15182*, electrical testing of the nozzles is no longer provided. The characterization of the hollow jet nozzles requires separate verifications of their electrical properties, however, as the aforementioned series of tests show. The water trajectory properties and therefore the conductivities of an extinguishing stream differ among the tested nozzles (CM multipurpose and C hollow jet).

  High-speed cameras enabled observation of the disintegration properties of the droplets on exiting the different types of nozzles. From this information we may conclude that the conductivity properties and measurements do not hold across the board for all nozzles. **Supplementation of the new standard by suitable electrical testing of the nozzles** would be appropriate and should be discussed by the corresponding standardization committee.

Recommendation for standardization:

DIN EN 15182 no longer provides for electrical testing of the nozzles. The characterization of the hollow jet nozzles requires separate verifications of their electrical properties, however, as the aforementioned series of tests show. Supplementation of the new standard by suitable electrical testing of the nozzles would be appropriate and should be discussed by the corresponding standardization committee.

4.5.2 Electrical safety situation with effects of artificial lighting

Series of tests at the Photovoltaic Institute of the Bern University of Applied Sciences, with support from the fire department, have shown that spotlights, such as those used by the fire department or the Federal Agency for Technical Relief during nighttime operations, can generally produce DC currents of significant levels in PV modules [43]. Minimum distances are therefore recommended for the spotlights to be erected. The measurements were conducted with halogen spotlights at an installed pilot plant with longitudinally oriented strings of crystalline PV modules, based on the usual PV system sizes and interconnections of roof-mounted systems on single-family houses.

A larger PV system will not lead to higher currents given the equally greater inhomogeneity of the irradiation. A more compact design (interconnection), on the other hand, can theoretically generate higher currents. Other practical studies, such as those by Underwriters Laboratories [44], led to the result of a theoretically possible electrical hazard for rescue workers from artificial lighting.

To obtain generally applicable information on a minimum safety distance, the project carried out additional series of tests covering

(1) the spotlight types commonly used by rescue workers
(2) the different types of modules mounted on German roofs
(3) the most critical case of compact design (string)
(4) the most critical case at largely normal incidence

Consideration of the worst-case combination to be defined here should yield a generally applicable recommendation including a safety supplement.

The spotlight selection considered only technologies applied in the German hazard prevention sector. The Cologne Professional Fire Department, the Cologne Volunteer Fire Department, the Porz-Langel Fire Brigade and the Siegburg section of the Federal Agency for Technical Relief supported the studies with loans of spotlights and construction of the desired combinations.

A survey of professional fire departments in Germany as well as various hazard prevention organizations found that primarily spotlights with halogen bulbs with an output of 1,000 or 1,500 W are used. These spotlights are generally mounted on extendable tripods and on light trusses on lamp poles, turntable ladders and work cranes. Depending on the version, however, use as ground spotlights is also conceivable. Halogen spotlights with an output above 1,500 W are rarely encountered. Generally several spotlights mounted on light trusses are used, typically up to 8 or 10 units per structure. Besides halogen emitters, in individual cases spotlights with halogen-metal vapor lamps (HM), high-pressure sodium lamps (HS) and high-pressure mercury lamps (HM) are used on tripods and light trusses. Here the power input generally lies at 1,000 W per lamp, and seldom higher.

The aforementioned lamp types are those most often used at the scene of a fire and designed for use under difficult conditions, although they require a very high power infeed. For this reason, spotlights with LED and xenon technologies are also being increasingly used. At present, LED spotlights with a power input of up to 150 W are in use. Xenon spotlights, on the other hand, are mostly used for 360° lighting on emergency vehicles and are rather untypical for the study.

A multi-staged study was conducted:

1. Determination of the most critical spotlight technology – module technology pairing according to the light spectra relevant in each case (worst-case pairing)
2. Studies on the homogeneity of the light cones of the spotlights
3. Measurements on compact module arrangements (approximately square form, with comparatively highest attainable homogeneity in spotlight emittance – worst-case arrangement)
4. Determination of the dependence of the generated electrical currents and voltages on the distance of the light source to the module field and on the power level of employed spotlight or spotlight combination (here with worst-case technology pairing)

4.5.2.1 Worst-case pair

All spotlights were spectrally measured, whereby it was found that the spectral composition of the light did not depend on the power category and was largely independent of the particular manufacturer; see also Figure 4-22 in the case of 5 different halogen spotlights.

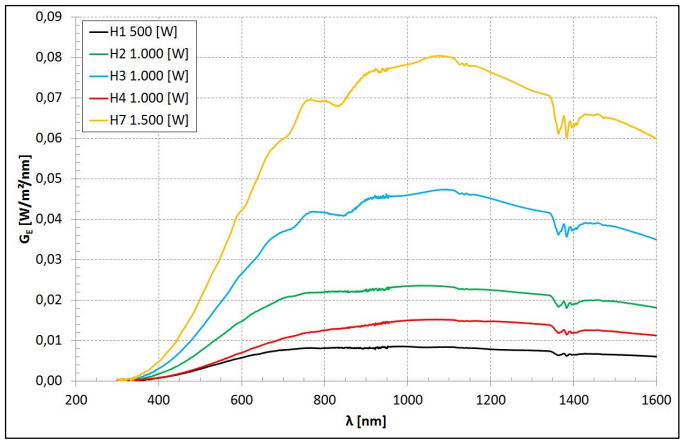


Figure 4-22: Light spectra from halogen emitters from different manufacturers and of different power categories.

By comparison, the spectral sensitivities of the different commercially available module technologies should be considered (Figure 4-23) and superimposed with the determined light spectra of the spotlight technologies. Figure 4-24 shows the results of all combinations of spotlight types and module types.

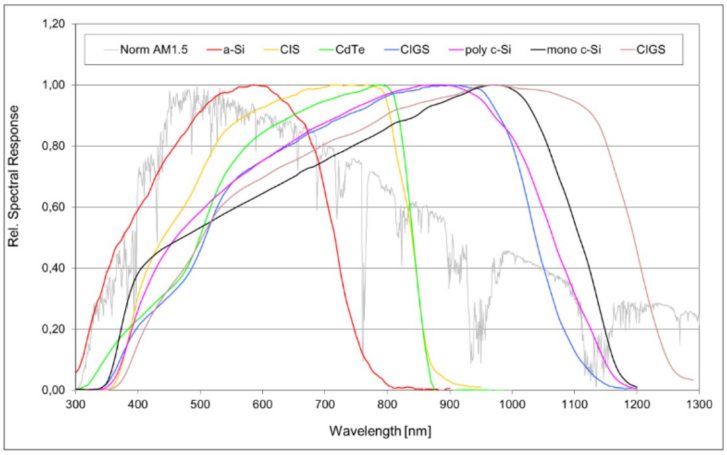


Figure 4-23: Spectral sensitivities of different module technologies

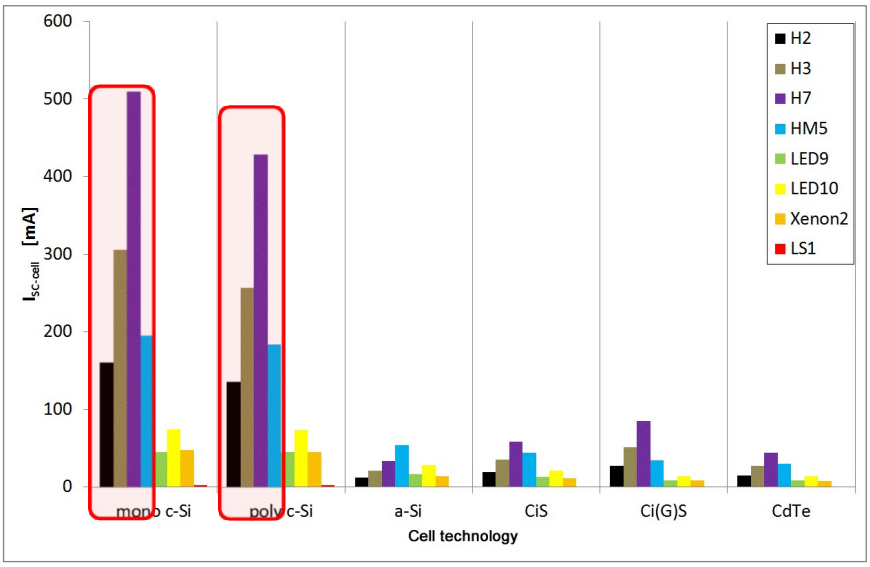


Figure 4-24: Generated short-circuit currents in different spotlight type – module type combinations

The result determined was worst-case pairing of halogen emitter and crystalline module as per the above composition – that is, precisely the pair that is most commonly encountered in practice at present. The results also indicate that the increased use of LED spotlights to be expected in the future will significantly reduce the danger potential.

Although the CIGS technology can accommodate an equally large spectral width, the measured currents are significantly lower than those in crystalline modules because of the considerably lower rated output of a thin-film module.

4.5.2.2 Homogeneity studies

The studies showed that the homogeneity of the produced light increases with the distance. On the other hand, the illumination intensity on the module sharply decreases as the distance increases (theoretically under idealized conditions in proportion to the square of the distance). The most critical case given the attainable current intensity is thus the combination of an emitter with a module, which while not practically relevant can be used to validate the worst-case scenario.

The practical testing comprised 2 series of tests:

In a first step, the generated currents and voltages were measured in a single module, in a second step in a string of 6 serially connected modules in a maximally compact design (2 x 3 modules stacked atop one another). The construction was specially manufactured by Energiebau Solarstromsysteme (Cologne) for this purpose; see Figure 4-25 and Figure 4-26.

Figure 4-25: Halogen operational emitters of THW Siegburg illuminate a compact construction of six modules

Figure 4-26: Measurement of the irradiance on the module plane produced by the emitters (above, below, on side and centered)

Tests were conducted with distances of 5 to 20 m with different lamp technologies (also combined, e.g. halogen, metal vapor). For the sake of simplicity, the short-circuit current was used for assessing the danger potential. Owing to the flat I-U characteristic of the PV module, this current is slightly higher than an assumed current flowing through the human body (with a minimum of 500 Ω) and thereby also increases the safety factor of the information.

Figure 4-27 shows the measured values of the test series with a compact string of 6 modules. The intersections with the limits laid down by IEC 60479-1 regarding effects on the human body show us the minimum distances to be set.

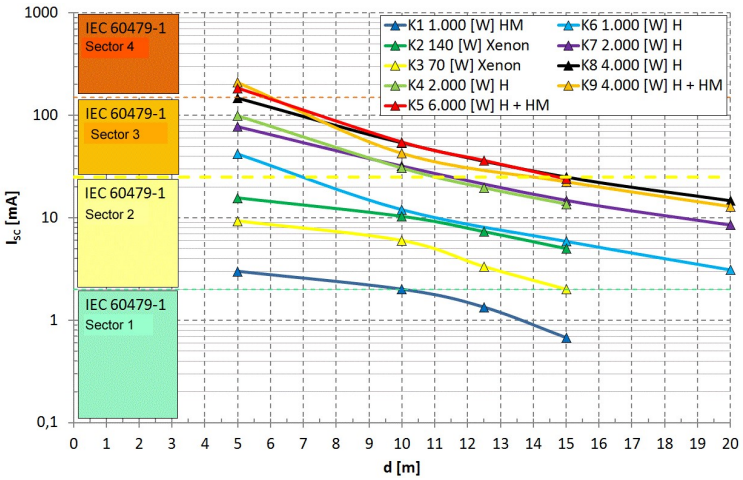


Figure 4-27: Short-circuit current measured and extrapolated with irradiation by halogen emitters of different outputs.

4.5.2.3 Recommendation for minimum distances

The analysis and extrapolation of the measured values yielded the following derived relationship between total output of the emitters and the distance to the module field with an assumed limit value of I_{sc} = 25 mA:

Basic distance with total power input of the emitters up to max. 1 kW:

$$d_{P_{inp=1kW}} = 10\ m \qquad [1]$$

Distance formula with emitter power input greater than 1 kW:

$$d\ P_{inp>1kW} = 10\ m + P_{inp\,[kW]} \times 1.5\ m/kW \qquad [2]$$

with

d = minimum distance between spotlight and module surface

P_{inp} = total emitter power input in kW

With an emitter power of 4 kW, a distance of 10 m + 4 kW x 1.5 m / kW = 16 m must therefore be maintained. The following table lists the minimum distances according to the above formula for some typically used operational emitter power levels.

Table 4-13: Examples of recommended minimum distances for commonly used emitter power levels.

Emitter power in kW (power input)	Recommended minimum distance in m
1	10
2	13
4	16
6	19
8	22

4.5.2.4 Assessment of admissibility or safety factors:

The calculation formula incorporated an additional safety factor, i.e. all actual measured values in fact lie below the distances computed with the formula. Additional safety factors were also used owing to deliberately chosen worst-case conditions; see Table 4-14:

Table 4-14: Safety factors for assessing test results

Boundary conditions in the test	Boundary conditions in operational use?
Combinations of the most critical spotlight technology used	Probably, since widespread at present. May be increasingly superseded by non-critical LED technology
Most critical module type used	Probable, since most widespread
Isc of the employed standard modules (4.7 A)	This will increase in line with the development of more powerful cells / modules
Normal incidence at module surface	Very improbable
Maximum light distribution homogeneity	Not possible
Bodily resistance R_B = 0 Ω	> 500 Ω
No shading of the modules	Partial shading from (e.g.) smoke possible

4.5.2.5 Conclusions

Summary

As in previous work, the results of the studies again show that artificial lighting is quite able to generate hazardous voltages and currents in a PV system and thus confirm the studies by BFH and UL.

Given compliance with the specified minimum distances of the illuminants and in particular the use of LED spotlights, we must assume a negligible hazard from illumination with artificial lighting, however.

In addition, the project conducted the studies with different spotlight technologies and different common power categories and with the usual distances and under defined worst-case conditions (technology, string geometry, normal incidence). In practice, these different worst-case conditions will not all obtain simultaneously; see Table 4-14.

In particular, the homogeneity of irradiation in the test arrangement at normal incidence will not be attained in practice, so that the above distance recommendation will generally include several safety factors (not further quantifiable).

The only boundary condition in the test series to be assessed as critical consists in the parameters of the employed, currently typical crystalline standard modules (2012). If modules in individual cases have considerably greater efficiency, higher currents than the values measured here and incorporated in the distance recommendation may also be generated.

This distance recommendation accordingly applies to the typical night-time (firefighting) operations at single- and multi-family houses with typical PV systems, but does not provide any guarantee for an altogether de-energized and voltage-free PV system, i.e. it provides no substitute for the necessary caution and maintaining of distance as with every electrical system.

4.6 Pollutant release in fire cases

4.6.1 Objective

A photovoltaic system operates with zero emissions independently of the employed module technology during its operating time, currently estimated to be 30 years, i.e. no toxic substances are released into the environment. Uncertainty still prevails today about the emission level of a PV system in case of fire with partial or even complete destruction of components. Different types of plastic and other combustible materials as well as, in small levels, toxic heavy metals form part of any PV system. A possible release of gaseous toxic substances under the effect of heat in a fire is therefore incontestable. The Environmental Committee in Brussels exempted all renewable energy technologies from the new regulation on the cadmium ban in the amended RoHS [45].

This section examines different issues related to fires involving PV systems. These issues comprise the possible additional hazard to firefighting personnel or other people in the vicinity of the fire source from toxic gas emissions, possible effects on the soil from massive amounts of quench water and also the possible spread of toxic gases or soot particles because of thermal and/or weather-related motions of the air beyond the immediate neighborhood.

We now examine modules and other components of a solar installation as to their typical components and therefore pollutants possibly released in case of a fire, their maximum concentrations (worst-case scenario) and their possible spread over the surroundings. We determine the risks of the employed materials for critical emissions and if necessary derive recommendations for material selections.

Figure 4-28 lists the sources of emissions to be considered in a PV system fire and their potential hazard for the different protective goals.

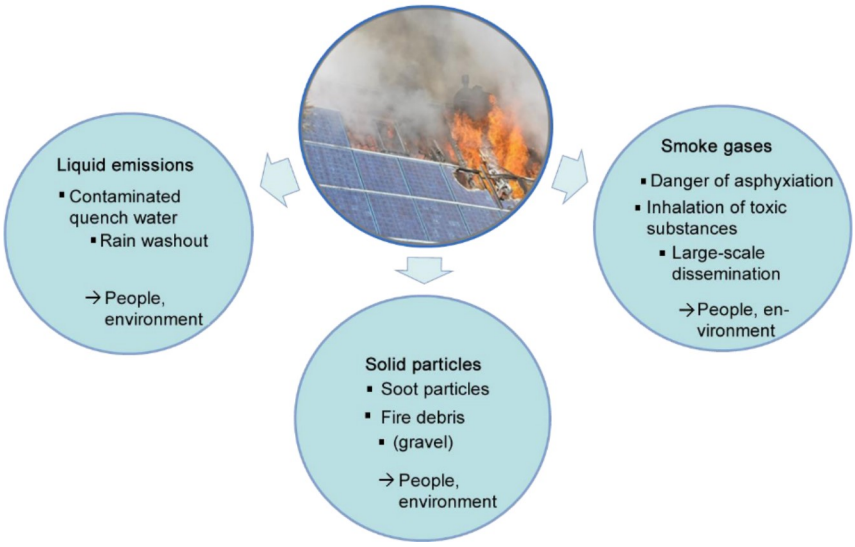


Figure 4-28: Emissions and hazards in case of fire

4.6.2 State of knowledge

According to the present state of knowledge about toxic emissions from photovoltaic systems, depending on the design, neither do intact modules produce critical gas emissions during their normal operating period nor is any release of pollutants into the soil to be expected. On the other hand, severe damage to the solar modules from hail, direct lightning strike or fire, for example, may lead to the release of pollutants in “small” amounts, e.g. [46] [47] [48].

The question whether these releases of pollutants in the event of an accident can reach levels critical for human beings and/or the environment has not been finally clarified to date. Previous studies primarily concerned thin-film modules on a cadmium telluride basis (CdTe), since metallic cadmium and cadmium compounds are classified as severely toxic in many respects: namely as carcinogenic, mutagenic and harmful to the fetus, and moreover have the dangerous property of accumulating in the body so that multiple exposure to very small doses can already cause serious health damage [49]. This must be considered when assessing the risk to firefighting personnel. The risk of absorption comes mainly from inhalation or swallowing. Cadmium is also severely hazardous to water. The possible entry into the soil through the quench water must therefore also be regarded as very critical.

The discussion about CdTe modules conducted mainly during the years 2010 – 2011 was pushed through (not wholly without self-interest) by representatives of the competing crystalline module technology, who demanded inclusion of photovoltaics in the scope of the RoHS, which would have directly pushed CdTe technology and therefore the greatest competitor out of the PV market. Several studies on cadmium telluride in PV modules were conducted, with the focus on modules manufactured by First Solar and Abound Solar.

In early 2012 the Fraunhofer Center for Silicon Photovoltaics (CSP) published a comprehensive review of completed work and its results through 2011 [50].

The conclusion drawn was that the emissions of cadmium and cadmium compounds verified in previous studies did not attain any critical concentration levels. The applicable AEGL-2 (Acute Exposure Guideline Levels values (accessible online at [51])) serve as comparable values, representing the threshold above which irreversible or long-term health damage can occur.

The practical significance of the information obtained from these studies for risk assessments in the event of actual PV system fires must be qualified, however, if we look at some of the experimental work and the conclusions drawn therefrom in detail.

For example, in 2005 a US study [47] investigated the behavior of CdTe module specimens under the effects of heat at different temperature levels from 760°C to 1,100°C. Gas emissions, mass lost, residue and Cd distribution in the fused glass residue were meticulously analyzed. We find that the diffusion of cadmium into the surrounding gas increases with the temperature, with a relatively constant emission rate of 0.5% being measured. On the other hand, the predominant share of the cadmium is encapsulated in the glass. It is conjectured that entire modules will release only about 0.4% of their cadmium content owing to the relationship of outside edges to surface area.

The measurements were performed on small specimens lying in a basin. The melted material was collected in the basin. Cadmium from the inner CdTe layer was able to escape only through the side

edges; see Figure 4-29. In actual installed modules in the PV system the glass fragments, melting material can drip down and a large part of the CdTe layer or glass can be exposed together with the diffused cadmium. Theoretically it would be possible that the level of emitted gaseous cadmium under these circumstances is greater than the 0.5% measured in the lab.

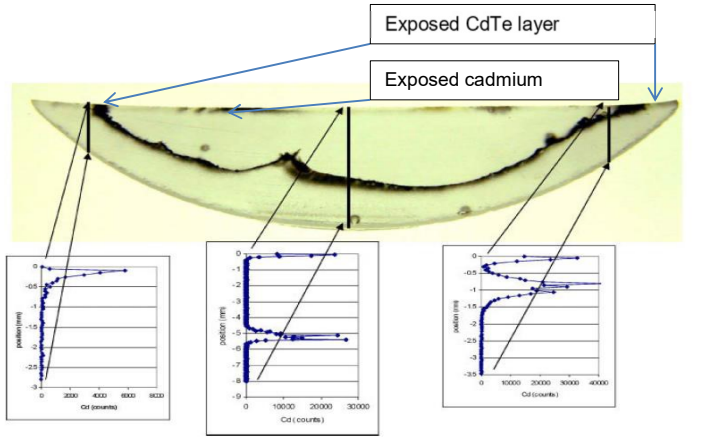


Figure 8. X-ray fluorescence microprobe analysis–vertical slice from middle of sample heated at 1000°C; Cd counts in the center and the sides of the slice

Figure 4-29: CdTe module specimen with Cd level curve within the fused and re-cooled sample, source: **[47]**

A study from 2011 on possible cadmium emissions related to rainwater flushing of fractured CdTe modules and smoke gases from PV fires [52] concluded that health risks for residents or employees and rescue workers from cadmium emissions into the soil, groundwater or air are improbable. Possible risks from deposits of the heavy metals lead and cadmium in the soil from open-space installations in or near agricultural areas were investigated by the Bavarian Agency for Agriculture [46]. While the risks from a possible washout were classified as minimal, to be on the safe side the recommendation was made that defective solar modules be quickly removed.

The first smoke gas studies were already conducted in 1994 by order of BP Solar. With the technology available at the time, 10-minute exposure levels below the applicable limits as per AEGL (Acute Exposure Guideline Levels (accessible at [51]) were found at temperatures of 800 – 900 °C for the measured concentrations and therefore classified as non-critical.

Other research studies on the release of heavy metals from PV modules on fire were conducted in 2011 and 2013 by the Federal Institute for Materials Research and Testing (Bundesanstalt für Materialforschung und -prüfung, BAM) [53], [12]. Among other things, the studies subjected small (75 mm x 75 mm) specimens from different 50 kW/m² module technologies to heat exposure and both the smoke gas composition and residue were analyzed. After about 8 minutes of such stress the module assembly failed, accompanied by a significant increase in gas emission. It was found that the specimens or fire debris still contained on the average 94% of the heavy metals from the initial specimens after the fire stress. Conversely, approximately 6% must have been released in these lab tests.
Initial values for CdTe modules were approximately 7g Cd level/m², which agrees with the specified

lower limits in the literature [54]. Given a large spread in the results, the authors recommended further studies.

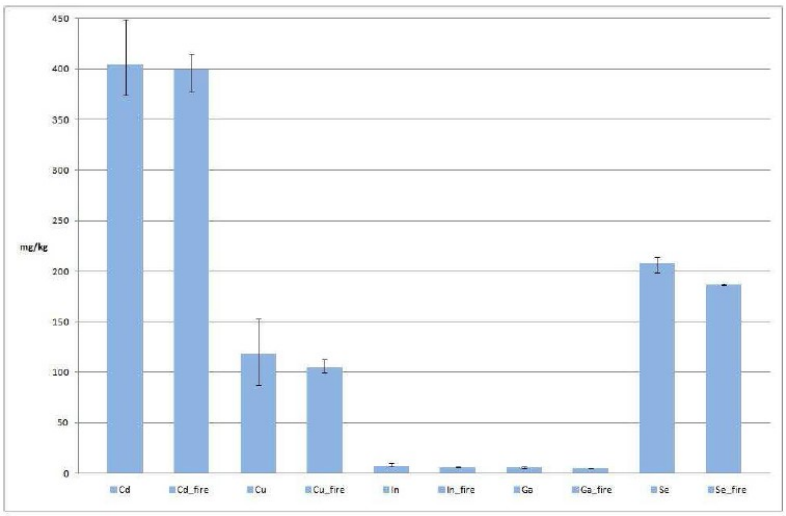


Figure 4-30: Residue analysis: Before and after fire test on CdTe and CIGS module specific (source: BAM 2013, **[12]**)

The distribution of cadmium pollutant emissions into the environment from roof-mounted PV systems on fire is the subject of an independent study conducted in 2011 by the Bavarian State Office of the Environment [55]. The distribution of outgased cadmium was then studied for different scenarios in consideration of the wind. Various installation sizes and different heat output levels were considered and in each case the cadmium concentration near the ground indicated for distances from 100 m. As a result, it was found that even in the worst case the Cd concentration at 30-600 µg/m3 lay clearly below the AEGL-2 values (1400 µg/m3; AEGL-2 10 minutes), so that a hazard to the environment can be practically ruled out.

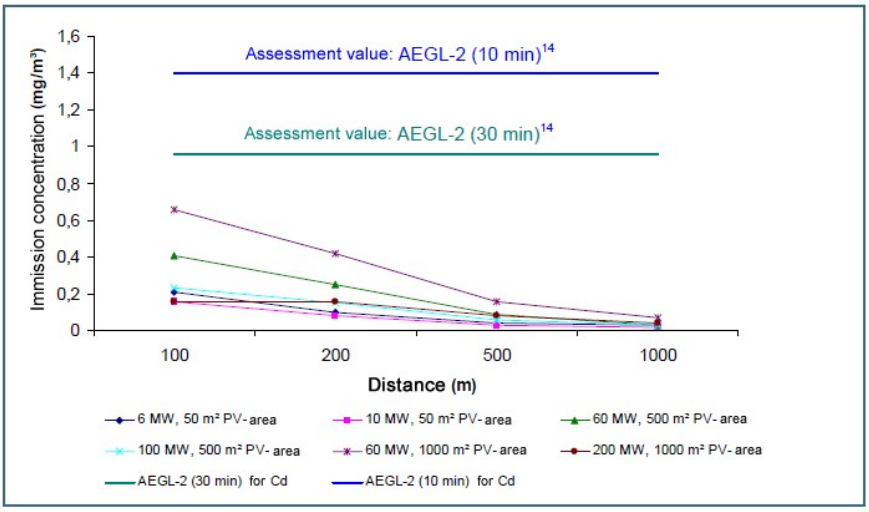


Figure 4-31: Cadmium immission concentration as a function of the distance to the fire site with a maximum cadmium content of 66 g/m (worst case)

Unfortunately, this positive result does not suffice for resolving the issue in this study. For assessing the hazard to firefighters from toxic fire effluents, considerably smaller distances of about 8 – 50 m to the emission site are relevant. Here too considerably higher concentrations occur than at distances > 100 m, depending on thermal upthrust, wind force and wind direction.

Figure 4-32 shows a typical distribution of air pollutants, here NO_2. The emission source in this case is a heavily traveled road (from a study by the Austrian Environmental Agency [56]).

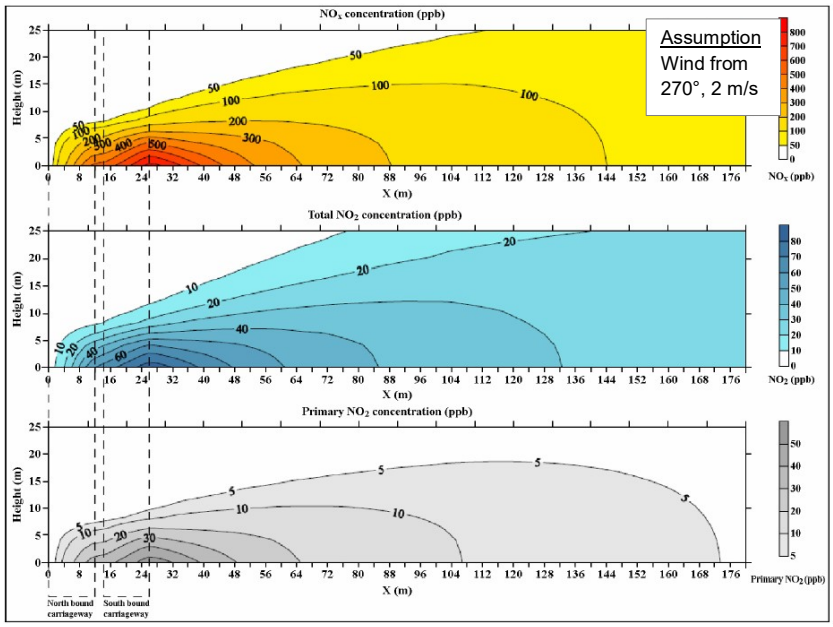


Figure 4-32: Example of pollutant concentration as a function of distance and height (source: Austrian Environmental Agency, **[56]**)

Given the rather low wind force in this example, an air pollutant concentration of approximately 10 ppb is specified on the ground along the wind direction at a 100 m distance (bottom graph), coming from a source emission of 50 ppb. In the relevant distance range of approximately 8 – 50 m, we find the overall spread of concentrations to lie between 50 and 10 ppb.

This means that in the close-up range a multiple value, in this example 5 times the value, of the pollutant concentration can exist at a distance of 100 m. From the results of the study by the Bavarian State Office of the Environment [55] we thus find ourselves well above the AEGL-2 limit for 30 minutes as well as that for 10 minutes. On the other hand, the thermal influence in the pollutant emission has a mitigating effect, bringing about greater propagation upwards in case of a fire and relieving the space near the ground.

The magnitude of this influence in practice depends on the specific fire properties and the particular environmental and weather conditions and is hardly quantifiable given the complexity of the influential factors.

Summary

Previous studies on emissions in case of damage and fire in particular show only low emission rates of toxic gases or soot levels of up to a maximum of 6% of the pollutant level in the damaged module. Most of the harmful substances were encapsulated in the fused glass part in these studies. The respective

authors found that the results of smoke studies on the one hand and distribution simulations on the other posed no significant risk to humans or the environment.

Despite the positive results from previous studies, the subject of pollutant emissions in case of fire cannot be regarded as settled as non-critical for the following reasons:

- Previous smoke gas studies and residue analyses were in each case performed on small specimens with side lengths of only a few centimeters. A large spread of results was obtained. Additional information should be provided by analytic lab studies on whole modules under realistic conditions in the fire lab specially equipped for this purpose.

- To date no tests have been performed with incomplete combustion through quenching, for example. (To date the literature describes no studies of this scenario.)

- The risk consideration for firefighters represents a special case. Rescue workers wear respiratory protection when operating in the vicinity of a PV system. An estimation of the concentrations of toxic substances at distances less than 100 m should be made in addition to the aforementioned data from the Bavarian State Office of the Environment.

- Fire department crews may be exposed to pollutants for longer than 10 minutes in practice. This is also reflected by special maximum exposure concentrations for fire departments that refer to 4 hours.

- Heavy metals accumulate in the body, and repeated exposure is conceivable, a fact that must be taken into account by a risk assessment. A different approach to limit considerations is therefore necessary.

4.6.3 Compositions of the modules and components

Because of their complex design, PV systems, in particular PV modules, contain numerous types of materials. For estimating theoretically possible releases of pollutants, typically used materials are analyzed and their behavior or possible chemical reactions in a fire event determined.

Table 4-15: Basic compositions of PV components

Component	Composition
Modules	
Frames	Metals, plastics
Carrier material	Glass, plastic film, metallic foil
Back rails	Metals, plastics
Solar cells	Depending on the technology: Silicon, plastic films, metallic foil, dyes, various (heavy) metals
Embedding	Cast resin, plastic films
Sealing compound	Rubber, silicone
Cell connectors	Metals, alloys
Junction boxes	Plastics, metals, diodes
Cables, plugs	Plastics, metals
Substructure	Metals, plastics
DC junction boxes	Metals, glass, plastics
Inverters	Metals, glass, plastics

In quantitative terms, the PV modules with their substructures and connecting cables as well as plug connectors make up by far most of a PV system, with the modules numbering from around a dozen in small roof-mounted systems on single-family houses to several tens of thousands in large (open-space) systems. While substructures and cables are made from rather non-critical metals and polymers that must be considered because of smoke gases, depending on the technology the PV modules contain numerous materials that in part are also classified as severely dangerous to health even in small amounts. The following considerations of materials focus on PV modules with their technology-dependent compositions.

PV modules are usually divided into three main groups based on the employed cell technologies: Crystalline modules, thin-film modules and modules with “other” (new) technologies (Table 4-16).

Table 4-16: PV technologies

Crystalline silicon (thick-film)	Thin film	Other technologies
•sc-Si (monocrystalline) • mc-Si (polycrystalline)	• **Silicon** • a-Si (amorphous silicon) μ-Si (micromorphous silicon) • **Semiconductor** •CdTe (cadmium telluride) •CIGS/CIS (copper indium – gallium selenium) •GaAs (gallium arsenide) •CZTS (copper zinc tin sulfide)	• Dye cells • Organic plastic cells • Concentrator cells (CPV, e.g. triple- junction cells)

For estimating the practical relevance of the material composition to be considered, we consider the market shares (frequency of use) of the most important module or cell technologies:

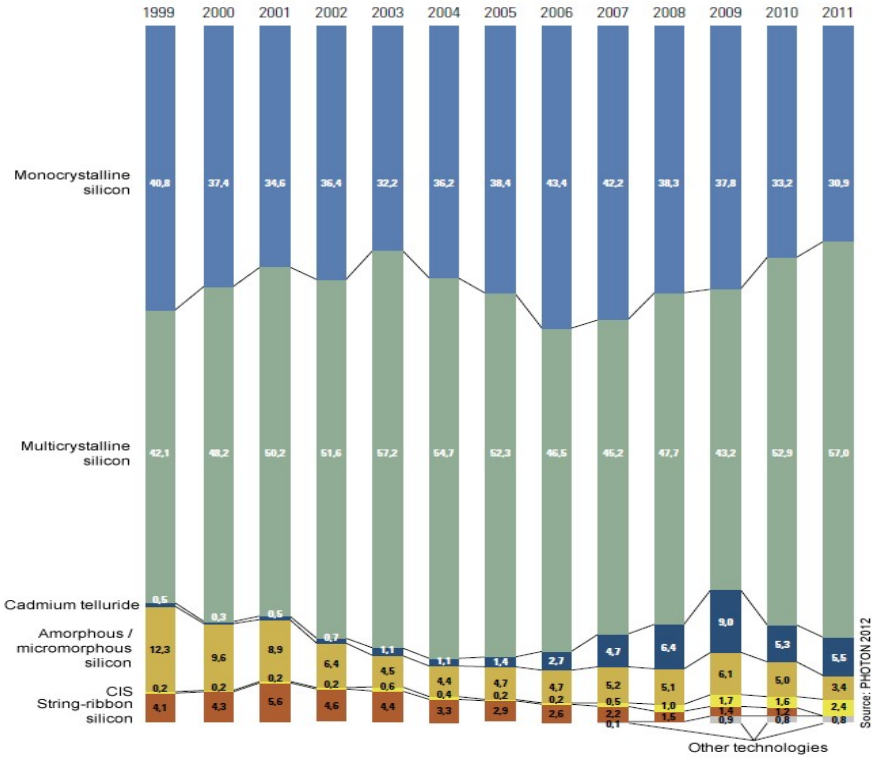


Figure 4-33: Market shares of the most common cell technologies (source: Photon Europe GmbH, April 2012)

The market share of the crystalline modules remains relatively constant between 80% and 90% as the clearly leading technology, while the total share of all thin-film technologies falls between 10% and 20%, with the trend declining over the last 3 years because of the drop in price of crystalline modules. Within the groups there are shifts with a continued predominance of cadmium telluride modules, along with an equally growing share of CIGS modules. Other cell technologies, like dye-containing or polymer modules, have so far not played any prominent role in the market.

In the following, we therefore consider typical silicon-based crystalline thin-film modules as well as proportionally the most important thin-film modules with cells made of amorphous silicon and cadmium telluride along with copper indium gallium selenium semiconductors.

Crystalline standard modules

The crystalline standard modules prevailing in the market are primarily manufactured as glass-film modules with aluminum frames. In addition, there are frameless modules as glass-glass versions. A crystalline standard module thus consists basically of an upper glass plate, the PV cells with attached metallic contact tabs and connectors, the cell embedding, a backsheet, the junction box and an aluminum frame. The mass fractions are dominated by glass and the frame (approx. 85 – 90%). The remainder breaks down into different plastics, silicon (cells, silicones) as well as copper and, in small amounts, other metals like silver, selenium and lead.

Current Si standard modules with an output of approx. 230 – 330 Wp are about 1.6 m² (1,650 x 990 x 40 mm) in size and weight about 18 – 19 kg.

The most important materials and their mass fractions in a crystalline standard module were compiled from studies conducted by the Institute for Ecology and Politics in Hamburg (Ökopol) from 2004 and 2007 [7] [8] as well as from an older detailed analysis by TÜV Rheinland [57] and other sources. Noteworthy is that no current analyses from the last two years were found and that studies through 2011 cited as their data source the aforementioned Ökopol studies, which we therefore use as a basis here as well.

Table 4-17: Example of the composition of a standard Si module, 215 Wp; source: **[8]**

Component	Quantity (2003) according to [Ökopol 2004]	Quantity 2007	
	%	%	kg/kWp
Glas	62,7	74,16	77,3
Frame (e.g. AlMg-Si0.5)	22,0	10,30	10,7
EVA	7,5	6,55	6,8
Solar cells	4,0	3,48	3,6
Backsheet film(Tedlar)	2,5	3,60	3,8
Junction box	1,2		
Adhesive, casting compounds	No data	1,16	1,2
Weight/kWp	103,6 kg/kWp		102,3
Cu	0,37	0,57	
Ag	0,14	0,004 – 0,006	
Sn	0,12	0,12	
Pb	0,12	0,07	
Si	No data	3%	

Compared with crystalline thick-film modules, amorphous silicon modules show no significant deviations in material composition regarding harmful substances and will not be separately considered in the following.

Table 4-18 lists the researched, typically used substances for components of a crystalline PV module. The literature did not include the connecting cable with plug. Typically they must be considered as constituting a mass fraction of approx. 3.5% and containing approx. 400 g of polymers (in the case of newer solar cables, these are usually cross-linked polyolefins, besides copper, tin and aluminum) for the conductor materials. The percentages and derived masses per m² module surface given in Table 4-18 must therefore be understood only as approximations.

Table 4-18: Materials and average mass fractions of a typical crystalline standard module, glass film (single-plate laminate)

Component	Materials	Material composition (examples)	Mass [%]	Approx. mass [g/m²]
Frame	Metal	Aluminum	8 - 10	1,060
	Plastic	Polyurethane, polyamide		
Glass	Tempered glass, annealed glass	Glass (Si, Na, Ca, Mg)	74 - 76	8,850
	Front plate, LSG	Glass, PVB film		
Cells	Crystalline	Silicon	3.6	424
Cell stringing **Connectors**	Tin-plated copper bands	Copper, tin, silver, lead, bismuth[2] (only 10-30 µm thick)	0.8	94
Backsheet	Tedlar film	PET, PVF, PA	5	590
Embedding		EVA, acrylate	6	708
Seals, adhesives	Frame sealing tape	Rubber, silicone, acrylate, PE foam, polyurethane, ethylene-propylene-copolymers	1 - 2	177
Junction boxes	Plastics, metal	ABS, PET, aluminum	1 - 2	177

Thin-film modules

Besides the technologies also based on silicon, thin-film modules use various light-absorbing semiconductor materials (cadmium telluride, gallium/indium, gallium arsenide, etc.) that are impressed on a carrier material – primarily glass, but also plastic or metallic film. Thin-film modules primarily use frameless structures (glass-glass modules or flexible modules with film covering). The design of the

module types is much more varied than with crystalline modules, so that a “standard thin-film module” cannot be defined.

The glass part is much greater in glass-glass thin-film modules than in crystalline ones.

Table 4-19 and Table 4-20 below list the typical compositions of modules with CdTe cells and CIS/CIGS cells as quantitatively the most widespread thin-film technologies.

Table 4-19: Typical composition of a CdTe module (120 x 60 cm), source: **[8]**

Material	Thickness	Weight per unit area	Weight per unit power
		g/m²	G/Wp*
Glass carrier layer	3 mm	7500	71
TCO-SnO_2	<1 µm	6,9	0,07
CdS	<0,1 µm	0,483	0,005
CdTe	7µm	18	0,17
Back contact	1µm	2,7	0,03
EVA	0,5mm	500	4,8
Front glass	2 mm	7500	71
CuSn-Band		6,94	0,07
Connection box		21,7	0,2
Cable		57,8	0,6
Total		15.615	149

Table 4-20: Typical compositions of CIGS modules (three manufacturers), source: **[8]**

	Weight(g/m²)		
	Producer A	Producer B	Producer C
Si_3N_4	0,5		
Mo	4	5	
CuInGaSe	10	12	9,5
Selenium	5	6	4,5
ZnO	7	6	0,7
CdS	0,2	0	0,24
ITO			
Polyamide carrier layer			35
Glass carrier layer	7500	7500	
Front glass	7500	7500	
PIB seal	500		
Encapsulation(PVB, EVA, PU, PE)	200	500	No data
Polymer adhesive	400		
Adhesive tape		100	
Aluminium frame	3000	1800	
J-Box PP	400	100	
Polymer and copper cables	400	200	
Polyester label	1	1	
Glass total	**15000**	**15000**	
Polymer total	**1701**	**701**	
Total weight/m²	**19927**	**17730**	

The average proportionate quantities of the metallic materials relevant for thin-film modules according to the literature were extrapolated to a system size with an assumed module surface of 50 m². The approximate quantitative parts are given in

Table 4-21.

Table 4-21: Metals, materials and mass fractions of thin-film modules (CIS / CIGS and CdTe)

Cells	Material composition	Mass	
		%	g/50 m²
CIS / CIGS	Copper (incl. cable), Cu	0.8	6,000
approx. 3% market share	Indium, In	0.02	150
	Selenium, Se	0.03	225
	Zinc, Zn	0.03	225
	Gallium, Ga	0.01	75
	Arsenic, As	0.01	75
	Molybdenum, Mo	0.07	525
	Cadmium, CdS	0.001	8
CdTe	Cadmium, Cd	0.07	450
approx. 5% market share	Tellurium, Te	0.07	450

For a PV system with approx. 50 m² CdTe module area (approx. 70 modules per 1200 x 600 mm with altogether approx. 5.6 kWp), approx. 450 g cadmium must be expected according to the sources.

Roof-mounted system substructures for the most part consist of aluminum and stainless steel. Exceptions occur in the form of plastic trays (PE), e.g. for flat roofs (e.g. ConSole+ from Renusol), however. The trays are reaction-to-fire class E (as per DIN EN 13501-112010-011) according to information from the manufacturers. The trays are “normally flammable” as per existing requirements and therefore also combustible.

Construction materials of building-integrated solar systems do not differ from conventional façade and overhead glazing structures without solar elements, so that they need not be further considered here.

4.6.4 Composition of the fire effluents

Effects greatly depend on the type of fire. This applies to the production of smoke and gas as well as to the extent of damage. The produced substances and compounds were analyzed for different fire scenarios [58].

In a fully developed fire with high temperatures and oxygen supply, the organic components are largely converted through combustion to the oxidation products of carbon (C), hydrogen (H) and oxygen (O) carbon monoxide (CO), carbon dioxide (CO_2) and water (H_2O).

Bound heteroatoms like fluorine (F), chlorine (Cl) and nitrogen (N) are converted during a fire to the corresponding (highly toxic) hydrogen halides (HF, HCl) or to nitrogen oxides (NO and NO_2).

At decreasing temperature and with oxygen supplied, the products from organic materials become too numerous to mention. Partially oxidized and cracked compounds increasingly occur. In the partial oxidation of organic carbon, carbon monoxide (CO) dominates the smoke gas composition. In smoldering fires cracked compounds like plastic monomers dominate.

Below we consider the substances mentioned in the previous section in reference to the production and composition of fire effluents and smoke. Assumed is a fully developed fire scenario, characterized by temperatures above 600°C with a sufficient supply of oxygen [58].

For assessing the relevance for firefighting personnel we consider the quantities contained in the modules in addition to their toxicity.

Glass

Glass, quantitatively the main component of a typical module, does not chemically change even at high temperatures, since it already exists in an inert oxidized state. It contains no critical parts.

Metals

Aluminum can combust and change to aluminum oxide only at very high temperatures that are usually not attained in a typical fire. Aluminum can therefore be classified as inert.

Copper from supply lines and contacts burns under the considered conditions to become copper oxide, which has no toxic relevance.

Tin and lead are used in solder compounds, with the lead content making up about 40%. In a fire, these metals also convert to their metal oxides – both are toxic. Under fire conditions, lead can be released as smoke, while tin is slightly volatile.

Cadmium is used as a semiconductor material in CdTe modules, and is contained as small amounts in other cell technologies. Because of the slight oxidability of cadmium, we must assume that at higher temperatures cadmium will partially convert to cadmium oxide (CdO), which is significantly less volatile than metallic cadmium. Both cadmium and cadmium oxide have high-level toxicity. The Cd parts released in gaseous form make up about 25% of the inventory [9], while the parts released altogether as particulates and gas make up about 70% [7]. Relevant gaseous parts in the (cooled) ambient air are not to be expected. During a fire, the release of Cd/CdO particulates in the range 1 – 4 mg/m³ is at most to be expected. In the more favorable case, cadmium is chemically bound as silicate by the glass envelope. Compared with the maximum exposure concentration value of 0.4 mg/m³ (see section 4.6.5, p. 162), cadmium must be considered relevant for firefighting operations.

Arsenic (As), molybdenum (Mo), zinc (Zn), gallium (Ga), indium (In), selenium (Se)

These metals are primarily relevant to considerations of CIGS technology. In case of fire, the corresponding oxides like MoO_2 Ga_2O_3, ZnO, SeO_2 and CdO predominate. Highly volatile metals like selenium (and, as described, cadmium) can also vaporize and appear as a gas or (in a cooled state) as smoke (particles). In particular, selenium, as well as the expected selenium oxide (SeO_2), is highly

volatile. **Arsenic** is a toxic, non-essential heavy metal. Arsenic and its compounds qualify as carcinogenic substances. There are also grounds for suspecting **selenium** to have cancer-causing potential. On the other hand, the acute toxicity of elemental selenium (e.g. when taken in orally) is considered very low.

Studies on heavy metal residue in the incineration of waste have found the following release rates for toxic metals [59], [60], [61]].

Table 4-22: Metals released at 1,000°C in percent (solid particles in smoke gas and as gas)

Metal	Proportion released at 1000°C in %	
	Particles/gas	Gaseous phase
Se	70	70
As	60	40
In	(5)	
Ga	(10)	
Mo	(5)	
Pb	30	12
Zn	30	21
Cd	70	25
Sn	10	
Cu	10	

The specified metals are released in gaseous form and as airborne particulates. According to [59] large amounts of As and Se are released at 1,000°C. Cd and Zn enter the gaseous phase to about 25% and Pb to about 10%. The percentage not incorporated in the remaining ash, and therefore emitted in particulate form (air-borne ash), is much higher for nearly all observed metals, and in particular 70% for arsenic and cadmium. Apart from selenium, the released metals or metal compounds do not occur in gaseous form when cooled to below 200°C. The numerical values for Ga, In and Mo are estimates.

Plastics and organic materials

These include the employed sealing compounds, films, junction boxes, cables and possibly module frames as well. Quantitatively, the embedding material and backsheet are especially important.

The following maximum formation rates were used as a basis for the production of the pollutants carbon monoxide, hydrogen chloride, benzene, hydrogen cyanide, formaldehyde, styrene and hydrogen fluoride from polymers [62]. The estimated, maximum formation concentrations 10 – 20 m at close range (see Table 4-24) were derived therefrom.

Table 4-23: Maximum release rates for polymers in a fire.

Component	Polymers	mg/g polymers	ng/g polymers
CO	All	580	
HCN	PAN (25 % in ABS)	101 (25)	
HCN	Polyamides	60	
HCl	PVC	284	
Benzene	PVC	24	
PCCD	PVC		1,8
Formaldehyde	PE	7	
Styrene	PS (50 % in ABS)	710 (355)	

The share of polymers in crystalline Si modules is 5 – 10%, or 500 – 1.500 g/m². This share consists of the polymer EVA (embedding film) and PET/PVF (backsheet). If these films are used, especially emissions of CO and formaldehyde must be expected as lead substances. Added is the release of hydrogen fluoride due to the fluoride content in the PVF (if used).

Given a PV area of 50 m², altogether 25 – 75 kg of polymers are affected, which can be estimated to lead to the following maximum concentrations of selected toxic substances at close range. The maximum exposure concentration was specified here as the toxicological threshold. Section 4.6.5 will discuss the existing threshold values.

Table 4-24: Maximum concentrations at close range

Component	Concentration in mg/m³			Maximum exposure concentration mg/m³
	25 kg polymers	50 kg polymers	75 kg polymers	
CO	100	**200**	**300**	38
Formaldehyde	1,3	**2,5**	**3,8**	1,25
HF	**25**			10

The theoretically possible CO concentrations can significantly exceed toxicological thresholds at close range. The maximum expected concentrations for the components formaldehyde and hydrogen fluoride are also two to three times the permissible maximum exposure concentration.

The installed cables with plugs and boxes contribute additional polymers (in the case of older systems, possibly chlorine-containing PVC or nitrogen-containing ABS) to smoke gas formation: for a 50 m² module area this will amount to about 5 kg of polymers. These quantities do not suffice for exceeding the corresponding maximum exposure concentrations for the possibly occurring HCl, HCN, benzene or PCCD/F boxes.

4.6.5 Toxicological thresholds

4.6.5.1 Smoke gases

The currently most important assessment levels for hazardous situations are the AEGL (Acute Exposure Guideline Levels). These are incidence assessment values as per the 12th Federal Immission Control Ordinance (BIMSCHV). They have been respectively declared for different exposure times: 10 min, 30 min, 1h, 4h, 8h. For the incidence assessment values 3 levels each are defined, describing the following degrees of impact [51]:

AEGL-1/ERPG-1	Threshold for noticeable malaise
AEGL-2/ERPG-2	Threshold for irreversible or other serious, long-term health effects or escape-hindering effects
AEGL-3/ERPG-3	Threshold for life-threatening or fatal effects

Level 2 is considered relevant for pollutant concentrations.

Examples of other assessment series in Germany are the MAC (maximum allowable concentration for an 8h workday and 40h/week) and the maximum exposure concentration (German: ETW) for firefighters for 4 hours' exposure [63].

Various other assessment levels exist on the international level; we mention the ERPG (Emergency Response Planning Guidelines) and PAC (Protective Action Criteria) here as representative examples. The PAC values are a compilation of existing limits in the form of prioritized lists.

4.6.5.2 Solid pollutants

The Federal Soil Protection and Contaminated Sites Ordinance [64], Annex 2, defines test levels for the direct absorption of pollutants into the soil. Different categories are listed, such as play areas, residential areas, parks and industrial zones. For the considerations in these studies, the residential area category was used for the purpose of comparisons.

4.6.5.3 Harmful substances in quench water

For assessing the amounts of harmful substances in quench water we lack directly comparable limits. For estimating which concentrations of liquid pollutants must be qualified as critical, we applied the Sewage Sludge Ordinance for Agriculture (AbfKlärV) [65]. It specifies the thresholds for pollution of (industrial) effluent sludge containing heavy metals and other harmful substances for the purpose of protecting the environment, in particular the soil.

4.6.6 Lab tests

In connection with the BMU research project underlying the present study, experimental studies were conducted at the fire testing center of CURRENTA during June 2014 with the aim of characterizing the release of harmful substances by photovoltaic modules in case of fire.

The experimental program covered three different module types (Table 4-25). In each case both commercially available and current modules were studied. A flame was applied to the backs of the inclined modules with a gas burner, in order to simulate a possible fire emergence scenario among roof-mounted PV applications. Pollution analyses were conducted on smoke gas, fire residue and quench water samples.

Table 4-25: Module types

Type	Design	Frame	Length (mm)	Width (mm)	Thickness (mm)
Polycrystalline c-Si	Glass film	Aluminum	1,655	1,000	45*
Thin-film, CIGS	Glass film	Aluminum	1,255	980	35*
Thin film, CdTe	Glass-glass	None	1,200	600	8
* Frame thickness					

4.6.6.1 Test setup

The PV modules were mounted with profile rails arranged crosswise on a fiber cement mounting plate, located on a test platform inclined 23° relative the horizontal plane (figure 5-34). The inclination was selected as in the roof fire test as per UL 790. The modules protruded 45 cm beyond the front edge of the mounting plate and a flame was applied to their undersides in this area. The gas burner described in UL 790 served as the ignition source, producing a flame approximately 100 cm in width (Figure 4-34). The burner was positioned 10 cm below the front edge of the module, with the horizontal distance to the module front edge also being 10 cm.

On the front and back of the module five thermal elements each were arranged along the longitudinal axis of the module. The distances to the module front edge were 10, 40, 70, 100 and 130 cm. In the temperature diagrams contained in the Appendix, “MS-01” (module back) and “MS-06” (module front) designate the measuring points along the module front edge.

For the quench water tests, two extinguishing nozzles were installed in the upper part of the test setup in the interspace between the module and the mounting plate. To catch the quench water running off over the mounting plate a 1.75 × 1.50 m² steel tray was placed on the floor of the test building.

To apply the flame to module areas of similar size, for the c-Si modules the tests were performed on one module along the longitudinal direction (length: 1,655 mm), for the CIS modules on two modules along the transverse direction (total length: 1,960 mm) and for the CdTe modules on three modules along the transverse direction (total length: 1,840 mm incl. installation distance).

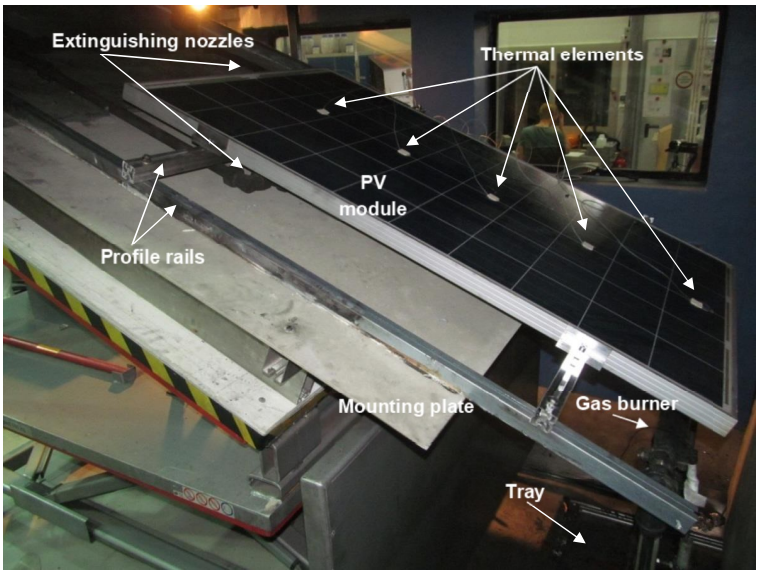


Figure 4-34: Test setup (shown here with a c-Si module)

Figure 4-35: Gas burner

4.6.6.2 Performance of test

On each module type, tests were performed with a burner output of 25 kW and 150 kW, in order to analyze the fire behavior and pollutant release of the modules at different thermal stress intensities (Figure 4-36). In addition, a further test was performed on each module type with a burner output of 150 kW, such that after six to seven minutes the fire was extinguished in each case with 20 l of quench water over a period of 45 s.

The tests were performed underneath an exhaust hood as per ISO 9705, with an exhaust flow rate of about 1 m³/s. The following variables were measured:

- Heat release rate
- Smoke production rate
- Temperatures on front and back of the module
- Mass loss of the modules and mass of the fire residue
- Destroyed module surface
- Formation rates of the gas compounds carbon dioxide (CO_2), carbon monoxide (CO), hydrogen cyanide (HCN), hydrogen chloride (HCl), hydrogen bromide (HBr), hydrogen fluoride (HF), nitrogen monoxide (NO), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2)
- Amounts of arsenic, lead, cadmium and selenium contained in the smoke gases
- Amounts of arsenic, lead, cadmium and selenium contained in the fire residue
- Amounts of arsenic, lead, cadmium and selenium contained in the quench water

In addition, two reference tests were performed with (non-combustible) calcium silicate plates instead of the modules in order to determine which smoke, CO_2 and CO formation rates the gas burner caused under the planned operating conditions. These measurement values were deducted from the actual measurement results, so that listed test results exclusively referred to the PV module emissions.

Smoke gas analysis

For determining the arsenic, lead, cadmium and selenium content, a partial stream from the waste air flow was conducted through a filter system and through a sorbent. The analysis was performed with ICP-MS. The measurement results listed in section 4 correspond to the sum of the particle-bound and to the filterable parts.

The gas compounds (except formaldehyde) were analyzed continually over time with an FTIR spectrometer connected to the exhaust tube of the extraction system. Section 4 lists the concentrations averaged over the duration of the test.

For determining the formaldehyde content, an absorption cartridge was used, with the analysis being performed with HPLC.

Fire residue analysis

The fire residue consisted of damaged, fallen-off parts of modules that accumulated during the test on the mounting plate of the test frame and in the tray placed underneath. The fire residue was first swept together and thoroughly mixed. Two samples were taken and pulverized with a granulator. The arsenic, lead, cadmium and selenium levels were determined with ICP-MS.

Quench water analysis

After mixing the quench water collected in the tray, two samples were taken and analyzed as to the arsenic, lead, cadmium and selenium levels by means of ICP-MS.

Figure 4-36: Fire test with a burner output of 25 kW (top) and 150 kW (bottom)

4.6.6.3 Test results

Appendix IX contains the full test results. Here we show selected results. Altogether 9 tests were performed, as listed in the following table:

Table 4-26: Test designation

	25 kW burner output	150 kW burner output	150 kW burner output, quench water test
Module type c-Si	1A	1B	1C
Module type CIS	2A	2B	2C
Module type CdTe	3A	3B	3C

Fire behavior

In the 25 kW burner output experiments, only locally limited damage occurred on all three module types. With 150 kW burner output, the modules were largely destroyed, as illustrated in the following photos.

Figure 4-37: Degree of damage with c-Si and 25 kW burner output (top) and 150 kW (bottom)

Table 4-27: Comparison of selected results from the 9 fire tests

Mass loss in %	25 kW burner output	150 kW burner output	150 kW burner output, quench water test
Module type c-Si	2.3	72.5	47.8
Module type CIS	7.9	85.2	18.7
Module type CdTe	0.1	32.6	31.5

Smoke production in m² *	25 kW burner output	150 kW burner output	150 kW burner output, quench water test
Module type c-Si	41	182	73
Module type CIS	92	358	274
Module type CdTe	5	133	86

** Smoke production in m² means the extrapolation of all produced smoke particles onto a 2-dimensional plane*

Heat release in kJ	25 kW burner output	150 kW burner output	150 kW burner output, quench water test
Module type c-Si	7,631	59,197	27,747
Module type CIS	9,699	84,712	17,506
Module type CdTe	785	15,809	9,786

The comparison shows large differences among all 3 parameters: mass loss, (total) smoke production and (total) heat release, depending on the design. Owing to the lack of a backsheet, the glass-glass module (CdTe) exhibits significantly better properties of fire behavior compared with the two other modules.

In comparing the two glass-film modules, it must be kept in mind that the CIS made a greater mass available, the incinerated mass was also greater and that consequently the thermal output was also greater.

If we relate the smoke production to the incinerated mass in each case, the difference becomes less. Altogether, the fire behavior of the CIS module type again presented a less favorable case compared with the c-Si module type (see

Table 4-28).

Table 4-28: Total smoke production in m² * standardized to 1g incinerated mass

Smoke production in m²/incinerated mass	25 kW burner output	150 kW burner output
Module type c-Si	0.13	0.11
Module type CIS	0.28	0.13

* Smoke production in m² means the extrapolation of all produced smoke particles onto a 2-dimensional plane

Chemical analyses

The following tables list the measured values for each substance referring to a specific unit. The gas analysis refers to one standard cubic meter of smoke gas, while the residue analysis refers to one kilogram of fire residue and the quemch water analysis refers to one liter of extinguishing water

Also specified are the total released quantities yielded by multiplying the measured concentration and the total volume of the smoke gas, the total mass of the fire residue or the total volume of the quench water used.

Smoke gas analysis

The concentrations as per DIN EN 45545-2:2013 were measured and averaged over the test period: Test A / B: 20 min, test C: 10 min (quenching after approx. 7 min)

Table 4-29: Average smoke gas concentrations from c-Si module

		Test 1A	Test 1B	Test 1C
Arsenic	(µg/m³)	1.1	0.8	0.1
Lead	(µg/m³)	50	630	1,010
Cadmium	(µg/m³)	6.5	60	77
Selenium	(µg/m³)	24	10	9.8
Carbon dioxide	(mg/m³)	842	3,786	3,068
Carbon monoxide	(mg/m³)	6	30	30
Hydrogen cyanide	(mg/m³)	n.d.	n.d.	n.d.
Hydrogen chloride	(mg/m³)	n.d.	n.d.	n.d.
Hydrogen bromide	(mg/m³)	n.d.	n.d.	n.d.
Hydrogen fluoride	(mg/m³)	n.d.	n.d.	n.d.

Nitrogen monoxide	(mg/m³)	n.d.	n.d.	n.d.
Nitrogen dioxide	(mg/m³)	n.d.	n.d.	n.d.
Sulfur dioxide	(mg/m³)	n.d.	n.d.	n.d.
Formaldehyde	(mg/m³)	1.0	0.9	1.8

Table 4-30: Average smoke gas concentrations from CIS module

		Test 2A	Test 2B	Test 2C
Arsenic	(µg/m³)	1.5	1.6	1.0
Lead	(µg/m³)	250	270	480
Cadmium	(µg/m³)	12	14	34
Selenium	(µg/m³)	4.8	40	8.0
Carbon dioxide	(mg/m³)	615	5,817	2,751
Carbon monoxide	(mg/m³)	11	237	382
Hydrogen cyanide	(mg/m³)	n.d.	n.d.	n.d.
Hydrogen chloride	(mg/m³)	n.d.	n.d.	n.d.
Hydrogen bromide	(mg/m³)	n.d.	n.d.	n.d.
Hydrogen fluoride	(mg/m³)	n.d.	n.d.	n.d.
Nitrogen monoxide	(mg/m³)	n.d.	n.d.	n.d.
Nitrogen dioxide	(mg/m³)	n.d.	n.d.	n.d.
Sulfur dioxide	(mg/m³)	n.d.	n.d.	n.d.
Formaldehyde	(mg/m³)	1.2	2.1	4.9

Table 4-31: Average smoke gas concentrations from Cd-Te module

		Test 3A	Test 3B	Test 3C
Arsenic	(µg/m³)	0.3	0.2	0.2
Lead	(µg/m³)	34	120	1,330
Cadmium	(µg/m³)	9.9	37	48
Selenium	(µg/m³)	4.2	4.7	2.2
Carbon dioxide	(mg/m³)	42	1,453	1,495

Carbon monoxide (mg/m³)	1	63	90
Hydrogen cyanide (mg/m³)	n.d.	n.d.	n.d.
Hydrogen chloride (mg/m³)	n.d.	n.d.	n.d.
Hydrogen bromide (mg/m³)	n.d.	n.d.	n.d.
Hydrogen fluoride (mg/m³)	n.d.	n.d.	n.d.
Nitrogen monoxide (mg/m³)	n.d.	n.d.	n.d.
Nitrogen dioxide (mg/m³)	n.d.	n.d.	n.d.
Sulfur dioxide (mg/m³)	n.d.	n.d.	n.d.
Formaldehyde (mg/m³)	0.4	1.6	2.6

n.d. = not detectable

Comparison with toxicological thresholds

CO, CO_2:

The measured values show significant exceeding of the threshold > a factor of 10.

Hydrogen halides and nitrogen oxides:

The measured concentrations lie below the detection limit (and also below the toxicological thresholds)

Heavy metals:

The measured values lie well below the thresholds:

Pb < 0.1% GW (PAC =120 mg/m³ 60 min)
Cd < 10% GW (AEGL-2 30 min = 0.96 mg/m³)
Se < 20% GW (PAC=0.2 mg/m³)
As < 1% GW (PAC=0.58 mg/m³)

Assessment of the results

A direct comparison of the measured values with the toxicological thresholds is not possible because of the differences in exposure time. The boundary conditions vary with each fire, i.e. each fire is unique! The thresholds are used merely to estimate the order of magnitude of a possible hazard to people.

The present ventilated test arrangement (1m³/s) dilutes the pollutant concentration in the waste air to an extent not quantifiable with precision. A rough estimate of the worst case in the event of pure convection would yield approximately 10 times the concentration of the measured pollutants in the immediate vicinity (approx. 2-5 m above the fire source). This means that in the extreme case the toxicological thresholds would be approached with either cadmium or selenium given an exposure of 30 or 60 minutes.

Conclusion

Measurements of the smoke gas concentration for the components CO and CO_2 found the thresholds to be significantly exceeded. Hydrogen halides and nitrogen oxides were not present in measurable concentrations.

For the heavy metals cadmium and selenium, toxicological thresholds can be exceeded in the worst case in the immediate vicinity to the site of emission. The general public is at no risk from hazardous concentrations in the smoke gases.

Residue analysis

This section focuses on those soil pollutants that can be especially relevant to human health. They include on the one hand widespread pollution levels with risks to agriculture and groundwater and on the other hand soil impairments that can especially lead to hazards in residential areas. Of particular interest here are sensitive areas of use such as children's playgrounds and home and small gardens, Annex 2 of the Federal Soil Protection and Contaminated Sites Ordinance [64] updated in 2012 specifies test values for the direct absorption of pollutants into the soil. These test values are defined for four different categories: play areas, residential areas, parks and industrial zones. For estimating the risk of soil contamination from the toxic residue measured in lab tests, in particular lead, cadmium and arsenic, the test values from the residential area category were used.

As expected, preparation of the module residue for analysis proved to be very time-consuming, also owing to the information from other studies. Given the nonhomogeneous module remnants (Figure 4-38), the tests yield no generally applicable information, however the fire residue analysis detected lead, cadmium, arsenic and selenium in all investigated test samples of the c-Si, CIS and CdTe technologies.

Figure 4-38: Fire residue from 2 CIGS modules: Al frame, fused glass, baked plastic residue, soot and ash

The identified quantities of harmful substances vary greatly among the examined test samples of the three technologies. The following graphs show the measured values and corresponding test values as per the Federal Soil Protection and Contaminated Sites Ordinance for lead and cadmium.

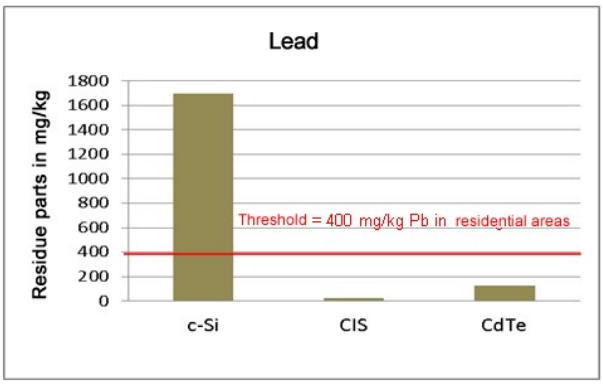


Figure 4-39: Average lead level in fire residue

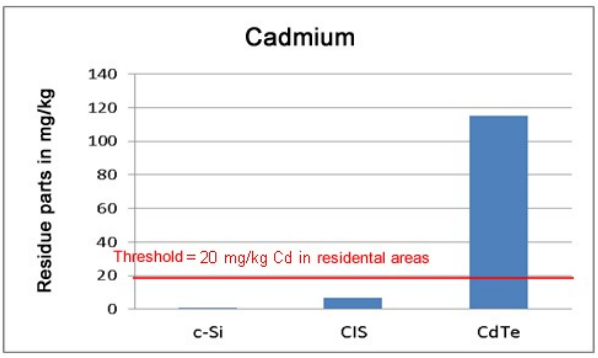


Figure 4-40: Average cadmium level in fire residue

Figure 4-39 shows that the fire residue from the crystalline module on the average exceeded the test value for lead as per the Soil Protection Ordinance by a factor of 4, while the thin-film modules exhibited non-critical levels.

On the other hand, Figure 4-40 shows that cadmium exceeded the test value by a factor of 5 in the case of the CdTe module. If the area under consideration is being used as a home garden or children's playground, the permissible test value as per the Soil Protection Ordinance decreases to 2 mg/kg, *so that particular attention must be given to the cadmium level in the soil.* In this case, the measured residue concentration from the CIS module also falls in the critical range. For the crystalline module, measurements did not show the test value to be exceeded.

For arsenic, measurements detected no critical levels.

Conclusion

Depending on the technology, the fire residue from PV modules can contain concentrations of lead or cadmium that can create critical levels of contamination in the soil.

Professional disposal of fire residue and, if necessary, soil replacement are therefore urgently recommended.

Quench water analysis

The large volume of quench water can allow detached harmful substances or suspended particles to move from the fire residue into the surroundings and the soil as well. The possible wetting of objects like parts of buildings, balconies and terraces, as well as firefighters' clothing, with contaminated quench water must be noted and kept in mind when further use is contemplated.

Investigations found no pollutant limit levels for water-based soil contamination. The risk assessment employed the Sewage Sludge Ordinance for Agriculture for the contamination of industrial sludge with

heavy metals and other harmful substances [65]. The maximum permissible concentrations are given per unit of ground area (mg/m²), while the concentrations of harmful substances in the quench water are measured per unit volume (mg/m³). While a direct comparison is therefore not possible, a rough estimate could be made.

Figure 4-41 lists the measured concentrations of lead and cadmium for the individual module technologies.

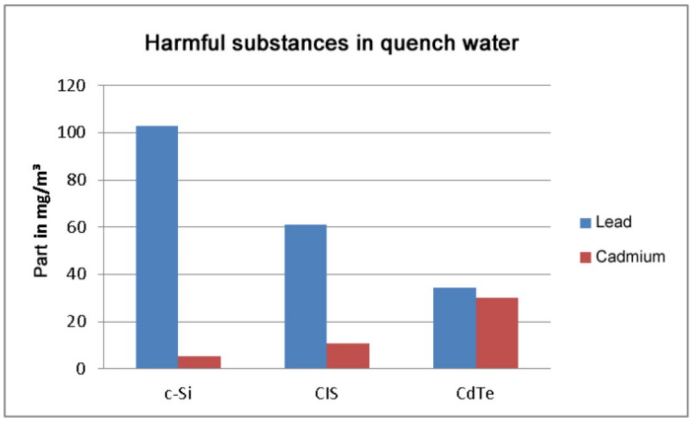


Figure 4-41: Measured concentrations of lead and cadmium in quench water

Assessment of the measurement results:

The threshold for lead is exceeded only with a 1 m³ of quench water over an area of soil less than 1 dm² (c-Si).

The threshold for cadmium is exceeded only with 1 m³ of quench water over an area of soil less than 2 m² (CdTe).

While the precondition for lead evidently should not be attained, under unfavorable conditions (e.g. runoff of the quench water over an edge) the precondition for cadmium is theoretically possible.

Conclusion

In a CdTe module fire, critical cadmium levels can enter the soil via the quench water under worst-case conditions

We therefore recommend soil sampling and analysis.

4.6.7 Summary

- PV module fires release additional contaminants into the environment in relevant quantities, depending on the cell technology and to a particular extent also on the polymers used.
- The contaminant emissions from PV modules must be rated as an additive contribution, since each roof timber fire or house fire involves a large fire load with toxic substances.
- Large-scale lab studies under ventilated conditions show no exceeding of limits in the smoke gas for investigated heavy metals and hydrogen halides (the worst case was estimated). A precise consideration of thresholds is not possible because of the uniqueness of each fire event.
- As expected, toxic heavy metals, in particular lead (c-Si) and cadmium (CdTe), were measured in fire residue in quantities potentially exceeding the thresholds among the test samples. The inhomogeneity of the residue allows no generalizations to be made.
- The measured cadmium concentration in the quench water indicates possibly critical soil contamination from CdTe modules.

5 Optimization measures for product and system safety

5.1 Fire prevention

Following the introduction in the preceding sections to determining the risks and hazard potential from electric arcs in reference to fire emergence and firefighting, we now turn to generally applicable and specific measures for reducing risks.

Of main concern are the definitions and aims of preventive fire protection that can be derived above all from the requirements in the Model Building Regulation (MBO) or the State Building Codes (German: LBO). In this regard, the clear and succinct formulation in § 14 of the MBO applies:

Structural installations shall be arranged, erected, modified and maintained so as to prevent the emergence of a fire and the spread of fire and smoke and to enable in the event of a fire the rescue of human beings and animals as well as effective fire extinguishing operations.

In sum: solar systems must comply with this standard in full!

The Model Building Regulation (MBO) is the mandatory guideline for the construction industry. Since building law is state (*Länder*) law in Germany, the 16 LBOs of the respective German states (*Länder*) apply analogously with their requirements and definitions. The preventive fire protection must be understood as the sum of all measures preventing emergence and spread of fire.

§ 61 of the MBO, article 2, sentence b) states:

Solar energy systems and solar collectors in and on roofs and on outer wall surfaces as well as those independent of buildings with a height of up to 3 m and a total length of up to 9 m are construction projects not requiring authorization.

According to the MBO, solar systems belong to technical building equipment. “Not subject to authorization” does not mean that the MBO or LBOs do not apply. On the contrary, building law (fire protection, distance spaces, regulations governing the protection of historical buildings and monuments) and regulations on building products and types of construction, statics and stability and traffic safety must be complied with. As a consequence, the sum of all measures for preventive fire protection comprises many requirements pertaining to the installation, material selection and operation of the system in general as well as specific requirements;

- Compliance with building and installation regulations, building codes of the German states
- Advising of the technical authorities on construction and on requirements relevant to fire protection
- Careful planning with technicians
- High-quality material and components
- Proper execution and inspection
- Maintenance of the systems

The following sections will address the aforementioned general points in more detail. As an example, we single out building over fire walls. Fire walls in buildings prevent the spread of fires and prevent an increase in the fire propagation potential of burning material in an attic, for example. It is therefore

impermissible that solar systems bridge fire compartments and firewalls, since potentially combustible materials, such as polymer backsheets and cables, can promote fire propagation.

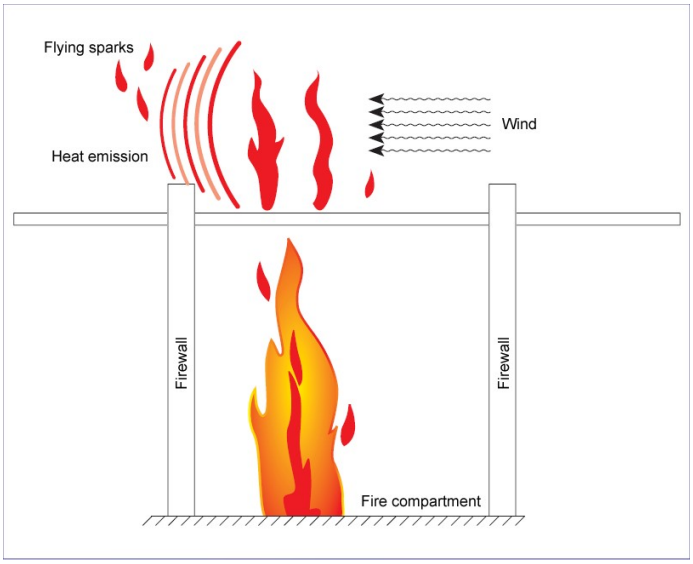


Figure 5-1: Functioning of a firewall, source: BSW

Special constructions as can be found among high-rise buildings (hotels, etc.) as per MBO § 2 also require further specifications. PV installations on facades must satisfy at least the requirement of *low flammability*, whereas for roofs *normal flammability* along with hard roofing (resistance to flying sparks and radiant heat) generally suffices.

In the matter of preventive fire protection, the building codes are supplemented by special building codes (regulation on places of public assembly, such as stadiums, regulation on places of accommodation, such as hotels, regulation on places of sale, such as shopping centers).

It must be ensured with the utmost care that no additional fire risks arise from PV installations or that such risks are reduced to a minimum. Improper installation and use of defective products as well as insufficient maintenance of PV systems can increase these risks.

In the following, this Guideline specifies in further detail the overview of existing rules and other measures for preventive fire protection and risk minimization in production and operational safety.

Conclusion

§ 14 of the MBO:

Structural installations shall be arranged, erected, modified and maintained so as to prevent the emergence of a fire and the spread of fire and smoke and to enable in the event of a fire the rescue of human beings and animals as well as effective fire extinguishing operations.

5.2 Quality assurance measures in production and their impact on risk assessment

5.2.1 Manufacturing process

Many errors and defects in the type of construction that can contribute to an increased fire risk can be avoided through improved quality control in production. To this end, TÜV Rheinland conducts regular company inspections (at least once a year) among the manufacturers, the purpose of which is to indicate any insufficient quality controls or inadequate quality assurance measures. According to a mandatory table defined for TÜV Rheinland inspectors worldwide, such defects and deficiencies fall either under the category of *recommendations* or under the category of *deviations*, with a *deviation* requiring rectification by the module manufacturer.

Manufacturers of crystalline silicon modules have undertaken a series of neuralgic production steps regarding any subsequent electric arc or fire risk. They include first of all *stringing*, in which the solar cells are generally interconnected to form a string in a soldering process. Nowadays this process is almost always fully automatic with so-called “stringers.” If important parameters like the soldering temperature and soldering time (depending on the employed cell) are not cleanly set or not exactly measured, soldering errors can occur that can lead to increased transition resistance and thereby to an increased electric arc risk.

TÜV Rheinland accordingly requires that manufacturers conduct regular (ideally inline) checks of the soldering temperature as well as regular calibrations of the sensors and measuring equipment. Proof of a regular *pull test* for the quality control of the connections at the contacts must also be provided.

Analogous problems can arise in the subsequent and in most cases manually performed connecting of the strings (*interconnection*). Here too the soldering temperature must be measured in any case and the employed measuring device calibrated.

As one of the final process steps, when the junction box is connected at the contacts the positive and negative terminals are generally fixed in place in the junction box mounted on the module. This is done either mechanically, e.g. with a clip fastener, or with a further soldering process for which the same quality requirements as mentioned above apply.

The production of thin-film modules involves the interconnection of monolithically manufactured cells generally with a longitudinal and a transverse contact strip. As with the crystalline silicon modules, the contact strips must be of the correct size. The strips are fixed in place through (e.g.) ultrasound welding or by soldering. Here too process monitoring must ensure that no disruptions in the current flow occur.

The junction box connection and the quality assurance requirements are the same as those in crystalline silicon module production.

Besides the inline tests, there are a series of useful offline tests for verifying the electrical and fire safety of the modules. They include the hot-spot test, which simulates the shading of individual cells, and the reverse-current test, which sends a current through the module in the reverse direction. In both cases critical heating levels can occur. TÜV Rheinland therefore recommends performing such tests with ready-produced modules.

It is also useful to perform incoming inspection tests on individual components of the module design, such as diodes and junction boxes, provided by other manufacturers. Diodes should undergo functional spot checks, since the failure of a diode may not be noticeable during regular operation in the field, depending on the nature of the failure.

In addition to their functionality, junction boxes can be inspected for good electrical insulation and as to whether they do not significantly increase the total series resistance. The adhesive bond of the junction box to the back of the module (often employing special glue supplied with the box) should be tested as to its adhesive properties through (e.g.) simple mechanical tensile tests. It is also recommended to check the firm seating of the box lid.

If the module design contains crimp connections, the transition resistance should be systematically measured and checked.

Another instructive aid is electroluminescence (recommended in offline mode, but should also be performed 100% inline) as well as infrared imaging (e.g. of modules in test operation), in order to detect defective or critical contact at an early stage. Electroluminescence imaging is especially useful *prior* to lamination, since cell fractures, micro-cracks, defective connections, etc., can then be detected in due time before the laminate runs through the further time-consuming and costly production stages. The imaging can also be performed for the final product, directly before delivery, however.

Mobile equipment can also detect possible electrostatic discharges at module components during individual production stages. For example, during the production process TÜV Rheinland can measure the static field charge on the backs of the modules that arises from transport of the modules from (e.g.) the box to the frame assembly. Should no suitable grounding measure (for discharging) be taken, the risk will then be that bypass diodes become damaged from a sudden static discharge on connection and are delivered to the field in defective form. While the issue of electro static discharge (ESD) must not be underestimated, it can already be avoided during production.

Generally, the introduction of new materials, as well as new suppliers of materials and components of modules, should be carefully inspected and undergo appropriate quality tests during production, since new materials often present a safety risk for the final module.

Complete traceability for the entire production process is also crucial (ideally on an *electronic* data basis), in order to connect any faults that become apparent only in the field to the corresponding conditions during the production of the defective modules. This traceability should comprise the employed materials and their suppliers as well as all process machinery, process parameters and quality tests undertaken for the corresponding batch of modules.

To ensure a constant level for all aforementioned quality tests and to minimize subjective influences in performance of the test, it is crucial that regular employee training units and sessions be conducted, documented and the acquired qualification levels summarized in (e.g.) a competence matrix. Work instructions should always be kept up to date and made locally available during the particular process steps.

Further qualification procedures are also useful, such as inline measuring procedures for checking the soldering quality between the cells (see section 5.2.3) as well as expanded requirement criteria for qualifying inflammable materials of modules and components; see example in section 3.3.

Conclusion

Trust is good, but testing is better!

A variety of options are available for internal quality control. Not to be forgotten is increased attention to supplied parts during production (such as junction boxes). For the standardization we recommend defining intensified quality assurance measures in production, on both the component and module levels. Many manufacturers already operate on a high level. A standardized quality assurance catalog makes a uniform measure of quality possible and allows the avoidance of risks through continual internal monitoring of the products.

5.2.2 Design modifications (module and system)

In the past, the further development of technologies for cell-cell connections generally led to the use of two busbars or cell connectors. An established standard today is rather three busbars (see section 3.4.1), or even wholly different types of connections, involving more than three busbars. The fact that cell connectors can detach from the cells or the connections or break up themselves as the result of thermo-mechanical load changes, production-related or purely mechanical effects, affects the probability of electric arc creation, given the number of available cell connectors. With at least three cell

connectors, the risk of electric arc creation as well as the premature reduction of power loss, related to increased transition resistance in the cell design, is already reduced. The current can then flow off via the other undamaged cell connectors.

For the special case of building-integrated photovoltaics (BIPV), electric arc safety plays an even greater role. Because of the replacement of top roofing layers by PV modules, the lower layers are freely exposed and especially endangered by an electric arc event at the back of the modules. Useful recommendations for the module design in BIPV applications can be derived from the consideration of the materials which, in the event of an ignition, have fire-propagating properties given the vicinity of an electric arc. In evaluating these materials the manufacturer or distributor must explore the possibilities of the following material/component specifications:

- Selection of the junction box: There exist non-combustible junction boxes that in the event of an electric arc in the junction box at least delay, if not prevent, fire propagation into the roof interior. Manufacturers must endeavor to conduct the appropriate tests and to discuss this form of risk minimization.

- Determination of backsheets with low FSI: Safety standard IEC61730 with the ASTM 162 standard requires that the Flame Spread Index (FSI) be determined for backsheets. The specification is that backsheet be max. 100. The FSI is influenced by the exhaust temperature during a fire and the propagation speed at the sample. Tests have shown that an FSI <10 is realizable. This entails relatively severe restrictions in the spread of a fire through the individual backsheet.

We can therefore recommend that sheets with these properties (FSI < 10) should be used with BIPVs.

Glass as backing substrate: For BIPVs the option of purely glass-glass modules allows dispensing with polymer materials as rear wall insulators. Here too such a material setup can minimize the risk of arcing. Certain encapsulation materials like EVA and PVB are used in the PV industry at a rate over 90%.

Individually (not in combination), the materials are highly flammable, but can also accelerate a heat release in the final module construction.

It therefore makes sense possibly to work with fire-inhibiting materials like silicone as encapsulating materials here too in the case of building-integrated PVs.

Conclusion

Given the varied areas of application of PV modules and the various requirements (e.g. BIPVs), the selection of suitable components must aim at increasing electric arc safety.

Risks can thus be reduced if the module design is adapted to the risk situations.

Similar discussions are also being conducted regarding the use of PV modules in various climates.

5.2.3 Safety qualification of modules and components

To ensure long-term reliability of the modules and components with an eye to reducing the risk of or avoiding electric arcs, different testing and control mechanisms have been developed that can be used for the components as well as for the module production process. Individual procedures are based on normative foundations and have been adjusted or supplemented.

Stricter conditions compared with current normative requirements are in part necessary in order to readjust damage patterns observed in the field.

Long-term resistance of cell connectors

TÜV Rheinland conducted comprehensive tests on partially defective PV modules (hotspots at cell connectors, micro-cracks) from the field. Here the PV modules were variously aged. The established temperature and moisture cycles were employed as tests from the IEC qualification (Thermal Cycling and Damp Heat). The PV modules were then mechanically and dynamically stressed with current feed (forward bias at 1,2…2 Isc). This stress especially affected the cell connectors and led to sharp local temperature increases.

Significant temperature differences compared with the surrounding materials and connecting appeared especially where increased transition resistance already existed.

Figure 5-2 shows an example of a module that after approx. 2,000 dynamic load cycles (as per EN 12211/12210) produced a fire burst as the result of a short electric arc in the pressure cycle at a cell connection point. While the connection technology of these modules (here: cell connectors soldered between the cells) are not the state of the art of secure connection options, here it was possible to produce an electric arc without artificially and mechanically damage to the cell connectors.

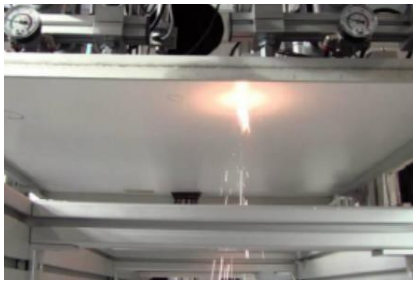


Figure 5-2: Electric arc within a PV module

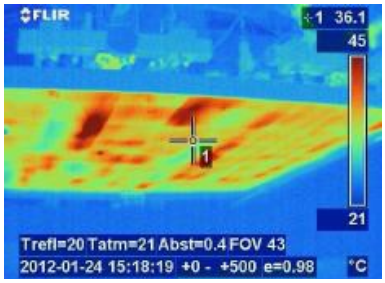


Figure 5-3: IR image

In the module shown the electric arc ignited at the moment of maximum pressure during the cycle. The entire current then flowed through the second busbar of the affected string. Here the remaining cell connector broke open in the next pressure cycle. Shortly thereafter the diodes were destroyed by the brief high voltage. The entire module current was conducted through the bypass diode. The diode was conductive, and a voltage could no longer be built up. In all tests, the modules underwent EL imaging and their IV characteristics were determined before and after the measurements, and during the stress tests the modules were observed through IR imaging.

In order to show the current flow distribution in a cell through EL imaging, an unstressed module from another manufacturer was prepared so that cell connectors were separated in a meandering pattern. The result was a zig-zagged course that the current had to follow. This induced a particular stress of the remaining intact cell connectors. After a brief mechanical stress period, no electric arcs occurred at the stressed cell connectors, contrary to expectations. The current flowed through the cell at the transition of a micro-crack lying exactly between the cell connectors. Here individual light flashes and scorching occurred along the crack; see Figure 5-4:

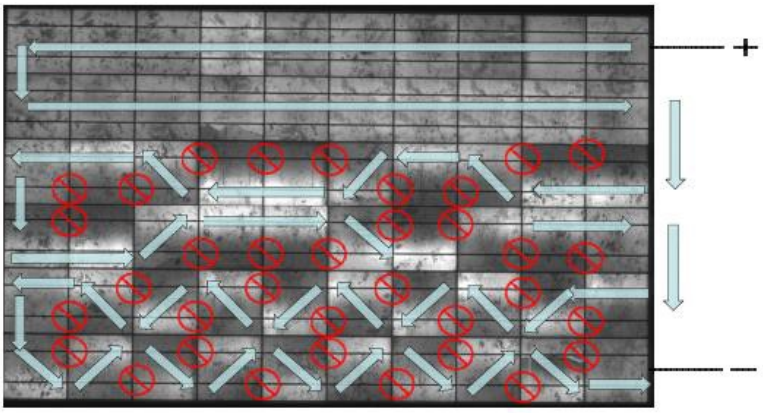


Figure 5-4: Prepared PV module with meandering transectioning of the conductor ribbons

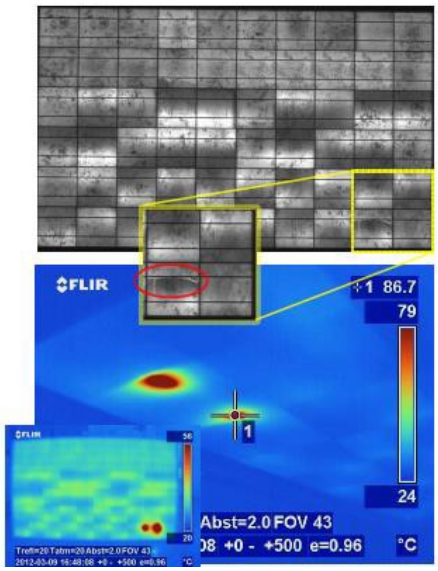


Figure 5-5: EL image with enlarged cell crack
Bottom: IR image with hotspots at the cell transitions

Figure 5-6: Marks along the cell fracture as the result of scorching and light flashes

Further tests were performed in which local scorching was induced on the backsheet of a further module and considerable temperature elevations were found at different modules. No further electric arcs occurred within 2,000 load cycles. An interesting finding in the dynamic load cycle was that temperature differences in the module of ± 10K can occur within approx. 15 s between the pressure load zero phase and the tensile load.

The following figure shows a test sequence that can indicate the reliability of contact connections. This sequence is one variant among other conceivable scenarios for subjecting modules to a particular stress through dynamic flexing. The conductor ribbons and in particular the contact connections in the module are dynamically stressed through stretching and compressing. Their sturdiness is a measure of “electric arc safety.” The dynamic stress here is based in each case on the load cycle sequence of EN 12210/12211.

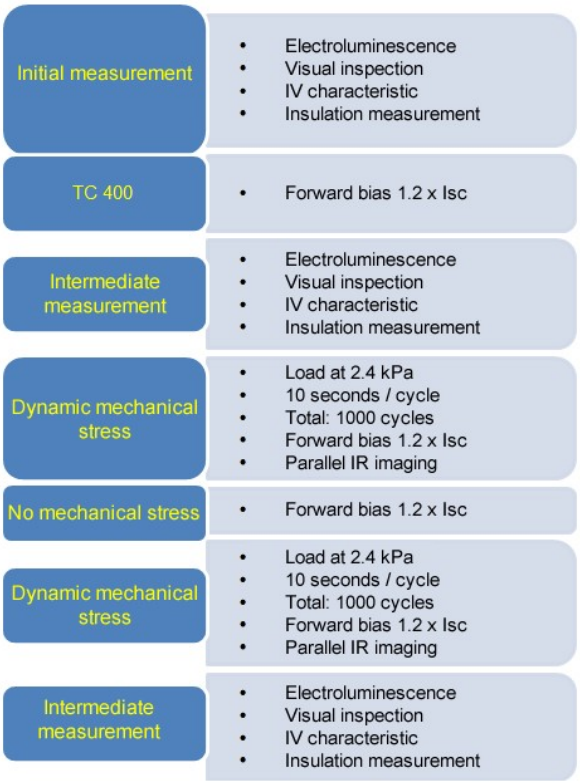


Figure 5-7: Test sequence for PV modules for determining electric arc susceptibility at cell connections

Before and after each stress step the modules must be examined for local temperature elevations by means of electroluminescence imaging and infrared imaging. Despite the long stressing procedure, no loss of contact or impairments from increased series resistance may occur.

We recommend random sampling for the accompanying tests during production, with new installations or modifications of materials or processes in soldering, lamination or stringing, continually through the entire production period.

Recommendation for standardization

Introduction of a dynamic mechanical test method with simultaneous current feed to the modules. A corresponding method should serve determination of the stress capacity of the cell connectors

Qualification of the soldered connection through inline measuring procedures

In addition to the methods mentioned in 5.1 for quality assurance in production, possibilities must be explored for monitoring the soldering quality at the cell connectors inline, i.e. as an integral part of production. Potential electric arc emergence sites were thoroughly discussed with the aim of reducing the risk of arcing.

Given an installed system output of more than 30 GWp in Germany, we easily recognize that the connections at contacts deserve particular attention with additional quality assurance measures. Given a module output of 200 W, around 150 million modules are installed at present with altogether about 10 billion solar cells (@ 3 Wp) and over 50 billion soldering points.
For checking cell connectors, in the following we describe a procedure developed at the Fraunhofer ISE and already presented in 1997 in Bad Staffelstein. [66]

The quality of the connection between two neighboring solar cells can be assessed without contact by means of capacitively or inductively induced currents. Figure 5-8 shows the basic principle of the inductive measurement method, in which an alternating current is pressed into the module and the current flow into the two cell connectors is registered by a current sensor. If the current splits unequally, a contacting fault exists.

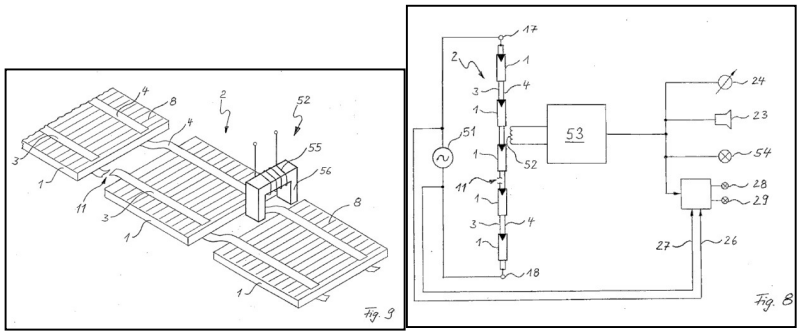


Figure 5-8: Schematic layout of the inductive measurement method for investigating connection faults between two cells.

A stress test (TC-1000 test as per IEC61215, -40°C – +85°C) indicated the suitability of the method for qualifying cell connections [28]. The increase in local transition resistance led to a reduction in performance (by approx. 50%). EL and IR imaging can reveal considerable impairment from the mechanical motions due to the temperature changes at the soldered points between or at the cells. In the EL image black cell zones represent inactive parts, while lighter areas indicate increased current density.

In practice, the module in an installation showed reduced performance, but the overall current flow was not interrupted. Nevertheless, temperature differences are discernible on the cell surfaces and cell transitions. Figure 5-9 shows that IR and EL images do not correlate 100% with one another. Consequently a detection method with higher resolution makes sense:

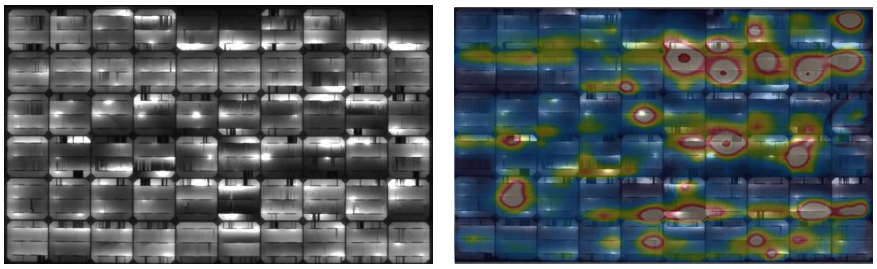


Figure 5-9: Comparison of EL and IR imaging at an aged module.

Here the cell impairment, especially at the cell transitions, is clearly discernible. A 100% correlation between IR and EL is not possible, however [28].

A series of tests employed an inductive method to measure the current carrying capacity of the cell connectors in the module shown above by coupling a high-frequency current per string via a function generator. At each of the cell transitions the busbars were measured with a sensor and their properties examined following the aging test.

The sensor basically consists of a coil with which voltages are inductively induced given the alternating field and in turn read out at an oscilloscope. Figure 5-10 shows the voltages induced in the inductive sensor by the string currents in the cell connectors (numbers designate relative sizes proportional to the string current). Here the differences in the current flows of the connectors are very clearly discernible.

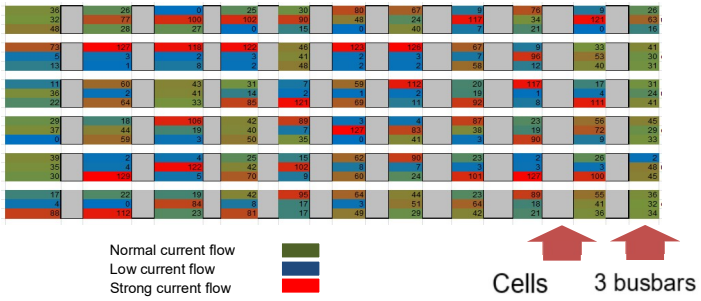


Figure 5-10: Voltage induced in the sensor by the string current in the cell connectors (relative magnitudes, proportional to the string current) **[28]**

These tests suggest using the same procedure to test and implement an inline method for module production.

Based on the inductive measurement method, parallel detecting sensors can thus be placed above a conveyor belt and during an intermediate step, for example before or after the lamination, they can be used to examine the conductivity and quality of the soldered connections as a function of position. Figure 5-11 shows this layout schematically:

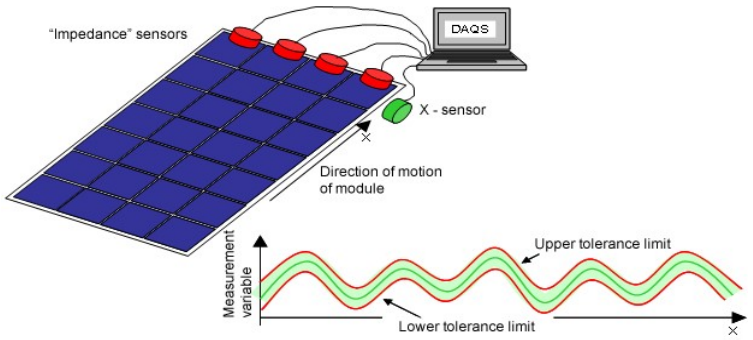


Figure 5-11: Inline method for detecting cell connection faults **[66]**]

Following the completed basic and successful tests, the following aspects are still open items and are recommended for further studies within a development project:

- Definition of permissible limits for deviations
- Correlation with other measurement procedures (EL, IR, etc.)
- Influence of lighting / current flow during the measurement
- Suitability for other cell/module technologies (e.g. back contact)
- Set up measurement stand with multiple sensors and measurement value recording
- Test combinations of different procedures
- Development of "intelligent" software (e.g. self-learning)
- Installation and testing of prototype system in a module production line
- Implementation in industrial product with industrial partner

Fire stress of components

With the application of solar modules in and on buildings, since 2012 solar modules have been declared by the DIBt as regulated building products with restrictions. These include roof-mounted, building-integrated and independent PV modules with an installation angle less than 75° and a mechanically held glass top of max. 2 m² [67]. If the modules are roof-integrated in a system, i.e. they replace the outer roof cladding, the distributor in Germany must hold a general building authority test certificate for sufficient resistance to flying sparks and radiant heat [67]. The state building codes require that building products be normally flammable if they are to be installed in buildings.

"Normally flammable" means meeting the requirements from EN 13501-1 with at least class E. This flammability classification describes a test method in which a matchstick-sized flame is applied to defined samples in order to examine the ignition.

Figure 5-12: Test method for flammability as per EN 13501-1

The usual fire classifications which the modules underwent come from the US UL 790 and describe a test method for roofs. The fire classes applied there are unfamiliar in Germany and should therefore be supplemented by appropriate categories that will provide the employed handicraft with a familiar assessment.

We therefore recommend specific labeling of the products according to the classification of the European EN 13501-1.

Since the PV modules usually do not meet the size requirements of the test method (ISO 11925-2) specified in EN 13501-1, an investigation at the overall product is not feasible. The module manufacturer can apply a corresponding declaration to the overall product if test records exist of the fire behavior both at the laminate and at other critical polymer materials. The ignition characteristics of the junction boxes, plug connectors and PV cables must be examined as per IEC 62790 (or EN 50548), IEC 62852 (or EN 50521) and prEN 50618 (or TÜV Rheinland 2PfG 1169) in a heating wire or gas flame test. Here it also assessed whether materials drip while burning or glowing.

Not considered to date are normative requirements and therefore component-oriented fire requirements for adhesive bonds. Internal as well as external lab tests must examine the bonded and adhesive joints between laminate and frame, but also with the junction box, and identify any deviations from the requirement from the European classification.

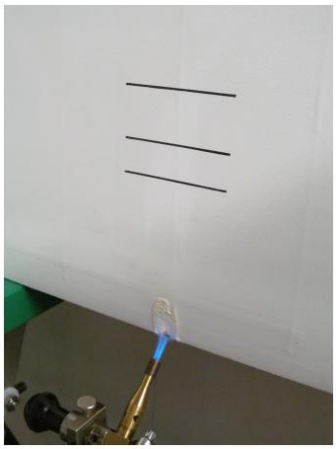


Figure 5-13: Material qualification for flammability

These tests serve material qualification but are not comparable to the EN 13501-1 classification given the test description.

Consequently, the fire behavior of the components and the module must be declared with respect to these requirements. This additional marking will help planners, architects and especially rescue workers in assessing risks of ignition.

In order to further analyze how the normative fire requirements for junction boxes are to be assessed, we conducted a series of comparisons with these specimens to determine the inflammability of box components.

The aim was to determine whether the test requirements from the established rules for module junction boxes are sufficient, so that the inflammability of materials in the event of an electric arc is sufficiently low.

A risk potential for electric arcing in a junction is generally shared by the bypass diode, introduction and connection of the main strings and the cable exit.

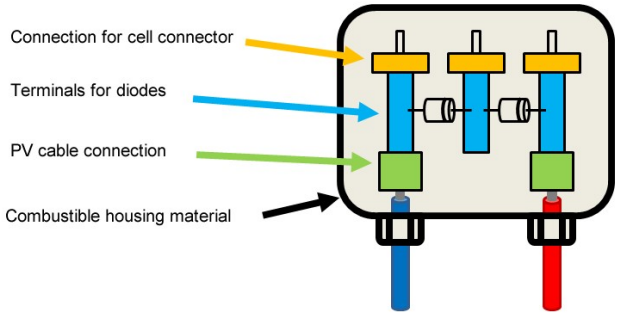


Figure 5-14: PV junction box with terminal connections

In the event of an electric arc, it must be assumed that surrounding materials will be stressed by the extremely high temperatures of the arc (> 5,000°C).

For the safety qualification it must be examined whether the surrounding materials can effect fire propagation in the event of an electric arc, i.e. whether material parts drip while burning or even continue burning on their own after the electric arc is extinguished. This is especially important if a switch or circuit breaker is used.

In this regard TÜV Rheinland has conducted studies going beyond the standard and supplementing the normative test background with realistic test arrangements. The fire tests were conducted based on the test as per EN 60695-11-20: this test is also referenced in EN 50548 for PV junction boxes. EN 60695 arranges all specimens in the upright position, however. Since modules are predominantly installed at an inclination of 20° to 60° (facade installations excepted), however, we also chose an inclined design for the test arrangement. As Figure 5-15 shows, we chose an angle between 30° and 50° in order to determine whether this arrangement would influence the fire properties of the junction box.

The purpose of this test setup was also to determine the critical character of the influence of any dripping materials on actual construction materials, such as roof membranes, insulation materials, etc., which is especially important when considering roof-integrated systems.

The test flame was applied to places where electric arcs could occur in practice in the event of a fault.

The flame impingement employed a 500 W flame as described in EN60695-11-20. Flame impingement cycles with impingements of 5 x 5 seconds with 5-second pauses in-between as described in this standard were used.

Figure 5-15: Flame impingement of lid in area of the line connections and flame impingement of the screwed cable gland of a specimen [source: TÜV Rheinland]

To determine whether the supporting surface could be ignited by dripping burning material, a thin layer of cotton wadding was placed 300 mm below the point of flame impingement, as also described in EN 60695-11-20.

The assessment of the test results was also based on EN 60695-11-20. To this end, the afterburning or afterglow time is recorded (Table 5-1) and it is noted down whether material has dripped and whether the cotton wadding underlayer ignited.

Table 5-1: Assessment criteria for test results (source: DIN EN 60695-11-20)

Criteria	**Category** **5VB**
Afterburn time with flame plus afterglow time after the fifth flame impingement	≤ 60 s
Did the cotton wadding ignite from burning particles or drops from the specimen?	No
Did the specimen burn completely?	No

Table 5-2: Overview – comparison of the performed tests with normative measurements

	Applied test setup	**Normative test setup (EN 50548)**
Specimen	Complete junction box mounted on support surface	Material specimen from final sample
Inclination	30° to 50° from the vertical	Vertical
Distance from support surface	300 mm	
Surface support padding	A layer of uncompressed cotton wadding	
Test flame	500 W flame as per EN 60695-11-20, calibrated as per IEC 60695-11-3	
Flame impingement	5 times (5 s impingement + 5 s pause)	
Point of application	From the outside, in area of the connection terminal for PV cable	Bottom edge of the specimen
Assessment	5VB as per DIN EN 60695-11-20 sec. 8.4 (see table 1)	

Altogether 45 inflammability studies were conducted. Samples from eight different manufacturers and altogether 19 different junction box types underwent testing. To confirm the repeatability of the tests, if possible more than one test was performed per junction box type and material.

Results

The tests have shown that most of the specimens were able to fulfill the criteria. Merely 13 flame impingements that had to be rated as “not passed”.

One sort of material was especially conspicuous because it continued burning for a long time in the altered arrangement and its burning droplets ignited the cotton wadding and the roof membrane material. In retesting with an arrangement exactly according to EN60695-11-20 the material did fulfill its requirements, however (!).

Other tests showed that often not the housing material, but add-on parts like union nuts at screwed cable glands or seals, promoted continued burning, which presents a risk in practice.

Conclusion

The tests presented here form the basis of studies on the behavior of the junction box components under the influence of a flame or electric arc, given the surrounding building materials.

Recommendation for standardization:

The concrete practical test proposal should be considered in a future adaptation for EN 50548 and should be integrated in a comprehensive product safety concept with an eye to practical installations.

Adhesive bond between laminate and junction boxes: tensile tests

The influence of defective laminate bonds between encapsulation materials and insulating backsheets of PV modules on the corrosion process (via diffused water) at connectors plays just as large a role in the long-term behavior from a safety perspective as mechanical integrity and the influence on performance characteristics. To determine the quality level of the adhesive bond between the laminate parts, we can determine the adhesive forces through tensile tests – through measurements also before and after simulated environmental conditions.

Comparative tests at TÜV Rheinland [68] show that the quality of the laminate installed in the field greatly varies in terms of tensile strength (Figure 5-17 and Figure 5-18).

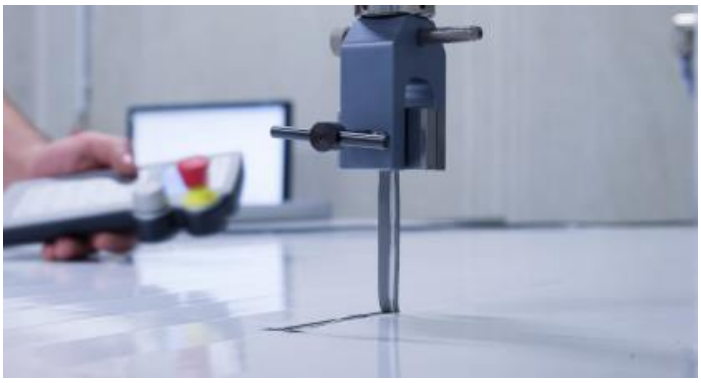


Figure 5-16: Test stand for testing the peel-off force

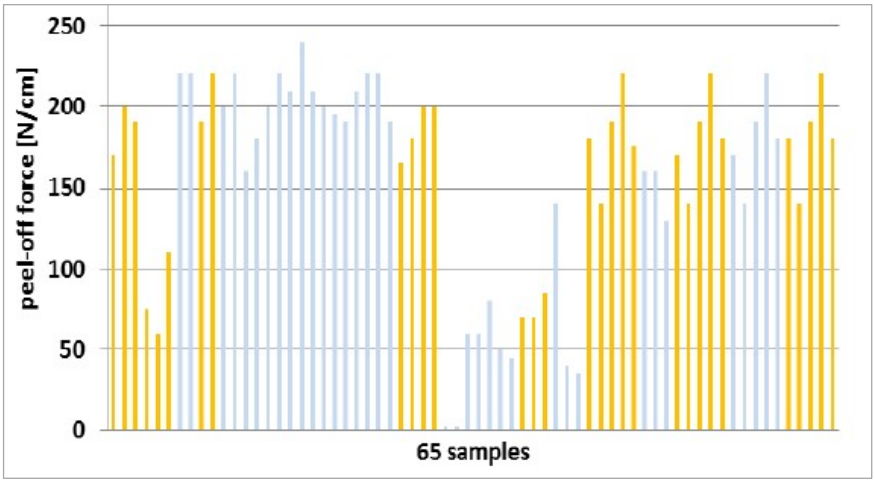


Figure 5-17: Comparison series for determining the tensile strength of laminate bonds between EVA and backsheet

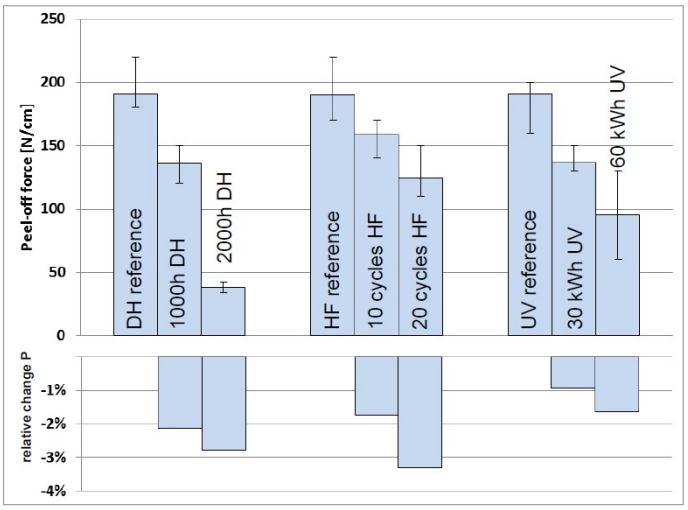


Figure 5-18: Determination of aging before and after simulated environmental conditions in the case of the adhesive force of laminate layers.

The adhesive force is influenced by aging. Environmental effects make the backsheet brittle. Besides affecting the insulation properties, this condition also accelerates contact aging.

To determine the laminate quality, generally the following mechanical properties can be investigated:

- Tension-elongation diagram of before and after aging
- Yield stress and tensile strength
- Change in the elastic modulus

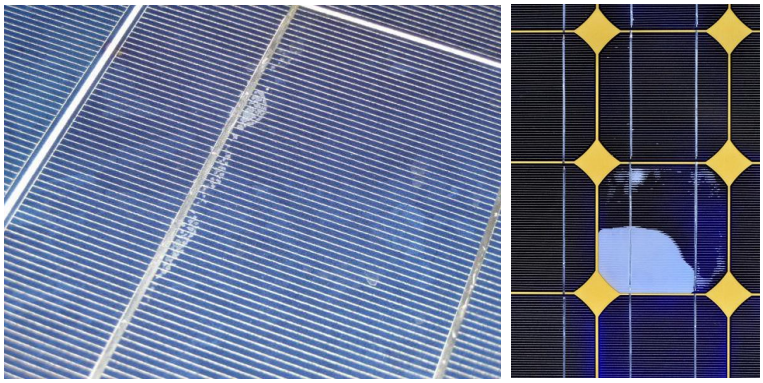


Figure 5-19: Example: delamination near a busbar.

Regarding the retention force of junction boxes, applicable standards, e.g. within the UL 1703 (standard for flat-plate photovoltaic modules), require that the connecting cables within the wiring compartment test be tested with the maximum weight of the module, but at least with 155 N. This is equivalent to stress that would occur if clearly incorrect handling in practice led to modules being improperly transported on their backs and held at the connecting cables.

This high retention force certainly deserves further discussion, since in practice stress would be explainable only by untrained installation personnel, which despite testing would be avoidable. Moreover, the wiring compartment test is defined, in which the connecting cables are pulled with 89 N along different directions. These stress requirements govern the robustness of termination test from IEC 61215 (or IEC 60068-2-21), in which the connecting cables are pulled with less than 40 N.

In the current standardization discussion for Edition 3 of IEC 61215, the test is also to be adapted to handling situations in practice, with stressing depending on the conductor cross sections (up to 155 N with 55 mm conductor cross section). A torsion test is also included that is to simulate cable twisting during installation. In addition, the new edition will also require an investigation of the retention force of the junction box (with 40 N for 30 minutes), which will stress the adhesive or adhesive bond to the backsheet. The test result is assessed according to the insulation properties (creepage distances).

With natural, vertical tension, depending on the weight of the cables and plugs, the weight is only a few grams. The existing tests refer to the sufficient retention force of screwed connections or permanent connections between the junction box and module cable, but also to the durability of the adhesive bond between the junction box and the backsheet.

From the aforementioned test sequences, the IEC test standard provides application-oriented definitions for investigating the retention force of the module cables at the junction box in spot checks during production, whether at the incoming goods inspection by the supplier or on delivery of the completed PV module.

Determination of contact resistance at critical connections in the module junction box

The currently planned modification A2 within EN 50548 and the planned first edition of IEC 62790 (“Junction boxes for photovoltaic modules”) define additions pertaining to requirements relevant for fire protection. They refer primarily to the reliability of contact connections inside the junction box. For the improved qualification of the contact resistance, measurements are performed for determining the contact resistance between connection points for the module cable and for the cell connectors inside the junction box. The comparison measurements are performed before and after the temperature cycle test.

The contact resistance may altogether have an initial value not greater than 5 mΩ and after the aging tests must not be greater than 150%. For the measurement, the junction box is short-circuited to the cell connector terminals and fed 1 A (Figure 5-20).

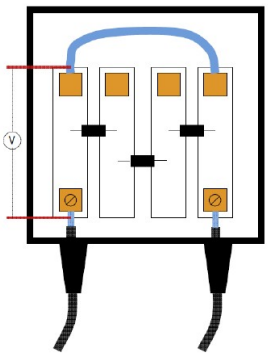


Figure 5-20: Measurement points for determining the contact resistance within the junction box standard (EN 50548:2011 + A1:2013)

Moreover, internal plug connectors (inside the junction box) must meet the applicable requirements from EN 50521:2008/A1:2012 or IEC 62852 ed. 1 (FDIS) ("Connectors for photovoltaic systems"), where the accelerated temperature cycle test here has a cycle number of 800.

An impending amendment to part 1 of the safety standard for PV modules, EN 61730-1:2007/A11:2014: *"Photovoltaic PV) Module Safety Qualification - Part 1:* Requirements for Construction," requires for Europe that components like junction boxes and connectors fulfill the aforementioned standard requirements. This has so far not been the case in the IEC version. Here people are continuing to work on improving the safety standard by means of a second edition of the IEC 61730 series.

Inflammability of backsheets

At present, IEC 61730-1 requires of backsheets a so-called flame-spread index with a maximum value of FSI 100 via the ASTM standard E 162. This value is computed from the propagation properties of the flame at the test specimen within predefined measuring marks. Besides the flame propagation speed (the faster, the higher the FSI), the temperature in the exhaust unit also determines the result.

Series of comparison tests were performed on backsheets and frontsheets according to different methods (ISO, ASTM, UL) using specimens from different sheet manufacturers.

The purpose of the studies was to determine tendencies among the materials and their properties and to allow a qualitative preselection of module materials as components of the laminate by means of a suitable development of test methods.

In the past, an estimate of fire behavior was lacking for the final product. For the tests, APA, ETFE, PPE, TPT and PA (as a conventional vapor barrier) were available as materials: Besides the aforementioned ASTM standard, we also employed the ISO standards 11925-2 (also important as a test basis for the construction material classification), ISO 5658-2 and 95/28 EC.

Table 5-3: List of specimens and applied tests.

Lab no.	Letter	Test	Dimensions	Thickness	Material	Quantity
L20056A	A	UL 94	200*50	0,43	APA	15
L20056B	A	ISO 11925-2	250*90	0,43	APA	12
L20056C	A	ISO 5658-2	800*155	0,43	APA	3
L20056D	A	95/28 EG	560*170	0,43	APA	3
L20057A	B	ASTM E 162	457*152	0,1	ETFE-frontsheet-F1	4
L20057B	B	ISO 11925-2	250*90	0,1	ETFE-frontsheet-F1	12
L20057C	B	ISO 5658-2	800*155	0,1	ETFE-frontsheet-F1	3
L20057D	B	95/28 EG	560*170	0,1	ETFE-frontsheet-F1	3
L20058A	C	ASTM E 162	457*152	0,28	TPT	6
L20058B	C	ISO 11925-2	250*90	0,28	TPT	24
L20058C	C	ISO 5658-2	800*155	0,28	TPT	6
L20058D	C	95/28 EG	560*170	0,28	TPT	6
L20059A	D	ASTM E 162	457*152	0,35	PPE	4
L20059B	D	ISO 11925-2	250*90	0,35	PPE	12
L20059C	D	ISO 5658-2	800*155	0,35	PPE	3
L20059D	D	95/28 EG	560*170	0,35	PPE	3
Climatic mem.	E	ASTM E 162	457*152	0,06	PA (vapor lock)	6
Climatic mem.	E	ISO 11925-2	250*90	0,06	PA (vapor lock)	14
Climatic mem.	E	ISO 5658-2	800*155	0,06	PA (vapor lock)	4
Climatic mem.	E	95/28 EG	560*170	0,06	PA (vapor lock)	6
Climatic mem.	E	UL 94	200*50	0,06	PA (vapor lock)	12

In summary, we can say that the fire behavior was similarly assessed for all test samples in each test. The statement on the quality of the materials is thus reflected in each test application, so that initially all methods seem equally suitable.

In the case of ISO 11925-2, not only was the individual specimen tested, but a laminate as well, with calcium silicate (CaSi) serving as a substratum, a composite material. The sheet specimen was then clamped, not bonded, to the CaSi. The results greatly deviated from those without CaSi, so that a test with individual films (consistently negative except for ETFE) is not comparable with a final-application test. CaSi support shows flame propagation similar to that with the construction material classification at the final product (module as material composite).

Films C and D show severe fire behavior, which in reality would not occur as such in the material composite, however. Thin films generally behave better. They quickly withdraw from the heat by melting. In the material composite, the PVB or EVA again determines the fire properties, which are potentially worse compared with the backsheet films, which in the case of thinner backsheets could potentially pose a problem.

All tests are suitable for making a preselection of backsheet films. They are no substitute for final-application testing of material composites, however. The ASTM standard does not suffice for making a reliable inference from the backsheet film to the module as the overall product.

Nevertheless, all standards offer the possibility of determining the quality of the individual materials. ASTM E 162 and ISO 11925-2 allow use of CaSi as a substrate, a use that based on comparisons with final specimens (module: test at backsheet film; see also 02/2011) promises a significant trend.

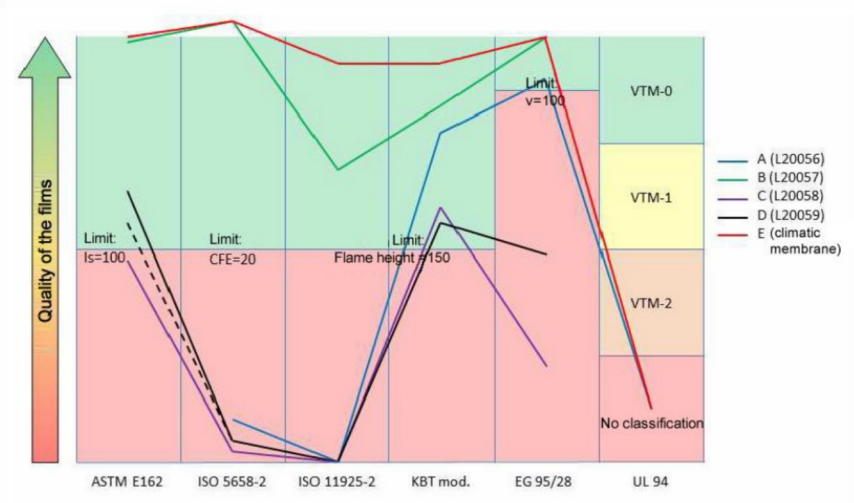


Figure 5-21: List of specimens and applied tests.

Recommendations for standardization:

We recommend including final-application tests as per the requirements in IEC 61730-1. A flame propagation and inflammability test on the individual polymer backsheet film alone is not sufficient.

Given the experience of Currenta and TÜV Rheinland in roof stress testing as per UL 790 (fire test within IEC 61730-2) on modules, we also recommend, in individual tests of backsheets, considering the later inside of the film in a flame propagation examination, since here other materials than the actually declared film core layers may sometimes be used.

These results and findings are being provided to the WG 2 standardization of the IEC TC 82 and have also been incorporated in current drafts of a revision of the IEC 61730.

5.2.4 Transport safety measures

The preceding sections have described the fire risk potential of cell cracks. In a concrete case, minor fire damage occurred along the cell crack from a current flow running diagonally through a cell (as the consequence of poorly connected cell connectors). In response to this issue, this Guideline also includes a note on transport safety and cargo safety.

Mechanical vibrations and shocks occur from transient or oscillating motions during transport, with the transport cargo being shifted from its rest position from bumps on the road or even handling.

Series of tests determined the resonance frequencies of modules (at approx. 11 Hz) under the effects of vibrations (shaking platform) during longer periods of action. In individual cases the stress sufficed to produce cell breakage and damage [69]. Other influences during transport can affect not only the mechanical cell stability, but also tension in the glass (as with oblique loads).

If incorrectly positioned during transport, module backsheets are endangered by contact with the forklift, through rod pressure, prong insertions, etc.

Figure 5-22: Left: incorrect handling with pressure from forklift prongs, right: improper transport of solar modules.

To reduce the risk of damage during transport as much as possible, influential factors critical to performance and safety must be avoided. The aforementioned damage to backsheets (scratches, detachment of materials) have been discovered in practice and present a considerable risk even prior to operation of the system, due to errors in transport and handling or to inadequate packaging.

We therefore recommend using only qualified packaging certified according to the international standard IEC 62759-1, for example. In accordance with this standard packaging is inspected as to its suitability for transporting PV modules.

5.3 Safe system operation

5.3.1 Prevention of electric arcs/overheating – selecting and dimensioning components

To prevent fire incidents, it is important to avoid electric arcs and local overheating in the PV system.

Here the focus must lie on the best possible quality in *component selection, planning, installation and maintenance*, despite the existing price pressure. An electric arc has a much higher probability of occurring in a poorly constructed PV system than in a high-quality one. Component manufacturers as well as planners and installation companies should take the appropriate measures and comply with the appropriate specifications.

5.3.1.1 Selection of suitable components

The first step in installing a PV system is the selection of its components. Modules, plugs, cables, inverters and other components should be selected that present the least risk of fire. This will be the case if the component manufacturer attends with the utmost care to the quality of the connection points.

Regarding **modules**, the manufacturer must minimize the number of soldering points and maximize the quality of the soldering, including inside the junction box. Spring-type terminals should be preferred over screw terminals. Carefully arranged strain relief at the module connecting cables can prevent stress at the cables leading to consequential damage at the connection to the junction box.

Plug connectors should visibly and firmly snap in and maintain a permanently low transition resistance. Generally, contemporary systems from brand names should be installed as plug connectors and collective boxes.

With screw terminal systems the danger of an unstable and therefore potentially hazardous connection is much higher than with contemporary spring-type terminals, so that the former should no longer be used.

Solar cables must be UV-resistant to a high degree and always be double-insulated, since then the risk of a parallel electric arc will be significantly less.

Inverters with integrated insulation monitoring have the effect that an (initial) fault to ground will already be noticed, practically preventing an indirect connection of both terminals via the ground potential.

5.3.1.2 Planning regarding electric arcs

The detailed planning of the PV system design can itself contribute much to fire safety. Conversely, some coarse faults should be avoided when planning the system, since they significantly increase the risks of fire emergence.

Current PV modules are equipped with bypass diodes that prevent high block voltages at the cells in the event of partial shading and thereby guard against overheating, or so-called hotspots, in the module.

These bypass diodes can fail, however. Possible causes are overvoltage during manufacture, transport or installation, but also during operation in the vicinity of a lightning strike.

Persistent or frequently alternating shading events also often lead to thermal overload and increased cycle stress of bypass diodes.

Generally the best protection against hot spots is therefore to install modules so as to avoid shading, in particular for longer periods of time, as much as possible. Especially sharply cast shadows from intense insolation are harmful and should not occur. Less critical are shadows in the morning or evening such that the sun rays are incident at a relatively flat angle, so that the currents and additional heating are relatively low.

Often safety components like **fuses and switches** are integrated in the DC part of PV systems. In the individual case it must then always be checked whether this measure is really necessary. Each additional component poses the risk of additional contact points and other sources of faults. A “sleek” system with as few components as possible has the advantage of having fewer points where damage could occur to the system.

Smaller systems with fewer than three parallel strings require no string fuses, since the modules can sustain any reverse currents that these fuses would otherwise prevent from occurring [35]. This applies to most roof systems on single or multi-family houses. If the use of fuses is nevertheless necessary, they must be able to meet the special requirements of photovoltaics, in which the rated operating current is hardly less than the short-circuit current.

The same applies to the installation of switches in the DC wiring. Power can then be switched off to parts of the system, which can be useful in repairs or other structural measures or in case of fire department rescue operations (“fire department switch”). Concerning the risk of fire emergence in a PV system, however, additional switches are simply yet another source of faults, so that it must be considered whether the protective goal could not also be achieved by protecting the DC cable against contact by routing it under plaster or through cable ducts, for example.

Should switches nevertheless be installed, they must be designed for the special requirements of photovoltaics – it is not enough to use ordinary DC switches and comply with the specifications on maximum currents and voltages, since photovoltaics presents a current-voltage characteristic different from ordinary DC voltage sources.

A fatal error that is nevertheless occasionally made is to **place system components in areas with highly inflammable materials**, such as straw, litter and sawdust.

In particular the inverters, which themselves generate heat, must never be used in such surroundings.

Other components, such as cables through such areas, can also increase the risk of fire, since heating or even a spark in the electrical installation can cause a fire.

5.3.1.3 Proper installation

The company performing the installation is especially important when it comes to setting up fire-safe PV systems. Damage has often occurred in the past due to gross deficiencies in installation.

Especially critical installation flaws occurring in the past concerned the installed **plug connectors**. Very dangerous and unfortunately occasionally occurring faults concern the incomplete insertion or coupling of plugs from different manufacturers. The latter problem can occur if different plug connector makes

are mechanically compatible with one another. Notwithstanding this mechanical compatibility, the transition resistance can increase, leading to increased heating and long-term damage to the connection. In installing connections on site a suitable tool must be used to ensure the optimal contact pressure.

Other wiring problems concern **unsuitable cable routing** without sufficient fastening, running over sharp edges, disregard of minimum bending radii and construction over **fire protection compartments**.

To avoid flashovers from conductors that may conduct lightning currents (**lightning arresters)** to the components and to the wiring of a PV system, a distance of at least 0.5 m should be maintained (see also section 3.5.1). DIN EN 62305-3 (VDE 0185-305-3) contains a calculation of the (minimum) separation distance.

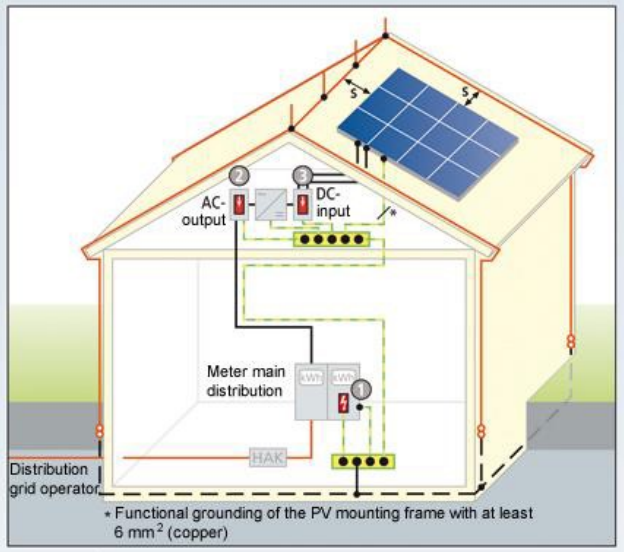


Figure 5-23: Surge protection concept for a PV system with external lightning protection with separation distance s; source: Dehn, Blitzplaner **[70]**

This does not concern the equipotential bonding conductor, however, which should always lie close to the DC cables. In addition, the size of the loops formed by the wiring must always be kept small, so that a lightning strike can at most induce surges of minimal danger.

At the same time, however, the risk of a parallel electric arc, i.e. contact between two conducts of opposite polarity, must be kept as low as possible.

Both requirements are fulfilled by routing double-insulated cables alongside one another or – ideally – routing the two main lines in two directly adjacent cable conduit systems or in conduit systems separated by a partition. The use of separated conduit systems for positive and negative is required only when laying the cables through combustible surroundings.

Occasionally installers are observed suspending modules from the cables for the sake of convenience. Even if the connection terminals of the cables typically come with strain relief, they are not designed for such stress. This practice must absolutely be avoided.

If **string fuses or DC switches** are to be used, they must be able continually to bear the system current – the current carrying capability can decrease due to heating if components are installed directly next to one another.

All specified distances must also be absolutely heeded when **installing the inverters**. While often neglected, this can have serious consequences if system components fail or even catch fire from the resulting overheating. Not permitted is mounting on combustible materials like wood.

If not already taken care of in the system planning, a professional installation company should now at the latest fully avoid installing system components in **surroundings with highly inflammable materials** (such as hay, straw, sawdust, fuels, etc.).

5.3.1.4 Acceptance inspections and regular maintenance

Besides the items to be contained in the system documentation, DIN EN 62446 (VDE 0126-23):2010-07 also describes the following tests and measurements for commissioning, as well as the recurring inspections and measurements for operation without unpredictable legal risks

(compiled on the basis of the following information: [71])

All tests should be performed during assembly and on completion in reference to IEC 60364-6 (DIN VDE 0100-600:2008-06).

Inspection of the DC system:

- Proof must be submitted that the DC system in general has been designed, selected and installed as per the requirements in IEC 60364-6 and in particular the requirements of DIN VDE 0100-712.
- The DC components are designed for operation with direct current and the highest possible voltage of the DC system as well as for the highest possible rated current.
- Protection by application of protection class II or equivalent insulation at the DC end has been implemented.
- PV string cable, PV generator cable and PV DC main cable have been selected and installed so as to minimize the risk of short-circuiting to ground and other types of short circuits; this is usually achieved by means of cables with protective insulation and reinforced insulation (often called “double insulation”).
- The wiring system has been selected and installed so as to resist expected external influences, such as wind, icing, temperature and insolation.
- For systems without string overcurrent protection, the string cables must be dimensioned greater than the theoretically possible maximum reverse current, for safety’s sake. The string

cables must be routed so as to handle the maximum additive reverse current from the parallel strings.

- Strings may be connected in parallel only given identical string polarity and approximately identical open-circuit voltage, otherwise hazardous faults not manageable by protection systems may occur.
- String overcurrent protection devices for systems must be installed and correctly designed according to the local technical connection conditions or according to the manufacturer's instructions for protection of the PV modules.
- A direct current load-break switch at the DC end of the inverter must be installed.
- If string diodes are installed, their block voltage must be at least 2·x UOC at STC of the PV string. While unusual, protective circuits (such as surge suppressors, snubber capacitors connected in parallel) should nevertheless be considered.
- If a DC conductor is grounded, at least a simple partition must exist between the AC and DC ends. The ground connections must be protected against corrosion.
- If protection potential equalization conductors are installed, they must run parallel and in the closest possible distance from the DC and AC cables or lines and the accessories.

Surge protection:

- The areas of all wiring loops must be as small as possible in order to reduce voltages induced by a lightning strike.
- Existing protection potential equalization conductors of the PV generator frame must be grounded. These conductors must be arranged parallel to and have the closest possible contact with the DC cables.
- The module frames need not be individually grounded.

The **alternating current system** has been generally designed selected and installed as per the requirements in IEC 60364 and in particular the requirements of DIN VDE 0100-712:

- At the AC end, a device must be planned for disconnecting the inverter, by means of the upstream line fuses, for example.
- All circuit breakers and switching devices must be connected so that the PV installation is located at the “load end” and the public power supply is located at the “feed-in” end.
- Operating parameters of the inverter must be programmed according to the local technical connection conditions or according to the manufacturer's specifications.

All circuits, protective devices, switches and connection terminals are **suitably labeled**:

- Warnings about voltage after disconnection from the power supply must be attached.

- The AC main switch must be clearly labeled.
- At the interconnection point warnings must be present for the dual supply.
- A schematic wiring diagram must be posted on site.
- The protective settings of the inverter and details of the installation must be specified on site.
- Emergency shutdown procedures must be specified on site.
- All labels and markings must be permanently and suitably affixed.

Test steps:

The following part discusses the measurements required in the standard VDE 0126-23, in order to explain to the technician the necessary test steps and their technical implementation in everyday work.

1. Test of all AC circuits as per DIN VDE 0100-60
2. Inspection of the DC system
3. Continuity testing of the protection and bonding conductors
4. Polarity test of each string
5. Test of the open-circuit voltage of each string
6. Test of the short-circuit current of each string
7. Function test
8. Insulation resistance measurement of the DC circuits

While this sequence of measurements in the standard is not always the quickest way for the technician, the test steps should be logically performed in the specified order.

The measurements on the opened string should be compiled, i.e. the function test should be performed with commissioning of the inverter only after the insulation measurement.

Electric arcs in a PV system typically do not occur abruptly and without previous indications, but are usually triggered by aging phenomena (degradation). Signs are already apparent in advance. **Regular maintenance** (e.g. every 2 years) can identify critical points in due time and rectify the causes of faults.

The most important test here is a **thorough visual inspection of the system** by a professional. Much damage can be easily detected by the naked eye. They include module breakage, discoloration or deformation of modules and junction boxes, porous or abraded cables, plug connectors melted by heat and excessive dirt.
Heat build-ups can be detected especially effectively using an **infrared camera**. Both the modules and the BOS components can then be checked and excessively heated components promptly replaced.

DC switches installed in PV systems are usually operated only in the case of a fault. If the system is running normally, it is always switched on. Switches often have the property that their transition resistance significantly increases if not operated, however. This can lead to heat build-ups which in the

long run can become electric arcs. For example, a switch actually intended as a safety element can certainly cause a fire if regular maintenance is not performed.

Some switch manufacturers recommend **operating their DC switches ten times in succession once a year.** Any oxide layers will then rub off and the transition resistance will significantly decrease [72]. In addition, this practice can prevent the contacts of a switch from sticking when operated.

This measure is urgently recommended for all mechanically operating DC circuit breakers.

An important goal of maintenance of a PV system is the discovery of **defective bypass diodes**. Open bypass diodes in particular are relatively difficult to detect, but the occurrence of a second fault can promote the occurrence of an electric arc. As long as the solar module is free of faults and not shaded, failure of a bypass diode will not impair the PV system. The protective function performed by the diode will no longer be available, however. Shading will then lead to intense heating of the affected module areas and to considerable yield loss.

More serious from the perspective of fire protection is the fact that an additional interruption of the current path in the module (e.g. ribbon tear-off, micro-cracks, etc.) makes the occurrence of an electric arc quite probable, however.

During maintenance, *fully alloyed (permanently conductive) bypass diodes* can be discovered with the aid of an infrared camera from approx. 300 W/m² irradiation owing to a slightly higher temperature of the affected module section (see Figure 5-24)

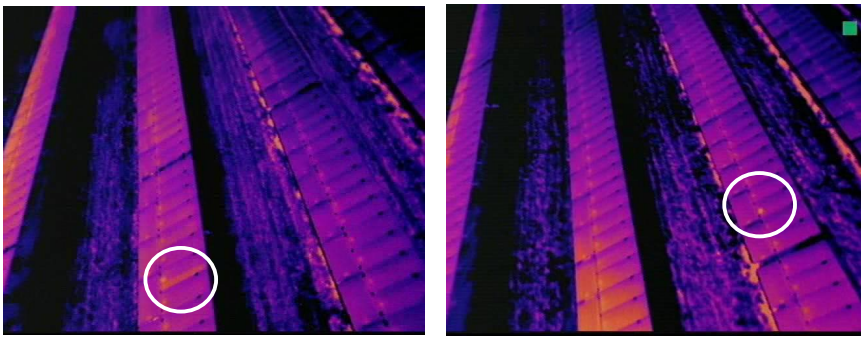


Figure 5-24: Left: heated bypass diode and affected right string, right: significantly heated bypass diode in IR overview image from drone in an approx. 5-year old open-space installation, photo: TÜV Rheinland

Another, irradiation-independent and reliable detection method is the **comparative measurement of open-circuit voltages** of the individual strings.

On the other hand, the case more relevant for fire protection, namely *partially conducting or open-circuit bypass diodes*, is more difficult to discover. If the PV connection diodes can be examined with an infrared camera, a partially conducting bypass diode can be identified from its significantly increased temperature (Figure 5-24, right).

Here too there are proposals for wire-bound measurement methods, listed in section 5.5. The search for defective bypass diodes is urgently necessary *following a lightning strike at the PV system or after a lightning strike at a lightning protection system in the immediate vicinity*.

5.3.2 Installation specifications (system planning including fire protection planning)

The planning and installation of PV systems must attend to fire protection. The corresponding fire protection requirements of the Model Building Regulation as well as any other building requirements, the professional fire protection rules and the VDE application rule VDE-AR-E 2100-712 must be complied with.

In March 2011, the German Solar Industry Association (BSW), the German Solar Energy Society (DGS), German Electrical and Electronic Manufacturers' Association (ZVEH), the Munich Professional Fire Department and the Registered Federal Association of Technical Planners and Experts in Preventive Fire Protection (BFSB) jointly issued the professional rules for the “Planning, Installation and Maintenance of PV System for Fire Protection.” These rules were also coordinated with the Consortium of the Heads of Professional Fire Departments in Germany (AGBF Bund), and are therefore recognized as state of the art.

Compiled here are the pre-existing requirements of the various rules & regulations for buildings and electrical installations. Gaps in regulations are identified and measures presented for filling them. The professional fire protection rules were developed by an interdisciplinary working group comprising fire department, fire protection and PV experts, fire protection building contractors, planners and installers.

For details on the issues, every installer and planner is advised to download the information at **www.dgs-berlin.de** (see Appendix, p. 249). It can be ordered in brochure form from the BSW at **www.solarwirtschaft.de**.

The quality of components, planning, construction and installation crucially affects the risks of operating errors that can lead to fire emergence (from an electric arc, for example).

The modules and inverters should have the corresponding **certificates**. DIN VDE 0100-712 on “Low-voltage electrical installations - Part 7-712: Requirements for special installations or locations – Photovoltaic (PV) systems” states the mandatory foundations of the installation. This standard also entails mandatory compliance of the system with protection class II.

The **plug connections** must be professionally performed. No variations in plug connections or unsuitable plug connections may be used.

Only **suitable PV string fuses** as per draft standard IEC 60263-6 should be used. Systems with one to three strings need not contain fuses. Note: Unsuitable fuses or the unsuitable design and installation of fuse holders increase the electric arc risk!

Generally **inverters with insulation monitoring** must be used. In addition, proper integration in existing or necessary **lightning and surge protection systems** is essential. The requirements of lightning and surge protection in particular according to standard supplement sheet 5 of VDE 62305-3 on “Lightning

and Overvoltage Protection for Photovoltaic Power Supply Systems" should be heeded and complied with.

The modules and cables should be **professionally mounted**. PV modules should be mounted on site as per the module manufacturer's assembly instructions and with inspection of snow and wind loads as per DIN1055 parts 4 and 5 or Eurocode 1. This inspection should also occur for the mounting system, e.g. by means of system statics and for the transmission of stress to the roof structure or building.

Errors and flaws in the electrical installation can be discovered through inspections as per EN 62446 on "Grid-connected photovoltaic systems – Minimum requirements for system documentation, commissioning tests and inspection".

The generally recognized state of the art, standards and certifications, guidelines and rules based on them, as well as instructions of the "DGS – Guidelines on Photovoltaic Systems," should be heeded. They provide the foundations for good PV system quality.

DC cables, inverters or generator junction boxes (GJB) must not be installed in the areas of stairs or exits.

Electrical components like GJBs and inverters must be installed on non-combustible supporting surfaces.

In particular, cables should be professionally selected, installed, mounted and routed. Only suitable cables compliant with the "Requirement Profile for PV System Cables" as per VDE-AR-E 2283-4, designation: design PV1-F, should be used outdoors, for example.

Mounting and strain relief according to regulations as well as permissible bending radii must be heeded. Cables must not be routed over sharp edges.

Cables should be protected against gnawing animals not only in rural areas (raccoons in urban environments).

Notes on safe installation sites for inverters

The ventilation slots and heat sinks of inverters must be free to ensure optimal cooling.

For the same reason the devices should not be installed closely above one another. Here the manufacturer's specifications must be absolutely followed.

Inverters must not be mounted on wood walls or on other combustible materials!

A metal plate serving as a shield between the inverter and a wood wall is not recommended, since the plate will conduct the release heat of the inverter, restrict the air exchange with the wood and therefore make self-ignition possible.

A structural panel of construction material class A1 (= non-combustible), such as calcium silicate with a thickness of 15 mm and protruding 10 cm all around, is best suited as a foundation. Inverters should not be mounted in areas containing combustible materials.

The devices should be protected against aggressive fumes, water vapor and fine dust. Ammonia fumes can occur in barns or stalls, for example, and cause damage to the inverter.

5.3.3 PV systems at or on buildings

Generally the installation of PV systems should not affect the protective function of roofs and firewalls. Buildings and roofs are subject to various requirements from the respective state building codes (LBOs) as well as to the Model Building Regulation (MBO) to prevent the spread of a building fire to other buildings or parts of the building (see section 5.2.1 on Fire Protection).

They include in particular the requirement of "hard roofing" for in-roof solutions as well as the use of materials with a classification of at least fire classification B2 "Normally flammable," class B2 as per DIN 4102 (old) or class E as per EN 13501 (new) for on-roof solutions. Most PV modules with glass can be assigned to class B2 or E.

The module providers should present proof of this classification with a declaration of conformity from the manufacturer.

For roof-integrated systems proof of "hard roofing" is generally provided by the manufacturer in the form of building authority test certificates. The "Information Document for the Manufacture, Planning and Execution of Solar Systems" of 7/2012 from the German Institute for Structural Engineering (DIBt) states, for example: "Solar systems must consist of at least normally flammable construction materials (§ 26 sec. 1 MBO). If such systems are arranged in or on the building envelope, outside wall surfaces as well as outside wall cladding of buildings of building classes 4 and 5 must be flame-retardant (§ 28, sec. 3, sentence 1 MBO).

Components with combustible construction materials must not be installed across firewalls (§ 30 sec. 5, sentence 1, clause 2, sec. 7 sentences 1, 2 MBO)."

In addition, the MBO defines the execution of firewalls and the distances between the so-called normally flammable materials and the firewalls. These definitions are intended to prevent fire propagation from flying sparks or heat radiation. For example, § 32 of the MBO stipulates, among other things, that dormer-like roof structures made of combustible construction materials must have a distance of at least 1.25 meters from the firewall. This applies analogously to PV modules and other components of the system.

Occasionally PV modules have been built over fire compartments, the cables pushed through fire compartments or led through firewalls without protection. Cables routed through or over a firewall must be compartmentalized according to the fire protection rules of the Regulation on Model Conduit Installation (MLAR). Otherwise there is a danger of fire propagation by virtue of the so-called wick effect of the insulation material. The employed materials must be suitable for outside applications.

The following shows an example of an economical solution for passing PV cable strings across fire protection walls by means of “fire protection bandages” (approved by the DIBT).

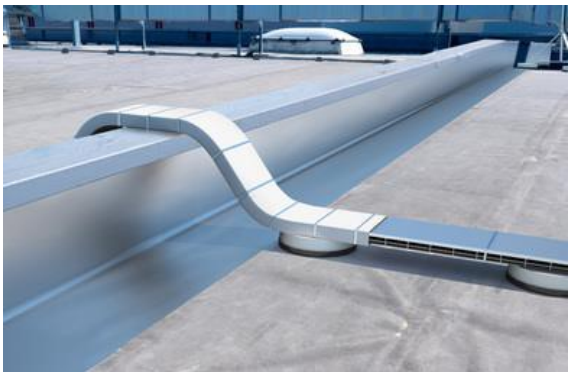


Figure 5-25: Fire protection bandages can prevent fire propagation across firewalls, photo: Obo Bettermann. **[73]**

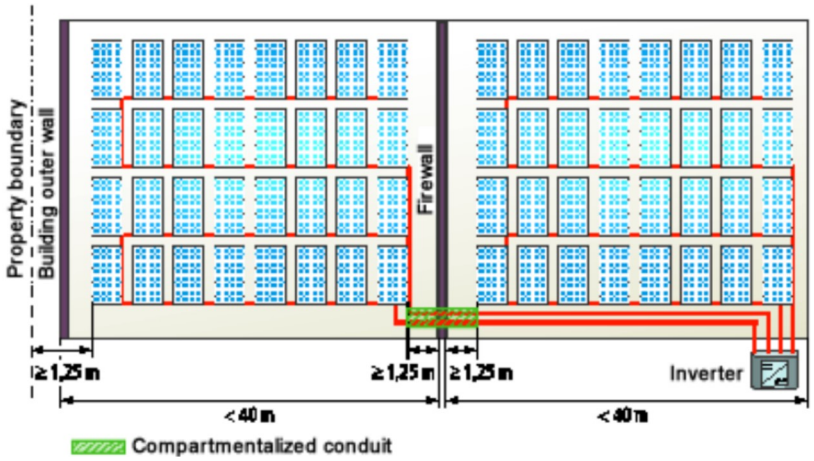


Figure 5-26: Cable routed across firewall and module distances from firewall or property boundary [source: DGS Berlin]

Firewalls must extend at least 30 cm beyond normally flammable material and therefore beyond the upper edge of the PV generator. As already mentioned, normally flammable materials may be installed only at certain distances from firewalls. For this reason, normally flammable PV modules installed above the roof covering must comply with a distance of at least 1.25 m (Figure 5-26).

Planning requirements for firefighting

In the event of a building fire, firefighters must be able to arrive at the source of the fire quickly and safely. Some such operations cannot avoid penetrating the roof structure directly from the roof and extinguishing the fire there. In this case, an electrically live system, such as a PV system, could be a hindrance, especially if it covers the entire roof surface, which should therefore be avoided.

Possible access points to the roof structure are as varied as the types of buildings. Here are examples of the most important roof variants with possible access (Figure 5-27):

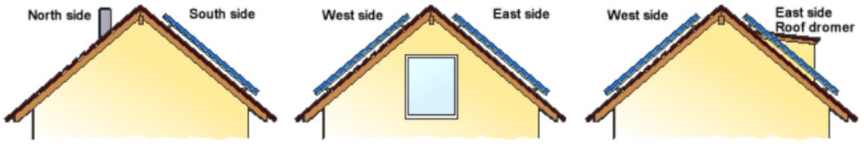
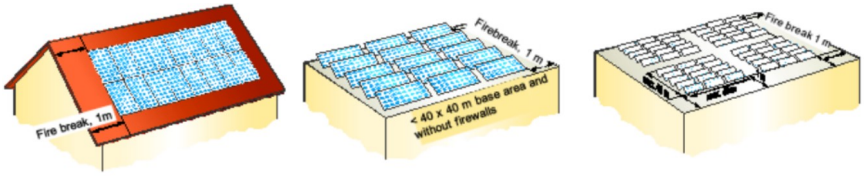


Figure 5-27: Different types of access for firefighters to a pitched roof *[source: DGS Berlin]*

In many cases firefighters can access the roof structure via the second half (often northern half) of the roof not covered by a PV generator and from there tackle the fire at a sufficient distance from live system parts. If both roof halves are occupied, as is the case with roofs facing east, other roof access options must be used.

Other possible passages are through dormer windows or gable windows. These windows must have the dimensions of a so-called “necessary window” suitable as a rescue route and be accessible to rescue workers. The minimum dimensions of such a window are a clear width of 90 cm and a clear height of 120 cm as per the Model Building Regulation.

If access to the roof structure is possible neither through roof areas at the rear nor through windows, a suitable partial area of the roof must remain free. For rescue workers a fire break of at least 1 m in width is already helpful in extinguishing operations (Figure 5-28).



a) Pitched roof occupied on both sides

b) Medium-sized roof on buildings with base area less than 40 m x 40 m

c) Large roof on building with base area greater than 40 m x 40 m

Figure 5-28: Access possibilities for firefighters *[source: DGS Berlin]*

For roofs without other access possibilities and with a base area less than 40 x 40 m, 1-meter fire breaks must be implemented on the longer side. An additional fire break is also recommended with system widths of 20 meters or more. If larger PV systems are planned, *the generator areas must be subdivided into max. 40 x 40 meter sections.* Between these sections pathways of at least 1 meter are required. Important in planning the distances to live parts is to take into account the PV modules themselves as well as the cables and other system components. Fire protection experts should participate in the planning of PV systems on special structures as defined in the building codes of the particular state and be consulted in cases of special roof shapes.

Electrical installation requirements

The VDE application rule VDE-AR-2100-712 on “Minimum requirements on the DC part of a PV system in case of firefighting or technical assistance” must be heeded during installation. Since the PV generator carries a voltage of up to 1,000 V during the day that cannot be turned off, firefighting operations can be hindered.

Firefighters must therefore follow the safety rules when extinguishing electrical installations as laid down in VDE 0132. Appropriate safety distances of one or five meters must then be maintained when extinguishing fires with a spray nozzle or jet nozzle, respectively.

Outside the building this extinguishing distance to the PV system can generally be maintained without problems. On the other hand, the safety cannot always be maintained in a firefighting assault or when rescuing people in the building, given limited visibility from smoke, for example. For this reason VDE AR-2100-712 stipulates **the avoidance of hazardous exposed DC voltages in the building in case of fire** as a protective goal in planning and installing PV systems, to allow safe rescue operations and firefighting inside the building.

To achieve this protective goal, the following minimum requirements on planning, construction and installation of PV systems as per VDE-AR2100-712 must be implemented.

- *Marking of PV systems and cable routing* is mandatory at each system. This concerns affixing the standardized information sign on the house connection box as well as affixing a general

schematic for rescue workers at the delivery point of the electrical system, e.g. the house connection box or building main distributor.

- In addition, *either structural or technical installation measures* must be taken to protect against exposed hazardous voltages in the building.
- The following structural installation measures are possible:

1. Fire-protected routing of DC cables in the building that cannot be turned off. The fire resistance of the cable system depends on the particular state building code in effect (at least F30, however). This measure can be implemented by (e.g.) in-wall routing as per VDE 0100-520 or by means of fire protection conduits and shafts as per EN 1366 or DIN 4102.
2. Routing of the DC part of a PV system outside the building by (e.g.):
   - routing the DC cables outside the building and leading them directly into the electrical operation room or to the house connection point or
   - installing the inverters outside or at the building entry point. If the inverter is installed at the building entry point, the fire compartments in particular must be preserved and the corresponding firewalls implemented.
3. Fire-resistant routing of PV DC cables in the building so as to prevent contact. 1 meter above arm's reach of people without aids (ladders, etc.) and routing on cable support systems as per DIN 4102-12. With this type of routing, the cable support system must be included in the function potential equalization.

Generally for the DC cable installation an unprotected zone of up to one meter about the PV generator on the roof and about the inverter in the building is permissible and must be labeled accordingly in the documentation for the rescue workers.

DC cables in the building that cannot be switched off can be routed under at least 15 mm thick mineral plaster as per the "in-wall" model cable system guideline. Routing through installation shafts and ducts made of non-combustible materials with a fire resistance capability of at least F30.

If the structural measures are not (or cannot) be implemented, one of the following technical installation measures must be implemented:

1. Installation of a DC isolator with remote triggering for disconnecting the DC main cable in the building or for disconnecting the module string or
2. use of module switch-off devices, which to date have not been authorized by a corresponding product standard in the rules & regulations, however.

Only the output DC system can then be considered as a protected zone. The continuous current-carrying capacity of the switch-off device must be designed for at least 1.25 times the $I_{SC\ STC}$ value at the connection point. On occurrence of an internal fault, the device must go to a safe state (*fail-safe principle*), e.g. disconnection in case of a fault with a separator, *otherwise the functioning of the device must be monitored daily*. If necessary, in order not to impair the functioning of the switch-off device,

other devices may have to be used that prevent reverse currents from inverters or from parallel strings such as string diodes or string fuses.

On triggering by an external enable signal, e.g. from a control unit or an inverter, which must persist (fail-safe principle), the switch-off device must respond if within a period of max. 15 seconds the enable signal ceases to be applied. The device should switch on again when the enable signal returns.

Devices for disconnecting the string or PV generator must comply with the requirements on switchgear as per EN 60947-3 or EN 60947-2. Devices for switching off in or at the junction box of the module must comply with at least the requirements on temperature testing of the bypass diodes in IEC 61215 or IEC 61646. The device for switching off the module can be a semi-conductor switch without a disconnecting function, if a switch-off can be ensured given the typical failure mechanisms.

For the aforementioned switch-off devices, other requirements, such as adapted service life tests and defined failure probabilities, must still be laid down in a product standard.

Table 5-4: Overview of the fire protection measures of VDE AR 2102100-712

Identification and documentation	
1. Sign identifying the PV system at the house connection box or main building distribution board 2. General schematics for rescue workers 3. Supplements to existing fire department schematics	
and structural installation measures 1. Fire-protected routing of DC cables in the building that cannot be turned off. or 2. Routing of the DC part of a PV system outside the building or 3. Fire-resistant routing protected against contact	**or technical installation measures** 1. Devices for disconnecting the string or PV generator* or 2. Devices for shutting down the PV module* * Remark: Requirements on the devices must still be laid down in the product standards.

5.3.4 Open-space systems

Planning must give attention to suitable freedom of motion for the firefighters. Lanes between the generator sections must be left free for firefighting vehicles, especially to the inverters and transformer stations. We recommend dividing the generator tables into fire compartments and leaving the center aisles free, to rule out the risk of fire propagation.

The **system monitoring should be equipped with fire monitoring** and a **fire alarm system** should be installed. The pertinent fire department should be informed about the PV system, including cable

routing, and receive schematics for operations. The fire department should have access to the fire alarm system.

Ground cables must be connected properly and routed with protection against mechanical damage, such as grass cuttings. The connections in the transformer and inverters must also be properly carried out, with protection against mechanical damage. In general, **the installation must be ground-leakage-proof and short-circuit-proof**.

Fire stress and fire hazards should be minimized by the following measures:

- Use suitable material for the substructure
- Route cables with protection against rodents
- Following the installation, leave no combustible materials behind on the premises (cartons, packaging, etc.)
- Prevent excessive vegetation underneath the PV system (mow regularly, especially underneath the PV system) and remove grass cuttings from the system
- Regular maintenance of the ventilation system for the inverter units

5.3.5 Electric arc detection

If the instructions listed in section 5.3.1 for preventing electric arcs and overheating are heeded, the probability of a PV system starting a fire is very low. Generally such a strategy qualifies as fully sufficient.

In the USA the electric arc risk must be assessed differently. PV systems are often installed with grounded PV generators, a practice that increases the risk of parallel electric arcs. Houses are often built from combustible materials like wood and roofs are fitted with bitumen tar paper.

Another approach is therefore taken: The National Electric Code 2011 [74] stipulates the installation of available electric arc detectors in building-integrated PV systems (based on the situation with certain domestic AC circuits, where this has already been the case for years).

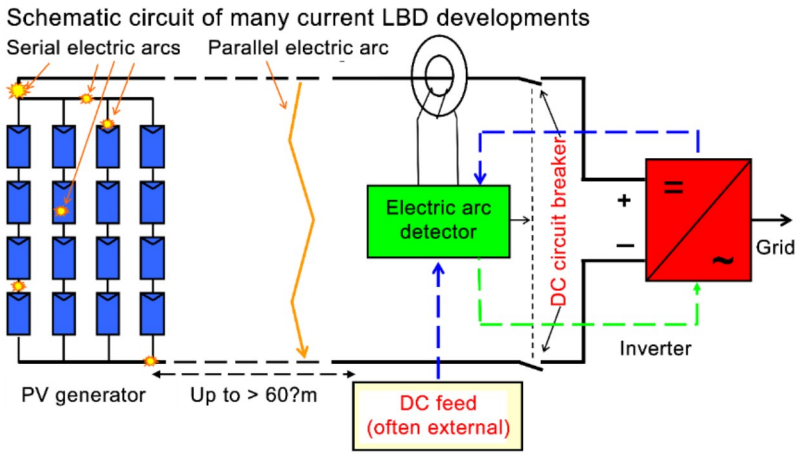


Figure 5-29: Typical schematic circuit of current LBD developments. Feed-in and shutdown by inverter (if integrated) or externally; Analysis of the disturbance currents of the electric arc in the range 1 – 500 kHz (depending on manufacturer) [6].

In Germany and Europe there exist no comparable installation regulations for electric arc detectors at present. Nevertheless, their use may be recommended, since there is no 100% protection against electric arc events.

Conceivable would be a recommendation for systems such that a fire event would pose a particular hazard to life and limb or where material values requiring special protection are present, as in public buildings like kindergartens, schools, retirement homes, hospitals or even museums or archives.

Here it is essential that the electric arc detector continually operate with reliability, however.

This presents a challenge not to be underestimated. It must be ensured that the electric arc detector remains fully functional over a very long time period of time, if possible during the entire service life of the PV system, without itself causing any faults in the system. Protective measures such as an integrated self-test could be helpful here.

An electric arc detector is moreover useful only if it can be assumed to **reliably detect electric arcs**. Owing to the large variety of PV systems in which the detector is to be used, this criterion is anything but trivial. Electric arcs in modules produce different noise patterns than those in serial terminals. Different cable lengths greatly differ in their dampening of electric arc signatures. Interference from inverters, switching transients, or coupled radio signals can mask or overlay the noise coming from the electric arc.

Only very robust detection algorithms tested on different systems can ensure real added utility here.

Even more critical is the subject of **faulty activation**. An electric arc detector leading to faulty activation will be hardly welcomed by system operators. When an electric arc detector causes the shutdown of a

PV system, the exact fault location is after all fully unknown. The system must then be elaborately checked in order to locate and eliminate the fault.

It is even more difficult to prove that no electric arc has occurred, and that a false alarm was the case. In cases of doubt, only a technician can do this, namely after checking each individual module, all connection points and the complete wiring.

This will generate considerable costs and create great insecurity among customers. Moreover, the danger is great that following a few such fault detections the system owner will simply override an unreliable electric arc detector in order to avoid costs and further yield losses.

Wire-bound electric arc detectors have a high potential for faulty activation:

- Discontinuities in the current can also be caused by (e.g.) passing clouds or sudden shading by (e.g.) leaves or bird droppings.
- Neighboring electronic devices or even radio signals can produce interference patterns that can be captured via the extended wiring of a PV system. These interference patterns can increase signal parts in the same frequency ranges as are typical for electric arcs.
- The inverter as a system component with its switching frequencies used for energy conversion (approx. from 1 kHz to several 10 kHz and the corresponding harmonics) can also cause interference and noise that can be misinterpreted as the effects of an electric arc.

This last point is especially difficult to tackle since each inverter produces a different interference spectrum, which is also influenced by processes like MPP tracking, partial load operation and grid services.

Constructing an electric arc detector that will function together with any commercially available inverter and under all operating conditions is therefore a very demanding affair.

Besides robust and thoroughly tested detection algorithms, *expedient switch-off concepts* (e.g. slightly time-delayed shutdowns or (following a certain waiting time in a deactivated state) multiple restarts on a trial basis before final shutdown) can also provide a remedy, if permitted by the standards.

Conclusion

Summarizing, we can say that electric arc detectors can add to safety in especially hazardous situations.

This will be the case only if the employed electric arc detector can reliably detect electric arc situations and faulty activations can be ruled out with high probability.

Careful selection of such a device is therefore essential.

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5.3.6 Batteries and charge controllers

Grid-independent PV systems with batteries and charge controllers did not form part of the research project underlying this report. Since batteries are also being increasingly used in grid-connected PV systems, however, we list here the minimum requirements for the purpose of avoiding fires.

Standard EN 50272-2:2001 (VDE 0510 part 2 or IEC 62485-2) describes in detail the safety requirements on batteries and battery systems for stationary lead and NiCd batteries.

The following discusses only the **measures for avoiding overheating and electric arc formation** in the switchgear and cable routing as well as the **measures against the risk of explosion**. These measures must also be taken with Li ion batteries.

- The rated voltage is the product of the number of serially connected cells and the rated voltage of a single cell (lead battery: 2V, nickel/cadmium battery: 1.2V). This does not correspond to the voltage during charging (higher) and discharging (lower).
- In the battery cables and in the cables of all devices connected to the DC bus, such as charge controllers, battery inverters or chargers, disconnectors for all terminals (positive and negative) must be provided. In contrast to the PV DC switches, they need not be able to disconnect at the rated current; even plugs or special clamps may be used.

  Since the operating personnel for PV systems are accustomed to disconnections under load and in order to facilitate maintenance, we urgently recommend the use of separators with load disconnection capacity when accommodating charge controllers, inverters and battery in separate housings.
- Since the battery as a voltage source can supply extremely high short-circuit currents, the cables must be routed up to the battery fuses so as to be protected against ground leakage and short circuiting. As with PV DC cables, we recommend the use of double-insulated, single-core cables. Insulated DC systems and galvanically non-separated battery inverters require fuse protection at all terminals. Grounded DC systems and galvanically non-separating battery inverters with a neutral conductor led through them require fuse protection only for the non-grounded conductor.
- During charging and especially during overcharging, gas escapes from all cells and batteries in the case of lead and NiCd batteries. This gas is produced by the overload current through electrolysis. The gases consist of oxygen and hydrogen.

  Natural or technical ventilation must keep the hydrogen concentration below 4% (volume concentration). EN 50272-2:2001 provides a detailed formula and table for calculating this volume flow. With maintenance-free lead batteries containing sealed cells and electrolytes bound in gel or non-woven material, this volume flow is five times less compared with closed cells containing liquid electrolytes. Sufficient ventilation can therefore usually be ensured here with two small openings to the outside in the battery chamber.
- Lithium ion batteries must not be overcharged to prevent gas production. Since the alcohol-containing electrolyte can escape under unfavorable conditions in the event of a fault, a minimum space is suggested for most lithium batteries.

5.4 Special fire requirements for PV systems on and at roofs

A parallel project supported by the Federal Economic Ministry of Economics and Technology (BMWi; reference number 01FS12053), TÜV Rheinland, Currenta GmbH and Co. OHG and Wuppertal University is conducting pre-normative work on fire requirements of PV systems on and at roofs.

The central objective of this project is to define fire testing methods which, adapted to the product constellation of roof-integrated and roof-mounted PV systems, capture realistic fire loads from the effects of external fires.

These test methods should be derived from the findings of test series consisting of specific aspects and applications of the combination of established European roof fire tests.

These test methods are to yield qualifying statements on fire propagation by building-integrated photovoltaics (BIPV) respectively on the influence at the underlying roof cladding by photovoltaic rooftop systems in the event of flying sparks and radiant heat.

The findings are to be incorporated into international European standardization and there significantly serve the work on a harmonized test specification.

The test series should determine the influences on BIPV on the basis of existing European fire stress tests for roofs. Above all, suitable incendiary devices, wind load parameters and additional radiation sources should be selected as crucial for the performance of tests with simulated fires.

For PV rooftop systems the effects of on-roof module installation for the scenario of a fire source lying between the PV system and roof covering (e.g. originating in flying sparks from external fires or straying fireworks) are being examined for the first time.

Here the different types of roofing in Germany and the different positioning of the incendiary devices (position and setup) are also to be characterized by means of temperature measurements.

The findings from this test series should enable the applicants to assess to what extent fire tests are required for PV systems in order to reliably prevent fire propagation into the building interior from external sources or to prevent such propagation from adding to the risks from PV rooftop systems.

The tests examined different roof structures and different PV installation systems.

For the roofing materials and roof structures the following configurations were selected, representing both the so-called “soft” and “hard” roof variants (see also section 6.2.2):

Configuration 1:

1st (= uppermost) layer: unsanded bitumen sheeting, d = 5.0 mm
2nd layer: polystyrene insulating boards, d = 80 mm
3rd position: bitumen sheeting with aluminum vapor lock, d = 5.0 mm.

Configuration 2:

1st layer: unsanded bitumen sheeting, d = 5.2 mm
2nd layer: unsanded bitumen sheeting, d = 5.0 mm
3rd layer: polyurethane insulating boards, d = 80 mm
4th layer: bitumen sheeting with aluminum vapor lock, d = 5.0 mm.

Configuration 3:

1st layer: PVC sheeting, d = 1.5 mm
2nd layer: mineral wool insulating boards, d = 80 mm
3rd layer: bitumen sheeting with aluminum vapor lock, d = 5.0 mm.

Configuration 4:

1st layer: roofing tiles including battens, d ≈ 80 mm
2nd layer: roofing membrane, d ≈ 2 mm
3rd layer: common rafter clamping felt made of glass wool, d = 200 mm.

Configuration 5:

1st layer: in-roof module, inserted in a virtual roof covering consisting of CaSi boards and roof battens, d = 50 mm
2nd layer: roofing membrane, d ≈ 2 mm
3rd layer: common rafter clamping felt made of glass wool, d = 200 mm.

In addition, for the testing a burner system was selected as the ignition initiator, which was also validated and examined as to its reproducibility in the application.

The developed burner was compared with the wood wool basket for all roof configurations. Here no PV modules were used at first.

It was possible to demonstrate that the burner produced the same heat release rates as the wood wool burning as per ENV 1187-1. Accordingly, the gas burner was also used for the other roof configurations, with PV modules.

Altogether it was found that the roof design/configuration considerably influenced the tests results!

For example, in the tests with the bitumen sheeting the roof elements and other layers burned off completely, as did the modules. This applies to both the soft and hard types of roofing. This "downgrading" of hard roofing, actually classified as B_{roof} (t1), can be explained by the upward heat dissipation significantly limited by the elevated PV module design.

Soft roofing originally already received a low classification.

The rooftop systems used in the tests for elevating the PV modules on flat roofs correspond to a worst case of systems used in practice: on the one hand flying sparks can get between modules and roof surfaces and on the other hand materials can freely drip from the modules onto the roof covering.

Figure 5-30: Left: elastomer bitumen sheet underlay, EPS insulating boards, bitumen vapor lock sheet with new gas burner. Right: PVC roof sealing sheet, mineral wool insulating boards, bitumen vapor lock sheet.

At present there also exist elevation systems preventing just this risk from flying sparks (through (e.g.) rear walls in the structure, ballast by means of gravel). In addition, non-flammable or flame-retardant underlays (e.g. protective mats) between the substructure and the roof surface can prevent or greatly limit fire propagation. For assessing suitability further tests are necessary and have been rated as appropriate.

Non-critical were the tests with PVC flat roof sheeting in conjunction with roofing tiles installed parallel to the roof. Here the destruction was limited to the area of the ignition initiator.

Figure 5-31: Left: roof-parallel structure with concrete roofing tiles and PV module. Right: the ignition initiator was placed between the module and the roof surface.

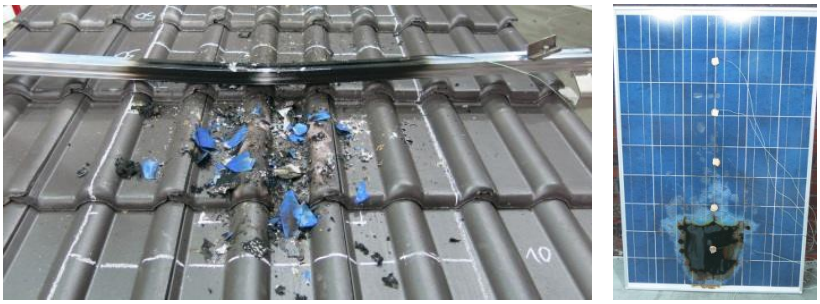


Figure 5-32: Result after test. Module was destroyed, no burn-through at the roof surface.

Nor did the tests on roof integration reveal any critical events, so that the classification criteria defined in EN 13501-5 for the structures remain in effect.

Regarding roof integration, it must be noted that other plastic elements are usually also used for the system structures in order to ensure rain-tightness with shingled modules or modules installed edge to edge. The variety of systems currently in use cannot be captured by the tests performed in this project.

The test with plaster therefore focused on a roof-integrated installation with calcium silicate boards arranged flush to one another. At the same time, regular roof underlays are used (normally flammable roofing membrane, and insulation made of flame-retardant mineral wool).

No fire propagation or ignition via or at the PV module occurred in these measurements. **For a subsequent test method to be harmonized, however, it must be clearly defined which materials (and fire classes) of the roof configuration are to be used in the test.**

Depending on the test result, it can then be decided whether a BIPV system may be used without restriction or only in combination with certain materials.

Within the project, the requirement case of **plastic trays forming a flat roof mounting system** was not considered (the fire case with these trays mentioned in section 3.3, p. 52, occurred only after completion of the tests).

The task of the project was to supply requirements as a recommendation for subsequent standardization work. To this end comprehensive results and positions have been formulated. A definition of test sequences and requirements could not be exhaustively discussed in this project.

For the use of roof-integrated PV systems, the **definitions and test methods of ENV 1187** can be used, a standard that has long been established for roof coverings. The tests showed that method 1 is applicable for an upper roofing system. The positioning of the incendiary device or burner must be specified as in ENV 1187-1. Here the system joints (module or module-roof connection) must be stressed each with an ignition source.

As in the usual test of roof coverings, the EN 13501-5 classification criteria can also be applied.

An appropriate test method must also require that the roofing materials, like the roofing membrane, etc., be recorded, in order to include any necessary restrictions on the use of the systems in combination with different materials. Conceivable is that the PV modules with certain substructures will correspond to poorer fire resistance classes than regular roof coverings, like tiles.

As a whole, either the wood wool basket or even the burner can be used here. Both incendiary devices are suitable.

For roof-parallel PV systems a typical roofing tile type should be defined for the tests. Alternatively, this can also be a non-combustible layer, for example calcium silicate, in order to simulate comparable substructures and roofing situations.

Here other FE studies are possible for comparing regular roof coverings with potential substitute materials for the lab tests. The use of the burner is advantageous, since owing to its size the wood wool basket cannot fit between the PV module and the roof surface. A standardization discussion must take this fact into account.

The usual roof distance in the tests should not exceed 8 cm between the underside of the module and the roof surface, unless the manufacturer can improve the fire protection with a larger distance.

In the test requirements testing should therefore generally be performed according to the manufacturer's specifications as to the manufacturer's assembly situation.

The same applies to elevated roof-mounted systems on flat roofs, where the two variants of ignition sources have led to great differences in the speed and extent of fire propagation!

Testing of rooftop systems especially for the setup on flat roofs with the manufacturer's particular mounting system is useful, since this type of construction alone, irrespective of the roofing layers, can itself prevent fire propagation.

On the other hand, some module manufacturers do not use their own flat-roof mounting system, but purchase such a system from an external supplier, or the installer assembles modules and systems from different manufacturers.

For modules without a corresponding mounting system a practical solution for the standardization must be developed in order on the one hand to minimize the testing labor and on the other hand to ensure the greatest possible qualification via the test method.

For all the aforementioned cases EN 13501-5 must be used as the classification basis, since the protective goal is still to prevent flames from penetrating the interior of the building.

Other parameters like duration of testing and wind speed will have to be the subject of future standardization discussions. The present project could not carry out any diversification in this regard.

With the support of five European countries, it was decided that in the fall of 2014 a New Work Item Proposal would take up the work on developing a fire test method for roof-installed PV systems.

The national committee has also decided in favor of this undertaking. The following title was chosen: "External fire exposure to roofs in combination with photovoltaic (PV) arrays – Test method(s)". The research results here will serve as the starting point of further discussions.

The standardization project is to be regarded as a joint working paper together with CEN representatives, i.e. as concerning the European standardization for technical construction matters.

Conclusion

The European test methods for roof-mounted PV systems currently present no harmonized picture regarding building codes. PV modules have so far been tested as per IEC 61730-2 with the US test method UL 790.

Because of the many standards applicable in Europe regarding the testing of inflammability and fire propagation properties of roofs, the European EN 61730 has to date not considered fire testing of PV modules!

For the purpose of study and unification, European standardization is therefore currently developing together with Cenelec and CEN a method taking into account the different modes of installation on roofs.

5.5 Commissioning and operation

Following creation of a PV system at the customer's end, commission must take place. This should ensure proper, risk-free functioning of the system. Usually proper functioning is verified by commissioning tests documented by commissioning logs.

DIN EN 62446 VDE 0126-23 on "Photovoltaic (PV) systems – Requirements for testing, documentation and maintenance - Part 1: Grid-connected systems – Documentation, commissioning tests and inspection" primarily applies to PV systems and documents the minimum requirements for commissioning. They refer mainly to the DC part, however.

For the AC part and the overall system the usual electrical engineering norms and standards (such as VDE 0100 part 610) apply.

Commissioning is usually performed by the system installer. The latter must confirm that the system has started operation properly and can continue to be operated without risk. The system can then be transferred to the owner or operator. Following handover to the owner (subject to inspection), the latter is liable for the risks or damage caused by operation. Consequently the owner must ensure proper operation, or may entrust this task to an operator.

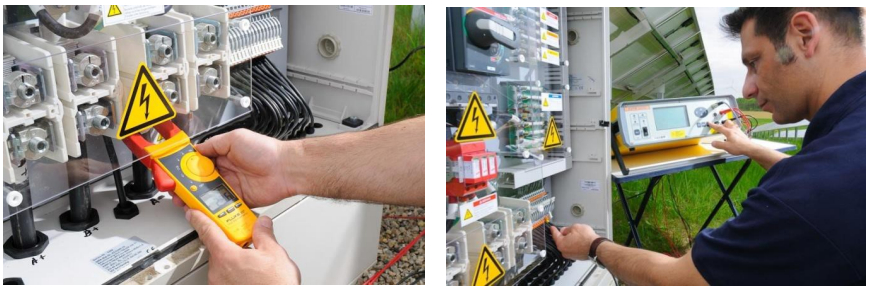


Figure 5-33: String measurements on generator junction boxes

Logically the operator should receive appropriate instruction prior to handover of the system. All documents necessary or helpful for operation and maintenance must also be provided to the owner.

This documentation must include in particular:

- System description (e.g. with general schematic)
- Wiring and circuit diagrams
- Product data sheets
- Operating instructions
- Any certificates, certificates of guarantee, etc.
- Commissioning logs
- Verification of stability, if appropriate

Also helpful are:

- Service address
- Maintenance recommendations

The owner is obligated to monitor proper operation of the system. The owner must accordingly take suitable measures, namely monitoring of the operating parameters (via status displays, etc., for example) and perform appropriate maintenance and inspections. The following sections will discuss these points in detail.

5.5.1 Acceptance inspection

Like every structural system, a PV system requires an acceptance inspection.

The inspection is to be performed formally by the owner or operator. Since the latter will usually not have the appropriate technical background, that party will often entrust this acceptance inspection to appropriate companies (specialist companies, engineering firms, test centers, etc.) or bring in specialists.

On acceptance the owner declares that the system meets the agreed specification in type and design (subject to concealed defects) and that the contractually agreed services have been rendered.

Legally, at this point at the latest full payment of the account receivable (via the contractual delivery price) to the system installer is due (in the absence of a different arrangement and of any defects).

In addition, as already described in the section on “Commissioning,” the owner assumes responsibility for operation of the system.

Consequently, acceptance has far-reaching implications for the owner and should be conducted with the utmost care, in particular in order to rule out safety risks (from e.g. electric shock or fire). A careful inspection should reliably detect any defects or deviations from the version type, quality and specified properties. An inspection can also yield demands for improvement or redelivery.

Since owners often lack the appropriate technical background for a qualified assessment of the system, it is advisable to bring in specialists. Besides technical qualification and technical orientation of the service provider(s), a certain store of experience in assessing PV systems is extremely useful. Qualified companies are sufficiently and everywhere available.

The scope of the tests and checks performed in the inspection should be adapted to the type, size and complexity of the system as well as to particular environmental conditions or a special requirement profile. For example, a building-integrated PV system has more checkpoints than a roof-parallel system. For a large-scale system with a corresponding investment volume, a more in-depth performance inspection is also advisable compared with a small system. The decision ultimately lies with the owner or investor. Claims may also come from banks or insurers, however.

Figure 5-34: Visual inspection (left at the inverter) and measurement (right at the GJB) as part of the acceptance inspection

A qualified acceptance inspection should comprise the following key points:

- Checking of the documentation
  - Completeness
  - Correct selection and design of components
  - Suitability of the components for the given purpose
  - Interplay of the individual components

- Comparison of the installed system against the specification
  - System parameters (design and dimensioning)
  - Orientation and alignment of the generator
  - Component selection
  - Workmanship
  - Realization of assured properties

- Comprehensive visual inspection
  - Determination of compliance with relevant standards and guidelines
  - Check for absence of defects

- Testing and measuring
  - e.g. string measurements (short-circuit current, open-circuit voltage, insulation resistance)
  - e.g. thermographic examination
  - e.g. activation of technical safety parts of system
  - e.g. U/I characteristic curve measurements
  - e.g. mechanical measurements

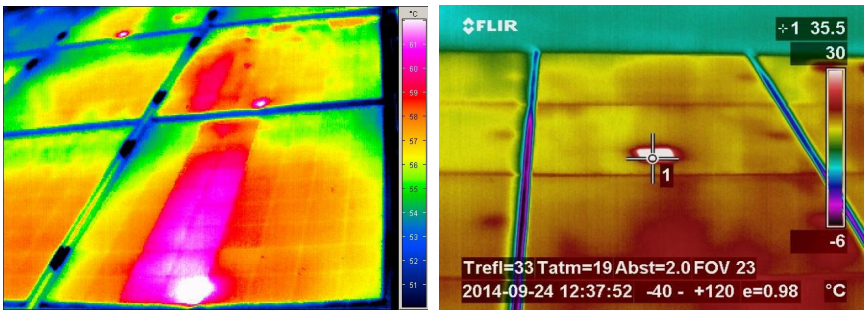


Figure 5-35: Examples of thermography at the PV generator

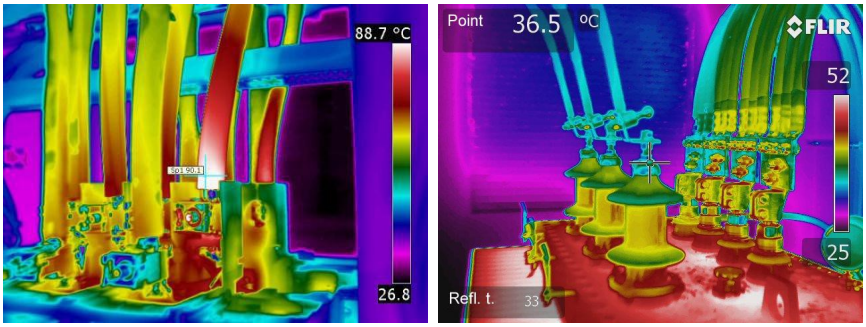


Figure 5-36: Examples of thermography in the subdistributor and at the transformer

Important is that all relevant system parts from the module to the in-feed point be considered. The system also includes (e.g.) the module substructure and the foundation or anchoring

The assessment of the system should also consider the quality of the work performed as well as the suitability of the system for long-term operation (20 years and more).

Besides the main assessment criteria, other criteria can certainly play an important role, such as:

- Easy maintenance
- Impact on people and the environment
- Realization of assured properties

Conclusion

A comprehensive and detailed system acceptance inspection significantly reduces the failure and safety risks, since defects and deficient quality can be detected and rectified.

5.5.2 Maintenance and inspection

Contrary to past statements made by some component manufacturers and system installers, PV systems are in no way maintenance-free!

They are subject to high stress from external factors, in particular climatic influences (wind, rain, hail, snow pressure, UV radiation, rapid changes in temperature, etc.).

In addition, typical aging mechanisms also occur among PV systems. As with all components and systems, malfunctions or premature failure can occur. In addition, extraordinary events or influences (e.g. marten bites, aggressive substances, extreme temperatures, lightning strikes, etc.) can lead to damage or accelerated aging. Besides yield losses, these types of damage or material changes can also cause (e.g.) local overheating, which in the worst case can lead to thermal destruction of components, to the formation of a stable DC electric arc, and even to a fire in the PV system.

Consequently regular inspections and maintenance measures are required to ensure safe and proper operation. Appropriate inspections and maintenance of the system can equally increase the system yield.

Different measures and intervals are useful depending on the type of system and stress. Besides fixed intervals, additional event-controlled inspection and maintenance are useful. They should be carried out in case of certain events (e.g. after a storm, malfunction messages, system failure, drop in yield, etc.).

The following is a list of generally applicable inspection and maintenance measures.

Typical inspection measures:

- Visual inspection (e.g. for external damage or material changes)
- Check of the system parameters (status displays, error messages, yields, etc.)
- Testing and measuring (here the same measures as in commissioning, or a subset thereof, come into question; often only spot checks)

Typical maintenance measures

- Cleaning of PV modules and meteorological sensors
- Cleaning of cooling fins and ventilation ducts or filters
- Maintenance of green areas and cutting back of plant growth
- Replacement of wear parts
- Testing and activation of safety devices (see note in section 3.3.3.2)
- Adjustment or calibration of parameters

Note that different types of qualification and equipment are required for implementing the individual points. For example, certain measures can be carried out by the operator himself. Others must be carried out by specialists (e.g. an electrician) with the appropriate qualification and equipment.

On the market many providers are available for PV system maintenance. Often so-called full-maintenance agreements are offered. Note that the measures to be implemented are often included in the agreement and also that intervals are stipulated.

Often combined maintenance and operating agreements are offered. The advantage here is that both responsibilities coincide and no interface issues arise. On the other hand, usually a control mechanism is lacking here.

Conclusion

Inspections conducted routinely and in the event of special events, as well as regular maintenance, contribute towards minimizing the failure risk in the long term and avoiding hazardous situations.

5.5.3 Switching and disconnecting devices

For carrying out inspections and maintenance, the PV generator and inverter must be electrically disconnected. Section 6.3 describes the special problems of shutdown on the module level in the event of fire department or other rescue operations.

For measuring individual strings, they must be separated. The appropriate devices for disconnection and separation are therefore required. Often they will be implemented in generator junction boxes that can be equipped with a load-break switch and disconnect terminals or fuse holders with a disconnecting function.

Figure 5-37: Generator junction boxes with load switch and disconnect terminals

In the case of string inverters, disconnection is partially integrated in the inverter. Disconnection of the strings is possible here by means of the plug connector at the inverter input.

Generally only the **load switch or load-break switch** may be operated under load. All other disconnectors may be operated only if load-free. Usually the corresponding warning labels will be attached. The accident prevention regulations must be followed (in particular the BGVA3).

Note: Reverse polarity voltages may occur from parallel connections in coupling boxes or in the inverter. The PV modules are always live when irradiated.

Figure 5-38: Fuse holder with disconnecting function

Figure 5-39: Disconnector with fuse

Figure 5-40: Load-break switch

The corresponding disconnecting devices must also be provided at the **AC end**. They are usually located directly at the inverter (central inverter), alternatively in subdistributors.

Switching and disconnecting devices also occur in the transformer station or, in the case of large systems, in the medium voltage station (Figure 5-41). Here the corresponding devices for disconnection, short-circuiting and grounding must be reserved (e.g. a grounding and short circuit kit for the transformer, see Figure 5-42).

Appropriate switching actions may at these points be performed only by specialists with switching authorization and if necessary protective equipment.

Figure 5-41: Medium voltage station

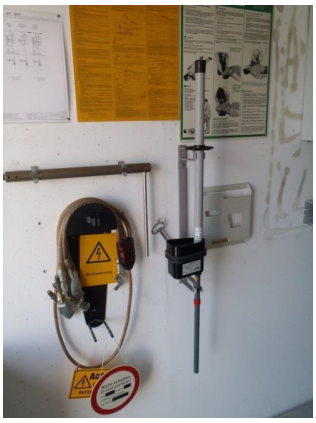


Figure 5-42: A grounding and short circuit kit for the transformer

5.5.4 Automatic system monitoring

As described in the preceding sections, it cannot necessarily be assumed that PV systems will operate over the entire operating period (usually at least 20 years, in the case of new systems the assumption is 30 years) without malfunctions and without changes in performance or yield. To limit yield losses from malfunctions, partial failure or reductions in performance as much as possible, qualified parameter monitoring as well as quick detection and reporting of faults is required.

This is usually made possible by system monitoring.

Since the system parameters are directly influenced by the irradiation conditions and the temperature level, no direct performance parameter can be derived without knowledge of these environmental conditions. Accordingly, the sensors, including the irradiation measuring devices, must be of high quality.

The devices require **regular checking and calibration** as well as systematic maintenance in order to keep measurement inaccuracies at a low level.

Performance parameters can be determined and analyzed by correlating the weather data with the system parameters. A very widespread parameter is the so-called “Performance Ratio” (PR), which specifies the ratio of supplied energy to the irradiation energy and thus serves as a measure of the efficiency of the PV system.

The error detection options depend on the type and quality of the monitoring system. For example, a detailed string current monitoring can quickly detect and localize a failure or a significant power decrease in the strings. Deviations can be detected by relative comparisons between parallel strings Problems with individual inverters (e.g. delayed start-up or intermittent failures) can also be detected in this way.

In PV power plants (very large systems) several strings are often grouped to limit the amount of data

Various solutions are available on the market. Figure 5-43 shows typical string monitoring; here the time-dependence of all string currents in different resolutions (time intervals) of an inverter can be displayed and analyzed.

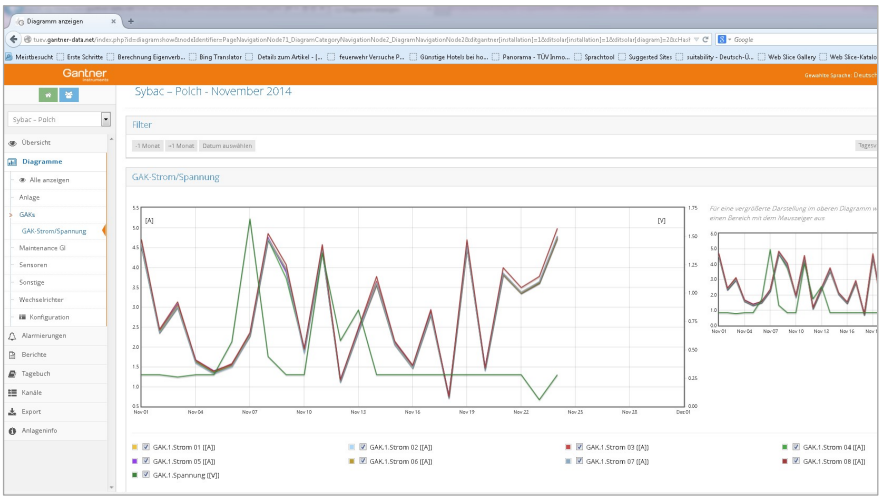


Figure 5-43: Example of online monitoring portal with string current monitoring

5.6 Devices for switching off solar modules and generators

5.6.1 Task

Solar cells generate an electric voltage as long as they are illuminated. While at very low irradiation this voltage is low, it quickly increases with increasing irradiance to full voltage. The current supplied by a solar cell is proportional to the irradiance.

Compared with batteries, solar generators cannot be switched off without additional measures. This property deviating from the usual voltage sources requires special scope both during the installation and maintenance of the PV systems and in any required rescue operations at buildings with PV systems or even at open-space systems.

Rapid growth in PV systems led around 2008 to intensified discussions on whether the absence of a switch-off feature poses an unmanageable risk to rescue workers and whether firefighters should deliberately let buildings with PV systems burn down. Ultimately, these discussions led in 2010 to a decision by the Interior Ministers' Conference of the German States to the effect that all PV modules without exception must have a switch-off feature. The standardization committees of the DKE were requested to prepare corresponding product and installation standards. A working group was organized to formulate the VDE application rule VDE-AR-E 2100-712 describing basic "measures for the DC part of a photovoltaic system for maintaining electrical safety in the event of firefighting or technical assistance" [75], [76].

Since no established state of the art yet exists in the matter of module and generator shutdown that could serve as the foundation for a product standard, this application rule describes merely technical and organizational minimum requirements for obtaining a safe system condition.

A shutdown is generally not required, but is an optional solution if structural measures (e.g. safe routing of cables, placement of cables and inverter outdoors) are implemented but are not regarded as sufficient (see also section 6.3.3: Electrical installation requirements).

The aforementioned controversial discussions of the danger potential for rescue workers have also initiated the preparation of comprehensive information material for fire departments and rescue workers as well as advanced training measures. The greater objectivity in reasoning has led fire departments to shift away from the general demand for a shutdown on the grounds that theoretically any switch-off device can fail.

Since rescue workers during an operation are hardly able to follow the "five safety rules" [77] **when handling electrical installations, they must assume (despite the possible presence of a switch-off device) that the installation is <u>not</u> de-energized.**

They must accordingly adhere to the proven basic rules of approaching electrical installations only at the prescribed distance of 1 m for live parts and 1 m for extinguishing operations with a spray jet and 5 m with a full jet.

Given over 1.5 million PV systems installed in Germany by the end of 2014, with a total output of approx. 38 GW, there remains a crucial question of whether switch-off devices can be retrofitted and whether such retrofitting can be required. Besides these technical questions, there are also legal issues as to how to incorporate protection of stock, for example.

It must therefore be assumed that in both the medium and long term rescue workers will encounter installations both with and without such switch-off devices. Since which is the case will usually be unknown, in the future rescue workers will have to treat each installation as though it cannot be switched off.

In other countries, especially the USA, other approaches prevail. Here, under the heading "Rapid Shutdown (NEC 690.12)," the current National Electric Code [78] incorporated the demand that each photovoltaic system – whether building-integrated or in an open space – can be switched off within 10

seconds. Here a residual voltage of 30 volts or a residual power of 240 VA may persist. These requirements do not relieve rescue workers of the responsibility for complying with their past safety rules.

5.6.2 General requirements on systems for switching off a solar generator or a solar module

In the past, numerous proposals for shutting down PV systems in emergency situations have already been made and tested. They have been compiled and evaluated in (e.g.) [79] and [80].

An initial class of possibilities is based on **expansive, lightproof covering of the solar generator** by means of (e.g.) extinguishing foam, tarps or even an opaque gel. These approaches have so far not been technically constructive or, from the fire department's perspective, practical. Extinguishing foam generally does not adhere to the typically inclined and smooth module surfaces, gel application is too time-consuming and tarps require practically zero wind and cannot be used with larger installations (see Figure 5-44). At a house fire possibly hazardous to people, rescue workers will always first attempt an inside attack in accordance with the proven rules of conduct and not give primary attention to covering the solar generator. These theoretical principles for shutting down solar generators are not covered by application rule VDE-AR-E 2100-712.

Figure 5-44: Tests on lightproof covering of PV modules, photo: http://pv-notaus.de/gefahren.html

The second class of systems performs an **electrical shutdown within the PV system** itself. This can theoretically occur on difficult levels from the module to the inverter, with different levels of personal protection being attainable. The required additional work also differs from measure to measure. The aforementioned application rule considers only PV systems at or on top of buildings.

A switch-off feature has to date not been required of open-space systems, but could be advantageous if (e.g.) people from a motor vehicle or plane have to be rescued from such a system (e.g. noise barrier along a highway).

The basic function required in application rule VDE-AR-E 2100-712 requires that in the event of a power failure or shutdown of the inverter the DC cables routed in a building be automatically switched off by a protective device located outside the building.

“Switched off” here means that

- the voltage must be less than 120 V
- the total of all short-circuit currents at the output end must be less than 12 mA
- the energy of the DC system at the output end must be less than 350 mJ.

Like bypass diodes, the switching devices must be able to continually conduct 1.25 times the rated short-circuit current, and they should have a fail-safe feature, i.e. in the event of a malfunction automatically enter a safe off-state. If this is not ensured (as in the case of semi-conductor switches, for example), a daily function test is necessary when cutting in the inverter in the morning, for example.

In addition, the systems must not lead to impermissible operating states such as reverse currents within generators if individual modules are switched off by a short-circuiting device either unintentionally or after a time delay.

The switch-off devices must be actively switched on by an enable signal. If this signal is not continually applied, a shutdown must occur within a maximum of 15 seconds. This enable signal may be generated only in the presence of supply voltage, but can be suppressed by other switching and monitoring devices (e.g. fire alarm systems) or even manually.

On entry of a normal operating state (e.g. recurrence of supply voltage) the switch-off device may automatically cut in again.

On stand-alone systems the enable signal must be interrupted if the system forming the stand-alone network is switched off.

5.6.3 Technical devices for switching off solar modules and generators

The application rule considers the possibilities for shutdown on the generator level and on the module level. Both the options of disconnection and of short-circuiting are included.

Figure 5-45 shows an example of a device for disconnection at the generator end or at the building entry point. Such disconnecting devices known as “*fire department switches*” must meet the requirements on switchgear as per DIN EN 60947-3 (VDE 0660-107) or DIN EN 60947-2 (VDE 0660-101).

Other requirements must still be laid down in a product standard.

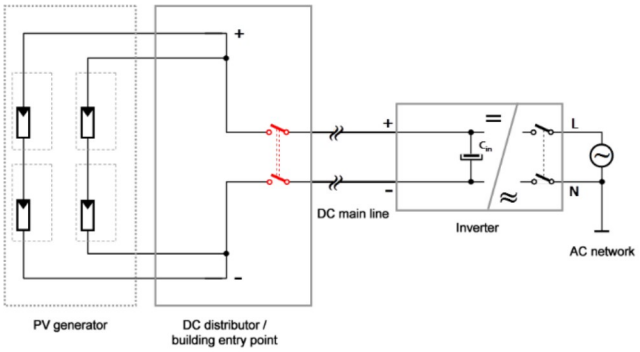


Figure 5-45: Example of device for disconnection at the generator end

Shutdown by continual short-circuiting of the solar generator as per Figure 5-46 is not permitted according to the application rule. The reason is that while the cables downstream from the short-circuit point will be de-energized, at a disconnection point in the short-circuited string the full string voltage occurs, which ultimately presents a greater hazard potential within the solar generator itself. Constant short-circuiting must therefore be avoided. Brief (15 s) short-circuiting for turning off parallel electric arcs between two live cables is permissible, although such parallel electric arcs are extremely rare.

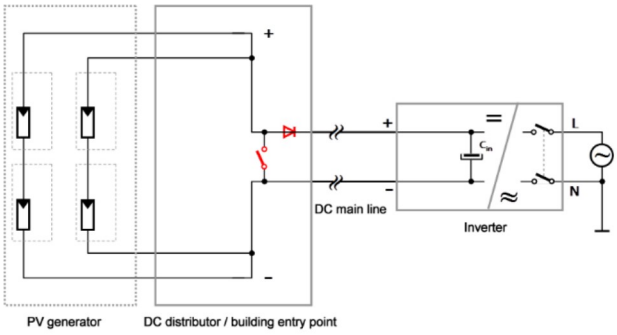


Figure 5-46: Example of device for short-circuiting at the generator end

Figure 5-47 shows a device for shutting down a solar module through disconnection. Although not expressly mentioned in the application rule, this also includes modules with integrated or allocated DC/DC or DC/AC converters providing an equivalent function. Essential here is that the switch-off device can also be a semi-conductor switch without a disconnecting function if the typical failure mechanism ensures a shutdown. If this is not ensured, a daily automatic function test is required; see above.

The requirements on such devices for shutting down a PV module must still be specified in a product standard.

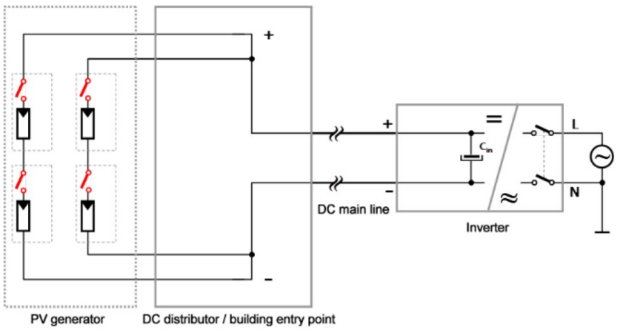


Figure 5-47: Typical device for shutdown by series switch on module level.

The device shown in Figure 5-48 for short-circuiting on the module level was in particular rejected by the module manufacturers during the public opposition proceedings on the application rule. No final

result could be obtained, so that the requirements on such devices for short-circuiting a PV module must still be laid down in a product standard.

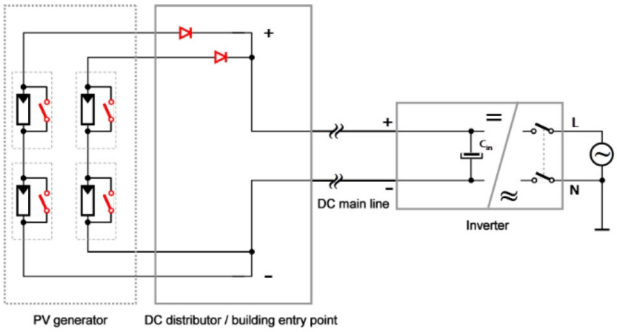


Figure 5-48: Typical device for shutdown by short-circuiting on module level.

5.6.4 Summary

The VDE application rule describes a series of measures for preserving electrical safety in the event of firefighting or technical assistance.

A shutdown of the solar generator or of the individual modules is not mandatory, but is an option.

A further conclusion from the studies on the load-break switch from 3.3.3.2 is that switches react to constantly increasing ambient temperatures with accelerated contact degradation. Planning should oversize the switches: like the DC lines, the switches should have a load capacity of at least 125% of the rated current of the system. Switches subject to elevated ambient temperatures must be designed as per the manufacturer's derating specifications:

- All switches should be inspected once a year in order to discover any signs of overheating.
- All switches should undergo maintenance once a year and then be operated ten times.

The detailed technical requirements on such shutdown or short-circuiting systems must still be laid down in product standards. A joint research project with support from the Federal Ministry for Economic Affairs and Energy (BMWi) with reference number 0325596F is currently implementing basic pre-normative work on the subject. The partners, TÜV Rheinland LGA Products, E-T-A Elektrotechnische Apparate, Q3 Energieelektronik, Eaton Industries and SMA Solar Technology, are concerned with aging and reliability testing of these devices.

5.7 Identification marking and information commitments

Generally rescue workers must maintain the distances as per VDE0132 during extinguishing operations. If switch-off devices as per the VDE application rule VDE-AR-2100-712 are used in PV systems, the particular output DC system may be considered as a protected area. The switch-off devices and the area protected after shutdown should be separately indicated in the general plan.

Recommendation Once module switch-off devices certified as per a product standard come on the market, a separate sign with (e.g.) green border and supplemented with a module switch symbol should be used. Rescue workers will then be able to discern quickly that no hazardous DC voltage can exist at the generator.

Generally it would be a good idea if the information as to whether a PV system exists on a building would already be available at the firehouse prior to the crew's departure. Keeping this information up to date is a challenge, however. An additional problem is that not all firehouse computers have internet access. Useful would be a central database in the internet that the state authorities could access and the distribution of the address data to the pertinent administrative districts or directly to the fire department switchboards or firehouses.

The registrations of the PV systems sent to the Federal Network Agency would generally be suitable for this purpose. A corresponding request from the project group was denied by the Federal Network Agency, however.

The compilation and evaluation of all network operators' system registrations on the Web pages of the DGS: www.energymap.info (csv file with address data of all systems registered under the Renewable Energy Sources Act in Germany) would be generally suitable. A suitable online user interface for address and postal code searches would still have to be developed, however. A bigger problem lies in the deficient up-to-dateness and in the missing address data. Registration by the network operators occurs up to 18 months following commissioning.

Over 10,000 PV systems currently contain no address data. The addresses usually specify the grid connection point, which may not match the system location. All data would have to be checked or, better, the network operators compelled to properly comply with their legal obligation (Renewable Energy Sources Act § 52).

6 Measures for improving the operational safety of rescue workers

6.1 System identification

PV systems on roofs are not always visible, especially with severe smoke development. At present, no central file is available that promptly registers all installed PV systems. Quick and clear information for the fire department and other rescue workers must therefore be ensured at the actual scene of the fire.

Identification at the house connection box will enable firefighters to quickly ascertain the presence of a PV system on the building. For the purpose of identification, a warning sign Figure 6-1) as per application rule VDE-AR2100-712 must be affixed at the delivery point of the PV system, e.g. at the house connection box or building main distributor (a corresponding sticker can be obtained online from the Deutsche Gesellschaft für Sonnenenergie e.V. (DGS)).

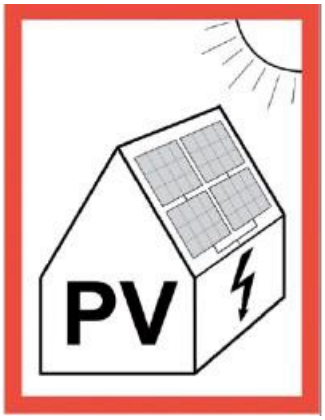


Figure 6-1: PV sign as per VDE-AR2100-712

6.2 Fire department schematic – cable routing and technical equipment

In addition, a general plan (Figure 6-2) as per application rule VDE-AR2100-712 must be present in suitable form (posted or otherwise displayed) at the delivery point of the electrical system to assist rescue workers in quickly determining the locations of live components in the building. Any fire department diagram as per DIN 14095 should be revised prior to commissioning.

The general plan must depict the types and locations of the PV system components as simply and as clearly as possible. These include

- all live cables that cannot be switched off
- live PV DC cables routed in the building and protected against fire
- location of the PV generator
- positions of all DC disconnecting devices.

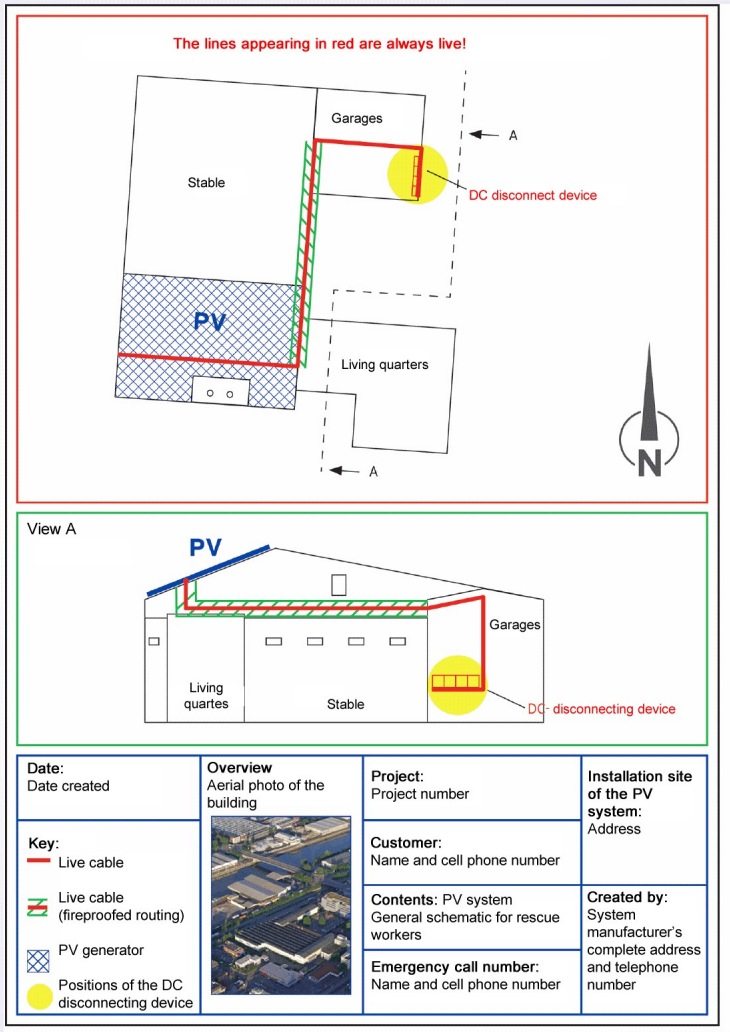


Figure 6-2: Example of a general plan for rescue workers as per VDE-AR-2100-712

6.3 Operational specification in case of fire

Section 5 already considered the variety of possible fire incident scenarios. Although these situations differ in tactical and technical procedures in the operational case, we can summarize the technical, organizational and personal protective measures as follows.

Technical measures

Technical measures should automatically bring the PV system to a safe state regardless of the malfunction. The safe state obtains if even untrained persons can work on the system without danger. Additional human intervention should not be required for attaining a safe state. **Normative technical solutions are under development.**

Organizational measures

The consideration of organizational measures did not separately address any generally common procedures in cases of fire and technical assistance, such as the use of breathing protective equipment and attention to possible debris zones.

Among all considered scenarios, basically the safety distance may be mentioned from an organizational perspective. A distinction must be made between the basic distance on the part of the rescue workers and the distance to be maintained during extinguishing operations. The brochure on “Electrical Hazards at the Scene of a Fire” (GUV-I 8677) published by the Deutsche Gesetzliche Unfallversicherung e.V. (Registered German Social Accident Insurance) requires a minimum distance to be maintained from all low-voltage systems and system components. If possible or if the situation is unclear, the safety area must be cordoned off.

Extinguishing operations are subject to differentiated safety distances as per the standard on “Firefighting and technical assistance in or near electrical installations” (DIN VDE 0132) from the Verband der Elektrotechnik, Elektronik und Informationstechnik e.V. (Registered Association of the Electrical, Electronic and Information Technology). The distances were also confirmed for PV systems in the practical testing of the research project.

Work in the area of or at a damaged PV system may be performed only by electricians. Technicians can also bring the system to a safe state so as to allow safe work. If the system or the switch elements are still undamaged, the system can be partially shut down by even untrained personnel (see BSW pocket map). Personal protective equipment as per the applicable standards must be worn for all work.

In particular, in the case of high-voltage systems, all work must be performed exclusively by specially qualified electricians.

If artificial lighting is used, safety distances as per section 4.5.2 of the research project apply as a recommendation.

Personal measures

To minimize hazards to personnel, in addition to all technical and organizational measures, knowledge about the hazards, effects and safety measures must be conveyed through training and reinforced through continual advanced training. Important in conveying this knowledge is standardized training content. It can be imparted only by technically qualified personnel. The training should comprise both a theoretical part and an on-site practical part. In addition, specialist companies can provide support to the training.

6.4 Operational specification if PV system flooded (danger of explosion)

Operations in the area of flooded PV systems require expanded organizational measures in addition to the activities already described in section 7.3. In addition to compliance with the usual safety distances, flooded areas may be entered only if no voltage is present (GUV-I 8677). To ensure the absence of voltage, an electrician should disconnect from the generator all system parts standing under water. In this way any further hydrogen production can be avoided.

Because of the possible detonating gas formation, explosion measurements must be performed as the emergency team proceeds with its work. If these measurements determine a danger of explosion or there are concrete indications of such a danger, the area cordoned off for this danger must be adapted according to the usual distances.

In addition, damage to electrical accumulators can release toxic and caustic gases (such as HF).

Selective ventilation of the affected areas can counteract these hazards.

7 Summary and outlook

This Guideline summarizes the results from over 3 years of research work by the consortium with support from other PV experts, professional associations, industrial partners, fire departments, installation companies, insurance companies and operators.

The work comprised several groups of topics:

- Fire risk assessment in PV systems, regarding both the effects of a fire from outside the system and the fire emergence risks within the PV system itself.
- Risk assessment during PV fire for rescue workers, in particular firefighters and strategies for avoiding risks
- Evaluation of possibilities for minimizing fire emergence and fire propagation risks within the PV systems
- Derivation of recommendations regarding component and system design, materials, quality assurance in manufacture, installation and operation

For the risk analysis, between 2011 and 2013 comprehensive research was conducted on actual fire damage to PV systems, including an online survey as well as surveys of professional fire departments and PV insurers in Germany. 430 cases of fire or heat damage in PV systems were investigated, in approximately half of which the PV system was considered the cause or probable cause. The studies found that in around a third of the cases the damage was caused by the PV components themselves, in another third by planning errors and in a final third by installation errors. Disproportionately many of the fire incidents occurred around mid-day or early afternoon and during the summer months, i.e. at high irradiance and therefore high current load. In these cases, defective and possibly pre-damaged components failed.

Given the findings from research and lab tests, an expert committee conducted an FMEA (“Failure Mode and Effects Analysis”). The main causal source of fault was found to be the “human factor so that the derived recommendations concern mainly quality assurance for the components as well as the planning and workmanship of the PV systems.

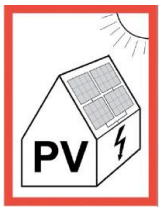
For the standardization we recommend defining intensified quality assurance measures in production, on both the component and module levels. Many manufacturers are already operating on a high level. A standardized quality assurance catalog will provide a uniform measure of quality and help prevent risks through the continual monitoring of the products.

Regular testing of the systems by independent third parties was deemed very purposeful. Additional safety components can further reduce the risk, but were ranked only in second place, following professional planning and construction of the systems with high-quality components.

In many cases defective or prematurely aged contacts of components were identified as sources of risks, both inside the modules themselves (junction boxes!) and among plug connectors and connections at contacts in collector boxes and inverters. These defects lead in the long term to overheating, which ultimately can cause scorching or an electric arc. The particular surrounding materials and installation situation then determine the further development of the damage. For example, inverter installations on or above a combustible supporting surface (wooden board), as often found by appraisers, can have devastating consequences in the event of a fault, as can (normally flammable) foil sheeting or wooden beams of the roof structures when BIPV modules are used.

Despite quality assurance measures, overheating or electric arcs cannot be ruled out 100%. Electric arc detectors can in principle additionally reduce risks, but only if they have greater detection reliability and a lower tendency to faulty activation. Owing to the electric arc characteristics and many possible interference factors, this improvement is very challenging and moreover inverter-specific. Here further

development is called for. Intensive research in the project already indicated approaches that require still further development. Another open issue is the necessary robustness for guaranteeing functionality during the currently estimated 25 – 30 years' operating time of the PV systems.



The project declared information on the presence of a PV system on a building to be a basic factor for firefighters' operational safety, a requirement to be implemented by a defined marking by means of a warning sign at the entrance area or at the house connection box.

Risks for firefighters come especially from the DC voltage produced at the generator field, voltage that persists even after disconnection from the grid at the DC end as long as light is impinging upon the modules.

At present no established state of the art exists for module and generator shutdowns and consequently no product and installation standards exist as yet. The standardization committees of the DKE have thus far developed an application rule (VDE-AR-E 2100-712) describing the technical and organizational minimum requirements for obtaining a safe system state in case of an emergency. A shutdown is generally not required, but is an optional solution if structural measures (e.g. safe routing of cables, placement of cables and inverter outdoors) are not regarded as sufficient.

Since rescue of people always has priority for emergency teams in tense situations under time pressure, compliance with the "five rules of safety" when dealing with electrical installations will hardly be possible. Despite the possible presence of a switch-off device, they will have to assume that the system is not de-energized.

This hazard can be counteracted by maintaining a minimum distance of 1 m, as is generally recommended for electrical installations. In particular, in cases of fire incidents with very restricted visibility, unclear situations in the building and the possible necessity of rescuing people, damaged DC cables pose an electrical hazard of high degree for the rescue workers. The risk-reducing routing of PV system cables inside or on top of the building therefore deserves particular attention. They should be routed as much as possible outside the building or through fire-protected conduits.

Series of conductivity tests have confirmed that if the specified minimum distances – 5 m with full jet and 1 m with spray jet – are maintained, then no danger to the rescue workers from hazardous electric currents via the extinguishing water jet will occur. To be kept in mind is the use of approved nozzles and water as an extinguishing agent, since foam additives will increase conductivity. The measurements moreover made clear that wet turn-out gear practically no longer provides protective insulation. Flooded basements with electrical installations such as inverters or electrical accumulators (batteries) pose a danger to life in the case of a fault! In addition to the risk of electric shock, caustic and explosive gases (electrolytic gases) can form. Good ventilation is therefore essential.

Studies on emissions during fires have found contamination levels added to the CO and CO_2 levels usually produced in house fires. Possible exceedances of toxicological limits among the heavy metals like lead and cadmium released depending on the technology were found only in the immediate vicinity of the fire site and only under very unfavorable conditions. On the basis of our research of the literature, our own fire tests and a propagation simulation, we can rule out any hazard to the environment from gaseous pollutants related to burning PV modules. Fire residue can contain toxic heavy metals like lead and cadmium in amounts exceeding the limits (soil thresholds for residential areas). In the event of damaged CdTe modules, quench water may introduce critical amounts of cadmium into the soil. While the measurement results cannot be generalized, they indicate a risk potential. We therefore regard the proper disposal of fire residue as crucial. In the event of more extensive fire damage to CdTe modules, we recommend soil examinations in the immediate vicinity.

Comprehensive series of tests with artificial lighting (spotlights) have confirmed that under certain conditions operational spotlights can generate dangerously high currents in the modules. The project

arrived at a generally applicable and simple distance formula that will enable firefighters to quickly determine the minimum distance for the employed spotlight power and thereby avoid electrical hazards from DC currents during night-time operations.

During its runtime the project increasingly used PV systems with accumulators. The state subsidies for these systems particularly in the small system segment and the rapid development of accumulator technologies lead us to expect increasing dissemination over the coming years. This research project was able to assess the new installation situations and risks only in individual cases.

A further research project headed by TÜV Rheinland will analyze the particular properties and risks from electrical accumulators in cases of damage. The full title runs: *Safety and reliability of photovoltaic systems with accumulator systems with particular consideration of fire risks and fire extinguishing strategies*.

In conclusion from the studies conducted in this and other parallel research projects, we may state that the fire emergence risk in PV systems is very low given planning in accordance with fire protection, use of high-quality components and proper installation. While overheating from contact aging during the operating time cannot be ruled out, it usually occurs only over longer periods of time. In the worst case an electric arc can occur. Direct current electric arcs are not self-extinguishing and therefore pose no risk of fire propagation. Regular inspections and maintenance can prevent more serious damage, as can inspection following special events such as storms or earthquakes. For special installation situations, electric arc detectors with switch-off devices can provide additional safety. These devices still require further development in terms of reliability and longevity.

PV systems pose no special danger for firefighters if the safety distances are maintained, as is the case with any other live electrical systems. An elementary and effective protective measure for firefighters is an easily visible sign indicating the presence of a PV system on the building.

8 Supplement

I. List of professional publications from the project

- *Fire Safety at PV Systems – Fire Prevention and Fire Fighting*, 15.02.2011, Photon PV Safety Conference, San Francisco – USA, F. Reil.
- *Normanforderungen zur Brandsicherheit sowie erweiterte Maßnahmen zur Brandvorbeugung und –bekämpfung*, 18.02.2011, 1st PV User Conference, Cologne, F. Reil.
- *Normanforderungen zur Brandsicherheit sowie erweiterte Maßnahmen zur Brandvorbeugung und –bekämpfung*, 18.03.2011, Argesolar Practice Workshop, Saarbrücken, F. Reil.
- *German Research Project: Fire Safety Risks at PV Systems and Risk Minimization*, 12.04.2011, Photon PV Safety Conference, Berlin, F. Reil.
- *Brandschutz an PV-Anlagen – Aktuelle Normanforderungen und Forschungsaktivitäten*, 14.04.2011, PV Components Workshop, Cologne, F. Reil
- *Normanforderungen für den Brandschutz von PV-Anlagen und Ausblick*, 17.05.2011, Bauzentrum München, Munich, F. Reil
- *Normanforderungen für den Brandschutz von PV-Anlagen und Ausblick*, 25.05.2011, Bauzentrum München, Munich, W. Vaaßen
- *Technische Möglichkeiten zur Abschaltung von Solargeneratoren im Schadensfalle – eine Übersicht und Bewertung*
  04. 03 2011, 26. Symposium on Photovoltaic Solar Energy,
  Bad Staffelstein, pages 594 – 599, Dr. H. Schmidt
- *Übersicht und Bewertung der verschiedenen Abschaltlösungen,*
  08.06.2011, DGS Workshop on "Photovoltaics and Fire Protection," Munich,
  Dr. H. Schmidt
- *Determination of Fire Safety Risks at PV Systems and Development of Risk Minimization Measures*, September 2011, EUPVSEC 2011, Hamburg, F. Reil, W. Vaaßen, A. Sepanski, B. van Heeckeren, F. Gülenc, Dr. H. Schmidt, R.Grab, G. Bopp, H. Laukamp, S. Phillip, H. Thiem, A. Richter, A. Krutzke, R. Haselhuhn, M. Halfmann, F. Volkenborn, Prof. Dr. H. Häberlin
- *Brandrisiken in PV-Anlagen und Erstellung von Sicherheitskonzepten,* November 2011, VDI Technical Form – PV and Fire Protection – A Smoldering Conflict, Düsseldorf, A. Sepanski, F. Reil, W. Vaaßen
- *Brandschutz an PV-Anlagen-Aktuelle Normanforderungen und Forschungsaktivitäten*, October 2011, TRLP Inverter Symposium, Cologne, F. Reil
- *Qualitätskontrolle von PV-Anlagen im Systemhaus*, January 2012, Fire Protection Workshop, Cologne, A. Richter
- *Statistische Schadensanalyse an deutschen PV-Anlagen*, January 2012, Fire Protection Workshop, Cologne, H. Laukamp
- *Lichtbogenversuche an Modulen und Komponenten*, January 2012, Fire Protection Workshop, Cologne, A. Sepanski

- *Elektrische Gefährdung der Feuerwehren durch PV-Anlagen (Messung elektrischer Leitfähigkeiten)*, January 2012, Fire Protection Workshop, Cologne, H. Thiem
- *Gefährdung beim Löschangriff an PV-Anlagen bei Mond- und Kunstlicht*, January 2012, Fire Protection Workshop, Cologne, Prof. Dr. H. Häberlin
- *Baustoffklassifizierung und Entflammbarkeitsuntersuchungen an PV-Modulen*, January 2012, Fire Protection Workshop, Cologne, F. Reil
- *Anforderung an die Qualitätssicherung*, January 2012, Fire Protection Workshop, Cologne, J. Althaus
- *Brandschutz bei BIPV,* January 2012, Fire Protection Workshop, Cologne, F. Reil
- *Brandschutzgerechte Installationen,* January 2012, Fire Protection Workshop, Cologne, R. Haselhuhn
- *Lichtbogenerkennung – Normüberblick und technische Anforderungen,* January 2012, Fire Protection Workshop, Cologne, S. Philipp
- *Sicherheitskonzepte zum Schutz vor elektrischem Schlag,* January 2012, Fire Protection Workshop, Cologne, S. Philipp
- *Fire Protection and Safety Concepts*, January 2012, 2nd Inverter and PV System Technology Forum, Berlin, H. Schmidt
- *PV Systems - a Fire Hazard? - Myths and facts from German experiences*, 2012, 27th EU PVSEC, H. Laukamp, G. Bopp, R. Grab, H. Häberlin, B. van Heeckeren, S. Phillip, F. Reil, H. Schmidt, A. Sepanski, H. Thiem, W. Vaaßen
- *Qualifizierung und Risikobetrachtung von Lichtbögen in PV-Modulen,* OTTI: PV Symposium, Bad Staffelstein, 2013, F. Reil, W.Vaaßen, A.Sepanski, B. van Heeckeren
- *Lichtbogendetektion in PV-Anlagen*, OTTI: PV Symposium, Bad Staffelstein, 2013, R. Grab, Prof. Dr. H. Häberlin, R. Schmitz, L. Borgna, Dr. H. Schmidt, H. Laukamp, G. Bopp, F. Reil
- *Brandverhalten von PV-Modulen*, VDI "Technische Sicherheit January 2013, M. Halfmann, Dr. B. Bansemer:
- *Lichtbogenerkennung bei PV-Modulen,* 9th Workshop on Photovoltaic Module Technology, 30.11.2012, S. Philipp:
- *PV Systems - a Fire Hazard? - Myths and facts from German experiences,* 27th EU PVSEC, 26.9.2012, H. Laukamp
- *Schadens- und Brandfallanalyse an PV-Anlagen,* 2nd Workshop on PV Fire Protection, 24.01.2013, Freiburg, H. Laukamp:
- *Risikoanalyse von PV-Systemen mit der FMEA-Methodik,* 2nd Workshop on PV Fire Protection, 24.01.2013, Freiburg, Dr. H. Schmidt:
- *Erarbeitung neuer Prüfmethoden für Lichtbogendetektoren,* 2nd Workshop on PV Fire Protection, 24.01.2013, Freiburg, R. Grab
- *Technische Brandrisikominimierung bei Gebäudeintegrierter Photovoltaik (BIPV),* 2nd Workshop on PV Fire Protection, 24.01.2013, Freiburg, F. Reil:

- *Fehleranalyseverfahren für Bypassdioden,* 2nd Workshop on PV Fire Protection, 24.01.2013, Freiburg, Dr. H. Schmidt:
- *Brandschutz an PV-Anlagen*, Solarpraxis PV Systemtechnik, Düsseldorf, 08.03.2013, F. Reil
- *Bestimmung von Brandrisiken an PV-Anlagen und Ableitung von Maßnahmen zur Risikominimierung*, Fortbildungsstätte der Berufsfeuerwehren NRW AGBF NRW, Münster, 22.10.2012, F. Reil
- *Bauregelung des DIBt mit Baustoffklassifizierung von PV-Modulen*, 10th Workshop on Module Technology, Cologne (represented by Alexander Werner, BSW), 30.11.2012, F. Reil
- *Bestimmung von Brandrisiken an PV-Anlagen und Ableitung von Maßnahmen zur Risikominimierung*, Berlin Science Days, Berlin, 27.11.2012, F. Reil:
- *Baulicher Brandschutz an PV-Anlagen*, NRW Consumer Protection, Siegburg, 23.11.2013, F. Reil
- *Entzündbarkeit von Solarmodulen und Komponenten*, TLRP Inverter Workshop, Cologne 20.11.2012, F. Reil
- *Comparison of Different DC Arc Spectra – Derivation of Proposals for the Development of an International Arc Fault Detector Standard*, IEEE PVSC Publication, Tampa, USA, 2013
- *Determination of Arcing Risks in PV Modules with Derivation of Risk Minimization Measures* IEEE PVSC Publication, Tampa, USA, 2013
- *Qualität in der Photovoltaik – Werterhalt und Ertragssicherung durch Wartung*, EnergieAgentur NRW, Düsseldorf, 2013
- *Zusammenfassung Schadensfallerhebung und -analyse,* Results of an Extensive Collection of Data on Damage Incidents, Fire Protection Workshop, Cologne, January 2014, H. Laukamp, Dr. H. Schmidt, Fraunhofer-Institut für Solare Energiesysteme ISE
- *Lichtbogendetektion in PV-Anlagen,* Fire Protection Workshop, Cologne, January 2014, R. Grab, Fraunhofer-Institut für Solare Energiesysteme ISE, Prof. Dr. H. Häberlin, L. Borgna, Berner Fachhochschule Technik und Informatik, BFH-TI
- *Hinweise zu einer ganzheitlichen Installation zur Brandrisikominimierung*, Cologne, January 2014, R. Haselhuhn, Deutsche Gesellschaft für Sonnenenergie e.V. DGS
- *Installationsempfehlungen und Diskussionsstand der zukünftigen PV Installationsnorm IEC 60364-9-1,* Fire Protection Workshop, Cologne, January 2014, G. Bopp, H. Laukamp, Fraunhofer-Institut für Solare Energiesysteme ISE
- *Neuartige Methoden zur Qualitätssicherung und Fehlersuche,* Brandschutz-Workshop, Cologne January 2014, *N.Bogdanski, TÜV Rheinland Energie und Umwelt GmbH, Dr. H. Schmidt, Fraunhofer-Institut für Solare Energiesysteme ISE*
- *Emissionen von Solarmodulen im Brandfall, Brandschutz-Workshop*, Cologne, January 2014, A. Sepanski, TÜV Rheinland Energie und Umwelt GmbH
- *Elektrische Risiken für Einsatzkräfte, Rückblick und neue Ergebnisse*, Fire Protection Workshop, Cologne January 2014, Horst Thiem, Berufsfeuerwehr München, M. Reichard, A. Sepanski, F. Reil, TÜV Rheinland Energie und Umwelt GmbH

- *Emissionen von Photovoltaikmodulen im Brandfall,* 11th Workshop on Module Technology, Cologne, November 2014, A. Sepanski, TÜV Rheinland Energie und Umwelt GmbH, B. Bansemer Currenta GmbH

Two television reports from *Bavarian Broadcasting* (*Geld+Leben* broadcast in 2011) and ARD (*Plusminus*) covered the debate on fire protection at PV systems. The present research project was also mentioned in the ARD broadcast.

In its broadcast *hitec* in December 2011, the German-language TV station *3SAT* intensively documented the conductivity measurements and referred to the work of the research project. The project homepage contains a link to the segment. The subject was also treated in the *WDR* program *Kopfball*, with very intuitive explanations of the topics covered in section 5.5.

II. Document download

- Brochure on “Brandschutzgerechte Planung, Errichtung und Instandhaltung von PV-Anlagen” (Planning, Installation and Maintenance of PV systems for Fire Protection): http://www.dgs.de/fileadmin/bilder/Dokumente/PV-Brandschutz_DRUCK_24_02_2011.pdf

- DIBT paper on “Hinweise für die Herstellung, Planung und Ausführung von Solaranlagen” (Information for the Manufacture, Planning and Implementation of Solar Systems) https://www.dibt.de/de/Fachbereiche/Abteilung_I.html

- BSW Solar, Information Sheet for Rescue Workers – Operations at Stationary Lithium Solar Energy Accumulators – Information for Firefighting and Technical Assistance http://bsw.li/1u5Yqz5

III. Websites

- Project homepage: http://www.pv-brandsicherheit.de
- Homepages of the project partners:
  - TÜV Rheinland Energie und Umwelt GmbH: www.tuv.com/PV
  - Fraunhofer Institut Solare Energiesysteme: www.ise.fraunhofer.de
  - Deutsche Gesellschaft für Sonnenenergie, Landesverband Berlin-Brandenburg e.V: http://www.dgs-berlin.de
  - Munich Fire Department / Fire Technology: http://www.muenchen.de/rathaus/Stadtverwaltung/Kreisverwaltungsreferat/Branddirektion-Muenchen.html
  - Currenta GmbH & Co. OHG: Analysis: http://www.analytik.currenta.de
  - Energiebau Solarstromsysteme GmbH: http://www.energiebau.de
  - Bern University of Applied Sciences: http://www.bfh.ch
    Photovoltaics Lab of Bern University of Applied Sciences: http://www.pvtest.ch
- Deutsche Gesellschaft für Sonnenenergie: http://www.dgs.de
- Bundesverband Solarwirtschaft: http://www.solarwirtschaft.de
  Guidelines on planning and installation of photovoltaic systems and other professional publications:
  http://www.dgs-berlin.de/de/publikationen/photovoltaikleitfaden.html
- German Federal Network Agency: http://www.bundesnetzagentur.de
  Photovoltaic system registry:
  http://www.bundesnetzagentur.de/cln_1411/DE/Sachgebiete/ElektrizitaetundGas/Unternehmen_Institutionen/ErneuerbareEnergien/Anlagenregister/Anlagenregister_node.html

IV. Survey

The survey on incidents of overheating and fire related to PV systems continues to be available online. The data continue to be collected in 2015. We appreciate your support.

You can reach us online at: http://www.pv-brandsicherheit.de

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VII. List of abbreviations

Abbreviation	Description
ABS	Acrylnitrile-butadiene-styrene copolymer
AEGL	Acute Exposure Guideline Level
a-Si	Amorphous silicon (thin-film module)
AR	Anti-reflective layer
ASTM	ASTM International (originally American Society for Testing and Materials)
Forward bias	Voltage applied across a P-N junction in the forward direction
BBodSchgV	Bundes-Bodenschutz- und Altlastenverordnung (Federal Soil Protection and Contaminated Sites Ordinance)
BIMSCHV	Federal Immission Control Ordinance
BMU	Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety)
BMWi	Bundesministerium für Wirtschaft und Energie (Federal Ministry for Economic Affairs and Energy)
CdTe	Cadmium telluride
CPS	Concentrated Solar Power
DIN	Deutsches Institut für Normung e. V. (German Institute for Standardization)
ETW	Einsatz-Toleranz-Werte (maximum exposure concentration)
EL	Electroluminescence
ERPG	Emergency Response Planning Guidelines
EVA	Ethylene-vinyl-acetate
EN	European Norms
FSI	Flame Spread Index
FTIR	Fourier transformation infrared spectrometer
GAK (GJB)	Generatoranschlusskasten (generator junction box)
HPLC	High Performance Liquid Chromatography
NN (msl)	Normalnull (mean sea level)
IR	Infrared (thermography)
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
IEC	International Electrotechnical Commission
c-Si	Crystalline silicon (thick-film module)
CIS	Copper indium diselenide
LBO	Landesbauordnung (state building code)
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
Mpp	Maximum Power Point
ML	Mechanical Load

μ -Si	Micromorphous silicon
MBO	Musterbauordnung (Model Building Regulation)
PA	Polyamide
PAC	Protective Action Criteria
PET	Polyethylene terephthalate
PSA	Persönliche Schutzausrüstung (personal protective equipment)
PVB	Polyvinyl butyral
PVF	Polyvinyl fluoride
STC	Standard Test Conditions
IV	Current x voltage diagram (also I/U characteristic)
UL	Underwriters Laboratories
VFDB	Vereinigung zur Förderung des Deutschen Brandschutzes (Association for the Promotion of German Fire Protection)
WT	Wet Leakage

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IX. Appendices

a) FMEA results

Results of the FMEA analysis of fire risks in PV systems, Dec. 10, 2012, Frankfurt

			Actual status				Improved status					
Component involved / location	Potential faults	Potential causes	Probability of occurrence	Probability of fire emergence (significance)	Probability of detection	RPN	Possible remedial measures	Probability of occurrence	Probability of fire emergence (significance)	Probability of detection	RPN	Comments
DC plug												
PV connectors	Plug connector scorched	Plug not fully inserted	4	7	8	224	Training of the installers	3	7	8	168	
							Plug design: Snap tabs, touch & feel, color ring, etc.	2	7	7	98	
							Acceptance inspection (DIN 0126-23)	4	7	7	196	
							Acceptance inspection (revised methods, e.g. IR)	4	7	6	168	Develop new measuring methods
							Regular repeat inspections (DIN 0126-23)	4	7	7	196	
							Regular repeat inspections (revised method, e.g. IR)	4	7	5	140	
							Electric arc detector	4	4	7	112	If functioning reliable
		Plug mechanically damaged or corroded due to improper installation, weather conditions, animal bites, production faults	4	7	7	196	Training of the installers	3	7	7	147	
							Acceptance inspection (DIN 0126-23)	4	7	7	196	
							Regular repeat inspections (DIN 0126-23)	4	7	5	140	
							Electric arc detector	4	4	6	96	
							Insulation measurement	4	7	5	140	
		Plugs poorly crimped at the factory (also within distributors, inverters, etc.)	3	7	7	147	QA measures at manufacturer					
							Acceptance inspection (visual, IR, new measuring procedures)					

			Actual status				Improved status					
Component involved / location	Potential faults	Potential causes	Probability of occurrence	Probability of fire emergence (significance)	Probability of detection	RPN	Possible remedial measures	Probability of occurrence	Probability of fire emergence (significance)	Probability of detection	RPN	Comments
		*Plugs poorly crimped **at the factory** (also within distributors, inverters, etc.)*	3	7	7	147	*Regular repeat inspections (visual, IR, new measuring procedures)*					
							Electric arc detector					
		Plugs poorly crimped on site	7	7	7	343	*Training of the installers*	4	7	7	196	
							Plug design: Contacts connected without tool	3	7	7	147	
							Regular repeat inspections (DIN 0126-23)	7	7	5	245	
							Electric arc detector	7	4	6	168	
		*Plugs from **different manufacturers** (fakes) combined*	7	7	9	441	*Training of the planners/ installers*	4	7	9	252	
							Suitability for standardized, compatible plugs	1	7	9	63	
							Normative exclusion of incompatible connections	2	7	9	126	
AC plug												
		Screw contacts insufficiently tightened	3	6	5	90	*Training of the installers*					
							Acceptance inspection (visual, IR, new measuring procedures)					
							Regular repeat inspections (visual, IR, new measuring procedures)					
AC plug	*Plug scorched*	*Impermissibly rigid cable at unsuitable plug*	5	5	4	100	*Training of the installers*					
							Acceptance inspection (visual, IR, new measuring procedure)					
		Impermissibly flexible cable without suitable conductor sleeves	5	4	7	140	*Training of the installers*					

			Actual status				Improved status					
Component involved / location	Potential faults	Potential causes	Probability of occurrence	Probability of fire emergence (significance)	Probability of detection	RPN	Possible remedial measures	Probability of occurrence	Probability of fire emergence (significance)	Probability of detection	RPN	Comments
		Impermissibly flexible cable without suitable conductor sleeves	5	4	7	140	*Acceptance inspection (visual, IR, new measuring procedures)*					
Screw terminals (DC)												
Screw terminals in field distributors, inverters (DC end)	*terminals scorched*	*Screw contacts insufficiently tightened, cables unsuitably introduced*	7	7	6	294	*Training of the installers, torque wrench*	4	7	6	168	
							Acceptance inspection (DIN 0126-23)	7	7	5	245	
							Acceptance inspection (improved, e.g. with IR or contact resistance measurement)	7	7	3	147	
							Regular repeat inspections (DIN 0126-23)	7	7	4	196	
							Regular repeat inspections (improved, e.g. with IR)	7	7	3	147	
							Preferred use of spring-type terminals (where possible)	3	7	3	63	
							Structural modifications of generator junction boxes	5	7	4	140	*e.g. simpler, straight-line introduction of cables*
							Electric arc detector	7	4	6	168	
		Undersized, too tightly packed (ambient temperature, derating), no potential separator plates, etc.	5	8	7	280	*Improve planning*	3	8	7	168	
							Acceptance inspection (DIN 0126-23)	5	8	5	200	
							Improved acceptance inspection (e.g. resistance measurement, IR)	5	8	4	160	
							Inspection by third party (PV expert)	5	8	2	80	
		Cable insulation also clamped in	5	7	8	280	*Training of the installers*	5	7	8	280	*Not helpful in this case*
							Acceptance inspection (DIN 0126-23)	5	7	8	280	

			Actual status				Improved status					
Component involved / location	Potential faults	Potential causes	Probability of occurrence	Probability of fire emergence (significance)	Probability of detection	RPN	Possible remedial measures	Probability of occurrence	Probability of fire emergence (significance)	Probability of detection	RPN	Comments
		Cable insulation also clamped in	5	7	8	280	*Expanded acceptance inspection (with thermal camera)*	5	7	4	140	
							Structural modification of the terminal strip (alignment)	4	7	6	168	
		Improper workmanship of aluminum lines	7	8	6	336	*Training of the installers*	5	8	6	240	
							Acceptance inspection (DIN 0126-23)	7	8	5	280	
							Expanded acceptance inspection (with thermal camera)	7	8	3	168	
							Inspection by third party (PV expert with aluminum background)	7	8	3	168	
							Electric arc detector	7	7	6	294	*Large cross sections -> large output ->consequence: parallel electric arc*
Screw terminals (AC)												
		Screw contacts insufficiently tightened, cables unsuitably introduced	6	6	6	216	*Training of the installers, torque wrench*	4	6	6	144	
							Acceptance inspection (DIN 0126-23)	6	6	5	180	
							Acceptance inspection (improved, e.g. with IR orcontact resistance measurement)	6	6	3	108	
							Regular repeat inspections (DIN 0126-23)	6	6	4	144	
							Regular repeat inspections (improved, e.g. with IR)	6	6	3	108	
							Preferred use of spring-type terminals (where possible)	3	6	3	54	
							Structural modifications of generator junction boxes	5	6	4	120	*e.g. easier, straight introduction of lines*
							Electric arc detector					*Electric arc in copper lines only at very high temperature, effect unclear*

			Actual status				Improved status					
Component involved / location	Potential faults	Potential causes	Probability of occurrence	Probability of fire emergence (significance)	Probability of detection	RPN	Possible remedial measures	Probability of occurrence	Probability of fire emergence (significance)	Probability of detection	RPN	Comments
Screw terminals in field distributors, inverters (AC end)	terminals scorched	Undersized, too tightly packed (ambient temperature, derating), no potential separator plates, etc.	5	7	7	245	Improve planning	3	7	7	147	
							Acceptance inspection (DIN 0100-600)	5	7	5	175	
							Improved acceptance inspection (e.g. resistance measurement, IR)	5	7	4	140	
							Inspection by third party (PV expert)	5	7	2	70	
		Cable insulation also clamped in	5	6	8	240	Training of the installers	5	6	8	240	
							Acceptance inspection (DIN 0100-600)	5	6	8	240	
							Expanded acceptance inspection (with thermal camera)	5	6	4	120	
							Structural modification of the terminal strip (alignment)	4	6	6	144	
		Improper workmanship of aluminum lines	7	8	6	336	Training of the installers	5	8	6	240	Not helpful in this case
							Acceptance inspection (DIN 0100-600)	7	8	5	280	
							Expanded acceptance inspection (with thermal camera)	7	8	3	168	
							Inspection by third party (PV expert with aluminum background)	7	8	3	168	
							Electric arc detector	7	4	5	140	Electric arcing with copper
Soldered connections												
Soldered joints within the module (cell connector, cross connector)	Soldered points scorched, possibly electric arcs in the module	Poor soldering, aging from mechanical / thermal stress	7	6	9	378	QA improvement at manufacturer (24h)	2	6	9	108	
							Regular repeat inspection (DIN 0126-23)	7	6	8	336	

			Actual status					Improved status					
Component involved / location	Potential faults	Potential causes	Probability of occurrence	Probability of fire emergence (significance)	Probability of detection	RPN		Possible remedial measures	Probability of occurrence	Probability of fire emergence (significance)	Probability of detection	RPN	Comments
		Poor soldering, aging from mechanical/ thermal stress	7	6	9	378		*Regular, improved repeat inspections (with IR)*	7	6	3	126	*If the sun is shining*
								Electric arc detector	7	4	7	196	
Diodes													
Bypass and string diodes	*Diodes short-circuited or open*	*Overvoltage from static discharge during module production and installation*	4	4	9	144		*QA measures, training of installers*					
								Surge protection at the diodes					
		Overvoltage from electrical storm or switching operations in the system	6	4	8	192		*Regular lightning strike*	4	4	8	128	
								Surge protection at the diodes, voltage-proof diodes	3	4	8	96	
								Expanded repeat inspections (IR, new measuring procedures)	6	4	4	96	
		Long-term failure from thermal overload and temperature cycles with variable shading	4	4	9	144		*Use of "cool" technologies*					
								Regular repeat inspections (visual, IR, new measuring procedures)					
Module													
Module	*Open circuits, insulation flaws*	*Torn-off cell connectors (straps)*	4	6	8	192		*Manufacturer's design modifications, QA measures*	2	6	8	96	
								Regular repeat inspections (IR, new measuring procedures)	4	6	4	96	
								Electric arc detector	4	4	7	112	
		Cell breakage	2	3	8	48							
		Glass breakage	6	5	2	60		*Improved mounting technology*					

			Actual status					Improved status					
Component involved / location	Potential faults	Potential causes	Probability of occurrence	Probability of fire emergence (significance)	Probability of detection	RPN	Possible remedial measures	Probability of occurrence	Probability of fire emergence (significance)	Probability of detection	RPN	Comments
		Glass breakage	6	5	2	60	*Repeat inspections (visual, IR, new measuring procedure)*					
							Electric arc detector					
		Damage to the backing film from mounting error, aging (delamination) or vandalism	5	4	7	140	*Training of the installers*					
							Insulation monitoring through inverter					
							Acceptance inspection (visual, IR, new measuring procedures)					
							Regular repeat inspections (visual, IR, new measuring procedures)					
		Cell damage such as micro-cracks, snail tracks, etc.	8	2	6	96	*Avoidance of causes through design and QA measures*					
							Regular repeat inspections (visual, IR, new measuring procedures)					
DC fuses												
DC fuses	*Overheating, deficient switching characteristics*	*Use of unsuitable fuses, e.g. AC fuses or insufficient voltage or current parameters or unsuitable installation*	6	8	7	336	*Improved planning, selection of suitable components*	2	8	7	112	
							Dispense with DC fuses if possible	1	1	1	1	*Note: Only if possible (2 or 3 strings)*
							Acceptance inspection (as per DIN 0126-23)	6	8	4	192	
							Acceptance inspection by third party (PV expert)	6	8	2	96	
AC fuses												
AC fuses	*Overheating*	*Overheating by excessive bundling, high ambient temperatures (derating), etc.*	6	6	5	180	*Improved planning selection of suitable components*	3	6	5	90	
							Acceptance inspection (as per DIN 0100-600)	6	6	3	108	

			Actual status				Improved status					
Component involved / location	Potential faults	Potential causes	Probability of occurrence	Probability of fire emergence (significance)	Probability of detection	RPN	Possible remedial measures	Probability of occurrence	Probability of fire emergence (significance)	Probability of detection	RPN	Comments
		Overheating by excessive bundling, high ambient temperatures (derating), etc.	6	6	5	180	Regular repeat inspections (as per DIN 0105-100)	6	6	2	72	Brown discoloration also discernible
Cable (DC and AC)												
Cable (DC and AC)	Mechanical damage, insulation flaws, electric arcs	Long-term damage from weather conditions (UV radiation,humidity, temperature cycles, etc.)	7	7	4	196	Selection of suitable components	4	7	4	112	
							Protected cable routing	3	7	4	84	
							Cable routing in separated protected tubing	3	5	4	60	
							Insulation monitoring through inverter	7	7	2	98	Actually already state of the art
							Regular repeat inspections (as per DIN 0126-23)	7	7	3	147	
							Electric arc detector	7	7	4	196	Parallel and ground electric arcs
		Damage from negligent installation	7	5	4	140	Training of the installers					
							Acceptance inspection (visual, insulation measurement)					
		Electrical overload due to cross section or heaped routing	5	5	6	150	Improved planning, selection of suitable components					
							Acceptance inspection (visual, IR)					
DC switch												
DC switch within or outside the inverter		Not DC suitable	3	8	6	144	Improved planning, selection of suitable components					
							Acceptance inspection (visual, IR, new measuring procedures)					
		Rated voltage and current insufficient	6	8	6	288	Improved planning, selection of suitable components	2	8	6	96	

			Actual status					Improved status					
Component involved / location	Potential faults	Potential causes	Probability of occurrence	Probability of fire emergence (significance)	Probability of detection	RPN	Possible remedial measures	Probability of occurrence	Probability of fire emergence (significance)	Probability of detection	RPN	Comments
		Rated voltage and current insufficient	6	8	6	288	Acceptance inspection (as per DIN 0126-23)	6	8	3	144	Contact holder Switches must be actuated
Inverter												
Inverter		Ventilation clogged /out of order	6	4	5	120	Selection of a cleaner location					
							Fail-safe behavior of the inverter					
							Regular maintenance /cleaning					
							Regular repeat inspections (visual, IR, new measuring procedures)					
		Ambient temperature too high	5	4	5	100	Improved planning, selection of suitable components					
							Ventilation measures					
		Internal electrical defects	4	4	8	128	Good design, high manufacturing quality					
							Surge protection					
							Metallic housing					
							Electric arc detector /module shutdown					
Moisture												
General installation	Corrosion from moisture	Unsuitable protection class (IP xx) / deficient air exchange	5	4	6	120	Improved planning, selection of suitable components					Select the correct protection class for the given installation site
							Acceptance inspection (visual, IR, new measuring procedures)					
		Cable introduced into PG cable glands from above	4	4	3	48	Training of the installers					

			Actual status				Improved status					
Component involved / location	Potential faults	Potential causes	Probability of occurrence	Probability of fire emergence (significance)	Probability of detection	RPN	Possible remedial measures	Probability of occurrence	Probability of fire emergence (significance)	Probability of detection	RPN	Comments
		Cable introduced into PG cable glands from above	4	4	3	48	*Acceptance inspection (visual, IR, new measuring procedures)*					
Fire hazard												
General installation		*Mounting on combustible surface (e.g. wooden board or chipboard) or insurroundings containingeasily combustible objects (e.g. straw, hay, fuels, etc.)*	6	6	5	180	*Selection of a suitable location*	1	6	5	30	
							Compliance with pertinent VDE and building codes	2	6	5	60	
							Compliance with the manufacturer's specifications	3	6	5	90	*If appropriate*
							Acceptance inspection (as per DIN 0126-23)	6	6	3	108	
							Regular repeat inspections (as per DIN 0126-23)	6	6	3	108	*Change in use of the space possible*
J box soldered connections												
Soldered connections inside the junction box	*Soldered points scorched, possibly electric arcs in the module or in the junction box*	*Poor soldering, aging from mechanical / thermal stress*	5	7	9	315	*QA improvement at manufacturer*	2	7	9	126	
							Regular repeat nspection (DIN 0126-23)	5	7	9	315	
							Expanded regular repeat inspections (with IR)	5	7	3	105	
							Electric arc detector	5	4	8	160	

CURRENTA

b) Laboratory tests on PV module emissions

1. Subject and purpose of investigation

In connection with the BMU research project on “Assessing Fire Risks in Photovoltaic Systems and Developing Safety Concepts for Risk Minimization,” experimental studies were conducted at the fire testing center of CURRENTA during June 2014 with the aim of characterizing the release of harmful substances by photovoltaic modules in case of fire. The experimental program covered three different module types (table 1). A flame was applied to the backs of the inclined modules with a gas burner, in order to simulate a possible fire emergence scenario among roof-mounted PV applications. Pollution analyses were conducted on smoke gas, fire residue and quench water samples.

Type	Design	Frame	Length (mm)	Width (mm)	Thickness (mm)
c-Si	Glass film	Aluminum	1,655	1,000	45*
CIS	Glass film	Aluminum	1,255	980	35*
CdTe	Glass-glass	None	1,200	600	8
* Frame thickness					

Table 1: Investigated module types

2. Test setup

The PV modules were mounted with profile rails 40 mm high and arranged crosswise on a fiber cement mounting plate, located on a test platform inclined 23° relative the horizontal plane (figure 1). The inclination was selected as in the roof fire test as per UL 790. The modules protruded 45 cm beyond the front edge of the mounting plate and a flame was applied to their undersides in this area. The gas burner described in UL 790 served as the ignition source, producing a flame approximately 100 cm in width (figure 2). The burner was positioned 10 cm below the front edge of the module, with the horizontal distance to the module front edge also being 10 cm.

On the front and back of the module five thermal elements each were arranged along the longitudinal axis of the module. The distances to the module front edge were 10, 40, 70, 100 and 130 cm. In the temperature diagrams contained in the Appendix, “MS-01” (module back) and “MS-06” (module front edge) designate the measuring points on the module front edge.

For the quench water tests, two extinguishing nozzles were installed in the upper part of the test setup in the interspace between the module and the mounting plate. To catch the quench water running off the mounting plate, a 1.75 × 1.50 m² steel tray was placed on the floor of the test building.

To apply the flame to module areas of similar size, for the c-Si modules the tests were performed on one module along the longitudinal direction (length: 1655 mm), for the CIS modules on two modules along the transverse direction (total length: 1960 mm) and for the CdTe modules on three modules along the transverse direction (total length: 1840 mm incl. mounting distance).

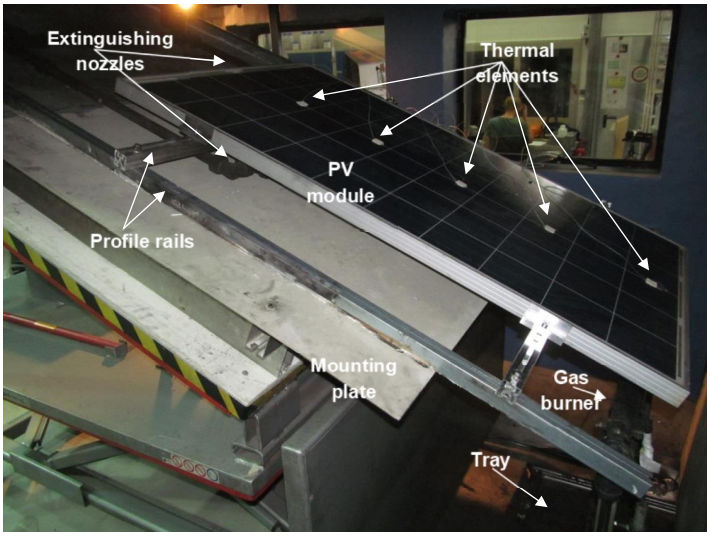


Figure 1: Test setup (shown here with a c-Si module)

Figure 2: Gas burner

3. Performance of test

On each module type, tests were performed with a burner output of 25 kW and 150 kW, in order to analyze the fire behavior and pollutant release of the modules at different thermal stress intensities (figure 3). In addition, a further test was performed on each module type with a burner output of 150 kW, such that after six to seven minutes the fire was extinguished in each case with 20 l quench water over a period of 45 s.

The tests were performed underneath an exhaust hood as per ISO 9705, with an exhaust flow rate of about 1 m³/s. The following variables were measured:

- Heat release rate
- Smoke production rate
- Temperatures on front and back of the module
- Mass loss of the modules and mass of the fire residue
- Destroyed module surface
  - Formation rates of the gas compounds carbon dioxide (CO_2), carbon monoxide(CO), hydrogen cyanide (HCN), hydrogen chloride (HCl), hydrogen bromide (HBr), hydrogen fluoride (HF), nitrogen monoxide (NO), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2)
- Amounts of arsenic, lead, cadmium and selenium contained in the smoke gases
- Amounts of arsenic, lead, cadmium and selenium contained in the fire residue
- Amounts of arsenic, lead, cadmium and selenium contained in the quench water

In addition, two reference tests were performed with (non-combustible) calcium silicate plates instead of the modules in order to determine which smoke, CO_2 and CO formation rates the gas burner caused under the planned operating conditions. These measurement values were deducted from the actual measurement results, so that the test results listed in section 4 exclusively referred to the PV module emissions.

Smoke gas analysis

For determining the arsenic, lead, cadmium and selenium levels, a partial stream from the waste air flow was conducted through a filter system and through a sorbent. The analysis was performed with ICP-MS. The measurement results listed in section 4 correspond to the sum of the particle-bound and to the filterable parts.

The gas compounds (except formaldehyde) were analyzed continually over time with an FTIR spectrometer connected to the exhaust tube of the extraction system. Section 4 lists the concentrations averaged over the duration of the test.

For determining the formaldehyde content, an absorption cartridge was used, with the analysis being performed with HPLC.

Fire residue analysis

The fire residue consisted of damaged, fallen-off parts of modules that accumulated on the mounting plate of the test frame and in the tray placed underneath during the test. The fire residue was first swept together and thoroughly mixed. Two samples were taken and pulverized with a granulator. The arsenic, lead, cadmium and selenium levels were determined with ICP-MS.

Quench water analysis

After mixing the quench water collected in the tray, two samples were taken and analyzed as to the arsenic, lead, cadmium and selenium levels by means of ICP-MS.

CURRENTA analyzed the arsenic, lead, cadmium and selenium levels in its Elemental Analysis department, smoke gas samples and formaldehyde levels in its Air Analysis department and fire residue pulverization in its Environmental Analysis department.

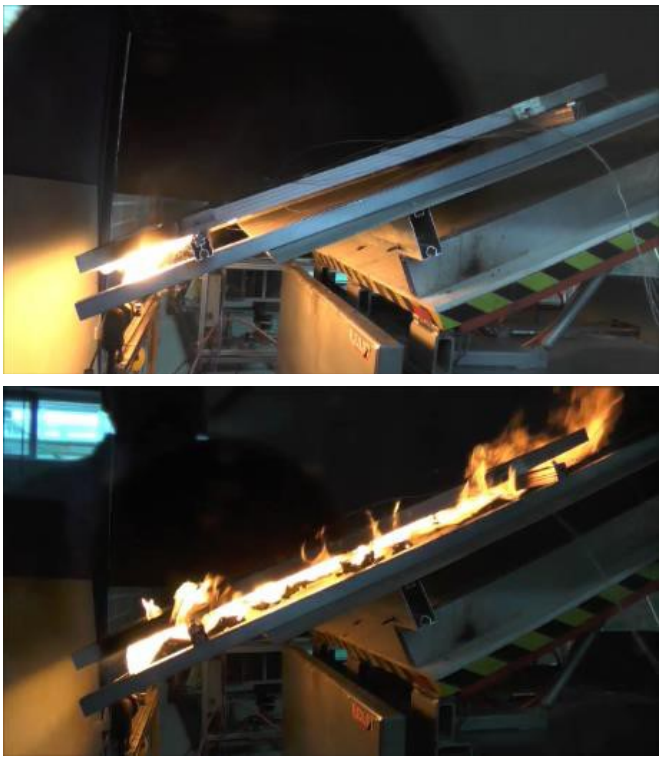


Figure 3: Fire test with a burner output of 25 kW (top) and 150 kW (bottom)

4. Test results

Altogether nine tests were performed, as listed in the following table:

	25 kW burner output	150 kW burner output	150 kW burner output, quench water test
Module type c-Si	1A	1B	1C
Module type CIS	2A	2B	2C
Module type CdTe	3A	3B	3C

Table 2: Test designation

In the 25 kW burner output experiments, only locally limited, primarily surface, damage occurred on all three module types. At 150 kW burner output, the modules were destroyed over wide areas; the test documentation appears in the appendix to the report.

The results of the chemical analysis are specified in the following as masses of the respective analytes relative to one standard cubic meter of smoke gas, one kilogram of fire residue or one liter of quench water. Also listed are the total released quantities yielded by multiplying the measured concentration and the total volume of the smoke gas, the total mass of the fire residue or the total volume of the quench water used.

n.d.: not detectable

n.i.: not investigated

4.1 Module type c-Si

Heat release, smoke development and damage to the specimen

		Test 1A	Test 1B	Test 1C
Test duration	(s)	1,200	1,200	600
Maximum heat release rate	(kW)	29.2	246.6	272.9
Average heat release rate	(kW)	6.4	49.3	46.2
Total heat release	(kJ)	7,631	59,197	27,747
Maximum smoke production rate*	(m²/s)	0.12	0.78	2.05
Average smoke production rate*	(m²/s)	0.03	0.15	0.12
Total smoke production*	(m²)	41	182	73
Initial mass of specimen	(g)	19,978	20,022	19,882
Residual mass of specimen	(g)	19,525	5,502	10,375
Mass loss	(g)	453	14,520	9,507
Mass loss	(%)	2.3	72.5	47.8
Mass of fire residue	(g)	143	12,798	n.i.
Burned mass	(g)	310	1,722	n.i.
Destroyed area	(m²)	0.54	1.53	0.97

***** *The smoke production is given in m², i.e. the area projected by the sum of all smoke particles onto a 2-dimensional plane*

Table 3: Fire-technological parameters for module type c-Si

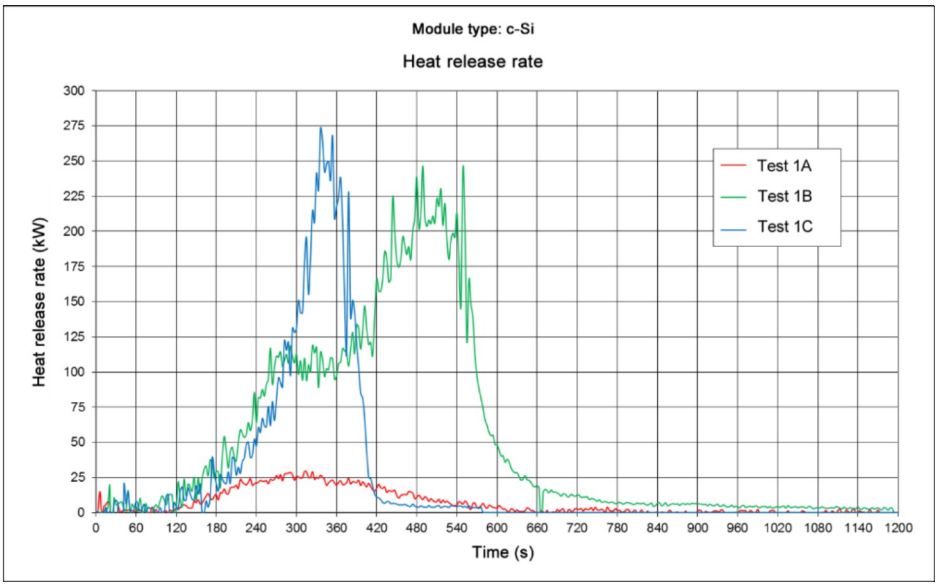


Figure 4: Module type c-Si heat release rate

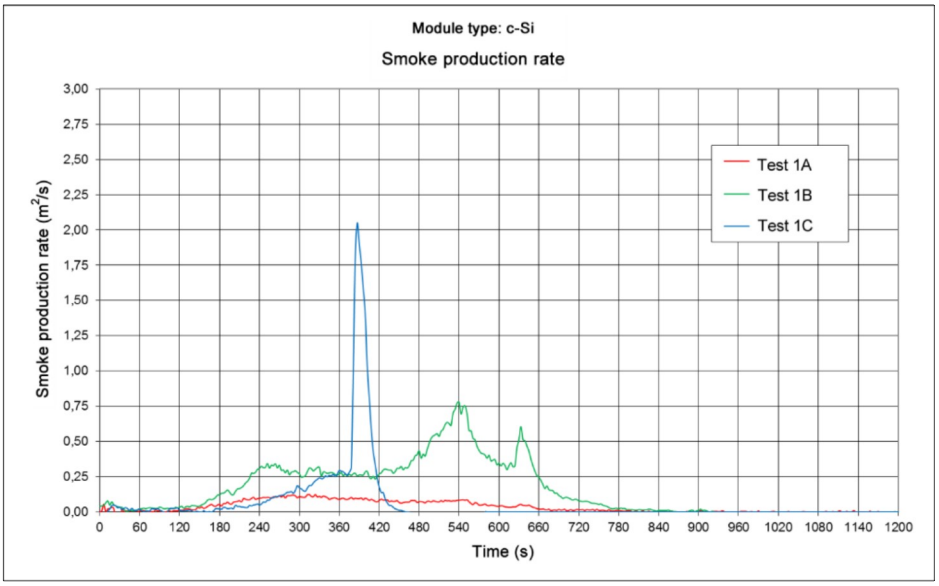


Figure 5: Module type c-Si smoke production rate

Smoke gas analysis

		Test 1A	Test 1B	Test 1C
Arsenic	(µg/m³)	1.1	0.8	0.1
Lead	(µg/m³)	50	630	1,010
Cadmium	(µg/m³)	6.5	60	77
Selenium	(µg/m³)	24	10	9.8
Carbon dioxide	(mg/m³)	842	3,786	3,068
Carbon monoxide	(mg/m³)	6	30	30
Hydrogen cyanide	(mg/m³)	n.d.	n.d.	n.d.
Hydrogen chloride	(mg/m³)	n.d.	n.d.	n.d.
Hydrogen bromide	(mg/m³)	n.d.	n.d.	n.d.
Hydrogen fluoride	(mg/m³)	n.d.	n.d.	n.d.
Nitrogen monoxide	(mg/m³)	n.d.	n.d.	n.d.
Nitrogen dioxide	(mg/m³)	n.d.	n.d.	n.d.
Sulfur dioxide	(mg/m³)	n.d.	n.d.	n.d.
Formaldehyde	(mg/m³)	1.0	0.9	1.8

Table 4: Module type c-Si smoke gas analysis – measurement values (time-averaged)

		Test 1A	Test 1B	Test 1C
Arsenic	(mg)	1.3	1.0	0.1
Lead	(mg)	61	760	600
Cadmium	(mg)	7.9	72	46
Selenium	(mg)	29	12	5.8
Carbon dioxide	(g)	1,020	4,543	1,822
Carbon monoxide	(g)	7	36	18
Formaldehyde	(g)	1.2	1.1	1.1

Table 5: Module type c-Si smoke gas analysis – computed total release

Fire residue analysis

		Test 1A		Test 1B		Test 1C	
		Specimen 1	Specimen 2	Specimen 1	Specimen 2	Specimen 1	Specimen 2
Arsenic	(mg/kg)	48	30	11	9.1	n.i.	n.i.
Lead	(mg/kg)	4,800	6,400	700	2,700	n.i.	n.i.
Cadmium	(mg/kg)	0.3	2.5	0.4	1.4	n.i.	n.i.
Selenium	(mg/kg)	0.5	110	0.3	20	n.i.	n.i.

Table 6: Module type c-Si fire residue analysis – measurement values

		Test 1A		Test 1B		Test 1C	
		Specimen 1	Specimen 2	Specimen 1	Specimen 2	Specimen 1	Specimen 2
Arsenic	(mg)	6.9	4.3	140	120	n.i.	n.i.
Lead	(mg)	690	920	9,000	35,000	n.i.	n.i.
Cadmium	(mg)	0.04	0.36	5.1	18	n.i.	n.i.
Selenium	(mg)	0.07	16	3.8	260	n.i.	n.i.

Table 7: Module type c-Si fire residue analysis – computed total release

Quench water analysis

		Test 1A		Test 1B		Test 1C	
		Specimen 1	Specimen 2	Specimen 1	Specimen 2	Specimen 1	Specimen 2
Arsenic	(µg/l)	n.i.	n.i.	n.i.	n.i.	0.9	1.2
Lead	Lead(µg/l)	n.i.	n.i.	n.i.	n.i.	76	130
Cadmium	(µg/l)	n.i.	n.i.	n.i.	n.i.	4.9	5.7
Selenium	(µg/l)	n.i.	n.i.	n.i.	n.i.	13	3.6

Table 8: Module type c-Si quench water analysis – measurement values

		Test 1A		Test 1B		Test 1C	
		Specimen 1	Specimen 2	Specimen 1	Specimen 2	Specimen 1	Specimen 2
Arsenic	(mg)	n.i.	n.i.	n.i.	n.i.	0.02	0.02
Lead	(mg)	n.i.	n.i.	n.i.	n.i.	1.5	2.6
Cadmium	(mg)	n.i.	n.i.	n.i.	n.i.	0.10	0.11
Selenium	(mg)	n.i.	n.i.	n.i.	n.i.	0.26	0.07

Table 9: Module type c-Si quench water analysis – computed total release

4.2 Module type CIS

Heat release, smoke development and damage to the specimen

		Test 2A	Test 2B	Test 2C
Test duration	(s)	1,200	1,200	600
Maximum heat release rate	(kW)	41.7	184.1	186.3
Average heat release rate	(kW)	8.1	70.6	29.2
Total heat release	(kJ)	9,699	84,712	17,506
Maximum smoke production rate	(m²/s)	0.34	0.92	2.94
Average smoke production rate	(m²/s)	0.08	0.30	0.46
Total smoke production	(m²)	92	358	274
Initial mass of specimen	(g)	39,165	39,099	39,124
Residual mass of specimen	(g)	36,075	5,805	31,806
Mass loss	(g)	3,090	33,294	7,318
Mass loss	(%)	7.9	85.2	18.7
Mass of fire residue	(g)	2,758	30,547	n.i.
Burned mass	(g)	332	2,747	n.i.
Destroyed area	(m²)	0.45	2.36	2.34

Table 10: Fire-technological parameters for module type CIS

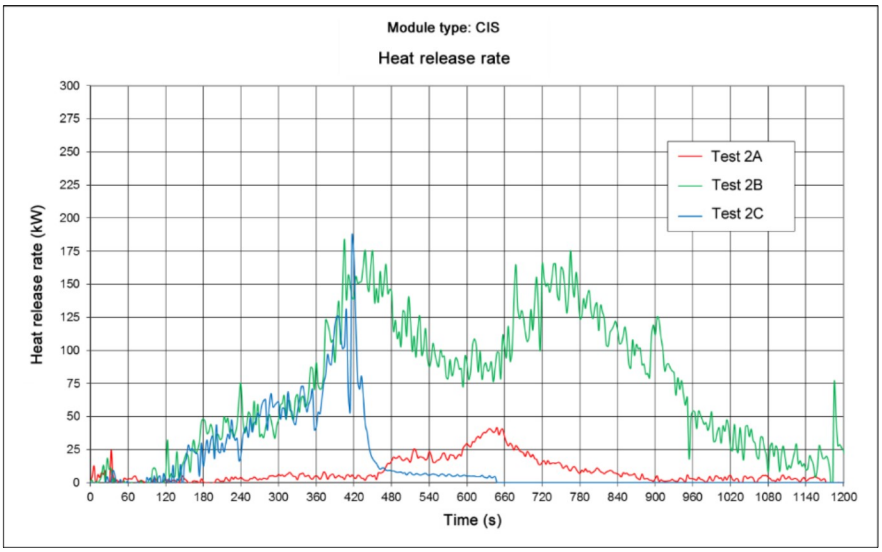


Figure 6: Module type CIS heat release rate

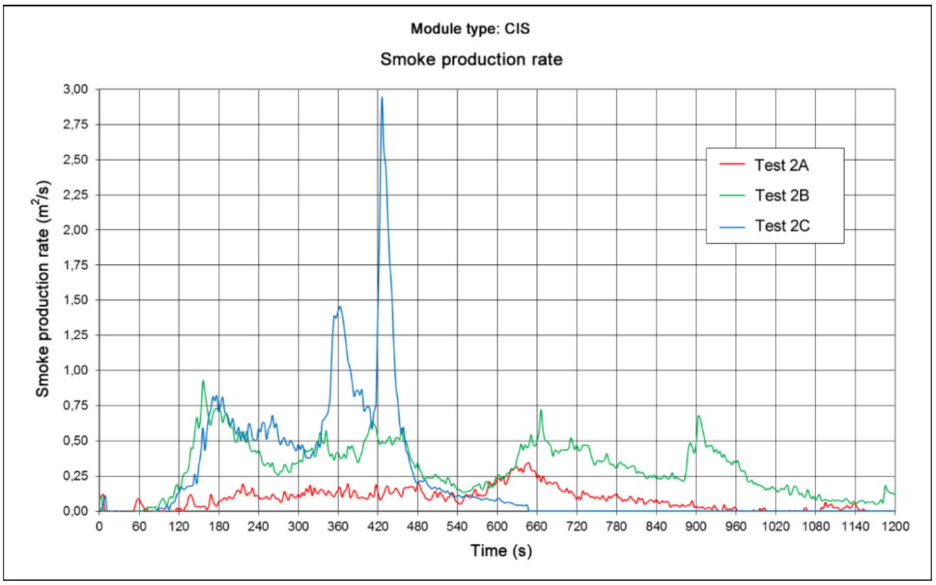


Figure 7: Module type CIS smoke production rate

Smoke gas analysis

		Test 2A	Test 2B	Test 2C
Arsenic	(µg/m³)	1.5	1.6	1.0
Lead	(µg/m³)	250	270	480
Cadmium	(µg/m³)	12	14	34
Selenium	(µg/m³)	4.8	40	8.0
Carbon dioxide	(mg/m³)	615	5,817	2,751
Carbon monoxide	(mg/m³)	11	237	382
Hydrogen cyanide	(mg/m³)	n.d.	n.d.	n.d.
Hydrogen chloride	(mg/m³)	n.d.	n.d.	n.d.
Hydrogen bromide	(mg/m³)	n.d.	n.d.	n.d.
Hydrogen fluoride	(mg/m³)	n.d.	n.d.	n.d.
Nitrogen monoxide	(mg/m³)	n.d.	n.d.	n.d.
Nitrogen dioxide	(mg/m³)	n.d.	n.d.	n.d.
Sulfur dioxide	(mg/m³)	n.d.	n.d.	n.d.
Formaldehyde	(mg/m³)	1.2	2.1	4.9

Table 11: Module type CIS smoke gas analysis – measurement values (time-averaged)

		Test 2A	Test 2B	Test 2C
Arsenic	(mg)	1.9	1.8	0.6
Lead	(mg)	310	300	290
Cadmium	(mg)	15	16	20
Selenium	(mg)	5.9	45	4.8
Carbon dioxide	(g)	760	6,492	1,634
Carbon monoxide	(g)	14	265	227
Formaldehyde	(g)	1.5	2.3	2.9

Table 12: Module type CIS smoke gas analysis – computed total release

Fire residue analysis

		Test 2A		Test 2B		Test 2C	
		Specimen 1	Specimen 2	Specimen 1	Specimen 2	Specimen 1	Specimen 2
Arsenic	(mg/kg)	1.7	2.2	1.7	2.5	n.i.	n.i.
Lead	(mg/kg)	23	26	23	29	n.i.	n.i.
Cadmium	(mg/kg)	5.9	5.9	6.0	7.4	n.i.	n.i.
Selenium	(mg/kg)	350	260	360	110	n.i.	n.i.

Table 13: Module type CIS fire residue analysis – measurement values

		Test 2A		Test 2B		Test 2C	
		Specimen 1	Specimen 2	Specimen 1	Specimen 2	Specimen 1	Specimen 2
Arsenic	(mg)	4.7	6.1	52	76	n.i.	n.i.
Lead	(mg)	63	72	700	890	n.i.	n.i.
Cadmium	(mg)	16	16	180	230	n.i.	n.i.
Selenium	(mg)	970	720	11,000	3,400	n.i.	n.i.

Table 14: Module type CIS fire residue analysis – computed total release

Quench water analysis

		Test 2A		Test 2B		Test 2C	
		Specimen 1	Specimen 2	Specimen 1	Specimen 2	Specimen 1	Specimen 2
Arsenic	(µg/l)	n.i.	n.i.	n.i.	n.i.	0.7	0.9
Lead	(µg/l)	n.i.	n.i.	n.i.	n.i.	61	61
Cadmium	(µg/l)	n.i.	n.i.	n.i.	n.i.	12	9.5
Selenium	(µg/l)	n.i.	n.i.	n.i.	n.i.	240	700

Table 15: Module type CIS quench water analysis – measurement values

		Test 2A		Test 2B		Test 2C	
		Specimen 1	Specimen 2	Specimen 1	Specimen 2	Specimen 1	Specimen 2
Arsenic	(mg)	n.i.	n.i.	n.i.	n.i.	0.01	0.02
Lead	(mg)	n.i.	n.i.	n.i.	n.i.	1.2	1.2
Cadmium	(mg)	n.i.	n.i.	n.i.	n.i.	0.24	0.19
Selenium	(mg)	n.i.	n.i.	n.i.	n.i.	4.8	14

Table 16: Module type CIS quench water analysis – computed total release

Module type CdTe

Heat release, smoke development and damage to the specimen

		Test 3A	Test 3B	Test 3C
Test duration	(s)	1,800	1,200	600
Maximum heat release rate	(kW)	15.3	66.5	88.2
Average heat release rate	(kW)	0.4	13.2	16.3
Total heat release	(kJ)	785	15,809	9,786
Maximum smoke production rate	(m²/s)	0.08	0.23	0.87
Average smoke production rate	(m²/s)	0.003	0.11	0.14
Total smoke production	(m²)	5	133	86
Initial mass of specimen	(g)	35,583	35,540	35,527
Residual mass of specimen	(g)	35,552	23,942	24,334
Mass loss	(g)	31	11,598	11,193
Mass loss	(%)	0.1	32.6	31.5
Mass of fire residue	(g)	2	11,035	n.i.
Burned mass	(g)	29	563	n.i.
Destroyed area	(m²)	0.03	0.32	0.82

Table 17: Fire-technological parameters for module type CdTe

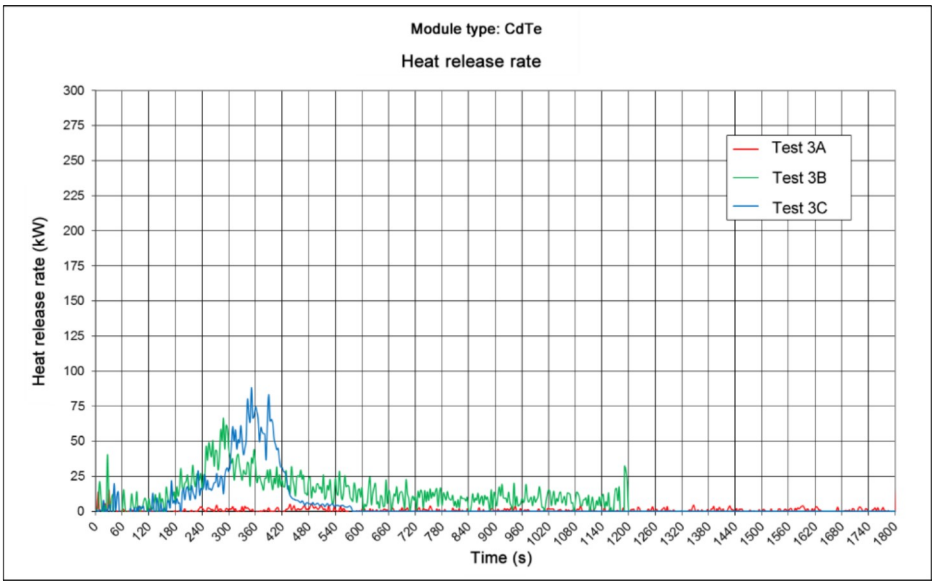


Figure 8: Module type CdTe heat release rate

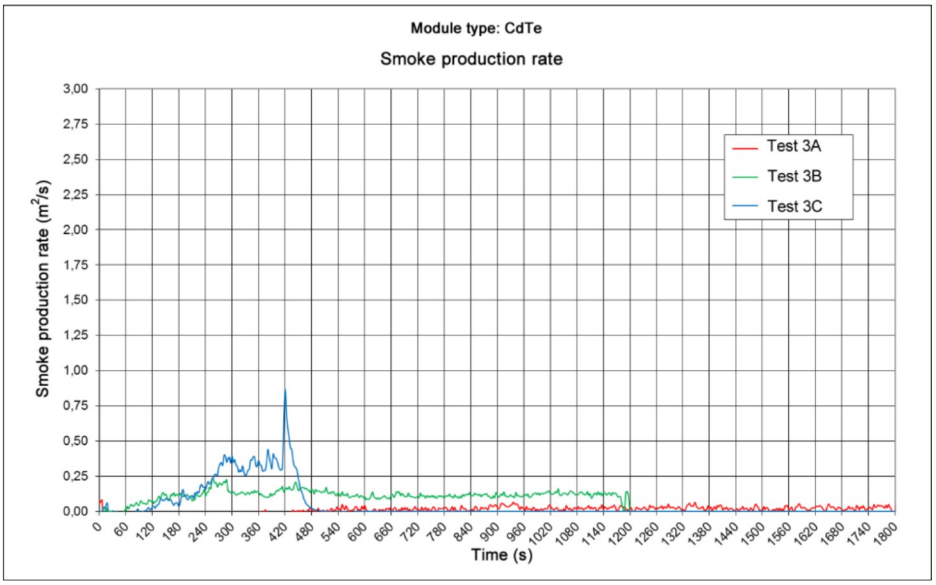


Figure 9: Module type CdTe smoke production rate

Smoke gas analysis

		Test 3A	Test 3B	Test 3C
Arsenic	(µg/m³)	0.3	0.2	0.2
Lead	(µg/m³)	34	120	1,330
Cadmium	(µg/m³)	9.9	37	48
Selenium	(µg/m³)	4.2	4.7	2.2
Carbon dioxide	(mg/m³)	42	1,453	1,495
Carbon monoxide	(mg/m³)	1	63	90
Hydrogen cyanide	(mg/m³)	n.d.	n.d.	n.d.
Hydrogen chloride	(mg/m³)	n.d.	n.d.	n.d.
Hydrogen bromide	(mg/m³)	n.d.	n.d.	n.d.
Hydrogen fluoride	(mg/m³)	n.d.	n.d.	n.d.
Nitrogen monoxide	(mg/m³)	n.d.	n.d.	n.d.
Nitrogen dioxide	(mg/m³)	n.d.	n.d.	n.d.
Sulfur dioxide	(mg/m³)	n.d.	n.d.	n.d.
Formaldehyde	(mg/m³)	0.4	1.6	2.6

Table 18: Module type CdTe smoke gas analysis – measurement values (time-averaged)

		Test 3A	Test 3B	Test 3C
Arsenic	(mg)	0.6	0.2	0.1
Lead	(mg)	64	140	800
Cadmium	(mg)	19	43	29
Selenium	(mg)	7.9	5.4	1.3
Carbon dioxide	(g)	79	1,674	897
Carbon monoxide	(g)	2	73	54
Formaldehyde	(g)	0.8	1.8	1.6

Table 19: Module type CdTe smoke gas analysis – computed total release

Fire residue analysis

		Test 3A		Test 3B		Test 3C	
		Specimen 1	Specimen 2	Specimen 1	Specimen 2	Specimen 1	Specimen 2
Arsenic	(mg/kg)	2.2	8.2	0.6	0.9	n.i.	n.i.
Lead	(mg/kg)	17	160	52	200	n.i.	n.i.
Cadmium	(mg/kg)	2.0	7.4	120	110	n.i.	n.i.
Selenium	(mg/kg)	300	250	2.8	3.6	n.i.	n.i.

Table 20: Module type CdTe fire residue analysis – measurement values

		Test 3A		Test 3B		Test 3C	
		Specimen 1	Specimen 2	Specimen 1	Specimen 2	Specimen 1	Specimen 2
Arsenic	(mg)	0.004	0.02	6.6	9.9	n.i.	n.i.
Lead	(mg)	0.03	0.3	570	2,200	n.i.	n.i.
Cadmium	(mg)	0.004	0.02	1,300	1,200	n.i.	n.i.
Selenium	(mg)	0.6	0.5	31	40	n.i.	n.i.

Table 21: Module type CdTe fire residue analysis – computed total release

Quench water analysis

		Test 3A		Test 3B		Test 3C	
		Specimen 1	Specimen 2	Specimen 1	Specimen 2	Specimen 1	Specimen 2
Arsenic	(µg/l)	n.i.	n.i.	n.i.	n.i.	1.4	1.4
Lead	(µg/l)	n.i.	n.i.	n.i.	n.i.	35	34
Cadmium	(µg/l)	n.i.	n.i.	n.i.	n.i.	7.1	53
Selenium	(µg/l)	n.i.	n.i.	n.i.	n.i.	73	47

Table 22: Module type CdTe quench water analysis – measurement values

		Test 3A		Test 3B		Test 3C	
		Specimen 1	Specimen 2	Specimen 1	Specimen 2	Specimen 1	Specimen 2
Arsenic	(mg)	n.i.	n.i.	n.i.	n.i.	0.03	0.03
Lead	(mg)	n.i.	n.i.	n.i.	n.i.	0.70	0.68
Cadmium	(mg)	n.i.	n.i.	n.i.	n.i.	0.14	1.1
Selenium	(mg)	n.i.	n.i.	n.i.	n.i.	1.5	0.94

Table 23: Module type CdTe quench water analysis – computed total release

c) PV passport

PV Passport No. _____-_____-_____

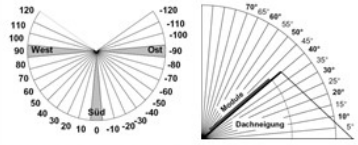
PHOTOVOLTAIC SYSTEM

Installed system capacity

Nominal output of all modules _____kWp

Alignment and roof pitch

Alignment / Roof pitch



Please circle the appropriate degree

Photo / description of system

(Type of building, sloped roof, flat roof, contiguous system or divided into sections, rooftop/integrated, ...)

Feed-in management pursuant to EEG

☐ Effective power reduction ☐ Remote control capability

System operator / Contractor

(First and last name or name of company)

Street, house number

Postal code, city

Location of system (if different from above)

Building/property owner (first and last name or name of company)

Street, house number

Postal code, city

Commissioning, metering system

Date of commissioning: _____

Feed-in / reference meter No.: _____

Meter reading at handover_____ kWh

PV measuring device, meter No.: _____

Meter reading at handover_____ kWh

Demand and yield forecasts

Expected electricity yield: _____kWh/year

Of which, expected direct consumption: _____ %

☐ No forecasts have been made

Storage system in place (see storage passport)

☐ no ☐ yes :_____kWh

PV PASSPORT ISSUING BODY

This PV passport was issued by:

Company

Authorized person (first name, last name)

Street, house number

Postal code, city

The signee confirms that all information contained in this PV Passport and in Annexes 1 – 4 applies to the PV system that is described above and handed over to the buyer [1,2]

Date, signature of system builder/system vendor

www.photovoltaik-anlagenpass.de

This seal confirms that the issuing company is registered with the BSW and ZVEH "PV Quality Group" (*Qualitätsgemeinschaft Photovoltaik*); see Internet site for benefits and list of installers.

Company stamp:

PV Passport Seal with Registration number

1) The PV Passport is only complete with Annexes (1) to (4)
2) While this PV Passport was compiled with greatest possible care, a guarantee for the attested characteristics cannot be given in terms of liability regardless of negligence.

PV Passport, version 10/2013 – All rights reside with BSW-Solar/ZVEH – see www.photovoltaik-anlagenpass.de

SHIFTING THE LIMITS

Low Voltage Arc Generation tests for 690.11 and requirements for Arc-Fault Circuit Protection

White Paper

Fronius USA LLC

Version 1 06/2020

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Gender-specific wording refers equally to female and male form.

INTRODUCTION AND SUMMARY

Current National Electric Code (NEC) requires Arc Fault Circuit Interrupter (AFCI) circuits to be used when the PV solar system voltage is greater than 80V DC. The underlying assumption is that it would be difficult and/or impossible to form an arc that could cause a significant risk at voltages below this threshold. Since the requirement of AFCI was adopted in the 2011 NEC code, however, modules have only become more efficient.

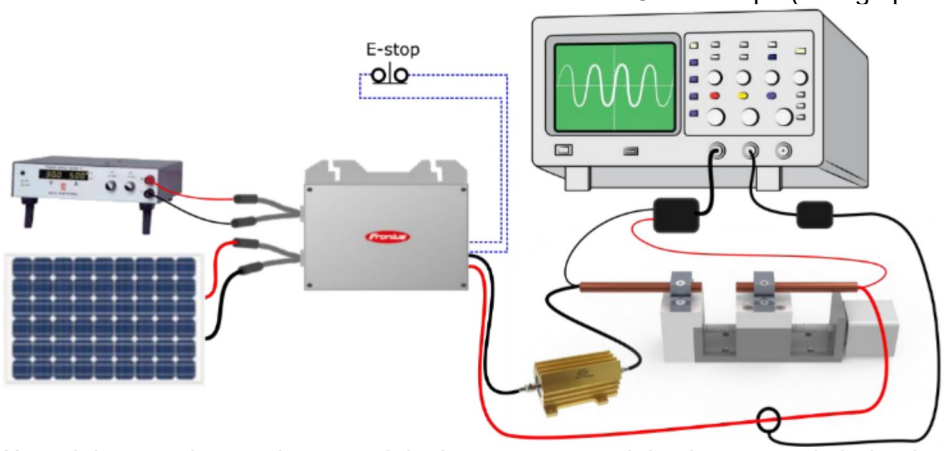
In 2011, the average module was 200W, when now, as of 2020, the average module is 320W. In the future, it is certain that modules will only get more efficient, resulting in even higher output power, which will increase the risk of dangerous arcs on a single module.

Fronius has done preliminary research and learned that arcs can be generated at voltages much lower than 80V and thus believes that there is a possibility of arcing with current and future modules that could be the ignition point of a fire.

TEST EQUIPMENT

Representing realistic scenarios is key for gathering data without bias. To do so, equipment used must be applicable to the situation and to what is commonly found in the current market.
To test the hypothesis as accurately as possible, the following equipment was used:

- 1 Silfab 320 60 cell PV module
- 3.5Ω 500W Resistive load
- Stepper driven linear stage
- Generic MC4 Connectors
- Fronius Rapid Shutdown Box
- DC power supply (for Rapid Shutdown Box)
- Oscilloscope (voltage probe/current ct)



A 320W module was chosen, because it is the average module size currently being installed for residential applications. Higher wattage modules are available, but if a dangerous arc can be generated with a lower wattage module, then one can certainly be formed with a higher wattage module.

In series with the module and the arc generator was a 3.5Ω 500W load resistor. This was manufactured specifically for the characteristics of this module, so that the experiment would not pull more than the rated capacity of the module. Simply just shorting the module is not representative of real world conditions and would damage the module.

The actual driver in this experiment is a stepper driven linear stage that was built to separate the MC4 connectors at a desired rate and distance, simulating a connector that was loose or pushed back into its connector.

A Fronius Rapid Shutdown Box was used as a remote disconnect switch to safely work on the system and to remove and prepare the arc generating unit. A ”Quattro” version of the box was used because it has two channels that are isolated from each other. Channel 1 was used to power the box itself and channel 2 functioned as the disconnect for this experiment.

An oscilloscope was used to monitor current and voltage of the module, as well as to show visible disturbances in voltage/current in the event of an arc.
To measure and document the heat produced by any arcing, a thermal camera was used.

RESULTING ARCS

Testing was done at times of the day when irradiance was at its peak. During each test, new MC4 connectors were installed on the test unit. It was observed that at the initial retraction, a larger arc would be generated, which would be sustained for a few seconds. Afterwards a series of smaller arcs was generated. These would continuously cause damage to the connectors, even to the point of welding or melting the connectors together – most of the times leading up to larger and larger arcs that would continuously grow until a run-away event occurred.

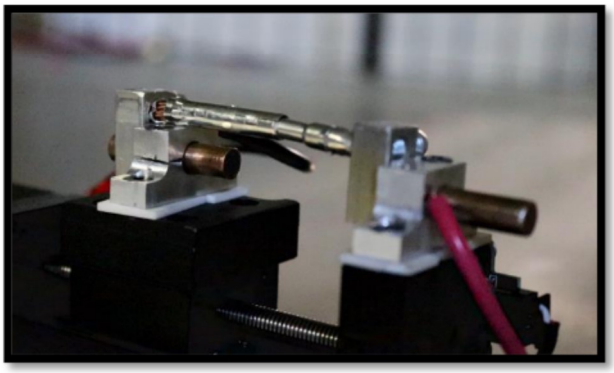


Fig. 1: Before

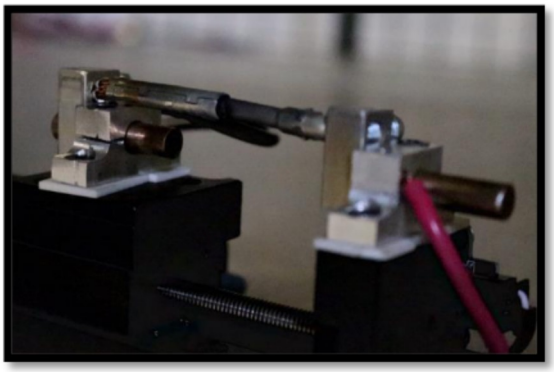


Fig. 2: After

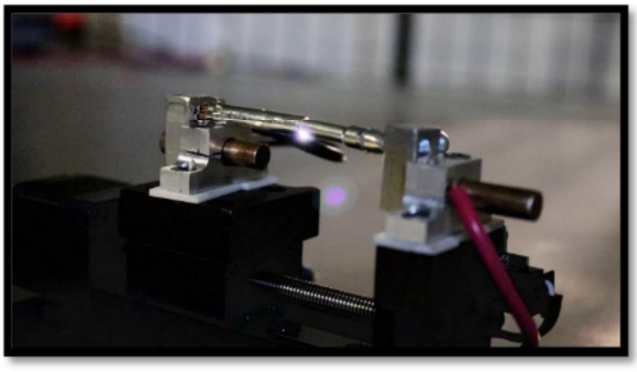


Fig. 3: Initial Arc

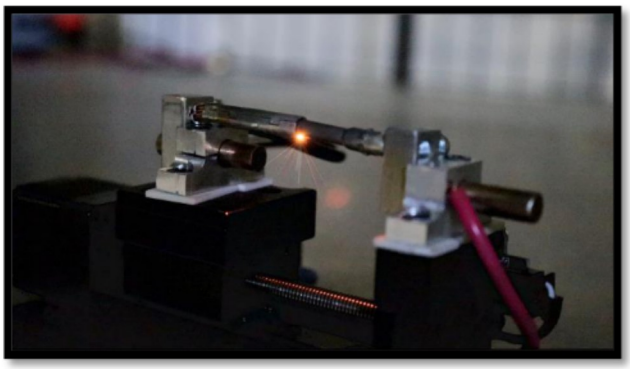


Fig. 4: Simmering Arc with spatter

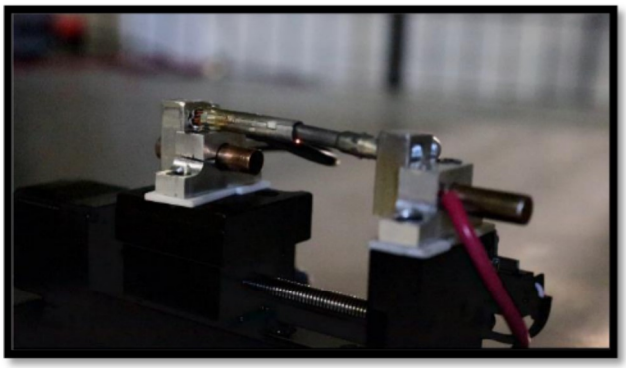


Fig. 5: Simmering Arc

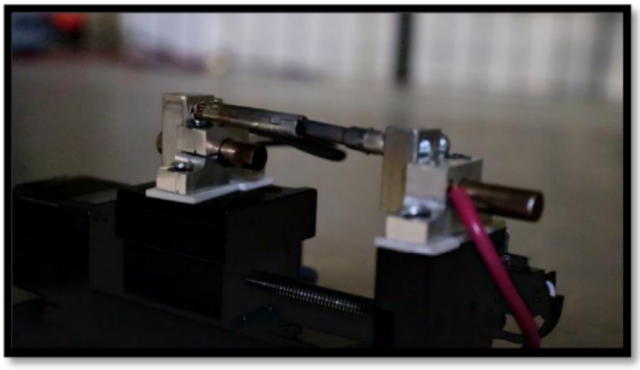


Fig. 6: Double Simmering Arc

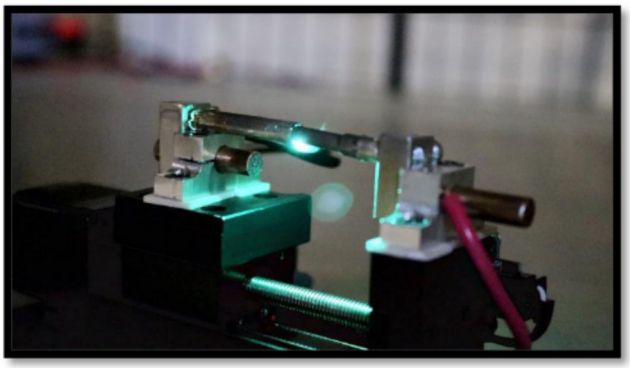


Fig. 7: Run-Away Arc

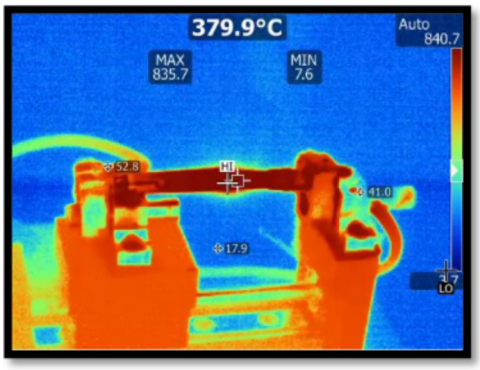


Fig. 101: Thermal Cam Run-Away Arc

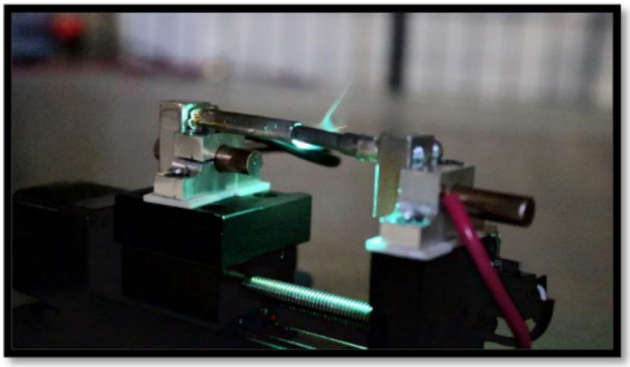


Fig. 8: Run-Away Arc 2

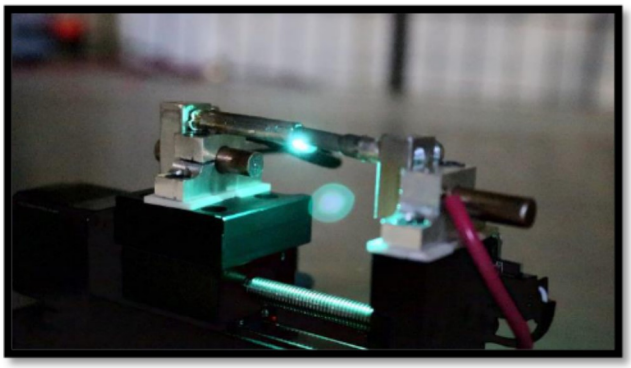


Fig. 12: Run-Away Arc 4

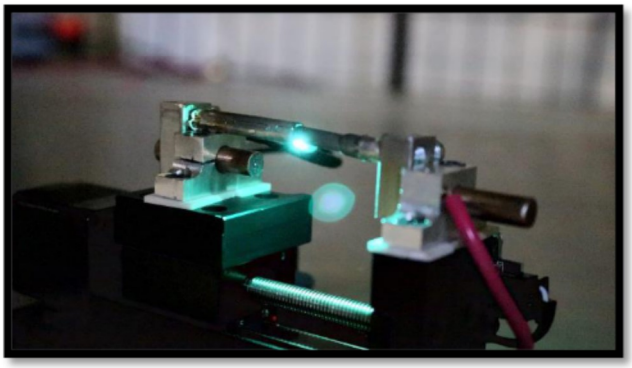


Fig. 9: Run-Away Arc 3

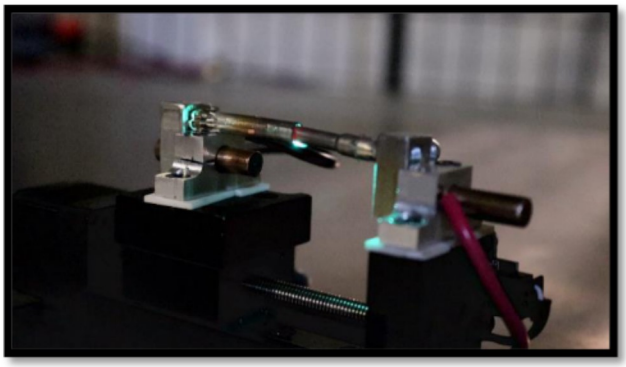


Fig. 11: Run-Away Arc 5

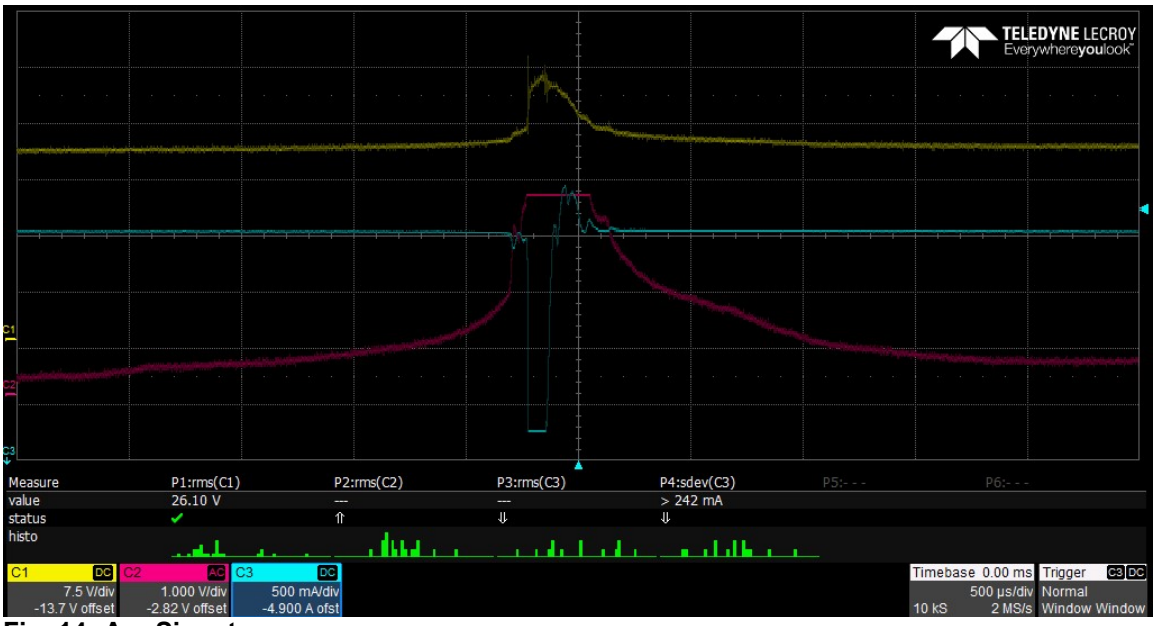


Fig. 14: Arc Signature

CONCLUSION

After a series of tests, it has been confirmed that it is indeed possible to generate a dangerous arc from a single module. Though not a continuous display of bright green light, the cumulative damage caused by smaller arcs can melt away the connector until a runaway event is triggered. This arcing can reach temperatures hot enough to melt and ignite ABS plastic, which is commonly used in MC4 connectors.

SOLUTION

Arcing is not simply an issue for circuits with large voltages, even a single 320W module is capable of causing damage with a faulty connection. Over time, as PV modules become more efficient, the dangers of arcing with single modules will be even more prevalent. Thus, similar steps as with string inverters should to be taken: require arc fault detection on all PV circuits regardless of voltage and more on a basis of output power. To improve fire safety of PV solar systems, it is highly recommended that all rooftop DC circuits have Arc Fault Detection, without any voltage limitation.

Public Input No. 4189-NFPA 70-2020 [Section No. 690.11]

690.11 Arc-Fault Circuit Protection (Direct Current).

Photovoltaic systems with PV system dc circuits ~~operating at 80 volts dc or greater between any two conductors~~ shall be protected by a listed PV arc-fault circuit interrupter or other system components listed to provide equivalent protection. The system shall detect and interrupt arcing faults resulting from a failure in the intended continuity of a conductor, connection, module, or other system component in the PV system dc circuits.

Informational Note: Annex A includes the reference for the *Photovoltaic DC Arc-Fault Circuit Protection* product standard.

Exception: For PV systems not installed on or in buildings, PV output circuits and dc-to-dc converter output circuits that are installed in metallic raceways or metal-clad cables, or installed in enclosed metallic cable trays, or are underground shall be permitted without arc-fault circuit protection. Detached structures whose sole purpose is to house PV system equipment shall not be considered buildings according to this exception.

Additional Proposed Changes

File Name	Description	Approved
2018-06-14_PV_Fire_Safety_Fire_Guideline_Translation_V04_20180614_FINAL.pdf	Assessing Fire Risks in Photovoltaic Systems and Developing Safety Concepts for Risk Minimization	

Statement of Problem and Substantiation for Public Input

limiting arc fault detection to an operating potential of 80V or above is an arbitrary value. We are beginning to regularly find melted copper and melted plastic MC4 connectors where only a single 60 cell module is connected and voltages are under 40V. We have independently tested arcs on a single 60 cell module in full sun and observed electrical arc ignition.

Third party testing has also shown that photovoltaic system arcs can ignite at voltages much lower than 80V. Per the paper Assessing Fire Risks in Photovoltaic Systems and Developing Safety Concepts for Risk Minimization:

Both the minimum voltage and the minimum current of an electric arc depend on the material. In the case of copper, they are 13 V and 0.4 A, respectively, according to the literature [4]. Series of measurements performed at TÜV Rheinland have confirmed these magnitudes [5]

[4] P. Slade, Electrical Contacts, Marcel-Dekker, New York, 1999.
[5] J. Zornikau, Investigation of the formation of arcs in photovoltaic modules and assessment of the risks, Diplomarbeit, TÜV Rheinland, Köln, 2007.

For these reasons, arc fault detection should be required in photovoltaic DC circuits operating at 12V or greater. Because practically all photovoltaic systems operate at over 12V this should be refined to state that ALL photovoltaic DC circuits shall be protected by arc-fault circuit interrupter.

Submitter Information Verification

Submitter Full Name: Scott Carman
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Street Address:
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Submittal Date: Thu Sep 10 01:01:16 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: The 80 volt threshold is retained. The substantiation did not provide documentation of arc-fault issues in the field below 80 volts.

Public Input No. 3044-NFPA 70-2020 [New Section after 690.12]

690.13 Overvoltage Protection

(A) DC Protection. Surge-protective devices (SPDs) shall be installed for the protection of solar photovoltaic (PV) systems and PV system dc circuits. The SPDs shall be listed and marked "PV SPD"

(B) AC Protection. Surge-protective devices (SPDs) shall be installed for the protection of electric power production and distribution network circuits and equipment supplied by a solar PV system. The SPDs shall be listed and comply with Part II of Article 242.

Information Note: For further information on surge-protective devices (SPDs) for 50 or 60 Hz power circuits not exceeding 1000 volts and for solar photovoltaic (PV) applications up to 1500 volts dc, see UL 1449, Standard for Surge Protective Devices. Additional information can be found in NFPA 70 780-2020, Standard for the Installation of Lightning Protection Systems which contains detailed information on the installation of overvoltage protection for solar PV systems in Chapter 12 of the standard.

Statement of Problem and Substantiation for Public Input

This intent of this public input is to add overvoltage protection requirements to solar PV systems that are highly susceptible to transient voltages and surge currents from direct or nearby lightning strikes. The protection helps reduce the potential for fire and damage to the solar PV system, premises wiring system, interconnected utilities or other on-site power sources, and the building or structure supporting the solar PV system. Protection from overvoltage requirements for both roof-mounted and ground-mounted solar arrays can also be found in the NFPA 780, Standard for the Installation of Lightning Protection Systems. This public input attempts to harmonize the NFPA 780 with the NFPA 70 and provides a pointer to the applicable chapter of the NFPA 780 for additional guidance in an Information Note.
Part (A) mandates protection of the “dc” side of the PV system with UL 1449 listed PV SPDs. Part (B) mandates protection on the “ac” side of the PV system with UL 1449 listed SPDs in accordance with Part II. of Article 242. In addition to the pointer to Chapter 12 of the NFPA 780, the Informational note also provides a pointer to UL 1449 where additional information on SPDs, 1000 volts or less and PV SPDs for applications up to 1500 volts dc can be found.

Submitter Information Verification

Submitter Full Name: Megan Hayes
Organization: Nema
Street Address:
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Zip:
Submittal Date: Fri Sep 04 10:32:46 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9204-NFPA 70-2021 RESPONSE TO PI 3311: The language previously located in 690.51 is not included here as it is duplicative in the listing requirements. RESPONSE TO PI 3044: Adequate substantiation was not provided to justify the proposed requirement in Article 690. CMP-4 requires additional case evidence of the issues in order to further consider a mandatory requirement for SPDs in this section of the code.

Statement: The new definition of electronic power converters allows for the removal of all the items on the list that are covered directly by the definition. Items related PV hazard control are added.

Public Input No. 3520-NFPA 70-2020 [Section No. 690.12]

690.12 Rapid Shutdown of PV Systems on Buildings.

PV system circuits installed on or in buildings shall include a rapid shutdown function to reduce shock hazard for firefighters in accordance with 690.12 (A) through (D).

Exception: *Ground-mounted PV system circuits that enter buildings, of which the sole purpose is to house PV system equipment, shall not be required to comply with 690.12* .

(A) Controlled Conductors.

Requirements for controlled conductors shall apply to the following:

(1) PV system dc circuits

(2) Inverter output circuits originating from inverters located within the array boundary

Informational Note: The rapid shutdown function reduces the risk of electrical shock that dc circuits in a PV system could pose for firefighters. The ac output conductors from PV systems that include inverters will either be de-energized after shutdown initiation or will remain energized by other sources such as a utility service. To prevent PV arrays with attached inverters from having energized ac conductors within the PV array(s), those circuits are also specifically controlled after shutdown initiation.

(B) Controlled Limits.

The use of the term *array boundary* in this section is defined as 305 mm (1 ft) from the array in all directions. Controlled conductors outside the array boundary shall comply with 690.12(B)(1) and inside the array boundary shall comply with 690.12(B)(2) .

(1) Outside the Array Boundary.

Controlled conductors located outside the boundary or more than 1 m (3 ft) from the point of entry inside a building shall be limited to not more than 30 volts within 30 seconds of rapid shutdown initiation. Voltage shall be measured between any two conductors and between any conductor and ground.

(2) Inside the Array Boundary.

The PV system shall comply with one of the following:

(1) A PV hazard control system listed for the purpose shall be installed in accordance with the instructions included with the listing or field labeling. Where a hazard control system requires initiation to transition to a controlled state, the rapid shutdown initiation device required in 690.12(C) shall perform this initiation.

Informational Note: A listed or field-labeled hazard PV control system is comprised of either an individual piece of equipment that fulfills the necessary functions or multiple pieces of equipment coordinated to perform the functions as described in the installation instructions to reduce the risk of electric shock hazard within a damaged PV array for fire fighters. See UL 3741, *Photovoltaic Hazard Control* .

(2) Controlled conductors located inside the boundary shall be limited to not more than 80 volts within 30 seconds of rapid shutdown initiation. Voltage shall be measured between any two conductors and between any conductor and ground.

(3) PV arrays shall have no exposed wiring methods or conductive parts and be installed more than 2.5 m (8 ft) from exposed grounded conductive parts or ground.

~~**(C)** Initiation Device.~~

~~The initiation device(s) shall initiate the rapid shutdown function of the PV system. The device's "off" position shall indicate that the rapid shutdown function has been initiated for all PV systems connected to that device. For one-family and two-family dwellings an initiation device(s) shall be located at a readily accessible location outside the building.~~

~~For a single PV system, the rapid shutdown initiation shall occur by the operation of any single initiationdevice. Devices shall consist of at least one or more of the following:~~

(1) ~~Service disconnecting means~~

(2) ~~PV system disconnecting means~~

(3) ~~Readily accessible switch that plainly indicates whether it is in the "off" or "on" position~~

~~Informational Note: Examples of where an initiation device that complies with 690.12(C)(3) would be used is where a PV system is connected to an optional standby or stand-alone system.~~

~~Where multiple PV systems are installed with rapid shutdown functions on a single service, the initiation device(s) shall consist of not more than six switches or six sets of circuit breakers, or a combination of not more than six switches and sets of circuit breakers, mounted in a single enclosure, or in a group of separate enclosures. These initiation device(s) shall initiate the rapid shutdown of all PV systems with rapid shutdown functions on that service.~~

~~**(D)** Equipment.~~

~~Equipment that performs the rapid shutdown functions, other than initiation devices such as listed disconnect switches, circuit breakers, or control switches, shall be listed for providing rapid shutdown protection.~~

Statement of Problem and Substantiation for Public Input

Rapid shutdown adds substantial safety issues to the deployment of solar systems. Current rapid shutdown systems available result in significantly more connections. Each of these additional connections creates safety risks in the form of additional points of failure as well as increased time on the roof for the installers. This dramatically increases the risk of failure at the component level as well as increasing the risk to any technicians, installers, or servicemen by increasing the amount of time required on the roof for the installation and subsequent service of each of these additional connection points. Also rapid shutdown has been extremely unreliable to date costing the end user un-necessary downtime and lost profitability from their investment at the same time giving a false sense of security. We've serviced and installed thousands of solar systems. Since the introduction of rapid shutdown devices a significant amount of our service technician's time spent on the roof was due to problems with rapid shutdown devices.

Submitter Information Verification

Submitter Full Name: Melissa Sims
Organization: Ecological Systems LLC
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 20:20:57 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: Revisions to the UL1741 safety requirements for rapid shutdown equipment have increased the reliability and safety rapid shutdown equipment and systems. Furthermore, UL3741 PV Hazard Control Systems standard includes new evaluation criteria that allow for passive protection options as well as a reduced the number of active electronic isolation and attenuation devices to reduce hazards for fire fighters while performing their work on buildings with PV arrays. The claims were not substantiated. The purpose of the NEC is the practical safeguarding of persons and property from hazards arising from the use of electricity.

Public Input No. 4099-NFPA 70-2020 [Section No. 690.12]

690.12 Rapid Shutdown of PV Systems on Buildings.

PV system circuits installed on or in buildings shall include a rapid shutdown function to reduce shock hazard for firefighters in accordance with 690.12(A) through (D).

Exception: Ground-mounted PV system circuits that enter buildings, of which the sole purpose is to house PV system equipment, shall not be required to comply with 690.12.

(A) Controlled Conductors.

Requirements for controlled conductors shall apply to the following:

(1) PV system dc circuits

(2) Inverter output circuits originating from inverters located within the array boundary

Informational Note: The rapid shutdown function reduces the risk of electrical shock that dc circuits in a PV system could pose for firefighters. The ac output conductors from PV systems that include inverters will either be de-energized after shutdown initiation or will remain energized by other sources such as a utility service. To prevent PV arrays with attached inverters from having energized ac conductors within the PV array(s), those circuits are also specifically controlled after shutdown initiation.

(B) Controlled Limits.

The use of the term *array boundary* in this section is defined as 305 mm (1 ft) from the array in all directions. Controlled conductors outside the array boundary shall comply with 690.12(B)(1) ~~and inside the array boundary shall comply with 690 .12(B)(2) .~~

(1) Outside the Array Boundary.

Controlled conductors located outside the boundary or more than 1 m (3 ft) from the point of entry inside a building shall be limited to not more than 30 volts within 30 seconds of rapid shutdown initiation. Voltage shall be measured between any two conductors and between any conductor and ground.

(

2) Inside the Array Boundary.

The PV system shall comply with one of the following:A PV hazard control system listed for the purpose shall be installed in accordance with the instructions included with the listing or field labeling. Where a hazard control system requires initiation to transition to a controlled state, the rapid shutdown initiation device required in 690.12(

C)

shall perform this initiation.

Informational Note: A listed or field-labeled hazard PV control system is comprised of either an individual piece of equipment that fulfills the necessary functions or multiple pieces of equipment coordinated to perform the functions as described in the installation instructions to reduce the risk of electric shock hazard within a damaged PV array for fire fighters. See UL 3741, *Photovoltaic Hazard Control* .

- Controlled conductors located inside the boundary shall be limited to not more than 80 volts within 30 seconds of rapid shutdown initiation. Voltage shall be measured between any two conductors and between any conductor and ground.
- PV arrays shall have no exposed wiring methods or conductive parts and be installed more than 2.5 m (8 ft) from exposed grounded conductive parts or ground.

(C)

– Initiation Device.

The initiation device(s) shall initiate the rapid shutdown function of the PV system. The device's "off" position shall indicate that the rapid shutdown function has been initiated for all PV systems connected to that device. For one-family and two-family dwellings an initiation device(s) shall be located at a readily accessible location outside the building.

For a single PV system, the rapid shutdown initiation shall occur by the operation of any single initiationdevice. Devices shall consist of at least one or more of the following:

(1) - Service disconnecting means

(2) - PV system disconnecting means

(3) - Readily accessible switch that plainly indicates whether it is in the "off" or "on" position

Informational Note: Examples of where an initiation device that complies with 690.12(C)(3) would be used is where a PV system is connected to an optional standby or stand-alone system.

Where multiple PV systems are installed with rapid shutdown functions on a single service, the initiation device(s) shall consist of not more than six switches or six sets of circuit breakers, or a combination of not more than six switches and sets of circuit breakers, mounted in a single enclosure, or in a group of separate enclosures. These initiation device(s) shall initiate the rapid shutdown of all PV systems with rapid shutdown functions on that service.

(D) Equipment.

Equipment that performs the rapid shutdown functions, other than initiation devices such as listed disconnect switches, circuit breakers, or control switches, shall be listed for providing rapid shutdown protection.

Additional Proposed Changes

File Name	Description	Approved

2020-09-09-Rapid_Shutdown-WhitePaper.pdf Explanation of the safety issue

Statement of Problem and Substantiation for Public Input

The attached White Paper “Arc-Fault Detection at Photovoltaic Systems” shows that Module level Power Electronics (MLPEs) are interfering with state-of-the-art Arc-Fault Detection. This has an unintended consequence of the “inside the array boundary” equipment making the PV system more unsafe and rapid shutdown causing the problem it was designed to protect. At the moment their isn’t a standard is addressing these problems. 690.12(B)(2) should be removed, until this problem is addressed and working solutions are readily available, re-implementing of the 690.12(B)(2) makes sense.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 4105-NFPA 70-2020 [Section No. 690.12(D)]	

Submitter Information Verification

Submitter Full Name: Chris Connell
Organization: Fronius USA LLC
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 09 20:40:49 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: This is a certification issue that is already addressed in UL1741 requirements for PV rapid shutdown systems. UL1741 Paragraph 88.18 requires validation that the system still complies with the PV arc fault protection requirements in UL1699B. It appears that the combination of equipment tested in support of this public input were not compliant with the most recent published rapid shutdown requirements that require, testing to validate a rapid shutdown system that includes PV arc fault protection does not eliminate compliance with UL1699B.

Arc fault detection in Photovoltaic systems

Motivation

This document outlines the current methodology of arc fault circuit interrupters (AFCI) in photovoltaic (PV) systems and the main challenges that exist if module level power electronics (MLPEs) are included in a system. The MLPE definition used in this white paper pertains to devices outside of microinverters. Thus, the focus is on MLPE devices that are used in conjunction with string inverters.

Conclusion

- Based on numerous references cited in this paper, we can adhere that spectral arc detection is state-of-the-art
- We value the evolution in the standard for arc detection in PV systems. However, based on current requirements of UL 1741 and UL 1699B, a specific test isn't required to test string inverters and MLPE devices together. Most testing laboratories aren't even performing a test (UL 1741, 88.18, recommended AFCI & PVRSE testing together) when doing a PVRSS certification. Justification of this is done via "engineering judgement" and that the inverters are already UL 1699B certified, and thus do not require an AFCI test with the MLPE device. This leads to a lack of testing an inverter in conjunction with an MLPE device to UL 1699B and thus an unsafe scenario. This scenario allows for testing residential and commercial rooftop installations to be impractical compared to installation circumstances in the field.
- Noise generated from MLPE devices causes a situation where string inverter manufacturers are faced with two options:
  (1) Incorporate the noise from MLPE into the AFCI algorithm to avoid false trips
  Resulting in an incapability to detect arcs in a real life scenarios (while passing UL 1699B).
  (2) Do not incorporate the noise level
  Resulting in regular false trips from the MLPE device in PV Systems.
- Thus, 690.11 and 690.12 are conflicting with each other and are seen as incompatible. We show in Figure 6 that the current state-of-the-art arc fault detection approach cannot detect an arc signature if the sensor signal is compromised by the additional noise from MLPEs.

AFD Basics

Arcs describe the phenomena when the dielectric constant of an insulating material is exceeded and a breakdown occurs, which then continues to burn even after the initial charge dissipated [Ref. 1]. Once an arc is established, the voltage necessary to sustain it is much lower than the initial voltage needed to create an arc. The arc might burn as long as the energy loss due to dissipation is equal or less than the energy produced by the arc.

Arc faults in PV systems can be categorized in three types (see Figure 1):

1) Ground arc faults
2) Serial arc faults
3) Parallel arc faults

Type (1) arcs can be considered as negligible, since modern inverters are required to be equipped with a residual measurement current unit (RCMU), which would detect a significant current drain much before an arc takes place.
Type (3) arcs are also of less interest, since proper isolation between two conducting lines is mandatory for every PV installation.
The most severe arc incidents, which are also considered in UL 1699B [Ref. 2-3], are serial arcs (2).

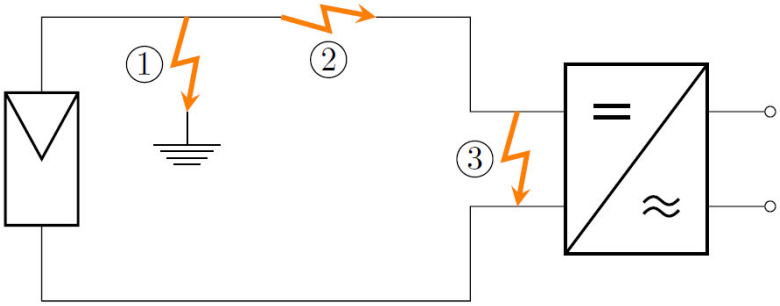

Figure 1: Arc categories in PV system.

From an electrical DC perspective, a serial arc event can be modeled as an additional resistance in the DC path of the PV array [Ref 4]. However, this resistance is only the range of mΩ and other devices (including the inverter) can create similar voltage/ current signals. In other words, a simple large-scale electrical behavior analysis is insufficient. Voltage and current spectra show an inverse relationship to frequency [Ref. 5], which is characteristic of the “pink noise” generated during electrical arcing. Arc detection using a spectral analysis of electrical noise can be found in multiple references [Ref 6-14].

Normative arc detection

UL 1699B-2018 Ed. 1 [Ref. 3] uses a ring and ball setup (schematic shown in Figure 2) which should provide a reproducible and standardized arc test on the one hand and a challenging and realistic arc scenario on the other hand.

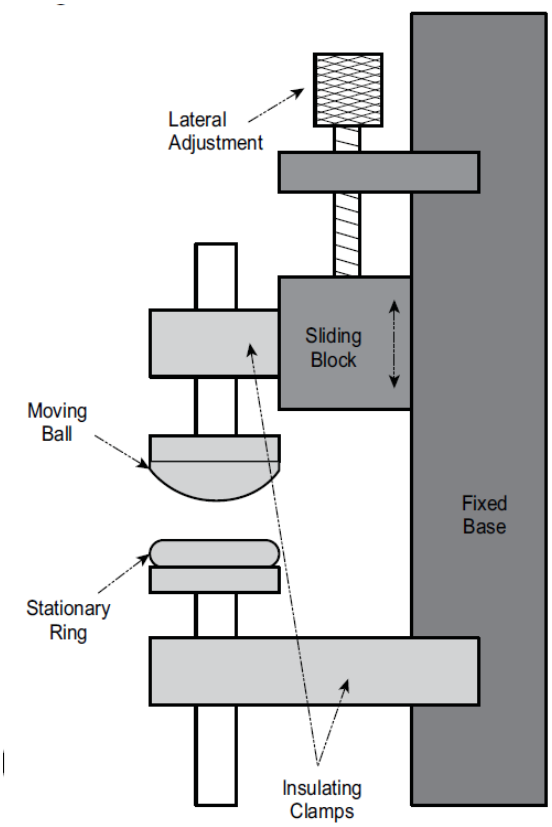

Figure 2: Ring and ball measurement apparatus according to [Ref. 2]

UL 1699B-2013 (Outline of Investigation) [Ref. 2] used a different test setup. Here, a piece of steel wool was manually inserted between two cylindrical electrodes (Figure 3a and Figure 3b), which was then ignited and burnt by the electrical current, which consequently led to a stable burning arc.

Figure 3a

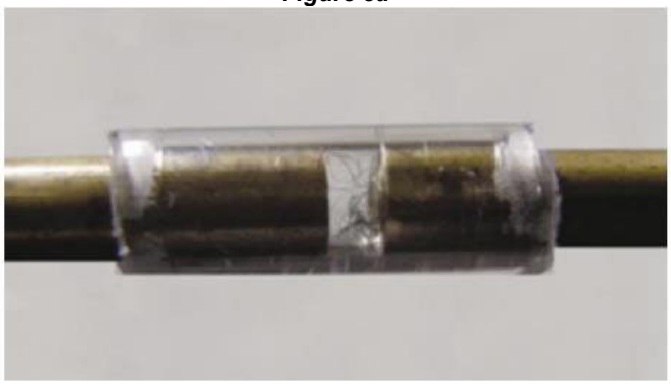

Figure 3b

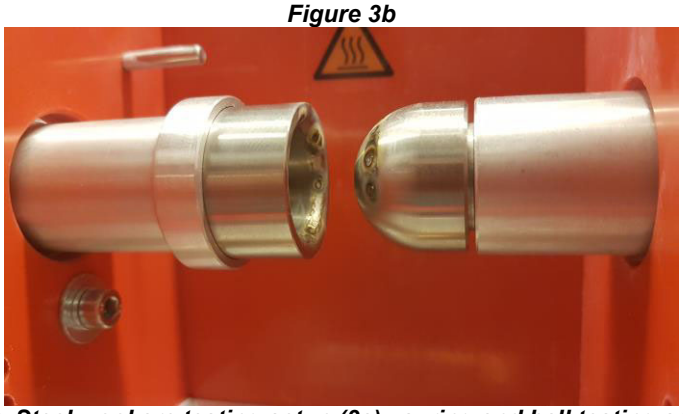

Figure 3: Steel wool arc testing setup (3a) vs. ring and ball testing setup (3b)

Despite the difference in the arc creation, the arc burning signature in time and spectral domain are similar. As mentioned above, revision of the arc creation methodology aims at an improved repeatability of the tests. Also, a simplification of the procedure and a higher similarity to real arc events is achieved by the ring and ball setup. There might be some miscellaneous differences between steel wool and ring and ball within the first millisecond (ms) of the arc ignition, but these are caused by the experimental setup and are not subject of a true arc event. Please see [Ref. 5] for further insight into the motivation for the UL 1699B parameter selections. However, several influencing factors affect the final signal shape:

- variable cable lengths creating resonance peaks
- masking effects caused by parallel PV strings
- sensor bandwidth and transfer function
- external devices within the PV array (e.g. MLPEs, external sensors, etc.)

The first two points are considered in the new UL 1699B standard by mandatory decoupling networks and string/line models, while the third is subject to the manufacturer providing an adequate solution. The last point, however, remains untreated.

In summary, we welcome the improvements of the new UL standard, but we also have reservations about how realistic the UL-setup reflects the circumstances of real installations – especially if external devices within the PV array are used, such as MLPE.

Measurement results

Figure 5 shows a measurement result from the worst case scenario of the test conditions from [Ref. 3] (see Table 1). A coarse schematic is given. The measurement equipment is given in [Table 2].

Figure 5a shows the time domain signal of the current probe (left y-axis) together with the arc voltage (yellow signal on right y-axis) acquired by using a voltage differential probe. Note that such a measurement source is not available in a real-world scenario. However, it allows for precise determination of the time range when the arc was burning (red signal in Figure 5a). The gaps within the red signals are areas where the Power Line Communication (PLC) signal was active. PLC signal influences are excluded in all subsequent measurements for better comparison.

Figure 5b shows the spectra of the non-arc (blue) and arc (red) signal. Within the range between approx. 50-200 kHz the arc and non-arc spectra are well-separated and with an approx. 17 dB margin, which we can distinguish between an arc and non-arc condition (green area in Figure 5b). Note that the line impedance resonance and harmonics of switching frequencies effects cause numerous peaks outside this area, which prohibit a robust detection.

Parameter	Value
Setup	Fig. 29.14
Total number of strings (n)	2
C4 of Half string	20 µF
Test no. from Table 29.2	3
Position of Arc Generator	Middle Of String

Table 1: Selected UL 1699B-2018 parameters for worst-case arc testing

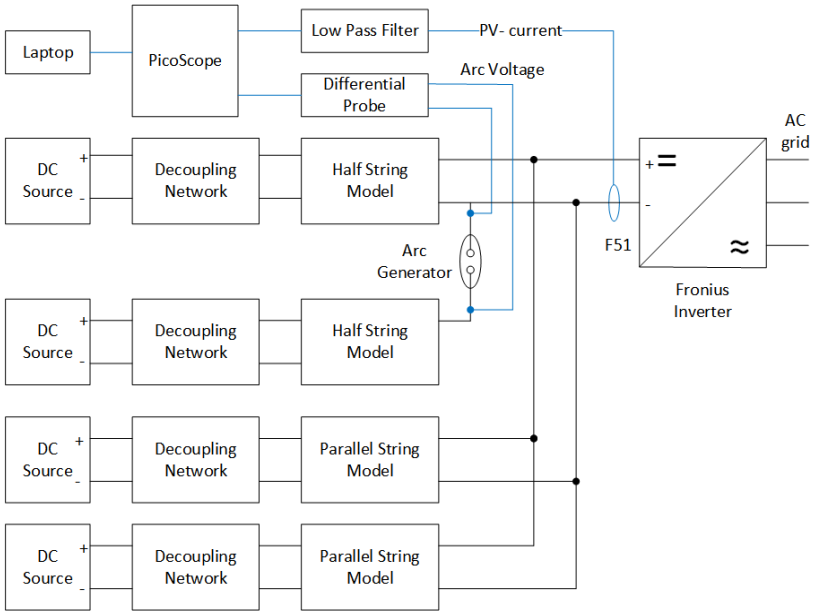

Figure 4: Schematic of measurement setup. Black are power-conducting lines, blue sensing lines.

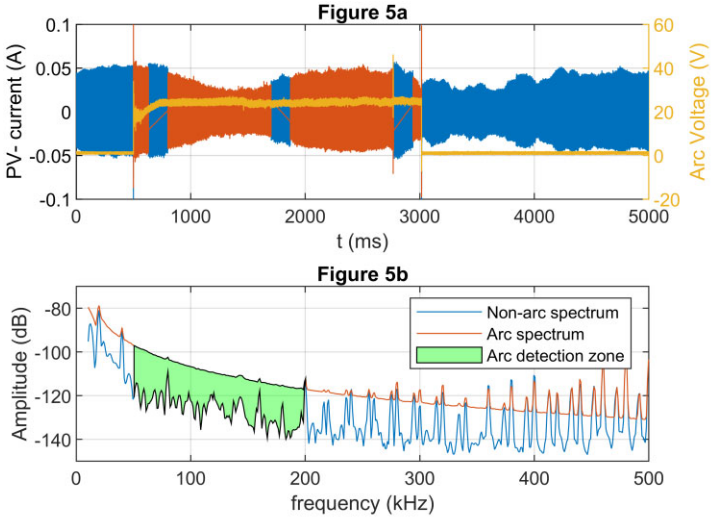

Figure 5: Comparison of arc vs. non-arc spectra. Figure 5a shows the time signals of the current probe raw data (blue) and the signal range where arc was burning (red), i.e. arc voltage > 15 V. Figure 5b shows the according spectrum of the arc and non-arc sections from the time signals of Figure 5a. The arc detection zone marks the area between approx. 50-200 kHz with the biggest difference between arc and non-arc spectrum.

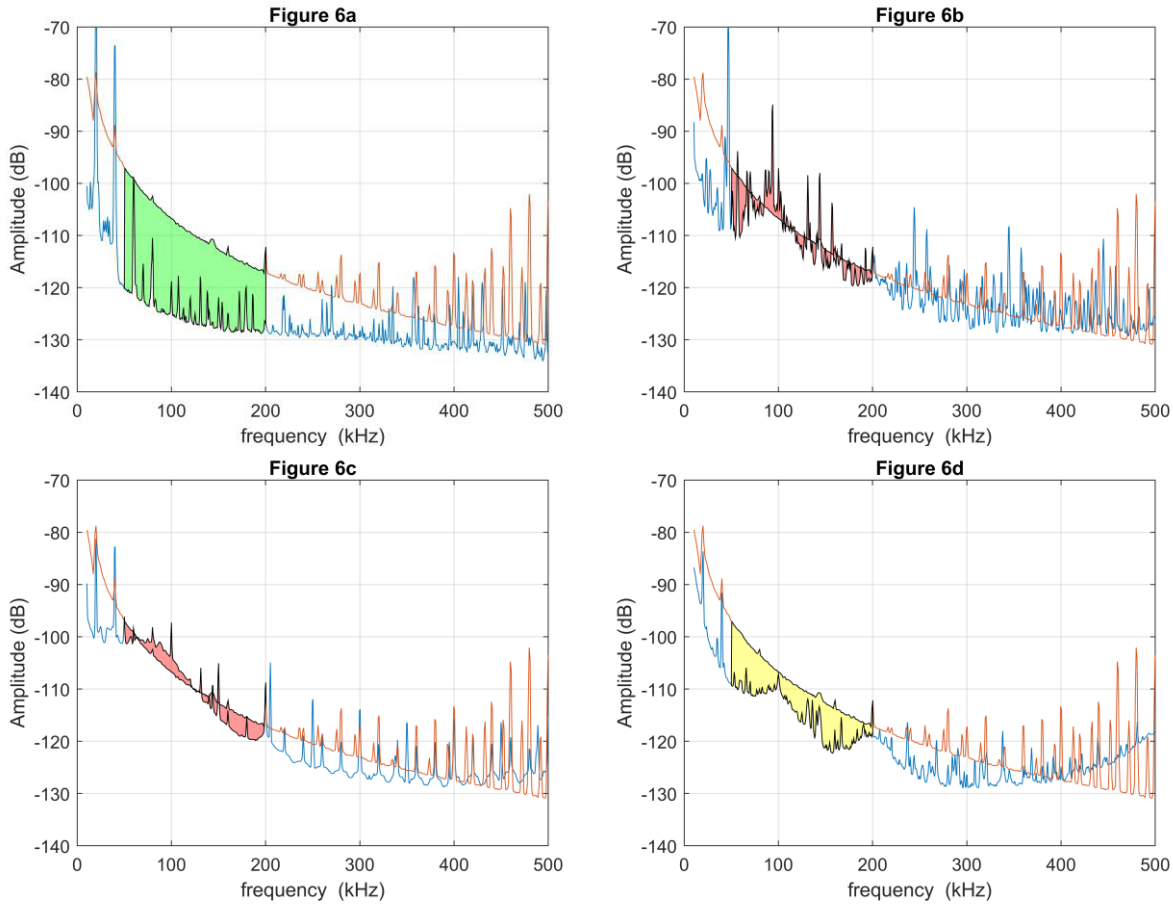

Figure 6: Comparison of arc spectrum (red) against spectra from various field installations (blue).
Figure 6a: Reference installation with <u>no</u> MLPEs consisting of four strings with each 22 bifacial modules (PVP 280 Wp – total 24 kWp).
Figure 6b: One string installation with six PV modules (Kioto 270 Wp –total 1.6 kWp) and MLPE#1
Figure 6c: Five strings installation with each 14 modules (VSUN 330 Wp –total 23 kWp) and MLPE#2
Figure 6d: One string installation with 20 modules (Sanyo 260 Wp – total 5.2 kWp) and MLPE#3

We see in Figure 6 that the MLPE devices create an increased noise floor, which matches or exceeds the noise floor from the arc spectrum of Figure 5. Note that we've deliberately chosen very different PV system setups and we are excluding any manufacturer details.

Hence, a proper arc detection with a spectral evaluation is not possible anymore!

Only with MLPE#3 the arc detection probability is just reduced.

Measurement equipment

Error! Reference source not found. contains a list of the used equipment to acquire the signals in the previous section. All further equipment (e.g. arc generator, decouple networks, etc.) are either manufactured by Fronius internally or of no relevance (e.g. laptop, cables, etc.). For the F-51 recordings we used the impedance calibration data from the manufacturer, interpolated on our frequency range.

Device	Description	Specification
Inverter	FRONIUS Symo Adv. 20.0-3 208-480	
Current probe	Fischer Custom Communication F-51	Range 10 kHz – 500 MHz
Filter	Mini-Circuits SLP-1.9+ Low Pass Filter	Range DC-1.9 MHz
Voltage probe	TESTEC Differential Probe TT-SI9101	Attenuation 1/100
Scope	PicoScope 5243B	Samplerate 3.906 MSps, 15 Bit, Duration: 5 s
Processing	Matlab 2019b	incl. Signal Processing Toolbox 8.3

Table 2: List of used equipment

Alternative arc detection techniques

The conclusion of these results is that spectral arc detection is not possible anymore without being highly susceptible to false trippings. [Ref. 1] lists several different approaches like:

- Spread spectrum time domain reflectometry (SSTDR),
- Resonance Tuned electrical resonator,
- Minimum covariance determinant (MCD),
- Change in direction of current at the on-set of fault,
- Artificial neural network (ANN) of graph-based semi-supervised learning technique.

However, to the best of our knowledge, we can state that spectral arc fault detection is a widespread industrial standard. Moreover, the robustness of these alternatives against arc-like events is hard to determine, which is tantamount to detecting an arc.

Conclusion

- Based on numerous references cited in this paper, we can adhere that spectral arc detection is state-of-the-art
- We value the evolution in the standard for arc detection in PV systems. However, based on current requirements of UL 1741 and UL 1699B, a specific test isn't required to test string inverters and MLPE devices together. Most testing laboratories aren't even performing a test (UL 1741, 88.18, recommended AFCI & PVRSE testing together) when doing a PVRSS certification. Justification of this is done via "engineering judgement" and that the inverters are already UL 1699B certified, and thus do not require an AFCI test with the MLPE device. This leads to a lack of testing an inverter in conjunction with an MLPE device to UL 1699B and thus an unsafe scenario. This scenario allows for testing residential and commercial rooftop installations to be impractical compared to installation circumstances in the field.
- Noise generated from MLPE devices causes a situation where string inverter manufacturers are faced with two options:
  (3) Incorporate the noise from MLPE into the AFCI algorithm to avoid false trips
  Resulting in an incapability to detect arcs in a real life scenarios (while passing UL 1699B).
  (4) Do not incorporate the noise level
  Resulting in regular false trips from the MLPE device in PV Systems.
- Thus, 690.11 and 690.12 are conflicting with each other and are seen as incompatible. We show in Figure 6 that the current state-of-the-art arc fault detection approach cannot detect an arc signature if the sensor signal is compromised by the additional noise from MLPEs.

Solution

First and foremost, we support rapid shutdown when it is properly implemented. Currently, we believe that there are too many unintended consequences of the implementation of this code, which actually creates additional risks and issues. We would purpose a 4 step method:

1) Remove the inside of the array boundary (690.12 B(2)) voltage requirement, keeping 690.12 B(1) the same. Other changes, such as 690.12 (B) will also need to be revised (controlled limits) and would be an editorial, fixing mention of the inside of the array boundary.
2) Implement a separate standard for MLPE, which requires specific noise levels, temperature testing specific of thermal events, and testing of the internal switches.
3) Make needed changes to UL 1741 and UL 1699B in a way that practical real life scenarios are being tested with MLPE & arc fault detection together.
4) Re-introduce “690.12 Inside of the array boundary, 80V requirement”.

FAQ

Q: Why do you need 17 dB of margin?
A: There isn’t a specific need for 17 dB of margin, however, in order to perfectly detect the differences, a minimal margin of 17 dB is required. Having less makes it more difficult to detect arcs and the more unreliable the algorithm becomes. Any manufacturer (see references) doing spectral arc analysis would experience the same issue.

Q: Why is spectral arc analysis used and not another method if this problem exists?
A: As explained at the top of page two, a serial arc can be seen as an additional resistance in the DC path and can create a very similar voltage and current. However, this resistance is only the range of mΩ and other devices (including the inverter) can create similar voltage/ current signals. In other words, a simple large-scale electrical behavior analysis is insufficient.

References

[1] M. K. Alam et al. “*A Comprehensive Review of Catastrophic Faults in PV Arrays: Types, Detection, and Mitigation Techniques*”. IEEE Journal of Photovoltaics 5.3 (Mai 2015), p. 982–997.

[2] UL 1699B OUTLINE OF INVESTIGATION – FOR PHOTOVOLTAIC (PV) DC ARC-FAULT CIRCUIT PROTECTION - Issue Number 2 - JANUARY 14, 2013.

[3] UL 1699B Standard for Safety for Photovoltaic (PV) DC Arc-Fault Circuit Protection, First Edition, Dated August 22, 2018.

[4] Hertha Marks Ayrton. *The Electric Arc*. New York: D. Van Nostrand Company, 1902.

[5] Jay Johnson, *PV AFCI FOR FIRE PROTECTION*, Arc Fault Forum 2012, p.52.

[6] U.S. Pat. No. 5 835 321 A “Arc fault detection apparatus and circuit breaker incorporating same”, Robert T. Elms, John C. Schlotterer, Eaton Corporation.

[7] U.S. Pat. No. 5 706 159 A *Circuit interrupter including an electric arc monitoring circuit* Charles R. Dollar, Woothi Strickland, Siemens Energy & Automation Inc.

[8] U.S. Pat. No. 5 729 145 A *Method and apparatus for detecting arcing in AC power systems by monitoring high frequency noise*, Frederick K. Blades, Siemens Energy & Automation Inc.

[9] U.S. Pat. No. 6 362 628 A1 *ARC FAULT CIRCUIT DETECTOR DEVICE DETECTING PULSE WIDTH MODULATION OF ARC NOISE*, Bruce M. Macbeth, Thomas N. Packard, Syracuse NY.

[10] U.S. Pat. No. 5 805 397 A *Arcing fault detector with multiple channel sensing and circuit breaker incorporating same*, Raymond W. MacKenzie, Eaton Corporation.

[11] EU Pat. No. 2 850 708 B1 *METHOD AND APPARATUS FOR LOCALIZING AND QUENCHING AN ARC*, Holger Behrends, SMA Solar Technology AG, §25.

[12] EU Pat. No. 2 388 602 B1 *Method for diagnosing contacts of a photovoltaic assembly and device*, Markus Hopf et al. SMA Solar Technology AG, §33.

[13] 5SM6 Arc Fault Detection Unit, Siemens AG 2012

[14] AN-2154: RD-195 DC Arc Detection Evaluation Board (Rev. F), Texas Instruments 2012

Public Input No. 1783-NFPA 70-2020 [New Section after 690.12(A)]

Devices used for PV rapid shutdown.

A commonly quoted statement found in many Solar PV seminars and training.

"No specifics as to the location of the rapid shutdown initiating device to allow AHJs, System Integrators and First Responders the flexibility to locate devices and warning labels at location most appropriate for the specific installation."

Many AHJ's are requiring a Rapid shutdown device be installed within 3 feet outside the array boundary.

The NEC refers to controlled conductors.

Article 690.12 should clearly state if this is the intent or clarify that the Initiation Device may be installed more than 3 feet from the array boundary as long as the controlled conductor requirement is met.

Commonly the Solar PV inverters, mounted on the roof, are more than 3 feet from the array boundary. The rapid shut down function is contained in the inverters and the PV source conductors meet the 30 volts/30 seconds requirement. However, many jurisdictions reject this scheme and are requiring additional devices at the array boundary. The Utility has required a Solar Pv disconnecting means which serves as the Initiation Device.

(C) Initiation Device. The initiation device(s) shall initiate

the rapid shutdown function of the PV system. The device “off”

position shall indicate that the rapid shutdown function has

been initiated for all PV systems connected to that device.The initiation device shall shall shut down all PV circuit controlled conductors as per 690.12.(B)(1)

Statement of Problem and Substantiation for Public Input

Clearly state that the intent is to shut down all PV controlled conductors with 3 feet of the array boundary regardless of the location of the PV shut down equipment or initiation device.

Submitter Information Verification

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State:
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Submittal Date: Thu Jul 02 13:18:38 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: In accordance with the Regulations Governing the Development of NFPA Standards, the information provided by the commenter is not clear, does not make use of style manual language and does not include a specific proposal shown in legislative text. Additionally, there was no technical justification to expand the distance to 3 ft.

Public Input No. 4465-NFPA 70-2020 [Section No. 690.12(A)]

(A) Controlled Conductors.

Requirements for controlled conductors shall apply to the following:

(1) PV system dc circuits

(2) Inverter output circuits originating from inverters located within the array boundary

Informational Note: The rapid shutdown function reduces the risk of electrical shock that dc circuits in a PV system could pose for firefighters. The ac output conductors from PV systems that include inverters will either be de-energized after shutdown initiation or will remain energized by other sources such as a utility service. To prevent PV arrays with attached inverters from having energized ac conductors within the PV array(s), those circuits are also specifically controlled after shutdown initiation.

Exception: PV system circuits originating within or from arrays not attached to buildings that terminate on the exterior of buildings and PV system circuits installed in accordance with 230.6 shall not be considered controlled conductors for the purposes of 690.12.

Additional Proposed Changes

File Name	Description	Approved
690.12_A_supporting_image.pdf	Supporting image with substantiation	

Statement of Problem and Substantiation for Public Input

{see attachment for image}
This exception is necessary to clarify the intention of the opening statement in 690.12 “PV system circuits installed on or in buildings.” This phrase has caused confusion in the field where AHJs have required Rapid Shutdown on ground-mounted PV systems that terminate on the outside wall of a house. Moving the termination point 3” away from the outside wall of the house fixes the language problem, but that is not the intent of the requirement for Rapid Shutdown. The purpose of rapid shutdown is to reduce of shock hazard for firefighters in operations on occupied buildings, where the shock hazard is prevalent around rooftop PV arrays. Currently, rapid shutdown applies to any PV circuit that interfaces with a building. Ground-mounted arrays in a field and arrays mounted on parking lot shade structures or similar structures are in non-enclosed, open air spaces with free ventilation. Often such ground-mounted PV arrays, particularly near commercial and industrial buildings, are routed to a nearby building in order to place the electrical equipment in a common location such as a service pad, electrical room, or mounted on the exterior of a building (see figure below). These ground-mounted arrays and their circuits are unlikely to be hazards for firefighters therefore rapid shutdown was not intended to apply to these arrays and circuits.

This PI clarifies the interface between the PV circuits and a building to determine whether controlled conductors requirements apply. 230.6 refers to requirements for service conductors to be considered outside the building. Circuits from a ground-mounted PV array that are located on the exterior of a building in open air or otherwise considered outside a building according to 230.6 would be separate from rapid shutdown firefighter concerns of rescue operations within a building. These circuits differentiate from those of rooftop arrays which remain subject to controlled conductor requirements.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.

This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI's submitted.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain, P.E., SEIA; Bill Brooks, PVICC; John Berdner, PVICC, Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing, Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower; Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

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Submitter Full Name: Evelyn Butler
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Submittal Date: Thu Sep 10 13:33:12 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9229-NFPA 70-2021

Statement: This revision clarifies the interface between the PV circuits and a building to determine whether controlled conductor requirements apply. Section 230.6 refers to requirements for service conductors to be considered outside the building. Circuits from a ground-mounted PV array that are located on the exterior of a building in open air or otherwise considered outside a building according to Section 230.6 would be separate from rapid shutdown firefighter concerns of rescue operations within a building. These circuits differentiate from those of rooftop arrays which remain subject to controlled conductor requirements. The purpose of rapid shutdown is to reduce of shock hazard for firefighters in operations on buildings, where the shock hazard is prevalent around rooftop PV arrays.

690.12(A)
Substantiation

This exception is necessary to clarify the intention of the opening statement in 690.12 “PV system circuits installed on or in buildings.” This phrase has caused confusion in the field where AHJs have required Rapid Shutdown on ground-mounted PV systems that terminate on the outside wall of a house. Moving the termination point 3” away from the outside wall of the house fixes the language problem, but that is not the intent of the requirement for Rapid Shutdown. The purpose of rapid shutdown is to reduce of shock hazard for firefighters in operations on occupied buildings, where the shock hazard is prevalent around rooftop PV arrays. Currently, rapid shutdown applies to any PV circuit that interfaces with a building. Ground-mounted arrays in a field and arrays mounted on parking lot shade structures or similar structures are in non-enclosed, open air spaces with free ventilation. Often such ground-mounted PV arrays, particularly near commercial and industrial buildings, are routed to a nearby building in order to place the electrical equipment in a common location such as a service pad, electrical room, or mounted on the exterior of a building (see figure below). These ground-mounted arrays and their circuits are unlikely to be hazards for firefighters therefore rapid shutdown was not intended to apply to these arrays and circuits.

This PI clarifies the interface between the PV circuits and a building to determine whether controlled conductors requirements apply. 230.6 refers to requirements for service conductors to be considered outside the building. Circuits from a ground-mounted PV array that are located on the exterior of a building in open air or otherwise considered outside a building according to 230.6 would be separate from rapid shutdown firefighter concerns of rescue operations within a building. These circuits differentiate from those of rooftop arrays which remain subject to controlled conductor requirements.

Public Input No. 3797-NFPA 70-2020 [Section No. 690.12(B)]

(B) Controlled Limits.

The use of the term *array boundary* in this section is defined as 305 mm (1 ft) from the array in all directions. Controlled conductors outside the array boundary shall comply with 690.12(B)(1) ~~and inside the array boundary shall comply with 690.12(B)(2)~~ .

(1) Outside the Array Boundary.

Controlled conductors located outside the boundary or more than 1 m (3 ft) from the point of entry inside a building shall be limited to not more than 30 volts within 30 seconds of rapid shutdown initiation. Voltage shall be measured between any two conductors and between any conductor and ground.

~~**(2)** Inside the Array Boundary.~~

~~The PV system shall comply with one of the following:~~

(1) ~~A PV hazard control system listed for the purpose shall be installed in accordance with the instructions included with the listing or field labeling. Where a hazard control system requires initiation to transition to a controlled state, the rapid shutdown initiation device required in 690.12(C) shall perform this initiation.~~

~~Informational Note: A listed or field-labeled hazard PV control system is comprised of either an individual piece of equipment that fulfills the necessary functions or multiple pieces of equipment coordinated to perform the functions as described in the installation instructions to reduce the risk of electric shock hazard within a damaged PV array for fire fighters. See UL 3741, *Photovoltaic Hazard Control* .~~

(2) ~~Controlled conductors located inside the boundary shall be limited to not more than 80 volts within 30 seconds of rapid shutdown initiation. Voltage shall be measured between any two conductors and between any conductor and ground.~~

(3) ~~PV arrays shall have no exposed wiring methods or conductive parts and be installed more than 2.5 m (8 ft) from exposed grounded conductive parts or ground.~~

Statement of Problem and Substantiation for Public Input

Adding additional hardware or software to a PV array increases the risk of fire hazards from including more points of junction.

There is no clear indicator that the devices are actually dead or alive and should still be treated as high voltage. It isn't like Visible blade disconnects where you can verify that conductors are dead.

Adding additional points of potential failure also increases risk or falling injuries as these roof units often go bad.

Often MPLE are operated like small computers or PLC and failures are bound to happen.

Submitter Information Verification

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State:
Zip:
Submittal Date: Wed Sep 09 13:02:59 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: There are many reasons to use module level electronics in PV arrays. Dc to dc converters and optimizers are used for other reasons besides PV rapid shutdown so removal of the proposed text will not likely reduce the number of electrical connections. The published UL1741 requirements for rapid shutdown require functionally safety evaluation that would put the device in a controlled state under failure conditions. The substantiation was based upon anecdotal claims and did not include supporting field data for the removal of all PV rapid shutdown protection inside PV arrays. Worker safety for installers and service persons who are required to take preventative action prior to performing work via wear proper PPE including fall protection is significantly lower than the risks posed to fire fighters fighting fires on buildings.

Public Input No. 4191-NFPA 70-2020 [Section No. 690.12(B)]

(B) Controlled Limits.

The use of the term *array boundary* in this section is defined as 305 mm (1 ft) from the array in all directions. Controlled conductors outside the array boundary shall comply with 690.12(B)(1) ~~and inside the array boundary shall comply with 690 . 12(B)(2).~~

(1) Outside the Array Boundary.

Controlled conductors located outside the boundary or more than 1 m (3 ft) from the point of entry inside a building shall be limited to not more than 30 volts within 30 seconds of rapid shutdown initiation. Voltage shall be measured between any two conductors and between any conductor and ground.

~~**(2)** Inside the Array Boundary.~~

~~The PV system shall comply with one of the following:~~

(1) ~~A PV hazard control system listed for the purpose shall be installed in accordance with the instructions included with the listing or field labeling. Where a hazard control system requires initiation to transition to a controlled state, the rapid shutdown initiation device required in 690.12(C) shall perform this initiation.~~

~~Informational Note: A listed or field-labeled hazard PV control system is comprised of either an individual piece of equipment that fulfills the necessary functions or multiple pieces of equipment coordinated to perform the functions as described in the installation instructions to reduce the risk of electric shock hazard within a damaged PV array for fire fighters. See UL 3741, *Photovoltaic Hazard Control* .~~

(2) ~~Controlled conductors located inside the boundary shall be limited to not more than 80 volts within 30 seconds of rapid shutdown initiation. Voltage shall be measured between any two conductors and between any conductor and ground.~~

(3) ~~PV arrays shall have no exposed wiring methods or conductive parts and be installed more than 2.5 m (8 ft) from exposed grounded conductive parts or ground.~~

Additional Proposed Changes

File Name	Description	Approved
IMG_20200428_180227.jpg		

Statement of Problem and Substantiation for Public Input

MLSD (Module Level Shutdown Device) is now required per code. With even one module per device (operating < 40V), we are finding melted and burnt out connectors which is causing fire hazards. The amount of mismatched connectors is greatly increased with MLSD requirements. Below is a example to illustrate the increase in mismatched connectors in a typical residential system.

In a typical 26 module array without MLSD there are:
24 factory match pairs
4 non-factory home run connections
28 total

The same system with MLSD will now have:
24 factory matched pairs between MLSD

52 non-factory matched connections from modules to MLSD device
4 non-factory home run connections
80 total

Additionally the amount of roof-top work required to service systems with MLSD is greatly increased. Working on elevated pitched services near roof edges is widely regarded as an extreme risk to workers. In 2018, there were 320 fatal falls to a lower level out of 1,008 construction fatalities (BLS data). While module level shutdown was intended to reduce injuries, it has had the unintended affect of increasing risk and injuries by significantly increasing the time workers must work and service existing systems from an elevated platform.

At the same time, these devices do not have requirements to not interfere with the operation of other devices connected to the same system, preventing them from properly detecting ark and ground faults. Because these devices isolate the module source circuits from the array output circuits technicians are unable to properly test system wiring for faults. For example, it is no longer possible to use a isolation testing device to test for pinched source circuit wires or other faults when MLPD prevent this without removing each individual module which is highly unsafe.

Fpr this reason the requirement Module Level Rapid shutdown (inside the array boundary) should be removed to drastically reduce the amount of mismatched connectors reducing fire hazard, drastically reducing service work from unsafe elevated platforms, and reducing fire hazard and safety by allowing other devices to properly detect arc and ground faults. This also returns the ability of technicians to properly test the DC circuits of an array.

Submitter Information Verification

Submitter Full Name: Scott Carman
Organization: Paragon Solar
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 10 01:03:34 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: Many PV arrays include dc-to-dc converters and optimizers so the removal of PV rapid shutdown inside the array will not likely reduce the number of electrical connections. The published UL6703 safety standard for PV connectors includes specific requirements for evaluating multiple vendor’s PV connectors for intermatability. Mating of mismatched connectors that are not certified for intermatability is an inappropriate use of equipment and is not permitted by the NEC. Installers and service persons are required to take preventative actions prior to performing work including wearing appropriate PPE for the hazards involved including fall protection. The proposed claims were not substantiated. UL1741 Paragraph 88.18 requires validation PV rapid shutdown system still complies with the PV arc fault protection requirements in UL1699B. It appears that the combination of equipment tested in support of this public input were not compliant with the most recent published rapid shutdown requirements that require, testing to validate a rapid shutdown system that includes PV arc fault protection does not eliminate compliance with UL1699B.

Public Input No. 2848-NFPA 70-2020 [Section No. 690.12(B)(2)]

~~**(2)** Inside the Array Boundary.~~

~~The PV system shall comply with one of the following:~~

(1) ~~A PV hazard control system listed for the purpose shall be installed in accordance with the instructions included with the listing or field labeling. Where a hazard control system requires initiation to transition to a controlled state, the rapid shutdown initiation device required in 690.12(C) shall perform this initiation.~~

~~Informational Note: A listed or field-labeled hazard PV control system is comprised of either an individual piece of equipment that fulfills the necessary functions or multiple pieces of equipment coordinated to perform the functions as described in the installation instructions to reduce the risk of electric shock hazard within a damaged PV array for fire fighters. See UL 3741, *Photovoltaic Hazard Control* .~~

(2) ~~Controlled conductors located inside the boundary shall be limited to not more than 80 volts within 30 seconds of rapid shutdown initiation. Voltage shall be measured between any two conductors and between any conductor and ground.~~

(3) ~~PV arrays shall have no exposed wiring methods or conductive parts and be installed more than 2.5 m (8 ft) from exposed grounded conductive parts or ground.~~

Statement of Problem and Substantiation for Public Input

From my experience in the field, there is a safety confliction between AFCI and rapid shutdown devices (PVRSE) on rooftops. This is a safety concern for me and my installers as I need systems to work seamlessly and safety is our top priority.

Submitter Information Verification

Submitter Full Name: Clayton Hanks
Organization: CH Electrical
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 02 14:43:57 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: Many PV arrays include dc-to-dc converters and optimizers so the removal of PV rapid shutdown inside the array will not likely reduce the number of electrical connections. The published UL6703 safety standard for PV connectors includes specific requirements for evaluating multiple vendor's PV connectors for intermatability. Mating of mismatched connectors that are not certified for intermatability is an inappropriate use of equipment and is not permitted by the NEC. Installers and service persons are required to take preventative actions prior to performing work including wearing appropriate PPE for the hazards involved including fall protection. The proposed claims were not substantiated.

UL1741 Paragraph 88.18 requires validation PV rapid shutdown system still complies with the PV arc fault protection requirements in UL1699B. It appears that the combination of equipment tested in support of this public input were not compliant with the most recent published rapid shutdown requirements that require, testing to validate a rapid shutdown system that includes PV arc fault protection does not eliminate compliance with UL1699B.

Public Input No. 3662-NFPA 70-2020 [Section No. 690.12(B)(2)]

(2) Inside the Array Boundary.

~~The PV system shall comply with one of the following:A~~ A listed PV hazard control system ~~listed for the purpose~~ shall be installed in accordance with the instructions included with the listing or field labeling. Where a hazard control system requires initiation to transition to a controlled state, the rapid shutdown initiation device required in 690.12(C) shall perform this initiation.

Informational Note: A listed or field-labeled hazard PV control system is comprised of either an individual piece of equipment that fulfills the necessary functions or multiple pieces of equipment coordinated to perform the functions as described in the installation instructions to reduce the risk of electric shock hazard within a damaged PV array for fire fighters. See UL 3741, *Photovoltaic Hazard Control* .

- ~~Controlled conductors located inside the boundary shall be limited to not more than 80 volts within 30 seconds of rapid shutdown initiation. Voltage shall be measured between any two conductors and between any conductor and ground.~~
- ~~PV arrays shall have no exposed wiring methods or conductive parts and be installed more than 2.5 m (8 ft) from exposed grounded conductive parts or ground.~~

Statement of Problem and Substantiation for Public Input

The Standard for Photovoltaic Hazard Control, UL 3741, was developed based upon safety science and is the best option to reduce hazards for fire fighters that need to perform firefighting work in and around PV arrays installed on buildings. A listed PV hazard control system is the safest and most reliable solution, negating the need for options (2) and (3). The option (2) 80V limit was an negotiated / estimated voltage intended to be a compromise between traditional electric shock hazard limits and what was thought to be a feasible implementation. Option (2) was not based upon detailed shock hazard science, does not account for the many differences in PV equipment and system implementations, and relies exclusively upon a system implemented in the field rather than an engineered and tested hazard control system. The systems described in option (3) could yield a plausible implementation that may pass a UL3741 evaluation; however, technological progress has supported reliance on demonstrating compliance with the product standard specific to the intended safety purpose. Based on these evolutions a listed PV hazard control system is the best solution for safety.

UL 3741 was developed based on a US Department of Energy (US DOE) research grant, being jointly conducted by UL LLC and Sandia National Laboratories, specifically developed to evaluate the shock hazards to fire fighters working on PV arrays. The research investigated common fire fighter PPE, work practices, working conditions, and foreseeable abnormal conditions and identified science-based criteria to reasonably limit hazards for fire fighters performing their duties on buildings with PV systems. The UL Standards Technical Panel (STP) UL 3741 includes AHJs, Fire Fighters, NEC experts, representatives from the PV industry, and representatives from US National Labs. Researched conducted as part of the US DOE grant, combined with PV rapid shutdown requirements from UL 1741, and ground fault protection requirements from UL62109-1 -2, provided an excellent foundation for the development of UL 3741. This Standard has passed the initial ballot and the STP is addressing comments received during the ballot period. UL3741 is expected to be published by the end of 2020.

Submitter Information Verification

Submitter Full Name: Timothy Zgonena
Organization: UL LLC
Street Address:

City:
State:
Zip:
Submittal Date: Wed Sep 09 10:19:43 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: There is a desire to provide a means to evaluate non PV hazard control protection measures in the field.

Public Input No. 4456-NFPA 70-2020 [Section No. 690.12(B)(2)]

(2) Inside the Array Boundary.

The PV system shall comply with one of the following:

(1) ~~A~~ The PV system shall provide shock hazard control ~~system listed~~ for ~~the purpose shall be~~ firefighters through the use of a PV hazard control system (PVHCS) installed in accordance with the instructions included with the listing or field labeling. Where a hazard control system requires initiation to transition to a controlled state, the rapid shutdown initiation device required in 690.12(C) shall perform this initiation.

Informational Note: A ~~listed or field-labeled hazard PV control system is comprised of either an individual piece of equipment that fulfills the necessary functions or multiple pieces of equipment coordinated to perform the functions as described in the installation instructions~~ PVHCS is often comprised of one or more pieces of PV hazard control equipment (PVHCE) combined to form a system per the instructions of a PVHCS installed per the instructions that perform the functions to reduce the risk of electric shock hazard within a ~~damaged~~ PV array ~~for fire fighters~~ . See UL 3741, *Photovoltaic Hazard Control*.

(2) ~~Controlled conductors located~~ The PV system shall provide shock hazard control for firefighters by limiting the voltage inside the array boundary ~~shall be limited~~ to not more than ~~80 volts~~ 80 volts within ~~30 seconds~~ 30 seconds of rapid shutdown initiation. Voltage shall be measured between any two conductors and between any conductor and ground.

~~PV arrays shall have no exposed wiring methods or conductive parts and be installed more than 2.5 m (8 ft) from exposed grounded conductive parts or ground.~~

Informational Note: Common methods include the use of PV equipment with a limited maximum voltage of 80 volts as determined by 690.7, PV rapid shutdown equipment (PVRSE), PV hazard control equipment (PVHCE), or any combination of these.

Statement of Problem and Substantiation for Public Input

The changes to 690.12(B)(2) are based on the soon to be published UL3741 for firefighter shock hazard control and provide clarification of how the different listed equipment or listed systems will be identified in UL3741.

The changes to 690.12(B)(2)(1) uses the UL3741 term, PV hazard control system (PVHCS), to describe the hazard control system. The informative note explains that creating a PVHCS can be done by combining one or more pieces of listed equipment, termed PV hazard control equipment (PVHCE) in UL3741, to form a system (when installed per the listing and instructions for each piece of equipment) or by a listed PVHCS where the complete system is listed by one entity and installed per that entities instructions.

The changes to 690.12(B)(2)(2) clarify that this option also provides shock hazard control for firefighters and differentiates the option from 690.12(B)(2)(1). The code had previously established that less than 80 volts was an acceptable level for internal to the array and this concept was not changed. However, based on the wording, it was not clear whether the limit just applied to the external wiring or if it also considered voltage levels within equipment (such as a PV module or electronic device located inside the array boundary). The changes keep that value and the informational note explains the methods that can accomplish that. If the 80 volts is relied on, than the informational note clarifies that this is the maximum voltage of equipment within the array after activation of the rapid shutdown initiator. No UL3741 listing is required. Any equipment that would be energized with higher than 80 volts after activation of the rapid shutdown initiator would fall under a UL3741 investigation even if that voltage was internal to equipment and not just the exposed wiring. Other options would be: using a listed PVRSE at a PV module with a maximum output voltage less than 80 volts, using a listed PVHCE from UL3741 or any combination of these.

The option provided by 690.12(B)(2)(3) is no longer applicable with the above two options. The design

either falls within option 2 or option 1. Therefore, this option is deleted since there is not enough criteria specified to determine an adequate PVHCS.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI's submitted.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain, P.E., SEIA; Bill Brooks, PVICC; John Berdner, PVICC, Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing, Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower; Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

Submitter Information Verification

Submitter Full Name: Evelyn Butler
Organization: Solar Energy Industries Assn
Affiliation: PV Industry Forum (PVIF)
Street Address:
City:
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Zip:
Submittal Date: Thu Sep 10 13:25:14 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9235-NFPA 70-2021

Statement: This revision provides a simple option to reduce shock hazards for fire fighters by limiting voltage inside the array and inside the equipment.

The option provided by 690.12(B)(2)(3) is no longer applicable with the first two options. The design either falls within option 2 or option 1 as a listed PV hazard control system. Therefore, this option is deleted since there is not enough criteria specified to determine an adequate PVHCS

Public Input No. 4494-NFPA 70-2020 [Section No. 690.12(B) [Excluding any Sub-Sections]]

The use of the term *array boundary* in this section is defined as 305 mm (1 ft) from the array in all directions. Controlled conductors outside the array boundary shall comply with 690.12(B)(1) and inside the array boundary shall comply with 690.12(B)(2) . Equipment and systems listed for the purpose shall be permitted to meet the requirements of both inside and outside the array as defined by the manufacturer's instructions included with the listing.

Statement of Problem and Substantiation for Public Input

Note that despite the legislative text shown, this input only seeks to add a new last sentence. The existing language is unchanged. This additional language is to clarify that products, such as those listed as rapid shutdown equipment (RSE), can be used to provide the necessary functions for the requirements within the array boundary [690.12(B)(2)] and those outside the array boundary[690.12(B)(1)]. A simple example of this is a microinverter installed on a PV module with a maximum voltage less than 80Volts. The listed microinverter reduces the voltage on its ac output to less than 30V in less than 30 seconds while the PV module side of the inverter stays energized at up to 80V in compliance with 690.12(B)(2)(2). No additional certifications are required for the microinverter that is listed as RSE.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI's submitted.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain, P.E., SEIA; Bill Brooks, PVICC; John Berdner, PVICC, Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing, Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower; Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett,

DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

Submitter Information Verification

Submitter Full Name: Evelyn Butler
Organization: Solar Energy Industries Assn
Affiliation: PV Industry Forum (PVIF)
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 10 14:14:51 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9239-NFPA 70-2021 - The phrase “listed for the purpose” was not included as it was redundant to other requirements for listing of equipment.

Statement: This additional language clarifies that products, such as those listed as rapid shutdown equipment (RSE), can be used to provide the necessary functions for the requirements within the array boundary [690.12(B)(2)] and those outside the array boundary[690.12(B)(1)].

Public Input No. 3221-NFPA 70-2020 [Section No. 690.12(C)]

(C) Initiation Device.

The initiation device(s) shall initiate the rapid shutdown function of the PV system. The device's "off" position shall indicate that the rapid shutdown function has been initiated for all PV systems connected to that device. For one-family and two-family dwellings an initiation device(s) shall be located at a readily accessible location outside the building. The initiation device shall be labeled "PV RAPID SHUTDOWN DISCONNECT"

For a single PV system, the rapid shutdown initiation shall occur by the operation of any single ~~initiationdevice~~ initiation device . Devices shall consist of at least one or more of the following:

(1) Service disconnecting means

(2) PV system disconnecting means

(3) Readily accessible switch that plainly indicates whether it is in the "off" or "on" position

Informational Note: Examples of where an initiation device that complies with 690.12(C)(3) would be used is where a PV system is connected to an optional standby or stand-alone system.

Where multiple PV systems are installed with rapid shutdown functions on a single service, the initiation device(s) shall consist of not more than six switches or six sets of circuit breakers, or a combination of not more than six switches and sets of circuit breakers, mounted in a single enclosure, or in a group of separate enclosures. These initiation device(s) shall initiate the rapid shutdown of all PV systems with rapid shutdown functions on that service.

Statement of Problem and Substantiation for Public Input

The proposed language will add clarity for the Firefighter or other person who is charged with disconnecting the photovoltaic (PV) system during an emergency situation. As an Electrical Inspector, I have requested installers to label the disconnect in this fashion, as this labeling is presently not required to plainly indicate which disconnect or other initiation device is for the rapid shutdown of the PV system. As an Electrical Inspector and as a volunteer Firefighter, it is very important to label these devices with their purpose. We, as Electrical Inspectors and Instructors, keep educating the Firefighters that the rapid shutdown is on newer PV systems to assist in making these systems safe when a fire event occurs, but we fail to label the initiation devices a "PV RAPID SHUTDOWN DEVICE" so the Firefighters know which disconnect to turn off when needed. By adding this requirement into the NEC, this will make it very clear the purpose of this device and clear up confusion on which disconnect or imitation device to turn to the off postion.

Submitter Information Verification

Submitter Full Name: Robert Fahey
Organization: City of Janesville
Street Address:
City:
State:
Zip:
Submittal Date: Sun Sep 06 20:55:20 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9243-NFPA 70-2021

Statement: Marking requirements are moved to more relevant section 690.12(D). In addition, slight variations that have existed in color, formatting, and marking language requirements between the Fire Code and the NEC have made it unnecessarily difficult for enforcement and inspections agencies to align. The specific color requirement was removed to accommodate local requirements that may differ.

Public Input No. 4053-NFPA 70-2020 [Section No. 690.12(C)]

(C) Initiation Device.

The initiation device(s) shall initiate the rapid shutdown function of the PV system. The device's "off" position shall indicate that the rapid shutdown function has been initiated for all PV systems connected to that device. For one-family and two-family dwellings an initiation device(s) ~~shall~~ shall ~~be~~ ~~located at a readily accessible location outside the building~~ meet the following requirements .

(1) Be located in a readily accessible location outside the building

(2) Be located within 1 m (3 ft) of any required emergency service disconnect or where there is no required emergency service disconnect, shall be located within 1 m (3 ft) of any other power source emergency disconnect

(3) If remotely controlled, the remote-control system shall be "fail safe" where the rapid shut down system is automatically activated on loss of control signal or control power

(4) Be labeled to comply with 690.56(2).

For a single PV system, the rapid shutdown initiation shall occur by the operation of any single initiationdevice. Devices shall consist of at least one or more of the following:

(1) Service disconnecting means

(2) PV system disconnecting means

(3) Readily accessible switch that plainly indicates whether it is in the "off" or "on" position

Informational Note: Examples of where an initiation device that complies with 690.12(C)(3) would be used is where a PV system is connected to an optional standby or stand-alone system.

Where multiple PV systems are installed with rapid shutdown functions on a single service, the initiation device(s) shall consist of not more than six switches or six sets of circuit breakers, or a combination of not more than six switches and sets of circuit breakers, mounted in a single enclosure, or in a group of separate enclosures. These initiation device(s) shall initiate the rapid shutdown of all PV systems with rapid shutdown functions on that service.

Statement of Problem and Substantiation for Public Input

This proposal is one of several related, but separate proposals involving the 2020 NEC requirements for external (outside the building) emergency disconnects on one- and two-family dwellings for energy sources such as the utility service, batteries, energy storage systems (ESS), wind systems and also stand-alone PV systems plus PV rapid shutdown systems. The intent of these proposals is to require multiple emergency disconnects to be grouped in one location to increase safety for Fire Service first responders.

Also, when remote activation of these disconnects is allowed, the proposal establishes an additional safety requirement that the remote controls be fail safe and in the event of loss of control power or control signal, the emergency disconnect shall automatically be opened.

It has been determined that some inverter manufacturers are already starting to put inputs on their products to allow an external remote shutdown control system that is fail safe. Also, it has been determined that adding such a fail-safe remotely controlled emergency disconnect system is relatively inexpensive using voltage-trip circuit breakers and a relay on large battery banks or ESS.

Submitter Information Verification

Submitter Full Name: John Wiles

Organization: Southwest Technology Development Institute, New Mexico State University

Street Address:

City:

State:

Zip:

Submittal Date: Wed Sep 09 19:17:58 EDT 2020

Committee: NEC-P04

Committee Statement

Resolution: Grouping is unnecessary and can be impractical in many applications since the requirements in Sections 705.10, 710.10 and 712.10 all require identification of power source disconnecting means be identified at the service location. Rapid shutdown equipment and systems are evaluated to be “fail safe” as part of the listing to the published UL1741 requirements.

Public Input No. 4341-NFPA 70-2020 [Section No. 690.12(C)]

(C) Initiation Device.

The initiation device(s) shall initiate the rapid shutdown function of the PV system. The device's "off" position shall indicate that the rapid shutdown function has been initiated for all PV systems connected to that device. For one-family and two-family dwellings an initiation device(s) shall be located at a readily accessible location outside the building.

For a single PV system, the rapid shutdown initiation shall occur by the operation of any single initiationdevice. Devices shall consist of at least one or more of the following:

(1) Service disconnecting means

(2) PV system disconnecting means

(3) Readily accessible switch that plainly indicates whether it is in the "off" or "on" position

Informational Note: Examples of where an initiation device that complies with 690.12(C)(3) would be used is where a PV system is connected to an optional standby or stand-alone system.

Where multiple PV systems are installed with rapid shutdown functions on a single service, the initiation device(s) shall consist of not more than six switches or six sets of circuit breakers, or a combination of not more than six switches and sets of circuit breakers ~~, mounted~~ in a ~~single enclosure, or in a~~ group of separate enclosures. These initiation device(s) shall initiate the rapid shutdown of all PV systems with rapid shutdown functions on that service.

Statement of Problem and Substantiation for Public Input

Section 230.71(B) no longer permits the up to six service disconnecting means to be mounted in a single enclosure. As presently written, 690.12(C) is in conflict with 230.71(B).

Submitter Information Verification

Submitter Full Name: L. Keith Lofland
Organization: IAEI
Affiliation: None
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 10 10:47:50 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: PV rapid shutdown initiation devices are not service disconnects and do not need to follow the same rules. Additionally, the separation of initiation devices may provide easier access for fire fighters to initiate the shutdown before fire fighting.

Public Input No. 4500-NFPA 70-2020 [Section No. 690.12(C)]

(C) Initiation Device.

~~The initiation~~ Where circuits identified in 690.12(A) are required to meet the requirements in 690.12(B), an initiation device(s) shall be provided and shall initiate the rapid shutdown function ~~of the PV system~~ . The device's "off" position shall indicate that the rapid shutdown function has been initiated for all PV systems connected to that device. For one-family and two-family dwellings an initiation device(s) ~~shall~~ , where required, shall be located at a readily accessible location outside the building.

For a single PV system, the rapid shutdown initiation shall occur by the operation of any single initiationdevice. Devices shall consist of at least one or more of the following:

(1) Service disconnecting means

(2) PV system disconnecting means

(3) Readily accessible switch that plainly indicates whether it is in the "off" or "on" position

Informational Note: Examples of where an initiation device that complies with 690.12(C)(3) would be used is where a PV system is connected to an optional standby or stand-alone system.

Where multiple PV systems are installed with rapid shutdown functions on a single service, the initiation device(s) shall consist of not more than six switches or six sets of circuit breakers, or a combination of not more than six switches and sets of circuit breakers, mounted in a single enclosure, or in a group of separate enclosures. These initiation device(s) shall initiate the rapid shutdown of all PV systems with rapid shutdown functions on that service.

Statement of Problem and Substantiation for Public Input

This additional language is to clarify that initiation devices are only required when the installation requires a rapid shutdown function. No such device is necessary when the function is not required for the PV system.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI's submitted.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain, P.E., SEIA; Bill Brooks, PVICC; John Berdner, PVICC, Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing, Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower; Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural

Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

Submitter Information Verification

Submitter Full Name: Evelyn Butler
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Submittal Date: Thu Sep 10 14:19:22 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9246-NFPA 70-2021
Statement: This additional language clarifies that initiation devices are only required when the installation requires a rapid shutdown function. No such device is necessary when the function is not required for the PV

system.

Public Input No. 1302-NFPA 70-2020 [Section No. 690.12(D)]

(D) Equipment.

Equipment that performs the rapid shutdown functions, other than initiation devices such as listed disconnect switches, circuit breakers, or control switches, shall be listed ~~for providing rapid shutdown protection.~~ and identified as a PV rapid shutdown system or as a PV hazard control system.

Informational Note: See UL 3741, *Photovoltaic Hazard Control* .

Statement of Problem and Substantiation for Public Input

It has been identified by installers that there are field installation issues with the compatibility of individual listed PV Rapid Shutdown Equipment. Currently within UL 1741 and within UL 3741 there are required functional safety tests. This section should require that the products that perform PV rapid Shutdown not only be listed, but also identified as “photovoltaic rapid shutdown system” or “PV rapid shutdown system.” Individual listed PV Rapid Shutdown Equipment used as components outside of a listed PV Rapid Shutdown System will be limited in performance and may or may not address all of the critical aspects of its use in the end PV rapid shutdown System (PV Hazard Control System).

Submitter Information Verification

Submitter Full Name: Jeffrey Fecteau
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Affiliation: UL LLC
Street Address:
City:
State:
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Submittal Date: Thu May 28 18:38:35 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: Article 690 is being revised such that all of the equipment listing requirements are being relocated under Section 690.4(B).

Public Input No. 3803-NFPA 70-2020 [Section No. 690.12(D)]

(D) Equipment.

Equipment that performs the rapid shutdown functions, other than initiation devices such as listed disconnect switches, circuit breakers, or control switches, shall be listed for providing rapid shutdown protection. These devices should not interfere with other devices, or functions, including safety features such as Arc Fault Circuit Interuption or Ground Fault Circuit Interruption.

Statement of Problem and Substantiation for Public Input

If you are adding a system that increases the chances of someone getting hurt, either by causing an existing system to become a nuisance and end user circumvents or completely non functional, you really haven't gained anything at all.

Submitter Information Verification

Submitter Full Name: Jason Eiseman
Organization: Wellspring Components
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 09 13:12:11 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: This is a certification requirement that is already covered by UL1741, Paragraph 88.18. Furthermore, this proposed requirement is not enforceable in the field.

Public Input No. 4105-NFPA 70-2020 [Section No. 690.12(D)]

(D) Equipment.

Equipment that performs the rapid shutdown functions, other than initiation devices such as listed disconnect switches, circuit breakers, or control switches, shall be listed for providing rapid shutdown protection. These devices should not interfere with other devices or functions (e.g. Arc-Fault Circuit Interrupter (AFCI), Or Ground-Fault Circuit Interrupter (GFCI).

Additional Proposed Changes

File Name	Description	Approved
2020-09-09-Rapid_Shutdown-WhitePaper.pdf	Rapid Shutdown & AFCI documentation on safety issues.	

Statement of Problem and Substantiation for Public Input

The attached White Paper “Arc-Fault Detection at Photovoltaic Systems” shows that Module Level Power Electronics (MLPEs) are interfering with state-of-the-art Arc-Fault Detection. This shows that Module Level Shutdown (MLSD) unintentionally makes the PV system unsafe and MLSD is causing the problem which it is made to protect against, fires. At the moment no standard (e.g. UL 1741, or UL1699B) is addressing this problem. I believe it is the first step in fixing the issue.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 4099-NFPA 70-2020 [Section No. 690.12]	

Submitter Information Verification

Submitter Full Name: Chris Connell
Organization: Fronius USA LLC
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Submittal Date: Wed Sep 09 20:48:08 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: This is a certification requirement that is already covered by UL1741, Paragraph 88.18. Furthermore, this proposed requirement is not enforceable in the field.

Arc fault detection in Photovoltaic systems

Motivation

This document outlines the current methodology of arc fault circuit interrupters (AFCI) in photovoltaic (PV) systems and the main challenges that exist if module level power electronics (MLPEs) are included in a system. The MLPE definition used in this white paper pertains to devices outside of microinverters. Thus, the focus is on MLPE devices that are used in conjunction with string inverters.

Conclusion

- Based on numerous references cited in this paper, we can adhere that spectral arc detection is state-of-the-art
- We value the evolution in the standard for arc detection in PV systems. However, based on current requirements of UL 1741 and UL 1699B, a specific test isn't required to test string inverters and MLPE devices together. Most testing laboratories aren't even performing a test (UL 1741, 88.18, recommended AFCI & PVRSE testing together) when doing a PVRSS certification. Justification of this is done via "engineering judgement" and that the inverters are already UL 1699B certified, and thus do not require an AFCI test with the MLPE device. This leads to a lack of testing an inverter in conjunction with an MLPE device to UL 1699B and thus an unsafe scenario. This scenario allows for testing residential and commercial rooftop installations to be impractical compared to installation circumstances in the field.
- Noise generated from MLPE devices causes a situation where string inverter manufacturers are faced with two options:
  (1) Incorporate the noise from MLPE into the AFCI algorithm to avoid false trips
  Resulting in an incapability to detect arcs in a real life scenarios (while passing UL 1699B).
  (2) Do not incorporate the noise level
  Resulting in regular false trips from the MLPE device in PV Systems.
- Thus, 690.11 and 690.12 are conflicting with each other and are seen as incompatible. We show in Figure 6 that the current state-of-the-art arc fault detection approach cannot detect an arc signature if the sensor signal is compromised by the additional noise from MLPEs.

AFD Basics

Arcs describe the phenomena when the dielectric constant of an insulating material is exceeded and a breakdown occurs, which then continues to burn even after the initial charge dissipated [Ref. 1]. Once an arc is established, the voltage necessary to sustain it is much lower than the initial voltage needed to create an arc. The arc might burn as long as the energy loss due to dissipation is equal or less than the energy produced by the arc.

Arc faults in PV systems can be categorized in three types (see Figure 1):

1) Ground arc faults
2) Serial arc faults
3) Parallel arc faults

Type (1) arcs can be considered as negligible, since modern inverters are required to be equipped with a residual measurement current unit (RCMU), which would detect a significant current drain much before an arc takes place.
Type (3) arcs are also of less interest, since proper isolation between two conducting lines is mandatory for every PV installation.
The most severe arc incidents, which are also considered in UL 1699B [Ref. 2-3], are serial arcs (2).

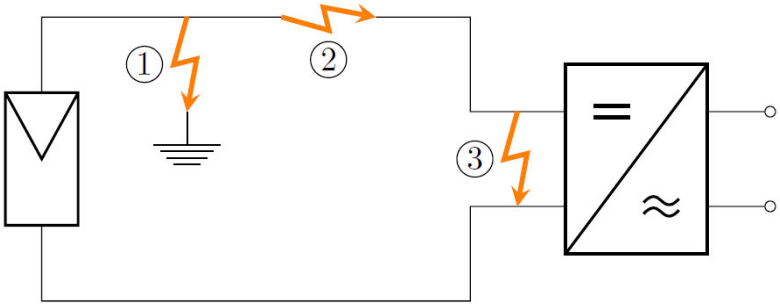

Figure 1: Arc categories in PV system.

From an electrical DC perspective, a serial arc event can be modeled as an additional resistance in the DC path of the PV array [Ref 4]. However, this resistance is only the range of mΩ and other devices (including the inverter) can create similar voltage/ current signals. In other words, a simple large-scale electrical behavior analysis is insufficient. Voltage and current spectra show an inverse relationship to frequency [Ref. 5], which is characteristic of the “pink noise” generated during electrical arcing. Arc detection using a spectral analysis of electrical noise can be found in multiple references [Ref 6-14].

Normative arc detection

UL 1699B-2018 Ed. 1 [Ref. 3] uses a ring and ball setup (schematic shown in Figure 2) which should provide a reproducible and standardized arc test on the one hand and a challenging and realistic arc scenario on the other hand.

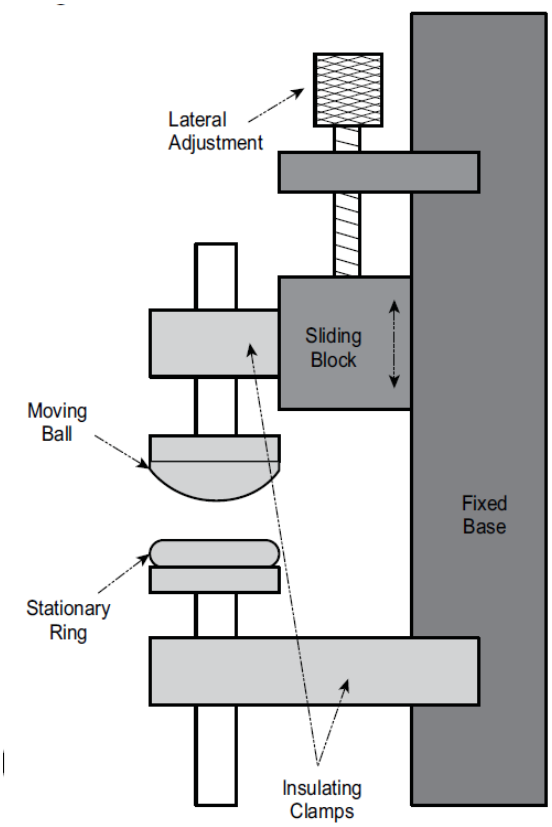

Figure 2: Ring and ball measurement apparatus according to [Ref. 2]

UL 1699B-2013 (Outline of Investigation) [Ref. 2] used a different test setup. Here, a piece of steel wool was manually inserted between two cylindrical electrodes (Figure 3a and Figure 3b), which was then ignited and burnt by the electrical current, which consequently led to a stable burning arc.

Figure 3a

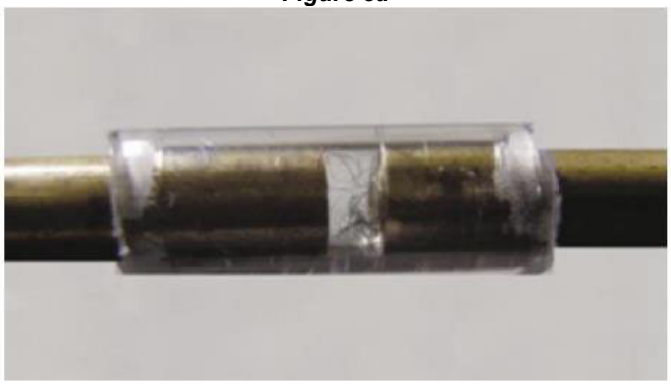

Figure 3b

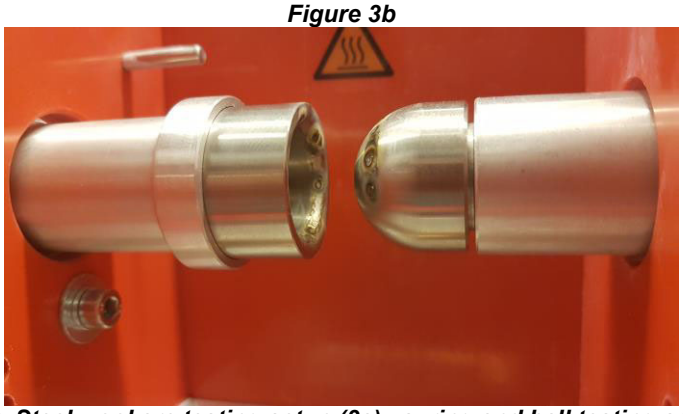

Figure 3: Steel wool arc testing setup (3a) vs. ring and ball testing setup (3b)

Despite the difference in the arc creation, the arc burning signature in time and spectral domain are similar. As mentioned above, revision of the arc creation methodology aims at an improved repeatability of the tests. Also, a simplification of the procedure and a higher similarity to real arc events is achieved by the ring and ball setup. There might be some miscellaneous differences between steel wool and ring and ball within the first millisecond (ms) of the arc ignition, but these are caused by the experimental setup and are not subject of a true arc event. Please see [Ref. 5] for further insight into the motivation for the UL 1699B parameter selections. However, several influencing factors affect the final signal shape:

- variable cable lengths creating resonance peaks
- masking effects caused by parallel PV strings
- sensor bandwidth and transfer function
- external devices within the PV array (e.g. MLPEs, external sensors, etc.)

The first two points are considered in the new UL 1699B standard by mandatory decoupling networks and string/line models, while the third is subject to the manufacturer providing an adequate solution. The last point, however, remains untreated.

In summary, we welcome the improvements of the new UL standard, but we also have reservations about how realistic the UL-setup reflects the circumstances of real installations – especially if external devices within the PV array are used, such as MLPE.

Measurement results

Figure 5 shows a measurement result from the worst case scenario of the test conditions from [Ref. 3] (see Table 1). A coarse schematic is given. The measurement equipment is given in [Table 2].

Figure 5a shows the time domain signal of the current probe (left y-axis) together with the arc voltage (yellow signal on right y-axis) acquired by using a voltage differential probe. Note that such a measurement source is not available in a real-world scenario. However, it allows for precise determination of the time range when the arc was burning (red signal in Figure 5a). The gaps within the red signals are areas where the Power Line Communication (PLC) signal was active. PLC signal influences are excluded in all subsequent measurements for better comparison.

Figure 5b shows the spectra of the non-arc (blue) and arc (red) signal. Within the range between approx. 50-200 kHz the arc and non-arc spectra are well-separated and with an approx. 17 dB margin, which we can distinguish between an arc and non-arc condition (green area in Figure 5b). Note that the line impedance resonance and harmonics of switching frequencies effects cause numerous peaks outside this area, which prohibit a robust detection.

Parameter	Value
Setup	Fig. 29.14
Total number of strings (n)	2
C4 of Half string	20 µF
Test no. from Table 29.2	3
Position of Arc Generator	Middle Of String

Table 1: Selected UL 1699B-2018 parameters for worst-case arc testing

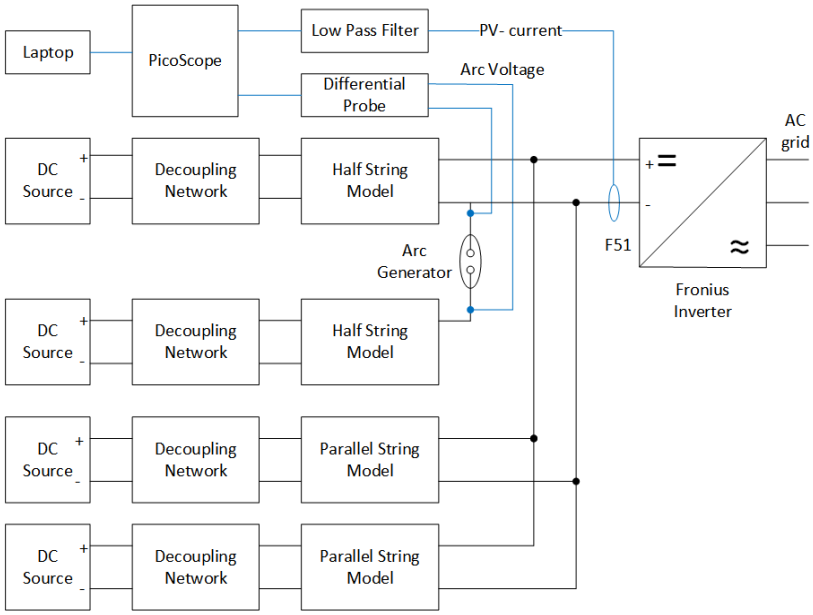

Figure 4: Schematic of measurement setup. Black are power-conducting lines, blue sensing lines.

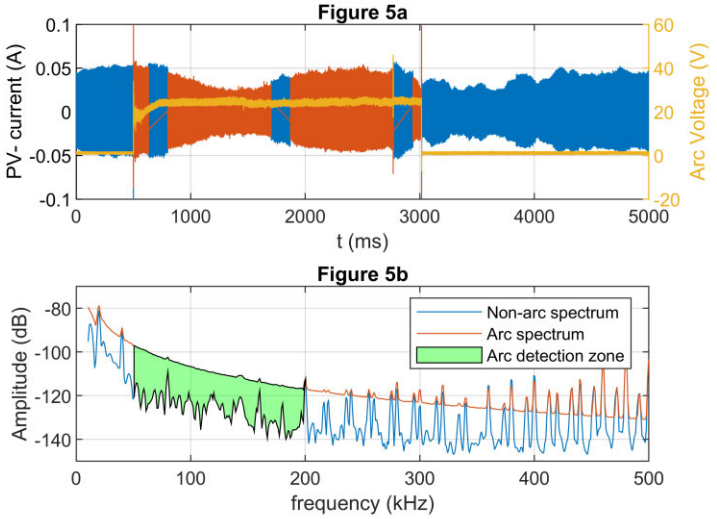

Figure 5: Comparison of arc vs. non-arc spectra. Figure 5a shows the time signals of the current probe raw data (blue) and the signal range where arc was burning (red), i.e. arc voltage > 15 V. Figure 5b shows the according spectrum of the arc and non-arc sections from the time signals of Figure 5a. The arc detection zone marks the area between approx. 50-200 kHz with the biggest difference between arc and non-arc spectrum.

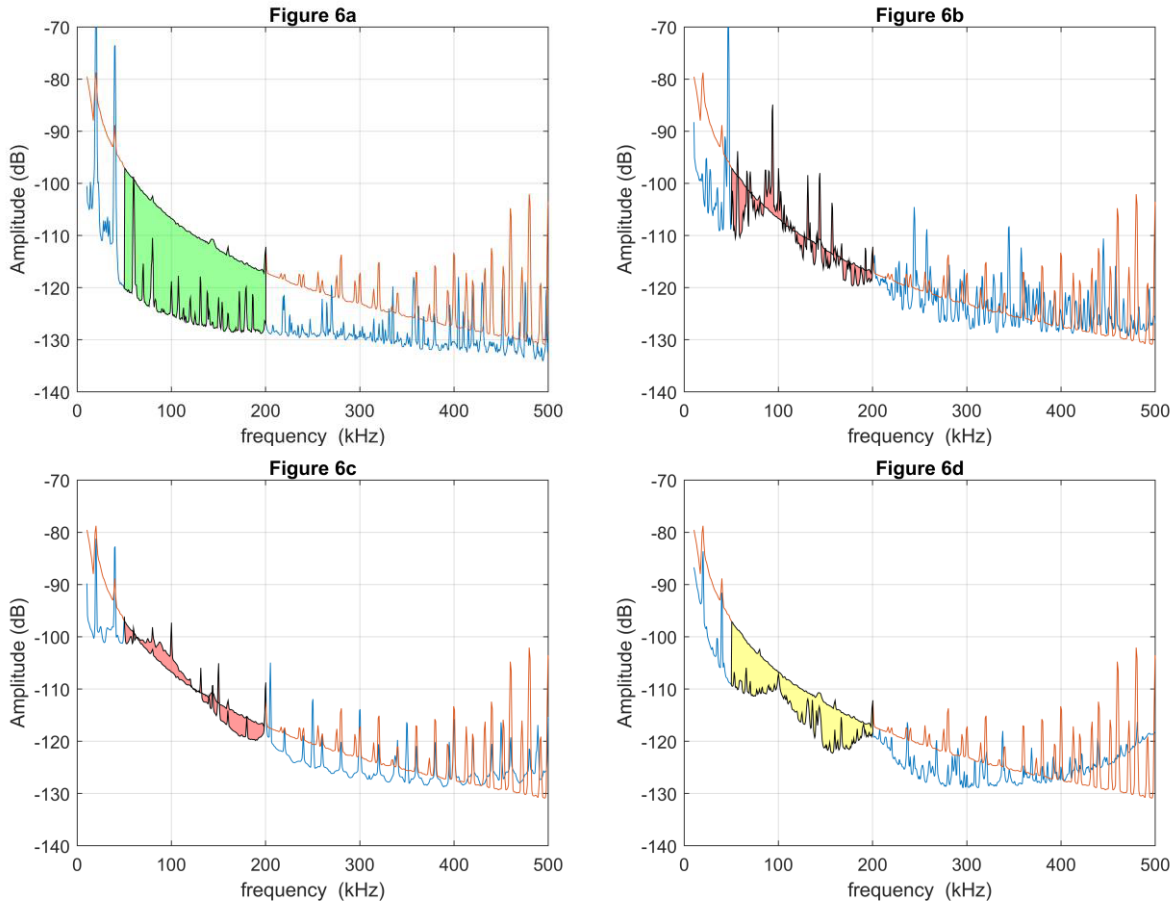

Figure 6: Comparison of arc spectrum (red) against spectra from various field installations (blue).
Figure 6a: Reference installation with <u>no</u> MLPEs consisting of four strings with each 22 bifacial modules (PVP 280 Wp – total 24 kWp).
Figure 6b: One string installation with six PV modules (Kioto 270 Wp –total 1.6 kWp) and MLPE#1
Figure 6c: Five strings installation with each 14 modules (VSUN 330 Wp –total 23 kWp) and MLPE#2
Figure 6d: One string installation with 20 modules (Sanyo 260 Wp – total 5.2 kWp) and MLPE#3

We see in Figure 6 that the MLPE devices create an increased noise floor, which matches or exceeds the noise floor from the arc spectrum of Figure 5. Note that we've deliberately chosen very different PV system setups and we are excluding any manufacturer details.

Hence, a proper arc detection with a spectral evaluation is not possible anymore!

Only with MLPE#3 the arc detection probability is just reduced.

Measurement equipment

Error! Reference source not found. contains a list of the used equipment to acquire the signals in the previous section. All further equipment (e.g. arc generator, decouple networks, etc.) are either manufactured by Fronius internally or of no relevance (e.g. laptop, cables, etc.). For the F-51 recordings we used the impedance calibration data from the manufacturer, interpolated on our frequency range.

Device	Description	Specification
Inverter	FRONIUS Symo Adv. 20.0-3 208-480	
Current probe	Fischer Custom Communication F-51	Range 10 kHz – 500 MHz
Filter	Mini-Circuits SLP-1.9+ Low Pass Filter	Range DC-1.9 MHz
Voltage probe	TESTEC Differential Probe TT-SI9101	Attenuation 1/100
Scope	PicoScope 5243B	Samplerate 3.906 MSps, 15 Bit, Duration: 5 s
Processing	Matlab 2019b	incl. Signal Processing Toolbox 8.3

Table 2: List of used equipment

Alternative arc detection techniques

The conclusion of these results is that spectral arc detection is not possible anymore without being highly susceptible to false trippings. [Ref. 1] lists several different approaches like:

- Spread spectrum time domain reflectometry (SSTDR),
- Resonance Tuned electrical resonator,
- Minimum covariance determinant (MCD),
- Change in direction of current at the on-set of fault,
- Artificial neural network (ANN) of graph-based semi-supervised learning technique.

However, to the best of our knowledge, we can state that spectral arc fault detection is a widespread industrial standard. Moreover, the robustness of these alternatives against arc-like events is hard to determine, which is tantamount to detecting an arc.

Conclusion

- Based on numerous references cited in this paper, we can adhere that spectral arc detection is state-of-the-art
- We value the evolution in the standard for arc detection in PV systems. However, based on current requirements of UL 1741 and UL 1699B, a specific test isn't required to test string inverters and MLPE devices together. Most testing laboratories aren't even performing a test (UL 1741, 88.18, recommended AFCI & PVRSE testing together) when doing a PVRSS certification. Justification of this is done via "engineering judgement" and that the inverters are already UL 1699B certified, and thus do not require an AFCI test with the MLPE device. This leads to a lack of testing an inverter in conjunction with an MLPE device to UL 1699B and thus an unsafe scenario. This scenario allows for testing residential and commercial rooftop installations to be impractical compared to installation circumstances in the field.
- Noise generated from MLPE devices causes a situation where string inverter manufacturers are faced with two options:
  (3) Incorporate the noise from MLPE into the AFCI algorithm to avoid false trips
  Resulting in an incapability to detect arcs in a real life scenarios (while passing UL 1699B).
  (4) Do not incorporate the noise level
  Resulting in regular false trips from the MLPE device in PV Systems.
- Thus, 690.11 and 690.12 are conflicting with each other and are seen as incompatible. We show in Figure 6 that the current state-of-the-art arc fault detection approach cannot detect an arc signature if the sensor signal is compromised by the additional noise from MLPEs.

Solution

First and foremost, we support rapid shutdown when it is properly implemented. Currently, we believe that there are too many unintended consequences of the implementation of this code, which actually creates additional risks and issues. We would purpose a 4 step method:

1) Remove the inside of the array boundary (690.12 B(2)) voltage requirement, keeping 690.12 B(1) the same. Other changes, such as 690.12 (B) will also need to be revised (controlled limits) and would be an editorial, fixing mention of the inside of the array boundary.
2) Implement a separate standard for MLPE, which requires specific noise levels, temperature testing specific of thermal events, and testing of the internal switches.
3) Make needed changes to UL 1741 and UL 1699B in a way that practical real life scenarios are being tested with MLPE & arc fault detection together.
4) Re-introduce “690.12 Inside of the array boundary, 80V requirement”.

FAQ

Q: Why do you need 17 dB of margin?
A: There isn’t a specific need for 17 dB of margin, however, in order to perfectly detect the differences, a minimal margin of 17 dB is required. Having less makes it more difficult to detect arcs and the more unreliable the algorithm becomes. Any manufacturer (see references) doing spectral arc analysis would experience the same issue.

Q: Why is spectral arc analysis used and not another method if this problem exists?
A: As explained at the top of page two, a serial arc can be seen as an additional resistance in the DC path and can create a very similar voltage and current. However, this resistance is only the range of mΩ and other devices (including the inverter) can create similar voltage/ current signals. In other words, a simple large-scale electrical behavior analysis is insufficient.

References

[1] M. K. Alam et al. “*A Comprehensive Review of Catastrophic Faults in PV Arrays: Types, Detection, and Mitigation Techniques*”. IEEE Journal of Photovoltaics 5.3 (Mai 2015), p. 982–997.

[2] UL 1699B OUTLINE OF INVESTIGATION – FOR PHOTOVOLTAIC (PV) DC ARC-FAULT CIRCUIT PROTECTION - Issue Number 2 - JANUARY 14, 2013.

[3] UL 1699B Standard for Safety for Photovoltaic (PV) DC Arc-Fault Circuit Protection, First Edition, Dated August 22, 2018.

[4] Hertha Marks Ayrton. *The Electric Arc*. New York: D. Van Nostrand Company, 1902.

[5] Jay Johnson, *PV AFCI FOR FIRE PROTECTION*, Arc Fault Forum 2012, p.52.

[6] U.S. Pat. No. 5 835 321 A “Arc fault detection apparatus and circuit breaker incorporating same”, Robert T. Elms, John C. Schlotterer, Eaton Corporation.

[7] U.S. Pat. No. 5 706 159 A *Circuit interrupter including an electric arc monitoring circuit* Charles R. Dollar, Woothi Strickland, Siemens Energy & Automation Inc.

[8] U.S. Pat. No. 5 729 145 A *Method and apparatus for detecting arcing in AC power systems by monitoring high frequency noise*, Frederick K. Blades, Siemens Energy & Automation Inc.

[9] U.S. Pat. No. 6 362 628 A1 *ARC FAULT CIRCUIT DETECTOR DEVICE DETECTING PULSE WIDTH MODULATION OF ARC NOISE*, Bruce M. Macbeth, Thomas N. Packard, Syracuse NY.

[10] U.S. Pat. No. 5 805 397 A *Arcing fault detector with multiple channel sensing and circuit breaker incorporating same*, Raymond W. MacKenzie, Eaton Corporation.

[11] EU Pat. No. 2 850 708 B1 *METHOD AND APPARATUS FOR LOCALIZING AND QUENCHING AN ARC*, Holger Behrends, SMA Solar Technology AG, §25.

[12] EU Pat. No. 2 388 602 B1 *Method for diagnosing contacts of a photovoltaic assembly and device*, Markus Hopf et al. SMA Solar Technology AG, §33.

[13] 5SM6 Arc Fault Detection Unit, Siemens AG 2012

[14] AN-2154: RD-195 DC Arc Detection Evaluation Board (Rev. F), Texas Instruments 2012

Public Input No. 4193-NFPA 70-2020 [Section No. 690.12(D)]

(D) Equipment.

Equipment that performs the rapid shutdown functions, other than initiation devices such as listed disconnect switches, circuit breakers, or control switches, shall be listed for providing rapid shutdown protection. Devices connected to the DC conductors of a photovoltaic array shall not interfere with other devices of the same system to function as required by 690.41(B) Ground-Fault Protection, and 690.11 Arc-Fault Circuit Protection (Direct Current)

Statement of Problem and Substantiation for Public Input

MLPE, which is now required per code (690.12). We have found that these devices interfere with proper functioning of arc fault detection and ground-fault detection of other devices such as string inverters, on the same system. If module Level Power Electronics are to be required by code, they should not prevent or interfere with the arc-fault detection and ground fault-detection required by code of these other devices.

Submitter Information Verification

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Zip:
Submittal Date: Thu Sep 10 01:17:40 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: This is a certification requirement that is already covered by UL1741, Paragraph 88.18. Furthermore, this proposed requirement is not enforceable in the field.

Public Input No. 4472-NFPA 70-2020 [Section No. 690.12(D)]

~~(D) Equipment.~~

~~Equipment that performs the rapid shutdown functions, other than initiation devices such as listed disconnect switches, circuit breakers, or control switches, shall be listed for providing rapid shutdown protection.~~

Statement of Problem and Substantiation for Public Input

This proposal moves the language from 690.12(D) to 690.4(B). The language in 690.12(D) serves the same purpose as 690.4(B), which requires that equipment shall be listed for its purpose. The proposed change condenses the language related to listings in 690. The informational note is intended to maintain the distinction that was in 690.12(D) related to listed switches and circuit breakers used rapid shutdown initiators. While those devices are commonly used to comply with 690.12 requirements, they need not have specific listings for rapid shutdown or PV hazard control if they are simply performing a switching function within their ratings. This statement is generally true of general purpose listed devices used in PV systems so the informational note is made more general for that reason.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI's submitted.
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Submitter Information Verification

Submitter Full Name: Evelyn Butler
Organization: Solar Energy Industries Assn
Affiliation: PV Industry Forum (PVIF)
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 10 13:38:39 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9247-NFPA 70-2021
Statement: The requirement for listed rapid shutdown equipment and system is deleted from 690.12(D). Section 690.4(B) addresses PV equipment and certification requirements.

Public Input No. 3986-NFPA 70-2020 [Section No. 690.12 [Excluding any Sub-Sections]]

PV system circuits installed on or in buildings shall include a rapid shutdown function to reduce shock hazard for firefighters in accordance with 690.12(A) through (D).

Exception 1 : Ground-mounted PV system circuits that enter buildings, of which the sole purpose is to house PV system equipment, shall not be required to comply with 690.12.

Exception 2: Rapid shutdown function need not be provided where the fire code official has determined that PV system circuits do not expose a fire fighter to electrical shock hazards during fire-fighting operations for that type and configuration of building or structure.

Statement of Problem and Substantiation for Public Input

This public input is submitted to provide the Code Making Panel another option for debate on how to improve the scope of the requirement for Rapid Shutdown of PV Systems on Buildings. The initial development of language for Rapid Shutdown was based on consideration of hazards related to fire-fighting rooftop operations for rooftop PV systems. Unfortunately, the language "installed on or in buildings" is overly restrictive for some types of PV installations, primarily because the NEC definitions of "building" and "structure" are overly broad. For example, an elevated PV support structure installed over a parking lot falls within the definition of building, but there are no rooftop operations involved with fire-fighting, as fire fighters will not go on top of those structures during a fire event, and will instead attack the fire from the ground.

2020 NEC Definitions:

Building. A structure that stands alone or that is separated from adjoining structures by fire walls. (CMP-1)

Structure: That which is built or constructed, other than equipment. (CMP-1)

Because a building is defined as "a structure," and a structure is defined as "that which is built or constructed," almost anything made by the hands of humans can be considered to be a building under current NEC definitions. This is problematic.

This Public Input is not intended to compete against other PI's as a stand-alone solution, but instead is intended to encourage the Code Making Panel to consider fire fighting operations that benefit from -- or do not benefit from -- Rapid Shutdown to improve fire fighter safety, while considering how to improve the primary charging language for Rapid Shutdown to more specifically describe the type of building for which Rapid Shutdown is needed.

The language of this Public Input is inspired by similar exception language for rooftop access pathways and setbacks found in 2021 International Fire Code Section 1205.2 Access and Pathways, Exceptions 2 and 3, and in 2021 NFPA 1 Fire Code Section 11.12.3.1.2. These sections allow the fire code official the flexibility to exempt or modify requirements for access pathways and setbacks where rooftop operations are not employed.

For Rapid Shutdown requirements, the Code Making Panel could consider developing a list of use cases for which Rapid Shutdown is not needed because it does not enhance fire fighter safety, and then debate final charging language (or exceptions) that would require Rapid Shutdown in those use cases where it helps, and not require it where it does not improve safety.

For example, consider the following (incomplete) list of use cases:

- Elevated PV support structures commonly found over parking lots on grade

- Elevated PV support structures commonly found on the upper-most level of a parking garage
- Elevated PV support structure over an agricultural use, such as over a cranberry bog or as a livestock shade structure.
- Elevated PV support structure over a vegetative roof.
- PV on detached garages for one- or two-family dwellings
- PV on detached sheds for one- or two-family dwellings
- PV on patio cover or trellis for one- or two-family dwellings
- PV on agricultural buildings
- Pole-mounted PV systems (tracking or fixed)
- Single-axis trackers
- Fixed-tilt ground mounts
- Float-o-voltaics

- BIPV facade systems (on cladding, spandrel glass, or windows)
- BIPV facade systems at a height greater than 75-feet above grade

This list of use cases could be expanded, based on experiences of CMP members or interested parties. Hopefully, this partial list of use cases will inform the discussion of CMP members when considering final language for 2023 NEC Rapid Shutdown.

Submitter Information Verification

Submitter Full Name: Joe Cain
Organization: Representing Self
Affiliation: Representing Self
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 09 16:47:44 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9229-NFPA 70-2021

Statement: This revision clarifies the interface between the PV circuits and a building to determine whether controlled conductor requirements apply. Section 230.6 refers to requirements for service conductors to be considered outside the building. Circuits from a ground-mounted PV array that are located on the exterior of a building in open air or otherwise considered outside a building according to Section 230.6 would be separate from rapid shutdown firefighter concerns of rescue operations within a building. These circuits differentiate from those of rooftop arrays which remain subject to controlled conductor requirements. The purpose of rapid shutdown is to reduce of shock hazard for firefighters in operations on buildings, where the shock hazard is prevalent around rooftop PV arrays.

Public Input No. 4405-NFPA 70-2020 [Section No. 690.12 [Excluding any Sub-Sections]]

PV system circuits installed on or in buildings shall include a rapid shutdown function to reduce shock hazard for firefighters in accordance with 690.12(A) through (D).

Exception: Ground-mounted PV system circuits that enter buildings, of which the sole purpose is to house PV system equipment, shall not be required to comply with 690.12.

Exeption: Small PV systems of 25 kw or less, with an OCV of 150 or less, on concrete structures, like a concrete roof of a concrete house, shall not be required to comply with 690.12. A label must be installed next to the main disconect of the facility explaining that the property have a PV system without a RapidShutdown Disconnect.

Additional Proposed Changes

File Name	Description	Approved
exeption_for_RS_of_systems_installed_in_concrete_roofs.pdf		

Statement of Problem and Substantiation for Public Input

RS implementation in PR has left low income families and small comercial without the possibilities to install PV backup systems because the increase in cost and complexity. Emergency responder dont make ventilation holes in concrete roofs. An Exemption of the RS requirement for concrete roofs will help reduce cost and complexity of the PV system make it more accessible to low income families and small comercial applications.

Submitter Information Verification

Submitter Full Name: Homar Torres
Organization: ecologicall
Affiliation: ACONER
Street Address:
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Zip:
Submittal Date: Thu Sep 10 12:12:39 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: Concrete structures can still have fires as not all building materials are not flammable. Additionally, the PV array may be the source of the fire.

Renewable energy systems have proven in recent years to be the fastest growing commercial, industrial, and residential energy alternative. Technological advances in this industry make the incorporation of these systems more and more accessible and necessary as an alternative for energy generation to alleviate the burden on traditional systems. After the hurricane season of 2017, where it was clearly evidenced that Global Warming has raised the temperatures of the Atlantic Ocean to levels never seen before. These temperatures in the ocean water have contributed to the development of extreme hurricanes. Since 2005, these extreme events of force majeure began to create a new paradigm in terms of Emergency Management and Disaster Management.

In the local context, the damages caused by Hurricane María completely destroyed the electrical distribution system. In addition, the earthquakes destroyed part of Costa Sur, the biggest power plant in Puerto Rico, also cause substantial damage other power plants, transmission, and distribution system. Because of all the bureaucracy of the government and the Puerto Rico Electric Power Authority (PREPA) been in bankrupt, the processes to restore will take decades.

Up to 12 month without power in some areas after Hurricane Maria, cause 4,645 deaths, because of the lack of power to preserve food, to preserve medicines, operate medical equipment, operate communication devices, pump potable water for people to drink, to clean, to bath.

Meanwhile, hurricanes will continue to threaten the island again. The humanitarian crisis has reached unsuspected levels. The public health system collapsed from: Hospitals, Health Centers, Medical Offices, Laboratories, Renal Centers, Hospice Bedridden Patients and “Home Care” programs were affected and will be affected again as new atmospheric phenomena arrive, or worse yet a Major Earthquake.

Faced with this picture, the Emergency Preparedness phase together with the Mitigation phase are our only defense weapons. We are an Island, and as such it is impossible to pre-position resources from other jurisdictions before the threat of atmospheric events. We also have seismic vulnerability, which does not warn us and therefore we have to raise our guard and put ourselves on ALERT.

Been a small, Island, PR have to import everything, for this reason, electrical and technologic equipment are more expensive. High income families and corporations are securing their energy needs with expensive and luxury last technologies batteries. But, a big part of the Island live under poverty, The implementation of Rapid Shutdown in PR, can increase in over $3,000 the cost of a simple small backup system, leaving low income families with no market choices to install PV Backup system to protect their family members from the disasters PR is experimenting every year and the daily power failures of a grid that can collapse at any moment.

Exemption for 25kw systems or less installed in concrete structures with concrete roof.

Rapid Shutdown have changed a lot since it was first mentioned. But we have to maintain focus on what it is main purpose, so any changes don’t bend its original reason to exit.
In some jurisdictions, Firefighters and other emergency responders, access roofs in order to make holes for ventilation procedures, or gain access to the interior of the property. In concrete buildings with concrete roof, emergency responders will never access a roof to make a hole! Its is simply impossible for it to happen!
So, if emergency responders will never access a roof with heavy machinery to make a ventilation hole in a solid concrete roof, then, the risk of electrical shock does not exist at all!

Why 25kw or less?

Because my petition is focused on reducing the complexity and cost for low income houses and small commercial, backup systems. For example, 48v battery base systems with arrays of 150Vdc in open circuit. Typically, one single inverter system may have from 12 up to 48 PV panels. Two inverters in parallel may have from 36 to 96 PV panels. These 150 Vdc pv arrays have less hazards than larger 600 Vdc arrays. And because emergency responders never go to a roof to make a ventilation hole in a concrete roof, there is not risk at all.

I personally don't work with large commercial systems, but the board should consider have less strict rules for all concrete buildings with concrete roofs. Integration of RS in PV Systems larger than 25.1 KW should be discussed later with professionals that works those type of systems.

Petition:

To make an exception of the 690.12 for 25kw or less PV systems installed in concrete buildings with concrete roofs.

Homar Torres Arzola, PE, MEM

Member of the board of ACONER, the Association of Energy Consultants of Puerto Rico.

www.aconer.com

Public Input No. 4445-NFPA 70-2020 [Section No. 690.12 [Excluding any Sub-Sections]]

PV system circuits installed on or in buildings ~~shall~~ with occupiable spaces or habitable rooms shall include a rapid shutdown function to reduce shock hazard for firefighters in accordance with 690.12(A) through (D).

Exception:

~~Ground-mounted~~

PV system

~~circuits that enter buildings, of which the sole purpose is to house PV system equipment,~~

equipment or circuits installed on or in buildings or structures without occupiable spaces or habitable rooms, including but not limited to equipment attached to ground mounting structures, detached garages, parking shade structures, carports, trellises and similar structures, shall not be required to

~~comply with 690.12 .~~

include a rapid shutdown function.

Informational Note: Exceptions for rapid shutdown are intended to be consistent with fire codes that have limitations as to the types of buildings firefighters typically perform rooftop operations.

Statement of Problem and Substantiation for Public Input

The intent of this proposal is to clearly define that PV systems, installed in or on locations where firefighters will perform rooftop operations, require rapid shutdown (RSD) functions to allow firefighters to safely perform vertical ventilation and rescue operations. Basic firefighting methods are performed when there is an enclosed space below the PV system where the occupants may be working, living, or engaged in other similar actions. RSD was not envisioned for PV systems installed on solar carports, accessory structures, or ground mounted arrays since any heat, smoke, or occupants could egress through the open sides of the structure. For this purpose, the definitions of “habitable rooms” from the NEC and “occupiable space” from the International Building Code are referenced to indicate when rooftop operations would be performed. The defined area where RSD is required is an enclosed space, designed for human occupancy, where living, sleeping, eating, cooking, or working is performed and there are means of egress, light, and ventilation facilities.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF’s effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI’s as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI’s submitted.

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Submitter Information Verification

Submitter Full Name: Evelyn Butler
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Street Address:
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Submittal Date: Thu Sep 10 13:10:21 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9278-NFPA 70-2021 PI 4504 was not technically correct. While the UL1741 requirements for the input and output ports of standalone and interactive inverters are required to discharge in 5 minutes or less, these products still need to be evaluated as PV rapid shutdown equipment to comply with the 30Vdc and 15Vac in 30Sec. Additionally, some inverters are multimode and will need additional consideration for PV rapid shutdown.

Statement: New Exception No. 2 is aligned with an existing exception to requirements for firefighter roof top access and pathways in the building and fire codes.

The proposed text regarding the types of installations that do not require rapid shutdown was added to the informational note to provide supplemental clarification per the style manual.

Public Input No. 4504-NFPA 70-2020 [Section No. 690.12 [Excluding any Sub-Sections]]

PV system circuits installed on or in buildings shall include a rapid shutdown function to reduce shock hazard for firefighters in accordance with 690.12(A) through (D). For the purposes of this section, PV systems installed on a carport where the carport has no walls and is not attached to a building, shall be considered as a ground-mounted PV system.

Exception: Ground-mounted PV system circuits that enter buildings, of which the sole purpose is to house PV system equipment, shall not be required to comply with 690.12.

Exception No. 2: Ground-mounted PV systems utilizing listed utility-interactive inverter(s) where only inverter AC output circuit(s) are installed on or within buildings, shall not be required to comply with 690.12. For such systems there shall be provided a readily accessible AC disconnect or overcurrent protection device on the outside of the building to disrupt the inverter(s) interaction with the electric utility when the disconnect is opened.

Statement of Problem and Substantiation for Public Input

Justification for adding second sentence of 690.12: : The 2020 NEC does not give any direction on if a PV system mounted on a carport is to be treated like a PV system on a building, or if it should be treated like a ground-mounted PV system. This has caused significant confusion across the country when AHJ's try to apply the requirements of NEC 690.12. However, the functionality of a solar PV system mounted on a carport is not any different than a ground-mounted PV system. Also, there is not any reason for a firefighter to get on top of a carport which contains a solar PV system. It's been stressed through the last several code cycles that rapid shutdown requirements for PV system are specifically for protecting firefighters. The words "for firefighters" were even added to Section 690.12 in the 2020 NEC. Because of this, a PV system mounted on a carport should not be any different than a ground-mounted PV system when determining whether or not rapid shutdown requirements of NEC 690.12 apply to such system.

Justification for adding 2nd exception: Providing rapid shutdown equipment for PV systems can often be difficult and expensive. Since a ground-mounted PV system does not pose the same hazards as a roof-mounted PV system for firefighters, there needs to be more flexibility on when rapid shutdown equipment is required for a ground-mounted PV system. Adding the proposed exception #2 would add more flexibility to the design of a PV system and save costs.The AC output circuit of a listed utility-interactive inverter can easily be shut down simply by opening an AC disconnect switch or breaker that interrupts the link between the inverter(s) and the electric utility grid. All the firefighters would have to do is shut down the service disconnect(s) to the building or shut off an AC disconnect for the PV system. By doing so the listed utility-interactive inverter(s) would shut down and ensure there's no live PV AC circuit wiring on or in the building. Yes, the wiring at the array (under the solar modules) would remain energized, but such does not affect nor present a hazard to firefighters. Adding the proposed exception #2 to 690.12 would afford firefighters protection from live wiring while at the same time simplify the solar PV installation and reduce the amount of required equipment. Many jurisdictions are already allowing ground-mounted PV systems and PV systems mounted on carports to not meet the requirements of 690.12(B)(2) (often called "module-level" rapid shutdown) as long as the inverter(s) are mounted at or immediately adjacent to the PV array. The proposed exception #2 is in line with such practice.

Submitter Information Verification

Submitter Full Name: Doug Smith
Organization: West Coast Code Consultants (WC3)
Street Address:
City:

State:
Zip:
Submittal Date: Thu Sep 10 14:22:31 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9278-NFPA 70-2021 PI 4504 was not technically correct. While the UL1741 requirements for the input and output ports of standalone and interactive inverters are required to discharge in 5 minutes or less, these products still need to be evaluated as PV rapid shutdown equipment to comply with the 30Vdc and 15Vac in 30Sec. Additionally, some inverters are multimode and will need additional consideration for PV rapid shutdown.

Statement: New Exception No. 2 is aligned with an existing exception to requirements for firefighter roof top access and pathways in the building and fire codes.

The proposed text regarding the types of installations that do not require rapid shutdown was added to the informational note to provide supplemental clarification per the style manual.

Public Input No. 1862-NFPA 70-2020 [Section No. 690.13(A)]

(A) Location.

(1) Readily Accessible. The PV system disconnecting means shall be installed at a readily accessible location.

(2) Restriction to Unqualified Persons. Where disconnecting means of systems above 30 ~~V are~~ volts are readily accessible to unqualified persons, any enclosure door or hinged cover that exposes live parts when open shall be locked or require a tool to open.

Informational Note: PV systems installed in accordance with 690.12 address the concerns related to energized conductors entering a building.

Statement of Problem and Substantiation for Public Input

Revision into a list format of each us use and application.

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
Street Address:
City:
State:
Zip:
Submittal Date: Sat Jul 11 19:04:04 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9443-NFPA 70-2021

Statement: This section has been revised into a list format for ease of use and application. The requirement in the section addressing access to unqualified persons has been restated to better align with terms used elsewhere in this Code and to provide clarity that the cover must be locked, not any disconnect handle. The informational note language is deleted in keeping with NEC Style Manual recommendations as Section 690.12 has been included in this Code for 3 cycles so is well-known.

Public Input No. 2979-NFPA 70-2020 [Section No. 690.13(C)]

(C) Maximum Number of Disconnects.

Each PV system disconnecting means shall consist of not more than six switches or six sets of circuit breakers, or a combination of not more than six switches and sets of circuit breakers, mounted in a single enclosure, or in a group of separate enclosures. A single PV system disconnecting means shall be permitted for the combined ac output of one or more inverters or ac modules~~ in an interactive system~~ .

Informational Note: This requirement does not limit the number of PV systems connected to a service as permitted in 690.4(D). This requirement allows up to six disconnecting means to disconnect a single PV system. For PV systems where all power is converted through interactive inverters, a dedicated circuit breaker, in 705.12(B)(1), is an example of a single PV system disconnecting means.

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

Interactive system is no longer a defined term as this definition is being changed as part of public inputs of this task group. This public input removes the reference to this as this last sentence is not needed here and could cause confusion.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2684-NFPA 70-2020 [Definition: Interactive System.]	Definition / Term change

Submitter Information Verification

Submitter Full Name: Thomas Domitrovich
Organization: Eaton Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 03 18:13:47 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9263-NFPA 70-2021
Statement: The reference to an interactive system is removed since the inclusion of this term in this sentence is unnecessary to apply the requirements and its presence could cause confusion.

Public Input No. 1871-NFPA 70-2020 [Section No. 690.13(E)]

(E) Type of Disconnect.

The PV system disconnecting means shall simultaneously disconnect the PV system conductors that are not solidly grounded from all conductors of other wiring systems. The PV system disconnecting means or its remote operating device or the enclosure providing access to the disconnecting means shall be capable of being locked in accordance with 110.25. The PV system disconnecting means shall be one of the following:

(1) A manually operable switch or circuit breaker

(2) A connector meeting the requirements of 690.33(D)(1) or (D)(3)

(3) A pull-out switch with the required interrupting rating

(4) A remote-controlled switch or circuit breaker that is operable locally and opens automatically when control power is interrupted

(5) A device listed or approved for the intended application

~~Informational Note:~~

(1) Fused disconnects, unless otherwise marked, shall be considered suitable for backfeed. Circuit breakers not marked “line” and “load”

~~may not~~

(1) shall be considered suitable for backfeed . Circuit breakers marked “line” and “load” shall be considered suitable for backfeed or reverse current if specifically rated .

Statement of Problem and Substantiation for Public Input

The replacement of the informational note with "Fused disconnects, unless otherwise marked, shall be considered suitable for backfeed. Circuit breakers not marked “line” and “load” shall be considered suitable for backfeed. Circuit breakers marked “line” and “load” shall be considered suitable for backfeed or reverse current if specifically rated." was a 100% extraction from 705.12(D). It is always great when NEC rules are consistent between articles – plus this is great information.

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
Street Address:
City:
State:
Zip:
Submittal Date: Mon Jul 13 10:34:44 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: The suitability of a circuit breaker to provide overcurrent protection at its rating under reverse current is dependent on its evaluation and listing.

Public Input No. 3663-NFPA 70-2020 [Section No. 690.15(A)]

(A D) Location and Control .

Isolating devices or equipment disconnecting means shall ~~be installed in circuits connected to equipment at a location~~ comply with one or more of the following:

(1) Located within the equipment

~~, or within sight and within 3 m (10 ft) of the equipment. An equipment disconnecting means shall be permitted to be remote from the equipment where the equipment disconnecting means can be remotely operated from within 3 m (10 ft) of the equipment. Where disconnecting means of equipment operating above 30 volts are readily accessible to unqualified persons, any enclosure door or hinged cover that exposes live parts when open shall be locked or require a tool to open~~

(1)

(2) Located in sight from, and readily accessible from the equipment for those to whom access is required

(3) Lockable in accordance with 110.25

(4) Provided with remote controls to activate the disconnecting means where the remote controls for the disconnecting means are not located within sight of the equipment, the disconnecting means is lockable in accordance with 110.25, and the location of the controls are marked on the disconnecting means .

Statement of Problem and Substantiation for Public Input

There are three primary components to this PI, each of which is interrelated.
(1) 690.15(A) and 690.15(D) are switched to improve readability
(2) The modified 690.15(A) Type of Disconnecting Means is modified for clarity:
- Item 1 in the list item already exists, but is reworded for clarity
- Item 2 in the list is modified to clarify that listed equipment may have a mechanism or series of operations that can allow for safe servicing of equipment by removing current. In this scenario, the equipment would remove current and would need to be listed for this type of operation. This type of equipment would allow a technician to safely operate an isolating device where the circuit normally operates at any current level. For example, this is a common configuration in systems as part of listed equipment where current must be removed before accessing fuse holders that are used as isolating devices.
- Item 3 in the list is modified to clarify that an equipment disconnecting means is allowed on any circuit, not just on circuits greater than 30A.

(3) The modified 690.15(D) Location and Control is modified as a list for clarity. The list item covering “remote controls” is based on the language at 480.7(D). This change would clearly allow for remote operation where the remote operation device is not within sight of the equipment, and would require the disconnect to be lockable in these circumstances, even when the disconnecting means is within sight of the equipment.
References to 3m (10ft) are removed and where they would have been used, replaced with “readily accessible for whom access is required.” This is language used elsewhere in the Code, for example, disconnecting means for rooftop air conditioning equipment. This removes possibilities that equipment may be close to the isolating means but at a different level, behind a fence, or otherwise not readily accessible during servicing.

The requirement to secure hinged covers and doors has been deleted since 110.27 should provide requirements for guarding of all electrical equipment. See related PI.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar

Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain, P.E., SEIA; Bill Brooks, Brooks Engineering/PVICC; Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing, Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower; Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Ben Chamberlain, Olivewood Energy; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3661-NFPA 70-2020 [Section No. 690.15(D)]	These section locations are switched.
Public Input No. 3926-NFPA 70-2020 [New Section after 110.27(C)]	For guarding of certain equipment
Public Input No. 3661-NFPA 70-2020 [Section No. 690.15(D)]	
Public Input No. 3926-NFPA 70-2020 [New Section after 110.27(C)]	

Submitter Information Verification

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Submittal Date: Wed Sep 09 10:21:41 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9268-NFPA 70-2021

Statement: The first level subdivision numbering has been changed to move this section from (A) to (D), and a small title change has been made to improve the application of this section. The existing text is reorganized into a list for clarity. References to distances have been removed to align requirements in this section with similar requirements in this Code through the use of the defined term “in sight from” and the addition of the phrase “readily accessible for whom access is required.” This addresses installations where equipment may be close to its disconnecting means but at a different level, behind a fence, or otherwise not readily accessible during servicing.

Allowances for remote operation have been reorganized into a list for ease of use and clarity.

The requirement to secure hinged covers and doors has been deleted since it has been moved to general requirements in Article 690.

Public Input No. 3668-NFPA 70-2020 [Section No. 690.15(C)]

(C) Equipment Disconnecting Means.

Equipment disconnecting means shall comply with each of the following:

(1) Equipment disconnecting means shall have ratings sufficient for the maximum circuit current, available fault current, and voltage that is available at the terminals.

(2) Equipment disconnecting means shall simultaneously disconnect all current-carrying conductors that are not solidly grounded to the circuit to which it is connected.

(3) Equipment disconnecting means shall be externally operable without exposing the operator to contact with energized parts and shall indicate whether in the open (off) or closed (on) position. Where not within sight or not within 3 m (10 ft) of the equipment, the disconnecting means or its remote operating device or the enclosure providing access to the disconnecting means shall be capable of being locked in accordance with 110.25 .

(4) Equipment disconnecting means, where used, shall be one of the types in 690.13(E) (1) through (E)(5).

Equipment disconnecting means, other than those complying with 690.33, shall be marked in accordance with the warning in 690.13(B) if the line and load terminals can be energized in the open position.

Informational Note: A common installation practice is to terminate PV source-side dc conductors in the same manner that utility source-side ac conductors are generally connected on the line side of a disconnecting means. This practice is more likely to de-energize load-side terminals, blades, and fuses when the disconnect is in the open position and no energized sources are connected to the load side of the disconnect.

Statement of Problem and Substantiation for Public Input

The existing text is reorganized as a list for readability, and to clarify that all of the listed items are required for equipment disconnecting means used for isolating equipment. Despite the appearance of the legislative text, the only new text that is being added is between the charging paragraph and the first list item one.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain, P.E., SEIA; Bill Brooks, Brooks Engineering/PVICC; Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing, Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower;

Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Ben Chamberlain, Olivewood Energy; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

Submitter Information Verification

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Submittal Date: Wed Sep 09 10:29:32 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9272-NFPA 70-2021
Statement: The existing text is reorganized as a list for readability, and to clarify that all the listed items are required for equipment disconnecting means used for isolation of equipment.

Public Input No. 3661-NFPA 70-2020 [Section No. 690.15(D)]

(~~D~~ A) Type of Disconnecting Means.

Where disconnects are required to isolate equipment, the disconnecting means shall ~~be~~ comply with one or more of the following applicable types:

~~An equipment disconnecting means in accordance with~~ 690.15(C) ~~shall be required to isolate dc~~

(1) For circuits with a maximum circuit current ~~over~~

(2) of 30 amperes ~~.An~~

(3) or less, an isolating device in accordance with 690.15(B) ~~shall be permitted for circuits other than those covered by~~

(4)

(5) For any circuit, an isolating device where there are means as part of listed equipment to first remove current and then allow access to the isolating device

(6) For any circuit, an equipment disconnecting means in accordance with 690.15(~~D~~

(7) C) ~~(1).~~

(8)

Additional Proposed Changes

File Name	Description	Approved
690.15_D_correct_text.pdf	Correct text for the PI for this section	

Statement of Problem and Substantiation for Public Input

There are three primary components to this PI, each of which is interrelated.
(1) 690.15(A) and 690.15(D) are switched to improve readability
(2) The modified 690.15(A) Type of Disconnecting Means is modified for clarity:
- Item 1 in the list item already exists, but is reworded for clarity
- Item 2 in the list is modified to clarify that listed equipment may have a mechanism or series of operations that can allow for safe servicing of equipment by removing current. In this scenario, the equipment would remove current and would need to be listed for this type of operation. This type of equipment would allow a technician to safely operate an isolating device where the circuit normally operates at any current level. For example, this is a common configuration in systems as part of listed equipment where current must be removed before accessing fuse holders that are used as isolating devices.
- Item 3 in the list is modified to clarify that an equipment disconnecting means is allowed on any circuit, not just on circuits greater than 30A.

(3) The modified 690.15(D) Location and Control is modified as a list for clarity. The list item covering “remote controls” is based on the language at 480.7(D). This change would clearly allow for remote operation where the remote operation device is not within sight of the equipment, and would require the disconnect to be lockable in these circumstances, even when the disconnecting means is within sight of the equipment.
References to 3m (10ft) are removed and where they would have been used, replaced with “readily accessible for whom access is required.” This is language used elsewhere in the Code, for example,

disconnecting means for rooftop air conditioning equipment. This removes possibilities that equipment may be close to the isolating means but at a different level, behind a fence, or otherwise not readily accessible during servicing.

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This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
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Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3663-NFPA 70-2020 [Section No. 690.15(A)]	These section locations are switched
Public Input No. 3663-NFPA 70-2020 [Section No. 690.15(A)]	

Submitter Information Verification

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Submittal Date: Wed Sep 09 10:15:09 EDT 2020

Committee: NEC-P04

Committee Statement

Resolution: FR-9273-NFPA 70-2021

Statement: The first level subdivision numbering has been changed to move this section from (D) to (A) to improve the application of this section. The existing text is reorganized into a list for clarity. The existing requirements in previous list item 1 & 2 have been reorganized for ease of use. Modifications to the wording clarifies that disconnecting means complying with 690.15(C) are permitted in any circuit regardless of current rating.

New list item 2 recognizes that some listed equipment may utilize isolation devices for circuits with currents greater than 30 amperes provided there are means to ensure current flow is interrupted prior to anyone servicing this equipment having access to the isolation device. This type of equipment is in use today and allows a technician to safely isolate equipment that requires servicing, but where a disconnect type as noted in 690.15(C) cannot be installed. A common application in PV systems is a listed combiner box where current is removed before opening fuse holders that are used as isolating devices.

690.15(~~D~~A) Type of Disconnecting Means.

Where disconnects are required to isolate equipment, the disconnecting means shall ~~be~~ comply with one or more of the following applicable types:

~~1. An equipment disconnecting means in accordance with 690.15(C) shall be required to isolate dc circuits with a maximum circuit current over 30 amperes.~~

~~2. An isolating device in accordance with 690.15(B) shall be permitted for circuits other than those covered by 690.15(D)(1).~~

1. For circuits with a maximum circuit current of 30 amperes or less, an isolating device in accordance with 690.15(B)
2. For any circuit, an isolating device where there are means as part of listed equipment to first remove current and then allow access to the isolating device
3. For any circuit, an equipment disconnecting means in accordance with 690.15(C)

Public Input No. 1157-NFPA 70-2020 [Section No. 690.31(A)]

(A) Wiring Systems.

All raceway and cable wiring methods included in this *Code*, other wiring systems and fittings specifically listed for use in PV arrays, and wiring as part of a listed system shall be permitted. Where wiring devices with integral enclosures are used, sufficient length of cable shall be provided to facilitate replacement.

Where PV source and output circuits operating at voltages greater than 30 volts are installed immediately under the array and in readily accessible locations, circuit conductors shall be guarded ~~or installed in Type MC cable or in raceway.~~ by either of the following methods:

1. Surround the array with substantial fencing with a 1.8 m (6 ft) minimum height and with a lockable gate if gated.

2. Install metallic mesh 19 gauge or greater with openings of 1/2" or less to the underside of the array covering the cabling.

PV source and output circuits shall be provided with physical protection by a raceway or MC cable for every portion immediately outside the arrays. PV cabling that isn't within a raceway or MC cable on the underside of array(s) shall be regarded as live parts.

The ampacity of 105°C (221°F) and 125°C (257°F) conductors shall be permitted to be determined by Table 690.31(A)(b). For ambient temperatures greater than 30°C (86°F), the ampacities of these conductors shall be corrected in accordance with Table 690.31(A)(a).

Table 690.31(A)(a) Correction Factors

	Temperature Rating of Conductor		
Ambient Temperature (°C)	**105°C (221°F)**	**125°C (257°F)**	**Ambient Temperature (°F)**
30	1	1	86
31–35	0.97	0.97	87–95
36–40	0.93	0.95	96–104
41–45	0.89	0.92	105–113
46–50	0.86	0.89	114–122
51–55	0.82	0.86	123–131
56–60	0.77	0.83	132–140
61–65	0.73	0.79	141–149
66–70	0.68	0.76	150–158
71–75	0.63	0.73	159–167
76–80	0.58	0.69	168–176
81–85	0.52	0.65	177–185
86–90	0.45	0.61	186–194
91–95	0.37	0.56	195–203
96–100	0.26	0.51	204–212
101–105	—	0.46	213–221
106–110	—	0.4	222–230
111–115	—	0.32	231–239
116–120	—	0.23	240–248

Table 690.31(A)(b) Ampacities of Insulated Conductors Rated Up To and Including 2000 Volts, 105°C Through 125°C (221°F Through 257°F), Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried), Based on Ambient Temperature of 30°C (86°F)

AWG	**Types**

	PVC, CPE, XLPE 105°C	XLPE, EPDM 125°C
18	15	16
16	19	20
14	29	31
12	36	39
10	46	50
8	64	69
6	81	87
4	109	118
3	129	139
2	143	154
1	168	181
1/0	193	208
2/0	229	247
3/0	263	284
4/0	301	325

Informational Note: See 110.14(C) for conductor temperature limitations due to termination provisions.

Statement of Problem and Substantiation for Public Input

Guidelines are needed for guarding readily accessible PV cabling.

Submitter Information Verification

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Submittal Date: Tue May 19 07:56:07 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9279-NFPA 70-2021

Statement: This section has been reorganized to add new subdivisions and titles for improved use. The newly titled 690.31(A)(2) has been expanded to cover all PV dc circuits since the prevention of access to readily accessible single conductors in PV systems for safety reasons is applicable to these conductors regardless of the presence of any dc converters. The application of the newly titled 690.31(A)(2) section has been clarified to better address what conditions it applies to. The list of acceptable cable types has been expanded to include multiconductor jacketed cables to align with 690.31(C)(3) and has been rearranged for clarity. It is noted that the definition of the term “guarded” is included in Article 100 of this Code. Modifications to the table titles have been made to align with the new section subdivision numbering.

Public Input No. 3838-NFPA 70-2020 [Section No. 690.31(A)]

(A) Wiring Systems.

All raceway and cable wiring methods included in Chapter 3 of this *Code*, other wiring systems and fittings specifically listed for use in PV arrays, and wiring as part of a listed system shall be permitted. Where wiring devices with integral enclosures are used, sufficient length of cable shall be provided to facilitate replacement.

Where PV source and output circuits operating at voltages greater than 30 volts are installed in readily accessible locations, circuit conductors shall be guarded or installed in Type MC cable or in raceway. The ampacity of 105°C (221°F) and 125°C (257°F) conductors shall be permitted to be determined by Table 690.31(A)(b). For ambient temperatures greater than 30°C (86°F), the ampacities of these conductors shall be corrected in accordance with Table 690.31(A)(a).

Table 690.31(A)(a) Correction Factors

Ambient Temperature (°C)	Temperature Rating of Conductor 105°C (221°F)	125°C (257°F)	Ambient Temperature (°F)
30	1	1	86
31–35	0.97	0.97	87–95
36–40	0.93	0.95	96–104
41–45	0.89	0.92	105–113
46–50	0.86	0.89	114–122
51–55	0.82	0.86	123–131
56–60	0.77	0.83	132–140
61–65	0.73	0.79	141–149
66–70	0.68	0.76	150–158
71–75	0.63	0.73	159–167
76–80	0.58	0.69	168–176
81–85	0.52	0.65	177–185
86–90	0.45	0.61	186–194
91–95	0.37	0.56	195–203
96–100	0.26	0.51	204–212
101–105	—	0.46	213–221
106–110	—	0.4	222–230
111–115	—	0.32	231–239
116–120	—	0.23	240–248

Table 690.31(A)(b) Ampacities of Insulated Conductors Rated Up To and Including 2000 Volts, 105°C Through 125°C (221°F Through 257°F), Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried), Based on Ambient Temperature of 30°C (86°F)

AWG	Types	
	PVC, CPE, XLPE 105°C	XLPE, EPDM 125°C
18	15	16
16	19	20
14	29	31
12	36	39
10	46	50
8	64	69

AWG	Types	
	PVC, CPE, XLPE 105°C	XLPE, EPDM 125°C
6	81	87
4	109	118
3	129	139
2	143	154
1	168	181
1/0	193	208
2/0	229	247
3/0	263	284
4/0	301	325

Informational Note: See 110.14(C) for conductor temperature limitations due to termination provisions.

Statement of Problem and Substantiation for Public Input

This Public Input is submitted on behalf of a Correlating Committee Long-Range Planning Task Group consisting of Robert Osborne (Chair), Paul Barnhart, Lou Grahor, David Temple, Donny Cook, Dean Hunter, Mike Querry, Roger McDaniel, Dave Burns, Rod Belisle, and Kevin Rogers. This Public Input, along with other companion Public Inputs, was developed with the goal of improving usability and providing a platform to increase the focus on requirements associated with Medium or High Voltage.

This Task Group's initial tasks were to establish a demarcation for what can be referred to as Medium or High Voltage. The recommendation has been to establish this threshold as being equipment rated over 1000 Vac, 1500 Vdc.

Using these limits, the Task Group set out to identify a structure to better align requirements, improve consistency in approach, improve usability, and create the opportunity for Code Making Panels to have an increased focus on higher voltage applications

This proposed change provides consistency in the Alternative Energy articles in order to address the wiring system(s) and/or method(s) that could be encountered within or as a part of the system (solar, wind or energy storage) installation. By adding the reference back to Chapter 3, the new text will correlate with the existing language found in NEC 692.31 for "Wiring Systems" for Fuel Cell Systems and provide direction to the installer, so that regardless of the voltage, all wiring systems and methods would comply with the applicable Chapter 3 Article.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3728-NFPA 70-2020 [Global Input]	Companion Public Input (New Articles 245 and 495)
Public Input No. 3765-NFPA 70-2020 [New Section after 250.194(B)]	Companion Public Input (New Article 255)
Public Input No. 3772-NFPA 70-2020 [New Section after 110.79]	Companion Public Input (New Article 115)
Public Input No. 3815-NFPA 70-2020 [New Section after 200.11]	Companion Public Input (New Article 205)
Public Input No. 3819-NFPA 70-2020 [Global Input]	Companion Public Input (New Article 235)

Public Input No. 3827-NFPA 70-2020 [Global Input]

Public Input No. 3846-NFPA 70-2020 [Section No. 694.30(A)]

Public Input No. 3849-NFPA 70-2020 [New Part after IV.]

Public Input No. 3728-NFPA 70-2020 [Global Input]

Public Input No. 3765-NFPA 70-2020 [New Section after 250.194(B)]

Public Input No. 3772-NFPA 70-2020 [New Section after 110.79]

Public Input No. 3815-NFPA 70-2020 [New Section after 200.11]

Public Input No. 3819-NFPA 70-2020 [Global Input]

Public Input No. 3827-NFPA 70-2020 [Global Input]

Public Input No. 3846-NFPA 70-2020 [Section No. 694.30(A)]

Public Input No. 3849-NFPA 70-2020 [New Part after IV.]

Companion Public Input (New Article 305)

Companion Public Input (New Section 694.30(A))

Companion Public Input (New Section 706.30)

Submitter Information Verification

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Submittal Date: Wed Sep 09 13:50:48 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9279-NFPA 70-2021

Statement: This section has been reorganized to add new subdivisions and titles for improved use. The newly titled 690.31(A)(2) has been expanded to cover all PV dc circuits since the prevention of access to readily accessible single conductors in PV systems for safety reasons is applicable to these conductors regardless of the presence of any dc converters. The application of the newly titled 690.31(A)(2) section has been clarified to better address what conditions it applies to. The list of acceptable cable types has been expanded to include multiconductor jacketed cables to align with 690.31(C)(3) and has been rearranged for clarity. It is noted that the definition of the term “guarded” is included in Article 100 of this Code. Modifications to the table titles have been made to align with the new section subdivision numbering.

Public Input No. 4203-NFPA 70-2020 [Section No. 690.31(A)]

(A) Wiring Systems.

All raceway and cable wiring methods included in this *Code*, other wiring systems and fittings specifically listed for use in PV arrays, and wiring as part of a listed system shall be permitted. Where wiring devices with integral enclosures are used, sufficient length of cable shall be provided to facilitate replacement.

Where PV ~~source and output circuits~~ system dc circuits operating at voltages greater than 30 volts are installed in readily accessible locations, circuit conductors shall be guarded or installed in Type MC cable or in raceway. The ampacity of 105°C (221°F) and 125°C (257°F) conductors shall be permitted to be determined by Table 690.31(A)(b). For ambient temperatures greater than 30°C (86°F), the ampacities of these conductors shall be corrected in accordance with Table 690.31(A)(a).

Table 690.31(A)(a) Correction Factors

Ambient Temperature (°C)	Temperature Rating of Conductor 105°C (221°F)	125°C (257°F)	Ambient Temperature (°F)
30	1	1	86
31–35	0.97	0.97	87–95
36–40	0.93	0.95	96–104
41–45	0.89	0.92	105–113
46–50	0.86	0.89	114–122
51–55	0.82	0.86	123–131
56–60	0.77	0.83	132–140
61–65	0.73	0.79	141–149
66–70	0.68	0.76	150–158
71–75	0.63	0.73	159–167
76–80	0.58	0.69	168–176
81–85	0.52	0.65	177–185
86–90	0.45	0.61	186–194
91–95	0.37	0.56	195–203
96–100	0.26	0.51	204–212
101–105	—	0.46	213–221
106–110	—	0.4	222–230
111–115	—	0.32	231–239
116–120	—	0.23	240–248

Table 690.31(A)(b) Ampacities of Insulated Conductors Rated Up To and Including 2000 Volts, 105°C Through 125°C (221°F Through 257°F), Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried), Based on Ambient Temperature of 30°C (86°F)

AWG	Types PVC, CPE, XLPE 105°C	XLPE, EPDM 125°C
18	15	16
16	19	20
14	29	31
12	36	39
10	46	50

AWG	Types	
	PVC, CPE, XLPE 105°C	XLPE, EPDM 125°C
8	64	69
6	81	87
4	109	118
3	129	139
2	143	154
1	168	181
1/0	193	208
2/0	229	247
3/0	263	284
4/0	301	325

Informational Note: See 110.14(C) for conductor temperature limitations due to termination provisions.

Statement of Problem and Substantiation for Public Input

This change is needed to remove the reference to PV output circuits in the related PIs. Applying the more general term “PV system dc conductors” to this section is more appropriate.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF’s effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI’s as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI’s submitted.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain, P.E., SEIA; Bill Brooks, PVICC; John Berdner, PVICC, Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing, Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower; Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger,

Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3701-NFPA 70-2020 [Definition: PV Output Circuit.]	deletion of old term

Submitter Information Verification

Submitter Full Name: Evelyn Butler
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Submittal Date: Thu Sep 10 05:37:11 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9279-NFPA 70-2021

Statement: This section has been reorganized to add new subdivisions and titles for improved use. The newly titled 690.31(A)(2) has been expanded to cover all PV dc circuits since the prevention of access to readily accessible single conductors in PV systems for safety reasons is applicable to these conductors regardless of the presence of any dc converters. The application of the newly titled 690.31(A)(2) section has been clarified to better address what conditions it applies to. The list of acceptable cable types has been expanded to include multiconductor jacketed cables to align with 690.31(C)(3) and has been rearranged for clarity. It is noted that the definition of the term “guarded” is included in Article 100 of this Code. Modifications to the table titles have been made to align with the new section subdivision numbering.

Public Input No. 3345-NFPA 70-2020 [Section No. 690.31(B) [Excluding any Sub-Sections]]

PV system dc circuits and Class 1 remote control, signaling, and power-limited circuits of a PV system shall be permitted to occupy the same equipment wiring enclosure, cable, or raceway. PV system dc circuits shall not occupy the same equipment wiring enclosure, cable, or ~~raceway. as~~ raceway as other non-PV systems, or inverter output circuits, unless the PV system dc circuits are separated from other circuits by a barrier or partition. PV system circuit conductors shall be identified and grouped as required by 690.31(B)(1) and (B)(2).

Exception: PV system dc circuits utilizing multiconductor jacketed cable or metal-clad cable assemblies or listed wiring harnesses identified for the application shall be permitted to occupy the same wiring method as inverter output circuits and other non-PV systems. All conductors, harnesses, or assemblies shall have an insulation rating equal to at least the maximum circuit voltage applied to any conductor within the enclosure, cable, or raceway.

Statement of Problem and Substantiation for Public Input

There is a misplaced period in the 2020 code. This proposal makes a correction.

Submitter Information Verification

Submitter Full Name: John Cowans
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Submittal Date: Tue Sep 08 08:54:31 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9280-NFPA 70-2021

Statement: This section has been reorganized and edited for clarity.

New Section 690.31(B)(1): A clarification addressing minimum voltage ratings for conductors and cables has been added to better align with similar requirements in 300.3(C). A reference to listed equipment has been added to allow for other methods of compliance not stated here. For instance it is common for listed PV equipment such as inverters to use spacings and guarding instead of barriers for this purpose. The addition of jacketed cables as a requirement for remote control, signaling, or power limited circuits serving a PV system in the same wiring method has been made to address concerns over the need for additional physical protection for these circuits in these locations. An allowance for inverter output circuits to be located with PV system dc conductors has been added in limited applications where boxes or wireways are used. This use is common when transitioning between raceways especially with power conversion equipment such as inverters. The requirement for minimum voltage ratings from the original exception has been struck since this is now a general requirement to all options within this exception.

New Section 690.31(B)(2): Former (B)(1) has been reorganized into a list for clarity. The exception has been moved to apply to all items in the list.

New Section 690.31(B)(3): Clarifications have been made to former (B)(2) new 3 to address the different circuits covered in this section more clearly to aid in interpretation and application of these requirements.

Public Input No. 4204-NFPA 70-2020 [Section No. 690.31(B) [Excluding any Sub-Sections]]

PV system dc circuits ~~and Class 1 remote control, signaling, and power-limited circuits of a PV system~~ shall be permitted to occupy the same equipment wiring enclosure, cable, or raceway ~~. PV system dc circuits shall not occupy the same equipment wiring enclosure, cable, or raceway. as other non-PV systems, or inverter output circuits, unless the PV system dc circuits are separated from other circuits by a barrier or partition. PV system~~ with conductors of different systems where installed in accordance with 300.3(C). PV system circuit conductors shall be identified and grouped as required by 690.31(B)(1) and (B)(2).

~~*Exception: PV system dc circuits utilizing multiconductor jacketed cable or metal-clad cable assemblies or listed wiring harnesses identified for the application shall be permitted to occupy the same wiring method as inverter output circuits and other non-PV systems. All conductors, harnesses, or assemblies shall have an insulation rating equal to at least the maximum circuit voltage applied to any conductor within the enclosure, cable, or raceway.*~~

Statement of Problem and Substantiation for Public Input

PV systems, and the equipment utilized within them, have evolved significantly over the past 15 years. All major equipment used to build PV systems requires listings, most are specifically listed for use in PV systems. This is especially true for power conversion equipment used in PV systems. Per 300.3(C)(1), conductors of ac and dc circuits rated 1000V or less are allowed to occupy the same wiring enclosure, cable, or raceway, so long as insulation ratings are sufficiently rated. Additionally, there are important restrictions within 300.3(C) to prevent the mixing of other circuits such as those used for remote control, signaling, and communications. These same general rules in 300.3 should apply to conductors associated with PV systems. The previous text suggests there are different requirements within PV systems but is insufficient to clarify what they are. Leveraging the general rules in 300.3(C) is the best approach toward promoting consistent installations and enforcement within PV systems and where the wiring from PV systems must be connected to other systems. The exception is struck as this is unnecessary with this change.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI's submitted.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain, P.E., SEIA; Bill Brooks, PVICC; John Berdner, PVICC, Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing, Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower; Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional

Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

Submitter Information Verification

Submitter Full Name: Evelyn Butler
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Submittal Date: Thu Sep 10 05:41:09 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9280-NFPA 70-2021

Statement: This section has been reorganized and edited for clarity.

New Section 690.31(B)(1): A clarification addressing minimum voltage ratings for conductors and cables has been added to better align with similar requirements in 300.3(C). A reference to listed equipment has been added to allow for other methods of compliance not stated here. For instance it is common for listed PV equipment such as inverters to use spacings and guarding instead of barriers for this purpose. The addition of jacketed cables as a requirement for remote control, signaling, or power limited circuits serving a PV system in the same wiring method has been made to address concerns over the need for additional physical protection for these circuits in these locations. An allowance for inverter output circuits to be located with PV system dc conductors has been added in limited applications where boxes or wireways are used. This use is common when transitioning between raceways especially with power conversion equipment such as inverters. The requirement for minimum voltage ratings from the original exception has been struck since this is now a general requirement to all options within this exception.

New Section 690.31(B)(2): Former (B)(1) has been reorganized into a list for clarity. The exception has been moved to apply to all items in the list.

New Section 690.31(B)(3): Clarifications have been made to former (B)(2) new 3 to address the different circuits covered in this section more clearly to aid in interpretation and application of these requirements.

Public Input No. 4514-NFPA 70-2020 [Section No. 690.31(B) [Excluding any Sub-Sections]]

PV system dc circuits and Class 1 remote control, signaling, and power-limited circuits of a PV system shall be permitted to occupy the same equipment wiring enclosure, cable, or raceway. PV system dc circuits shall not occupy the same equipment wiring enclosure, cable, or raceway. as other non-PV systems, or inverter output circuits, unless the PV system dc circuits are separated from other circuits by a barrier or partition. PV system circuit conductors shall be identified and grouped as required by 690.31(B)(1) and (B)(2).

Exception: PV system dc circuits utilizing multiconductor jacketed cable or metal-clad cable assemblies or flexible metal conduit or listed wiring harnesses identified for the application shall be permitted to occupy the same wiring method as inverter output circuits and other non-PV systems. All conductors, harnesses, or assemblies shall have an insulation rating equal to at least the maximum circuit voltage applied to any conductor within the enclosure, cable, or raceway.

Statement of Problem and Substantiation for Public Input

Justification: For PV systems it is often difficult to keep circuits separated in accordance with NEC 690.31(B). The exception of 690.31(B) already allows for multiconductor jacketed cable, MC cable, and listed wiring harnesses. Installers are often complaining that these options are not always viable for an installation. Adding flexible metal conduit to the list of acceptable barriers will allow more flexibility and options for the installer. Flexible metal conduit would also be equivalent protection as MC cable or wiring harnesses, and certainly provides more protection than multiconductor jacketed cable.

Submitter Information Verification

Submitter Full Name: Doug Smith
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Submittal Date: Thu Sep 10 14:32:16 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9280-NFPA 70-2021
Statement: This section has been reorganized and edited for clarity.

New Section 690.31(B)(1): A clarification addressing minimum voltage ratings for conductors and cables has been added to better align with similar requirements in 300.3(C). A reference to listed equipment has been added to allow for other methods of compliance not stated here. For instance it is common for listed PV equipment such as inverters to use spacings and guarding instead of barriers for this purpose. The addition of jacketed cables as a requirement for remote control, signaling, or power limited circuits serving a PV system in the same wiring method has been made to address concerns over the need for additional physical protection for these circuits in these locations. An allowance for inverter output circuits to be located with PV system dc conductors has been added in limited applications where boxes or wireways are used. This use is common when

transitioning between raceways especially with power conversion equipment such as inverters. The requirement for minimum voltage ratings from the original exception has been struck since this is now a general requirement to all options within this exception.

New Section 690.31(B)(2): Former (B)(1) has been reorganized into a list for clarity. The exception has been moved to apply to all items in the list.

New Section 690.31(B)(3): Clarifications have been made to former (B)(2) new 3 to address the different circuits covered in this section more clearly to aid in interpretation and application of these requirements.

Public Input No. 464-NFPA 70-2020 [Section No. 690.31(B) [Excluding any Sub-Sections]]

PV system dc circuits and Class 1 remote control, signaling, and power-limited circuits of a PV system shall be permitted to occupy the same equipment wiring enclosure, cable, or raceway. PV system dc circuits shall not occupy the same equipment wiring enclosure, cable, or raceway. as other non-PV systems, or inverter output circuits, unless the PV system dc circuits are separated from other circuits by a barrier or partition. PV system circuit conductors shall be identified and grouped as required by 690.31(B)(1) and (B)(2).

Exception No. 1 : PV system dc circuits utilizing multiconductor jacketed cable or metal-clad cable assemblies or listed wiring harnesses identified for the application shall be permitted to occupy the same wiring method as inverter output circuits and other non-PV systems. All conductors, harnesses, or assemblies shall have an insulation rating equal to at least the maximum circuit voltage applied to any conductor within the enclosure, cable, or raceway.

Exception No. 2: PV system dc circuits shall be permitted to occupy the same equipment wiring enclosure without a barrier or partition where the equipment is listed for the use.

Statement of Problem and Substantiation for Public Input

The listing process for inverters does permit ac, dc, and Article 725 circuits to occupy the same enclosure where the circuits have the proper spacing and separations. The proposed exception will provide clarity to AHJs that these circuits are permitted to be within the same equipment enclosure without physical barriers where proper spacing is maintained and the equipment is listed for the use in accordance with 110.3(B).

Submitter Information Verification

Submitter Full Name: Brian Baughman
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Submittal Date: Fri Feb 14 12:43:52 EST 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9280-NFPA 70-2021
Statement: This section has been reorganized and edited for clarity.

New Section 690.31(B)(1): A clarification addressing minimum voltage ratings for conductors and cables has been added to better align with similar requirements in 300.3(C). A reference to listed equipment has been added to allow for other methods of compliance not stated here. For instance it is common for listed PV equipment such as inverters to use spacings and guarding instead of barriers for this purpose. The addition of jacketed cables as a requirement for remote control, signaling, or power limited circuits serving a PV system in the same wiring method has been made to address concerns over the need for additional physical protection for these circuits in these locations. An allowance for inverter output circuits to be located with PV system dc conductors has been added in

limited applications where boxes or wireways are used. This use is common when transitioning between raceways especially with power conversion equipment such as inverters. The requirement for minimum voltage ratings from the original exception has been struck since this is now a general requirement to all options within this exception.

New Section 690.31(B)(2): Former (B)(1) has been reorganized into a list for clarity. The exception has been moved to apply to all items in the list.

New Section 690.31(B)(3): Clarifications have been made to former (B)(2) new 3 to address the different circuits covered in this section more clearly to aid in interpretation and application of these requirements.

Public Input No. 1625-NFPA 70-2020 [Section No. 690.31(C)]

(C) Cables.

Type PV wire or cable and Type distributed generation (DG) cable shall be listed.

Informational Note 1 : See UL 4703, *Standard for Photovoltaic Wire*, for PV wire and UL 3003, *Distributed Generation Cables*, for DG cable.

Informational Note 2: PV wire and cable and DG cable have a nonstandard outer diameter. Table 1 of Chapter 9 contains the allowable percent of cross section of conduit and tubing for conductors and cables.

(1) Single-Conductor Cable.

Single-conductor cable in exposed outdoor locations in PV system dc circuits within the PV array shall be permitted to be one of the following:

(1) PV wire or cable

(2) Single-conductor cable marked sunlight resistant and Type USE-2 and Type RHW-2

Exposed cables shall be supported and secured at intervals not to exceed 600 mm (24 in.) by cable ties, straps, hangers, or similar fittings listed and identified for securement and support in outdoor locations. PV wire or cable shall be permitted in all locations where RHW-2 is permitted.

Exception: PV systems meeting the requirements of 691.4 shall be permitted to have support and securement intervals as defined in the engineered design.

(2) Cable Tray.

Single-conductor PV wire or cable of all sizes or distributed generation (DG) cable of all sizes, with or without a cable tray rating, shall be permitted in cable trays installed in outdoor locations, provided that the cables are supported at intervals not to exceed 300 mm (12 in.) and secured at intervals not to exceed 1.4 m (4½ ft).

~~Informational Note: PV wire and cable and DG cable have a nonstandard outer diameter. Table 1 of Chapter 9 contains the allowable percent of cross section of conduit and tubing for conductors and cables.~~

(3) Multiconductor Jacketed Cables.

Where part of a listed PV assembly, multiconductor jacketed cables shall be installed in accordance with the included instructions. Where not part of a listed assembly, or where not otherwise covered in this *Code*, multiconductor jacketed cables, including DG cable, shall be installed in accordance with the product listing and shall be permitted in PV systems. These cables shall be installed in accordance with the following:

(1) In raceways, where on or in buildings other than rooftops

(2) Where not in raceways, in accordance with the following:

(3) Marked sunlight resistant in exposed outdoor locations

(4) Protected or guarded, where subject to physical damage

(5) Closely follow the surface of support structures

(6) Secured at intervals not exceeding 1.8 m (6 ft)

(7) Secured within 600 mm (24 in.) of mating connectors or entering enclosures

(8) Marked direct burial, where buried in the earth

(4) Flexible Cords and Cables Connected to Tracking PV Arrays.

Flexible cords and flexible cables, where connected to moving parts of tracking PV arrays, shall comply with Article 400 and shall be of a type identified as a hard service cord or portable power cable; they shall be suitable for extra-hard usage, listed for outdoor use, water resistant, and sunlight resistant. Allowable ampacities shall be in accordance with 400.5. Stranded copper PV wire shall be permitted to be connected to moving parts of tracking PV arrays in accordance with the minimum number of strands specified in Table 690.31(C)(4).

Table 690.31(C)(4) Minimum PV Wire Strands

PV Wire AWG	Minimum Strands
18	17
16–10	19
8–4	49
2	130
1 AWG–1000 MCM	259

(5) Flexible, Fine-Stranded Cables.

Flexible, fine-stranded cables shall be terminated only with terminals, lugs, devices, or connectors in accordance with 110.14.

(6) Small-Conductor Cables.

Single-conductor cables listed for outdoor use that are sunlight resistant and moisture resistant in sizes 16 AWG and 18 AWG shall be permitted for module interconnections where such cables meet the ampacity requirements of 400.5. Section 310.14 shall be used to determine the cable ampacity adjustment and correction factors.

Statement of Problem and Substantiation for Public Input

Please move the Informational Note from (2) to before (1) so that it applies to both (C)(1) and (C)(2).

Submitter Information Verification

Submitter Full Name: Mike Holt
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Submittal Date: Wed Jun 24 14:54:30 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9281-NFPA 70-2021
Statement: Text from the informational note to 690.31(C)(2) has been moved to the existing informational note in 690.31(C) since it applies to all installations of these cable types. The pointer to Chapter 9 has been removed as unnecessary to correctly apply the requirements in this section.

Public Input No. 2933-NFPA 70-2020 [Section No. 690.31(C)(1)]

(1) Single-Conductor Cable.

Single-conductor cable in exposed outdoor locations in PV system dc circuits within the PV array shall be permitted to be one of the following:

(1) PV wire or cable

(2) Single-conductor cable marked sunlight resistant and Type USE-2 and Type RHW-2

Exposed cables shall be supported and secured at intervals not to exceed ~~600~~ 1400 mm (~~24~~ 54 in.) by cable ties, straps, hangers, or similar fittings listed and identified for securement and support in outdoor locations. PV wire or cable shall be permitted in all locations where RHW-2 is permitted.

Exception: PV systems meeting the requirements of 691.4 shall be permitted to have support and securement intervals as defined in the engineered design.

Statement of Problem and Substantiation for Public Input

These cables typically fall into the NM, SE, USE, or TC-ER rated type cable and this language over rides the allowed support spacing that the articles in Chapter 3 cover for those cable types and in doing so force unnecessary cost to be incurred to meet the 24" minimum support requirement. The 24" seems like an arbitrary distance with no justification as the sections for NM, USE, and TC-ER all allow for larger unsupported distances.

Submitter Information Verification

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Submittal Date: Thu Sep 03 10:55:50 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9282-NFPA 70-2021

Statement: This section subdivision has been reorganized into a list to provide improvements in the application of these requirements. An allowance for greater support distances for larger single conductors has been provided to align with similar requirements in Article 338.10(B)(4)(b) that were referenced in earlier versions of this Code. The existing exception was moved to correctly apply only to new (a). Text within the informational note is moved to the charging paragraph of 690.31(C).

Public Input No. 4616-NFPA 70-2020 [Section No. 690.31(C)(1)]

(1) Single-Conductor Cable.

Single conductors or Single -conductor cable in exposed outdoor locations in PV system dc circuits within the PV array shall be ~~permitted to be one of the following:~~ Type PV wire.

~~(1) PV wire or cable~~

~~(2) Single-conductor cable marked sunlight resistant and Type USE-2 and Type RHW-2~~

Exception: Single-conductor cable marked sunlight resistant and Type USE-2 and Type RHW-2 shall be permitted to replace existing USE-2 and RHW-2 conductors ~~,~~ in existing PV arrays , where installation, service and maintenance are only performed by qualified persons.

Exposed cables shall be supported and secured at intervals not to exceed 600 mm (24 in.) by cable ties, straps, hangers, or similar fittings listed and identified for securement and support in outdoor locations. PV wire or cable shall be permitted in all locations where RHW-2 is permitted.

Exception: PV systems meeting the requirements of 691.4 shall be permitted to have support and securement intervals as defined in the engineered design.

Statement of Problem and Substantiation for Public Input

Mechanical damage to exposed PV module and/or string wiring is known to have caused electrical faults. Electrical faults are a known cause of fires. PV wire is required to have 60 mils of insulation thickness, whereas USE-2/RHW-2 is 45 mils. This additional thickness is to compensate for the lack of mechanical protection typically given to an RHW-2 that is installed in a conduit or other raceway. In addition, PV wire is required to pass the vertical flame test, whereas USE-2/RHW-2 is required to pass the less severe horizontal flame test. PV wire is required to pass a cold bend at -40C, whereas USE-2/RHW-2 requires testing at -25C. Therefore, USE-2/RHW-2 is less robust than PV wire.

USE-2 wire was initially permitted for use in PV systems due to the lack of other options. Now that PV wire is readily available and in widespread use, and because mechanical damage is a known cause of electrical faults, it is prudent to restrict the use of USE-2/RHW-2 to installations where this wire type was already in place, and where the installation will be serviced and maintained by qualified persons.

Submitter Information Verification

Submitter Full Name: John Kovacik
Organization: UL LLC
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 10 15:52:40 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: Insufficient justification has been provided for removing a previously acceptable conductor type. The thickness of insulation is not relevant for conductors that are otherwise rated the same. Temperature ratings of conductors must be properly selected for their environment in compliance with other sections of this Code. Technical substantiation for the need to require

the unique flame spread performance in these applications was not provided.

Public Input No. 1754-NFPA 70-2020 [Section No. 690.31(C)(2)]

(2) Cable Tray.

Single-conductor PV wire or cable of all sizes or distributed generation (DG) cable of all sizes, with or without a cable tray rating, shall be permitted in cable trays installed in outdoor locations, provided that the cables are supported at intervals not to exceed 300 mm (12 in.) and secured at intervals not to exceed 1.4 m (4½ ft).

Informational Note: PV wire and cable and DG cable have a nonstandard outer diameter. ~~Table 1 of Chapter 9 contains the allowable percent of cross section of conduit and tubing for conductors and cables.~~

Statement of Problem and Substantiation for Public Input

Chapter 9, Table 1 refers to conduit and tubing but not cable tray so it is not applicable here. The unnecessary text should be deleted to clarify the IN.

Submitter Information Verification

Submitter Full Name: Marvin Hamon
Organization: Pure Power Engineering
Street Address:
City:
State:
Zip:
Submittal Date: Fri Jun 26 12:05:20 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9281-NFPA 70-2021
Statement: Text from the informational note to 690.31(C)(2) has been moved to the existing informational note in 690.31(C) since it applies to all installations of these cable types. The pointer to Chapter 9 has been removed as unnecessary to correctly apply the requirements in this section.

Public Input No. 2932-NFPA 70-2020 [Section No. 690.31(C)(2)]

(2) Cable Tray.

Single-conductor PV wire or cable of all sizes ~~or distributed generation (DG) cable of all sizes~~ , with or without a cable tray rating, shall be permitted in cable trays installed in outdoor locations, provided that the cables are supported at intervals not to exceed 300 mm (12 in.) and secured at intervals not to exceed ~~1.4 m (4 1/2 ft~~ 1400 m (54 in.).

Informational Note: PV wire and cable and DG cable have a nonstandard outer diameter. Table 1 of Chapter 9 contains the allowable percent of cross section of conduit and tubing for conductors and cables.

Statement of Problem and Substantiation for Public Input

690.31(C)(1) states cable types and DG Cable is not listed there. Also dimension information should be consistently stated using the same units.

Submitter Information Verification

Submitter Full Name: Douglas Mutcher
Organization: Westwood Professional Services
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 03 10:50:44 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9283-NFPA 70-2021

Statement: Units have been updated to align with other units used in this section. While 690.31(C)(2) has allowed the use of PV or DG cable in cable tray, Article 392 does not fully describe the requirements for cable sized smaller than 1/0 AWG. For example, 392.22(B)(1) only informs the designer of requirements for 1/0 AWG and larger for ladder or ventilated trough cable trays, which are now often used for PV systems. 392.20(D) notes that single conductors of 1/0 to 4/0 AWG shall be installed in a single layer, unless conductors are bound together to comprise a circuit group. Language from these two sections is included as newly numbered items (1)-(3). Additionally, 392.80(A)(2) imposes ampacity adjustment factors in various conductor configurations, and these rules are expanded here to also apply to smaller single conductors.

Note to the CC to forward this FR to CMP 8 to consider addressing in Article 392, making these changes unnecessary.

Public Input No. 4207-NFPA 70-2020 [Section No. 690.31(C)(2)]

(2) Cable Tray.

Single-conductor PV wire or cable of all sizes or distributed generation (DG) cable of all sizes, with or without a cable tray rating, shall be permitted in cable trays installed in outdoor locations, provided that the cables are supported at intervals not to exceed 300 mm (12 in.) and secured at intervals not to exceed 1.4 m (4½ ft).

Where installed in uncovered cable trays, ampacity of single-conductor PV wire smaller than 1/0 AWG shall be determined according to the 392.80(A)(2) adjustment factors for 1/0 AWG single-conductor cable.

Where single-conductor PV wire smaller than 1/0 AWG is installed in ladder or ventilated trough cable trays:

(1) All single conductors shall be installed in a single layer

(2) Conductors that are bound together to comprise each circuit pair shall be permitted to be installed in other than a single layer.

(3) The sum of diameters of all single conductor cables shall not exceed the cable tray width.

Informational Note: PV wire and cable and DG cable have a nonstandard outer diameter. Table 1 of Chapter 9 contains the allowable percent of cross section of conduit and tubing for conductors and cables.

Statement of Problem and Substantiation for Public Input

While 690.31(C)(2) has allowed the use of PV or DG cable in cable tray, Article 392 does not fully describe the requirements for cable sized smaller than 1/0 AWG. For example, 392.22(B)(1) only informs the designer of requirements for 1/0 AWG and larger for ladder or ventilated trough cable trays, which are now often used for PV systems. 392.20(D) notes that single conductors of 1/0 to 4/0 AWG shall be installed in a single layer, unless conductors are bound together to comprise a circuit group. Language from these two sections is included in this PI as newly-numbered items (1)-(3).
Additionally, 392.80(A)(2) imposes ampacity adjustment factors in various conductor configurations, and these rules are expanded here to also apply to smaller single conductors

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI's submitted.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain, P.E., SEIA; Bill Brooks, PVICC; John Berdner, PVICC, Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing,

Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower; Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

Submitter Information Verification

Submitter Full Name: Evelyn Butler
Organization: Solar Energy Industries Assn
Affiliation: PV Industry Forum (PVIF)
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 10 05:54:17 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9283-NFPA 70-2021

Statement: Units have been updated to align with other units used in this section. While 690.31(C)(2) has allowed the use of PV or DG cable in cable tray, Article 392 does not fully describe the requirements for cable sized smaller than 1/0 AWG. For example, 392.22(B)(1) only informs the designer of requirements for 1/0 AWG and larger for ladder or ventilated trough cable trays, which are now often used for PV systems. 392.20(D) notes that single conductors of 1/0 to 4/0 AWG shall be installed in a single layer, unless conductors are bound together to comprise a circuit group. Language from these two sections is included as newly numbered items (1)-(3). Additionally, 392.80(A)(2) imposes ampacity adjustment factors in various conductor configurations, and these rules are expanded here to also apply to smaller single conductors.

Note to the CC to forward this FR to CMP 8 to consider addressing in Article 392, making these changes unnecessary.

Public Input No. 1863-NFPA 70-2020 [Section No. 690.31(D)]

(D) Direct-Current Circuits on or in Buildings.

Where inside buildings, PV system dc circuits that exceed 30 volts or 8 amperes shall be contained in metal raceways, in Type MC metal-clad cable that complies with 250.118(10)(b) or 250.118(10)c) , or in metal enclosures.

Exception: PV hazard control systems installed in accordance with 690.12(B)(2)(1) shall be permitted to be provided with or listed for use with nonmetallic enclosure(s), nonmetallic raceway(s), and cables other than Type MC metal-clad cable(s), at the point of penetration of the surface of the building to the PV hazard control actuator.

Wiring methods on or in buildings shall comply with the additional installation requirements in 690.31(D)(1) and (D)(2).

(1) Flexible Wiring Methods.

Where flexible metal conduit (FMC) smaller than metric designator 21 (trade size ¾) or Type MC cable smaller than 25 mm (1 in.) in diameter containing PV power circuit conductors is installed across ceilings or floor joists, the raceway or cable shall be protected by substantial guard strips that are at least as high as the raceway or cable. Where run exposed, other than within 1.8 m (6 ft) of their connection to equipment, these wiring methods shall closely follow the building surface or be protected from physical damage by an approved means.

(2) Marking and Labeling Required.

Unless located and arranged so the purpose is evident, the following wiring methods and enclosures that contain PV system dc circuit conductors shall be marked with the wording PHOTOVOLTAIC POWER SOURCE or SOLAR PV DC CIRCUIT by means of permanently affixed labels or other approved permanent marking:

(1) Exposed raceways, cable trays, and other wiring methods

(2) Covers or enclosures of pull boxes and junction boxes

(3) Conduit bodies in which any of the available conduit openings are unused

The labels or markings shall be visible after installation. All letters shall be capitalized and shall be a minimum height of 9.5 mm (⅜ in.) in white on a red background. Labels shall appear on every section of the wiring system that is separated by enclosures, walls, partitions, ceilings, or floors. Spacing between labels or markings, or between a label and a marking, shall not be more than 3 m (10 ft). Labels required by this section shall be suitable for the environment where they are installed.

Statement of Problem and Substantiation for Public Input

Referencing 250.118(10) is too general since the metal sheath of Type MC cable in accordance with 250.118(10)(a) is not suitable as an effective ground-fault current path. But 250.118(10)(b) and 250.118(10)(c) is a suitable wiring method.

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
Street Address:
City:
State:

Zip:

Submittal Date: Sat Jul 11 19:06:49 EDT 2020

Committee: NEC-P04

Committee Statement

Resolution: FR-9285-NFPA 70-2021

Statement: Rapid shutdown requirements in 690.12 control conductors located within buildings. The 2020 690.31(D)(1) requirements addressing the location of certain wiring methods predated the implementation of, and are rendered unnecessary by the updated rapid shutdown requirements in 690.12. The same requirements for these wiring methods that exist for all other applications are sufficient as described in Articles 330 and 348. Section 690.31(C)(3) defines wiring methods not already defined in Chapter 3, but Chapter 3 wiring methods are sufficient to ensure safe installation of these “flexible wiring methods.”

With the deletion of 690.31(D)(1) text, the section is better structured by moving the original (D) language

into a re-titled (D)(1) and (D)(2) remains unchanged except for removing the superfluous “required” from the title.

Public Input No. 4205-NFPA 70-2020 [Section No. 690.31(D)]

(D) Direct-Current Circuits on or in Buildings.

Wiring methods on or in buildings shall comply with the installation requirements in 690.31(D)(1) and (D)(2).

(1) Metal Raceways and Enclosures .

Where inside buildings, PV system dc circuits that exceed 30 volts or 8 amperes shall be contained in metal raceways, in Type MC metal-clad cable that complies with 250.118(10) , or in metal enclosures.

Exception: PV hazard control systems installed in accordance with 690.12(B)(2) (1) shall be permitted to be provided with or listed for use with nonmetallic enclosure(s), nonmetallic raceway(s), and cables other than Type MC metal-clad cable(s), at the point of penetration of the surface of the building to the PV hazard control actuator.

~~Wiring methods on or in buildings shall comply with the additional installation requirements in 690.31~~

(

~~D)(1) and (D)(~~

2)

.

~~(1) (2)~~

–

~~Flexible Wiring Methods.~~

~~Where flexible metal conduit (FMC) smaller than metric designator 21 (trade size~~ **3 ⁄ 4** ~~) or Type MC cable smaller than 25 mm (1 in.) in diameter containing PV power circuit conductors is installed across ceilings or floor joists, the raceway or cable shall be protected by substantial guard strips that are at least as high as the raceway or cable. Where run exposed, other than within 1.8 m (6 ft) of their connection to equipment, these wiring methods shall closely follow the building surface or be protected from physical damage by an approved means.~~

~~Marking and Labeling~~

~~Required~~

.

~~Unless located and arranged so the purpose is evident, the following wiring methods and enclosures that contain PV system dc circuit conductors shall be marked with the wording PHOTOVOLTAIC POWER SOURCE or SOLAR PV DC CIRCUIT by means of permanently affixed labels or other approved permanent marking:~~

(1) ~~Exposed raceways, cable trays, and other wiring methods~~

(2) ~~Covers or enclosures of pull boxes and junction boxes~~

(3) ~~Conduit bodies in which any of the available conduit openings are unused~~

~~The labels or markings shall be visible after installation. All letters shall be capitalized and shall be a minimum height of 9.5 mm (~~ **3 ⁄ 8** ~~ in.) in white on a red background. Labels shall appear on every section of the wiring system that is separated by enclosures, walls, partitions, ceilings, or floors. Spacing between labels or markings, or between a label and a marking, shall not be more than 3 m (10 ft). Labels required by this section shall be suitable for the environment where they are installed.~~

Additional Proposed Changes

File Name	Description	Approved
690.31_D_correct_text.pdf	Correct text changes	

Statement of Problem and Substantiation for Public Input

Rapid shutdown requirements in 690.12 control conductors located within buildings during firefighting events. The 2020 690.31(D)(1) requirements addressing the location of certain wiring methods predated the implementation of, and are rendered unnecessary by the rapid shutdown requirements in 690.12. The same requirements for these wiring methods that exist for all other applications are sufficient as described in Articles 330 and 348. 690.31(C)(3) exists to define wiring methods not already defined in Chapter 3, but Chapter 3 wiring methods are sufficient to ensure safe installation of these “flexible wiring methods.”
With the deletion of 690.31(D)(1) text, the section is better structured by moving the original (D) language into a re-titled (D)(1) and (D)(2) remains unchanged except for removing the superfluous “Required” from the title.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF’s effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI’s as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI’s submitted.
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Submitter Information Verification

Submitter Full Name: Evelyn Butler
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Street Address:
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Zip:

Submittal Date: Thu Sep 10 05:43:55 EDT 2020

Committee: NEC-P04

Committee Statement

Resolution: FR-9285-NFPA 70-2021

Statement: Rapid shutdown requirements in 690.12 control conductors located within buildings. The 2020 690.31(D)(1) requirements addressing the location of certain wiring methods predated the implementation of, and are rendered unnecessary by the updated rapid shutdown requirements in 690.12. The same requirements for these wiring methods that exist for all other applications are sufficient as described in Articles 330 and 348. Section 690.31(C)(3) defines wiring methods not already defined in Chapter 3, but Chapter 3 wiring methods are sufficient to ensure safe installation of these “flexible wiring methods.”

With the deletion of 690.31(D)(1) text, the section is better structured by moving the original (D) language

into a re-titled (D)(1) and (D)(2) remains unchanged except for removing the superfluous “required” from the title.

Legislative Text:

690.31(D) Direct-Current Circuits on or in Buildings.
~~Where inside buildings, PV system dc circuits that exceed 30 volts or 8 amperes shall be contained in metal raceways, in Type MC metal-clad cable that complies with 250.118(10), or in metal enclosures.~~

~~*Exception: PV hazard control systems installed in accordance with 690.12(B)(2)(1) shall be permitted to be provided with or listed for use with nonmetallic enclosure(s), nonmetallic raceway(s), and cables other than Type MC metal-clad cable(s), at the point of penetration of the surface of the building to the PV hazard control actuator.*~~

Wiring methods on or in buildings shall comply with the ~~additional~~ installation requirements in 690.31(D)(1) and (D)(2).

690.31(D)(1) ~~Flexible Wiring Methods~~. Metal Raceways and Enclosures.
~~Where flexible metal conduit (FMC) smaller than metric designator 21 (trade size 3/4) or Type MC cable smaller than 25 mm (1 in.) in diameter containing PV power circuit conductors is installed across ceilings or floor joists, the raceway or cable shall be protected by substantial guard strips that are at least as high as the raceway or cable. Where run exposed, other than within 1.8 m (6 ft) of their connection to equipment, these wiring methods shall closely follow the building surface or be protected from physical damage by an approved means.~~
Where inside buildings, PV system dc circuits that exceed 30 volts or 8 amperes shall be contained in metal raceways, in Type MC metal-clad cable that complies with 250.118(10), or in metal enclosures.
Exception: PV hazard control systems installed in accordance with 690.12(B)(2)(1) shall be permitted to be provided with or listed for use with nonmetallic enclosure(s), nonmetallic raceway(s), and cables other than Type MC metal-clad cable(s), at the point of penetration of the surface of the building to the PV hazard control actuator.

690.31(D)(2) Marking and Labeling ~~Required~~.
Unless located and arranged so the purpose is evident, the following wiring methods and enclosures that contain PV system dc circuit conductors shall be marked with the wording PHOTOVOLTAIC POWER SOURCE or SOLAR PV DC CIRCUIT by means of permanently affixed labels or other approved permanent marking:

(1) Exposed raceways, cable trays, and other wiring methods
(2) Covers or enclosures of pull boxes and junction boxes
(3) Conduit bodies in which any of the available conduit openings are unused

The labels or markings shall be visible after installation. All letters shall be capitalized and shall be a minimum height of 9.5 mm (3/8 in.) in white on a red background. Labels shall appear on every section of the wiring system that is separated by enclosures, walls, partitions, ceilings, or floors. Spacing between labels or markings, or between a label and a marking, shall not be more than 3 m (10 ft). Labels required by this section shall be suitable for the environment where they are installed.

Clean Text:

690.31(D) Direct-Current Circuits on or in Buildings.
Wiring methods on or in buildings shall comply with the installation requirements in 690.31(D)(1) and (D)(2).

690.31(D)(1) Metal Raceways and Enclosures.
Where inside buildings, PV system dc circuits that exceed 30 volts or 8 amperes shall be contained in metal raceways, in Type MC metal-clad cable that complies with 250.118(10), or in metal enclosures.
Exception: PV hazard control systems installed in accordance with 690.12(B)(2)(1) shall be permitted to be provided with or listed for use with nonmetallic enclosure(s), nonmetallic raceway(s), and cables other than Type MC metal-clad cable(s), at the point of penetration of the surface of the building to the PV hazard control actuator.

690.31(D)(2) Marking and Labeling.
Unless located and arranged so the purpose is evident, the following wiring methods and enclosures that contain PV system dc circuit conductors shall be marked with the wording PHOTOVOLTAIC POWER SOURCE or SOLAR PV DC CIRCUIT by means of permanently affixed labels or other approved permanent marking:

(1) Exposed raceways, cable trays, and other wiring methods
(2) Covers or enclosures of pull boxes and junction boxes
(3) Conduit bodies in which any of the available conduit openings are unused

The labels or markings shall be visible after installation. All letters shall be capitalized and shall be a minimum height of 9.5 mm (3⁄8 in.) in white on a red background. Labels shall appear on every section of the wiring system that is separated by enclosures, walls, partitions, ceilings, or floors. Spacing between labels or markings, or between a label and a marking, shall not be more than 3 m (10 ft). Labels required by this section shall be suitable for the environment where they are installed.

Public Input No. 3588-NFPA 70-2020 [Section No. 690.31(D)(2)]

(2) Marking and Labeling Required.

(a) Unless located and arranged so the purpose is evident, the following wiring methods and enclosures that contain PV system dc circuit conductors shall be marked with the wording PHOTOVOLTAIC POWER SOURCE or SOLAR PV DC CIRCUIT by means of permanently affixed labels or other approved permanent marking:

(1) Exposed raceways, cable trays, and other wiring methods

(2) Covers or enclosures of pull boxes and junction boxes

(3) Conduit bodies in which any of the available conduit openings are unused

The labels or markings shall be visible after installation. All letters shall be capitalized and shall be a minimum height of 9.5 mm (⅜ in.) in white on a red background. Labels shall appear on every section of the wiring system that is separated by enclosures, walls, partitions, ceilings, or floors. Spacing between labels or markings, or between a label and a marking, shall not be more than 3 m (10 ft). Labels required by this section shall be suitable for the environment where they are installed.

(b) Building integrated PV systems installed as the roof covering shall have markings to identify any areas with electrical hazards hidden from view. Marking shall be reflective and visible from grade.

Statement of Problem and Substantiation for Public Input

This PI is one of three submitted on behalf of the NFPA 1/ NEC PV Joint Task Group. The Task Group is comprised of Ken Bush – NFPA 1 (Technical Committee Chair), Shane Clary – NFPA 1, Rebekah Hren – NEC Panel 4, Bruce Johnson – NFPA 1 (Task Group Chair) and Jim Rogers – NEC Panel 4 Chair. Three consensus proposals are being submitted by the Task Group with the purpose of fully harmonizing the PV system and power source labeling and marking requirements of the NEC with those of the Fire Code. Slight variations that have existed in color, formatting, and marking language requirements between the Fire Code and the NEC have made it unnecessarily difficult for enforcement and inspections agencies to align. As an example, the requirement for a yellow background on the Rapid Shutdown label in the NEC as compared to a red background in NFPA 1 could result in a jurisdiction requiring two labels serving the same purpose, though by their dual presence possibly causing confusion. Clearly this is not practical or desirable and the Codes should be harmonized. This PI specifically aligns the requirement for BIPV marking as required in NFPA 1 11.12.2.1.6.1 and 11.12.2.1.6.2.

Submitter Information Verification

Submitter Full Name: Rebekah Hren
Organization: IPPNC LLC
Affiliation: NFPA 1 / NEC PV Joint Task Group
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State:
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Submittal Date: Wed Sep 09 08:24:11 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: The installation and maintenance of PV systems is restricted to only qualified persons by this Code to ensure safe work practices are maintained. Section 690.12 requirements apply for those cases where there is a risk that unqualified persons may inadvertently damage PV equipment as part of emergency operations. The systems identified in the public input would fall under requirements to provide a rapid shutdown function and notification markings. Removal of 690.12(B)(2)(3) related to building integrated type systems makes the proposed requirement unnecessary. UL3741 addresses any hazards.

Public Input No. 4490-NFPA 70-2020 [Section No. 690.31(D) [Excluding any Sub-Sections]]

Where inside buildings, PV system dc circuits that exceed 30 volts or 8 amperes shall be contained in metal raceways, in Type MC metal-clad cable that complies with 250.118(10), or in metal enclosures.

Exception: PV systems with only listed class 2 limited power output circuits using 4-pair communications cables in accordnce with 725.154(A) shall comply with 725.144.

Exception: PV hazard control systems installed in accordance with 690.12(B)(2)(1) shall be permitted to be provided with or listed for use with nonmetallic enclosure(s), nonmetallic raceway(s), and cables other than Type MC metal-clad cable(s), at the point of penetration of the surface of the building to the PV hazard control actuator.

Wiring methods on or in buildings shall comply with the additional installation requirements in 690.31(D)(1) and (D)(2).

Statement of Problem and Substantiation for Public Input

Inside window film surfaces using limited power circuits should not apply to this requirement. By definition, these listed devices installed in accordance with article 725 are already safe.

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Committee: NEC-P04

Committee Statement

Resolution: FR-9285-NFPA 70-2021

Statement: Rapid shutdown requirements in 690.12 control conductors located within buildings. The 2020 690.31(D)(1) requirements addressing the location of certain wiring methods predated the implementation of, and are rendered unnecessary by the updated rapid shutdown requirements in 690.12. The same requirements for these wiring methods that exist for all other applications are sufficient as described in Articles 330 and 348. Section 690.31(C)(3) defines wiring methods not already defined in Chapter 3, but Chapter 3 wiring methods are sufficient to ensure safe installation of these “flexible wiring methods.”

With the deletion of 690.31(D)(1) text, the section is better structured by moving the original (D) language

into a re-titled (D)(1) and (D)(2) remains unchanged except for removing the superfluous “required” from the title.

Public Input No. 4206-NFPA 70-2020 [New Section after 690.31(F)]

690.31(G) Over 1000V Dc.

Equipment and wiring methods containing PV system dc circuits with a maximum voltage greater than 1000 volts shall comply with the following:

(1) Shall not be permitted on or in one- and two-family dwellings.

(2) Shall not be permitted within buildings containing habitable rooms.

(3) Where suitable for use in PV systems, equipment containing PV system dc circuits with a maximum voltage no greater than 1500 volts shall not be required to comply with Parts II and III of Article 490.

(4) Where installed on the exterior of buildings shall be located less than 3 m (10 ft) above grade. Wiring methods containing PV system dc circuits connected to this equipment shall not be permitted to attach to the building greater than a distance of 10 m (33 ft) along the building surface from the equipment.

(5) Where accessible to unqualified persons, the installation shall comply with 110.31(C)(1) and 110.31(D).

Statement of Problem and Substantiation for Public Input

The industry trend of 1500 Vdc ground-mounted arrays located near buildings creates a need to clarify Code language around wiring from different types of arrays interfacing with buildings. This proposal adds a new subsection to 690.31 to specify equipment and wiring methods of PV system circuits above 1000 Vdc. Items 1, 2, and 3 incorporate language moved from 690.7. 690.31 is a more relevant section than 690.7 for specifications of equipment over 1000 volts, since 690.31 concerns wiring methods and equipment requirements. Items 4 and 5 are introduced to provide limitations for equipment and wiring methods >1000 Vdc that are mounted on the exterior wall of a building.
Currently, it is permitted to install >1000 Vdc equipment mere inches from a building, yet it is not permitted to install >1000 Vdc equipment on the exterior wall of a building. Since the equipment is located outside in open air rather than enclosed, there is much less risk than that of PV arrays on a roof with circuits entwined with the building envelope and circuits inside a building. This proposal would allow, with certain limitations, inverters and associated dc equipment from a ground-mounted 1500Vdc array to be mounted on the outside wall of a building that is not a one- or two- family dwelling. Specific limitations include that the conductors shall be installed within several feet above grade to prevent the installation of overhead conductors; inaccessibility of equipment to unqualified persons (referencing 110.31); and limiting the extent of wiring and equipment that can be attached to the outside of the building. At the same time, PV arrays installed on a rooftop or integrated in a building and any PV system dc circuits inside a building would remain limited to 600Vdc for one- or two- family dwellings and 1000Vdc for other buildings.

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This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.

Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI's submitted.
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Committee: NEC-P04

Committee Statement

Resolution: FR-9286-NFPA 70-2021

Statement: The industry trend of 1500 Vdc PV arrays located near buildings creates a need to clarify requirements applying to ground-mounted arrays interfacing with buildings. List items 1, 2, and 3 incorporate language to coordinate with 690.7 . Section 690.31 is a more relevant section than 690.7 for specifications of equipment over 1000 volts, since 690.31 concerns wiring methods and equipment requirements. Items 4 and 5 are introduced to provide some limited allowance for equipment and wiring methods >1000 Vdc to be installed on the exterior wall of a building. Currently, it is permitted to install >1000 Vdc equipment immediately adjacent to a building but not on the exterior wall of that building. The original requirement was to prevent PV systems over 1000Vdc being installed on buildings. Item 4 maintains this prevention and allows for a very limited contact of these conductors. This new allowance does not apply to one- or two- family dwellings in keeping with existing requirements. The maximum height above grade prevents the use of overhead conductors. Inaccessibility of the equipment to unqualified persons (by referencing 110.31) is added to notify users to this requirement. These changes do not modify the voltage limits for PV arrays installed on a rooftop or integrated in a building as noted in 690.7.

Public Input No. 4208-NFPA 70-2020 [Section No. 690.33(C)]

(C) Type.

The mating connectors shall be of the latching or locking type. Mating connectors that are readily accessible and that are used in circuits operating at over 30 volts dc or 15 volts ac shall require a tool for opening. Where mating connectors are not of the identical type and brand, they shall be listed and identified for intermatability, as described in the manufacturer's instructions.

Informational Note: Information on tool requirements and intermatability can be found in the manufacturer's assembly instructions, in the required certification labeling on the product, or directly from the listing agency.

Statement of Problem and Substantiation for Public Input

The term intermatability is defined in the certification standard UL6703. Many products claim to have that capability, but fall short of meeting the requirements outlined in the standard. The UL6703 standard also outlines how a product complies with requiring a tool. Some AHJs and independent engineers have questioned products as not requiring a tool because they are able to open the connector with their fingers. The criteria for needing a tool is covered by UL6703 and not by ability of some people who are capable of opening a connector without a tool.

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Committee: NEC-P04

Committee Statement

Resolution: Per the guidelines of the NEC Style Manual this informational note would neither support nor improve the section requirements and it is duplicative of existing text.

Public Input No. 917-NFPA 70-2020 [Section No. 690.41]

690.41 ~~.~~ 41 PV System DC Circuit Grounding and Protection .

(A) PV System DC Circuit Grounding Configurations.

~~One or more~~ For each PV system dc circuit in a PV system, one of the following ~~system~~ grounding configurations shall be employed:

(1) 2-wire PV ~~arrays~~ system dc circuits with one functionally grounded conductor

(2) Bipolar PV ~~arrays~~ system dc circuits according to 690.7(C) with a functional ground reference (center tap)

(3) PV ~~arrays~~ system dc circuits not isolated from the grounded inverter output circuit

(4) Ungrounded PV ~~arrays~~

(5) system dc circuits

(6) Solidly grounded PV ~~arrays~~ system dc circuits as permitted in 690.41(B)

(7) PV ~~systems that use other methods that accomplish equivalent system protection in accordance with~~ 250.4(A) ~~with~~ system dc circuits protected by equipment listed and identified for the use

(B) Ground-Fault Protection.

PV system dc circuits that exceed 30 volts or 8 amperes shall be provided with dc ground-fault protection meeting the requirements of 690.41(B)(1) and (B)(2) to reduce fire hazards.

Solidly grounded PV source circuits with not more than two modules in parallel and not on or in buildings shall be permitted without ground-fault protection.

Informational Note: Not all inverters, charge controllers, or dc-to-dc converters include ground-fault protection. Equipment that does not have ground-fault protection often includes the following statement in the manual: “Warning: This unit is not provided with a GFDI device.”

(1) Ground-Fault Detection.

The ground-fault protection device or system shall detect ground fault(s) in the PV system dc ~~circuit conductors~~ circuits , including any ~~functional~~ functionally grounded conductors, and be listed for providing PV ground-fault protection. For dc-to-dc converters not listed as providing ground-fault protection, where required, listed ground fault protection equipment identified for the combination of the dc-to-dc converter and ground-fault protection device shall be installed to protect the circuit.

Informational Note: Some dc-to-dc converters without integral ground-fault protection on their input (source) side can prevent other ground-fault protection equipment from properly functioning on portions of PV system dc circuits.

(2) Faulted Circuits.

The faulted circuits shall be controlled by one of the following methods:

(1) The current-carrying conductors of the faulted circuit shall be automatically disconnected.

(2) The device providing ground-fault protection fed by the faulted circuit shall automatically cease to supply power to output circuits and interrupt the faulted PV system dc circuits from the ground reference in a functionally grounded ~~system~~ circuits .

(3) Indication of Faults.

Ground-fault protection equipment shall provide indication of ground faults at a readily accessible location.

Informational Note: Examples of indication include, but are not limited to, the following: remote indicator light, display, monitor, signal to a monitored alarm system, or receipt of notification by web-based services.

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

This section is modified to focused on DC circuit grounding. This is necessary as there may be multiple DC circuits requiring grounding in a PV system and there is no requirement that all dc circuits utilize the same circuit grounding configuration.

The terms Array and circuit conductors are inadequate to describe what requires grounding or is impacted by this section. These terms and various part of this section was reworded to reflect PV system dc circuits which is a defined term.

Note that there should only be 6 options and Terra has apparently made modifications. Item (4) should read “Ungrounded PV system dc circuits”.

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Committee: NEC-P04

Committee Statement

Resolution: FR-9287-NFPA 70-2021

Statement: This section is modified to focus on DC circuit grounding. This is necessary as there may be multiple DC circuits requiring grounding in a PV system and there is no requirement that all dc circuits utilize the same circuit grounding configuration. The terms “array” and “circuit conductors” were inadequate to describe what requires grounding or is impacted by this section.

The term "functional" in the phrase "functional grounded conductors" is replaced with "functionally" to be consistent with changes made in the 2020 code referring to functionally grounded systems.

Public Input No. 3799-NFPA 70-2020 [Section No. 690.41(B)(1)]

(1) Ground-Fault Detection.

The ground-fault protection device or system shall detect ground fault(s) in the PV system dc circuit conductors, including any ~~functional~~ functionally grounded conductors, and be listed for providing PV ground-fault protection. For dc-to-dc converters not listed as providing ground-fault protection, where required, listed ground fault protection equipment identified for the combination of the dc-to-dc converter and ground-fault protection device shall be installed to protect the circuit.

Informational Note: Some dc-to-dc converters without integral ground-fault protection on their input (source) side can prevent other ground-fault protection equipment from properly functioning on portions of PV system dc circuits.

Statement of Problem and Substantiation for Public Input

The term "functional" in the phrase "functional grounded conductors" needs to be replaced with "functionally" to be consistent with changes made in the 2020 code referring to functionally grounded systems.

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Committee: NEC-P04

Committee Statement

Resolution: FR-9287-NFPA 70-2021

Statement: This section is modified to focus on DC circuit grounding. This is necessary as there may be multiple DC circuits requiring grounding in a PV system and there is no requirement that all dc circuits utilize the same circuit grounding configuration. The terms “array” and “circuit conductors” were inadequate to describe what requires grounding or is impacted by this section.

The term "functional" in the phrase "functional grounded conductors" is replaced with "functionally" to be consistent with changes made in the 2020 code referring to functionally grounded systems.

Public Input No. 4347-NFPA 70-2020 [Section No. 690.41(B) [Excluding any Sub-Sections]]

PV system dc circuits that exceed 30 volts or 8 amperes shall be provided with dc ground-fault protection meeting the requirements of 690.41(B)(1) and (B)(2) to reduce fire hazards.

Solidly grounded PV source circuits with not more than two modules in parallel and not on or in buildings shall be permitted without ground-fault protection.

Informational Note: Not all inverters, charge controllers, or dc-to-dc converters include ground-fault detector interrupter (GFDI) protection. Equipment that does not have ~~ground-fault~~ GFDI protection often includes the following statement in the manual: “Warning: This unit is not provided with a GFDI device.”

Statement of Problem and Substantiation for Public Input

Informational notes are for providing information. While most people in the electrical industry are familiar with a ground-fault circuit interrupter (GFCI), I do not think that most folks are as familiar with a ground-fault detector interrupter (GFDI) device. We can't assume that everyone knows what we know. I have personally been ask in the seminar/webinar setting if this "GFDI" reference is a clerical error in the NEC.

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Committee: NEC-P04

Committee Statement

Resolution: FR-9288-NFPA 70-2021
Statement: This revision clarifies that PV GFDI is different than ground-fault protection used elsewhere in the Code. Detector/interrupter has been added to match UL 1741 definition.

Public Input No. 3801-NFPA 70-2020 [Section No. 690.42]

690.42 Point of System Grounding Connection.

Systems with a ground-fault protective device in accordance with 690.41(B) shall have any current-carrying conductor-to-ground connection made by the ground-fault protective device. For solidly grounded PV systems, the dc circuit grounding connection shall be made at any single point on the PV ~~output~~ system dc circuit(s) .

Statement of Problem and Substantiation for Public Input

This proposed change addresses and aligns with the related proposal to remove the terms “PV output circuits” and “dc to dc converter output circuits” from Article 690. Accordingly, the PI replaces the term “PV output circuit” with “PV system dc circuit(s).” The addition of the optional plural “(s)” reflects the fact that solidly grounded systems may have up to two strings. The use of “circuit(s)” clarifies that there should be only a single ground connection for the system dc circuit(s), regardless of whether there is one dc circuit or two parallel connected dc circuits.

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Committee: NEC-P04

Committee Statement

Resolution: FR-9289-NFPA 70-2021

Statement: New Section 690.42(A) focuses on the more common application of functionally grounded systems which are grounded through Ground-Fault protection. New section 690.42(B) focuses on solidly grounded circuits which are grounded differently than those in (A). This section clarifies that the grounding connection can be made to any point on the grounding electrode system which aligns with similar guidance / requirements found in Article 250.

Public Input No. 918-NFPA 70-2020 [Section No. 690.42]

690.42 Point of PV System DC Circuit Grounding Connection.

~~Systems with~~ **(A) Circuits with Ground-Fault Protection**

Circuits protected by a ground-fault protective device in accordance with 690.41(B) shall have any ~~current~~ circuit ~~-carrying conductor-~~ to-ground connection made by the ground-fault protective device.

(B) Solidly Grounded Circuits

For solidly grounded PV ~~systems~~ system dc circuits , the ~~dc circuit~~ grounding connection shall be made ~~at~~ from any single point on the PV ~~output circuit~~ system dc circuit to a point on the grounding electrode system .

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).
The title of 690.42 is changed adding “PV System DC Circuit” which is a defined term and will add clarity to what this section is impacting. The title is more specific.
This section is now separated into two first level subdivisions (A) and (B) focusing on Circuits with ground-fault protection and solidly grounded circuits respectively. This distinction adds clarity to this section on grounding as these are the two methods used for PV systems and are different in how they are grounded. Separating these into two separate first level subdivision aligns with guidance from the style manual as this section included two separate requirements.

New first level subdivision (A) focuses on the more common application of functionally grounded systems which are grounded through Ground-Fault protection.
New first level subdivision (B) focuses on solidly grounded circuits which are grounded differently than those in (A) of this section. This section points out that the grounding connection can be made to any point on the grounding electrode system which aligns with similar guidance / requirements found in Article 250.

The focus on this section has be aligned with PV system dc circuits for clarity throughout.

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Submittal Date: Thu Apr 30 16:19:31 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9289-NFPA 70-2021

Statement: New Section 690.42(A) focuses on the more common application of functionally grounded systems which are grounded through Ground-Fault protection. New section 690.42(B) focuses on solidly grounded circuits which are grounded differently than those in (A). This section clarifies that the grounding connection can be made to any point on the grounding electrode system which aligns with similar guidance / requirements found in Article 250.

Public Input No. 1378-NFPA 70-2020 [Section No. 690.43]

690.43 Equipment Grounding and Bonding.

Exposed non-current-carrying metal parts of PV module frames, electrical equipment, and conductor enclosures of PV systems shall be connected to an equipment grounding conductor in accordance with 250.134 or 250.136, regardless of voltage. Equipment grounding conductors and devices shall comply with 690.43(A) through (D).

(A) Photovoltaic Module Mounting Systems and Devices.

Devices and systems used for mounting PV modules that are also used for bonding module frames shall be listed, labeled, and identified for bonding PV modules. Devices that mount adjacent PV modules shall be permitted to bond adjacent PV modules.

(B) Equipment Secured to Grounded Metal ~~Supports~~ Support Structures .

Devices listed, labeled, and identified for bonding and grounding the metal parts of PV systems shall be permitted to bond the equipment to grounded metal ~~supports~~ support structures . Metallic support structures shall have identified bonding jumpers connected between separate metallic sections or shall be identified for equipment bonding and shall be connected to the equipment grounding conductor.

(C) With Circuit Conductors.

Equipment grounding conductors for the PV array and metal support structure where installed shall be contained within the same raceway or cable or otherwise run with the PV system conductors where those circuit conductors leave the vicinity of the PV array.

(D) Bonding for Over 250 Volts.

The bonding requirements contained in 250.97 shall apply only to solidly grounded PV system circuits operating over 250 volts to ground.

Statement of Problem and Substantiation for Public Input

Just some suggested 'editorial' edits.

Submitter Information Verification

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Submittal Date: Mon Jun 01 20:39:23 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: This section purposely uses the same nomenclature “metal supports” as 250.136 and should not be changed.

Public Input No. 3806-NFPA 70-2020 [Section No. 690.43(A)]

(A) Photovoltaic Module Mounting Systems and Devices.

Devices and systems used for mounting PV modules that are also used for bonding module frames shall be listed, labeled, and identified for bonding PV modules. ~~Devices that mount adjacent PV modules shall be permitted to bond adjacent PV modules~~

I nformational note: Some listed equipment including but not limited to PV module mounting systems, PV module clamping devices, and devices for bonding PV module frames, are evaluated for mounting and/or bonding individual or adjacent PV modules. See UL 2703, Standard for Mounting Systems, Mounting Devices, Clamping/Retention Devices, and Ground Lugs for Use with Flat-Plate Photovoltaic Modules and Panels for PV module clamps, and UL 3703, Standard for Solar Trackers for solar trackers. Manufacturer's instructions for equipment listed to these standards identify PV modules and equipment that have been evaluated for compatibility .

Statement of Problem and Substantiation for Public Input

This input is intended to address two separate issues. First, the 2nd sentence of the clause is unnecessary because the product listing described in the first sentence will define relevant uses for the devices and whether a device has been evaluated for the purpose of bonding adjacent PV modules. It is important to understand that the intent of deleting the sentence is not to suggest that devices should no longer be permitted to bond adjacent modules, just that the proper source for such distinctions should be in the product listings and not the code. The proposed Informational note adds additional contextual information about the listings and further makes the sentence unnecessary.
Second, the new informational note is proposed to help reduce confusion about how listings are applied to mounting/ grounding components, and how they are identified for compatibility with other modules and components. Currently these are applied inconsistently in the field leading to installation of inadequately evaluated parts. Specifically, mounting or bonding devices that have been listed (e.g. to UL 2703) identify in their installation instructions modules or other components with which they are tested for compatibility. They are not universally applicable. This informational note should hopefully provide better guidance to installers and AHJs to ensure that compatibility is verified.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI's submitted.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain, P.E., SEIA; Bill Brooks, PVICC; John Berdner, PVICC, Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing, Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower; Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural

Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Ben Chamberlain, Olivewood Energy; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

Submitter Information Verification

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Submittal Date: Wed Sep 09 13:13:57 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9290-NFPA 70-2021

Statement: The 2nd sentence is deleted be because the product listing described in the informational note will define relevant uses for the devices and whether a device has been evaluated for the purpose of bonding adjacent PV modules. The intent of deleting the sentence is not to suggest that devices should no longer be permitted to bond adjacent modules, just that the proper source for such distinctions should be in the product listings and not the code. The new informational note adds contextual information about the listing that helps apply these requirements.

This standard should be added to annex A list.

UL 2703, Standard for Mounting Systems, Mounting Devices, Clamping/Retention Devices, and Ground Lugs for Use with Flat-Plate Photovoltaic Modules and Panels

2703 First Edition, Dated January 28, 2015

This revision of ANSI/UL 2703 dated December 16, 2019

UL 3703, Standard for Solar Trackers

UL3703 First Edition, Dated October 8, 2015,

This revision of ANSI/UL 3703 dated April 7, 2020

Public Input No. 2635-NFPA 70-2020 [Section No. 690.43(C)]

(C) With Circuit Conductors.

Equipment grounding conductors for the PV array and support structure where installed shall be contained within the same raceway or cable or otherwise run with the PV system conductors where those circuit conductors leave the vicinity of the PV array.

Where equipment is installed outdoors on a roof, an equipment grounding conductor of the wire type shall be installed in outdoor portions of metallic raceway systems that use compression-type fittings.

Statement of Problem and Substantiation for Public Input

This input is being submitted on behalf of the Minnesota Department of Labor and Industry. The Department's 15 office/field staff, and 65 plus contract electrical inspectors complete over 150,000 electrical inspections annually and are involved in the daily enforcement and interpretation of the National Electrical Code.
It is very important that the effective ground fault path required in NEC section 690.43 always be present. The same concerns that exist for rooftop air-conditioning and refrigerating equipment exist for rooftop PV installations. The language from section 440.9 was used to make sure that if compression fittings are used in rooftop PV installations that a wire type equipment grounding conductor be installed in the conduit.

Submitter Information Verification

Submitter Full Name: Dean Hunter
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Submittal Date: Wed Aug 26 10:12:36 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: Article 250 is the correct place to address this concern. No technical substantiation of a problem with use of compression fittings specifically for PV systems was provided. EMT compression fittings are evaluated to UL 514b for resistance/continuity and are permitted for use as an EGC by 250.118. EMT is not permitted where subject to damage by 358.12.

Public Input No. 3808-NFPA 70-2020 [Section No. 690.43(C)]

(C) ~~With Circuit Conductors~~ Location .

Equipment grounding conductors ~~for the PV array and support structure where installed shall be contained within the same raceway or cable or otherwise run with~~ shall be permitted to be run separately from the PV system conductors ~~where those circuit~~ within the PV array. Where PV system conductors leave the vicinity of the PV array, equipment grounding conductors shall comply with 250 .134.

Statement of Problem and Substantiation for Public Input

The existing language of 690.43(C) is derived in part from 250.134, and its purpose is generally understood to state that equipment ground conductors, often not run with PV system conductors within the array, should do so once in raceways between the array and utilization equipment in other locations. However, the specific language has led to overly strict interpretation, particularly in the wiring transitions between above and below ground circuits in ground-mount system. In those instances, ground conductors are not run “with” circuit conductors until after the transition to underground, even though that transition could strictly be interpreted as having left the “vicinity of the array.” The language is also interpreted by some AHJs to override the allowance in 250.134 for ground conductors to be run separately from circuit conductors in dc circuits.

The proposed text changes achieve the following:
- Makes explicit that equipment grounding conductors may be run separately within the array
- Clarifies that where conductors leave the vicinity of the array, the EGCs shall comply with 250.134, rather than re-stating similar text.
- Prevents over-strict interpretation for wiring transitions because 250.134 appropriately allows for EGCs to be run separately from circuit conductors in dc circuits.

Changes the title of the clause to “Location” as it is no longer specific to EGCs run with circuit conductors.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF’s effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI’s as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI’s submitted.
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Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Ben Chamberlain, Olivewood Energy; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

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Committee: NEC-P04

Committee Statement

Resolution: FR-9292-NFPA 70-2021

Statement: This revision makes it explicit that equipment grounding conductors may be run separately within the array. It clarifies that where conductors leave the vicinity of the array, the EGCs shall comply with 250.134. This requirement prevents over-strict interpretation for wiring transitions because 250.134 appropriately allows for EGCs to be run separately from circuit conductors in dc circuits. The title is changed to “location” as it is no longer specific to EGCs run with circuit conductors.

Public Input No. 2636-NFPA 70-2020 [Section No. 690.45]

690.45 Size of Equipment Grounding Conductors.

Equipment grounding conductors for PV system circuits shall be sized in accordance with 250.122. Where no overcurrent protective device is used in the circuit, an assumed overcurrent device rated in accordance with 690.9(B) shall be used when applying Table 250.122.

~~Increases in equipment grounding conductor size to address voltage drop considerations shall not be required.~~

Statement of Problem and Substantiation for Public Input

This input is being submitted on behalf of the Minnesota Department of Labor and Industry. The Department's 15 office/field staff, and 65 plus contract electrical inspectors complete over 150,000 electrical inspections annually and are involved in the daily enforcement and interpretation of the National Electrical Code.
Deletion of the wording in the 2020 NEC will assure that an equipment grounding conductor maintains a low impedance effective ground fault path to assure proper operation of overcurrent devices and ground fault detectors.

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Submittal Date: Wed Aug 26 10:17:23 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: The 2020 revised language simplified the sizing of grounding conductors and allowed ac equipment grounding conductors to remain the same based on the overcurrent device ratings regardless of size increases for performance reasons.

Public Input No. 1379-NFPA 70-2020 [Section No. 690.47]

690.47 Grounding Electrode System.

(A) Buildings or Structures Supporting a PV System.

A building or structure(s) supporting a PV system shall utilize a grounding electrode system installed in accordance with Part III of Article 250.

~~PV array equipment grounding conductors shall be connected to a grounding electrode system in accordance with Part VII of Article 250. This connection shall be in addition to any other equipment grounding conductor requirements in 690.43(C) . The PV array equipment grounding conductors shall be sized in accordance with 690.45 .~~ For specific PV system grounding configurations permitted in 690.41(A), one of the following conditions shall apply:

(1) For PV systems that are not solidly grounded, the equipment grounding conductor for the output of the PV system, where connected to associated distribution equipment connected to a grounding electrode system, shall be permitted to be the only connection to ground for the system.

(2) For solidly grounded PV systems, as permitted in 690.41(A)(5), the grounded conductor shall be connected to a grounding electrode ~~system~~ in accordance with Part VII of Article 250, by means of a grounding electrode conductor sized in accordance with 250.166.

Informational Note: Most PV systems are functionally grounded systems rather than solidly grounded systems as defined in this *Code*. For functionally grounded PV systems with an interactive inverter output, the ac equipment grounding conductor is connected to associated grounded ac distribution equipment. This connection is most often the connection to ground for ground-fault protection and equipment grounding of the PV array.

(B) Auxiliary Grounding ~~Electrodes and Grounding~~ Electrode ~~Conductors~~ .

~~Additional grounding electrodes shall be permitted to be installed~~ Auxiliary grounding electrode(s) in accordance with 250. ~~52 and 250.~~ 54 ~~. Grounding electrodes~~ shall be permitted ~~to be connected directly to the PV module frame(s) or support structure. A grounding electrode conductor shall be sized according to 250.66 . A support structure~~ for ~~a ground-mounted PV array shall be permitted to be considered a grounding electrode if it meets the requirements of 250.52 . PV arrays mounted to buildings shall be permitted to use the metal structural frame of the building if the requirements of 250.68(C)(2) are met.~~ PV systems covered by this article.

Statement of Problem and Substantiation for Public Input

My edits to (A) were to streamline the requirements so that the rule focused on “grounding” and not the “equipment grounding conductor.” I revised (B) to reflect similar text used for Signs [600.7(A)(4)] relating to the use of an auxiliary electrode.

Submitter Information Verification

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Submittal Date: Mon Jun 01 20:42:43 EDT 2020

Committee: NEC-P04

Committee Statement

Resolution: FR-9500-NFPA 70-2021

Statement: This revision re-orders several statements for greater clarity including the sentences in the first paragraph and creates two subsections for greater readability. The first section, grounding electrodes, adds a provision for the metal in-ground structural steel members frequently used for ground-mounted PV systems to be considered grounding electrodes, if they are designed and tested under engineering supervision to show comparable earth resistance values as the similar but non-identical structures described in 250.52(A)(2). An informational note is added to provide supplemental information on where to find guidance on performing earth resistance tests that may meet the new provisions of this section. The second section - auxiliary electrodes - moves what was previously the first sentence of (B) Into section and adds contextual clarity.

Public Input No. 3811-NFPA 70-2020 [Section No. 690.47]

690.47 Grounding Electrode System.

(A) Buildings or Structures Supporting a PV System.

A building or structure(s) supporting a PV system shall utilize a grounding electrode system installed in accordance with ~~Part III of Article 250.~~ 690.47(B).

PV array equipment grounding conductors shall be connected to a grounding electrode system in accordance with Part VII of Article 250. This connection shall be in addition to any other equipment grounding conductor requirements in 690.43(C). The PV array equipment grounding conductors shall be sized in accordance with 690.45. For specific PV system grounding configurations permitted in 690.41(A), one of the following conditions shall apply:

(1) For PV systems that are not solidly grounded, the equipment grounding conductor for the output of the PV system, where connected to associated distribution equipment connected to a grounding electrode system, shall be permitted to be the only connection to ground for the system.

(2) For solidly grounded PV systems, as permitted in 690.41(A)(5), the grounded conductor shall be connected to a grounding electrode system by means of a grounding electrode conductor sized in accordance with 250.166.

Informational Note: Most PV systems are functionally grounded systems rather than solidly grounded systems as defined in this *Code*. For functionally grounded PV systems with an interactive inverter output, the ac equipment grounding conductor is connected to associated grounded ac distribution equipment. This connection is most often the connection to ground for ground-fault protection and equipment grounding of the PV array.

(B) Grounding Electrodes and Grounding Electrode Conductors.

Grounding electrodes in accordance with Part III of Article 250 shall be utilized for PV systems. Support structures consisting of at least one bare or electrically conductive coated iron or steel structural member that exposes not less than 0.186 m2 (2 ft2) of surface to exterior soil below a depth of 30” shall be permitted to meet the requirements of an electrode for grounding in 250.52(A). Where a portion of the support structure is utilized as the electrode, the grounding electrode conductor shall connect to the structural member acting as an electrode.

Additional grounding electrodes shall be permitted to be installed and connected to the equipment grounding conductor in accordance with ~~250.52 and 250.~~ 2 50. 54. Grounding electrodes shall be permitted to be connected directly to the PV module frame(s) or support structure. A grounding electrode conductor shall be sized according to 250.66. ~~A support structure for a ground-mounted~~ PV ~~array shall be permitted to be considered a grounding electrode if it meets the requirements of 250.52 . PV~~ arrays mounted to buildings shall be permitted to use the metal structural frame of the building to connect to the electrode if the requirements of 250.68(C)(2) are met.

If multiple structural member electrodes are present at a building or structure, it shall be permissible to bond only one compliant structural member into the grounding electrode system.

Additional Proposed Changes

File Name	Description	Approved
690.47_images.pdf	Supporting images.	

Statement of Problem and Substantiation for Public Input

The purpose of this public input is to create an explicit allowance for structural piers commonly used in

ground-mounted PV systems to be used as grounding electrodes. Currently, structural steel members driven to depths greater than 3 feet but less than 10 feet do not meet the requirements of 250.52(A)(2) and yet are perfectly substantial electrodes.

The proposed language changes the opening sentence of 690.47(A) to replace a broad reference to article 250 with a simple reference to 690.47(B), which is expanded in this proposal to clarify the use of structural members and piers as grounding electrodes.

The term “structures” has a basic definition in the NEC and can be as simple as a metal pole. Many ground-mounted PV support structures in the industry today are comprised of multiple metal support piles, typically embedded 6 ft into the earth. In large scale systems, these structures contain hundreds of support piles with at least 6 ft of direct contact with earth. Currently, 250.52(A)(5) allows rod and pipe electrodes to be considered as a grounding electrode system with a surface area of 2 ft2. Grounding electrodes specified by 250.52(A)(7) for plate electrodes have a similar surface area. Many ground-mounted PV support structures meet this minimum surface area and yet are not explicitly allowed.

Thickness of the electrode was excluded as part of this proposal. While 250.52(A)(7) for plate electrodes specifies a ¼” thickness, 250.52(A)(5) for rod and pipe electrodes do not specify a thickness requirement. The ¼” thickness for plate electrodes is understood to account for a worst-case scenario when no background information of site-specific soil corrosive properties is available. However, structural piles in ground-mounted PV arrays are designed for site-specific soil properties. PV structural pile design involves engineering oversight and accounts for expansive and corrosive soils, frost heave, wind, temperature cycles and other geotechnical factors. As such, the structural piles would be designed to remain intact for the life of the project.

Furthermore, PV structural piles are thicker than rod and pipe electrode requirements and the surface area of typical PV piles comfortably exceed the 2 ft2 requirement. 250.52(A)(5) for rod and pipe electrodes specifies at least trade size ¾ (thickness 0.107”), while PV system structural piles are typically at least 0.125” thick. The surface area of a typical pile is calculated to be 2.29 ft2 per foot length. Given that most piles are embedded at least 6 ft, the surface area of the piles well exceed the required surface area below a buried depth of 30”. Examples of typical piles are shown in the photos below.

The minimum buried depth specification of 30” follows 250.53(A)(4) and (5).
An additional sentence is added at the end of the clause to make it clear that a PV system could have 1000 steel piles that meet the minimum depth and surface area requirements and that those additional 999 steel piles need not be bonded together as a grounding electrode system. They merely need to be bonded to the equipment grounding conductor as required in 250.54.

Lastly, the phrase “to connect to the electrode” was added to the last sentence of the existing language to make it clearer that it is the building that is being used as the conductor to connect to the actual electrode.

Please see attachment for reference images.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF’s effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI’s as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI’s submitted.

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Committee: NEC-P04

Committee Statement

Resolution: FR-9500-NFPA 70-2021

Statement: This revision re-orders several statements for greater clarity including the sentences in the first paragraph and creates two subsections for greater readability. The first section, grounding electrodes, adds a provision for the metal in-ground structural steel members frequently used for ground-mounted PV systems to be considered grounding electrodes, if they are designed and tested under engineering supervision to show comparable earth resistance values as the similar but non-identical structures described in 250.52(A)(2). An informational note is added to provide supplemental information on where to find guidance on performing earth resistance tests that may meet the new provisions of this section. The second section - auxiliary electrodes - moves what was previously the first sentence of (B) Into section and adds contextual clarity.

CAT

Public Input No. 2791-NFPA 70-2020 [New Section after 690.51]

TITLE OF NEW CONTENT

690.52 **Building Integrated Photovoltaic (BIPV) Systems.** Where building integrated photovoltaic **(BIPV)** systems are installed in a manner that creates areas with electrical hazards to be hidden from view, the installer must clearly mark the hazardous areas to avoid. The hazardous areas shall be marked with the wording PV POWER HAZARD AREA by means of permanently affixed labels or other approved permanent markings. The labels shall be visible from grade after installation. All letters shall be capitalized and shall be a minimum height of 9.5 mm (3/8 in.) in white on a red background. Labels shall be reflective and appear on every hazardous area. Spacing between labels shall not be more than 3m (10 ft). Labels required by this section shall be suitable for the environment where they are installed.

Exception: Where the entire hazardous area is clearly visible as a single demarcated area from grade, only one label is required to be visible for each visible (from grade) compass direction. **BIPV** systems listed in accordance with Section 690.12(B)(2) of NFPA 70, where the removal or cutting away of portions of the **BIPV** system during firefighting operations have been determined to not expose a firefighter to electrical shock hazards.

Statement of Problem and Substantiation for Public Input

This code is being considered for Section 1205.2.3 of the 2021 IFC International Fire Code. We think the demand for this marking may be low as most BIPV system manufacturers will probably want to follow the exception to avoid the marking. They are also attempting to improve the language for the 2024 I-codes. Similar language will also appear in the 2021 IRC and in the 2021 NFPA1 Fire Code. We should adopt this in order to stay consistent with the other groups.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2792-NFPA 70-2020 [New Definition after Definition: Battery System.]	

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Committee: NEC-P04

Committee Statement

Resolution: The installation and maintenance of PV systems is restricted to only qualified persons by this Code to ensure safe work practices are maintained. Section 690.12 requirements apply for those cases where there is a risk that unqualified persons may inadvertently damage PV equipment as part of emergency operations. The systems identified in the public input would fall under requirements to provide a rapid shutdown function and notification

markings. Removal of 690.12(B)(2)(3) related to building integrated type systems makes the proposed requirement unnecessary. UL3741 addresses any hazards.

Public Input No. 2414-NFPA 70-2020 [Section No. 690.51]

690.51 Modules and AC Modules.

Modules and ac modules shall be lsited and marked in accordance with their listing.

Statement of Problem and Substantiation for Public Input

1) There appears to be an inference that is not yet explicitly stated; that AC modules and modules are NRTL Listed, but no such requirement is stated.
2) There is an apparent lack of consistency; in that of all PV equipment that may be NRTL Listed, only Modules and AC Modules shall be marked in accordance with said listing. Perhaps more of this type of "listing and marking" requirement would be prudent to add to other PV equipment categories of 690.
3) The group "modules and AC modules" is inferred to not be somewhat redundant, but rather are two distinct categories with their own definitions. The terms themselves (module vs AC module are may benefit from improved clarity in their independent distinctions.

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Committee: NEC-P04

Committee Statement

Resolution: FR-9586-NFPA 70-2021
Statement: To increase usability of the NEC, the enforcement requirements for marking of modules and ac modules should be found in one section, and Section 690.4 generally covers equipment listing requirements for PV systems, including ac modules. Previously, these related requirements for ac modules were found in Sections 690.4 and 690.51. This change is part of a larger initiative to group applicable but dispersed information into fewer, but more comprehensive, sections.

Public Input No. 3686-NFPA 70-2020 [Section No. 690.51]

~~**690.51** Modules and AC Modules.~~

~~Modules and ac modules shall be marked in accordance with their listing.~~

Statement of Problem and Substantiation for Public Input

To increase usability of the NEC, the enforcement requirements for marking of modules and ac modules should be found in one section, and 690.4 generally covers equipment listing requirements for PV systems, including ac modules. Previously, these related requirements for ac modules were found in Sections 690.4 and 690.51.
This change is part of a larger initiative to group applicable but dispersed information into fewer, but more comprehensive, sections.

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Related Public Inputs for This Document

Related Input	Relationship

Public Input No. 3684-NFPA 70-2020 [Section No. 690.4(B)]	This language is moved to 690.4
Public Input No. 3684-NFPA 70-2020 [Section No. 690.4(B)]	

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Submittal Date: Wed Sep 09 10:51:18 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9586-NFPA 70-2021

Statement: To increase usability of the NEC, the enforcement requirements for marking of modules and ac modules should be found in one section, and Section 690.4 generally covers equipment listing requirements for PV systems, including ac modules. Previously, these related requirements for ac modules were found in Sections 690.4 and 690.51. This change is part of a larger initiative to group applicable but dispersed information into fewer, but more comprehensive, sections.

Public Input No. 3693-NFPA 70-2020 [Section No. 690.53]

690.~~53~~ 7(D) Marking DC PV Circuits.

A permanent readily visible label indicating the highest maximum dc voltage in a PV system, calculated in accordance with 690.7, shall be provided by the installer at one of the following locations:

(1) DC PV system disconnecting means

(2) PV system electronic power conversion equipment

(3) Distribution equipment associated with the PV system

Statement of Problem and Substantiation for Public Input

To increase usability, the enforcement requirements for maximum PV system voltage should be in one section.
This change is part of a larger initiative to group applicable but dispersed information into fewer, but more comprehensive, sections.
In particular, marking and labeling requirements have historically been either interspersed through the Article or in the non-comprehensive Part VI. Marking. In lieu of Part VI never containing all of the marking requirements, the proposal is to group specific requirements in their applicable Sections wherever feasible.

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Committee: NEC-P04

Committee Statement

Resolution: FR-9587-NFPA 70-2021

Statement: Section 690.53 is moved to 690.7(D). To increase usability, the enforcement requirements for maximum PV system voltage are moved into one section. This change is part of a larger initiative to group applicable but dispersed information into fewer, but more comprehensive, sections. In particular, marking and labeling requirements have historically been either interspersed through the article or in the non-comprehensive Part VI. Marking. In lieu of Part VI not containing all of the marking requirements, the proposal is to group specific requirements in their applicable sections wherever feasible.

Public Input No. 2415-NFPA 70-2020 [Section No. 690.54]

690.54 Interactive System Point of Interconnection.

All interactive system(s) points of interconnection with other sources shall be marked ~~at an accessible location at the disconnecting means as a power source and~~ with the rated ac output current and the nominal operating ac ~~voltage.~~ voltage at the disconnecting means which serves as the source input from the interactive system. The disconnect means shall be at an accessible location.

Statement of Problem and Substantiation for Public Input

The intent warrants clarification by parsing the criterion into separate sentences, rather than using one sentence for all of it. As one example; the statement "...sources shall be marked at an accessible location..." could be interpreted multiple ways.

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Committee: NEC-P04

Committee Statement

Resolution: FR-9588-NFPA 70-2021

Statement: This revision is submitted in conjunction with the related revision to have the marking requirement now located in 690.54 in a more appropriate location in 705.14. Because this requirement is not specific to PV systems but instead is a more general requirement for labeling an interactive point of interconnection to other sources, it belongs in Article 705. The intent of this revision is not to change the marking requirement – which will still apply to interconnected PV systems – but rather to insure that it is applied across the board to all interconnected power sources.

Public Input No. 3795-NFPA 70-2020 [Section No. 690.54]

~~**690.54** Interactive System Point of Interconnection.~~

~~All interactive system(s) points of interconnection with other sources shall be marked at an accessible location at the disconnecting means as a power source and with the rated ac output current and the nominal operating ac voltage.~~

Statement of Problem and Substantiation for Public Input

This PI is submitted in conjunction with the related PI to move the marking requirement now located in 690.54 to a more appropriate location in 705.14. Because this requirement is not specific to PV systems but instead is a more general requirement for labeling an interactive point of interconnection to other sources, it belongs in Article 705. The intent of this PI is not to change the marking requirement – which will still apply to interconnected PV systems – but rather to insure that it is applied across the board to all interconnected power sources.

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Committee: NEC-P04

Committee Statement

Resolution: FR-9588-NFPA 70-2021

Statement: This revision is submitted in conjunction with the related revision to have the marking requirement now located in 690.54 in a more appropriate location in 705.14. Because this requirement is not specific to PV systems but instead is a more general requirement for labeling an interactive point of interconnection to other sources, it belongs in Article 705. The intent of this revision is not to change the marking requirement – which will still apply to interconnected PV systems – but rather to insure that it is applied across the board to all interconnected power sources.

Public Input No. 3698-NFPA 70-2020 [Section No. 690.55]

~~**690.55** Photovoltaic Systems Connected to Energy Storage Systems.~~

~~The PV system output circuit conductors shall be marked to indicate the polarity where connected to energy storage systems.~~

Statement of Problem and Substantiation for Public Input

The provisions for marking polarity on PV system dc circuit conductors are adequately addressed in Section 690.31(B)(1), and in many cases the connection between PV and ESS occurs on the ac side, in which case polarity as specified in 690.55 and 690.31(B)(1) are not relevant and other requirements and conventions apply.
Additionally, Article 706 has requirements for marking ESS disconnecting means [706.15(C)], directories of power sources (706.21), and connection to other sources (706.16), which refers to Articles 705, 710, and 712, including the marking and directory requirements therein.
Together, these requirements make a specific call out for the marking of a connection between PV and energy storage systems unnecessary.

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Submittal Date: Wed Sep 09 11:03:11 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9589-NFPA 70-2021

Statement: The provisions for marking polarity on PV system dc circuit conductors are adequately addressed in Section 690.31(B)(1), and in many cases the connection between PV and ESS occurs on the ac side, in which case polarity as specified in 690.55 and 690.31(B)(1) are not relevant and other requirements and conventions apply. Additionally, Article 706 has requirements for marking ESS disconnecting means [706.15(C)], directories of power sources (706.21), and connection to other sources (706.16), which refers to Articles 705, 710, and 712, including the marking and directory requirements therein. Together, these requirements make a specific call out for the marking of a connection between PV and energy storage systems unnecessary.

Public Input No. 2995-NFPA 70-2020 [Section No. 690.56]

690.56 Identification of Power Sources.

(A) Facilities with ~~Stand-Alone Systems~~ Other Sources .

Plaques or directories shall be installed in accordance with ~~710~~ 689 .10.

~~**(C)**~~

(B) ~~Facilities with Utility Services and Photovoltaic Systems.~~

~~Plaques or directories shall be installed in accordance with 705.10 and 712.10 , as required.~~

Buildings with Rapid Shutdown.

Buildings with PV systems shall have a permanent label located at each service equipment location to which the PV systems are connected or at an approved readily visible location and shall indicate the location of rapid shutdown initiation devices. The label shall include a simple diagram of a building with a roof and shall include the following words:

SOLAR PV SYSTEM IS EQUIPPED WITH RAPID SHUTDOWN.

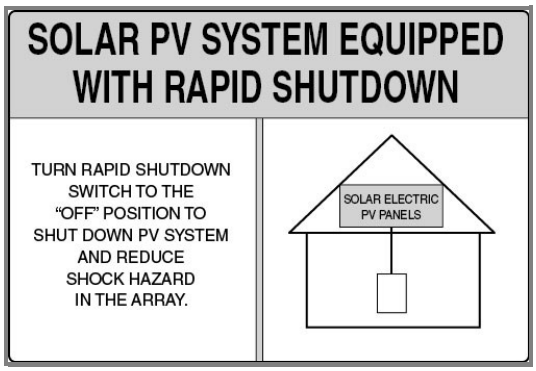
TURN RAPID SHUTDOWN SWITCH TO THE "OFF" POSITION TO SHUT DOWN

PV SYSTEM AND REDUCE SHOCK HAZARD IN ARRAY.

The title "SOLAR PV SYSTEM IS EQUIPPED WITH RAPID SHUTDOWN" shall utilize capitalized characters with a minimum height of 9.5 mm (⅜ in.) in black on yellow background, and the remaining characters shall be capitalized with a minimum height of 4.8 mm (3⁄16 in.) in black on white background.

Informational Note: See Informational Note Figure 690.56(C).

Figure Informational Note Figure 690.56(C) Label for Roof-Mounted PV Systems with Rapid Shutdown.



(1) Buildings with More Than One Rapid Shutdown Type.

For buildings that have PV systems with more than one rapid shutdown type or PV systems with no rapid shutdown, a detailed plan view diagram of the roof shall be provided showing each different PV system with a dotted line around areas that remain energized after rapid shutdown is initiated.

(2) Rapid Shutdown Switch.

A rapid shutdown switch shall have a label that includes the following wording located on or no more than 1 m (3 ft) from the switch:

RAPID SHUTDOWN SWITCH FOR SOLAR PV SYSTEM

The label shall be reflective, with all letters capitalized and having a minimum height of 9.5 mm (⅜ in.) in white on red background.

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

This modification is necessary as 710, 712 and 689 are combined as part of this task group effort into a new Article 689. The proper reference for plaques and directories is found in 689.10 only. In addition, this section was simplified as only one reference section exists. Changes simplify and add clarity.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2535-NFPA 70-2020 [Section No. 705.10]	
Public Input No. 2692-NFPA 70-2020 [Article 705]	

Submitter Information Verification

Submitter Full Name: Thomas Domitrovich
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Submittal Date: Thu Sep 03 20:07:10 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9613-NFPA 70-2021
Statement: With the reorganization of Part VI, Section 690.56 has been revised. The proper reference for plaques and directories is found in 705.10.

Public Input No. 3572-NFPA 70-2020 [Section No. 690.56(C)]

(C) Buildings with Rapid Shutdown.

Buildings with PV systems shall have a permanent label located at each service equipment location to which the PV systems are connected or at an approved readily visible location and shall indicate the location of rapid shutdown initiation devices. The label shall include a simple diagram of a building with a roof and shall include the following words:

SOLAR PV SYSTEM IS EQUIPPED WITH RAPID SHUTDOWN.

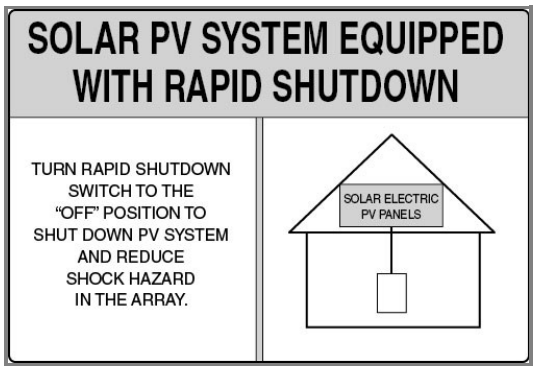
TURN RAPID SHUTDOWN SWITCH TO THE "OFF" POSITION TO SHUT DOWN

PV SYSTEM AND REDUCE SHOCK HAZARD IN ARRAY.

The ~~title "SOLAR PV SYSTEM IS EQUIPPED WITH RAPID SHUTDOWN" shall utilize capitalized characters with~~ label shall be reflective, with all letters capitalized and having a minimum height of 9.5 mm (⅜ in.) in ~~black on yellow background, and the remaining characters shall be capitalized with a minimum height of 4.8 mm (3⁄16 in.) in black on white~~ white on a red background.

Informational Note: See Informational Note Figure 690.56(C).

Figure Informational Note Figure 690.56(C) Label for Roof-Mounted PV Systems with Rapid Shutdown.



(1) Buildings with More Than One Rapid Shutdown Type.

For buildings that have PV systems with more than one rapid shutdown type or PV systems with no rapid shutdown, a detailed plan view diagram of the roof shall be provided showing each different PV system with a dotted line around areas that remain energized after rapid shutdown is initiated.

(2) Rapid Shutdown Switch.

A rapid shutdown switch shall have a label that includes the following wording located on or no more than 1 m (3 ft) from the switch:

RAPID SHUTDOWN SWITCH FOR SOLAR PV SYSTEM

The label shall be reflective, with all letters capitalized and having a minimum height of 9.5 mm (⅜ in.) in white on red background.

Statement of Problem and Substantiation for Public Input

This PI is one of three submitted on behalf of the NFPA 1/ NEC PV Joint Task Group. The Task Group is comprised of Ken Bush – NFPA 1 (Technical Committee Chair), Shane Clary – NFPA 1, Rebekah Hren – NEC Panel 4, Bruce Johnson – NFPA 1 (Task Group Chair) and Jim Rogers – NEC Panel 4 Chair. The three consensus proposals are being submitted by the Task Group with the purpose of fully harmonizing the PV system and power source labeling and marking requirements of the NEC with those of the Fire Code. Slight variations that have existed in color, formatting, and marking language requirements between the Fire Code and the NEC have made it unnecessarily difficult for enforcement and inspections agencies to align. As an example, the requirement for a yellow background on the Rapid Shutdown label in the NEC as compared to a red background in NFPA 1 could result in a jurisdiction requiring two labels serving the same purpose, though by their dual presence possibly causing confusion. Clearly this is not practical or desirable and the Codes should be harmonized. This PI specifically aligns Rapid Shutdown label reflectivity, font height, and red-on-white background color requirements in NFPA 1 11.12.2.1.1.2 with the NEC.

Submitter Information Verification

Submitter Full Name: Rebekah Hren
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Submittal Date: Wed Sep 09 08:08:12 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9243-NFPA 70-2021

Statement: Marking requirements are moved to more relevant section 690.12(D). In addition, slight variations that have existed in color, formatting, and marking language requirements between the Fire Code and the NEC have made it unnecessarily difficult for enforcement and inspections agencies to align. The specific color requirement was removed to accommodate local requirements that may differ.

Public Input No. 3696-NFPA 70-2020 [Section No. 690.56(C)]

690.12 (C E) – Marking for Buildings with Rapid Shutdown.

Buildings with PV systems shall have a permanent label located at each service equipment location to which the PV systems are connected or at an approved readily visible location and shall indicate the location of rapid shutdown initiation devices. The label shall include a simple diagram of a building with a roof and shall include the following words:

SOLAR PV SYSTEM IS EQUIPPED WITH RAPID SHUTDOWN.

TURN RAPID SHUTDOWN SWITCH TO THE "OFF" POSITION TO SHUT DOWN

PV SYSTEM AND REDUCE SHOCK HAZARD IN ARRAY.

The title "SOLAR PV SYSTEM IS EQUIPPED WITH RAPID SHUTDOWN" shall utilize capitalized characters with a minimum height of 9.5 mm (⅜ in.) in black on yellow background, and the remaining characters shall be capitalized with a minimum height of 4.8 mm (³⁄₁₆ in.) in black on white background.

Informational Note

~~: See Informational Note~~

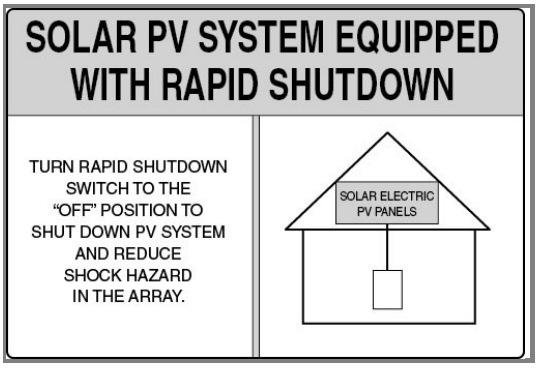
Figure 690.

~~56~~

12 (

~~C).~~

~~**Figure Informational Note Figure 690.56(C) E) Label for Roof-Mounted PV Systems with Rapid Shutdown.**~~



(1) Buildings with More Than One Rapid Shutdown Type.

For buildings that have PV systems with more than one rapid shutdown type or PV systems with no rapid shutdown, a detailed plan view diagram of the roof shall be provided showing each different PV system with a dotted line around areas that remain energized after rapid shutdown is initiated.

(2) Rapid Shutdown Switch.

A rapid shutdown switch shall have a label that includes the following wording located on or no more than 1 m (3 ft) from the switch:

RAPID SHUTDOWN SWITCH FOR SOLAR PV SYSTEM

The label shall be reflective, with all letters capitalized and having a minimum height of 9.5 mm (⅜ in.) in white on red background.

Statement of Problem and Substantiation for Public Input

To increase usability, the enforcement requirements for rapid shutdown should be located together in one section. This PI is not intended to change any intent of this Code requirement, it is simply merely moving the location of the existing language so labeling is co-located with other rapid shutdown requirements. This change is part of a larger initiative to group applicable but dispersed information into fewer, but more comprehensive, sections.
In particular, marking and labeling requirements have historically been either interspersed through the Article or in the non-comprehensive Part VI. Marking. In lieu of Part VI never containing all of the marking requirements, the proposal is to group specific requirements in their applicable sections wherever feasible.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain, P.E., SEIA; Bill Brooks, Brooks Engineering/PVICC; Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing, Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower; Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Ben Chamberlain, Olivewood Energy; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

Submitter Information Verification

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Submittal Date: Wed Sep 09 10:59:30 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9243-NFPA 70-2021

Statement: Marking requirements are moved to more relevant section 690.12(D). In addition, slight variations that have existed in color, formatting, and marking language requirements between the Fire Code and the NEC have made it unnecessarily difficult for enforcement and inspections agencies to align. The specific color requirement was removed to accommodate local requirements that may differ.

Public Input No. 2996-NFPA 70-2020 [Section No. 690.59]

~~**690.59** Connection to Other Sources.~~

~~PV systems connected to other sources shall be installed in accordance with Parts I and II of Article 705 and Article 712 .~~

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

This text is not necessary and the existing language violates the style manual. This is a reference to another Article and is not required and so is being deleted.

Submitter Information Verification

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Submittal Date: Thu Sep 03 20:24:52 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9494-NFPA 70-2021
Statement: This revision removes the reference to Article 712 as Article 705 covers the required connections.

Public Input No. 2997-NFPA 70-2020 [Section No. 690.71]

~~**690.71** General.~~

~~An energy storage system connected to a PV system shall be installed in accordance with Article 706 .~~

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

This Section violates the style manual and is not necessary. The realignment of alternative energy system articles will raise the awareness on all pertinent requirements in the NEC such that this type of reference is no longer necessary.

Submitter Information Verification

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Submittal Date: Thu Sep 03 20:35:57 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9296-NFPA 70-2021
Statement: This section is deleted since it does not modify Article 706 and is merely a pointer to an article that would already apply to an ESS installation. With this action there is no longer a need for a separate part so that title is also deleted.

Public Input No. 4334-NFPA 70-2020 [Section No. 690.71]

~~**690.71** General.~~

~~An energy storage system connected to a PV system shall be installed in accordance with Article 706.~~

Statement of Problem and Substantiation for Public Input

This language was added when Article 706 was new but since this is the third cycle for this article, this pointer is no longer needed. Additionally, it is not accurate or complete since Article 705 would also apply, along with potentially other articles.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI's submitted.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain, P.E., SEIA; Bill Brooks, PVICC; John Berdner, PVICC, Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing, Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower; Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

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Submittal Date: Thu Sep 10 10:32:11 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9296-NFPA 70-2021

Statement: This section is deleted since it does not modify Article 706 and is merely a pointer to an article that would already apply to an ESS installation. With this action there is no longer a need for a separate part so that title is also deleted.

Public Input No. 776-NFPA 70-2020 [New Section after 690.72]

TITLE OF NEW CONTENT

Type your content here ...

Part IX Electromagnetic Pulse (EMP) Protection

690.74 Electromagnetic Pulse (EMP) Protection. Protection for solar photovoltaic (PV) systems against the effects of electromagnetic pulses shall be provided at a minimum of Level 2. See 709.7 for levels of electromagnetic pulse protection.

Exception: The requirements of 709.7(A)(5) and 709.7(B)(3) shall not apply.

This requirement shall become effective January 1, 2026.

Statement of Problem and Substantiation for Public Input

A devastating electromagnetic pulse (EMP), caused by a sun-spot or a nuclear bomb exploded high in the atmosphere, can impress 50,000 volts per meter on unprotected electrical and electronic equipment. It is similar to a radio wave impressing a very small voltage on a radio antenna, only orders of magnitude larger. The problem is that a significant EMP will fry every electrical/electronic component or piece of equipment that is not protected.

The EMP won't directly harm or injure people, but because there is no longer a working electrical infrastructure, which may take years to repair/rebuild, people will die from the lack of clean water, medicine, food, fuel, and eventual rioting due to the breakdown of society. Unclassified studies, referenced at the end of this substantiation, have estimated from 66% to 90% of the US population will die within one year if a significant sun spot were to occur or if a nuclear explosion were to occur 25 to 250 miles over the Midwest.

Our US military already "hardens" systems/buildings so that our country's critical defensive capabilities are not completely destroyed. There are two major methods of protecting electrical/electronic systems. The first is that surge protective devices are installed on all "incoming" power and communications cables, shunting overvoltages to ground. The second is that Faraday cages are installed around equipment/rooms, preventing the EMP from reaching critical equipment/components.

The NEC® needs to address EMP protection for equipment, systems and special occupancies that are critical to our survival. Electrical and electronic equipment can and must be protected, as has been achieved by our military. Unfortunately, there are no requirements to protect civilian electrical and electronic equipment/systems from EMPs.

The NEC Correlating Committee has informally advised that an EMP Protection Article, if passed and adopted into the NEC®, would be most appropriately located after Article 708 (COPS). Thus, Public Input 756 has suggested a new Article 709 under jurisdiction of CMP 13, which already has purview over Emergency Systems (Article 700), Legally Required Standby Systems (Article 701), Optional Standby Systems (Article 702), and Critical Operations Power Systems (Article 708).

Levels of protection and associated protection requirements listed in the Public Input(s) are based upon the unclassified National Cybersecurity and Communications Integration Center report "Electromagnetic Pulse (EMP) Protection and Resilience Guidelines for Critical Infrastructure and Equipment". This study explains electromagnetic pulses and provides the necessary protective measures. It also contains estimates of the costs associated with properly protecting our electrical infrastructure.
The following table contains critical infrastructure components/special occupancies and the maximum time for outages caused by an EMP. Electrical components/infrastructure that is not functioning for periods longer than shown in this table may begin to cause injury or death to people and harm to society/economy.

Critical Infrastructure Component/Special Occupancy	Permitted Outage Time
Branch banking facilities	10 hours
Critical Operations Power Systems	10 minutes
Data centers	10 minutes
Direct current microgrids	10 hours
Drug stores/distribution centers	10 hours
Electrically driven or controlled irrigation machines	1 week
Elevators, dumbwaiters, escalators, moving walks, platform lifts, and stairway chairlifts	See facility requirements
Emergency systems	10 hours
Energy storage systems	10 hours
Fire alarm systems	1 week
Fire houses/stations	10 hours
Fire pumps	10 hours
Food processing and storage facilities	10 hours
Fuel cell systems	10 hours
Generators	10 hours
Grocery stores	10 hours
Hardware stores/home centers	10 hours
Healthcare facilities	See NFPA 99
Information technology equipment	10 minutes
Interconnected electric power production sources	10 minutes
Jails and prisons	10 minutes
Large-scale photovoltaic (PV) electric supply stations	10 hours
Legally required standby systems	10 hours
Modular data centers	10 minutes
Motor fuel dispensing facilities	1 week
Motors, motor circuits, and controllers	See facility requirements
Nuclear reactors	10 seconds
Optional standby systems	1 week
Petrochemical plants/facilities	10 hours
Pharmaceutical plants/facilities	10 hours
Police stations	10 minutes
Solar photovoltaic (PV) systems	10 hours
Stand-alone systems	10 hours
Storage batteries	See facility requirements
Transformers	See facility requirements
Waste water treatment facilities	10 minutes
Water supply facilities	10 hours
Wind electric systems	10 hours

An effectivity date of January 1, 2026 is chosen to allow time for engineering and industry to adequately pan and prepare for the required changes.

Opponents of EMP protection requirements will likely charge that it is too costly to protect our critical infrastructure, and that the NEC® is not a war-time document. A close reading of 90.1 reveals that there is no mention of the “cost” of safeguarding persons and property. Neither does 90.1 mention that safeguarding persons and property is only required during peacetime. Additionally, a significant EMP event, caused by a sunspot, would be an act of God, not an act of war.

The novel, “One Second After”, provides an understanding of what happens when the majority of all unprotected electrical and electronic equipment/systems is destroyed during an EMP event. An audio version of this book is available in two parts, for free, on YouTube.

This link provides the unclassified report “Electromagnetic Pulse (EMP) Protection and Resilience Guidelines for Critical Infrastructure and Equipment”
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&
ved=2ahUKEwjQhp2-77DoAhXBHM0KHboOB2QQFjACegQIBRAC&url=https%3A%2F
%2Fwww.cisa.gov%2Fsites%2Fdefault%2Ffiles%2Fpublications%2F19_0307_CISA_EMP-Protection-Resilience-Guidelines.pdf&usg=AOvVaw2n7jLtJAUJtOJKHPMqWsTE

This link provides the study predicting up to 90% of our population could die from an EMP event
http://www.firstempcommission.org/uploads/1/1/9/5/119571849
/nuclear_emp_attack_scenarios_and_combined-arms_cyber_warfare_by_peter_pry_july_2017.pdf

This link provides unclassified guidelines for facility EMP protection
https://info.publicintelligence.net/DHS-FacilitiesGuidelinesEMP.pdf

These links provide Parts 1 and 2 of a national plan for EMP protection.
https://interferencetechnology.com/a-national-plan-for-emp-protection-part-1/
https://interferencetechnology.com/national-plan-emp-protection-part-2-protection-buildings/

We have all just witnessed the chaos and pain caused by not having the “protections” in place to quickly defeat the Covid-19 virus. As unfortunate, costly, painful, and deadly as Covid-19 was, it would be child’s play when compared to a significant EMP event if our critical electrical/electronic infrastructure remains unprotected. Quite simply, NEC® requirements to protect electrical and electronic equipment from an EMP event, could literally save millions of American lives.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 756-NFPA 70-2020 [New Section after 708.64]	
Public Input No. 756-NFPA 70-2020 [New Section after 708.64]	

Submitter Information Verification

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Submittal Date: Mon Mar 23 16:06:20 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: EMP protection, in much the same way as lightning protection, should not be a requirement for all electrical systems. EMP protection is a design issue and the safety hazard of not having EMP has not been adequately provided in the substantiation.

Public Input No. 2998-NFPA 70-2020 [Section No. 690.72]

690.72 Self-Regulated PV Charge Control.

The PV source circuit shall be considered to comply with the requirements of ~~706~~ 695 .33 if:

(1) The PV source circuit is matched to the voltage rating and charge current requirements of the interconnected battery cells and,

(2) The maximum charging current multiplied by 1 hour is less than 3 percent of the rated battery capacity expressed in ampere-hours or as recommended by the battery manufacturer

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

This change aligns with an effort to re-organize the alternative energy sources NEC Articles into a series of articles closely located together. This reorganization places all sources alternate sources as follows:

689 On-Site Energy Sources
690 Solar Photovoltaic (PV) Systems
691 Large-Scale Photovoltaic (PV) Systems
692 Fuel Cell Systems
693 Generators
694 Wind Electric Systems
695 Energy Storage Systems
696 Storage Batteries

This public input aligns with changes that movie 706 to 695. This input supports this effort and to better align with the fact that this Article is closely related to emergency systems. This move makes way for alignment of alternative energy sources article arrangement. These articles are closely related to each other and this change is in alignment with the direction by the correlating committee to review alternative energy sources for conflicts and usability. This new alignment will create a similar structure as that found for hazardous locations. The new Article 689 is the a combination of Articles 705, 710 and 712 and will act to be the new general requirements for this series of alternative energy sources.

Submitter Information Verification

Submitter Full Name: Thomas Domitrovich
Organization: Eaton Corporation
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Submittal Date: Thu Sep 03 20:38:45 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9297-NFPA 70-2021

Statement: The reference to 706.33 is incomplete as this allowance for specific PV equipment applies more generally to the charging of batteries in any application.

Public Input No. 4641-NFPA 70-2020 [Section No. 690.72]

690.72 Self-Regulated PV Charge Control.

The PV source circuit shall be considered to comply with the requirements ~~of 706.33 if~~ for charge control of a battery if :

(1) The PV source circuit is matched to the voltage rating and charge current requirements of the interconnected battery cells and,

(2) The maximum charging current multiplied by 1 hour is less than 3 percent of the rated battery capacity expressed in ampere-hours or as recommended by the battery manufacturer

Statement of Problem and Substantiation for Public Input

The reference to 706 is not accurate as this allowance for specific PV equipment applies more generally to the charging of batteries.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI's submitted.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain, P.E., SEIA; Bill Brooks, PVICC; John Berdner, PVICC, Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing, Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower; Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

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Committee: NEC-P04

Committee Statement

Resolution: FR-9297-NFPA 70-2021
Statement: The reference to 706.33 is incomplete as this allowance for specific PV equipment applies more generally to the charging of batteries in any application.

Public Input No. 3971-NFPA 70-2020 [Section No. 691.1]

691.1 Scope.

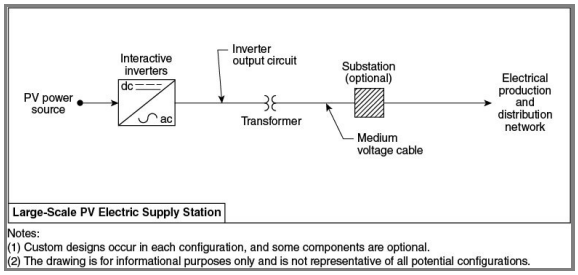
This article covers the installation of large-scale PV electric supply stations ~~with an inverter generating capacity of no less than 5000 kW, and~~ not under exclusive utility control.

Informational Note No. 1: Facilities covered by this article t ypically have a generating capacity of many megawatts located at a single premises or a group of sites from different locations being monitored and controlled from a central command center. These facilities have specific design and safety features, including those stated in 691.4, that are unique to large-scale PV facilities ~~and~~ . They are operated for the sole purpose of providing electric supply through a dedicated connection to a system operated by a regulated utility for the transfer of electric energy and commonly include communications for monitoring and control as specified by the regulating utility .

Informational Note No. 2: Section 90.2(B)(5) includes information about utility-owned properties not covered under this *Code*. For additional information on electric supply stations, see ANSI/IEEE C2-~~2017~~ , *National Electrical Safety Code*.

Informational Note No. 3: See Informational Note Figure 691.1.

Figure Informational Note Figure 691.1 Identification of Large-Scale PV Electric Supply Station Components.



Additional Proposed Changes

File Name	Description	Approved
PV_power_plants_5_MW_or_smaller.pdf		

Statement of Problem and Substantiation for Public Input

The proposed changes provide better clarification of how 691 is used in relationship to 690 and allows for smaller than 5000kW sites to be installed where they meet the restrictions and safety measures within this article.

Article 691 contains additional safety measures and restrictions that remove the need to apply a lot of the requirements in 690 while requiring engineering justification of how those requirements in 690 that do apply are complied with. These addition safety measures and restrictions have nothing to do with the generating capacity other than the feasibility of adding this extra expense to small facilities. The wording of 691 should not keep these smaller sites from applying these restrictions and additional requirements. With the introduction of more advanced equipment required by standards like IEEE1547-2018 (including communications and interoperability requirements) that equipment will be complying with before the 2023 code, it is more feasible to include these additional requirements to smaller sites. Or, even a group of sites being monitored and controlled by one command center.

For those requirements in 690 that should also apply to 691 equipment, the stamped engineered design and report shall include these details of conformance as stated in 691.6. Therefore, 691 should not be

viewed as a way to ignore 690. It puts the responsibility on the licensed engineer and the ability of the AHJ to question how compliance with 690 is met.

The development of Article 691 (Large-Scale Photovoltaic) was a great step forward, recognizing the uniqueness to this part of the photovoltaic industry. As the industry continues to develop, many of the facilities being constructed are falling below the 5000kW threshold mentioned in the Scope, however these facilities meet all of the other Special Requirements listed in Section 691.4. Recognizing that 5000kW was intended as the minimum size for a project, many AHJ's have and continue to accept projects below the 5000kW capacity.

Referring to the U.S. Energy Information Administration (EIA) webpage, an article from February 7, 2019 "Most U.S. utility-scale solar photovoltaic power plants are 5 megawatts or smaller" notes that "Currently, North Carolina has 433 utility-scale PV facilities with capacities no greater than 5 MW, the most of any state, and accounting for nearly a quarter of all utility-scale PV facilities in the country between 1 MW and 5 MW." (https://www.eia.gov/todayinenergy/detail.php?id=38272);

The EIA also tracks "'Monthly Update to Annual Electric Generator Report' supplements the annual survey form EIA-860 data", this information "monitors the current status of existing and proposed generating units at electric power plants with 1 megawatt or greater of combined nameplate capacity". (https://www.eia.gov/electricity/data/eia860M/) Downloading the spreadsheet and filtering by "Solar Photovoltaic", limiting the size to 5 MW, filtering "IPP" (Independent Power Producer), you find the following statistics: "Inventory of Operating Generators as of May 2020" equals 1,108 projects and the "Inventory of Planned Generators as of May 2020" equals 250 projects with the following breakdown: South Carolina (SC) @ 46, North Carolina (NC) @ 16, Illinois (IL) @ 11, Massachusetts (MA) @ 21. Additionally, the State of Illinois under it's "Power Agency Act" defines a "utility-scale solar project" that has a nameplate capacity that is greater than 2,000 kilowatts (https://www.ilga.gov/legislation /ilcs/ilcs5.asp?ActID=2934)

The ANSI/IEEE C2, National Electrical Safety Code is being updated, similarly to the NEC code cycle. Plus, Authority Having Jurisdiction` often are not in alignment with one another regarding which code cycle to utilize. Omission of the date (year), allows the code to remain relevant, while lifting the specific date reference.

An attachment is included with some of the references referred to in this substantiation.

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Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

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Committee: NEC-P04

Committee Statement

Resolution: FR-9299-NFPA 70-2021

Statement: This revision removes “stations with an inverter generating capacity of no less than 5000 kW” from the scope. The threshold is moved to 691.4

Informational Note No.1 was revised to help users understand where the special requirements that make up a large-scale system are located.

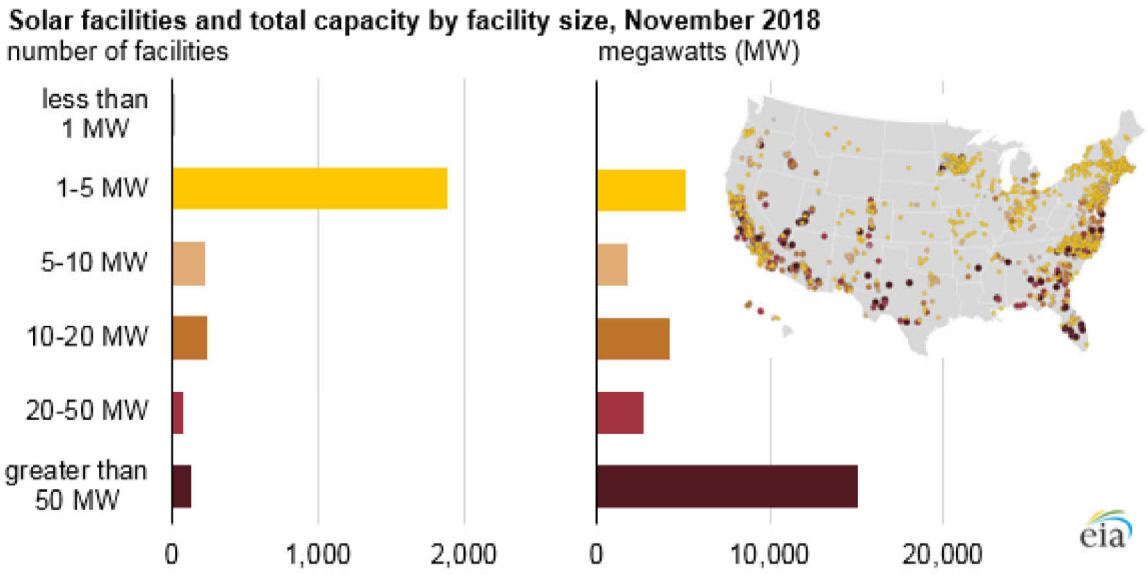
U.S. Energy Information Administration

Skip to sub-navigation

Today in Energy

February 7, 2019

Most U.S. utility-scale solar photovoltaic power plants are 5 megawatts or smaller



Source: U.S. Energy Information Administration, *Preliminary Monthly Electric Generator Inventory*, November 2018

The United States has more than 2,500 utility-scale solar photovoltaic (PV) electricity generating facilities. Most of these power plants are relatively small and collectively account for 2.5% of utility-scale electric generating capacity and 1.7% of annual electricity generation, based on data through November 2018.

EIA considers utility-scale generating facilities to be those where total generation capacity is one megawatt (MW) or greater. However, some utility-scale sites use more than one generating technology. At utility-scale facilities where PV is one of several technologies in use, the PV capacity itself may be less than one megawatt, but this is relatively rare: based on EIA's latest data, only 20 sites with a total combined capacity of 10 MW were in this category.

The growth in small utility-scale facilities is driven by several factors, many of which are tied to state-level policies and practices. For example, North Carolina used the Public Utilities Regulatory Policies Act of 1978 to allow utilities to set long-term purchase agreements with solar facilities, enabling solar developers to secure project funding more easily and spurring growth.

Currently, North Carolina has 433 utility-scale PV facilities with capacities no greater than 5 MW, the most of any state, and accounting for nearly a quarter of all utility-scale PV facilities in the country between 1 MW and 5 MW. These facilities collectively account for 1,803 MW of capacity, or 35% of the total U.S. PV capacity located at facilities with 1 MW to 5 MW of installed capacity.

In other states, the growth of small utility-scale PV capacity is encouraged by strategies that include, for example, community solar facilities. Community solar facilities offer a share of their solar capacity for sale to off-site customers who may not necessarily have access to solar generation. In these programs, customers may subscribe to a designated community solar

facility and receive monthly credits on their electric bills for the energy generated by the share of solar capacity they purchase. The average community solar facility has a capacity of 2.0 MW.

Growth in small utility-scale facilities is expected to continue through 2020. EIA's Preliminary Monthly Electric Generator Inventory for October 2018 reports that most of the 216 solar PV facilities that will come online by the end of 2020 will have capacities of five megawatts or less.

Solar PV facilities with less than one megawatt in capacity are not included in EIA's surveys of electricity generators, but their aggregate capacities are included in the EIA's survey of electric power sales, revenue, and energy efficiency and are represented in EIA's *Electric Power Monthly*. EIA estimates small-scale solar PV capacity to be about 40% of total solar capacity connected to the grid as of November 2018.

Principal contributor: Alex Mey

U.S. Energy Information Administration

Electricity

The monthly survey Form EIA-860M, 'Monthly Update to Annual Electric Generator Report' supplements the annual survey form EIA-860 data with monthly information that monitors the current status of existing and proposed generating units at electric power plants with 1 megawatt or greater of combined nameplate capacity. EIA estimates the current and near-term unit inventory of electric power generating capacity by integrating the information on these surveys along with ongoing EIA research of new units. However, creating this monthly estimate sometimes requires the use of data submitted on the annual EIA-860 before it has been fully verified by EIA. For this reason, reported capacities are EIA's preliminary estimates of capacity for that month. Estimates will be corrected without specific acknowledgement or explanation in subsequent month's inventory.

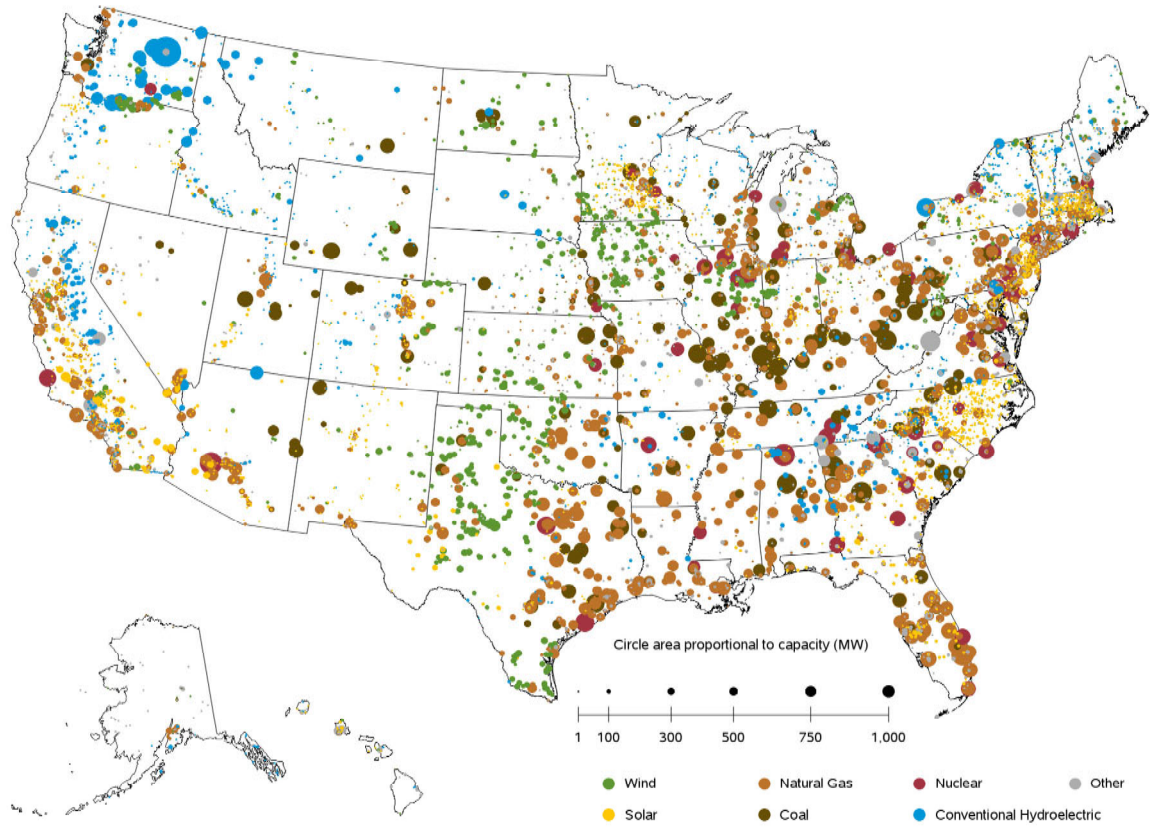
Starting with March 2017 data, Preliminary Monthly Electric Generator Inventory includes a comprehensive list of generators which retired since 2002. The list can be found on the 'Retired' tab of the datafile.

Starting with March 2018 data, *Preliminary Monthly Electric Generator Inventory* also includes data from Puerto Rico for existing, retired, and proposed generating units at electric power plants with combined nameplate capacity of 1 megawatt or greater.

Capacities reported in this preliminary inventory are best estimates of current generating capacity, but are not meant to be capacity commitments by the associated facilities.

The final inventory of generators is published each year with the annual EIA-860.

Operable utility-scale generating units as of May 2020



Sources: U.S. Energy Information Administration, Form EIA-860, 'Annual Electric Generator Report' and Form EIA-860M, 'Monthly Update to the Annual Electric Generator Report.'

EIA 860M

2020

Illinois Compiled Statutes

Information maintained by the Legislative Reference Bureau
Updating the database of the Illinois Compiled Statutes (ILCS) is an ongoing process. Recent laws may not yet be included in the ILCS database, but they are found on this site as Public Acts soon after they become law. For information concerning the relationship between statutes and Public Acts, refer to the Guide.

Because the statute database is maintained primarily for legislative drafting purposes, statutory changes are sometimes included in the statute database before they take effect. If the source note at the end of a Section of the statutes includes a Public Act that has not yet taken effect, the version of the law that is currently in effect may have already been removed from the database and you should refer to that Public Act to see the changes made to the current law.

EXECUTIVE BRANCH
(20 ILCS 3855/) Illinois Power Agency Act.

(20 ILCS 3855/Art. 1 heading)
ARTICLE 1

(Source: P.A. 95-481, eff. 8-28-07.)

(20 ILCS 3855/1-1)
Sec. 1-1. Short title. This Article may be cited as the Illinois Power Agency Act. References in this Article to "this Act" mean this Article.
(Source: P.A. 95-481, eff. 8-28-07.)

(20 ILCS 3855/1-5)
Sec. 1-5. Legislative declarations and findings. The General Assembly finds and declares:
(1) The health, welfare, and prosperity of all Illinois citizens require the provision of adequate, reliable, affordable, efficient, and environmentally sustainable electric service at the lowest total cost over time, taking into account any benefits of price stability.
(2) (Blank).
(3) (Blank).
(4) It is necessary to improve the process of procuring electricity to serve Illinois residents, to promote investment in energy efficiency and demand-response measures, and to maintain and support development of clean coal technologies, generation resources that operate at all hours of the day and under all weather conditions, zero emission facilities, and renewable resources.
(5) Procuring a diverse electricity supply portfolio will ensure the lowest total cost over time for adequate, reliable, efficient, and environmentally sustainable electric service.
(6) Including renewable resources and zero emission credits from zero emission facilities in that portfolio will reduce long-term direct and indirect costs to consumers by decreasing environmental impacts and by avoiding or delaying the need for new generation,

an agreement between the owner of a clean coal SNG brownfield facility and the gas utility, which agreement shall have the terms and conditions meeting the requirements of subsection (h-1) of Section 9-220 of the Public Utilities Act.

"Subscriber" means a person who (i) takes delivery service from an electric utility, and (ii) has a subscription of no less than 200 watts to a community renewable generation project that is located in the electric utility's service area. No subscriber's subscriptions may total more than 40% of the nameplate capacity of an individual community renewable generation project. Entities that are affiliated by virtue of a common parent shall not represent multiple subscriptions that total more than 40% of the nameplate capacity of an individual community renewable generation project.

"Subscription" means an interest in a community renewable generation project expressed in kilowatts, which is sized primarily to offset part or all of the subscriber's electricity usage.

"Substitute natural gas" or "SNG" means a gas manufactured by gasification of hydrocarbon feedstock, which is substantially interchangeable in use and distribution with conventional natural gas.

"Total resource cost test" or "TRC test" means a standard that is met if, for an investment in energy efficiency or demand-response measures, the benefit-cost ratio is greater than one. The benefit-cost ratio is the ratio of the net present value of the total benefits of the program to the net present value of the total costs as calculated over the lifetime of the measures. A total resource cost test compares the sum of avoided electric utility costs, representing the benefits that accrue to the system and the participant in the delivery of those efficiency measures and including avoided costs associated with reduced use of natural gas or other fuels, avoided costs associated with reduced water consumption, and avoided costs associated with reduced operation and maintenance costs, as well as other quantifiable societal benefits, to the sum of all incremental costs of end-use measures that are implemented due to the program (including both utility and participant contributions), plus costs to administer, deliver, and evaluate each demand-side program, to quantify the net savings obtained by substituting the demand-side program for supply resources. In calculating avoided costs of power and energy that an electric utility would otherwise have had to acquire, reasonable estimates shall be included of financial costs likely to be imposed by future regulations and legislation on emissions of greenhouse gases. In discounting future societal costs and benefits for the purpose of calculating net present values, a societal discount rate based on actual, long-term Treasury bond yields should be used. Notwithstanding anything to the contrary, the TRC test shall not include or take into account a calculation of market price suppression effects or demand reduction induced price effects.

"Utility-scale solar project" means an electric generating facility that:

(1) generates electricity using photovoltaic cells; and

(2) has a nameplate capacity that is greater than 2,000 kilowatts.

"Utility-scale wind project" means an electric generating facility that:

(1) generates electricity using wind; and

(2) has a nameplate capacity that is greater than 2,000 kilowatts.

"Zero emission credit" means a tradable credit that represents the environmental attributes of one megawatt hour of energy produced from a zero emission facility.

Public Input No. 3893-NFPA 70-2020 [Section No. 691.2]

(Relocate all definitions in the 691. 2 to Article 100, arrange them in alphabetical order and without any subdivisions.)

691. 2 Definitions.

The definitions in this section shall apply only within this article.

Electric Supply Stations.

Locations containing the generating stations and substations, including their associated generator, storage battery, transformer, and switchgear areas.

Generating Station.

A plant wherein electric energy is produced by conversion from some other form of energy (e.g., chemical, nuclear, solar, wind, mechanical, or hydraulic) by means of suitable apparatus.

Statement of Problem and Substantiation for Public Input

"The National Electrical Code has definitions in multiple parts in Article 100 and many definitions scattered through out the code many of them in the .2 section of the articles.
Most of the other standards under NFPA have their definitions in one location and this will allow the NEC the same requirement. The revisions to the NEC Style Manual require all the definitions to be relocated to Article 100. "

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Committee: NEC-P04

Committee Statement

Resolution: FR-9324-NFPA 70-2021

Statement: This revision moves all definitions previously in Section 2 of Articles 690, 692, 694 and 705 to Article 100.

The NEC Style Manual also requires that for definitions that apply in only one article, the article number in parentheses shall follow the definition.

CMP-4 identified the following definitions that apply to only one article:

690: AC Module System, AC Module, Array, Direct-Current Combiner, Module, Monopole Circuit, PV Output Circuit, PV Source Circuit, PV System DC Circuit.

692: Fuel Cell Output Circuit

694: Maximum Output Power, Maximum Voltage, Nacelle, Rated Power, Tower, Wind Turbine Output Circuit.

These have been moved to Article 100 with the relevant article number appended. All other definitions have been moved with no article number identified.

All definitions were moved with the annotation (CMP-4) appended to indicate the code panel responsible for the definition in accordance with NEC Style Manual Section 2.2.2.3.3.

Public Input No. 4013-NFPA 70-2020 [Section No. 691.4]

691.4 Special Requirements for Large-Scale PV Electric Supply Stations.

Large-scale PV electric supply stations shall be accessible only to authorized personnel and comply with the following:

(1) Electrical circuits and equipment shall be maintained and operated only by qualified personnel.

Informational Note: Refer to *NFPA 70E*-2018, *Standard for Electrical Safety in the Workplace*, for electrical safety requirements.

(2) Access to PV electric supply stations shall be restricted ~~by fencing or other adequate means~~ in accordance with 110.31. Field-applied hazard markings shall be applied in accordance with 110.21(B).

(3) The connection between the PV electric supply station and the system operated by a utility for the transfer of electrical energy shall be through medium- or high-voltage switch gear, substation, switch yard, or similar methods whose sole purpose shall be to safely and effectively interconnect the two systems.

(4) The electrical loads within the PV electric supply station shall only be used to power auxiliary equipment for the generation of the PV power.

(5) Large-scale PV electric supply stations shall not be installed on buildings.

Statement of Problem and Substantiation for Public Input

This change removes the qualifier so as not to imply any modification to 110.31 requirements and keeps the first part of the sentence which states 110.31 applies to the entire PV Electric Supply Station facility including all equipment.

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Committee: NEC-P04

Committee Statement

Resolution: FR-9302-NFPA 70-2021
Statement: The original language was not intended to imply any modification to 110.31. This First Revision clarifies that 110.31 applies to the entire PV electric supply station.

Public Input No. 4015-NFPA 70-2020 [Section No. 691.9]

691.9 Disconnecting Means for Isolating Photovoltaic Equipment.

~~Isolating devices shall not be required within sight of equipment and shall be permitted to be located remotely from equipment.~~ The engineered design required by 691.6 shall document disconnection procedures and means of isolating equipment.

Informational Note: For information on electrical system maintenance, see NFPA 70B-2019, *Recommended Practice for Electrical Equipment Maintenance*. For information on written procedures and conditions of maintenance, including lockout/tagout procedures, see NFPA *70E*-2018.

Buildings whose sole purpose is to house and protect supply station equipment shall not be required to comply with 690.12. Written standard operating procedures shall be available at the site detailing necessary shutdown procedures in the event of an emergency.

Statement of Problem and Substantiation for Public Input

This change removes the first sentence from 691.9 since it is unnecessary as this allowance exists within 690.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI's submitted.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain, P.E., SEIA; Bill Brooks, PVICC; John Berdner, PVICC, Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing, Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower; Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett,

DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

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Submittal Date: Wed Sep 09 17:29:30 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9306-NFPA 70-2021
Statement: This change modifies the first sentence in Section 691.9 to refer to any type of disconnection of equipment.

Public Input No. 2417-NFPA 70-2020 [Section No. 691.10]

691.10 Arc-Fault Mitigation.

PV ~~systems that do not comply with the requirements of~~ 690.11 ~~shall~~ systems shall include details of fire mitigation plans to address dc arc-faults in the documentation required in 691.6.

Statement of Problem and Substantiation for Public Input

1) To institute a provision for non-compliance to a separate segment of code, infers an alternate compliance path. However, 690.11 makes no mention of an alternate compliance path. Either this reference should be struck from this passage, or text added to 690.11 to correlate an understanding of an alternate compliance path.
2) The code text indicates that no consideration of DC arc fault is required if fencing details are included in the design documents. This intent does not seem reasonable as arc faults can be an issue for much more than fencing.

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Committee: NEC-P04

Committee Statement

Resolution: FR-9308-NFPA 70-2021
Statement: The title is changed to be more inclusive while the text still refers specifically to dc arc-fault mitigation. The informational note recognizes how fire mitigation plans will be addressed for a given facility and location. Since each jurisdiction may have unique challenges, not all plans will work in all locations.

Public Input No. 4018-NFPA 70-2020 [Section No. 691.10]

691.10 ~~Arc-Fault Mitigation~~ 10 Fire Mitigation .

PV systems that do not comply with the requirements of 690.11 shall include details of fire mitigation plans to address dc arc-faults in the documentation required in 691.6.

Informational Note: Fire mitigation plans typically are reviewed by the local fire agency and include topics such as access roads within the facility. Consideration of other requirements including the National Pollutant Discharge Elimination System (NPDES) or equivalent, pollinator habitats and other environmental restrictions are generally incorporated into the plan.

Statement of Problem and Substantiation for Public Input

The title change addresses fire mitigation, in lieu of arc-fault mitigation which represents the intent of this subsection better. Future fire mitigation requirements would fall within this subsection and would not necessarily address arc-fault mitigation.

The addition of the informational note is to recognize that other environmental regulations play into consideration in how the fire mitigation plan should be addressed for a given facility location. Since each jurisdiction has its unique challenges, not all plans will work in all locations.

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Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI's submitted.
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DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

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Submittal Date: Wed Sep 09 17:33:19 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9308-NFPA 70-2021

Statement: The title is changed to be more inclusive while the text still refers specifically to dc arc-fault mitigation. The informational note recognizes how fire mitigation plans will be addressed for a given facility and location. Since each jurisdiction may have unique challenges, not all plans will work in all locations.

Public Input No. 1499-NFPA 70-2020 [New Section after 691.11]

691.12 Energy Storage System.

An energy storage system connected to a large-scale PV electric supply station shall be installed in accordance with Article 706.

Statement of Problem and Substantiation for Public Input

Currently ESS's are being installed in conjunction with large-scale PV electric supply stations. As Article 706 is a relatively new article, there needs to be a requirement like 690.71 where users of this code are directed to the additional requirements of ESS's.

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Committee: NEC-P04

Committee Statement

Resolution: How an Article 691 system would interact with another power source is beyond the scope of Article 691. Article 706 applies based on the organization of this Code unless the AHJ institutes alternate means for the installation. NFPA 855 also covers these installations and has much more information regarding large-scale ESS.

Public Input No. 770-NFPA 70-2020 [New Section after 691.11]

TITLE OF NEW CONTENT

Type your content here ...

691.12Electromagnetic Pulse (EMP) Protection. Protection for large-scale photovoltaic (PV) electric supply stations against the effects of electromagnetic pulses shall be provided at a minimum of Level 2. See 709.7 for levels of electromagnetic pulse protection.

Exception: The requirements of 709.7(A)(5) and 709.7(B)(3) shall not apply.

This requirement shall become effective January 1, 2026.

Statement of Problem and Substantiation for Public Input

A devastating electromagnetic pulse (EMP), caused by a sun-spot or a nuclear bomb exploded high in the atmosphere, can impress 50,000 volts per meter on unprotected electrical and electronic equipment. It is similar to a radio wave impressing a very small voltage on a radio antenna, only orders of magnitude larger. The problem is that a significant EMP will fry every electrical/electronic component or piece of equipment that is not protected.

The EMP won't directly harm or injure people, but because there is no longer a working electrical infrastructure, which may take years to repair/rebuild, people will die from the lack of clean water, medicine, food, fuel, and eventual rioting due to the breakdown of society. Unclassified studies, referenced at the end of this substantiation, have estimated from 66% to 90% of the US population will die within one year if a significant sun spot were to occur or if a nuclear explosion were to occur 25 to 250 miles over the Midwest.

Our US military already "hardens" systems/buildings so that our country's critical defensive capabilities are not completely destroyed. There are two major methods of protecting electrical/electronic systems. The first is that surge protective devices are installed on all "incoming" power and communications cables, shunting overvoltages to ground. The second is that Faraday cages are installed around equipment/rooms, preventing the EMP from reaching critical equipment/components.

The NEC® needs to address EMP protection for equipment, systems and special occupancies that are critical to our survival. Electrical and electronic equipment can and must be protected, as has been achieved by our military. Unfortunately, there are no requirements to protect civilian electrical and electronic equipment/systems from EMPs.

The NEC Correlating Committee has informally advised that an EMP Protection Article, if passed and adopted into the NEC®, would be most appropriately located after Article 708 (COPS). Thus, Public Input 756 has suggested a new Article 709 under jurisdiction of CMP 13, which already has purview over Emergency Systems (Article 700), Legally Required Standby Systems (Article 701), Optional Standby Systems (Article 702), and Critical Operations Power Systems (Article 708).

Levels of protection and associated protection requirements listed in the Public Input(s) are based upon the unclassified National Cybersecurity and Communications Integration Center report "Electromagnetic Pulse (EMP) Protection and Resilience Guidelines for Critical Infrastructure and Equipment". This study explains electromagnetic pulses and provides the necessary protective measures. It also contains estimates of the costs associated with properly protecting our electrical infrastructure.
The following table contains critical infrastructure components/special occupancies and the maximum time for outages caused by an EMP. Electrical components/infrastructure that is not functioning for periods longer than shown in this table may begin to cause injury or death to people and harm to society/economy.
Critical Infrastructure Component/Special Occupancy Permitted Outage Time
Branch banking facilities 10 hours

Critical Operations Power Systems 10 minutes
Data centers 10 minutes
Direct current microgrids 10 hours
Drug stores/distribution centers 10 hours
Electrically driven or controlled irrigation machines 1 week
Elevators, dumbwaiters, escalators, moving walks, platform lifts, and stairway chairlifts See facility requirements
Emergency systems 10 hours
Energy storage systems 10 hours
Fire alarm systems 1 week
Fire houses/stations 10 hours
Fire pumps 10 hours
Food processing and storage facilities 10 hours
Fuel cell systems 10 hours
Generators 10 hours
Grocery stores 10 hours
Hardware stores/home centers 10 hours
Healthcare facilities See NFPA 99
Information technology equipment 10 minutes
Interconnected electric power production sources 10 minutes
Jails and prisons 10 minutes
Large-scale photovoltaic (PV) electric supply stations 10 hours
Legally required standby systems 10 hours
Modular data centers 10 minutes
Motor fuel dispensing facilities 1 week
Motors, motor circuits, and controllers See facility requirements
Nuclear reactors 10 seconds
Optional standby systems 1 week
Petrochemical plants/facilities 10 hours
Pharmaceutical plants/facilities 10 hours
Police stations 10 minutes
Solar photovoltaic (PV) systems 10 hours
Stand-alone systems 10 hours
Storage batteries See facility requirements
Transformers See facility requirements
Waste water treatment facilities 10 minutes
Water supply facilities 10 hours
Wind electric systems 10 hours

An effectivity date of January 1, 2026 is chosen to allow time for engineering and industry to adequately pan and prepare for the required changes.

Opponents of EMP protection requirements will likely charge that it is too costly to protect our critical infrastructure, and that the NEC® is not a war-time document. A close reading of 90.1 reveals that there is no mention of the “cost” of safeguarding persons and property. Neither does 90.1 mention that safeguarding persons and property is only required during peacetime. Additionally, a significant EMP event, caused by a sunspot, would be an act of God, not an act of war.

The novel, “One Second After”, provides an understanding of what happens when the majority of all unprotected electrical and electronic equipment/systems is destroyed during an EMP event. An audio version of this book is available in two parts, for free, on YouTube.

This link provides the unclassified report “Electromagnetic Pulse (EMP) Protection and Resilience Guidelines for Critical Infrastructure and Equipment”
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&ved=2ahUKEwjQhp2-77DoAhXBHM0KHboOB2QQFjACegQIBRAC&url=https%3A%2F%2Fwww.cisa.gov%2Fsites%2Fdefault%2Ffiles%2Fpublications%2F19_0307_CISA_EMP-Protection-Resilience-Guidelines.pdf&usg=AOvVaw2n7jLtJAUJtOJKHPMqWsTE

This link provides the study predicting up to 90% of our population could die from an EMP event
http://www.firstempcommission.org/uploads/1/1/9/5/119571849

/nuclear_emp_attack_scenarios_and_combined-arms_cyber_warfare_by_peter_pry_july_2017.pdf

This link provides unclassified guidelines for facility EMP protection
https://info.publicintelligence.net/DHS-FacilitiesGuidelinesEMP.pdf

These links provide Parts 1 and 2 of a national plan for EMP protection.
https://interferencetechnology.com/a-national-plan-for-emp-protection-part-1/
https://interferencetechnology.com/national-plan-emp-protection-part-2-protection-buildings/

We have all just witnessed the chaos and pain caused by not having the “protections” in place to quickly defeat the Covid-19 virus. As unfortunate, costly, painful, and deadly as Covid-19 was, it would be child’s play when compared to a significant EMP event if our critical electrical/electronic infrastructure remains unprotected. Quite simply, NEC® requirements to protect electrical and electronic equipment from an EMP event, could literally save millions of American lives.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 756-NFPA 70-2020 [New Section after 708.64]	
Public Input No. 756-NFPA 70-2020 [New Section after 708.64]	

Submitter Information Verification

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Submittal Date: Mon Mar 23 14:07:19 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: EMP protection, in much the same way as lightning protection, should not be a requirement for all electrical systems. EMP protection is a design issue and the safety hazard of not having EMP has not been adequately provided in the substantiation.

Public Input No. 3894-NFPA 70-2020 [Section No. 692.2]

(Relocate all definitions in the 692. 2 to Article 100, arrange them in alphabetical order and without any subdivisions.)

692. 2 Definitions.

The following definition(s) shall apply only within this article.

Fuel Cell Output Circuit.

The conductors used to connect the fuel cell system to its electrical point of delivery.

Informational Note: In the case of sites that have series- or parallel-connected multiple units, the term *output circuit* also refers to the conductors used to electrically interconnect the fuel cell system(s).

Statement of Problem and Substantiation for Public Input

"The National Electrical Code has definitions in multiple parts in Article 100 and many definitions scattered through out the code many of them in the .2 section of the articles.
Most of the other standards under NFPA have their definitions in one location and this will allow the NEC the same requirement. The revisions to the NEC Style Manual require all the definitions to be relocated to Article 100. "

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Submittal Date: Wed Sep 09 14:59:55 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9612-NFPA 70-2021
Statement: This term is not used within this article.

Public Input No. 2999-NFPA 70-2020 [Section No. 692.4(B)]

(B) Identification of Power Sources.

Fuel cell systems shall be ~~identified according to~~ ~~692.4(B)(1)~~ ~~through (B)(3).~~

~~**(1)** Interconnected AC Systems.~~

~~Plaques or directories shall be installed in accordance with~~ ~~705.10~~ ~~.~~

~~**(2)** DC Microgrid Systems.~~

~~Plaques or directories shall be~~

marked with p laques or directories installed in accordance with

~~712~~

689 .10 .

~~**(3)** Stand-Alone Systems.~~

~~Plaques or directories shall be installed in accordance with~~ ~~710.10~~ ~~.~~

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

This modification is necessary as 710, 712 and 689 are combined as part of this task group effort into a new Article 689. The proper reference for plaques and directories is found in 689.10 only. In addition, this section was simplified as only one reference section exists. Changes simplify and add clarity.

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Committee: NEC-P04

Committee Statement

Resolution: FR-9480-NFPA 70-2021
Statement: With the changes made to other articles, a single reference to this section is necessary. These references have been consolidated in Section 705.10.

Public Input No. 765-NFPA 70-2020 [New Section after 692.6]

TITLE OF NEW CONTENT

Type your content here ...

692.7 Electromagnetic Pulse (EMP) Protection. Protection for fuel cell systems against the effects of electromagnetic pulses shall be provided at a minimum of Level 2. See 709.7 for levels of electromagnetic pulse protection.

Exception: The requirements of 709.7(A)(5) and 709.7(B)(3) shall not apply.

This requirement shall become effective January 1, 2026.

Statement of Problem and Substantiation for Public Input

A devastating electromagnetic pulse (EMP), caused by a sun-spot or a nuclear bomb exploded high in the atmosphere, can impress 50,000 volts per meter on unprotected electrical and electronic equipment. It is similar to a radio wave impressing a very small voltage on a radio antenna, only orders of magnitude larger. The problem is that a significant EMP will fry every electrical/electronic component or piece of equipment that is not protected.

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Wind electric systems 10 hours

An effectivity date of January 1, 2026 is chosen to allow time for engineering and industry to adequately pan and prepare for the required changes.

Opponents of EMP protection requirements will likely charge that it is too costly to protect our critical infrastructure, and that the NEC® is not a war-time document. A close reading of 90.1 reveals that there is no mention of the “cost” of safeguarding persons and property. Neither does 90.1 mention that safeguarding persons and property is only required during peacetime. Additionally, a significant EMP event, caused by a sunspot, would be an act of God, not an act of war.

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http://www.firstempcommission.org/uploads/1/1/9/5/119571849

/nuclear_emp_attack_scenarios_and_combined-arms_cyber_warfare_by_peter_pry_july_2017.pdf

This link provides unclassified guidelines for facility EMP protection
https://info.publicintelligence.net/DHS-FacilitiesGuidelinesEMP.pdf

These links provide Parts 1 and 2 of a national plan for EMP protection.
https://interferencetechnology.com/a-national-plan-for-emp-protection-part-1/
https://interferencetechnology.com/national-plan-emp-protection-part-2-protection-buildings/

We have all just witnessed the chaos and pain caused by not having the “protections” in place to quickly defeat the Covid-19 virus. As unfortunate, costly, painful, and deadly as Covid-19 was, it would be child’s play when compared to a significant EMP event if our critical electrical/electronic infrastructure remains unprotected. Quite simply, NEC® requirements to protect electrical and electronic equipment from an EMP event, could literally save millions of American lives.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 756-NFPA 70-2020 [New Section after 708.64]	
Public Input No. 756-NFPA 70-2020 [New Section after 708.64]	

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Committee: NEC-P04

Committee Statement

Resolution: EMP protection, in much the same way as lightning protection, should not be a requirement for all electrical systems. EMP protection is a design issue and the safety hazard of not having EMP has not been adequately provided in the substantiation.

Public Input No. 2418-NFPA 70-2020 [Section No. 692.8(A)]

(A) Nameplate Rated Circuit Current.

The ~~nameplate(s) rated circuit current~~ nameplate rated current of a fuel cell system, used for circuit sizing, shall be the total of the rated current(s) indicated on the constituent fuel cell module nameplate(s).

Statement of Problem and Substantiation for Public Input

1) The first use of "nameplate current" used in the sentence does not identify the equipment or system intended to be associated to the requirement. The governing topic indicates it may be for a fuel cell system, but it is unclear due to pluralizing it as nameplate(s).
2) The use of the term "rated circuit current" is unclear to intent as "full load current" or as "circuit ampacity" (e.g. full load current plus some factor), or something else.
3) The second pluralized use of nameplate(s) infers a total sum of currents, where multiple fuel cells exist, may need to be applied; which could be clarified by expounding more description upon the term, such as "constituent fuel cell module nameplates."

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Submittal Date: Thu Aug 20 10:04:02 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: Nameplate information is part of the standard and listing requirements

Public Input No. 4103-NFPA 70-2020 [New Section after 692.13]

TITLE OF NEW CONTENT

Type your content here ...

692.15 Emergency Disconnect. For one- and two-family dwellings, an emergency disconnecting means shall comply with (1) through (4).

(1) Be located in a readily accessible location outside the building

(2) Be located within 1 m (3 ft) of any required emergency service disconnect or where there is no required emergency service disconnect, shall be located within 1 m (3 ft) of any other power source emergency disconnect or any PV rapid shutdown initiator

(3) If remotely controlled, the remote-control system shall be “fail safe” where the disconnect automatically opens on loss of control signal or control power

(4) Be labeled “EMERGENCY FUEL CELL DISCONNECT” and comply with 110.21(B).

Statement of Problem and Substantiation for Public Input

This proposal is one of several related, but separate proposals involving the 2020 NEC requirements for external (outside the building) emergency disconnects on one- and two-family dwellings for energy sources such as the utility service, batteries, energy storage systems (ESS), wind systems and also stand-alone PV systems plus PV rapid shutdown systems. The intent of these proposals is to require multiple emergency disconnects to be grouped in one location to increase safety for Fire Service first responders.

Also, when remote activation of these disconnects is allowed, the proposal establishes an additional safety requirement that the remote controls be “fail safe” and in the event of loss of control power or control signal, the emergency disconnect shall automatically be opened. It has been determined that some inverter manufacturers are already starting to put inputs on their products to allow an external remote shutdown control system that is fail safe.

It has been determined that adding such a fail-safe remotely controlled emergency disconnect system is relatively inexpensive using voltage-trip circuit breakers and a relay on large battery banks or ESS.

Submitter Information Verification

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Submittal Date:	Wed Sep 09 20:43:49 EDT 2020
Committee:	NEC-P04

Committee Statement

Resolution: The current plaque and markings identifying the disconnects are sufficient. The locations of

the disconnects may be required by the product listing standard. Requirements in 692.54 are adequate to provide emergency responders notification of the location of emergency shutoff. It is not possible to locate all disconnecting means at the same location for all installations. Where multiple disconnecting means exist the location must be identified by a site map/plaque

Public Input No. 4172-NFPA 70-2020 [Section No. 692.41(C)]

(C) Systems with Alternating-Current and Direct-Current Grounding Requirements.

When fuel ~~cell power systems~~ cell systems have both alternating-current (ac) and direct-current (dc) grounding requirements, the dc grounding system shall be bonded to the ac grounding system. The bonding conductor shall be sized according to 692.45. A single common grounding electrode and grounding bar may be used for both systems, in which case the common grounding electrode conductor shall be sized to meet the requirements of both 250.66 (ac) and 250.166 (dc).

Statement of Problem and Substantiation for Public Input

This public input is submitted on behalf of the task group formed under the direction of the Correlating Committee to harmonize terminology across NFPA70, 99, 110, and 111 that relate to emergency and standby power and energy storage. This task group was appointed to identify potential proposed changes to the 2023 edition of the NEC in the form of Public Inputs (PIs) that within the Task Group's scope of activity as specified by the Correlating Committee.
The task group members are; Alan Manche-Co-Chair, Todd Lottmann Co-Chair, Steve Froemming, David Stymiest, John Kovacik, Chad Kennedy, Duke Schamel, Linda Little, Jason D'Antona, Chris Coache, Mike McCabe, and Chad Beebe. This task group of balanced interests provided the expertise to develop these public inputs covering the harmonization of terms across NFPA70, 99, 110, and 111.
Public Inputs are being submitted in the following sections: Article 100 definitions, 480.2, 517.30 (B)(1), 517.30(B)(3), 517.31(D), 517.31(F), 517.41(B), 692.41(C), 695.3(C)(2), 700.2, 700.12(D)(1), 700.12(D)(2), 700.18, 701.2, 701.12(D)(1), and 708.20(F)(1)
Summary of Changes
These proposed PIs are intended provide consistent use of terms between the NEC®, NFPA 110, 111. These proposed revisions identified correlating terminology issues and looked across all three standards to determine the changes necessary to harmonize key terms. These public inputs were the changes recommended for the NEC by the task group.

Technical Substantiation
The following substantiation is provided for each change separated by section:
Article 100 – Uninterruptible Power Supply definition was revised to align with the NFPA111 definition.
480.2 – definition for storage battery revised to match NFPA855
517.30 (B)(1) – revised to text to align with references across NEC, NFPA110, and NFPA111
517.30(B)(3) – revised to text to align with references across NEC, NFPA110, and NFPA111
517.31(D) – revised to text to align with references across NEC, NFPA110, and NFPA111
517.31(F) – revised to text to align with references across NEC, NFPA110, and NFPA111
517.41(B) – revised to text to align with references across NEC, NFPA110, and NFPA111
692.41(C) – removed the word power since fuel cell system is a defined term in the NEC
695.3(C)(2) – revised to text to align with references across NEC, NFPA110, and NFPA111
700.2, - Added informational note number 2 to describe the interaction of the terms used in NFPA110 and NFPA111with emergency systems in the NEC. Revised definition for Branch-Circuit Emergency Lighting Transfer Switch to align with terminology in NFPA110 and NFPA111. Added informational note 3 to tie the levels defined in NFPA110 to the systems used in the NEC. This will aid in the interaction of these standards.
700.12(D)(1), - Normal service implies that the normal or primary power source can only be a utility per the NEC definition of "service." This section was revised to say power source to allow other types of sources for the normal power.
700.12(D)(2) – revised wording since legally required standby system and emergency system are defined terms.
700.18 – added the word "system" since emergency system is a defined term
701.2 - Added informational note 2 to tie the levels defined in NFPA110 to the systems used in the NEC. This will aid in the interaction of these standards. It also provides guidance as to which legally required standby systems are considered level 1 due to their critical nature tied to loss of life or serious injury versus the level 2 that is less critical.

701.12(D)(1) - Normal service implies that the normal or primary power source can only be a utility per the NEC definition of “service.” This section was revised to say power source to allow other types of sources for the normal power.
708.2 - Added informational note to tie the levels defined in NFPA110 to the systems used in the NEC. This will aid in the interaction of these standards.
708.20(F)(1) - Normal service implies that the normal or primary power source can only be a utility per the NEC definition of “service.” This section was revised to say power source to allow other types of sources for the normal power.

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Submittal Date: Wed Sep 09 23:38:55 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9311-NFPA 70-2021
Statement: Part V does not modify any existing requirements in Chapter 2. This part addressed system grounding configurations that are already adequately addressed in Article 250.

Public Input No. 3178-NFPA 70-2020 [Section No. 692.45]

~~**692.45** Size of Equipment Grounding Conductor.~~

~~The equipment grounding conductor shall be sized in accordance with 250.122 .~~

Statement of Problem and Substantiation for Public Input

Text in 692.45 of 2020 NEC does not supplement or modify the grounding requirements in 250.122, but simply repeats that general requirement. NEC 90.3 indicates those general requirements apply to special equipment without repeating the text.

Submitter Information Verification

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Committee: NEC-P04

Committee Statement

Resolution: FR-9311-NFPA 70-2021
Statement: Part V does not modify any existing requirements in Chapter 2. This part addressed system grounding configurations that are already adequately addressed in Article 250.

Public Input No. 3179-NFPA 70-2020 [Section No. 692.47]

~~**692.47** Grounding Electrode System.~~

~~Any auxiliary grounding electrode(s) required by the manufacturer shall be connected to the equipment grounding conductor specified in 250.118 .~~

Statement of Problem and Substantiation for Public Input

Text in 692.47 of 2020 NEC does not supplement or modify the grounding requirements in Article 250, but simply repeats that general requirement. NEC 90.3 indicates those general requirements apply to special equipment without repeating the text. The 2020 text actually references 250.118 that covers types of equipment grounding conductors rather than 250.54 that addresses an auxiliary grounding electrode which seems to be what this section is referring to. As indicated, reference to neither section is necessary as those general Article 250 requirements are applicable for fuel cells.

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Committee: NEC-P04

Committee Statement

Resolution: FR-9311-NFPA 70-2021
Statement: Part V does not modify any existing requirements in Chapter 2. This part addressed system grounding configurations that are already adequately addressed in Article 250.

Public Input No. 2422-NFPA 70-2020 [Section No. 692.54]

692.54 Fuel Shut-Off.

The primary disconnecting means of the building or circuits supplied shall be marked with a description and/or diagram that indicates the location of the manual fuel shut-off valve ~~shall be marked at the location of the primary disconnecting means of the building or circuits supplied~~ .

Statement of Problem and Substantiation for Public Input

Clarify intent of "the location of the...valve shall be marked at the location of the...disconnect"...

Submitter Information Verification

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Submittal Date: Thu Aug 20 13:20:50 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: Requirements exist in the Fire Code code and do not belong in the electrical code.

Public Input No. 4601-NFPA 70-2020 [Article 694]

Article 694 Wind Electric Systems

Part I. General

694.1 Scope.

This article applies to wind (turbine) electric systems that consist of one or more wind electric generators and their related alternators, generators, inverters, controllers, and associated equipment.

Informational Note: Some wind electric systems are interactive with other electric power sources *[see Figure 694.1(a)]* and some are stand-alone systems *[see Figure 694.1(b)]*. Some systems have ac output and some have dc output. Some systems contain electrical energy storage, such as batteries.

Figure 694.1(a) Identification of Wind Electric System Components — Interactive System.

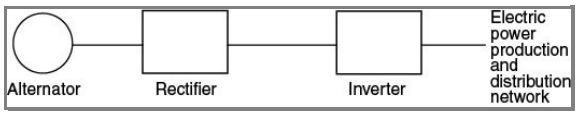
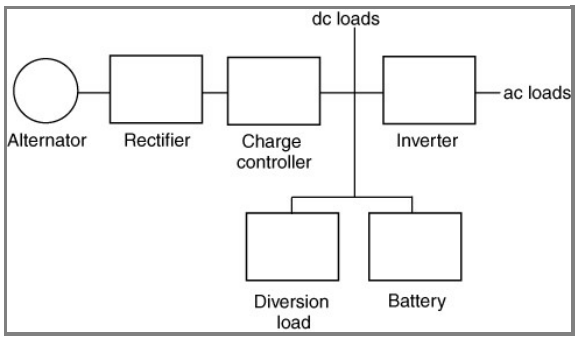


Figure 694.1(b) Identification of Wind Electric System Components — Stand-Alone System.



694.2 Definitions.

The definitions in this section shall apply only within this article.

Diversion Charge Controller.

Equipment that regulates the charging process of a battery or other energy storage device by diverting power from energy storage to dc or ac loads, or to an interconnected utility service.

Diversion Load.

A load connected to a diversion charge controller or diversion load controller, also known as a dump load.

Diversion Load Controller.

Equipment that regulates the output of a wind generator by diverting power from the generator to dc or ac loads or to an interconnected utility service.

Maximum Output Power.

The maximum 1 minute average power output a wind turbine produces in normal steady-state operation (instantaneous power output can be higher).

Maximum Voltage.

The maximum voltage the wind turbine produces in operation including open circuit conditions.

Nacelle.

An enclosure housing the alternator and other parts of a wind turbine.

Rated Power.

The output power of a wind turbine at its rated wind speed.

Informational Note: The method for measuring wind turbine power output is specified in IEC 61400-12-1, *Power Performance Measurements of Electricity Producing Wind Turbines*.

Tower (as applied to wind electric systems).

A pole or other structure that supports a wind turbine.

Wind Turbine.

A mechanical device that converts wind energy to electrical energy.

Wind Turbine Output Circuit.

The circuit conductors between the internal components of a wind turbine (which might include an alternator, integrated rectifier, controller, and/or inverter) and other equipment.

Informational Note: See also definitions for interconnected systems in Article 705.

694.7 Installation.

Systems covered by this article shall be installed only by qualified persons.

Informational Note: See Article 100 for the definition of *Qualified Person*.

(A) Wind Electric Systems.

A wind electric system(s) shall be permitted to supply a building or other structure in addition to other sources of supply.

(B) Equipment.

Wind electric systems shall be approved for the application in accordance with one of the following:

(1) Be listed

(2) Be evaluated for the application and have a field label applied

Wind electric systems undergoing evaluation for type certification and listing shall be permitted to be operated in a controlled location with access limited to qualified personnel.

Informational Note: Testing for certification and listing is typically performed under the supervision of a qualified electrical testing organization.

(C) Diversion Load Controllers.

A wind electric system employing a diversion load controller as the primary means of regulating the speed of a wind turbine rotor shall be equipped with an additional, independent, reliable means to prevent over-speed operation. An interconnected utility service shall not be considered to be a reliable diversion load.

(D) Surge Protective Devices (SPD).

A surge protective device shall be installed between a wind electric system and any loads served by the premises electrical system. The surge protective device shall be permitted to be a Type 3 SPD on the circuit serving a wind electric system or a Type 2 SPD located anywhere on the load side of the service disconnect. Surge protective devices shall be installed in accordance with Part II of Article 242.

(E) Receptacles.

A receptacle shall be permitted to be supplied by a wind electric system branch or feeder circuit for maintenance or data acquisition use. Receptacles shall be protected with an overcurrent device with a rating not to exceed the current rating of the receptacle. In addition to the requirements in 210.8, all 125-volt, single-phase, 15- and 20-ampere receptacles installed for maintenance of the wind turbine shall have ground-fault circuit-interrupter protection for personnel.

(F) Poles or Towers Supporting Wind Turbines Used as a Raceway.

A pole or tower shall be permitted to be used as a raceway if approved in accordance with one of the following:

(1) Be evaluated as part of the listing for the wind turbine

(2) Be listed for the application

(3) Be evaluated for the application and have a field label applied

(G) Working Clearances.

Working space shall be provided for electrical cabinets and other electrical equipment in accordance with 110.26(A).

For large wind turbines where service personnel enter the equipment, where conditions of maintenance and supervision ensure that only qualified persons perform the work, working clearances shall be permitted to comply with Table 694.7 for systems up to 1000 V nominal.

Table 694.7 Working Spaces

Nominal Voltage to Ground	Condition 1	Condition 2	Condition 3
0–150	900 mm (3 ft)	900 mm (3 ft)	900 mm (3 ft)
151–1000	900 mm (3 ft)	1.0 m (3 ft 6 in.)	1.2 m (4 ft)

Part II. Circuit Requirements

694.10 Maximum Voltage.

(A) Wind Turbine Output Circuits.

Wind turbine output circuits on or in one- and two-family dwellings shall be permitted to have a maximum voltage up to 600 volts.

(B) Direct-Current Utilization Circuits.

The voltage of dc utilization circuits shall comply with 210.6.

(C) Circuits over 150 Volts to Ground.

In one- and two-family dwellings, live parts in circuits over 150 volts to ground shall not be accessible to other than qualified persons while energized.

Informational Note: See 110.27 for guarding of live parts and 210.6 for branch circuit voltage limitations.

694.12 Circuit Sizing and Current.

(A) Calculation of Maximum Circuit Current.

The maximum current for a circuit shall be calculated in accordance with 694.12(A)(1) through (A)(3).

(1) Turbine Output Circuit Currents.

The maximum current shall be based on the circuit current of the wind turbine operating at maximum output power.

(2) Inverter Output Circuit Current.

The maximum output current shall be the inverter continuous output current rating.

(3) Stand-Alone Inverter Input Circuit Current.

The maximum input current shall be the stand-alone continuous inverter input current rating of the inverter producing rated power at the lowest input voltage.

(B) Ampacity and Overcurrent Device Ratings.

(1) Continuous Current.

Wind turbine electric system currents shall be considered to be continuous.

(2) Sizing of Conductors and Overcurrent Devices.

Circuit conductors and overcurrent devices shall be sized to carry not less than 125 percent of the maximum current as calculated in 694.12(A). The rating or setting of overcurrent devices shall be permitted in accordance with 240.4(B) and (C).

Exception: Circuits containing an assembly, together with its overcurrent devices, listed for continuous operation at 100 percent of its rating shall be permitted to be used at 100 percent of its rating.

694.15 Overcurrent Protection.

(A) Circuits and Equipment.

Turbine output circuits, inverter output circuits, and storage battery circuit conductors and equipment shall be protected in accordance with the requirements of Article 240. Circuits connected to more than one electrical source shall have overcurrent devices located so as to provide overcurrent protection from all sources.

Exception: An overcurrent device shall not be required for circuit conductors sized in accordance with 694.12(B) where the maximum current from all sources does not exceed the ampacity of the conductors.

Informational Note: Possible backfeed of current from any source of supply, including a supply through an inverter to the wind turbine output circuit, is a consideration in determining whether overcurrent protection from all sources is provided. Some wind electric systems rely on the turbine output circuit to regulate turbine speed. Inverters may also operate in reverse for turbine startup or speed control.

(B) Power Transformers.

Overcurrent protection for a transformer with sources on each side shall be provided in accordance with 450.3 by considering first one side of the transformer, then the other side of the transformer, as the primary.

Exception: A power transformer with a current rating on the side connected to the inverter output, which is not less than the rated continuous output current rating of the inverter, shall not be required to have overcurrent protection at the inverter.

(C) Direct-Current Rating.

Overcurrent devices, either fuses or circuit breakers, used in any dc portion of a wind electric system shall be listed for use in dc circuits and shall have appropriate voltage, current, and interrupting ratings.

Part III. Disconnecting Means

694.20 All Conductors.

Means shall be provided to disconnect all current-carrying conductors of a wind electric power source from all other conductors in a building or other structure. A switch, circuit breaker, or other device, either ac or dc, shall not be installed in a grounded conductor if operation of that switch, circuit breaker, or other device leaves the marked, grounded conductor in an ungrounded and energized state.

Exception: A wind turbine that uses the turbine output circuit for regulating turbine speed shall not require a turbine output circuit disconnecting means.

694.22 Additional Provisions.

Disconnecting means shall comply with 694.22(A) through (D).

(A) Disconnecting Means.

The disconnecting means shall not be required to be suitable for use as service equipment. The disconnecting means for ungrounded conductors shall consist of manually operable switches or circuit breakers complying with all of the following requirements:

(1) They shall be located where readily accessible.

(2) They shall be externally operable without exposing the operator to contact with live parts.

(3) They shall plainly indicate whether in the open or closed position.

(4) They shall have an interrupting rating sufficient for the nominal circuit voltage and the current that is available at the line terminals of the equipment.

Where all terminals of the disconnecting means are capable of being energized in the open position, a warning sign shall be mounted on or adjacent to the disconnecting means. The sign shall be clearly legible and shall have the following words or equivalent:

WARNING.

ELECTRIC SHOCK HAZARD.

DO NOT TOUCH TERMINALS.

TERMINALS ON BOTH THE LINE

AND LOAD SIDES MAY BE

ENERGIZED IN THE OPEN POSITION.

The warning sign(s) or label(s) shall comply with 110.21(B).

(B) Equipment.

Equipment such as rectifiers, controllers, output circuit isolating and shorting switches, and over-current devices shall be permitted on the wind turbine side of the disconnecting means.

(C) Requirements for Disconnecting Means.

(1) Location.

The wind electric system disconnecting means shall be installed at a readily accessible location either on or adjacent to the turbine tower, on the outside of a building or structure, or inside at the point of entrance of the wind system conductors.

Exception: Installations that comply with 694.30(C) shall be permitted to have the disconnecting means located remotely from the point of entry of the wind system conductors.

A wind turbine disconnecting means shall not be required to be located at the nacelle or tower.

The disconnecting means shall not be installed in bathrooms.

For one-family and two-family dwellings, a disconnecting means or manual shutdown button or switch shall be located at a readily accessible location outside the building.

(2) Marking.

Each turbine system disconnecting means shall be permanently marked to identify it as a wind electric system disconnect.

(3) Suitable for Use.

Turbine system disconnecting means shall be suitable for the prevailing conditions.

(4) Maximum Number of Disconnects.

The turbine disconnecting means shall consist of not more than six switches or six circuit breakers mounted in a single enclosure, in a group of separate enclosures, or in or on a switchgear.

(D) Equipment That Is Not Readily Accessible.

Rectifiers, controllers, and inverters shall be permitted to be mounted in nacelles or other exterior areas that are not readily accessible.

694.23 Turbine Shutdown.

(A) Manual Shutdown.

Wind turbines shall be required to have a readily accessible manual shutdown button or switch. Operation of the button or switch shall result in a parked turbine state that shall either stop the turbine rotor or allow limited rotor speed combined with a means to de-energize the turbine output circuit.

Exception: Turbines with a swept area of less than 50 m^2 (538 ft^2) shall not be required to have a manual shutdown button or switch.

(B) Shutdown Procedure.

The shutdown procedure for a wind turbine shall be defined and permanently posted at the location of a shutdown means and at the location of the turbine controller or disconnect, if the location is different.

694.24 Disconnection of Wind Electric System Equipment.

Means shall be provided to disconnect equipment, such as inverters, batteries, and charge controllers, from all ungrounded conductors of all sources. If the equipment is energized from more than one source, the disconnecting means shall be grouped and identified.

A single disconnecting means in accordance with 694.22 shall be permitted for the combined ac output of one or more inverters in an interactive system.

A shorting switch or plug shall be permitted to be used as an alternative to a disconnect in systems that regulate turbine speed using the turbine output circuit.

Exception: Equipment housed in a turbine nacelle shall not be required to have a disconnecting means.

694.26 Fuses.

Means shall be provided to disconnect a fuse from all sources of supply where the fuse is energized from both directions and is accessible to other than qualified persons. Switches, pullouts, or similar devices that are rated for the application shall be permitted to serve as a means to disconnect fuses from all sources of supply.

694.28 Installation and Service of a Wind Turbine.

Open circuiting, short circuiting, or mechanical brakes shall be used to disable a turbine for installation and service.

Informational Note: Some wind turbines rely on the connection from the alternator to a remote controller for speed regulation. Opening turbine output circuit conductors may cause mechanical damage to a turbine and create excessive voltages that could damage equipment or expose persons to electric shock.

Part IV. Wiring Methods

694.30 Permitted Methods.

(A) Wiring Systems.

All raceway and cable wiring methods included in this *Code*, and other wiring systems and fittings specifically intended for use on wind turbines, shall be permitted. In readily accessible locations, turbine output circuits that operate at voltages greater than 30 volts shall be installed in raceways.

(B) Flexible Cords and Cables.

Flexible cords and cables, where used to connect the moving parts of turbines or where used for ready removal for maintenance and repair, shall comply with Article 400 and shall be of a type identified as hard service cord or portable power cable, shall be suitable for extra-hard usage, shall be listed for outdoor use, and shall be water resistant. Cables exposed to sunlight shall be sunlight resistant. Flexible, fine-stranded cables shall be terminated only with terminals, lugs, devices, or connectors in accordance with 110.14(A).

(C) Direct-Current Turbine Output Circuits Inside a Building.

Direct-current turbine output circuits installed inside a building or structure shall be enclosed in metal raceways or installed in metal enclosures, or run in Type MC metal-clad cable that complies with 250.118(10), from the point of penetration of the surface of the building or structure to the first readily accessible disconnecting means.

Part V. Grounding and Bonding

694.40 Equipment Grounding and Bonding.

(A) General.

Exposed non–current-carrying metal parts of towers, turbine nacelles, other equipment, and conductor enclosures shall be grounded and bonded to the premises grounding and bonding system. Attached metal parts, such as turbine blades and tails that are not likely to become energized, shall not be required to be grounded or bonded.

(B) Tower Grounding and Bonding.

(1) Grounding Electrodes and Grounding Electrode Conductors.

A wind turbine tower shall be connected to a grounding electrode system. Where installed in close proximity to galvanized foundation or tower anchor components, galvanized grounding electrodes shall be used.

> Informational Note: Copper and copper-clad grounding electrodes, where used in highly conductive soils, can cause electrolytic corrosion of galvanized foundation and tower anchor components.

(2) Bonding Conductor.

Equipment grounding conductors or supply-side bonding jumpers, as applicable, shall be required between turbines, towers, and the premises grounding system.

(3) Tower Connections.

Equipment grounding, bonding, and grounding electrode conductors, where used, shall be connected to metallic towers using listed means. All mechanical elements used to terminate these conductors shall be accessible.

(4) Guy Wires.

Guy wires used to support turbine towers shall not be required to be connected to an equipment grounding conductor or to comply with the requirements of 250.110.

> Informational Note: Guy wires supporting grounded towers are unlikely to become energized under normal conditions, but partial lightning currents could flow through guy wires when exposed to a lightning environment. Grounding of metallic guy wires may be required by lightning standards. For information on lightning protection systems, see NFPA 780-2017, *Standard for the Installation of Lightning Protection Systems*.

Part VI. Marking

694.50 Interactive System Point of Interconnection.

All interactive system points of interconnection with other sources shall be marked at an accessible location at the disconnecting means and with the rated ac output current and the nominal operating ac voltage.

694.52 Power Systems Employing Energy Storage.

Wind electric systems employing energy storage shall be marked with the maximum operating voltage, any equalization voltage, and the polarity of the grounded circuit conductor.

694.54 Identification of Power Sources.

Wind turbine systems shall be identified according to 694.54(A) through (C).

(A) Interconnected AC Systems.

Plaques or directories shall be installed in accordance with 705.10.

(B) DC Microgrid Systems.

Plaques or directories shall be installed in accordance with 712.10.

(C) Stand-Alone Systems.

Plaques or directories shall be installed in accordance with 710.10.

694.56 Instructions for Disabling Turbine.

A plaque shall be installed at or adjacent to the turbine location providing basic instructions for disabling the turbine.

Part VII. Connection to Other Sources

694.60 Identified Interactive Equipment.

Only inverters that are listed, labeled, and identified as interactive shall be permitted in interactive systems.

694.62 Installation.

Wind electric systems, where connected to utility electric sources, shall comply with the requirements of Article 705.

694.66 Operating Voltage Range.

Wind electric systems connected to dedicated branch or feeder circuits shall be permitted to exceed normal voltage operating ranges on these circuits, provided that the voltage at any distribution equipment supplying other loads remains within normal ranges.

> Informational Note: Wind turbines might use the electric grid to dump energy from short-term wind gusts. Normal operating voltages are defined in ANSI C84.1-2006, *Voltage Ratings for Electric Power Systems and Equipment (60 Hz)*.

694.68 Point of Connection.

Points of connection to interconnected electric power sources shall comply with 705.12.

Part VII Large Scale Wind Electric Systems

This part covers the installation of wind electric supply stations with an inverter generating capacity of not less than 5000 Kw, and not under the exclusive utility control.

694.xx

Electric Supply Station

Locations containing the generating stations and substations, including their associated generator, storage battery, transformer and switchgear areas.

Generating Station

A plant wherein electric energy is produced by conversion from some other formof energy(e.g. chemical, nuclear, wind, mechanical or hydraulic0 BY MEANS OF SUITABLE APPARATUS.

694.xx Special Requirements for Large Scale Wind Electric Supply Stations

Large scal Wind electric supply stations shall be accessible only to qualified personnel and comply with the following:

(1) Electrical circuits and equipment shall be maintained and operated only by qualified personnel

(2) Access to Wind electric supply stations shall be restricted by fencing or other adequate means in accordance with 110.31 Field applied hazard marking shall applied in accordance with 110.21 (B)

(3) The connection of the wind electric supply station and the system operated by a utility for the transfer of electrical energy shall be through medium or high voltage switchgear, substation, switch yard or similar methods whose sole purpose shall be to safely and effectively interconnect the two systems.

(4) The electrical loads within the wind electric supply station shall only be used to power auxillary equipment for the generation of the wind power.

694.xx Equipment

(1) Listing and Labeling

(2)Be evaluated for the application and have a field label applied

(3) Where products compluing with 694.xx (1) or (2) are not available, by engineering review validating that the electrical equipment is evaluated and tested to relevant standards or industry proctices.

694.xx Engineered Design

Documentation of the electrical portion of the engineered design of the electric supply station shall be stamped and provided upon request to the AHJ. Additional stamped independent engineering reports detailing compliance of the design with applicable electrical standards and industry proctices shall be provided upon request of the AHJ, the independent engineer shall be a licensed professional electrical engineer retained by the system owner or installer. This documentatin shall include details of conformance of the design with Article 694 or other articles of this code.

694.xx Conformance to Construction to Engineered Design Same as 691.7 substitute Wind in place of PV

Documentation that the construction of the electric supply station conforms to the electrical engineered design shall be providedupon request to the AHJ.Additional stamped independent engineering reports detailing compliance of the design with applicable electrical standards and industry proctices shall be provided upon request of the AHJ, the independent engineer shall be a licensed professional electrical engineer retained by the system owner or installer. This documentatin where requested shall be available prior to commercial operation of the station

694.xx Operating Voltage

For large scale Wind electric supply stations, calculations shall be included in the documentation.

694.xx Disconnection means for Isolatining Wind Systems.

Isolating devices shall not be required within sight of equipment snd shall be permitted to be remotely locatedfrom the equipment. The engineered design shall document the disconnection procedures and means of isolating the equipment.

Informational note: For information on electrical system maintenance see NFPA 70 B-2019, Recommended practice for Electrical Equipment Maintenance. For information on written procedures snd conditions of maintenance, including lockout/tagout procedures, see NFPA 70E-2021

Building whosee sole purpose is to house and protect supply station equipment shall not be required to comply woith shut down requirements. Written operating instructions shall be available at the site detailing necessary shutdown procedures in the event of an emergency.

694.xx Arc-Fault Mitigation

Wind systems shall include details of fire mitigation plans to address arc-faults in the documentation.

694.xx Fence Bonding andGrounding

Fence Grounding requirements and details shall be included in the documentation.

Informational note See 250.194 for fence bonding and grounding requirements enclosing substation portions of electric supply stations. Grounding requirements for other portions of electric supply station fencing are accessed based on the presence of overhead conductors, proximity to generation and distribution equipment and associated to step and touch potential.

Statement of Problem and Substantiation for Public Input

As with Article 691 large scale wind electric supply stations have restricted access and by allowing for these modifications this equipment can be installed in a safe manner. these systems are not accessible by the general public.

Submitter Information Verification

Submitter Full Name: Wendell Whistler
Organization: IBEW Local 280
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 10 15:38:25 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: Large scale wind (greater than 5 MW) is very different to large scale solar. Sites are often NOT fenced. Access is limited by locked doors at turbine tower bases. There is already a requirement for qualified installers, and the addition that maintenance personnel also be qualified. The proposed text is not complete.

Public Input No. 3944-NFPA 70-2020 [Section No. 694.2]

(Relocate all definitions in the 694. 2 to Article 100, arrange them in alphabetical order and without any subdivisions.)

694. 2 Definitions.

The definitions in this section shall apply only within this article.

Diversion Charge Controller.

Equipment that regulates the charging process of a battery or other energy storage device by diverting power from energy storage to dc or ac loads, or to an interconnected utility service.

Diversion Load.

A load connected to a diversion charge controller or diversion load controller, also known as a dump load.

Diversion Load Controller.

Equipment that regulates the output of a wind generator by diverting power from the generator to dc or ac loads or to an interconnected utility service.

Maximum Output Power.

The maximum 1 minute average power output a wind turbine produces in normal steady-state operation (instantaneous power output can be higher).

Maximum Voltage.

The maximum voltage the wind turbine produces in operation including open circuit conditions.

Nacelle.

An enclosure housing the alternator and other parts of a wind turbine.

Rated Power.

The output power of a wind turbine at its rated wind speed.

Informational Note: The method for measuring wind turbine power output is specified in IEC 61400-12-1, *Power Performance Measurements of Electricity Producing Wind Turbines*.

Tower (as applied to wind electric systems).

A pole or other structure that supports a wind turbine.

Wind Turbine.

A mechanical device that converts wind energy to electrical energy.

Wind Turbine Output Circuit.

The circuit conductors between the internal components of a wind turbine (which might include an alternator, integrated rectifier, controller, and/or inverter) and other equipment.

Informational Note: See also definitions for interconnected systems in Article 705.

Statement of Problem and Substantiation for Public Input

"The National Electrical Code has definitions in multiple parts in Article 100 and many definitions scattered through out the code many of them in the .2 section of the articles.
Most of the other standards under NFPA have their definitions in one location and this will allow the NEC the same requirement. The revisions to the NEC Style Manual require all the definitions to be relocated to Article 100. "

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 09 16:03:48 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9324-NFPA 70-2021

Statement: This revision moves all definitions previously in Section 2 of Articles 690, 692, 694 and 705 to Article 100.

The NEC Style Manual also requires that for definitions that apply in only one article, the article number in parentheses shall follow the definition.

CMP-4 identified the following definitions that apply to only one article:

690: AC Module System, AC Module, Array, Direct-Current Combiner, Module, Monopole Circuit, PV Output Circuit, PV Source Circuit, PV System DC Circuit.

692: Fuel Cell Output Circuit

694: Maximum Output Power, Maximum Voltage, Nacelle, Rated Power, Tower, Wind Turbine Output Circuit.

These have been moved to Article 100 with the relevant article number appended. All other definitions have been moved with no article number identified.

All definitions were moved with the annotation (CMP-4) appended to indicate the code panel responsible for the definition in accordance with NEC Style Manual Section 2.2.2.3.3.

Public Input No. 3000-NFPA 70-2020 [Definition: Wind Turbine Output Circuit.]

Wind Turbine Output Circuit.

The circuit conductors between the internal components of a wind turbine (which might include an alternator, integrated rectifier, controller, and/or inverter) and other equipment.

~~Informational Note: See also definitions for interconnected systems in Article 705 .~~

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

Interconnected Systems is not a defined term. This is being deleted to increase clarity and remove possible points of confusion.

Submitter Information Verification

Submitter Full Name: Thomas Domitrovich
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City:
State:
Zip:
Submittal Date: Thu Sep 03 20:47:39 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9593-NFPA 70-2021
Statement: This definition was moved to Article 100. The informational note was removed as new organization of these articles makes it clear that all sources that are combined with other sources must be installed in accordance with Article 705. The reference to Article 705 is not necessary.

Public Input No. 780-NFPA 70-2020 [New Definition after Definition: Wind Turbine Output Circui...]

TITLE OF NEW CONTENT

Type your content here ...

694.5 Electromagnetic Pulse (EMP) Protection. Protection for wind electric systems against the effects of electromagnetic pulses shall be provided at a minimum of Level 2. See 709.7 for levels of electromagnetic pulse protection.

Exception: The requirements of 709.7(A)(5) and 709.7(B)(3) shall not apply.

This requirement shall become effective January 1, 2026.

Statement of Problem and Substantiation for Public Input

A devastating electromagnetic pulse (EMP), caused by a sun-spot or a nuclear bomb exploded high in the atmosphere, can impress 50,000 volts per meter on unprotected electrical and electronic equipment. It is similar to a radio wave impressing a very small voltage on a radio antenna, only orders of magnitude larger. The problem is that a significant EMP will fry every electrical/electronic component or piece of equipment that is not protected.

The EMP won't directly harm or injure people, but because there is no longer a working electrical infrastructure, which may take years to repair/rebuild, people will die from the lack of clean water, medicine, food, fuel, and eventual rioting due to the breakdown of society. Unclassified studies, referenced at the end of this substantiation, have estimated from 66% to 90% of the US population will die within one year if a significant sun spot were to occur or if a nuclear explosion were to occur 25 to 250 miles over the Midwest.

Our US military already "hardens" systems/buildings so that our country's critical defensive capabilities are not completely destroyed. There are two major methods of protecting electrical/electronic systems. The first is that surge protective devices are installed on all "incoming" power and communications cables, shunting overvoltages to ground. The second is that Faraday cages are installed around equipment/rooms, preventing the EMP from reaching critical equipment/components.

The NEC® needs to address EMP protection for equipment, systems and special occupancies that are critical to our survival. Electrical and electronic equipment can and must be protected, as has been achieved by our military. Unfortunately, there are no requirements to protect civilian electrical and electronic equipment/systems from EMPs.

The NEC Correlating Committee has informally advised that an EMP Protection Article, if passed and adopted into the NEC®, would be most appropriately located after Article 708 (COPS). Thus, Public Input 756 has suggested a new Article 709 under jurisdiction of CMP 13, which already has purview over Emergency Systems (Article 700), Legally Required Standby Systems (Article 701), Optional Standby Systems (Article 702), and Critical Operations Power Systems (Article 708).

Levels of protection and associated protection requirements listed in the Public Input(s) are based upon the unclassified National Cybersecurity and Communications Integration Center report "Electromagnetic Pulse (EMP) Protection and Resilience Guidelines for Critical Infrastructure and Equipment". This study explains electromagnetic pulses and provides the necessary protective measures. It also contains estimates of the costs associated with properly protecting our electrical infrastructure.
The following table contains critical infrastructure components/special occupancies and the maximum time for outages caused by an EMP. Electrical components/infrastructure that is not functioning for periods longer than shown in this table may begin to cause injury or death to people and harm to society/economy.
Critical Infrastructure Component/Special Occupancy Permitted Outage Time

Branch banking facilities 10 hours
Critical Operations Power Systems 10 minutes
Data centers 10 minutes
Direct current microgrids 10 hours
Drug stores/distribution centers 10 hours
Electrically driven or controlled irrigation machines 1 week
Elevators, dumbwaiters, escalators, moving walks, platform lifts, and stairway chairlifts See facility requirements
Emergency systems 10 hours
Energy storage systems 10 hours
Fire alarm systems 1 week
Fire houses/stations 10 hours
Fire pumps 10 hours
Food processing and storage facilities 10 hours
Fuel cell systems 10 hours
Generators 10 hours
Grocery stores 10 hours
Hardware stores/home centers 10 hours
Healthcare facilities See NFPA 99
Information technology equipment 10 minutes
Interconnected electric power production sources 10 minutes
Jails and prisons 10 minutes
Large-scale photovoltaic (PV) electric supply stations 10 hours
Legally required standby systems 10 hours
Modular data centers 10 minutes
Motor fuel dispensing facilities 1 week
Motors, motor circuits, and controllers See facility requirements
Nuclear reactors 10 seconds
Optional standby systems 1 week
Petrochemical plants/facilities 10 hours
Pharmaceutical plants/facilities 10 hours
Police stations 10 minutes
Solar photovoltaic (PV) systems 10 hours
Stand-alone systems 10 hours
Storage batteries See facility requirements
Transformers See facility requirements
Waste water treatment facilities 10 minutes
Water supply facilities 10 hours
Wind electric systems 10 hours

An effectivity date of January 1, 2026 is chosen to allow time for engineering and industry to adequately pan and prepare for the required changes.

Opponents of EMP protection requirements will likely charge that it is too costly to protect our critical infrastructure, and that the NEC® is not a war-time document. A close reading of 90.1 reveals that there is no mention of the “cost” of safeguarding persons and property. Neither does 90.1 mention that safeguarding persons and property is only required during peacetime. Additionally, a significant EMP event, caused by a sunspot, would be an act of God, not an act of war.

The novel, “One Second After”, provides an understanding of what happens when the majority of all unprotected electrical and electronic equipment/systems is destroyed during an EMP event. An audio version of this book is available in two parts, for free, on YouTube.

This link provides the unclassified report “Electromagnetic Pulse (EMP) Protection and Resilience Guidelines for Critical Infrastructure and Equipment”
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&ved=2ahUKEwjQhp2-77DoAhXBHM0KHboOB2QQFjACegQIBRAC&url=https%3A%2F%2Fwww.cisa.gov%2Fsites%2Fdefault%2Ffiles%2Fpublications%2F19_0307_CISA_EMP-Protection-Resilience-Guidelines.pdf&usg=AOvVaw2n7jLtJAUJtOJKHPMqWsTE

This link provides the study predicting up to 90% of our population could die from an EMP event

http://www.firstempcommission.org/uploads/1/1/9/5/119571849
/nuclear_emp_attack_scenarios_and_combined-arms_cyber_warfare_by_peter_pry_july_2017.pdf

This link provides unclassified guidelines for facility EMP protection
https://info.publicintelligence.net/DHS-FacilitiesGuidelinesEMP.pdf

These links provide Parts 1 and 2 of a national plan for EMP protection.
https://interferencetechnology.com/a-national-plan-for-emp-protection-part-1/
https://interferencetechnology.com/national-plan-emp-protection-part-2-protection-buildings/

We have all just witnessed the chaos and pain caused by not having the “protections” in place to quickly defeat the Covid-19 virus. As unfortunate, costly, painful, and deadly as Covid-19 was, it would be child’s play when compared to a significant EMP event if our critical electrical/electronic infrastructure remains unprotected. Quite simply, NEC® requirements to protect electrical and electronic equipment from an EMP event, could literally save millions of American lives.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 756-NFPA 70-2020 [New Section after 708.64]	
Public Input No. 756-NFPA 70-2020 [New Section after 708.64]	

Submitter Information Verification

Submitter Full Name: Vincent Saporita
Organization: Saporita Consulting
Affiliation: Saporita Consulting
Street Address:
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State:
Zip:
Submittal Date: Mon Mar 23 16:20:51 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: EMP protection, in much the same way as lightning protection, should not be a requirement for all electrical systems. EMP protection is a design issue and the safety hazard of not having EMP has not been adequately provided in the substantiation.

Public Input No. 477-NFPA 70-2020 [Section No. 694.7]

694.7 Installation and Maintenance .

Systems covered by this article shall be installed and maintained only by qualified persons.

Informational Note: See Article 100 for the definition of *Qualified Person*.

(A) Wind Electric Systems.

A wind electric system(s) shall be permitted to supply a building or other structure in addition to other sources of supply.

(B) Equipment.

Wind electric systems shall be approved for the application in accordance with one of the following:

(1) Be listed

(2) Be evaluated for the application and have a field label applied

Wind electric systems undergoing evaluation for type certification and listing shall be permitted to be operated in a controlled location with access limited to qualified personnel.

Informational Note: Testing for certification and listing is typically performed under the supervision of a qualified electrical testing organization.

(C) Diversion Load Controllers.

A wind electric system employing a diversion load controller as the primary means of regulating the speed of a wind turbine rotor shall be equipped with an additional, independent, reliable means to prevent over-speed operation. An interconnected utility service shall not be considered to be a reliable diversion load.

(D) Surge Protective Devices (SPD).

A surge protective device shall be installed between a wind electric system and any loads served by the premises electrical system. The surge protective device shall be permitted to be a Type 3 SPD on the circuit serving a wind electric system or a Type 2 SPD located anywhere on the load side of the service disconnect. Surge protective devices shall be installed in accordance with Part II of Article 242.

(E) Receptacles.

A receptacle shall be permitted to be supplied by a wind electric system branch or feeder circuit for maintenance or data acquisition use. Receptacles shall be protected with an overcurrent device with a rating not to exceed the current rating of the receptacle. In addition to the requirements in 210.8, all 125-volt, single-phase, 15- and 20-ampere receptacles installed for maintenance of the wind turbine shall have ground-fault circuit-interrupter protection for personnel.

(F) Poles or Towers Supporting Wind Turbines Used as a Raceway.

A pole or tower shall be permitted to be used as a raceway if approved in accordance with one of the following:

(1) Be evaluated as part of the listing for the wind turbine

(2) Be listed for the application

(3) Be evaluated for the application and have a field label applied

(G) Working Clearances.

Working space shall be provided for electrical cabinets and other electrical equipment in accordance with 110.26(A).

For large wind turbines where service personnel enter the equipment, where conditions of maintenance and supervision ensure that only qualified persons perform the work, working clearances shall be permitted to comply with Table 694.7 for systems up to 1000 V nominal.

Table 694.7 Working Spaces

Nominal Voltage to Ground	Condition 1	Condition 2	Condition 3
0–150	900 mm (3 ft)	900 mm (3 ft)	900 mm (3 ft)
151–1000	900 mm (3 ft)	1.0 m (3 ft 6 in.)	1.2 m (4 ft)

Statement of Problem and Substantiation for Public Input

The code needs to provide clarity that not only do wind electric systems need to be installed by qualified persons, these systems should also be maintained by qualified persons.

Submitter Information Verification

Submitter Full Name: Brian Baughman
Organization: Generac Power Systems Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Tue Feb 18 11:55:26 EST 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9329-NFPA 70-2021
Statement: This change provides clarity that not only do wind electric systems need to be constructed by qualified persons, these systems should also be maintained by qualified persons.

Public Input No. 3998-NFPA 70-2020 [Section No. 694.7(B)]

(B) Equipment.

Wind electric systems shall be approved for the application and installation location (onshore or off-shore) in accordance with one of the following:

(1) Be listed

(2) Be evaluated for the application and have a field label applied

Wind electric systems undergoing evaluation for type certification and listing shall be permitted to be operated in a controlled location with access limited to qualified personnel.

Informational Note: Testing for certification and listing is typically performed under the supervision of a qualified electrical testing organization.

Statement of Problem and Substantiation for Public Input

Off-shore wind turbines are becoming more common and these generators maybe located within the jurisdiction of the NEC. Requiring these systems to be listed for the specific application ensure these hazards are taken into consideration and facilitate inspection by the local AHJs.

Submitter Information Verification

Submitter Full Name: Timothy Zgonena
Organization: UL LLC
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 09 16:58:12 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9330-NFPA 70-2021
Statement: This change is in response to the emergence of off-shore wind installations that need additional requirements with respect to environment and accessibility.

Public Input No. 4002-NFPA 70-2020 [Section No. 694.7(B)]

(B) Equipment.

Wind electric systems shall be approved for the application in accordance with one of the following:

(1) Be listed

(2) Be evaluated for the application and have a field label applied

Wind electric systems undergoing evaluation for type certification and listing shall be permitted to be operated in a controlled location with access limited to qualified personnel.

Informational Note: ~~Testing for certification and listing~~ For further information on wind turbine equipment, see ANSI/ UL 6141 , Standard for Wind Turbines Permitting Entry of Personnel , and ANSI / UL 6142 , Standard for Small Wind Turbine Systems. Testing is typically performed under the supervision of a qualified electrical testing organization.

Statement of Problem and Substantiation for Public Input

Substantiation – The Standard for Wind Turbines Permitting Entry of Personnel, UL 6141, and the Standard for Small Wind Turbine Systems, UL 6142 were specifically written to address wind turbine equipment for the US market considering installation within the scope of the NEC and NESC. These two standards provide a certification (listing) pathway for equipment designed to US and international standards.

It is critical that wind turbines operate safely under normal and foreseeable abnormal fault conditions. The industrial control equipment standards often used for wind turbine components do not address the electrical and environmental conditions of use in the wind turbine application. It is safety critical that equipment be listed to the correct standard developed for wind turbine power production applications. This informational note is similar to the one used in 625 and 706 to provide guidance to the appropriate safety standard for the application.

Submitter Information Verification

Submitter Full Name: Timothy Zgonena
Organization: UL LLC
Street Address:
City:
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Zip:
Submittal Date: Wed Sep 09 17:02:33 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9332-NFPA 70-2021

Statement: The Standard for Wind Turbines Permitting Entry of Personnel, UL 6141, and the Standard for Small Wind Turbine Systems, UL 6142 were specifically written to address wind turbine equipment for the US market considering installation within the scope of the NEC and NESC. These two standards provide a certification (listing) pathway for equipment designed to US and international standards. It is critical that wind turbines operate safely under

normal and foreseeable abnormal fault conditions. The industrial control equipment standards often used for wind turbine components do not address the electrical and environmental conditions of use in the wind turbine application. It is safety critical that equipment be listed to the correct standard developed for wind turbine power production applications. This informational note is similar to the one used in Articles 625 and 706 to provide guidance to the appropriate safety standard for the application.

Public Input No. 3042-NFPA 70-2020 [Section No. 694.7(D)]

(D) ~~Surge Protective Devices (SPD).~~ Overvoltage Protection

A listed surge- protective device (SPD) shall be installed between a wind electric system and any loads served by the premises electrical system. The ~~surge protective device~~ SPD shall be permitted to be a Type 3 SPD on the circuit serving a wind electric system or a Type 2 SPD located anywhere on the load side of the service disconnect. ~~Surge protective devices~~ SPDs shall be installed in accordance with Part II of Article 242.

Statement of Problem and Substantiation for Public Input

The purpose of this public input is to correlate and harmonize all of the current sections of the code where “overvoltage protection” is required by:

1. Changing the section titles to “Overvoltage Protection” to properly correlate with Article 242.

2. Correcting the product description to “listed surge-protective device (SPD)” which is defined in Article 100 and correlates with Article 242.

3. Adding a pointer to “Part II. of Article 242” to ensure compliance with all of the requirements for SPDs are met when complying with the rule.

This public input is one of eleven correlating public inputs covering Sections 230.67, 501.35, 502.35, 620.51(E), 645.18, 670.6, 694.7(D), 695.15, 700.8, 708.20(D), and Informative Annex G.

Submitter Information Verification

Submitter Full Name: Megan Hayes
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Submittal Date: Fri Sep 04 10:25:08 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9334-NFPA 70-2021
Statement: The title was changed to better match Article 242. Repeated phrases were converted to the stated acronym “SPD”.

Public Input No. 3216-NFPA 70-2020 [Section No. 694.7(D)]

(D) ~~Surge Protective Devices (SPD).~~

~~A surge protective device~~

Overvoltage Protection.

Overvoltage protection shall be installed between a wind electric system and any loads served by the premises electrical system. The ~~surge~~ overvoltage protective device shall be permitted to be a VSGR, a Type 3 SPD on the circuit serving a wind electric system or a Type 2 SPD located anywhere on the load side of the service disconnect. ~~Surge~~ Overvoltage protective devices shall be installed in accordance with Part II of Article 242.

Additional Proposed Changes

File Name	Description	Approved
Code_Input.docx	input to improve overvoltage protection requirements	

Statement of Problem and Substantiation for Public Input

In the 2020 NEC cycle, ARTICLES 280 and 285 were combined to make ARTICLE 242. This was a positive change that began to address the issue of OVERVOLTAGE as a technical subject apart from particular product methods (SPDs and Surge Arresters). There are other technologies and products to address the issue of OVERVOLTAGE. This input attempts to add one such technology as well as correlate the other code references to the subject of OVERVOLTAGE, surge protective devices, and surge arresters to be consistent. This is important to allow for other technologies to be utilized without prejudice to certain products promoted by manufacturers.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3200-NFPA 70-2020 [Section No. 242.1]	
Public Input No. 3202-NFPA 70-2020 [New Article after 100]	
Public Input No. 3203-NFPA 70-2020 [New Article after 242]	
Public Input No. 3205-NFPA 70-2020 [Section No. 501.35]	
Public Input No. 3206-NFPA 70-2020 [Section No. 502.35]	
Public Input No. 3208-NFPA 70-2020 [Section No. 551.72(E)]	
Public Input No. 3209-NFPA 70-2020 [Section No. 490.24]	
Public Input No. 3210-NFPA 70-2020 [Section No. 490.48(A)]	
Public Input No. 3211-NFPA 70-2020 [Section No. 620.51(E)]	
Public Input No. 3212-NFPA 70-2020 [Section No. 645.18]	
Public Input No. 3214-NFPA 70-2020 [Section No. 670.6]	
Public Input No. 3217-NFPA 70-2020 [Section No. 695.15]	
Public Input No. 3218-NFPA 70-2020 [Section No. 700.8]	
Public Input No. 3219-NFPA 70-2020 [Section No. 708.20(D)]	

Submitter Information Verification

Submitter Full Name: Karl Cunningham

Organization: Self Employed
Street Address:
City:
State:
Zip:
Submittal Date: Sun Sep 06 18:51:51 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: The proposed acronym refers to a "voltage stabilizing ground reference system" that is not a listed overvoltage protection device.

Substantiation for Changes: In the 2020 NEC cycle, ARTICLES 280 and 285 were combined to make ARTICLE 242. This was a positive change that began to address the issue of OVERVOLTAGE as a technical subject apart from particular product methods (SPDs and Surge Arresters). There are other technologies and products to address the issue of OVERVOLTAGE. This input attempts to add one such technology as well as correlate the other code references to the subject of OVERVOLTAGE, surge protective devices, and surge arresters to be consistent. This is important to allow for other technologies to be utilized without prejudice to certain products promoted by manufacturers.

ARTICLE 100 - DEFINITIONS

Voltage Stabilizing Ground Reference (VSGR) System – an engineered assembly of interconnected passive inductive devices that utilize mutual counter electro-magnetic inductance to stabilize phase voltages of a connected supply system with respect to each other and to ground.

ARTICLE 242 Overvoltage Protection

Part I. General

242.1 Scope.
This article provides the general requirements, installation requirements, and connection requirements for overvoltage protection and overvoltage protective devices. Part II covers surge-protective devices (SPDs) permanently installed on premises wiring systems of not more than 1000 volts, nominal, while Part III covers surge arresters permanently installed on premises wiring systems over 1000 volts, nominal. Part IV covers Voltage Stabilizing Ground Reference (VSGR) systems permanently installed on premises wiring systems for any voltage.

Informational Note: Article 242 combines and replaces Articles 280 and 285 in *NFPA 70*-2017.

242.3 Other Articles.
Equipment shall be protected against overvoltage in accordance with the article in this *Code* that covers the type of equipment or location specified in Table 242.3.

Table 242.3 Other Articles

Equipment	Article
Class I locations	501
Class II locations	502
Community antenna television and radio distribution systems	820
Critical operations power systems	708

Table 242.3 Other Articles

Equipment	Article
Elevators, dumbwaiters, escalators, moving walks, platform lifts, and stairway chairlifts	620
Emergency systems	700
Equipment over 1000 volts, nominal	490
Fire pumps	695
Industrial machinery	670
Information technology equipment	645
Modular data centers	646
Outdoor overhead conductors over 1000 volts	399
Radio and television equipment	810
Receptacles, cord connectors, and attachment plugs (caps)	406
Wind electric systems	694

Part II. Surge-Protective Devices (SPDs), 1000 Volts or Less

Informational Note: Surge arresters 1000 volts or less are also known as Type 1 SPDs.

242.6 Uses Not Permitted.

An SPD device shall not be installed in the following:

1. (1)

   Circuits over 1000 volts

2. (2)

   On ungrounded systems, impedance grounded systems, or corner grounded delta systems unless listed specifically for use on these systems

3. (3)

   Where the rating of the SPD is less than the maximum continuous phase-to-ground voltage at the power frequency available at the point of application

242.8 Listing.
An SPD shall be a listed device.

242.10 Short-Circuit Current Rating.
The SPD shall be marked with a short-circuit current rating and shall not be installed at a point on the system where the available fault current is in excess of that rating. This marking requirement shall not apply to receptacles.

242.12 Type 1 SPDs.
Type 1 SPDs shall be installed in accordance with 242.12(A) and (B).

242.12(A) Installation.
Type 1 SPDs shall be permitted to be connected in accordance with one of the following:

1. (1)

   To the supply side of the service disconnect as permitted in 230.82(4)

2. (2)

   As specified in 242.14

242.12(B) At the Service.
When installed at services, Type 1 SPDs shall be connected to one of the following:

1. (1)

   Grounded service conductor

2. (2)

   Grounding electrode conductor

3. (3)

   Grounding electrode for the service

4. (4)

   Equipment grounding terminal in the service equipment

242.14 Type 2 SPDs.
Type 2 SPDs shall be installed in accordance with 242.14(A) through (C).

242.14(A) Service-Supplied Building or Structure.
Type 2 SPDs shall be connected anywhere on the load side of a service disconnect overcurrent device required in 230.91 unless installed in accordance with 230.82(8).

242.14(B) Feeder-Supplied Building or Structure.
Type 2 SPDs shall be connected at the building or structure anywhere on the load side of the first overcurrent device at the building or structure.

242.14(C) Separately Derived System.
The SPD shall be connected on the load side of the first overcurrent device in a separately derived system.

242.16 Type 3 SPDs.
Type 3 SPDs shall be permitted to be installed on the load side of branch-circuit overcurrent protection up to the equipment served. If included in the manufacturer's instructions, the Type 3 SPD connection shall be a minimum 10 m (30 ft) of conductor distance from the service or separately derived system disconnect.

242.18 Type 4 and Other Component Type SPDs.
Type 4 component assemblies and other component type SPDs shall only be installed by the equipment manufacturer.

242.20 Number Required.
Where used at a point on a circuit, the SPD shall be connected to each ungrounded conductor.

242.22 Location.
SPDs shall be permitted to be located indoors or outdoors and shall be made inaccessible to unqualified persons unless listed for installation in accessible locations.

242.24 Routing of Connections.
The conductors used to connect the SPD to the line or bus and to ground shall not be any longer than necessary and shall avoid unnecessary bends.

242.26 Connection.
Where an SPD device is installed, it shall comply with 242.12, 242.14, 242.16, 242.28. and 242.30.

242.28 Conductor Size.
Line and grounding conductors shall not be smaller than 14 AWG copper or 12 AWG aluminum.

242.30 Connection Between Conductors.
An SPD shall be permitted to be connected between any two conductors — ungrounded conductor(s), grounded conductor, equipment grounding conductor, or grounding electrode conductor. The grounded conductor and the equipment grounding conductor shall be interconnected only by the normal operation of the SPD during a surge.

242.32 Grounding Electrode Conductor Connections and Enclosures.
Except as indicated in this article, SPD grounding connections shall be made as specified in Article 250, Part III. Grounding electrode conductors installed in metal enclosures shall comply with 250.64(E).

Part III. Surge Arresters, Over 1000 Volts

242.40 Uses Not Permitted.
A surge arrester shall not be installed where the rating of the surge arrester is less than the maximum continuous phase-to-ground voltage at the power frequency available at the point of application.

242.42 Surge Arrester Selection.
The surge arresters shall comply with 242.42(A) and (B).

242.42(A) Rating.
The rating of a surge arrester shall be equal to or greater than the maximum continuous operating voltage available at the point of application.

242.42(A)(1) Solidly Grounded Systems.
The maximum continuous operating voltage shall be the phase-to-ground voltage of the system.

242.42(A)(2) Impedance or Ungrounded System.

The maximum continuous operating voltage shall be the phase-to-phase voltage of the system.

242.42(B) Silicon Carbide Types.
The rating of a silicon carbide-type surge arrester shall be not less than 125 percent of the rating specified in 242.42(A).

Informational Note No. 1: For further information on surge arresters, see IEEE C62.11-2012, *Standard for Metal-Oxide Surge Arresters for Alternating-Current Power Circuits (>1 kV)*, and IEEE C62.22-2009, *Guide for the Application of Metal-Oxide Surge Arresters for Alternating-Current Systems*.

Informational Note No. 2: The selection of a properly rated metal oxide arrester is based on considerations of maximum continuous operating voltage and the magnitude and duration of overvoltages at the arrester location as affected by phase-to-ground faults, system grounding techniques, switching surges, and other causes. See the manufacturer's application rules for selection of the specific arrester to be used at a particular location.

242.44 Number Required.
Where used at a point on a circuit, a surge arrester shall be connected to each ungrounded conductor. A single installation of such surge arresters shall be permitted to protect a number of interconnected circuits if no circuit is exposed to surges while disconnected from the surge arresters.

242.46 Location.
Surge arresters shall be permitted to be located indoors or outdoors. Surge arresters shall be made inaccessible to unqualified persons unless listed for installation in accessible locations.

242.48 Routing of Surge Arrester Equipment Grounding Conductors.
The conductor used to connect the surge arrester to line, bus, or equipment and to an equipment grounding conductor or grounding electrode connection point as provided in 242.50 shall not be any longer than necessary and shall avoid unnecessary bends.

242.50 Connection.
The arrester shall be connected to one of the following:

1. (1)

   Grounded service conductor

2. (2)

   Grounding electrode conductor

3. (3)

   Grounding electrode for the service

4. (4)

   Equipment grounding terminal in the service equipment

242.52 Surge-Arrester Conductors.
The conductor between the surge arrester and the line, and the surge arrester and the grounding connection, shall not be smaller than 6 AWG copper or aluminum.

242.54 Interconnections.
The surge arrester protecting a transformer that supplies a secondary distribution system shall be interconnected as specified in 242.54(A), (B), or (C).

242.54(A) Metal Interconnections.
A metal interconnection shall be made to the secondary grounded circuit conductor or the secondary circuit grounding electrode conductor, if, in addition to the direct grounding connection at the surge arrester, the connection complies with 242.54(A)(1) or (A)(2).

242.54(A)(1) Additional Grounding Connection.
The grounded conductor of the secondary has a grounding connection elsewhere to a continuous metal underground water piping system. In urban water-pipe areas where there are at least four water-pipe connections on the neutral conductor and not fewer than four such connections in each mile of neutral conductor, the metal interconnection shall be permitted to be made to the secondary neutral conductor with omission of the direct grounding connection at the surge arrester.

242.54(A)(2) Multigrounded Neutral System Connection.
The grounded conductor of the secondary system is part of a multigrounded neutral system or static wire of which the primary neutral conductor or static wire has at least four grounding connections in each 1.6 km (1 mile) of line in addition to a grounding connection at each service.

242.54(B) Through Spark Gap or Device.
Where the surge arrester grounding electrode conductor is not connected as in 242.54(A), or where the secondary is not grounded as in 242.54(A) but is otherwise grounded as in 250.52, an interconnection shall be made through a spark gap or listed device as required by 242.54(B)(1) or (B)(2).

242.54(B)(1) Ungrounded or Unigrounded Primary System.
For ungrounded or unigrounded primary systems, the spark gap for a listed device shall have a 60-Hz breakdown voltage of at least twice the primary circuit voltage but not necessarily more than 10 kV, and there shall be at least one other ground on the grounded conductor of the secondary that is not less than 6.0 m (20 ft) distant from the surge-arrester grounding electrode.

242.54(B)(2) Multigrounded Neutral Primary System.
For multigrounded neutral primary systems, the spark gap or listed device shall have a 60-Hz breakdown of not more than 3 kV, and there shall be at least one other ground on the grounded conductor of the secondary that is not less than 6.0 m (20 ft) distant from the surge-arrester grounding electrode.

242.54(C) By Special Permission.
An interconnection of the surge-arrester ground and the secondary neutral conductor, other than as provided in 242.54(A) or (B), shall be permitted to be made only by special permission.

242.56 Grounding Electrode Conductor Connections and Enclosures.
Except as indicated in this article, surge-arrester grounding electrode conductor connections shall be made as specified in Article 250, Parts III and X. Grounding electrode conductors installed in metal enclosures shall comply with 250.64(E).

Part IV. Voltage Stabilizing Ground Reference (VSGR) systems.

242.68 Listing.
A VSGR shall be a listed device or system composed of listed components.

242.70 Short-Circuit Current Rating.
The VSGR shall be marked with a short-circuit current rating and shall not be installed at a point on the system where the available fault current is in excess of that rating.

242.71 Voltage Rating.
The rating of the VSGR shall be equal to or greater than the maximum system continuous operating voltage at the point of application.

242.72 Installation.
VSGRs shall be installed in accordance with 242.72(A) through (C).

242.72(A) Service-Supplied Building or Structure.
VSGR shall be connected anywhere on the load side of a service disconnect overcurrent device required in 230.91 unless installed in accordance with 230.82(8).

242.72(B) Feeder-Supplied Building or Structure.
VSGR shall be connected at the building or structure anywhere on the load side of the first overcurrent device at the building or structure.

242.72(C) Separately Derived System.
VSGR shall be connected on the load side of the first overcurrent device in a separately derived system.

242.82 Location.
VSGRs shall be permitted to be located indoors or outdoors and shall be made inaccessible to unqualified persons unless listed for installation in accessible locations.

242.84 Conductor Size.
Line and grounding conductors shall not be smaller than 14 AWG copper or 12 AWG aluminum.

242.90 Connection Between Conductors.
VSGR connections shall follow the manufacturer's instructions for the system connections.

242.92 Grounding Electrode Conductor Connections and Enclosures.
Except as indicated in this article, VSGR grounding connections shall be made as specified in Article 250, Part III. Grounding electrode conductors installed in metal enclosures shall comply with 250.64(E).

501.35 Overvoltage ~~Surge~~ Protection.

501.35(A) Class I, Division 1.
Overvoltage protection devices, surge arresters, surge-protective devices, and capacitors shall be installed in enclosures identified for Class I, Division 1 locations. Surge-protective capacitors shall be of a type designed for specific duty.

501.35(B) Class I, Division 2.
Overvoltage protection devices, surge arresters and surge-protective devices shall be nonarcing, such as metal-oxide varistor (MOV) sealed type, and surge-protective capacitors shall be of a type designed for specific duty. Enclosures shall be permitted to be of the general-purpose type. Overvoltage ~~Surge~~ protection of types other than described in this paragraph shall be installed in enclosures identified for Class I, Division 1 locations.

502.35 Overvoltage ~~Surge~~ Protection — Class II, Divisions 1 and 2.
Overvoltage protection devices, surge arresters and surge-protective devices installed in a Class II, Division 1 location shall be in suitable enclosures. Surge-protective capacitors shall be of a type designed for specific duty.

551.72(E) Connected Devices.
The use of autotransformers shall not be permitted. The use of listed overvoltage and surge protective devices shall be permitted.

Table 490.24 Minimum Clearance of Live Parts

Note: The values given are the minimum clearance for rigid parts and bare conductors under favorable service conditions. They shall be increased for conductor movement or under unfavorable service conditions or wherever space limitations permit. The selection of the associated impulse withstand voltage for a particular system voltage is determined by the characteristics of the overvoltage ~~surge~~ protective equipment.

490.48(A) Design and Documentation.

(12) Overvoltage ~~Surge~~ arresters

620.51(E) Overvoltage ~~Surge~~ Protection.
Overvoltage protection shall be provided where any of the disconnecting means in 620.51 has been designated as supplying an emergency system load, a legally required system load, or a critical operation power system load, ~~listed surge protection shall be provided.~~

645.18 Overvoltage ~~Surge~~ Protection for Critical Operations Data Systems.
Overvoltage ~~Listed surge~~ protection shall be provided for critical operations data systems.

670.6 Surge Protection.
Industrial machinery with safety interlock control devices not effectively protected from voltage surges on the incoming supply circuit shall have overvoltage ~~surge~~ protection installed.

694.7(D) Overvoltage Protection ~~Surge Protective Devices (SPD).~~
Overvoltage protection ~~A surge protective device~~ shall be installed between a wind electric system and any loads served by the premises electrical system. The ~~surge~~ protective device shall be permitted to be a VSGR, or a Type 3 SPD on the circuit serving a wind electric system, or a Type 2 SPD located anywhere on the load side of the service disconnect. Overvoltage ~~Surge~~ protective devices shall be installed in accordance with Part II of Article 242.

695.15 Overvoltage ~~Surge~~ Protection.
Overvoltage ~~A listed surge~~ protection ~~device~~ shall be provided for ~~installed in or on~~ the fire pump controller.

700.8 Overvoltage ~~Surge~~ Protection.
Overvoltage protection ~~A listed SPD~~ shall be provided installed in ~~or on~~ for all emergency systems switchboards and panelboards.

708.20(D) Overvoltage ~~Surge~~ Protection ~~Devices~~.

Surge protection devices shall be provided at all facility distribution voltage levels

Public Input No. 4102-NFPA 70-2020 [Section No. 694.15(A)]

(A) Circuits and Equipment.

Turbine output circuits, inverter output circuits, and storage battery circuit conductors and equipment shall be protected in accordance ~~with the requirements of~~ with Article 240. Circuits connected to more than one electrical source shall have overcurrent devices located so as to provide overcurrent protection from all sources.

Exception: An overcurrent device shall not be required for circuit conductors sized in accordance with 694.12(B) where the maximum current from all sources does not exceed the ampacity of the conductors.

Informational Note: Possible backfeed of current from any source of supply, including a supply through an inverter to the wind turbine output circuit, is a consideration in determining whether overcurrent protection from all sources is provided. Some wind electric systems rely on the turbine output circuit to regulate turbine speed. Inverters may also operate in reverse for turbine startup or speed control.

Statement of Problem and Substantiation for Public Input

Deleting the words ""the requirements of"" does not change the meaning of the section.
The panel should consider revising the section due to a Style Manual issue 4.1.4 where a section shall not reference a complete article.

Submitter Information Verification

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Submittal Date: Wed Sep 09 20:43:22 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9335-NFPA 70-2021
Statement: Deleting "with the requirements of" does not change the meaning of the section. The whole article reference was changed to the relevant sections: Section 240.4 Protection of Conductors and Section 240.5 Protection of Flexible Cords, Flexible Cables, and Fixture Wires.

Public Input No. 4089-NFPA 70-2020 [Section No. 694.22(C)(1)]

(1) Location.

The wind electric system disconnecting means shall be installed at a readily accessible location either on or adjacent to the turbine tower, on the outside of a building or structure, or inside at the point of entrance of the wind system conductors.

Exception: Installations that comply with 694.30(C) shall be permitted to have the disconnecting means located remotely from the point of entry of the wind system conductors.

A wind turbine disconnecting means shall not be required to be located at the nacelle or tower.

The disconnecting means shall not be installed in bathrooms.

~~For one-family and two-family dwellings, a disconnecting means or manual shutdown button or switch shall be located at a readily accessible location outside the building.~~

694.22(C)(5). **Emergency Disconnect/Shutdown.** For one- and two-family dwellings, an emergency disconnecting or shutdown means shall comply with (1) through (4).

(1) Be located in a readily accessible location outside the building

(2) Be located within 1 m (3 ft) of any required emergency service disconnect or where there is no required emergency service disconnect, shall be located within 1 m (3 ft) of any other power source emergency disconnect or any PV rapid shutdown initiator

(3) If remotely controlled, the remote-control system shall be “fail safe” where the disconnect automatically opens or the wind system is shutdown on loss of control signal or control power

(4) Be labeled “EMERGENCY WIND SYSTEM DISCONNECT/SHUTDOWN” and comply with 110.21(B).

Statement of Problem and Substantiation for Public Input

This proposal is one of several related, but separate proposals involving the 2020 NEC requirements for external (outside the building) emergency disconnects on one- and two-family dwellings for energy sources such as the utility service, batteries, fuel cell systems, energy storage systems (ESS), wind systems and also stand-alone PV systems plus PV rapid shutdown systems. The intent of these proposals is to require multiple emergency disconnects to be grouped in one location to increase safety for Fire Service responders.

Also, when remote activation of these disconnects is allowed, the proposal establishes an additional safety requirement that the remote controls be fail safe and in the event of loss of control power or control signal, the emergency disconnect shall automatically be opened.

It has been determined that some inverter manufacturers are already starting to put inputs on their products to allow an external remote shutdown control system that is fail safe. Also, it has been determined that adding such a fail-safe remotely controlled emergency disconnect system is relatively inexpensive using voltage-trip circuit breakers and a relay on large battery banks or ESS.

Submitter Information Verification

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Committee: NEC-P04

Committee Statement

Resolution: There is already a requirement for a manual shutdown capability in Section 694.23. Section 694.22 refers to disconnecting means. Location information for the shutdown means is required to be placarded in 705.10. Shutdown instructions are required to be posted per Section 694.56: A plaque shall be installed at or adjacent to the turbine location providing basic instructions for disabling the turbine.

Public Input No. 2980-NFPA 70-2020 [Section No. 694.24]

694.24 Disconnection of Wind Electric System Equipment.

Means shall be provided to disconnect equipment, such as inverters, batteries, and charge controllers, from all ungrounded conductors of all sources. If the equipment is energized from more than one source, the disconnecting means shall be grouped and identified.

A single disconnecting means in accordance with 694.22 shall be permitted for the combined ac output of one or more inverters ~~in an interactive system~~ .

A shorting switch or plug shall be permitted to be used as an alternative to a disconnect in systems that regulate turbine speed using the turbine output circuit.

Exception: Equipment housed in a turbine nacelle shall not be required to have a disconnecting means.

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

As part of this task group's effort, the term Interactive system is being changed and will no longer exist should the PI be accepted. This section is accurate and more concise without this language. there is no need to add reference to the newly created term of interactive mode.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2684-NFPA 70-2020 [Definition: Interactive System.]	New Term / Definition

Submitter Information Verification

Submitter Full Name: Thomas Domitrovich
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Submittal Date: Thu Sep 03 18:20:33 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9337-NFPA 70-2021
Statement: Deleting "in an interactive system" improves clarity, does not change requirements and generalizes them to islanded and grid-connected modes.

Public Input No. 3846-NFPA 70-2020 [Section No. 694.30(A)]

(A) Wiring Systems.

All raceway and cable wiring methods included in Chapter 3 of this *Code*, and other wiring systems and fittings specifically intended for use on wind turbines, shall be permitted. In readily accessible locations, turbine output circuits that operate at voltages greater than 30 volts shall be installed in raceways.

Statement of Problem and Substantiation for Public Input

This Public Input is submitted on behalf of a Correlating Committee Long-Range Planning Task Group consisting of Robert Osborne (Chair), Paul Barnhart, Lou Grahor, David Temple, Donny Cook, Dean Hunter, Mike Querry, Roger McDaniel, Dave Burns, Rod Belisle, and Kevin Rogers. This Public Input, along with other companion Public Inputs, was developed with the goal of improving usability and providing a platform to increase the focus on requirements associated with Medium or High Voltage.

This Task Group's initial tasks were to establish a demarcation for what can be referred to as Medium or High Voltage. The recommendation has been to establish this threshold as being equipment rated over 1000 Vac, 1500 Vdc.

Using these limits, the Task Group set out to identify a structure to better align requirements, improve consistency in approach, improve usability, and create the opportunity for Code Making Panels to have an increased focus on higher voltage applications

This proposed change provides consistency in the Alternative Energy articles in order to address the wiring system(s) and/or method(s) that could be encountered within or as a part of the system (solar, wind or energy storage) installation. By adding the reference back to Chapter 3, the new text will correlate with the existing language found in NEC 692.31 for "Wiring Systems" for Fuel Cell Systems and provide direction to the installer, so that regardless of the voltage, all wiring systems and methods would comply with the applicable Chapter 3 Article.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3728-NFPA 70-2020 [Global Input]	Companion Public Input (Articles 245 and 495)
Public Input No. 3765-NFPA 70-2020 [New Section after 250.194(B)]	Companion Public Input (Article 255)
Public Input No. 3772-NFPA 70-2020 [New Section after 110.79]	Companion Public Input (Article 115)
Public Input No. 3815-NFPA 70-2020 [New Section after 200.11]	Companion Public Input (Article 205)
Public Input No. 3819-NFPA 70-2020 [Global Input]	Companion Public Input (Article 235)
Public Input No. 3827-NFPA 70-2020 [Global Input]	Companion Public Input (Article 305)
Public Input No. 3838-NFPA 70-2020 [Section No. 690.31(A)]	Companion Public Input (Section 690.31(A))
Public Input No. 3849-NFPA 70-2020 [New Part after IV.]	Companion Public Input (Section 706.30)
Public Input No. 3728-NFPA 70-2020 [Global Input]	

Public Input No. 3765-NFPA 70-2020 [New Section after 250.194(B)]

Public Input No. 3772-NFPA 70-2020 [New Section after 110.79]

Public Input No. 3815-NFPA 70-2020 [New Section after 200.11]

Public Input No. 3819-NFPA 70-2020 [Global Input]

Public Input No. 3827-NFPA 70-2020 [Global Input]

Public Input No. 3838-NFPA 70-2020 [Section No. 690.31(A)]

Public Input No. 3849-NFPA 70-2020 [New Part after IV.]

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Committee: NEC-P04

Committee Statement

Resolution: FR-9489-NFPA 70-2021

Statement: Recognition of acceptable wiring methods including special equipment has been edited for clarity and consistency with other articles.

Public Input No. 2981-NFPA 70-2020 [Section No. 694.50]

694.50 Interactive System Point of Interconnection.

~~All interactive system points~~ All points of interconnection with other sources shall be marked at an accessible location at the disconnecting means and with the rated ac output current and the nominal operating ac voltage.

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

The work of this committee includes modifying the term Interactive System found in Article 100. With this modification this term is no longer defined and so this section is impacted. This public input is simply removing this language as its removal helps remove possible confusion and this section is not technically impacted without it being there.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2684-NFPA 70-2020 [Definition: Interactive System.]	Term / Definition change

Submitter Information Verification

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Submittal Date: Thu Sep 03 18:24:46 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9340-NFPA 70-2021

Statement: This revision is submitted in conjunction with the related revision to move the marking requirement now located in 694.50 to a more appropriate location in 705.14. Because this requirement is not specific to wind systems but instead is a more general requirement for labeling an interactive point of interconnection to other sources, it belongs in Article 705. The intent of this revision is not to change the marking requirement – which will still apply to interconnected wind systems – but rather to insure that it is applied across the board to all interconnected power sources.

Public Input No. 3001-NFPA 70-2020 [Section No. 694.54]

694.54 Identification of Power Sources.

Wind turbine systems shall be ~~identified according to~~ 694.54(A) ~~through (C).~~

~~**(A)** Interconnected AC Systems.~~

~~Plaques or directories shall be installed in accordance with~~ 705.10 ~~.~~

~~**(B)** DC Microgrid Systems.~~

~~Plaques or directories shall be installed in accordance with~~ 712.10 ~~.~~

~~**(C)** Stand-Alone Systems.~~

~~Plaques or directories shall be installed in accordance with~~ 710.10 ~~.~~

marked with a plaque or directory installed in accordance with 689.10 .

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

This modification is necessary as 710, 712 and 689 are combined as part of this task group effort into a new Article 689. The proper reference for plaques and directories is found in 689.10 only. In addition, this section was simplified as only one reference section exists. Changes simplify and add clarity.

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Committee: NEC-P04

Committee Statement

Resolution: FR-9341-NFPA 70-2021
Statement: With the changes made to other articles, a single reference to this section is necessary. These references have been consolidated in Section 705.10.

Public Input No. 1500-NFPA 70-2020 [Section No. 694.62]

694.62 Installation.

(A) Utility.

Wind electric systems, where connected to utility electric sources, shall comply with the requirements of Article 705.

(B) Energy Storage System.

An energy storage system connected to a wind electric system shall be installed in accordance with Article 706.

Statement of Problem and Substantiation for Public Input

Currently ESS's are being installed in conjunction with wind systems. As Article 706 is a relatively new article, there needs to be a requirement like 690.71 where users of this code are directed to the additional requirements of ESS's.

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Committee: NEC-P04

Committee Statement

Resolution: New organization of these articles makes it clear that all sources that are combined with other sources must be installed in accordance with Article 705. A new reference to Article 706 is not necessary.

Public Input No. 3002-NFPA 70-2020 [Section No. 694.62]

~~**694.62** Installation.~~

~~Wind electric systems, where connected to utility electric sources, shall comply with the requirements of Article 705 .~~

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

New organization of these articles makes it clear that all sources that are combined with other sources must be installed in accordance with Article 689. The reference to Article 705, which violates the style manual, is not necessary.

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Committee: NEC-P04

Committee Statement

Resolution: FR-9496-NFPA 70-2021
Statement: The language is modified to match the language in Articles 690 and 692.

Public Input No. 1438-NFPA 70-2020 [Article 705]

Article 705 Interconnected Electric Power ~~Production~~ Generating Sources

Part I. General

705.1 Scope.

This article covers installation of one or more electric power ~~production~~ generating sources operating in parallel with a primary source(s) of electricity.

Informational Note: Examples of the types of primary sources include a utility supply or an on-site electric power source(s).

705.2 Definitions.

The definitions in this section shall apply within this article and throughout the *Code*.

Microgrid Interconnect Device (MID).

A device that enables a microgrid system to separate from and reconnect to operate in parallel with a primary power source.

Informational Note: Microgrid controllers typically are used to measure and evaluate electrical parameters and provide the logic for the signal to initiate and complete transition processes. IEEE Std 2030.7-2017, *IEEE Standard for the Specification of Microgrid Controllers*, and IEEE Std 2030.8-2018, *IEEE Standard for the Testing of Microgrid Controllers*, provide information on microgrid controllers. IEEE Std 1547-2018, *IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces*, provides information on interconnection requirements.

Microgrid System.

A premises wiring system that has generation, energy storage, and load(s), or any combination thereof, that includes the ability to disconnect from and parallel with the primary source.

Informational Note: The application of Article 705 to microgrid systems is limited by the exclusions in 90.2(B)(5) related to electric utilities. Additional information may be found in IEEE 1547, IEEE 2030.7, and IEEE 2030.8.

Power Source Output Circuit.

The conductors between power ~~production~~ generating equipment and the service or distribution equipment.

705.6 Equipment Approval.

All equipment shall be approved for the intended use. Interactive equipment intended to operate in parallel with electric power ~~production~~ generating sources including, but not limited to, interactive inverters, engine generators, energy storage equipment, and wind turbines shall be listed for interactive function or be evaluated for interactive function and have a field label applied, or both.

705.8 System Installation.

Installation of one or more electrical power ~~production~~ generating sources operating in parallel with a primary source(s) of electricity shall be performed only by qualified persons.

Informational Note: See Article 100 for the definition of *Qualified Person*.

705.10 Identification of Power Sources.

A permanent plaque or directory shall be installed at each service equipment location, or at an approved readily visible location. The plaque or directory shall denote the location of each power source disconnecting means for the building or structure and be grouped with other plaques or directories for other on-site sources. The plaque or directory shall be marked with the wording "CAUTION: MULTIPLE SOURCES OF POWER." Any posted diagrams shall be correctly oriented with respect to the diagram's location. The marking shall comply with 110.21(B).

Exception: Installations with multiple co-located power production sources shall be permitted to be identified as a group(s). The plaque or directory shall not be required to identify each power source individually.

705.11 Supply-Side Source Connections.

An electric power ~~production~~ generating source, where connected on the supply side of the service disconnecting means as permitted in 230.82(6), shall comply with 705.11(A) through (E).

(A) Output Rating.

The sum of the power source continuous current output ratings on a service, other than those controlled in accordance with 705.13, shall not exceed the ampacity of the service conductors.

Informational Note: See Article 100 definition for Service Conductors.

(B) Conductors.

The power source output circuit conductors from the service conductors point of connection to the first overcurrent protection device shall be sized in accordance with 705.28 and in no case sized smaller than 6 AWG copper or 4 AWG aluminum. These conductors shall be installed in accordance with 230.30 or 230.43.

(C) Overcurrent Protection.

The power source output circuit conductors shall be protected from overcurrent in accordance with 705.30. If fuses are not integral with the disconnecting means, the disconnecting means shall be located on the service side of the fuses. Where the power source output circuit conductors make their connection to the service outside of a building, they shall be protected by overcurrent devices in a readily accessible location outside the building or at the first readily accessible location where the power source conductors enter the building. Where the power source output circuit conductors make their connection to the service inside a building, they shall be protected with one of the following methods:

(1) With an overcurrent device located within 3 m (10 ft) of conductor length in dwelling units and 5 m (16.5 ft) in other than dwelling units from the point of connection to the service

(2) In other than a dwelling unit, with an overcurrent device located within 20 m (71 ft)of conductor length from the point of connection to the service, provided that cable limiters installed in all ungrounded conductors are located within 5 m (16.5 ft) of conductor length from the point of connection to the service

(D) Connections.

The connection of power source output circuit conductors to the service conductors shall be made using listed connectors as described in 110.14 and comply with all enclosure fill requirements Any modifications to existing equipment shall be made in accordance with the manufacturer's instructions or the modification must be evaluated for the application and have a field label applied. For meter socket enclosures or other equipment under the exclusive control of the electric utility, only connections approved by the electric utility shall be permitted.

(E) Ground-Fault Protection.

For connections rated 1000 amperes or more to solidly grounded wye services exceeding 150 volts to ground but not exceeding 1000 volts, phase-to-phase, ground-fault protection meeting the requirements of 230.95 shall be provided.

705.12 Load-Side Source Connections.

The output of an interconnected electric power source shall be permitted to be connected to the load side of the service disconnecting means of the other source(s) at any distribution equipment on the premises. Where distribution equipment or feeders are fed simultaneously by a primary source of electricity and one or more other power source and are capable of supplying multiple branch circuits or feeders, or both, the interconnecting equipment shall comply with 705.12(A) through (E). Where a power control system (PCS) is installed in accordance with 705.13, the setting of the PCS controller shall be considered the power-source output circuit current in 705.12(A) through (E).

(A) Dedicated Overcurrent and Disconnect.

Each source interconnection of one or more power sources installed in one system shall be made at a dedicated circuit breaker or fusible disconnecting means.

(B) Bus or Conductor Ampere Rating.

The power source output circuit current multiplied by 125 percent shall be used in ampacity calculations for 705.12(B)(1) through (B)(3).

(1) Feeders.

Where the power source output connection is made to a feeder, the feeder shall have an ampacity greater than or equal to 125 percent of the power-source output circuit current. Where the power-source output connection is made to a feeder at a location other than the opposite end of the feeder from the primary source overcurrent device, that portion of the feeder on the load side of the power source output connection shall be protected by one of the following:

(1) The feeder ampacity shall be not less than the sum of the primary source overcurrent device and 125 percent of the power-source output circuit current.

(2) An overcurrent device at the load side of the power source connection point shall be rated not greater than the ampacity of the feeder.

(2) Taps.

Where power source output connections are made at feeders, all taps shall be sized based on the sum of 125 percent of all power source(s) output circuit current(s) and the rating of the overcurrent device protecting the feeder conductors for sizing tap conductors using the calculations in 240.21(B).

(3) Busbars.

One of the following methods shall be used to determine the ratings of busbars:

(1) The sum of 125 percent of the power source(s) output circuit current and the rating of the overcurrent device protecting the busbar shall not exceed the ampacity of the busbar.

Informational Note: This general rule assumes no limitation in the number of the loads or sources applied to busbars or their locations.

(2) Where two sources, one a primary power source and the other another power source, are located at opposite ends of a busbar that contains loads, the sum of 125 percent of the power-source(s) output circuit current and the rating of the overcurrent device protecting the busbar shall not exceed 120 percent of the ampacity of the busbar. The busbar shall be sized for the loads connected in accordance with Article 220. A permanent warning label shall be applied to the distribution equipment adjacent to the back-fed breaker from the power source that displays the following or equivalent wording:

WARNING:

POWER SOURCE OUTPUT CONNECTION—

DO NOT RELOCATE THIS OVERCURRENT DEVICE.

The warning sign(s) or label(s) shall comply with 110.21(B).

(3) The sum of the ampere ratings of all overcurrent devices on panelboards, both load and supply devices, excluding the rating of the overcurrent device protecting the busbar, shall not exceed the ampacity of the busbar. The rating of the overcurrent device protecting the busbar shall not exceed the rating of the busbar. Permanent warning labels shall be applied to distribution equipment displaying the following or equivalent wording:

WARNING:

THIS EQUIPMENT FED BY MULTIPLE SOURCES.

TOTAL RATING OF ALL OVERCURRENT DEVICES

EXCLUDING MAIN SUPPLY OVERCURRENT DEVICE

SHALL NOT EXCEED AMPACITY OF BUSBAR.

The warning sign(s) or label(s) shall comply with 110.21(B).

(4) A connection at either end of a center-fed panelboard in dwellings shall be permitted where the sum of 125 percent of the power-source(s) output circuit current and the rating of the overcurrent device protecting the busbar does not exceed 120 percent of the current rating of the busbar.

(5) Connections shall be permitted on switchgear, switchboards, and panelboards in configurations other than those permitted in 705.12(B)(3)(1) through (B)(3)(4) where designed under engineering supervision that includes available fault-current and busbar load calculations.

(6) Connections shall be permitted on busbars of panelboards that supply lugs connected to feed-through conductors. The feed-through conductors shall be sized in accordance with 705.12(B)(1). Where an overcurrent device is installed at the supply end of the feed-through conductors, the busbar in the supplying panelboard shall be permitted to be sized in accordance with 705.12(B)(3)(1) through 705.12(B)(3)(3).

(C) Marking.

Equipment containing overcurrent devices in circuits supplying power to a busbar or conductor supplied from multiple sources shall be marked to indicate the presence of all sources.

(D) Suitable for Backfeed.

Fused disconnects, unless otherwise marked, shall be considered suitable for backfeed. Circuit breakers not marked “line” and “load” shall be considered suitable for backfeed. Circuit breakers marked “line” and “load” shall be considered suitable for backfeed or reverse current if specifically rated.

(E) Fastening.

Listed plug-in-type circuit breakers back-fed from electric power sources that are listed and identified as interactive shall be permitted to omit the additional fastener normally required by 408.36(D) for such applications.

705.13 Power Control Systems.

A power control system (PCS) shall be listed and evaluated to control the output of one or more power production sources, energy storage systems (ESS), and other equipment. The PCS shall limit current and loading on the busbars and conductors supplied by the PCS.

For the circuits connected to a PCS, the PCS shall limit the current to the ampacity of the conductors or the ratings of the busbars to which it is connected in accordance with 705.13(A) through (E).

(A) Monitoring.

The PCS controller shall monitor all currents within the PCS. Any busbar or conductor on the load side of the service disconnecting means that is not monitored by the PCS shall comply with 705.12. Where the PCS is connected in accordance with 705.11, the PCS shall monitor the service conductors and prevent overload of these conductors.

(B) Settings.

The sum of all PCS-controlled currents plus all monitored currents from other sources of supply shall not exceed the ampacity of any busbar or conductor supplied by the power production sources. Where the PCS is connected to an overcurrent device protecting any busbar or conductor not monitored by the PCS, the setting of the PCS controller shall be set within the ratings of that overcurrent device.

(C) Overcurrent Protection.

The PCS shall provide overcurrent protection either by overcurrent devices or by the PCS including the functionality as an overcurrent device in the product listing.

Informational Note: Some PCS are listed to provide overcurrent protection.

(D) Single Power Source Rating.

The rating of the overcurrent device for any single power source controlled by the PCS shall not exceed the rating of the busbar or the ampacity of the conductors to which it is connected.

(E) Access to Settings.

The access to settings of the PCS shall be restricted to qualified personnel in accordance with the requirements of 240.6(C).

705.14 Output Characteristics.

The output of a power ~~production~~ generating source operating in parallel with an electrical supply system shall be compatible with the voltage, wave shape, and frequency of the system to which it is connected. Synchronous generators operating in parallel with an electrical supply system shall be provided with the necessary equipment to establish and maintain a synchronous condition.

Informational Note: The term *compatible* does not necessarily mean matching the primary source wave shape.

705.16 Interrupting and Short-Circuit Current Rating.

Consideration shall be given to the contribution of fault currents from all interconnected power sources for the interrupting and short-circuit current ratings of equipment on interactive systems.

705.20 Disconnecting Means, Source.

Means shall be provided to disconnect power source output circuit conductors of electric power ~~production~~ generating equipment from conductors of other systems.

The disconnecting means shall comply with the following:

(1) Be one of the following types:

(2) A manually operable switch or circuit breaker

(3) A load-break-rated pull-out switch

(4) A power-operated or remote-controlled switch or circuit breaker that is manually operable locally and opens automatically when control power is interrupted

(5) A device listed or approved for the intended application

(6) Simultaneously disconnect all ungrounded conductors of the circuit

(7) Located where readily accessible

(8) Externally operable without exposed live parts

(9) Enclosures with doors or hinged covers with exposed live parts when open that require a tool to open or are lockable where readily accessible to unqualified persons

(10) Plainly indicate whether in the open (off) or closed (on) position

(11) Have ratings sufficient for the maximum circuit current, available fault current, and voltage that is available at the terminals

(12) Be marked in accordance with the warning in 690.13(B), where the line and load terminals are capable of being energized in the open position

Informational Note: With interconnected power sources, some equipment, including switches and fuses, is likely to be energized from both directions. See 240.40.

705.25 Wiring Methods.

(A) General.

All raceway and cable wiring methods included in Chapter 3 of this *Code* and other wiring systems and fittings specifically listed, intended, and identified for use with power production systems and equipment shall be permitted. Where wiring devices with integral enclosures are used, sufficient length of cable shall be provided to facilitate replacement.

(B) Flexible Cords and Cables.

Flexible cords and cables, where used to connect the moving parts of a power production system or where used for ready removal for maintenance and repair, shall comply with Article 400 and shall be listed and identified as DG Cable, Distributed Generation Cable, hard service cord, or portable power cable, shall be suitable for extra-hard usage, shall be listed for outdoor use, and shall be water resistant. Cables exposed to sunlight shall be sunlight resistant. Flexible, fine-stranded cables shall be terminated only with terminals, lugs, devices, or connectors in accordance with 110.14(A).

(C) Multiconductor Cable Assemblies.

Multiconductor cable assemblies used in accordance with their listings shall be permitted.

Informational Note: See UL 3003, *Distributed Generation Cables*, for additional information on DG Cable, Distributed Generation Cable. An ac module harness is one example of a multiconductor cable assembly.

705.28 Circuit Sizing and Current.

(A) Calculation of Maximum Circuit Current.

Where not elsewhere required or permitted in this *Code*, the maximum current for the circuit shall be the continuous output current rating of the power ~~production~~ generating equipment.

(B) Conductor Ampacity.

Where not elsewhere required or permitted in this *Code*, the circuit conductors shall be sized to carry not less than the largest of the following:

(1) The maximum currents in 705.28(A) multiplied by 125 percent without adjustment or correction factors

(2) The maximum currents in 705.28(A) with adjustment and correction factors

(3) Where connected to feeders, if smaller than the feeder conductors, the ampacity as calculated in 240.21(B) based on the over-current device protecting the feeder

(C) Neutral Conductors.

Neutral conductors shall be permitted to be sized in accordance with either 705.28(C)(1) or (C)(2).

(1) Single-Phase Line-to-Neutral Power Sources.

Where not elsewhere required or permitted in this *Code*, the ampacity of a neutral conductor to which a single-phase line-to-neutral power source is connected shall not be smaller than the ampacity in 705.28(B).

(2) Neutral Conductor Used Solely for Instrumentation, Voltage, Detection, or Phase Detection.

A power production equipment neutral conductor used solely for instrumentation, voltage detection, or phase detection shall be permitted to be sized in accordance with 250.102.

705.30 Overcurrent Protection.

(A) Circuit and Equipment.

Power source output circuit conductors and equipment shall be provided with overcurrent protection. Circuits connected to more than one electrical source shall have overcurrent devices located to provide overcurrent protection from all sources.

(B) Overcurrent Device Ratings.

The overcurrent devices in other than generator systems shall be sized to carry not less than 125 percent of the maximum currents as calculated in 705.28(A). The rating or setting of overcurrent devices shall be permitted in accordance with 240.4(B) and (C).

Exception: Circuits containing an assembly together with its overcurrent device(s) that is listed for continuous operation at 100 percent of its rating shall be permitted to be utilized at 100 percent of its rating.

(C) Power Transformers.

Transformers with sources on each side shall be provided with overcurrent protection in accordance with 450.3. The primary shall be the side connected to the largest source of available fault current. Secondary protection shall not be required for a transformer secondary that has a current rating not less than the sum of the rated continuous output currents of the power sources connected to that secondary.

(D) Generators.

Generators shall be provided with overcurrent protection in accordance with 445.12.

705.32 Ground-Fault Protection.

Where protection is installed in accordance with 230.95, the output of an interactive system shall be connected to the supply side of the ground-fault protection.

Exception: Connection shall be permitted to be made to the load side of ground-fault protection, if there is ground-fault protection for equipment from all ground-fault current sources.

705.40 Loss of Primary Source.

The output of electric power ~~production~~ generating equipment shall be automatically disconnected from all ungrounded conductors of the interconnected systems when one or more of the phases to which it is connected opens. The electric power ~~production~~ generating equipment shall not be reconnected until all the phases of the interconnected system to which it is connected are restored. This requirement shall not be applicable to electric power ~~production~~ generating equipment providing power to an emergency or legally required standby system.

Exception: A listed interactive inverter shall trip or shall be permitted to automatically cease exporting power when one or more of the phases of the interconnected system opens and shall not be required to automatically disconnect all ungrounded conductors from the primary source. A listed interactive inverter shall be permitted to automatically or manually resume exporting power to the interconnected system once all phases of the source to which it is connected are restored.

Informational Note No. 1: Risks to personnel and equipment associated with the primary source could occur if an interactive electric power production source can operate as an intentional island. Special detection methods are required to determine that a primary source supply system outage has occurred and whether there should be automatic disconnection. When the primary source supply system is restored, special detection methods are typically required to limit exposure of power production sources to out-of-phase reconnection.

Informational Note No. 2: Induction-generating equipment connected on systems with significant capacitance can become self-excited upon loss of the primary source and experience severe overvoltage as a result.

Interactive power ~~production~~ generating equipment shall be permitted to operate in island mode to supply loads that have been disconnected from the electric power production and distribution network.

705.45 Unbalanced Interconnections.

(A) Single Phase.

Single-phase power sources in interactive systems shall be connected to 3-phase power systems in order to limit unbalanced voltages at the point of interconnection to not more than 3 percent.

Informational Note: For interactive power sources, unbalanced voltages can be minimized by the same methods that are used for single-phase loads on a 3-phase power system. See ANSI/C84.1-2016, *Electric Power Systems and Equipment — Voltage Ratings (60 Hertz)*.

(B) Three Phase.

Three-phase power sources in interactive systems shall have all phases automatically de-energized upon loss of, or unbalanced, voltage in one or more phases unless the interconnected system is designed so that significant unbalanced voltages will not result.

Part II. Microgrid Systems

705.50 System Operation.

Microgrid systems shall be permitted to disconnect from the primary source of power or other interconnected electric power ~~production~~ generating sources and operate as an isolated microgrid system operating in island mode.

705.60 Primary Power Source Connection.

Connections to primary power sources that are external to the microgrid system shall comply with the requirements of 705.11, 705.12, or 705.13. Power source conductors connecting to a microgrid system, including conductors supplying distribution equipment, shall be considered as power source output conductors.

705.65 Reconnection to Primary Power Source.

Microgrid systems that reconnect to primary power sources shall be provided with the necessary equipment to establish a synchronous transition.

705.70 Microgrid Interconnect Devices (MID).

Microgrid interconnect devices shall comply with the following:

(1) Be required for any connection between a microgrid system and a primary power source

(2) Be evaluated for the application and have a field label applied or be listed for the application

(3) Have sufficient number of overcurrent devices located to provide overcurrent protection from all sources

Informational Note: MID functionality is often incorporated in an interactive or multimode inverter, energy storage system, or similar device identified for interactive operation.

Statement of Problem and Substantiation for Public Input

The term production is incorrect a electrical power is no produced. instead the correct term in generating

Submitter Information Verification

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Submittal Date: Thu Jun 04 12:27:34 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: The term, “power production” and its use is understood. Many may debate the use of the term “power production” versus “power generating” but the term is in common usage and is synonymous with “power generating”. Changing the term to “power generating” does not improve the meaning or the accuracy of this Code. Quoting from the U.S. Energy Information Administration: “Electricity in the United States is produced (generated) with diverse energy sources and technologies”

Public Input No. 2692-NFPA 70-2020 [Article 705]

~~**Article 705**~~ ~~Interconnected~~ Article 705 Onsite Electric ~~Power~~ Power Production Sources

Part I. General

705.1 Scope.

This article covers installation of one or more electric power production sources operating in parallel with a primary source(s) of electricity.

Informational Note: Examples of the types of primary sources include a utility supply or an on-site electric power source(s).

705.2 Definitions.

The definitions in this section shall apply within this article and throughout the *Code*.

Microgrid Interconnect Device (MID).

A device that enables a microgrid system to separate from and reconnect to operate in parallel with a primary power source.

Informational Note: Microgrid controllers typically are used to measure and evaluate electrical parameters and provide the logic for the signal to initiate and complete transition processes. IEEE Std 2030.7-2017, *IEEE Standard for the Specification of Microgrid Controllers*, and IEEE Std 2030.8-2018, *IEEE Standard for the Testing of Microgrid Controllers*, provide information on microgrid controllers. IEEE Std 1547-2018, *IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces*, provides information on interconnection requirements.

Microgrid System.

A premises wiring system that has generation, energy storage, and load(s), or any combination thereof, that includes the ability to disconnect from and parallel with the primary source.

Informational Note: The application of Article 705 to microgrid systems is limited by the exclusions in 90.2(B)(5) related to electric utilities. Additional information may be found in IEEE 1547, IEEE 2030.7, and IEEE 2030.8.

Power Source Output Circuit.

The conductors between power production equipment and the service or distribution equipment.

705.6 Equipment Approval.

All equipment shall be approved for the intended use. Interactive equipment intended to operate in parallel with electric power production sources including, but not limited to, interactive inverters, engine generators, energy storage equipment, and wind turbines shall be listed for interactive function or be evaluated for interactive function and have a field label applied, or both.

705.8 System Installation.

Installation of one or more electrical power production sources operating in parallel with a primary source(s) of electricity shall be performed only by qualified persons.

Informational Note: See Article 100 for the definition of *Qualified Person*.

705.10 Identification of Power Sources.

A permanent plaque or directory shall be installed at each service equipment location, or at an approved readily visible location. The plaque or directory shall denote the location of each power source disconnecting means for the building or structure and be grouped with other plaques or directories for other on-site sources. The plaque or directory shall be marked with the wording "CAUTION: MULTIPLE SOURCES OF POWER." Any posted diagrams shall be correctly oriented with respect to the diagram's location. The marking shall comply with 110.21(B).

Exception: Installations with multiple co-located power production sources shall be permitted to be identified as a group(s). The plaque or directory shall not be required to identify each power source individually.

705.11 Supply-Side Source Connections.

An electric power production source, where connected on the supply side of the service disconnecting means as permitted in 230.82(6), shall comply with 705.11(A) through (E).

(A) Output Rating.

The sum of the power source continuous current output ratings on a service, other than those controlled in accordance with 705.13, shall not exceed the ampacity of the service conductors.

Informational Note: See Article 100 definition for Service Conductors.

(B) Conductors.

The power source output circuit conductors from the service conductors point of connection to the first overcurrent protection device shall be sized in accordance with 705.28 and in no case sized smaller than 6 AWG copper or 4 AWG aluminum. These conductors shall be installed in accordance with 230.30 or 230.43.

(C) Overcurrent Protection.

The power source output circuit conductors shall be protected from overcurrent in accordance with 705.30. If fuses are not integral with the disconnecting means, the disconnecting means shall be located on the service side of the fuses. Where the power source output circuit conductors make their connection to the service outside of a building, they shall be protected by overcurrent devices in a readily accessible location outside the building or at the first readily accessible location where the power source conductors enter the building. Where the power source output circuit conductors make their connection to the service inside a building, they shall be protected with one of the following methods:

(1) With an overcurrent device located within 3 m (10 ft) of conductor length in dwelling units and 5 m (16.5 ft) in other than dwelling units from the point of connection to the service

(2) In other than a dwelling unit, with an overcurrent device located within 20 m (71 ft)of conductor length from the point of connection to the service, provided that cable limiters installed in all ungrounded conductors are located within 5 m (16.5 ft) of conductor length from the point of connection to the service

(D) Connections.

The connection of power source output circuit conductors to the service conductors shall be made using listed connectors as described in 110.14 and comply with all enclosure fill requirements Any modifications to existing equipment shall be made in accordance with the manufacturer's instructions or the modification must be evaluated for the application and have a field label applied. For meter socket enclosures or other equipment under the exclusive control of the electric utility, only connections approved by the electric utility shall be permitted.

(E) Ground-Fault Protection.

For connections rated 1000 amperes or more to solidly grounded wye services exceeding 150 volts to ground but not exceeding 1000 volts, phase-to-phase, ground-fault protection meeting the requirements of 230.95 shall be provided.

705.12 Load-Side Source Connections.

The output of an interconnected electric power source shall be permitted to be connected to the load side of the service disconnecting means of the other source(s) at any distribution equipment on the premises. Where distribution equipment or feeders are fed simultaneously by a primary source of electricity and one or more other power source and are capable of supplying multiple branch circuits or feeders, or both, the interconnecting equipment shall comply with 705.12(A) through (E). Where a power control system (PCS) is installed in accordance with 705.13, the setting of the PCS controller shall be considered the power-source output circuit current in 705.12(A) through (E).

(A) Dedicated Overcurrent and Disconnect.

Each source interconnection of one or more power sources installed in one system shall be made at a dedicated circuit breaker or fusible disconnecting means.

(B) Bus or Conductor Ampere Rating.

The power source output circuit current multiplied by 125 percent shall be used in ampacity calculations for 705.12(B)(1) through (B)(3).

(1) Feeders.

Where the power source output connection is made to a feeder, the feeder shall have an ampacity greater than or equal to 125 percent of the power-source output circuit current. Where the power-source output connection is made to a feeder at a location other than the opposite end of the feeder from the primary source overcurrent device, that portion of the feeder on the load side of the power source output connection shall be protected by one of the following:

(1) The feeder ampacity shall be not less than the sum of the primary source overcurrent device and 125 percent of the power-source output circuit current.

(2) An overcurrent device at the load side of the power source connection point shall be rated not greater than the ampacity of the feeder.

(2) Taps.

Where power source output connections are made at feeders, all taps shall be sized based on the sum of 125 percent of all power source(s) output circuit current(s) and the rating of the overcurrent device protecting the feeder conductors for sizing tap conductors using the calculations in 240.21(B).

(3) Busbars.

One of the following methods shall be used to determine the ratings of busbars:

(1) The sum of 125 percent of the power source(s) output circuit current and the rating of the overcurrent device protecting the busbar shall not exceed the ampacity of the busbar.

Informational Note: This general rule assumes no limitation in the number of the loads or sources applied to busbars or their locations.

(2) Where two sources, one a primary power source and the other another power source, are located at opposite ends of a busbar that contains loads, the sum of 125 percent of the power-source(s) output circuit current and the rating of the overcurrent device protecting the busbar shall not exceed 120 percent of the ampacity of the busbar. The busbar shall be sized for the loads connected in accordance with Article 220. A permanent warning label shall be applied to the distribution equipment adjacent to the back-fed breaker from the power source that displays the following or equivalent wording:

WARNING:

POWER SOURCE OUTPUT CONNECTION—

DO NOT RELOCATE THIS OVERCURRENT DEVICE.

The warning sign(s) or label(s) shall comply with 110.21(B).

(3) The sum of the ampere ratings of all overcurrent devices on panelboards, both load and supply devices, excluding the rating of the overcurrent device protecting the busbar, shall not exceed the ampacity of the busbar. The rating of the overcurrent device protecting the busbar shall not exceed the rating of the busbar. Permanent warning labels shall be applied to distribution equipment displaying the following or equivalent wording:

WARNING:

THIS EQUIPMENT FED BY MULTIPLE SOURCES.

TOTAL RATING OF ALL OVERCURRENT DEVICES

EXCLUDING MAIN SUPPLY OVERCURRENT DEVICE

SHALL NOT EXCEED AMPACITY OF BUSBAR.

The warning sign(s) or label(s) shall comply with 110.21(B).

(4) A connection at either end of a center-fed panelboard in dwellings shall be permitted where the sum of 125 percent of the power-source(s) output circuit current and the rating of the overcurrent device protecting the busbar does not exceed 120 percent of the current rating of the busbar.

(5) Connections shall be permitted on switchgear, switchboards, and panelboards in configurations other than those permitted in 705.12(B)(3)(1) through (B)(3)(4) where designed under engineering supervision that includes available fault-current and busbar load calculations.

(6) Connections shall be permitted on busbars of panelboards that supply lugs connected to feed-through conductors. The feed-through conductors shall be sized in accordance with 705.12(B)(1). Where an overcurrent device is installed at the supply end of the feed-through conductors, the busbar in the supplying panelboard shall be permitted to be sized in accordance with 705.12(B)(3)(1) through 705.12(B)(3)(3).

(C) Marking.

Equipment containing overcurrent devices in circuits supplying power to a busbar or conductor supplied from multiple sources shall be marked to indicate the presence of all sources.

(D) Suitable for Backfeed.

Fused disconnects, unless otherwise marked, shall be considered suitable for backfeed. Circuit breakers not marked “line” and “load” shall be considered suitable for backfeed. Circuit breakers marked “line” and “load” shall be considered suitable for backfeed or reverse current if specifically rated.

(E) Fastening.

Listed plug-in-type circuit breakers back-fed from electric power sources that are listed and identified as interactive shall be permitted to omit the additional fastener normally required by 408.36(D) for such applications.

705.13 Power Control Systems.

A power control system (PCS) shall be listed and evaluated to control the output of one or more power production sources, energy storage systems (ESS), and other equipment. The PCS shall limit current and loading on the busbars and conductors supplied by the PCS.

For the circuits connected to a PCS, the PCS shall limit the current to the ampacity of the conductors or the ratings of the busbars to which it is connected in accordance with 705.13(A) through (E).

(A) Monitoring.

The PCS controller shall monitor all currents within the PCS. Any busbar or conductor on the load side of the service disconnecting means that is not monitored by the PCS shall comply with 705.12. Where the PCS is connected in accordance with 705.11, the PCS shall monitor the service conductors and prevent overload of these conductors.

(B) Settings.

The sum of all PCS-controlled currents plus all monitored currents from other sources of supply shall not exceed the ampacity of any busbar or conductor supplied by the power production sources. Where the PCS is connected to an overcurrent device protecting any busbar or conductor not monitored by the PCS, the setting of the PCS controller shall be set within the ratings of that overcurrent device.

(C) Overcurrent Protection.

The PCS shall provide overcurrent protection either by overcurrent devices or by the PCS including the functionality as an overcurrent device in the product listing.

Informational Note: Some PCS are listed to provide overcurrent protection.

(D) Single Power Source Rating.

The rating of the overcurrent device for any single power source controlled by the PCS shall not exceed the rating of the busbar or the ampacity of the conductors to which it is connected.

(E) Access to Settings.

The access to settings of the PCS shall be restricted to qualified personnel in accordance with the requirements of 240.6(C).

705.14 Output Characteristics.

The output of a power production source operating in parallel with an electrical supply system shall be compatible with the voltage, wave shape, and frequency of the system to which it is connected. Synchronous generators operating in parallel with an electrical supply system shall be provided with the necessary equipment to establish and maintain a synchronous condition.

Informational Note: The term *compatible* does not necessarily mean matching the primary source wave shape.

705.16 Interrupting and Short-Circuit Current Rating.

Consideration shall be given to the contribution of fault currents from all interconnected power sources for the interrupting and short-circuit current ratings of equipment on interactive systems.

705.20 Disconnecting Means, Source.

Means shall be provided to disconnect power source output circuit conductors of electric power production equipment from conductors of other systems.

The disconnecting means shall comply with the following:

(1) Be one of the following types:

(2) A manually operable switch or circuit breaker

(3) A load-break-rated pull-out switch

(4) A power-operated or remote-controlled switch or circuit breaker that is manually operable locally and opens automatically when control power is interrupted

(5) A device listed or approved for the intended application

(6) Simultaneously disconnect all ungrounded conductors of the circuit

(7) Located where readily accessible

(8) Externally operable without exposed live parts

(9) Enclosures with doors or hinged covers with exposed live parts when open that require a tool to open or are lockable where readily accessible to unqualified persons

(10) Plainly indicate whether in the open (off) or closed (on) position

(11) Have ratings sufficient for the maximum circuit current, available fault current, and voltage that is available at the terminals

(12) Be marked in accordance with the warning in 690.13(B), where the line and load terminals are capable of being energized in the open position

Informational Note: With interconnected power sources, some equipment, including switches and fuses, is likely to be energized from both directions. See 240.40.

705.25 Wiring Methods.

(A) General.

All raceway and cable wiring methods included in Chapter 3 of this *Code* and other wiring systems and fittings specifically listed, intended, and identified for use with power production systems and equipment shall be permitted. Where wiring devices with integral enclosures are used, sufficient length of cable shall be provided to facilitate replacement.

(B) Flexible Cords and Cables.

Flexible cords and cables, where used to connect the moving parts of a power production system or where used for ready removal for maintenance and repair, shall comply with Article 400 and shall be listed and identified as DG Cable, Distributed Generation Cable, hard service cord, or portable power cable, shall be suitable for extra-hard usage, shall be listed for outdoor use, and shall be water resistant. Cables exposed to sunlight shall be sunlight resistant. Flexible, fine-stranded cables shall be terminated only with terminals, lugs, devices, or connectors in accordance with 110.14(A).

(C) Multiconductor Cable Assemblies.

Multiconductor cable assemblies used in accordance with their listings shall be permitted.

Informational Note: See UL 3003, *Distributed Generation Cables*, for additional information on DG Cable, Distributed Generation Cable. An ac module harness is one example of a multiconductor cable assembly.

705.28 Circuit Sizing and Current.

(A) Calculation of Maximum Circuit Current.

Where not elsewhere required or permitted in this *Code*, the maximum current for the circuit shall be the continuous output current rating of the power production equipment.

(B) Conductor Ampacity.

Where not elsewhere required or permitted in this *Code*, the circuit conductors shall be sized to carry not less than the largest of the following:

(1) The maximum currents in 705.28(A) multiplied by 125 percent without adjustment or correction factors

(2) The maximum currents in 705.28(A) with adjustment and correction factors

(3) Where connected to feeders, if smaller than the feeder conductors, the ampacity as calculated in 240.21(B) based on the over-current device protecting the feeder

(C) Neutral Conductors.

Neutral conductors shall be permitted to be sized in accordance with either 705.28(C)(1) or (C)(2).

(1) Single-Phase Line-to-Neutral Power Sources.

Where not elsewhere required or permitted in this *Code*, the ampacity of a neutral conductor to which a single-phase line-to-neutral power source is connected shall not be smaller than the ampacity in 705.28(B).

(2) Neutral Conductor Used Solely for Instrumentation, Voltage, Detection, or Phase Detection.

A power production equipment neutral conductor used solely for instrumentation, voltage detection, or phase detection shall be permitted to be sized in accordance with 250.102.

705.30 Overcurrent Protection.

(A) Circuit and Equipment.

Power source output circuit conductors and equipment shall be provided with overcurrent protection. Circuits connected to more than one electrical source shall have overcurrent devices located to provide overcurrent protection from all sources.

(B) Overcurrent Device Ratings.

The overcurrent devices in other than generator systems shall be sized to carry not less than 125 percent of the maximum currents as calculated in 705.28(A). The rating or setting of overcurrent devices shall be permitted in accordance with 240.4(B) and (C).

Exception: Circuits containing an assembly together with its overcurrent device(s) that is listed for continuous operation at 100 percent of its rating shall be permitted to be utilized at 100 percent of its rating.

(C) Power Transformers.

Transformers with sources on each side shall be provided with overcurrent protection in accordance with 450.3. The primary shall be the side connected to the largest source of available fault current. Secondary protection shall not be required for a transformer secondary that has a current rating not less than the sum of the rated continuous output currents of the power sources connected to that secondary.

(D) Generators.

Generators shall be provided with overcurrent protection in accordance with 445.12.

705.32 Ground-Fault Protection.

Where protection is installed in accordance with 230.95, the output of an interactive system shall be connected to the supply side of the ground-fault protection.

Exception: Connection shall be permitted to be made to the load side of ground-fault protection, if there is ground-fault protection for equipment from all ground-fault current sources.

705.40 Loss of Primary Source.

The output of electric power production equipment shall be automatically disconnected from all ungrounded conductors of the interconnected systems when one or more of the phases to which it is connected opens. The electric power production equipment shall not be reconnected until all the phases of the interconnected system to which it is connected are restored. This requirement shall not be applicable to electric power production equipment providing power to an emergency or legally required standby system.

Exception: A listed interactive inverter shall trip or shall be permitted to automatically cease exporting power when one or more of the phases of the interconnected system opens and shall not be required to automatically disconnect all ungrounded conductors from the primary source. A listed interactive inverter shall be permitted to automatically or manually resume exporting power to the interconnected system once all phases of the source to which it is connected are restored.

Informational Note No. 1: Risks to personnel and equipment associated with the primary source could occur if an interactive electric power production source can operate as an intentional island. Special detection methods are required to determine that a primary source supply system outage has occurred and whether there should be automatic disconnection. When the primary source supply system is restored, special detection methods are typically required to limit exposure of power production sources to out-of-phase reconnection.

Informational Note No. 2: Induction-generating equipment connected on systems with significant capacitance can become self-excited upon loss of the primary source and experience severe overvoltage as a result.

Interactive power production equipment shall be permitted to operate in island mode to supply loads that have been disconnected from the electric power production and distribution network.

705.45 Unbalanced Interconnections.

(A) Single Phase.

Single-phase power sources in interactive systems shall be connected to 3-phase power systems in order to limit unbalanced voltages at the point of interconnection to not more than 3 percent.

Informational Note: For interactive power sources, unbalanced voltages can be minimized by the same methods that are used for single-phase loads on a 3-phase power system. See ANSI/C84.1-2016, *Electric Power Systems and Equipment — Voltage Ratings (60 Hertz)*.

(B) Three Phase.

Three-phase power sources in interactive systems shall have all phases automatically de-energized upon loss of, or unbalanced, voltage in one or more phases unless the interconnected system is designed so that significant unbalanced voltages will not result.

Part II. Microgrid Systems

705.50 System Operation.

Microgrid systems shall be permitted to disconnect from the primary source of power or other interconnected electric power production sources and operate as an isolated microgrid system operating in island mode.

705.60 Primary Power Source Connection.

Connections to primary power sources that are external to the microgrid system shall comply with the requirements of 705.11, 705.12, or 705.13. Power source conductors connecting to a microgrid system, including conductors supplying distribution equipment, shall be considered as power source output conductors.

705.65 Reconnection to Primary Power Source.

Microgrid systems that reconnect to primary power sources shall be provided with the necessary equipment to establish a synchronous transition.

705.70 Microgrid Interconnect Devices (MID).

Microgrid interconnect devices shall comply with the following:

(1) Be required for any connection between a microgrid system and a primary power source

(2) Be evaluated for the application and have a field label applied or be listed for the application

(3) Have sufficient number of overcurrent devices located to provide overcurrent protection from all sources

Informational Note: MID functionality is often incorporated in an interactive or multimode inverter, energy storage system, or similar device identified for interactive operation.

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

This changes the title of Article 705 to align with the work of this taskgroup. We understand that the Correlating Committee has purview over scope and title. The changes included in this article by this task group includes expanding beyond just looking at interconnected systems and thus the existing title is not appropriate should these changes be accepted by the Code Making Panel.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2994-NFPA 70-2020 [Section No. 480.7(G)]	
Public Input No. 2995-NFPA 70-2020 [Section No. 690.56]	

Public Input No. 3011-NFPA 70-2020 [Definition:]

Public Input No. 4685-NFPA 70-2020 [Global Input]

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Committee: NEC-P04

Committee Statement

Resolution: Article 705 will continue to cover only those power systems interconnected with one another. A power system operating through a transfer switch and not interconnected to another source will still be covered by Article 702 and those power sources operating only independently of the utility will be covered in Article 710.

Public Input No. 2967-NFPA 70-2020 [Article 705]

Article 705 Interconnected Electric Power Production Sources

Part I. General

705.1 Scope.

This article

~~covers installation of one or more electric power~~ applies to the electrical safety of the installation, operation, and maintenance of systems consisting of circuits and equipment interconnecting electric power production sources operating in parallel. Unitized battery backup devices do not apply. The paralleled sources may be a combination of the following sources;

(1) On-site Power production sources operating in parallel to each other.

705.1(1) Informational Note 1: examples of power distribution topologies and operational configurations include, but are not limited to, a combination of the following;

(a) Power sources for required essential, emergency or critical power distribution systems. The power system generally has at least one preservation mode of operation due to code designated criticality of loads. When configured to supply power to other systems, a preservation often employs load shed to isolate it from normal power systems and optional standby power systems. Other modes of operation may supply normal power systems or optional standby power systems where permitted by code. Examples of required essential, emergency or critical power distribution systems include, but are not limited to, the following:

i. Emergency Power Supply System circuit in accordance with NFPA 110

ii. Stored Energy Power Supply System circuit in accordance with NFPA 111

iii. Essential Electrical System circuits in accordance with Article 517, or any of its sub-system branches as follows;

1. Life Safety Branch

2. Critical Branch

3. Equipment Branch

a. Equipment Branch A

b. Equipment Branch B

iv. Emergency system circuit in accordance with Article 700.

v. Legally required standby system circuit in accordance with Article 701.

vi. Optional standby system circuit in accordance with Article 702.

vii. Critical Operations Power system circuit in accordance with Article 708

viii. Fuel cell power supply system circuit, when used as a power source for power system type (iii) through (vii) above.

ix. A multi-source power system type derived to strictly serve fire pumps in accordance with Article 695. With its alternate source, as permitted from a power source type (1) through (8) above, or derived from an alternate normal power service to satisfy the reliability requirements.

(b) Power sources for normal power distribution systems.

705.1(1) Informational Note 2: example distribution gear includes equipment that parallels generators and equipment that supplies both an Optional Standby Power System and Essential Power Supply System.

(2) Power production sources operating in parallel with

~~a~~

primary source(s) of electricity.

705.1(2) Informational Note:

~~Examples of the types of primary sources include a utility supply or an on-site electric power source(s).~~

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examples of power distribution topologies and operational configurations include, but are not limited to, a combination of the following;

(a) A utility service power supply or other normal power source as the primary source(s), paralleled with other normal power source(s). Configurations include, but are not limited to, a combination of: distributed generation, distributed energy, on-site generation, district energy; whether utility-grid connected or not.

(b) Cogeneration or Combined Heat and Power (CHP) serving as a base load normal power supply, with a utility service power supply or other normal power source attending to the variable portion of the load.

(c) Microgrid power systems utilizing a decentralized group of electricity sources connected together and operating concurrently.

(d) Renewable energy source(s) connected to other renewable energy source(s), or connected to any other source(s), while operating concurrently.

(3) Spot Network with multiple primary source(s) of normal (typically utility) power concurrently supplying power to a common bus or bus system.

705.1(3) Informational Note: Spot Networks utilize the equivalent of a closed tie between facility source transformers. Spot Networks use reverse power circuit protection at the transformer secondary to guard against back-feeding a fault on the line side of either transformer primary, as required by 450.6(B).

705. 2 Definitions.

The definitions in this section shall apply within this article and throughout the *Code*.

Microgrid Interconnect Device (MID).

A device that enables a microgrid system to separate from and reconnect to operate in parallel with a primary power source.

Informational Note: Microgrid controllers typically are used to measure and evaluate electrical parameters and provide the logic for the signal to initiate and complete transition processes. IEEE Std 2030.7-2017, *IEEE Standard for the Specification of Microgrid Controllers*, and IEEE Std 2030.8-2018, *IEEE Standard for the Testing of Microgrid Controllers*, provide information on microgrid controllers. IEEE Std 1547-2018, *IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces*, provides information on interconnection requirements.

Microgrid System.

A premises wiring system that has generation, energy storage, and load(s), or any combination thereof, that includes the ability to disconnect from and parallel with the primary source.

Informational Note: The application of Article 705 to microgrid systems is limited by the exclusions in 90.2(B)(5) related to electric utilities. Additional information may be found in IEEE 1547, IEEE 2030.7, and IEEE 2030.8.

Power Source Output Circuit.

The conductors between power production equipment and the service or distribution equipment.

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3 Qualified Personnel.

The installation and maintenance of paralleling equipment and all associated wiring and interconnections shall be performed only by qualified persons. Informational Note: See Article 100 for the definition of qualified person.

705.4 System Requirements.

Each unit of the paralleling equipment system shall be provided with a nameplate plainly visible after installation and marked with the following:

(1) Manufacturer's name, trademark, or other descriptive marking by which the organization responsible for supplying the equipment can be identified

(2) Rated frequency

(3) Number of phases, if ac

(4) Rating (kW or kVA)

(5) Available fault current derived at the output terminals

(6) Maximum output and input current at the output terminals

(7) Maximum output and input voltage at the output terminals

(8) Utility-interactive capability, if applicable

706.5 Listing.

Paralleling distribution gear and systems shall be listed

705.6 Equipment Approval.

(1) All equipment shall be approved for the intended use.

(2) Where the paralleled power shall provide the backup alternate source, or any portion thereof, of a required emergency, critical or essential power system, the following shall apply;

(3) Listed equipment, suitable to the purpose, shall be utilized. If listed equipment is not available due to the custom nature of the application, the components and assemblies shall be listed to the extent possible.

(4) Documentation for design shall be given to the Authority Having Jurisdiction and approved prior to installation and energization. To include a grounding plan, an outline of operation schemes, and overview description of automated sequences.

Informational Note: Required emergency, critical or essential power systems include, but are not limited to, the following;

(i) Emergency Systems in accordance with Article 700.

(ii) Legally Required Standby System in accordance with Article 701.

(iii) Essential Electrical System in accordance with Article 517.

(iv) Fire pump circuits in accordance with Article 695.

(v) Critical Operations Power System in accordance with Article 708.

(vi) Emergency Power Supply System in accordance with NFPA 110.

(vii) Stored Energy Emergency Power Supply System (SEPSS) in accordance with NFPA 111.

(viii) Fuel Cell Power System in accordance with Parts II through VIII of Article 692 and not less than 2 hours of full-demand operation.

(c) The paralleling distribution equipment shall not substitute for Automatic Transfer Switches, where they are required to be listed for emergency use.

(3) Interactive equipment intended to operate in parallel with electric power production sources including, but not limited to, interactive inverters, engine generators, energy storage equipment, and wind turbines shall be listed for interactive function or be evaluated for interactive function and have a field label applied, or both.

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~~8 System Installation.~~

~~Installation of one or more electrical power production sources operating in parallel with a primary source(s) of electricity shall be performed only by qualified persons.~~

~~Informational Note: See Article 100 for the definition of *Qualified Person* .~~

~~**705.10** Identification of Power Sources.~~

~~A~~

~~7 Signs.~~

~~705.7(A) Sources and Service Entrance(s).~~

~~For each service equipment location and each on-site power source equipment location, a permanent plaque or directory shall be installed at~~

~~each service~~

~~the equipment location, or installed at an approved readily visible location. The plaque or directory shall denote the distinct name and the type of each power source. The plaque or directory shall denote the location of each power source disconnecting means for the building or structure . Multiple instances of a plaque or directory shall be consistent in appearance and be~~

~~grouped~~

~~grouped with other plaques or directories for other on-site sources or their disconnecting means . The plaque or directory shall be marked with the~~

~~wording~~

~~heading;~~

~~"CAUTION: MULTIPLE SOURCES OF POWER."~~

~~Any posted diagrams shall be correctly oriented with respect to the diagram's location. The marking shall comply with 110.21(B) .~~

~~Exception:~~

~~Installations with multiple co-located power production sources shall be permitted to be identified as a group(s). The plaque or directory shall not be required to identify each power source individually.~~

~~705. 7(B) Grounding.~~

~~Where removal of a grounding or bonding connection in a power source equipment interrupts the grounding electrode conductor connection to the grounded conductor of alternate power source(s), a warning sign shall be installed at the normal power source equipment stating:~~

~~WARNING~~

~~SHOCK HAZARD EXISTS IF GROUNDING ELECTRODE CONDUCTOR OR BONDING JUMPER CONNECTION IN THIS EQUIPMENT IS REMOVED WHILE ALTERNATE SOURCE(S) IS ENERGIZED.~~

~~Sign(s) and label(s) shall comply with 110.21(B).~~

705.8 System Installation.

Installation of electrical power production sources operating in parallel shall be performed only by qualified persons.

Where the power source into a paralleling system, or the power supplied by a paralleling system, is associated with other codified types of required essential, emergency or critical power, the system installation shall comply with those requirements. Those systems include, but are not limited to, the following:

(1) Emergency Power Supply System circuit in accordance with NFPA 110

(2) Stored Energy Power Supply System circuit in accordance with NFPA 111

(3) Essential Electrical System circuits in accordance with Article 517, or any of its sub-system branches as follows;

(4) Life Safety Branch

(5) Critical Branch

(6) Equipment Branch

(7) Equipment Branch A

(8) Equipment Branch B

(9) Emergency system circuit in accordance with Article 700.

(10) Legally required standby system circuit in accordance with Article 701.

(11) Optional standby system circuit in accordance with Article 702.

(12) Critical Operations Power system circuit in accordance with Article 708

(13) Fuel cell power supply system circuit, when used as a power source for power system type (3) through (7) above.

(14) A multi-source power system type derived to strictly serve fire pumps in accordance with Article 695. With its alternate source, as permitted from a power source type (1) through (8) above, or derived from an alternate normal power service to satisfy reliability requirements.

Informational Note: See Article 100 for the definition of *Qualified Person*.

Part II. Circuit Wiring

705.10 Wiring of High Criticality Loads

Wherever the parallel power equipment or parallel power system supplies power to required essential, emergency or critical power distribution systems, the following requirements shall apply.

705.10(A) Identification.

Power circuits shall be permanently marked so they will be readily identified as a component of a circuit or system by the following methods:

(1) All boxes and enclosures (including transfer switches, generators, and power distribution equipment) for power circuits shall be permanently marked as a component of a circuit or system associated with one of the power system types 705.8 through 705.8(9).

(2) Where boxes or enclosures are not encountered so that markings would be readily visible, exposed cable or raceway systems shall be permanently marked to be identified as a component of a circuit or system associated with one of the power system types 705.8(1) through 705.8(9). Marking shall be at intervals not to exceed 7.6 m (25 ft).

705.10(B) Wiring

Wiring of two or more emergency circuits supplied from the same source shall be permitted in the same raceway, cable, box, or cabinet.

(1) Wiring Involving Different Sources

Wiring from the alternate power source, used to supply a required power supply system, including wiring from the source's distribution overcurrent protection, shall be kept entirely independent of all other wiring and equipment derived from other sources (e.g. normal power source), unless otherwise permitted below;

a. Wiring of different sources in the transfer equipment enclosure where they terminate.

b. Branch circuit wiring from two sources within a common junction box, attached to dual source unit equipment.

(2) Distribution Wiring from Bus With Paralleled Sources

Wiring that supplies power from equipment used to parallel sources shall comply with the following;

a. Wiring circuit(s) supplying power to one of the power system types 705.8(1) through 705.8(9) shall comply with all applicable codes for the power system type(s).

b. Multiple feeders with overcurrent protection shall be selectively coordinated with the next downstream overcurrent protective device, including nonemergency system(s)

705.10(C) Design and Location

Equipment and wiring circuits shall be designed and located so as to minimize the hazards that might cause failure due to fire, icing, vandalism, and other adverse conditions, along with flooding that may occur from; weather, failed piping, sewer backup, or firefighting.

705.10(C)(1) Wiring Design and Location.

Wiring circuits shall be designed and located so as to minimize the hazards that might cause failure due to faults, excavation, or other disasters or occurrences. Design and install consideration shall be given to minimizing the probability of concurrent failure of redundant supply circuits.

705.10(C)(2) Equipment Design and Location

Where equipment function(s) and rating(s) are required below, they shall be marked by the manufacturer on the equipment.

a. Equipment design shall consider minimizing the probability of equipment failure and cable failure internal to the equipment to reduce disruption of loads.

b. Circuit breakers and switches shall be electrically operated and mechanically held.

c. Circuit breakers and switches shall be rated to withstand the number of load break operations for the life of the equipment, as reported in the manufacturer literature and recommended maintenance schedule; a copy of which, or its location, shall be posted at the equipment. Labeling and signage shall comply to 110.21(B).

d. Circuit breakers and switches shall be rated to perform a close and latch function to the available fault.

e. Circuit breaker and switch interrupting rating(s) shall be suitable to the available fault.

(1) For closed-transition switch schemes, where designed interrupting ratings rely upon a fault not drawing fault current from multiple sources concurrently, due to the brevity of switching sequence or for any other reason, a label shall be provided at each affected switch location indicating the associated design assumption(s), and that upon a fault condition, the switch should not be reclosed until the power supply from each respective source has been deenergized.

(2) Based upon possible switch schemes in compliance or out of compliance with design, and whether manual or automatic operation of the equipment, where there exists a potential to exceed the designed maximum available fault or exceed the interrupting rating for any system or component , a danger or warning label shall be provided at each switch location indicating the hazard of operating the breaker or switch outside the parameters of the design intent for distribution topologies. Signs and labels shall comply to 110.21(B).

(3) Where equipment is series rated, the engineered series rating calculations shall address any potential for manual or automatic configurations of the equipment to exceed design levels. Kirk-key lock out, or similar automated control-constraint means of prevention, shall be employed where particular switch configurations are relied upon for safe operation. A sign or label posted at each affected switch location shall convey the operation and maintenance terms for the switch configurations, where suitable to guard against operational non-compliance with the design.

Informational Note: ANSI Z535.4-2011, Product Safety Signs and Labels, provides guidelines for the design and durability of safety signs and labels for application to electrical equipment.

705.10(C)(2)(a) Indoor Equipment Location :

The room shall be separated from the rest of the building by construction with a 2-hour fire resistance rating.

The equipment may be located in either;

(1) Dedicated space(s) designated for essential power supply system equipment.

(2) Other electrical equipment space(s) dedicated to a codified non-normal power distribution type.

705.10(C)(2)(b) Outdoor Equipment Location

The equipment shall be installed in a suitable enclosure located outside the building and capable

of resisting the entrance of snow or rain at a maximum wind velocity as required by local building codes. No other equipment, except those that serve this space or equipment dedicated to the same power system type, shall be permitted in the enclosure.

705.10(C)(3) Feeder Equipment.

Equipment for feeder circuits (including transfer switches, transformers, and panelboards) shall be located either in spaces fully protected by an approved automatic fire protection system or in spaces with a 2-hour fire resistance rating.

705.10(C)(4) Generator Control Wiring.

Control conductors installed between the transfer equipment and the emergency generator shall be kept entirely independent of all other wiring and shall meet the conditions of 705.10(D)(2). The integrity of the generator remote start circuit shall be monitored for broken, disconnected, or shorted wires. Loss of integrity shall start the generator(s).

705. 11 Supply-Side Source Connections.

An electric power production source, where connected on the supply side of the service disconnecting means as permitted in 230.82(6), shall comply with 705.11(A) through (E).

(A) Output Rating.

The sum of the power source continuous current output ratings on a service, other than those controlled in accordance with 705.13, shall not exceed the ampacity of the service conductors.

Informational Note: See Article 100 definition for Service Conductors.

(B) Conductors.

The power source output circuit conductors from the service conductors point of connection to the first overcurrent protection device shall be sized in accordance with 705.28 and in no case sized smaller than 6 AWG copper or 4 AWG aluminum. These conductors shall be installed in accordance with 230.30 or 230.43.

(C) Overcurrent Protection.

The power source output circuit conductors shall be protected from overcurrent in accordance with 705.30. If fuses are not integral with the disconnecting means, the disconnecting means shall be located on the service side of the fuses. Where the power source output circuit conductors make their connection to the service outside of a building, they shall be protected by overcurrent devices in a readily accessible location outside the building or at the first readily accessible location where the power source conductors enter the building. Where the power source output circuit conductors make their connection to the service inside a building, they shall be protected with one of the following methods:

(1) With an overcurrent device located within 3 m (10 ft) of conductor length in dwelling units and 5 m (16.5 ft) in other than dwelling units from the point of connection to the service

(2) In other than a dwelling unit, with an overcurrent device located within 20 m (71 ft)of conductor length from the point of connection to the service, provided that cable limiters installed in all ungrounded conductors are located within 5 m (16.5 ft) of conductor length from the point of connection to the service

(D) Connections.

The connection of power source output circuit conductors to the service conductors shall be made using listed connectors as described in 110.14 and comply with all enclosure fill requirements Any modifications to existing equipment shall be made in accordance with the manufacturer's instructions or the modification must be evaluated for the application and have a field label applied. For meter socket enclosures or other equipment under the exclusive control of the electric utility, only connections approved by the electric utility shall be permitted.

(E) Ground-Fault Protection.

For connections rated 1000 amperes or more to solidly grounded wye services exceeding 150 volts to ground but not exceeding 1000 volts, phase-to-phase, ground-fault protection meeting the requirements of 230.95 shall be provided.

705.12 Load-Side Source Connections.

The output of an interconnected electric power source shall be permitted to be connected to the load side of the service disconnecting means of the other source(s) at any distribution equipment on the premises. Where distribution equipment or feeders are fed simultaneously by a primary source of electricity and one or more other power source and are capable of supplying multiple branch circuits or feeders, or both, the interconnecting equipment shall comply with 705.12(A) through (E). Where a power control system (PCS) is installed in accordance with 705.13, the setting of the PCS controller shall be considered the power-source output circuit current in 705.12(A) through (E).

(A) Dedicated Overcurrent and Disconnect.

Each source interconnection of one or more power sources installed in one system shall be made at a dedicated circuit breaker or fusible disconnecting means.

(B) Bus or Conductor Ampere Rating.

The power source output circuit current multiplied by 125 percent shall be used in ampacity calculations for 705.12(B)(1) through (B)(3).

(1) Feeders.

Where the power source output connection is made to a feeder, the feeder shall have an ampacity greater than or equal to 125 percent of the power-source output circuit current. Where the power-source output connection is made to a feeder at a location other than the opposite end of the feeder from the primary source overcurrent device, that portion of the feeder on the load side of the power source output connection shall be protected by one of the following:

(1) The feeder ampacity shall be not less than the sum of the primary source overcurrent device and 125 percent of the power-source output circuit current.

(2) An overcurrent device at the load side of the power source connection point shall be rated not greater than the ampacity of the feeder.

(2) Taps.

Where power source output connections are made at feeders, all taps shall be sized based on the sum of 125 percent of all power source(s) output circuit current(s) and the rating of the overcurrent device protecting the feeder conductors for sizing tap conductors using the calculations in 240.21(B).

(3) Busbars.

One of the following methods shall be used to determine the ratings of busbars:

(1) The sum of 125 percent of the power source(s) output circuit current and the rating of the overcurrent device protecting the busbar shall not exceed the ampacity of the busbar.

Informational Note: This general rule assumes no limitation in the number of the loads or sources applied to busbars or their locations.

(2) Where two sources, one a primary power source and the other another power source, are located at opposite ends of a busbar that contains loads, the sum of 125 percent of the power-source(s) output circuit current and the rating of the overcurrent device protecting the busbar shall not exceed 120 percent of the ampacity of the busbar. The busbar shall be sized for the loads connected in accordance with Article 220. A permanent warning label shall be applied to the distribution equipment adjacent to the back-fed breaker from the power source that displays the following or equivalent wording:

WARNING:

POWER SOURCE OUTPUT CONNECTION—

DO NOT RELOCATE THIS OVERCURRENT DEVICE.

The warning sign(s) or label(s) shall comply with 110.21(B).

(3) The sum of the ampere ratings of all overcurrent devices on panelboards, both load and supply devices, excluding the rating of the overcurrent device protecting the busbar, shall not exceed the ampacity of the busbar. The rating of the overcurrent device protecting the busbar shall not exceed the rating of the busbar. Permanent warning labels shall be applied to distribution equipment displaying the following or equivalent wording:

WARNING:

THIS EQUIPMENT FED BY MULTIPLE SOURCES.

TOTAL RATING OF ALL OVERCURRENT DEVICES

EXCLUDING MAIN SUPPLY OVERCURRENT DEVICE

SHALL NOT EXCEED AMPACITY OF BUSBAR.

The warning sign(s) or label(s) shall comply with 110.21(B).

(4) A connection at either end of a center-fed panelboard in dwellings shall be permitted where the sum of 125 percent of the power-source(s) output circuit current and the rating of the overcurrent device protecting the busbar does not exceed 120 percent of the current rating of the busbar.

(5) Connections shall be permitted on switchgear, switchboards, and panelboards in configurations other than those permitted in 705.12(B)(3)(1) through (B)(3)(4) where designed under engineering supervision that includes available fault-current and busbar load calculations.

(6) Connections shall be permitted on busbars of panelboards that supply lugs connected to feed-through conductors. The feed-through conductors shall be sized in accordance with 705.12(B)(1). Where an overcurrent device is installed at the supply end of the feed-through conductors, the busbar in the supplying panelboard shall be permitted to be sized in accordance with 705.12(B)(3)(1) through 705.12(B)(3)(3).

(C) Marking.

Equipment containing overcurrent devices in circuits supplying power to a busbar or conductor supplied from multiple sources shall be marked to indicate the presence of all sources.

(D) Suitable for Backfeed.

Fused disconnects, unless otherwise marked, shall be considered suitable for backfeed. Circuit breakers not marked “line” and “load” shall be considered suitable for backfeed. Circuit breakers marked “line” and “load” shall be considered suitable for backfeed or reverse current if specifically rated.

(E) Fastening.

Listed plug-in-type circuit breakers back-fed from electric power sources that are listed and identified as interactive shall be permitted to omit the additional fastener normally required by 408.36(D) for such applications.

705.13 Power Control Systems.

A power control system (PCS) shall be listed and evaluated to control the output of one or more power production sources, energy storage systems (ESS), and other equipment. The PCS shall limit current and loading on the busbars and conductors supplied by the PCS.

For the circuits connected to a PCS, the PCS shall limit the current to the ampacity of the conductors or the ratings of the busbars to which it is connected in accordance with 705.13(A) through (E).

(A) Monitoring.

The PCS controller shall monitor all currents within the PCS. Any busbar or conductor on the load side of the service disconnecting means that is not monitored by the PCS shall comply with 705.12. Where the PCS is connected in accordance with 705.11, the PCS shall monitor the service conductors and prevent overload of these conductors.

(B) Settings.

The sum of all PCS-controlled currents plus all monitored currents from other sources of supply shall not exceed the ampacity of any busbar or conductor supplied by the power production sources. Where the PCS is connected to an overcurrent device protecting any busbar or conductor not monitored by the PCS, the setting of the PCS controller shall be set within the ratings of that overcurrent device.

(C) Overcurrent Protection.

The PCS shall provide overcurrent protection either by overcurrent devices or by the PCS including the functionality as an overcurrent device in the product listing.

Informational Note: Some PCS are listed to provide overcurrent protection.

(D) Single Power Source Rating.

The rating of the overcurrent device for any single power source controlled by the PCS shall not exceed the rating of the busbar or the ampacity of the conductors to which it is connected.

(E) Access to Settings.

The access to settings of the PCS shall be restricted to qualified personnel in accordance with the requirements of 240.6(C).

705.14 Output Characteristics.

The output of a power production source operating in parallel with an electrical supply system shall be compatible with the voltage, wave shape, and frequency of the system to which it is connected. Synchronous generators operating in parallel with an electrical supply system shall be provided with the necessary equipment to establish and maintain a synchronous condition.

Informational Note: The term *compatible* does not necessarily mean matching the primary source wave shape.

705.16 Interrupting and Short-Circuit Current Rating.

Consideration shall be given to the contribution of fault currents from all interconnected power sources for the interrupting and short-circuit current ratings of equipment on interactive systems.

705.20 Disconnecting Means, Source.

Means shall be provided to disconnect power source output circuit conductors of electric power production equipment from conductors of other systems.

The disconnecting means shall comply with the following:

(1) Be one of the following types:

(2) A manually operable switch or circuit breaker

(3) A load-break-rated pull-out switch

(4) A power-operated or remote-controlled switch or circuit breaker that is manually operable locally and opens automatically when control power is interrupted

(5) A device listed or approved for the intended application

(6) Simultaneously disconnect all ungrounded conductors of the circuit

(7) Located where readily accessible

(8) Externally operable without exposed live parts

(9) Enclosures with doors or hinged covers with exposed live parts when open that require a tool to open or are lockable where readily accessible to unqualified persons

(10) Plainly indicate whether in the open (off) or closed (on) position

(11) Have ratings sufficient for the maximum circuit current, available fault current, and voltage that is available at the terminals

(12) Be marked in accordance with the warning in 690.13(B), where the line and load terminals are capable of being energized in the open position

Informational Note: With interconnected power sources, some equipment, including switches and fuses, is likely to be energized from both directions. See 240.40.

705.25 Wiring Methods.

(A) General.

All raceway and cable wiring methods included in Chapter 3 of this *Code* and other wiring systems and fittings specifically listed, intended, and identified for use with power production systems and equipment shall be permitted. Where wiring devices with integral enclosures are used, sufficient length of cable shall be provided to facilitate replacement.

(B) Flexible Cords and Cables.

Flexible cords and cables, where used to connect the moving parts of a power production system or where used for ready removal for maintenance and repair, shall comply with Article 400 and shall be listed and identified as DG Cable, Distributed Generation Cable, hard service cord, or portable power cable, shall be suitable for extra-hard usage, shall be listed for outdoor use, and shall be water resistant. Cables exposed to sunlight shall be sunlight resistant. Flexible, fine-stranded cables shall be terminated only with terminals, lugs, devices, or connectors in accordance with 110.14(A).

(C) Multiconductor Cable Assemblies.

Multiconductor cable assemblies used in accordance with their listings shall be permitted.

Informational Note: See UL 3003, *Distributed Generation Cables*, for additional information on DG Cable, Distributed Generation Cable. An ac module harness is one example of a multiconductor cable assembly.

705.28 Circuit Sizing and Current.

(A) Calculation of Maximum Circuit Current.

Where not elsewhere required or permitted in this *Code*, the maximum current for the circuit shall be the continuous output current rating of the power production equipment.

(B) Conductor Ampacity.

Where not elsewhere required or permitted in this *Code*, the circuit conductors shall be sized to carry not less than the largest of the following:

(1) The maximum currents in 705.28(A) multiplied by 125 percent without adjustment or correction factors

(2) The maximum currents in 705.28(A) with adjustment and correction factors

(3) Where connected to feeders, if smaller than the feeder conductors, the ampacity as calculated in 240.21(B) based on the over-current device protecting the feeder

(C) Neutral Conductors.

Neutral conductors shall be permitted to be sized in accordance with either 705.28(C)(1) or (C)(2).

(1) Single-Phase Line-to-Neutral Power Sources.

Where not elsewhere required or permitted in this *Code*, the ampacity of a neutral conductor to which a single-phase line-to-neutral power source is connected shall not be smaller than the ampacity in 705.28(B).

(2) Neutral Conductor Used Solely for Instrumentation, Voltage, Detection, or Phase Detection.

A power production equipment neutral conductor used solely for instrumentation, voltage detection, or phase detection shall be permitted to be sized in accordance with 250.102.

705.30 Overcurrent Protection.

(A) Circuit and Equipment.

Power source output circuit conductors and equipment shall be provided with overcurrent protection. Circuits connected to more than one electrical source shall have overcurrent devices located to provide overcurrent protection from all sources.

(B) Overcurrent Device Ratings.

The overcurrent devices in other than generator systems shall be sized to carry not less than 125 percent of the maximum currents as calculated in 705.28(A). The rating or setting of overcurrent devices shall be permitted in accordance with 240.4(B) and (C).

Exception: Circuits containing an assembly together with its overcurrent device(s) that is listed for continuous operation at 100 percent of its rating shall be permitted to be utilized at 100 percent of its rating.

(C) Power Transformers.

Transformers with sources on each side shall be provided with overcurrent protection in accordance with 450.3. The primary shall be the side connected to the largest source of available fault current. Secondary protection shall not be required for a transformer secondary that has a current rating not less than the sum of the rated continuous output currents of the power sources connected to that secondary.

(D) Generators.

Generators shall be provided with overcurrent protection in accordance with 445.12.

705.32 Ground-Fault Protection.

Where protection is installed in accordance with 230.95, the output of an interactive system shall be connected to the supply side of the ground-fault protection.

Exception: Connection shall be permitted to be made to the load side of ground-fault protection, if there is ground-fault protection for equipment from all ground-fault current sources.

705.40 Loss of Primary Source.

The output of electric power production equipment shall be automatically disconnected from all ungrounded conductors of the interconnected systems when one or more of the phases to which it is connected opens. The electric power production equipment shall not be reconnected until all the phases of the interconnected system to which it is connected are restored. This requirement shall not be applicable to electric power production equipment providing power to an emergency or legally required standby system.

Exception: A listed interactive inverter shall trip or shall be permitted to automatically cease exporting power when one or more of the phases of the interconnected system opens and shall not be required to automatically disconnect all ungrounded conductors from the primary source. A listed interactive inverter shall be permitted to automatically or manually resume exporting power to the interconnected system once all phases of the source to which it is connected are restored.

Informational Note No. 1: Risks to personnel and equipment associated with the primary source could occur if an interactive electric power production source can operate as an intentional island. Special detection methods are required to determine that a primary source supply system outage has occurred and whether there should be automatic disconnection. When the primary source supply system is restored, special detection methods are typically required to limit exposure of power production sources to out-of-phase reconnection.

Informational Note No. 2: Induction-generating equipment connected on systems with significant capacitance can become self-excited upon loss of the primary source and experience severe overvoltage as a result.

Interactive power production equipment shall be permitted to operate in island mode to supply loads that have been disconnected from the electric power production and distribution network.

705.45 Unbalanced Interconnections.

(A) Single Phase.

Single-phase power sources in interactive systems shall be connected to 3-phase power systems in order to limit unbalanced voltages at the point of interconnection to not more than 3 percent.

Informational Note: For interactive power sources, unbalanced voltages can be minimized by the same methods that are used for single-phase loads on a 3-phase power system. See ANSI/C84.1-2016, *Electric Power Systems and Equipment — Voltage Ratings (60 Hertz)*.

(B) Three Phase.

Three-phase power sources in interactive systems shall have all phases automatically de-energized upon loss of, or unbalanced, voltage in one or more phases unless the interconnected system is designed so that significant unbalanced voltages will not result.

Part II. Microgrid Systems

705.50 System Operation.

Microgrid systems shall be permitted to disconnect from the primary source of power or other interconnected electric power production sources and operate as an isolated microgrid system operating in island mode.

705.60 Primary Power Source Connection.

Connections to primary power sources that are external to the microgrid system shall comply with the requirements of 705.11, 705.12, or 705.13. Power source conductors connecting to a microgrid system, including conductors supplying distribution equipment, shall be considered as power source output conductors.

705.65 Reconnection to Primary Power Source.

Microgrid systems that reconnect to primary power sources shall be provided with the necessary equipment to establish a synchronous transition.

705.70 Microgrid Interconnect Devices (MID).

Microgrid interconnect devices shall comply with the following:

(1) Be required for any connection between a microgrid system and a primary power source

(2) Be evaluated for the application and have a field label applied or be listed for the application

(3) Have sufficient number of overcurrent devices located to provide overcurrent protection from all sources

Informational Note: MID functionality is often incorporated in an interactive or multimode inverter, energy storage system, or similar device identified for interactive operation.

Statement of Problem and Substantiation for Public Input

BASIS FOR CODE REVISION: …
1) Article 705's scope indicates that, as regards paralleled power systems, only the installation is covered. No other NEC code addresses power paralleling systems in regards to the equipment construction criterion, nor operation, nor its maintenance.
2) Paralleled power systems are commonly affiliated with design intentions for power reliability. Paralleled power systems may be relied upon as intermediate distribution between the source and load for required alternate power systems. For these applications, Article 705 does not yet have language suitable for minimum requirements consistent with other code requirements for a higher than "normal" reliability power system. Article 705 could include a sub-category of paralleled power systems for this purpose. If the intent is to not permit Article 705 to be used in the applications of alternate source of required power systems, that is yet to be stated clearly.
3) The term "utility" is commonly used in the article, whereas generally in the NEC, the term "service" is instead applied. If the term "utility" is not replaced, the terminology should be overtly correlated through definition(s) or in deliberate code text usage, so to clarify the conditions for their common meanings. If use continues, "electric utility", "electric utility service", or "electric utility supply" may be suitable terms.
4) The inclusion or exclusion of unitized battery systems as a potential power source in application of paralleling types of power systems is not yet clarified.

5) Only a narrow application scope of the potential forms of paralleled power are stated explicitly or inferenced by information note within this article; such as on-site power sources which are paralleled with a utility. This infers exclusion of Article 705 to particular types of paralleled power sources, such as a group of strictly generators, whose paralleling gear is not paralleled with utility. Other types of paralleled power system distribution topologies, that join normal sources with essential-class power source are either;

a. not explicitly stated to be covered by this article, …

b. or, are inadequately covered by this article due to the absence of stringent requirements typical to emergency-class systems.

6) Paralleling distribution gear that is not paralleled with utility has no other governing code article configured to serve as code guidance, but could be addressed in article 705 if revised to do so. NFPA 110 has some requirements associated with paralleling gear but there are the following gaps;

a. NFPA 110 scope indicates that its application is to emergency and standby systems (e.g. Article NEC Article 700 and 701 systems). However, this may be construed to exclude the following power system types, ;

(1) Stored Energy Power Supply System circuit in accordance with NFPA 111. Note that NFPA 111 uses a different context for the term "parallel", and does not address the context of paralleling power supply systems.

(2) Essential Electrical System circuits in accordance with Article 517. Note that Article 517 references NFPA 110 but that NFPA 110 does not identify Essential Electrical Systems of 517 in its own application of scope described in 1.1 and in the standard's title. The only reference in the NFPA 110 to Essential Electrical Systems is in its Appendix A.4.4.1. The 517 Essential Electrical System consists of the following sub-system branches as follows;

(A) Life Safety Branch
(B) Critical Branch
(C) Equipment Branch
i. Equipment Branch A
ii. Equipment Branch B

(3) Emergency system circuit in accordance with Article 700.
(4) Legally required standby system circuit in accordance with Article 701.
(5) Optional standby system circuit in accordance with Article 702.
(6) Critical Operations Power system circuit in accordance with Article 708
(7) Fuel cell power supply system circuit, when used as a power source for power system type (3) through (7) above.
(8) A multi-source power system type derived to strictly serve fire pumps in accordance with Article 695. With its alternate source, as permitted from a power source type (1) through (7) above, or an EPSS (per NFPA 110), or derived from an alternate normal power service to satisfy reliability requirements in accordance with Article 695.

b. NFPA 110 does not address the types of installation, operation, and maintenance considerations that may be suited to the NEC to address when load criticality is suited to addition stringency. As is addressed in NEC Article 700.

7) Paralleling gear covered by this article that serves emergency, critical or essential power systems has none of the usual material, design and install considerations that must otherwise comply to an elevated class of resilience due to load criticality, such as is covered in Article 700, or in lesser degree NFPA 110.

8) As written, paralleling gear covered by Article 705 that serves emergency, critical or essential power systems has no clearly stated disallowance of power source type(s) nor disallowance of power system type(s) that are to be supplied by the paralleling system. As such, this Article may be applied as an alternate compliance means to other articles where an Automatic Transfer Switch is meant to be used and listed for emergency use. Nor does it contain any constraint to any form of use other than an ATS in regards to essential-class power systems.

9) Essential power supply system equipment that supplies and distributes multi-source paralleled power to emergency, critical or essential power systems is not yet distinctly addressed in the NEC. A portion of this Article 705 could serve to address this application of paralleling equipment.

10) Paralleling distribution equipment is not yet consistent with other code intent for equipment meant to operate as an elevated class of resilience due to load criticality (e.g. "for emergency use"). When a set of ATSs for emergency use all have their alternate source power supplied by the same paralleling system, such a paralleling system can be the weak link when it has no stringent code requirements for resiliency. EPSS grade requirements for paralleling gear could be stated as a sub-part of Article 705. For example, paralleling system equipment, when applied to essential-class power systems, could be subject to the following types of elevated robustness;

a. The breakers and switches for EPSS grade paralleling applications can be correlated to some

elevated level of resiliency, such as 'Electrically operated and mechanically held', which is applied for emergency (NEC 700, 701, 708) and for all healthcare (NEC 517, NFPA 20).

b. Circuit breakers and switches can be rated to withstand the number of load break operations for the life of the equipment, as is done for transfer switches meant to distribute essential-class power.

c. Circuit breakers and switches can be rated to perform a close and latch function to the available fault, as is done for transfer switches meant to distribute essential-class power.

d. For closed-transition switch schemes, where designed interrupting ratings rely upon a fault not drawing fault current from multiple sources concurrently, due to the brevity of switching sequence or for any other reason, it could be addressed in code text to help ensure safe practices are followed.

e. Where there exists a potential for manual or automatic mis-operation of the equipment to exceed the designed maximum available fault or exceed the interrupting rating for any system or component, it could be addressed in code text to help ensure safe practices are followed.

f. Where equipment is series rated, and there exists a potential for manual or automatic mis-operation of the equipment to exceed the designed maximum, it could be addressed in code text to help ensure safe practices are followed.

11) Grounding for multiple-source equipment, if not designed specifically to the equipment and conditions, will manifest in many problematic ways and can effectively make ground fault detection untenable. Minimum requirements should be addressed.

12) The equipment guidelines in item-10 above refers to proposed code text edits (see Public Comment), which, in the current status of the Public Comment, is only being applied to essential-class power systems. However, certain aspects of these and other proposed edits could be crafted to also apply to normal power paralleling systems, either in whole or part. Such supplemental revisions may help ensure particular safe practices are followed for the normal power system equipment as well.

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Submittal Date: Thu Sep 03 15:12:21 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: This public input (PI) covers so many different items as to make it extremely difficult to address as part of the Public Input process. PIs are intended to address a single issue, not many issues. Many of the issues raised by this PI are addressed with other PIs. The submitter is encouraged to review the first draft and resubmit individual comments for items they believe have not been properly addressed.

Public Input No. 2529-NFPA 70-2020 [Section No. 705.1]

705.1 Scope.

This article covers installation of one or more electric power production sources operating in parallel with a primary source(s) of electricity, and installations not connected to an electric power production and distribution network ..

Informational Note: Examples of the types of primary sources include a utility supply or an on-site electric power source(s).

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13)
Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

The Scope had to be modified to align with the inclusion of Article 710 into this combined article.

Submitter Information Verification

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Submittal Date: Mon Aug 24 11:52:57 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: Article 705 covers all power sources operating as interconnected sources. Systems that operate only as stand-alone sources not interconnected to any other sources are covered in Article 710.

Public Input No. 4440-NFPA 70-2020 [Section No. 705.1]

705.1 Scope.

This article covers installation of one or more electric power production sources operating in parallel with a primary source(s) of electricity.

Informational Note: Examples of the types of primary sources include a utility supply or an on-site electric power source(s).

Informational Note Figure 705.1(a) Identification of Interconnected Electric Power Production Source Components in Common Configurations.

{see attachment for new image}

Note:

(1) These diagrams are intended to be a means of identification for system components, circuits, and connections.

(2) The system disconnect in these diagrams separates the system from all other systems.

(3) Not all disconnecting means required are shown.

(4) System grounding and equipment grounding are not shown.

(5) Custom designs occur in each configuration, and some components are optional.

Additional Proposed Changes

File Name	Description	Approved
705_1_IN_Figure_1a_correct.pdf	New suggested image	

Statement of Problem and Substantiation for Public Input

This PI is submitted in conjunction with the related PI which illustrates PV System DC Circuits definitions. PV Power Source is not a defined term in 690, and the use of this term on the diagram generates confusion. Article 705 uses the term “Power Source” to refer to the AC output of a power system, while this diagram currently uses the term to point to the DC side of a PV system. Substituting a term that is defined, PV System DC Circuit(s) improves the usability of these diagrams. In addition, swapping the “electric power production and distribution network” label for a more succinct and generalized term “Other Power Sources” will lessen confusion.

Additionally, making these diagrams more generic (not PV system specific) and moving them to 705 will allow them to be referenced for any type of power production source operating in parallel with a primary source.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each

individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI's submitted.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain, P.E., SEIA; Bill Brooks, PVICC; John Berdner, PVICC, Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing, Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower; Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

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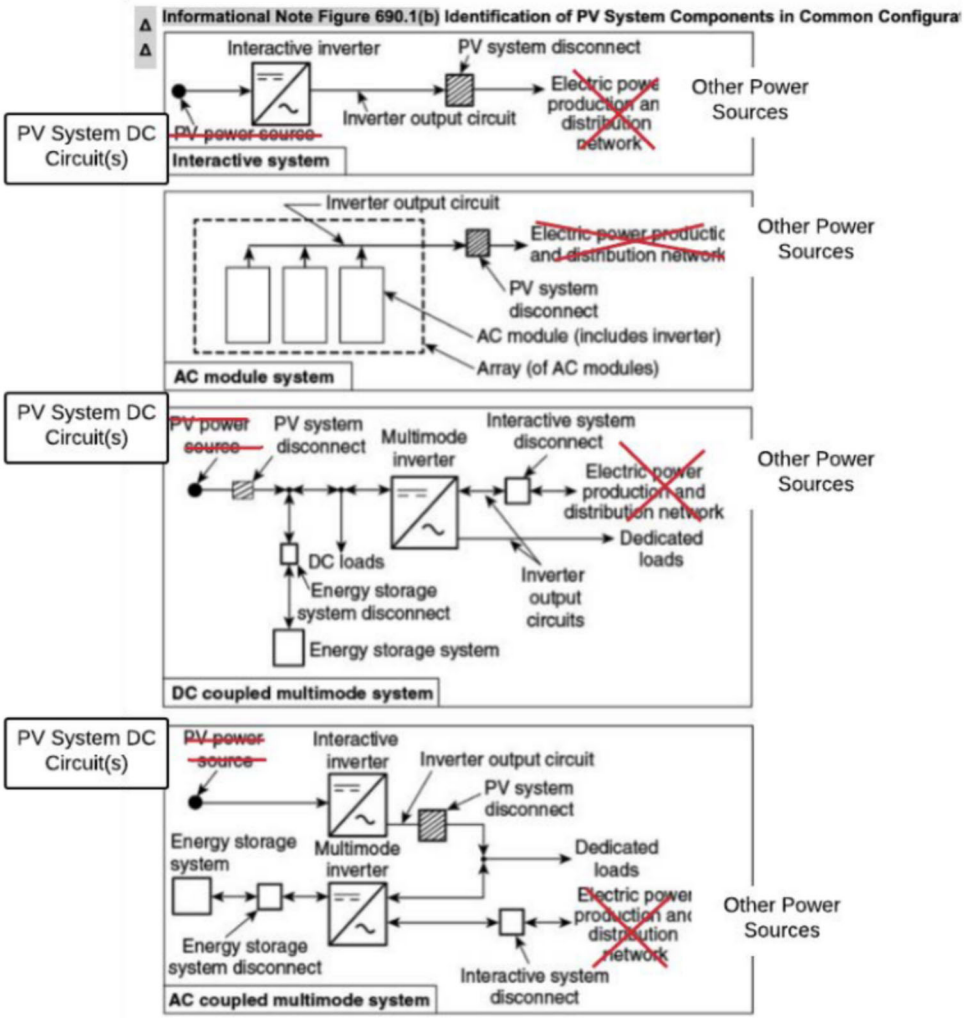
Committee: NEC-P04

Committee Statement

Resolution: FR-9594-NFPA 70-2021
Statement: Informational Note No. 2 and the diagrams are added to Section 705.1 to illustrate various terms used in Article 705 for a variety of power sources.

Informational Note Figure 705.1(a) Identification of Interconnected Electric Power Production Source Components in Common Configurations.



Notes on action:

Revised 690.1(b) / new 705.1(a) diagram with following changes:

- Change “PV Power source” ” to “PV System DC Circuits” on diagram
- Deleted Stand-Alone System Diagram

Public Input No. 2572-NFPA 70-2020 [New Section after 705.2]

705.3 Other Articles

Microgrid and stand-alone systems shall also comply with the applicable provisions of Table 705.3. Where requirements in this article differ from those in Table 705.3, the requirements in the other article shall apply.

Table 705.3 Other Articles

Equipment/Occupancy	Article
Health Care Facilities	517
Fire Pumps	695
Emergency Systems	700
Legally Required Standby Systems	701
Critical Operations Power Systems (COPS)	708

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

The addition of this section helps ensure that those areas that may reference sources of power that fall under the provisions of Article 705 when used for such installations as Emergency Systems, Legally Required Power Systems and other similar systems may modify some of the requirements in Article 705 such as those pertaining to sizing of the source.

Submitter Information Verification

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Submittal Date: Mon Aug 24 18:49:08 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9383-NFPA 70-2021

Statement: The recent changes to Section 90.4 in applying the NEC can cause some confusion as to which articles take precedent over others. The specific articles listed in Table 705.3 have more stringent requirements than Article 705 in some cases so for on-site power sources supplying these specific systems, the supplemental or modifying requirements in those articles apply. Article 702 is not required to be included in the Table in 705.3 as Article 702 is applicable to systems other than those covered by 705.

Public Input No. 3874-NFPA 70-2020 [Section No. 705.2]

705.2 Definitions.

The definitions in this section shall apply within this article and throughout the *Code*.

Microgrid Interconnect Device (MID).

A device that enables a microgrid system to separate from and reconnect to operate in parallel with a primary power source.

Informational Note: Microgrid controllers typically are used to measure and evaluate electrical parameters and provide the logic for the signal to initiate and complete transition processes. IEEE Std 2030.7-2017, *IEEE Standard for the Specification of Microgrid Controllers*, and IEEE Std 2030.8-2018, *IEEE Standard for the Testing of Microgrid Controllers*, provide information on microgrid controllers. IEEE Std 1547-2018, *IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces*, provides information on interconnection requirements.

Microgrid System.

A premises wiring system that has generation, energy storage, and load(s), or any combination thereof, that includes the ability to disconnect from and parallel with the primary source.

Informational Note: The application of Article 705 to microgrid systems is limited by the exclusions in 90.2(B)(5) related to electric utilities. Additional information may be found in IEEE 1547, IEEE 2030.7, and IEEE 2030.8.

PV Output Source (PVOS)

A source of power generated by a photovotaic system

Large Scale PV Output Source (PVO-LS)

A source of power from a large scale photovoltaic system

Generator Output Source (GOS)

A source of power generated from a prime mover system

Utilty Power ~~Source Output Circuit.~~

~~The conductors between power production equipment and the service or distribution equipment.~~

Production Source (UPPS)

A source of power from a commercial utility.

Fuel Cell Output (FCO)

A source of power from a fuel cell system.

Wind Electric Source (WES)

A source of power from a wind electric system

Statement of Problem and Substantiation for Public Input

The terms used in 705 can be very confusing. The definitions I provided would enable the wording in Article 705 as well as 690, 691, 692, 694 to be substantially more clear. Consistency in those code section would assist the electricians and inspectors.

Submitter Information Verification

Submitter Full Name: Mitch Maulik
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Submittal Date: Wed Sep 09 14:33:19 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: These proposed definitions are not used in the NEC. They are also self-defined terms and would not need a definition even if they were used.

Public Input No. 3955-NFPA 70-2020 [Section No. 705.2]

(Relocate all definitions in the 705. 2 to Article 100, arrange them in alphabetical order and without any subdivisions.)

705. 2 Definitions.

The definitions in this section shall apply within this article and throughout the *Code*.

Microgrid Interconnect Device (MID).

A device that enables a microgrid system to separate from and reconnect to operate in parallel with a primary power source.

Informational Note: Microgrid controllers typically are used to measure and evaluate electrical parameters and provide the logic for the signal to initiate and complete transition processes. IEEE Std 2030.7-2017, *IEEE Standard for the Specification of Microgrid Controllers*, and IEEE Std 2030.8-2018, *IEEE Standard for the Testing of Microgrid Controllers*, provide information on microgrid controllers. IEEE Std 1547-2018, *IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces*, provides information on interconnection requirements.

Microgrid System.

A premises wiring system that has generation, energy storage, and load(s), or any combination thereof, that includes the ability to disconnect from and parallel with the primary source.

Informational Note: The application of Article 705 to microgrid systems is limited by the exclusions in 90.2(B)(5) related to electric utilities. Additional information may be found in IEEE 1547, IEEE 2030.7, and IEEE 2030.8.

Power Source Output Circuit.

The conductors between power production equipment and the service or distribution equipment.

Statement of Problem and Substantiation for Public Input

"The National Electrical Code has definitions in multiple parts in Article 100 and many definitions scattered through out the code many of them in the .2 section of the articles.
Most of the other standards under NFPA have their definitions in one location and this will allow the NEC the same requirement. The revisions to the NEC Style Manual require all the definitions to be relocated to Article 100. "

Submitter Information Verification

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Submittal Date: Wed Sep 09 16:16:08 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9324-NFPA 70-2021

Statement: This revision moves all definitions previously in Section 2 of Articles 690, 692, 694 and 705 to Article 100.

The NEC Style Manual also requires that for definitions that apply in only one article, the article number in parentheses shall follow the definition.

CMP-4 identified the following definitions that apply to only one article:

690: AC Module System, AC Module, Array, Direct-Current Combiner, Module, Monopole Circuit, PV Output Circuit, PV Source Circuit, PV System DC Circuit.

692: Fuel Cell Output Circuit

694: Maximum Output Power, Maximum Voltage, Nacelle, Rated Power, Tower, Wind Turbine Output Circuit.

These have been moved to Article 100 with the relevant article number appended. All other definitions have been moved with no article number identified.

All definitions were moved with the annotation (CMP-4) appended to indicate the code panel responsible for the definition in accordance with NEC Style Manual Section 2.2.2.3.3.

Public Input No. 2530-NFPA 70-2020 [Definition: Microgrid Interconnect Device (MID).]

Microgrid Interconnect Device (MID).

A device that enables a microgrid system to separate from and reconnect to operate in parallel with a primary power source, or to operate in island mode .

Informational Note: Microgrid controllers typically are used to measure and evaluate electrical parameters and provide the logic for the signal to initiate and complete transition processes. IEEE Std 2030.7-2017, *IEEE Standard for the Specification of Microgrid Controllers*, and IEEE Std 2030.8-2018, *IEEE Standard for the Testing of Microgrid Controllers*, provide information on microgrid controllers. IEEE Std 1547-2018, *IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces*, provides information on interconnection requirements.

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13)
Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

Text added to align with Article 710 inclusion into this Article. Specifically, Section 710.1 Scope. Microgrid interconnect devices are used in microgrids to connect or disconnect with a utility. This change better aligns the definition with how it is used.

Submitter Information Verification

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Submittal Date: Mon Aug 24 12:01:23 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9359-NFPA 70-2021
Statement: The addition to this definition clarifies that the MID allows a microgrid system to operate in island mode.

Public Input No. 2531-NFPA 70-2020 [Definition: Microgrid System.]

Microgrid System.

A premises wiring system ~~that has generation, energy storage, and load(s), or any combination thereof, that~~ interconnected to an electric power production and distribution network or other primary power source that has any combination of generation and energy storage capable of operating in parallel and includes the ability to disconnect from ~~and parallel with~~ the primary source to operate in island mode .

Informational Note: The application of Article 705 to microgrid systems is limited by the exclusions in 90.2(B)(5) related to electric utilities. Additional information may be found in IEEE 1547, IEEE 2030.7, and IEEE 2030.8.

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

Clarifies that a microgrid system is a system interconnected with and interactive with another primary source such as a utility, that has capabilities of operating in island mode when isolated from that source. This is different from a Stand-alone system (as defined in the related PI).

Submitter Information Verification

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Submittal Date: Mon Aug 24 12:03:39 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9360-NFPA 70-2021
Statement: The revision of this definition clarifies that a microgrid, as define in the Code, is a system that can connect and disconnect from a utility service.

Public Input No. 738-NFPA 70-2020 [Definition: Microgrid System.]

Microgrid System.

A premises wiring system that has generation, energy storage, and load(s), or any combination thereof, that ~~includes the~~ may or may not include the ability to disconnect from and parallel with the primary source.

Informational Note: The application of Article 705 to microgrid systems is limited by the exclusions in 90.2(B)(5) related to electric utilities. Additional information may be found in IEEE 1547, IEEE 2030.7, and IEEE 2030.8.

Statement of Problem and Substantiation for Public Input

There are microgrid systems, in the Department of Defense for example, that are not connected to a utility. It could be that the only microgrid systems that are covered by NFPA70 are those that can also be connected to a utility. In that case, perhaps adding another sentence to the definition as follows: "A microgrid that does not have the ability to interconnect with a utility is not covered by this Code."

Submitter Information Verification

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Submittal Date: Sat Mar 21 22:25:07 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: Microgrids in the context of this Code are always “interactive microgrids”. Isolated microgrids are defined now as stand-alone systems. The statement that “A microgrid that does not have the ability to interconnect with a utility is not covered by this Code” is incorrect – standalone systems are covered.

Public Input No. 2532-NFPA 70-2020 [Definition: Power Source Output Circuit.]

Power Source Output Circuit.

The conductors between power production equipment and the service or ~~distribution equipment~~ other systems .

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

The definition was modified to align with the intent of a power source output circuit being those conductors in the alternative energy system up to where it connects with other systems such as at the service or any other location as part of a premises wiring systems such as distribution equipment or feeders found in these locations.

Submitter Information Verification

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Submittal Date: Mon Aug 24 12:10:13 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9362-NFPA 70-2021
Statement: The revision of this definition clarifies a power source output circuit is a circuit between a source and the connection point to other systems such as a service, distribution equipment or feeders.

Public Input No. 2533-NFPA 70-2020 [Section No. 705.6]

705.6 Equipment Approval.

All equipment shall be approved for the intended use ~~.~~ in accordance with one of the following:

(1) Be listed for the application

(2) Be evaluated for the application and have a field label applied

Interactive equipment intended to operate in parallel with electric power production sources including, but not limited to, interactive inverters, engine generators, energy storage equipment, and wind turbines shall be listed for interactive function or be evaluated for interactive function and have a field label applied, or both.

Informational Note: Inverters identified as "multimode" and "stand-alone" are specifically identified and certified to operate in this application. Stand-alone inverters operate in island mode. Multimode inverters operate in either island mode (previously called "stand-alone mode") or interactive mode, if it has been installed with the optional utility grid connection. A multimode inverter will only operate in island mode if it is never connected to an electric utility supply. Stand-alone inverters are not evaluated for and are not intended for connection to export power in parallel with an electric utility.

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

Language was added from 710.6 as this language is appropriate and applies to all alternative energy source systems as a general requirement which aligns with the new Article 705.

With this action 712.4 is effectively merged into 705 and deleted from Article 712. The new language is not exactly what was found in 712.4 but is all encompassing ensuring the proper equipment is used for the correct application and is listed as such.

Submitter Information Verification

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Submittal Date: Mon Aug 24 12:12:20 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9374-NFPA 70-2021
Statement: The first sentence is deleted as this is already covered in Section 110.2. The section was reorganized for clarity. An informational note provides similar information as is found in Article 710 and points to the standard found in the annex that is used to evaluate interactive

equipment.

Public Input No. 3956-NFPA 70-2020 [Section No. 705.6]

705.6 Equipment ~~Approval~~ for Interactive Use .

~~All equipment shall be approved for the intended use. Interactive~~ Interactive power production equipment intended to operate in parallel with electric power production sources including, but not limited to, interactive inverters, engine generators, energy storage equipment, and wind turbines shall be listed for interactive function or be evaluated for interactive function and have a field label applied, or both. Distribution equipment listed for the purpose of interconnecting interactive power production equipment with other systems shall not be required to meet the requirements of 705.12(B)(3) where installed in accordance with the manufacturer's instructions.

Statement of Problem and Substantiation for Public Input

The general requirement for approval for all equipment has been struck as unnecessary since it does not modify general requirements in 90.4. The defined term power production equipment is used here to add clarity. An allowance for distribution equipment listed specifically for the purpose of interconnecting interactive power production equipment has been added to recognize that equipment that may have ratings and other features not typically found in other distribution equipment. This equipment should not be scrutinized for busbar compliance in 705.12(B)(3) as these issues have been addressed as part of the listing. Several problems have surfaced in the field where AHJs have questioned and disallowed properly installed listed equipment because they perceive it violates 705.12(B)(3).

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI's submitted.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain, P.E., SEIA; Bill Brooks, PVICC; John Berdner, PVICC, Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing, Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower; Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Ben Chamberlain, Olivewood Energy; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener,

SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

Submitter Information Verification

Submitter Full Name: Evelyn Butler
Organization: Solar Energy Industries Assn
Affiliation: PV Industry Forum (PVIF)
Street Address:
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State:
Zip:
Submittal Date: Wed Sep 09 16:17:05 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9374-NFPA 70-2021
Statement: The first sentence is deleted as this is already covered in Section 110.2. The section was reorganized for clarity. An informational note provides similar information as is found in Article 710 and points to the standard found in the annex that is used to evaluate interactive equipment.

Public Input No. 4005-NFPA 70-2020 [Section No. 705.6]

705.6 Equipment Approval.

All equipment shall be approved for the intended use. Interactive equipment intended to operate in parallel with electric power production sources including, but not limited to, interactive inverters, engine generators, energy storage equipment, and wind turbines shall be listed for interactive function or be evaluated for interactive function and have a field label applied, or both.

Informational Note: For further information on interactive equipment, see ANSI/UL 1741, Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources.

Statement of Problem and Substantiation for Public Input

Substantiation – Interactive products are still being designed, built and listed (certified) using the incorrect product safety standards for the grid interactive applications. Grid interactive applications place power conversion equipment between two significantly sized and potentially hazardous power sources. It is critical that this equipment operate safely under normal and foreseeable abnormal fault conditions. The UPS and motor drive standards do not evaluate for fault conditions using two power sources and are not representative of failure modes in grid interactive applications. It is safety critical that listed equipment be evaluated to the correct standard. This informational note is similar to the one used in 625 and 706 to provide guidance to the appropriate safety standard for the application.

Submitter Information Verification

Submitter Full Name: Timothy Zgonena
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Street Address:
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Submittal Date: Wed Sep 09 17:05:18 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9374-NFPA 70-2021

Statement: The first sentence is deleted as this is already covered in Section 110.2. The section was reorganized for clarity. An informational note provides similar information as is found in Article 710 and points to the standard found in the annex that is used to evaluate interactive equipment.

Public Input No. 580-NFPA 70-2020 [Section No. 705.6]

705.6 Equipment Approval.

~~All equipment shall be approved for the intended use.~~

Interactive equipment intended to operate in parallel with electric power production sources including, but not limited to, interactive inverters, engine generators, energy storage equipment, and wind turbines shall be listed for interactive function or be evaluated for interactive function and have a field label applied, or both.

Statement of Problem and Substantiation for Public Input

My intention was only to delete the first sentence, but Terra had other plans.
Section 110.2 already covers the issue.

Submitter Information Verification

Submitter Full Name: Ryan Jackson
Organization: Ryan Jackson
Street Address:
City:
State:
Zip:
Submittal Date: Mon Mar 02 15:00:08 EST 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9374-NFPA 70-2021

Statement: The first sentence is deleted as this is already covered in Section 110.2. The section was reorganized for clarity. An informational note provides similar information as is found in Article 710 and points to the standard found in the annex that is used to evaluate interactive equipment.

Public Input No. 478-NFPA 70-2020 [Section No. 705.8]

705.8 System Installation.

Installation and maintenance of one or more electrical power production sources operating in parallel with a primary source(s) of electricity shall be performed only by qualified persons.

Informational Note: See Article 100 for the definition of *Qualified Person*.

Statement of Problem and Substantiation for Public Input

The code needs to address that maintenance of these systems also needs to be performed by qualified persons.

Submitter Information Verification

Submitter Full Name: Brian Baughman
Organization: Generac Power Systems Inc.
Street Address:
City:
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Submittal Date: Tue Feb 18 11:58:20 EST 2020
Committee: NEC-P04

Committee Statement

Resolution: The NEC is an installation document and should not include maintenance requirements that are unenforceable by construction enforcement.

Public Input No. 2535-NFPA 70-2020 [Section No. 705.10]

705.10 Identification of Power Sources.

A permanent plaque or directory shall be installed at each service equipment location, or at an approved readily visible location. Where the building is not supplied by a service, a permanent plaque or directory shall be installed at an approved readily visible location. The plaque or directory shall denote the location of each power source disconnecting means for the building or structure and be grouped with other plaques or directories for other on-site sources. ~~The~~ Where multiple sources supply the building, the plaque or directory shall be marked with the wording "CAUTION: MULTIPLE SOURCES OF POWER." ~~Any posted diagrams shall be correctly oriented with respect to the diagram's location.~~ The marking shall comply with 110.21(B).

Exception: Installations with multiple co-located power production sources shall be permitted to be identified as a group(s). The plaque or directory shall not be required to identify each power source individually.

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

This text replaces what is found in 712.10, "Directory". With the creation of 705 as a general requirement, this language incorporates the directory requirements found in Article 710 and Article 712 in sections 710.10 and 712.10 respectively. The requirement to orient the diagram "correctly" as found in 705 lacks the clarity necessary to ensure this is enforced uniformly. This new text that was added in the 2020 cycle has caused confusion and is not necessary since all markings require approval

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2982-NFPA 70-2020 [Section No. 230.2(E)]	
Public Input No. 2994-NFPA 70-2020 [Section No. 480.7(G)]	
Public Input No. 2995-NFPA 70-2020 [Section No. 690.56]	

Submitter Information Verification

Submitter Full Name: Thomas Domitrovich
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Submittal Date: Mon Aug 24 12:15:49 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9376-NFPA 70-2021

Statement: This first revision continues to refine the identification of power sources requirement by consolidating some of the wording, adding language about off-site emergency service information, and removing the requirement for proper orientation. The requirements are placed into a list to follow the NEC Style Manual.

Public Input No. 3583-NFPA 70-2020 [Section No. 705.10]

705.10 Identification of Power Sources.

A permanent plaque or directory shall be installed at each service equipment location, or at an approved readily visible location. The plaque or directory shall denote the location of each power source disconnecting means for the building or structure, indicate the name and emergency telephone number of the company currently servicing power source systems, and be grouped with other plaques or directories for other on-site sources. The plaque or directory shall be marked with the wording “CAUTION: MULTIPLE SOURCES OF POWER.” Any posted diagrams shall be correctly oriented with respect to the diagram's location. The marking shall comply with 110.21(B).

Exception: Installations with multiple co-located power production sources shall be permitted to be identified as a group(s). The plaque or directory shall not be required to identify each power source individually.

Statement of Problem and Substantiation for Public Input

This PI is one of three submitted on behalf of the NFPA 1/ NEC PV Joint Task Group. The Task Group is comprised of Ken Bush – NFPA 1 (Technical Committee Chair), Shane Clary – NFPA 1, Rebekah Hren – NEC Panel 4, Bruce Johnson – NFPA 1 (Task Group Chair) and Jim Rogers – NEC Panel 4 Chair. Three consensus proposals are being submitted by the Task Group with the purpose of fully harmonizing the PV system and power source labeling and marking requirements of the NEC with those of the Fire Code. Slight variations that have existed in color, formatting, and marking language requirements between the Fire Code and the NEC have made it unnecessarily difficult for enforcement and inspections agencies to align. As an example, the requirement for a yellow background on the Rapid Shutdown label in the NEC as compared to a red background in NFPA 1 could result in a jurisdiction requiring two labels serving the same purpose, though by their dual presence possibly causing confusion. Clearly this is not practical or desirable and the Codes should be harmonized. This PI specifically aligns the requirement for installer emergency information labeling as required in NFPA 1 11.12.2.1.5.

Submitter Information Verification

Submitter Full Name: Rebekah Hren
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City:
State:
Zip:
Submittal Date: Wed Sep 09 08:19:14 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9376-NFPA 70-2021
Statement: This first revision continues to refine the identification of power sources requirement by consolidating some of the wording, adding language about off-site emergency service information, and removing the requirement for proper orientation. The requirements are placed into a list to follow the NEC Style Manual.

Public Input No. 3983-NFPA 70-2020 [Section No. 705.11]

705.11 Supply-Side Source Connections.

An electric power production source, where connected on the supply side of the service disconnecting means as permitted in 230.82(6), shall comply with 705.11(A) through (E F).

(A) Output Rating.

The sum of the power source continuous current output ratings on a service, other than those controlled in accordance with 705.13, shall not exceed the ampacity of the service conductors.

Informational Note: See Article 100 definition for Service Conductors.

(B) Conductors.

The power source output circuit conductors from the service conductors point of connection to the first overcurrent protection device shall be sized in accordance with 705.28 and in no case sized smaller than 6 AWG copper or 4 AWG aluminum. These conductors shall be installed in accordance with 230.30 or 230.43.

(C) Overcurrent Protection.

The power source output circuit conductors shall be protected from overcurrent in accordance with 705.30. If fuses are not integral with the disconnecting means, the disconnecting means shall be located on the service side of the fuses. Where the power source output circuit conductors make their connection to the service outside of a building, they shall be protected by overcurrent devices in a readily accessible location outside the building or at the first readily accessible location where the power source conductors enter the building. Where the power source output circuit conductors make their connection to the service inside a building, they shall be protected with one of the following methods:

(1) With an overcurrent device located within 3 m (10 ft) of conductor length in dwelling units and 5 m (16.5 ft) in other than dwelling units from the point of connection to the service

(2) In other than a dwelling unit, with an overcurrent device located within 20 m (71 ft)of conductor length from the point of connection to the service, provided that cable limiters installed in all ungrounded conductors are located within 5 m (16.5 ft) of conductor length from the point of connection to the service

(D) Connections.

The connection of power source output circuit conductors to the service conductors shall be made using listed connectors as described in 110.14 and comply with all enclosure fill requirements Any modifications to existing equipment shall be made in accordance with the manufacturer's instructions or the modification must be evaluated for the application and have a field label applied. For meter socket enclosures or other equipment under the exclusive control of the electric utility, only connections approved by the electric utility shall be permitted.

(E) Ground-Fault Protection.

For connections rated 1000 amperes or more to solidly grounded wye services exceeding 150 volts to ground but not exceeding 1000 volts, phase-to-phase, ground-fault protection meeting the requirements of 230.95 shall be provided.

(F) Disconnecting Means

Disconnecting means rated 1000 volts or less shall be listed as suitable for use as service equipment.

Statement of Problem and Substantiation for Public Input

Connections to the line side of a service have the same hazards that are encountered for services.

Requiring the disconnecting means to be listed as suitable for use as service equipment ensures that sufficient barriers are in place to give the same level of safety to the electrical worker as for service equipment.

Submitter Information Verification

Submitter Full Name: Bill Brown
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Submittal Date: Wed Sep 09 16:41:32 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: Section 230.82(6) already requires all power source disconnects to be rated as service equipment.

Public Input No. 4295-NFPA 70-2020 [Section No. 705.11]

705.11 Supply-Side Source Connections.

An electric power production source, where connected on the supply side of the service disconnecting means as permitted in 230.82(6), shall comply with 705.11(A) through (~~E~~ F).

(A) Output Rating.

The sum of the power source continuous current output ratings on a service, other than those controlled in accordance with 705.13, shall not exceed the ampacity of the service conductors.

Informational Note: See Article 100 definition for Service Conductors.

(B) Conductors.

The power source output circuit conductors from the service conductors point of connection to the first overcurrent protection device shall be sized in accordance with 705.28 and in no case sized smaller than 6 AWG copper or 4 AWG aluminum. These conductors shall be installed in accordance with 230.30 or 230.43.

(C) Overcurrent Protection.

The power source output circuit conductors shall be protected from overcurrent in accordance with 705.30. If fuses are not integral with the disconnecting means, the disconnecting means shall be located on the service side of the fuses. Where the power source output circuit conductors make their connection to the service outside of a building, they shall be protected by overcurrent devices in a readily accessible location outside the building or at the first readily accessible location where the power source conductors enter the building. Where the power source output circuit conductors make their connection to the service inside a building, they shall be protected with one of the following methods:

(1) With an overcurrent device located within 3 m (10 ft) of conductor length in dwelling units and 5 m (16.5 ft) in other than dwelling units from the point of connection to the service

(2) In other than a dwelling unit, with an overcurrent device located within 20 m (71 ft)of conductor length from the point of connection to the service, provided that cable limiters installed in all ungrounded conductors are located within 5 m (16.5 ft) of conductor length from the point of connection to the service

(D) Connections.

The connection of power source output circuit conductors to the service conductors shall be made using listed connectors as described in 110.14 and comply with all enclosure fill requirements Any modifications to existing equipment shall be made in accordance with the manufacturer's instructions or the modification must be evaluated for the application and have a field label applied. For meter socket enclosures or other equipment under the exclusive control of the electric utility, only connections approved by the electric utility shall be permitted.

(E) Ground-Fault Protection.

For connections rated 1000 amperes or more to solidly grounded wye services exceeding 150 volts to ground but not exceeding 1000 volts, phase-to-phase, ground-fault protection meeting the requirements of 230.95 shall be provided.

(**F**) Grounding and Bonding

All metal enclosures, metallic wiring methods, and metal parts associated with the power source output circuit conductors shall be connected to the grounding electrode system for the service with only one of the following methods:

(1) Grounded Conductor Brought to Power Source Disconnecting Means. Where a grounded service conductor is brought to the power source disconnecting means, the grounded conductor shall be connected to the disconnecting means grounded conductor terminal or bus. A bonding conductor shall connect the grounded service conductor to each metal enclosure for the power source output circuit conductors . This bonding conductor shall be sized in accordance with 250.102 based on the size of the power source output circuit conductors.

(2) Grounded Conductor not Brought to Power Source Disconnecting Means. Where a grounded service conductor is not brought to the power source disconnecting means, each metal enclosure for the power source output circuit conductors shall be bonded using a separate bonding conductor sized in accordance with 250.102 based on the size the power source output circuit conductors. This separate bonding conductor shall be connected to the grounding electrode system.

Statement of Problem and Substantiation for Public Input

This language was removed by an appeal and floor action at the NFPA annual meeting. There was no technical substantiation submitted for the removal of this language just a concern that CMP 5 should be addressing bonding and grounding. This language was developed with a great deal of thought and input from various affected industries and the enforcement community. I have also submitted this to CMP 5 into 250.25 to see what their reaction is to this language.

Submitter Information Verification

Submitter Full Name: James Rogers
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Street Address:
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Submittal Date: Thu Sep 10 09:37:38 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9380-NFPA 70-2021

Statement: The title of Section 705.11 is changed to clarify that it refers to any connection to a service. The initial paragraph introducing Section 705.11 adds the phrase, “connection is permitted to a service as permitted in 230.2(A)(5)” to clarify that a supply-side source connection is an additional service.

Section 705.11(A) is moved to 705.11(A)(1) and modified for clarity.

The revision to 705.11(B) becomes (A) and covers the maximum size of power sources

based on service conductor size. It also specifically addresses the conductors from the point of connection to service conductors to the power source disconnecting means. The conductor requirements for power source output conductors are organized into a list to better comply with the NEC Style Manual.

Section 705.11(B) moves the section that used to be 705.11(D) Connections to (B) and splits the requirements into a list to better comply with the style manual. The reference to Section 110.14 is removed as unnecessary and the references to Sections 230.33 and 230.46 are added to clarify how splices and taps are made.

The new section 705.11(C) is added for the power source disconnecting means. The new section provides proper reference to the location sections of Article 230. It also clarifies that additional disconnecting means are permitted by Section 230.40 Exception 5.

The new section 705.11(D) is added for bonding and grounding. This language uses the balloted First Draft language of Section 705.11 of the 2020 NEC as it clearly addresses how metal parts are to be bonded and grounded.

The revision to the overcurrent protection section of 705.11 changes the first sentence to call out the exact run of conductors addressed in this section. The reference is changed from 705.30 to Part VII of Article 230. Since 230.95 is in Part VII, the ground-fault protection requirements are clarified as to what equipment requires ground-fault protection. This eliminates the need for a separate section on ground-fault protection so Section 705.11(E) is deleted.

A related FR to 705.32 clarifies that power sources are permitted to be connected to the load side in this instance as there is no other way to make this connection. Listings of this type of ground-fault protection equipment are certified for power flows in either direction.

Public Input No. 4519-NFPA 70-2020 [New Section after 705.11(B)]

(B) Disconnecting Means

The power source disconnecting means shall meet the requirements 705.20. The power source disconnecting means shall not be considered a service disconnecting means as required by 230.70. The requirements of 230.71 and 230.72 shall apply to the power source disconnecting means that are installed in accordance with 230.2(A)(5) or 230.40, Exception No. 5. The conductors connected to the service conductors shall be terminated on the line side of the disconnect. Equipment containing a power source disconnecting means rated 1000 volts or less shall be listed as suitable for use as service equipment.

Statement of Problem and Substantiation for Public Input

This language was approved 17-1 by CMP4 in the 2020 NEC. The requirements in this section are consistent with the requirements of 250.35(B) for non-separately derived generators. Any source on the supply side of the service disconnecting means must not be separately derived since it is physically impossible to be separately derived and also connected to the service conductors at the same time. This language was struck during the Annual meeting at nearly midnight without the benefit of proper review. CMP4 was obligated to reject the motion approved at the Annual meeting. This substantiation further clarifies why the language approved in the second draft was correct as it agrees with the language of 250.35(B). Since this section refers to 705.11(F), that section needs to be returned to the second draft language as well. The word “ahead” in the third sentence of the approved 2nd draft language is changed to “on the supply side” as the term ahead is not used elsewhere in 705.11.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF’s effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI’s as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI’s submitted.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain, P.E., SEIA; Bill Brooks, PVICC; John Berdner, PVICC, Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing, Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower; Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann

Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

Submitter Information Verification

Submitter Full Name: Evelyn Butler
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Street Address:
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Submittal Date: Thu Sep 10 14:35:38 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9380-NFPA 70-2021

Statement: The title of Section 705.11 is changed to clarify that it refers to any connection to a service. The initial paragraph introducing Section 705.11 adds the phrase, “connection is permitted to a service as permitted in 230.2(A)(5)” to clarify that a supply-side source connection is an additional service.

Section 705.11(A) is moved to 705.11(A)(1) and modified for clarity.

The revision to 705.11(B) becomes (A) and covers the maximum size of power sources based on service conductor size. It also specifically addresses the conductors from the point of connection to service conductors to the power source disconnecting means. The conductor requirements for power source output conductors are organized into a list to better comply with the NEC Style Manual.

Section 705.11(B) moves the section that used to be 705.11(D) Connections to (B) and splits the requirements into a list to better comply with the style manual. The reference to Section 110.14 is removed as unnecessary and the references to Sections 230.33 and 230.46 are added to clarify how splices and taps are made.

The new section 705.11(C) is added for the power source disconnecting means. The new section provides proper reference to the location sections of Article 230. It also clarifies that additional disconnecting means are permitted by Section 230.40 Exception 5.

The new section 705.11(D) is added for bonding and grounding. This language uses the balloted First Draft language of Section 705.11 of the 2020 NEC as it clearly addresses how metal parts are to be bonded and grounded.

The revision to the overcurrent protection section of 705.11 changes the first sentence to call out the exact run of conductors addressed in this section. The reference is changed from 705.30 to Part VII of Article 230. Since 230.95 is in Part VII, the ground-fault protection requirements are clarified as to what equipment requires ground-fault protection. This eliminates the need for a separate section on ground-fault protection so Section 705.11(E) is deleted.

A related FR to 705.32 clarifies that power sources are permitted to be connected to the load side in this instance as there is no other way to make this connection. Listings of this

type of ground-fault protection equipment are certified for power flows in either direction.

Public Input No. 3292-NFPA 70-2020 [Section No. 705.11(C)]

(C) Overcurrent Protection.

The power source output circuit conductors shall be protected from overcurrent in accordance with 705.30. If fuses are not integral with the disconnecting means, the disconnecting means shall be located on the service side of the fuses. Where the power source output circuit conductors make their connection to the service outside of a building, they shall be protected by overcurrent devices in a readily accessible location outside the building or at the first readily accessible location where the power source conductors enter the building. Where the power source output circuit conductors make their connection to the service inside a building, they shall be protected with one of the following methods:

(1) With an overcurrent device located within 3 m (10 ft) of conductor length in dwelling units and 5 m (16.5 ft) in other than dwelling units from the point of connection to the service

(2) In other than a dwelling unit, with an overcurrent device located within 20 m (~~71~~ 66 ft)of conductor length from the point of connection to the service, provided that cable limiters installed in all ungrounded conductors are located within 5 m (16.5 ft) of conductor length from the point of connection to the service

Statement of Problem and Substantiation for Public Input

20 meters does not in any way round to 71 feet. This should show 66 feet if the 20 meter distance is correct. If the 71 feet is correct, then the 20 meters should be 22 meters.

Submitter Information Verification

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Submittal Date: Mon Sep 07 15:28:34 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9380-NFPA 70-2021

Statement: The title of Section 705.11 is changed to clarify that it refers to any connection to a service. The initial paragraph introducing Section 705.11 adds the phrase, “connection is permitted to a service as permitted in 230.2(A)(5)” to clarify that a supply-side source connection is an additional service.

Section 705.11(A) is moved to 705.11(A)(1) and modified for clarity.

The revision to 705.11(B) becomes (A) and covers the maximum size of power sources based on service conductor size. It also specifically addresses the conductors from the point of connection to service conductors to the power source disconnecting means. The conductor requirements for power source output conductors are organized into a list to better comply with the NEC Style Manual.

Section 705.11(B) moves the section that used to be 705.11(D) Connections to (B) and splits the requirements into a list to better comply with the style manual. The reference to Section 110.14 is removed as unnecessary and the references to Sections 230.33 and 230.46 are added to clarify how splices and taps are made.

The new section 705.11(C) is added for the power source disconnecting means. The new section provides proper reference to the location sections of Article 230. It also clarifies that additional disconnecting means are permitted by Section 230.40 Exception 5.

The new section 705.11(D) is added for bonding and grounding. This language uses the balloted First Draft language of Section 705.11 of the 2020 NEC as it clearly addresses how metal parts are to be bonded and grounded.

The revision to the overcurrent protection section of 705.11 changes the first sentence to call out the exact run of conductors addressed in this section. The reference is changed from 705.30 to Part VII of Article 230. Since 230.95 is in Part VII, the ground-fault protection requirements are clarified as to what equipment requires ground-fault protection. This eliminates the need for a separate section on ground-fault protection so Section 705.11(E) is deleted.

A related FR to 705.32 clarifies that power sources are permitted to be connected to the load side in this instance as there is no other way to make this connection. Listings of this type of ground-fault protection equipment are certified for power flows in either direction.

Public Input No. 3841-NFPA 70-2020 [Section No. 705.11(C)]

(C) Overcurrent Protection.

The power source output circuit conductors shall be protected from overcurrent in accordance with 705.30. If fuses are not integral with the disconnecting means, the disconnecting means shall be located on the service side of the fuses. Where the power source output circuit conductors make their connection to the service outside of a building, they shall be protected by overcurrent devices in a readily accessible location outside the building or at the first readily accessible location where the power source conductors enter the building. Where the power source output circuit conductors make their connection to the service inside a building, they shall be protected with one of the following methods:

(1) With an overcurrent device located within 3 m (10 ft) of conductor length in dwelling units and 5 m (16.5 ft) in other than dwelling units from the point of connection to the service

(2) In other than a dwelling unit, with an overcurrent device located within 20 m (~~71 ft~~ 66 ft)of conductor length from the point of connection to the service, provided that cable limiters installed in all ungrounded conductors are located within 5 m (16.5 ft) of conductor length from the point of connection to the service

Informational Note: Cable limiters are distinguished from fuses by their intended purpose of providing only short circuit response: they are not designed to provide overload protection, under normal or fault conditions. In applications where three of more conductors are used in parallel, the need for additional cable limiters at the opposite end of the circuit may be necessary to protect the conductors from some fault conditions.

Statement of Problem and Substantiation for Public Input

There are two changes in this PI.
The first change corrects an inaccurate unit conversion between SI and imperial. In compliance with 90.9(D) this new proposed value is a more accurate approximation.

The second change addresses an issue where this Code allows conductors to be interconnected on the supply side of services through the use of cable limiters on the utility end of the conductors. While this requirement is not intended to negate other requirements applying to cable limiters, there have been reports from the field that this would not require that cable limiters be located elsewhere in these circuits. Since the use of three or more conductors in parallel will likely require the use of cable limiters at both ends of the conductors, this information note is being suggested to clarify that other factors may impact where and how cable limiters are used.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each

member is at their discretion to individually comment on PI's as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI's submitted.
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Submitter Information Verification

Submitter Full Name: Evelyn Butler
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Submittal Date: Wed Sep 09 13:52:10 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9380-NFPA 70-2021

Statement: The title of Section 705.11 is changed to clarify that it refers to any connection to a service. The initial paragraph introducing Section 705.11 adds the phrase, "connection is permitted to a service as permitted in 230.2(A)(5)" to clarify that a supply-side source connection is an additional service.

Section 705.11(A) is moved to 705.11(A)(1) and modified for clarity.

The revision to 705.11(B) becomes (A) and covers the maximum size of power sources based on service conductor size. It also specifically addresses the conductors from the point of connection to service conductors to the power source disconnecting means. The conductor requirements for power source output conductors are organized into a list to better comply with the NEC Style Manual.

Section 705.11(B) moves the section that used to be 705.11(D) Connections to (B) and splits the requirements into a list to better comply with the style manual. The reference to Section 110.14 is removed as unnecessary and the references to Sections 230.33 and 230.46 are added to clarify how splices and taps are made.

The new section 705.11(C) is added for the power source disconnecting means. The new

section provides proper reference to the location sections of Article 230. It also clarifies that additional disconnecting means are permitted by Section 230.40 Exception 5.

The new section 705.11(D) is added for bonding and grounding. This language uses the balloted First Draft language of Section 705.11 of the 2020 NEC as it clearly addresses how metal parts are to be bonded and grounded.

The revision to the overcurrent protection section of 705.11 changes the first sentence to call out the exact run of conductors addressed in this section. The reference is changed from 705.30 to Part VII of Article 230. Since 230.95 is in Part VII, the ground-fault protection requirements are clarified as to what equipment requires ground-fault protection. This eliminates the need for a separate section on ground-fault protection so Section 705.11(E) is deleted.

A related FR to 705.32 clarifies that power sources are permitted to be connected to the load side in this instance as there is no other way to make this connection. Listings of this type of ground-fault protection equipment are certified for power flows in either direction.

Public Input No. 4515-NFPA 70-2020 [New Section after 705.11(D)]

(D) Bonding and Grounding.

All metal enclosures, metal wiring methods, and metal parts associated with the power source output conductors in 705.11(B) shall be bonded in accordance with 250.92(B). The grounding terminal or bus for the disconnecting means in 705.11(F) shall be connected to a supply side bonding jumper, sized in accordance with 250.102, based on the size of the conductors in 705.11(B). The supply side bonding jumper shall be connected to the grounded service conductor within or on the supply side of the service disconnecting means. If the power production equipment requires a grounded conductor, no connection shall be made between the supply side bonding jumper and the grounded conductor at the disconnecting means in 705.11(F).

Statement of Problem and Substantiation for Public Input

This language was approved 17-1 by CMP4 in the 2020 NEC. The requirements in this section are consistent with the requirements of 250.35(B) for non-separately derived generators. Any source on the supply side of the service disconnecting means must not be separately derived since it is physically impossible to be separately derived and also connected to the service conductors at the same time. This language was struck during the Annual meeting at nearly midnight without the benefit of proper review. CMP4 was obligated to reject the motion approved at the Annual meeting. This substantiation further clarifies why the language approved in the second draft was correct as it agrees with the language of 250.35(B). Since this section refers to 705.11(F), that section needs to be returned to the second draft language as well. The word “ahead” in the third sentence of the approved 2nd draft language is changed to “on the supply side” as the term ahead is not used elsewhere in 705.11.

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This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF’s effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI’s as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI’s submitted.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain, P.E., SEIA; Bill Brooks, PVICC; John Berdner, PVICC, Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing, Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower; Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid

; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

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Submittal Date: Thu Sep 10 14:33:06 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9380-NFPA 70-2021

Statement: The title of Section 705.11 is changed to clarify that it refers to any connection to a service. The initial paragraph introducing Section 705.11 adds the phrase, “connection is permitted to a service as permitted in 230.2(A)(5)” to clarify that a supply-side source connection is an additional service.

Section 705.11(A) is moved to 705.11(A)(1) and modified for clarity.

The revision to 705.11(B) becomes (A) and covers the maximum size of power sources based on service conductor size. It also specifically addresses the conductors from the point of connection to service conductors to the power source disconnecting means. The conductor requirements for power source output conductors are organized into a list to better comply with the NEC Style Manual.

Section 705.11(B) moves the section that used to be 705.11(D) Connections to (B) and splits the requirements into a list to better comply with the style manual. The reference to Section 110.14 is removed as unnecessary and the references to Sections 230.33 and 230.46 are added to clarify how splices and taps are made.

The new section 705.11(C) is added for the power source disconnecting means. The new section provides proper reference to the location sections of Article 230. It also clarifies that additional disconnecting means are permitted by Section 230.40 Exception 5.

The new section 705.11(D) is added for bonding and grounding. This language uses the balloted First Draft language of Section 705.11 of the 2020 NEC as it clearly addresses how metal parts are to be bonded and grounded.

The revision to the overcurrent protection section of 705.11 changes the first sentence to call out the exact run of conductors addressed in this section. The reference is changed from 705.30 to Part VII of Article 230. Since 230.95 is in Part VII, the ground-fault protection requirements are clarified as to what equipment requires ground-fault protection. This eliminates the need for a separate section on ground-fault protection so Section 705.11(E) is deleted.

A related FR to 705.32 clarifies that power sources are permitted to be connected to the

load side in this instance as there is no other way to make this connection. Listings of this type of ground-fault protection equipment are certified for power flows in either direction.

Public Input No. 2425-NFPA 70-2020 [Section No. 705.11(D)]

(D) Connections.

The connection of power source output circuit conductors to the service conductors shall be made using listed connectors as described in 110.14 and comply with all enclosure fill requirements. Any modifications to existing equipment shall be made in accordance with the manufacturer's instructions or the modification must be evaluated for the application and have a field label applied. For meter socket enclosures or other equipment under the exclusive control of the electric utility, only connections approved by the electric utility shall be permitted.

Statement of Problem and Substantiation for Public Input

sentence period missing between "requirements Any"

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Committee: NEC-P04

Committee Statement

Resolution: FR-9380-NFPA 70-2021

Statement: The title of Section 705.11 is changed to clarify that it refers to any connection to a service. The initial paragraph introducing Section 705.11 adds the phrase, "connection is permitted to a service as permitted in 230.2(A)(5)" to clarify that a supply-side source connection is an additional service.

Section 705.11(A) is moved to 705.11(A)(1) and modified for clarity.

The revision to 705.11(B) becomes (A) and covers the maximum size of power sources based on service conductor size. It also specifically addresses the conductors from the point of connection to service conductors to the power source disconnecting means. The conductor requirements for power source output conductors are organized into a list to better comply with the NEC Style Manual.

Section 705.11(B) moves the section that used to be 705.11(D) Connections to (B) and splits the requirements into a list to better comply with the style manual. The reference to Section 110.14 is removed as unnecessary and the references to Sections 230.33 and 230.46 are added to clarify how splices and taps are made.

The new section 705.11(C) is added for the power source disconnecting means. The new section provides proper reference to the location sections of Article 230. It also clarifies that additional disconnecting means are permitted by Section 230.40 Exception 5.

The new section 705.11(D) is added for bonding and grounding. This language uses the

balloted First Draft language of Section 705.11 of the 2020 NEC as it clearly addresses how metal parts are to be bonded and grounded.

The revision to the overcurrent protection section of 705.11 changes the first sentence to call out the exact run of conductors addressed in this section. The reference is changed from 705.30 to Part VII of Article 230. Since 230.95 is in Part VII, the ground-fault protection requirements are clarified as to what equipment requires ground-fault protection. This eliminates the need for a separate section on ground-fault protection so Section 705.11(E) is deleted.

A related FR to 705.32 clarifies that power sources are permitted to be connected to the load side in this instance as there is no other way to make this connection. Listings of this type of ground-fault protection equipment are certified for power flows in either direction.

Public Input No. 4050-NFPA 70-2020 [New Section after 705.11(E)]

TITLE OF NEW CONTENT

Type your content here ...

705.11 Supply-Side Source Connections. An electric power production source , where connected on the supply side of the service disconnecting means as permitted in 230.82(6), shall comply with 705.11(A) through ~~(E)~~ (F).

(F) Grounding and Bonding . Power source output equipment grounding circuits and neutral circuits (if any) shall comply with the following.

(1) The power source output equipment grounding conductor or raceway shall be connected to the equipment grounding system in the service equipment.

(2) The power source neutral shall not be bonded to the equipment grounding system in any required power source disconnecting or metering equipment .

(3) The power source neutral shall be connected to the service neutral.

Statement of Problem and Substantiation for Public Input

Since power source output circuits cannot be defined as services and the Code does not specifically address how grounding and bonding should be addressed for these circuits, electricians, PV installers, and AHJs develop differing opinions on the requirements. Some of these opinions may lead to installations that may violate other NEC requirements and create safety issues such as unwanted neutral currents in the equipment grounding circuits.

The proposed language maintains the safety of the equipment grounding system. It also establishes that there should be no connection between the power source neutral and ground outside the service equipment where the main bonding jumper is located. This will eliminate the potential for unwanted neutral currents in the equipment grounding system.

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Submittal Date:	Wed Sep 09 19:09:08 EDT 2020
Committee:	NEC-P04

Committee Statement

Resolution: FR-9380-NFPA 70-2021

Statement: The title of Section 705.11 is changed to clarify that it refers to any connection to a service. The initial paragraph introducing Section 705.11 adds the phrase, “connection is permitted to a service as permitted in 230.2(A)(5)” to clarify that a supply-side source connection is an additional service.

Section 705.11(A) is moved to 705.11(A)(1) and modified for clarity.

The revision to 705.11(B) becomes (A) and covers the maximum size of power sources based on service conductor size. It also specifically addresses the conductors from the point of connection to service conductors to the power source disconnecting means. The conductor requirements for power source output conductors are organized into a list to better comply with the NEC Style Manual.

Section 705.11(B) moves the section that used to be 705.11(D) Connections to (B) and splits the requirements into a list to better comply with the style manual. The reference to Section 110.14 is removed as unnecessary and the references to Sections 230.33 and 230.46 are added to clarify how splices and taps are made.

The new section 705.11(C) is added for the power source disconnecting means. The new section provides proper reference to the location sections of Article 230. It also clarifies that additional disconnecting means are permitted by Section 230.40 Exception 5.

The new section 705.11(D) is added for bonding and grounding. This language uses the balloted First Draft language of Section 705.11 of the 2020 NEC as it clearly addresses how metal parts are to be bonded and grounded.

The revision to the overcurrent protection section of 705.11 changes the first sentence to call out the exact run of conductors addressed in this section. The reference is changed from 705.30 to Part VII of Article 230. Since 230.95 is in Part VII, the ground-fault protection requirements are clarified as to what equipment requires ground-fault protection. This eliminates the need for a separate section on ground-fault protection so Section 705.11(E) is deleted.

A related FR to 705.32 clarifies that power sources are permitted to be connected to the load side in this instance as there is no other way to make this connection. Listings of this type of ground-fault protection equipment are certified for power flows in either direction.

Public Input No. 4093-NFPA 70-2020 [Section No. 705.11(E)]

(E) Ground-Fault Protection.

~~For~~ ~~connections rated 1000 amperes or more to~~ Where power source connections rated at 1000 amperes or more are connected to solidly grounded wye ~~-~~ services exceeding 150 volts to ground but not exceeding 1000 volts, phase-to-phase, ground ~~-~~ fault ~~protection meeting the~~ protection on the power source circuits meeting the requirements of 230.95 shall be provided.

Statement of Problem and Substantiation for Public Input

As written, this section in the 2020 NEC does not clearly state that the ground fault protection is to be installed on the power source output circuit and not on the service conductors. The section should clearly state that the conductors that are to be protected from high ground faults originating from the utility service are the power source output conductors and other equipment connected to those circuits. The reference to Section 230.95 may cause confusion that could result in a second, unneeded installation of GFP equipment on the service conductors.

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Committee:	NEC-P04

Committee Statement

Resolution: FR-9380-NFPA 70-2021

Statement: The title of Section 705.11 is changed to clarify that it refers to any connection to a service. The initial paragraph introducing Section 705.11 adds the phrase, “connection is permitted to a service as permitted in 230.2(A)(5)” to clarify that a supply-side source connection is an additional service.

Section 705.11(A) is moved to 705.11(A)(1) and modified for clarity.

The revision to 705.11(B) becomes (A) and covers the maximum size of power sources based on service conductor size. It also specifically addresses the conductors from the point of connection to service conductors to the power source disconnecting means. The conductor requirements for power source output conductors are organized into a list to better comply with the NEC Style Manual.

Section 705.11(B) moves the section that used to be 705.11(D) Connections to (B) and splits the requirements into a list to better comply with the style manual. The reference to Section 110.14 is removed as unnecessary and the references to Sections 230.33 and 230.46 are added to clarify how splices and taps are made.

The new section 705.11(C) is added for the power source disconnecting means. The new section provides proper reference to the location sections of Article 230. It also clarifies that additional disconnecting means are permitted by Section 230.40 Exception 5.

The new section 705.11(D) is added for bonding and grounding. This language uses the balloted First Draft language of Section 705.11 of the 2020 NEC as it clearly addresses how metal parts are to be bonded and grounded.

The revision to the overcurrent protection section of 705.11 changes the first sentence to call out the exact run of conductors addressed in this section. The reference is changed from 705.30 to Part VII of Article 230. Since 230.95 is in Part VII, the ground-fault protection requirements are clarified as to what equipment requires ground-fault protection. This eliminates the need for a separate section on ground-fault protection so Section 705.11(E) is deleted.

A related FR to 705.32 clarifies that power sources are permitted to be connected to the load side in this instance as there is no other way to make this connection. Listings of this type of ground-fault protection equipment are certified for power flows in either direction.

Public Input No. 2307-NFPA 70-2020 [Section No. 705.11 [Excluding any Sub-Sections]]

An electric power production source, where connected on the supply side ~~of the service disconnecting means as permitted in~~ shall be connected through a service disconnect installed in accordance with 230.82(6) ~~,~~ and shall comply with 705.11(A) through (E).

Statement of Problem and Substantiation for Public Input

Section 705.11 deals with interconnection of solar photovoltaic systems, fuel cell systems, wind electric systems, energy storage systems, or interconnected electric power production sources connected on the supply side of the service. Because of the change in the definition of Service in the 2020 NEC and the proposed change in 230.82 (6), this item is to be revised. As discussed during the Electrical Section Meeting and the resultant Annual Meeting Floor action on this section, these alternate energy systems should be connected through a service disconnect meeting all of the requirements in Article 230 which would include the requirements in Part IV of Article 230 specifically for a service disconnect. This action would significantly reduce the confusion in the industry about how these systems should be interconnected with the electric utility.

Submitter Information Verification

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Submittal Date:	Fri Aug 14 10:29:43 EDT 2020
Committee:	NEC-P04

Committee Statement

Resolution: FR-9380-NFPA 70-2021

Statement: The title of Section 705.11 is changed to clarify that it refers to any connection to a service. The initial paragraph introducing Section 705.11 adds the phrase, “connection is permitted to a service as permitted in 230.2(A)(5)” to clarify that a supply-side source connection is an additional service.

Section 705.11(A) is moved to 705.11(A)(1) and modified for clarity.

The revision to 705.11(B) becomes (A) and covers the maximum size of power sources based on service conductor size. It also specifically addresses the conductors from the point of connection to service conductors to the power source disconnecting means. The conductor requirements for power source output conductors are organized into a list to better comply with the NEC Style Manual.

Section 705.11(B) moves the section that used to be 705.11(D) Connections to (B) and splits the requirements into a list to better comply with the style manual. The reference to

Section 110.14 is removed as unnecessary and the references to Sections 230.33 and 230.46 are added to clarify how splices and taps are made.

The new section 705.11(C) is added for the power source disconnecting means. The new section provides proper reference to the location sections of Article 230. It also clarifies that additional disconnecting means are permitted by Section 230.40 Exception 5.

The new section 705.11(D) is added for bonding and grounding. This language uses the balloted First Draft language of Section 705.11 of the 2020 NEC as it clearly addresses how metal parts are to be bonded and grounded.

The revision to the overcurrent protection section of 705.11 changes the first sentence to call out the exact run of conductors addressed in this section. The reference is changed from 705.30 to Part VII of Article 230. Since 230.95 is in Part VII, the ground-fault protection requirements are clarified as to what equipment requires ground-fault protection. This eliminates the need for a separate section on ground-fault protection so Section 705.11(E) is deleted.

A related FR to 705.32 clarifies that power sources are permitted to be connected to the load side in this instance as there is no other way to make this connection. Listings of this type of ground-fault protection equipment are certified for power flows in either direction.

Public Input No. 3951-NFPA 70-2020 [Section No. 705.12]

705.12 Load-Side Source Connections.

The output of an interconnected electric power source shall be permitted to be connected to the load side of the service disconnecting means of the other source(s) at any distribution equipment on the premises. Where distribution equipment or feeders are fed simultaneously by a primary source of electricity and one or more other power source and are capable of supplying multiple branch circuits or feeders, or both, the interconnecting equipment shall comply with 705.12(A) through (E). Where a power control system (PCS) is installed in accordance with 705.13, the setting of the PCS controller shall be considered the power-source output circuit current in 705.12(A) through (E).

(A) Dedicated Overcurrent and Disconnect.

Each source interconnection of one or more power sources installed in one system shall be made at a dedicated circuit breaker or fusible disconnecting means.

(B) Bus or Conductor Ampere Rating.

The power source output circuit current multiplied by 125 percent shall be used in ampacity calculations for 705.12(B)(1) through (B)(3).

(1) Feeders.

Where the power source output connection is made to a feeder, the feeder shall have an ampacity greater than or equal to 125 percent of the power-source output circuit current. Where the power-source output connection is made to a feeder at a location other than the opposite end of the feeder from the primary source overcurrent device, that portion of the feeder on the load side of the power source output connection shall be protected by one of the following:

(1) The feeder ampacity shall be not less than the sum of the primary source overcurrent device and 125 percent of the power-source output circuit current.

(2) An overcurrent device at the load side of the power source connection point shall be rated not greater than the ampacity of the feeder.

(2) Taps.

Where power source output connections are made at feeders, all taps shall be sized based on the sum of 125 percent of all power source(s) output circuit current(s) and the rating of the overcurrent device protecting the feeder conductors for sizing tap conductors using the calculations in 240.21(B).

(3) Busbars.

One of the following methods shall be used to determine the ratings of busbars:

(1) The sum of 125 percent of the power source(s) output circuit current and the rating of the overcurrent device protecting the busbar shall not exceed the ampacity of the busbar.

Informational Note: This general rule assumes no limitation in the number of the loads or sources applied to busbars or their locations.

(2) Where two sources, one a primary power source and the other another power source, are located at opposite ends of a busbar that contains loads, the sum of 125 percent of the power-source(s) output circuit current and the rating of the overcurrent device protecting the busbar shall not exceed 120 percent of the ampacity of the busbar. The busbar shall be sized for the loads connected in accordance with Article 220. A permanent warning label shall be applied to the distribution equipment adjacent to the back-fed breaker from the power source that displays the following or equivalent wording:

WARNING:

POWER SOURCE OUTPUT CONNECTION—

DO NOT RELOCATE THIS OVERCURRENT DEVICE.

The warning sign(s) or label(s) shall comply with 110.21(B).

(3) The sum of the ampere ratings of all overcurrent devices on panelboards, both load and supply devices, excluding the rating of the overcurrent device protecting the busbar, shall not exceed the ampacity of the busbar. The rating of the overcurrent device protecting the busbar shall not exceed the rating of the busbar. Permanent warning labels shall be applied to distribution equipment displaying the following or equivalent wording:

WARNING:

THIS EQUIPMENT FED BY MULTIPLE SOURCES.

TOTAL RATING OF ALL OVERCURRENT DEVICES

EXCLUDING MAIN SUPPLY OVERCURRENT DEVICE

SHALL NOT EXCEED AMPACITY OF BUSBAR.

The warning sign(s) or label(s) shall comply with 110.21(B).

(4) A connection at either end of a center-fed panelboard in dwellings shall be permitted where the sum of 125 percent of the power-source(s) output circuit current and the rating of the overcurrent device protecting the busbar does not exceed 120 percent of the current rating of the busbar.

(5) Connections shall be permitted on switchgear, switchboards, and panelboards in configurations other than those permitted in 705.12(B)(3)(1) through (B)(3)(4) where designed under engineering supervision that includes available fault-current and busbar load calculations.

(6) Connections shall be permitted on busbars of panelboards that supply lugs connected to feed-through conductors. The feed-through conductors shall be sized in accordance with 705.12(B)(1). Where an overcurrent device is installed at the supply end of the feed-through conductors, the busbar in the supplying panelboard shall be permitted to be sized in accordance with 705.12(B)(3)(1) through 705.12(B)(3)(3).

705.30 (~~C~~ E) Marking.

Equipment containing overcurrent devices in circuits supplying power to a busbar or conductor supplied from multiple sources shall be marked to indicate the presence of all sources.

705.30 (~~D~~ F) Suitable for Backfeed.

Fused disconnects, unless otherwise marked, shall be considered suitable for backfeed. Circuit breakers not marked “line” and “load” shall be considered suitable for backfeed. Circuit breakers marked “line” and “load” shall be considered suitable for backfeed or reverse current if specifically rated.

705.30 (~~E~~ G) Fastening.

Listed plug-in-type circuit breakers back-fed from electric power sources that are listed and identified as interactive shall be permitted to omit the additional fastener normally required by 408.36(D) for such applications.

Statement of Problem and Substantiation for Public Input

The requirements in subdivisions (C) through (E) are general requirements to all interconnections, not just load side. These are moved to new subdivisions within section 705.30 as they apply to the overcurrent protection device installation so that is a more suitable location.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.

Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI's submitted.
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Committee: NEC-P04

Committee Statement

Resolution: FR-9389-NFPA 70-2021

Statement: This revision edits the opening paragraph for clarity. Unnecessary language was deleted from the second sentence for simplicity. A third sentence is added to clarify the currents referred to in this section which were formerly in Section 705.12(B). The sentence relating to Section 705.13 is clarified, and the last sentence is added due to moving Sections 705.12(B)(4) through (6) to the overcurrent section.

Section 705.12(A) is deleted as the requirements for disconnection are adequately covered in Section 705.20 and the overcurrent protection is adequately covered in Section 705.30. The heading of 705.12(B) is deleted in the simplification and reorganization of the overall section.

The title of Section 705.12(B)(1) is changed to 705.12(A) Feeders and Feeder Taps in the section reorganization and pulls Section 705.12(B)(2) into this section as it relates to feeder taps. The language is turned into a list to match the NEC Style Manual and the section related to feeder taps becomes Item 3 on the list. Minor editorial changes are made for clarification.

The revision to 705.12(B)(2) clarifies the only tap calculations impacted by the tap rules in Section 240.21(B) by focusing on Sections 240.21(B)(2) and (4) and specifically addressing that the minimum ampacity calculation in those sections should be increased based on the additional fault current available from the power source overcurrent devices.

The revision to 705.12(B)(3) becomes 705.12(B) and exempts specifically listed equipment from the requirements of 705.12(B)(3) as those issues are covered by the product listing and instructions. The informational note is added to help enforcement better differentiate this specific equipment from equipment with no specific listing for the purpose of interconnecting sources. Minor editorial changes are made for clarity. Unnecessary words are eliminated from two marking requirements.

Former Section 705.12(B)(3)(5) is moved to (6) and edits the existing 705.12(B)(3)(6) for clarity since the overcurrent device could be on either end of the feed-through conductors and have the same result for how the busbars are treated. This added language helps to clarify that as long as an overcurrent device is on either end of feed-through conductors, such as conductors terminating at a main breaker in a subpanel, the busbar rules apply.

The reorganization of Section 705.12 is completed by deleting the three items formerly 705.12(C), (D), and (E) and inserting them into Section 705.30. The language in marking is simplified in the new 705.30(C) for clarity.

Public Input No. 3932-NFPA 70-2020 [Section No. 705.12(A)]

~~**(A)** Dedicated Overcurrent and Disconnect.~~

~~Each source interconnection of one or more power sources installed in one system shall be made at a dedicated circuit breaker or fusible disconnecting means.~~

Statement of Problem and Substantiation for Public Input

The language in this section is not needed since disconnection and overcurrent protection requirements are adequately covered within 705.20 and 705.30.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI's submitted.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain, P.E., SEIA; Bill Brooks, PVICC; John Berdner, PVICC, Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing, Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower; Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Ben Chamberlain, Olivewood Energy; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

Submitter Information Verification

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Submittal Date: Wed Sep 09 15:46:23 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9389-NFPA 70-2021

Statement: This revision edits the opening paragraph for clarity. Unnecessary language was deleted from the second sentence for simplicity. A third sentence is added to clarify the currents referred to in this section which were formerly in Section 705.12(B). The sentence relating to Section 705.13 is clarified, and the last sentence is added due to moving Sections 705.12(B)(4) through (6) to the overcurrent section.

Section 705.12(A) is deleted as the requirements for disconnection are adequately covered in Section 705.20 and the overcurrent protection is adequately covered in Section 705.30. The heading of 705.12(B) is deleted in the simplification and reorganization of the overall section.

The title of Section 705.12(B)(1) is changed to 705.12(A) Feeders and Feeder Taps in the section reorganization and pulls Section 705.12(B)(2) into this section as it relates to feeder taps. The language is turned into a list to match the NEC Style Manual and the section related to feeder taps becomes Item 3 on the list. Minor editorial changes are made for clarification.

The revision to 705.12(B)(2) clarifies the only tap calculations impacted by the tap rules in Section 240.21(B) by focusing on Sections 240.21(B)(2) and (4) and specifically addressing that the minimum ampacity calculation in those sections should be increased based on the additional fault current available from the power source overcurrent devices.

The revision to 705.12(B)(3) becomes 705.12(B) and exempts specifically listed equipment from the requirements of 705.12(B)(3) as those issues are covered by the product listing and instructions. The informational note is added to help enforcement better differentiate this specific equipment from equipment with no specific listing for the purpose of interconnecting sources. Minor editorial changes are made for clarity. Unnecessary words are eliminated from two marking requirements.

Former Section 705.12(B)(3)(5) is moved to (6) and edits the existing 705.12(B)(3)(6) for clarity since the overcurrent device could be on either end of the feed-through conductors and have the same result for how the busbars are treated. This added language helps to clarify that as long as an overcurrent device is on either end of feed-through conductors, such as conductors terminating at a main breaker in a subpanel, the busbar rules apply.

The reorganization of Section 705.12 is completed by deleting the three items formerly 705.12(C), (D), and (E) and inserting them into Section 705.30. The language in marking is simplified in the new 705.30(C) for clarity.

Public Input No. 2245-NFPA 70-2020 [Section No. 705.12(B)(2)]

(2) Taps.

Where power source output connections are made at feeders, ~~all taps~~ tap conductors in accordance with 240.21(B)(1) and (5) shall be sized based on the of 125 percent of all power source(s) output circuit current(s). Tap conductors in accordance with 240.21(B)(2) and (4) shall be sized based on the sum ~~of~~ of the of 125 percent of all power source(s) output circuit current(s) ~~and~~ and the rating of the overcurrent device protecting the feeder conductors ~~for sizing tap conductors using the calculations in 240~~ . ~~21(B).~~

Statement of Problem and Substantiation for Public Input

Article 705.12(B)(2) modifies all of the tap sizing rules in 240.21(B) by requiring the sum of the OCPD protecting the feeder and 125% of power source output circuit to be used for sizing all tap conductors under all installation conditions. As currently written in the 2020 NEC, the tap conductors installed under provisions 240.21(B)(1) and (5) would actually have to be larger than the actual feeder conductors under the modified requirements in 705.12(B)(2). Applying 705.12(B)(2) to 240.21(B)(1) in the 2020 NEC would not a allow a tap conductor less than 10 feet to be sized to the provisions in (1)(a) or (b) and would require a tap conductor for the connection of a 32A inverter to a 200A feeder to be sized for 240A. This would require a 250 kcmil copper tap conductor connection to a 3/0 AWG copper feeder conductor.

The modification to 705.12(B)(2) would allow tap conductors less than 10 feet in length or outside taps to be sized to just 125% of the power source output rating. Taps that are over 10 feet but up to 25 feet, and taps over 25 feet and up to 100A would still be calculated based of the sum of the feeder OCPD and 125% rating of the power source output circuit.

Submitter Information Verification

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Submittal Date: Wed Aug 12 12:12:04 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9389-NFPA 70-2021

Statement: This revision edits the opening paragraph for clarity. Unnecessary language was deleted from the second sentence for simplicity. A third sentence is added to clarify the currents referred to in this section which were formerly in Section 705.12(B). The sentence relating to Section 705.13 is clarified, and the last sentence is added due to moving Sections 705.12(B)(4) through (6) to the overcurrent section.

Section 705.12(A) is deleted as the requirements for disconnection are adequately covered in Section 705.20 and the overcurrent protection is adequately covered in Section 705.30. The heading of 705.12(B) is deleted in the simplification and reorganization of the overall section.

The title of Section 705.12(B)(1) is changed to 705.12(A) Feeders and Feeder Taps in the section reorganization and pulls Section 705.12(B)(2) into this section as it relates to feeder taps. The language is turned into a list to match the NEC Style Manual and the section related to feeder taps becomes Item 3 on the list. Minor editorial changes are made for clarification.

The revision to 705.12(B)(2) clarifies the only tap calculations impacted by the tap rules in Section 240.21(B) by focusing on Sections 240.21(B)(2) and (4) and specifically addressing that the minimum ampacity calculation in those sections should be increased based on the additional fault current available from the power source overcurrent devices.

The revision to 705.12(B)(3) becomes 705.12(B) and exempts specifically listed equipment from the requirements of 705.12(B)(3) as those issues are covered by the product listing and instructions. The informational note is added to help enforcement better differentiate this specific equipment from equipment with no specific listing for the purpose of interconnecting sources. Minor editorial changes are made for clarity. Unnecessary words are eliminated from two marking requirements.

Former Section 705.12(B)(3)(5) is moved to (6) and edits the existing 705.12(B)(3)(6) for clarity since the overcurrent device could be on either end of the feed-through conductors and have the same result for how the busbars are treated. This added language helps to clarify that as long as an overcurrent device is on either end of feed-through conductors, such as conductors terminating at a main breaker in a subpanel, the busbar rules apply.

The reorganization of Section 705.12 is completed by deleting the three items formerly 705.12(C), (D), and (E) and inserting them into Section 705.30. The language in marking is simplified in the new 705.30(C) for clarity.

Public Input No. 3293-NFPA 70-2020 [Section No. 705.12(B)(2)]

(2) Taps.

Where power source output connections are made at feeders, all taps shall be sized based on the ~~sum of~~ larger of 125 percent of all power source(s) output circuit current(s) ~~and the rating of the overcurrent device protecting the feeder conductors for sizing tap conductors using the calculations in~~ or as calculated in accordance with 240.21(B).

Statement of Problem and Substantiation for Public Input

The proposed change would simply require tap conductors to have an ampacity per the larger of the power production source's output current (multiplied by 125%) OR the minimum required ampacity for feeder taps found in NEC 240.21(B). This is not any different than the requirements currently found in the Section 705.28(B) of the 2020 NEC. Similar requirements can also be found in Section 705.65(C) of the 2017 NEC. The problem with the current wording of NEC 705.12(B)(2) (found in the 2020 NEC) is that strict reading of the section requires the tap conductors for power production output connections must be rated per the SUM of 125% the power production source (such as an inverter) output current AND the rating of the OCPD protecting the feeders being tapped. The current wording is problematic since it will essentially require that the tap conductors be larger than the feeder wires they are tapping onto. FOR EXAMPLE: A 3800W inverter with a rated output of 16A multiplied by 125% will require an OCPD of 20A. If making connection with taps onto existing feeder wires that are 3/0 copper (with the feeder wire OCPD rated 200A), the combined 20A of inverter output AND the 200A feeder OCPD requires the tap wires themselves to have an ampacity of not less than 220A. Such ampacity would require not smaller than 4/0 copper conductors for the tap wires (assuming temperatures of conductors and terminals at 75 degree C, per NEC Table 310.16). Since the "tap" conductors are now larger than the actual feeder wires being tapped onto, the "tap" wires no longer meet the definition of "tap conductor" per the definition found at the beginning of Article 240. Nor is there a definition of "taps" found in Article 705. Even if an AHJ would disregard any definition of taps currently found in the NEC and still try to enforce the current wording found in NEC 705.12(B)(2), there's still the issue with size and ratings of terminals that the "taps" would connect to. In the example given above, one could not simply install a 60A (or less) rated disconnect for the 20A fuses since the 60A disconnect does not have terminals large enough for the required 4/0 "tap" conductors. So, with the example system given, the installer would have to purchase a 200A rated disconnect (for the 20A fuses that act as the OCPD for the inverter). The 200A rated disconnect would have terminals large enough for the 4/0 "tap" wiring. This makes absolutely no sense at all and no solid justification has ever been given to justify the current wording in the NEC. In short, the wording found in 705.12(B)(2) of the 2020 NEC (and other similar wording found in past editions of the NEC) has caused much confusion and unnecessary over-rating of equipment and wiring. This submitter strongly encourages Panel 4 to update the current language of 705.12(B)(2) with requirements that are enforceable and make sense.

Submitter Information Verification

Submitter Full Name: Doug Smith
Organization: West Coast Code Consultants (WC3)
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Submittal Date: Mon Sep 07 15:33:53 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9389-NFPA 70-2021

Statement: This revision edits the opening paragraph for clarity. Unnecessary language was deleted from the second sentence for simplicity. A third sentence is added to clarify the currents referred to in this section which were formerly in Section 705.12(B). The sentence relating to Section 705.13 is clarified, and the last sentence is added due to moving Sections 705.12(B)(4) through (6) to the overcurrent section.

Section 705.12(A) is deleted as the requirements for disconnection are adequately covered in Section 705.20 and the overcurrent protection is adequately covered in Section 705.30. The heading of 705.12(B) is deleted in the simplification and reorganization of the overall section.

The title of Section 705.12(B)(1) is changed to 705.12(A) Feeders and Feeder Taps in the section reorganization and pulls Section 705.12(B)(2) into this section as it relates to feeder taps. The language is turned into a list to match the NEC Style Manual and the section related to feeder taps becomes Item 3 on the list. Minor editorial changes are made for clarification.

The revision to 705.12(B)(2) clarifies the only tap calculations impacted by the tap rules in Section 240.21(B) by focusing on Sections 240.21(B)(2) and (4) and specifically addressing that the minimum ampacity calculation in those sections should be increased based on the additional fault current available from the power source overcurrent devices.

The revision to 705.12(B)(3) becomes 705.12(B) and exempts specifically listed equipment from the requirements of 705.12(B)(3) as those issues are covered by the product listing and instructions. The informational note is added to help enforcement better differentiate this specific equipment from equipment with no specific listing for the purpose of interconnecting sources. Minor editorial changes are made for clarity. Unnecessary words are eliminated from two marking requirements.

Former Section 705.12(B)(3)(5) is moved to (6) and edits the existing 705.12(B)(3)(6) for clarity since the overcurrent device could be on either end of the feed-through conductors and have the same result for how the busbars are treated. This added language helps to clarify that as long as an overcurrent device is on either end of feed-through conductors, such as conductors terminating at a main breaker in a subpanel, the busbar rules apply.

The reorganization of Section 705.12 is completed by deleting the three items formerly 705.12(C), (D), and (E) and inserting them into Section 705.30. The language in marking is simplified in the new 705.30(C) for clarity.

Public Input No. 3834-NFPA 70-2020 [Section No. 705.12(B)(3)]

(3) Busbars.

One of the following methods shall be used to determine the ratings of busbars:

(1) The sum of 125 percent of the power source(s) output circuit current and the rating of the overcurrent device protecting the busbar shall not exceed the ampacity of the busbar.

Informational Note: This general rule assumes no limitation in the number of the loads or sources applied to busbars or their locations.

(2) Where two sources, one a primary power source and the other another power source, are located at opposite ends of a busbar that contains loads, the sum of 125 percent of the power-source(s) output circuit current and the rating of the overcurrent device protecting the busbar shall not exceed 120 percent of the ampacity of the busbar. The busbar shall be sized for the loads connected in accordance with Article 220. A permanent warning label shall be applied to the distribution equipment adjacent to the back-fed breaker from the power source that displays the following or equivalent wording:

WARNING:

POWER SOURCE OUTPUT

~~CONNECTION—~~

DO NOT RELOCATE THIS OVERCURRENT DEVICE.

The warning sign(s) or label(s) shall comply with 110.21(B).

(3) The sum of the ampere ratings of all overcurrent devices on panelboards, both load and supply devices, excluding the rating of the overcurrent device protecting the busbar, shall not exceed the ampacity of the busbar. The rating of the overcurrent device protecting the busbar shall not exceed the rating of the busbar. Permanent warning labels shall be applied to distribution equipment displaying the following or equivalent wording:

WARNING:

~~THIS~~

EQUIPMENT FED BY MULTIPLE SOURCES.

TOTAL RATING OF ALL OVERCURRENT DEVICES

EXCLUDING MAIN SUPPLY OVERCURRENT DEVICE

SHALL NOT EXCEED AMPACITY OF BUSBAR.

The warning sign(s) or label(s) shall comply with 110.21(B).

(4) A connection at either end of a center-fed panelboard in dwellings shall be permitted where the sum of 125 percent of the power-source(s) output circuit current and the rating of the overcurrent device protecting the busbar does not exceed 120 percent of the current rating of the busbar.

(5) Connections shall be permitted on switchgear, switchboards, and panelboards in configurations other than those permitted in 705.12(B)(3)(1) through (B)(3)(4) where designed under engineering supervision that includes available fault-current and busbar load calculations.

(6) Connections shall be permitted on busbars of panelboards that supply lugs connected to feed-through conductors. The feed-through conductors shall be sized in accordance with 705.12(B)(1). Where an overcurrent device is installed at the supply end of the feed-through conductors, the busbar in the supplying panelboard shall be permitted to be sized in accordance with 705.12(B)(3)(1) through 705.12(B)(3)(3).

Statement of Problem and Substantiation for Public Input

This change is intended to reduce the amount of text on this required label, without changing its meaning or effectiveness.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI's submitted.
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K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Ben Chamberlain, Olivewood Energy; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

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Committee: NEC-P04

Committee Statement

Resolution: FR-9389-NFPA 70-2021

Statement: This revision edits the opening paragraph for clarity. Unnecessary language was deleted from the second sentence for simplicity. A third sentence is added to clarify the currents referred to in this section which were formerly in Section 705.12(B). The sentence relating to Section 705.13 is clarified, and the last sentence is added due to moving Sections 705.12(B)(4) through (6) to the overcurrent section.

Section 705.12(A) is deleted as the requirements for disconnection are adequately covered in Section 705.20 and the overcurrent protection is adequately covered in Section 705.30. The heading of 705.12(B) is deleted in the simplification and reorganization of the overall section.

The title of Section 705.12(B)(1) is changed to 705.12(A) Feeders and Feeder Taps in the section reorganization and pulls Section 705.12(B)(2) into this section as it relates to feeder taps. The language is turned into a list to match the NEC Style Manual and the section related to feeder taps becomes Item 3 on the list. Minor editorial changes are made for clarification.

The revision to 705.12(B)(2) clarifies the only tap calculations impacted by the tap rules in Section 240.21(B) by focusing on Sections 240.21(B)(2) and (4) and specifically addressing that the minimum ampacity calculation in those sections should be increased based on the additional fault current available from the power source overcurrent devices.

The revision to 705.12(B)(3) becomes 705.12(B) and exempts specifically listed equipment from the requirements of 705.12(B)(3) as those issues are covered by the product listing and instructions. The informational note is added to help enforcement better differentiate this specific equipment from equipment with no specific listing for the purpose of interconnecting sources. Minor editorial changes are made for clarity. Unnecessary words are eliminated from two marking requirements.

Former Section 705.12(B)(3)(5) is moved to (6) and edits the existing 705.12(B)(3)(6) for clarity since the overcurrent device could be on either end of the feed-through conductors and have the same result for how the busbars are treated. This added language helps to clarify that as long as an overcurrent device is on either end of feed-through conductors, such as conductors terminating at a main breaker in a subpanel, the busbar rules apply.

The reorganization of Section 705.12 is completed by deleting the three items formerly 705.12(C), (D), and (E) and inserting them into Section 705.30. The language in marking is simplified in the new 705.30(C) for clarity.

Public Input No. 4188-NFPA 70-2020 [Section No. 705.12(B)(3)]

(3) Busbars.

~~One~~ Choose only one of the following methods~~ shall be used to~~ , according to the designed power source applications, to determine the ratings of busbars:

(1) The sum of 125 percent of the power source(s), 2 or more including the primary power source, output circuit current and the rating of the overcurrent device protecting the busbar shall not exceed the ampacity of the ~~busbar.~~

~~Informational Note: This general rule assumes no limitation in the number of the loads or sources applied to busbars or their locations.~~

~~Where two sources~~

(2) busbar when no other overcurrent breakers are installed in the panelboard.

(3) Where three sources , one a primary power source and

~~the~~

- only two other

~~another~~

- power

~~source~~

- sources , are located at opposite ends of a busbar that contains loads, the sum of 125 percent of the power-source(s) output circuit current and the rating of the overcurrent device protecting the busbar shall not exceed 120 percent of the ampacity of the busbar. The busbar shall be sized for the loads connected in accordance with Article 220 . A permanent warning label shall be applied to the distribution equipment adjacent to the back-fed breaker from the power source that displays the following or equivalent wording:

WARNING:

POWER SOURCE OUTPUT CONNECTION—

DO NOT RELOCATE THIS OVERCURRENT DEVICE.

The warning sign(s) or label(s) shall comply with 110.21(B) .

~~The~~

-
- Where there are other overcurrent breakers are installed in the panelboard for the premisis wiring and there is a primary power source and two or more other power sources, the sum of the ampere ratings of all overcurrent devices on panelboards, both load and supply devices, excluding the rating of the overcurrent device protecting the busbar, shall not exceed the ampacity of the busbar. The rating of the overcurrent device protecting the busbar shall not exceed the rating of the busbar. Permanent warning labels shall be applied to distribution equipment displaying the following or equivalent wording:

  WARNING:

  THIS EQUIPMENT FED BY MULTIPLE SOURCES.

  TOTAL RATING OF ALL OVERCURRENT DEVICES

  EXCLUDING MAIN SUPPLY OVERCURRENT DEVICE

  SHALL NOT EXCEED AMPACITY OF BUSBAR.

  The warning sign(s) or label(s) shall comply with 110.21(B) .
- A connection at either end of a center-fed panelboard in dwellings shall be permitted where the sum of 125 percent of the power-source(s) output circuit current and the rating of the overcurrent device protecting the busbar does not exceed 120 percent of the current rating of the busbar.
- Connections shall be permitted on switchgear, switchboards, and panelboards in configurations other than those permitted in 705.12(B) (3)(1) through (B)(3)(4) where designed under engineering supervision
  ~~that~~
-
- , manufactures specifications and Listing and Labeling that includes available fault-current and busbar load calculations.
- Connections shall be permitted on busbars of panelboards that supply lugs connected to feed-through conductors. The feed-through conductors shall be sized in accordance with 705.12(B)(1) . Where an overcurrent device is installed at the supply end of the feed-through conductors, the busbar in the supplying panelboard shall be permitted to be sized in accordance with 705.12(B)(3) (1) through 705.12(B)(3) (3).

Statement of Problem and Substantiation for Public Input

The application must be specific to the concept and design. Code reference compliance should not be based on Random selection of moving variables. the design constitutes the Code application.

This information brings clarity to an AHJ for an installation.

Submitter Information Verification

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Submittal Date: Thu Sep 10 01:00:47 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: Each panelboard can be evaluated and approved based on one of these six options. This is not a random selection of moving variables. Each option represents a method to keep the installation from ever having an overcurrent condition. The additional language does not improve clarity and may unnecessarily limit some options that are intended to be permitted.

Public Input No. 4202-NFPA 70-2020 [Section No. 705.12(B)(3)]

(3) Busbars.

One of the following methods shall be used to determine the ratings of busbars:

(1) The sum of 125 percent of the power source(s) output circuit current and the rating of the overcurrent device protecting the busbar shall not exceed the ampacity of the busbar.

Informational Note: This general rule assumes no limitation in the number of the loads or sources applied to busbars or their locations.

(2) Where two sources, one a primary power source and the other another power source, are located at opposite ends of a busbar that contains loads, the sum of 125 percent of the power-source(s) output circuit current and the rating of the overcurrent device protecting the busbar shall not exceed 120 percent of the ampacity of the busbar. The busbar shall be sized for the loads connected in accordance with Article 220. A permanent warning label shall be applied to the distribution equipment adjacent to the back-fed breaker from the power source that displays the following or equivalent wording:

WARNING:

POWER SOURCE OUTPUT CONNECTION—

DO NOT RELOCATE THIS OVERCURRENT DEVICE.

The warning sign(s) or label(s) shall comply with 110.21(B).

(3) The sum of the ampere ratings of all overcurrent devices on panelboards, both load and supply devices, excluding the rating of the overcurrent device protecting the busbar, shall not exceed the ampacity of the busbar. The rating of the overcurrent device protecting the busbar shall not exceed the rating of the busbar. Permanent warning labels shall be applied to distribution equipment displaying the following or equivalent wording:

WARNING:

THIS EQUIPMENT FED BY MULTIPLE SOURCES.

TOTAL RATING OF ALL OVERCURRENT DEVICES

EXCLUDING MAIN SUPPLY OVERCURRENT DEVICE

SHALL NOT EXCEED AMPACITY OF BUSBAR.

The warning sign(s) or label(s) shall comply with 110.21(B).

(4) A connection at either end of a center-fed panelboard in dwellings shall be permitted where the sum of 125 percent of the power-source(s) output circuit current and the rating of the overcurrent device protecting the busbar does not exceed 120 percent of the current rating of the busbar.

(5) Connections shall be permitted on ~~switchgear, switchboards, and panelboards in configurations other than those permitted in 705.12(B) (3)(1) through (B)(3)(4) where designed under engineering supervision that includes available fault-current and busbar load calculations.Connections shall be permitted on~~

(6) busbars of panelboards that supply lugs connected to feed-through conductors , or are supplied by feed-through conductors . The feed-through conductors shall be sized in accordance with 705.12(B)(1) . Where an overcurrent device is installed at ~~the supply~~

(7) either end of the feed-through conductors, the ~~busbar in the supplying~~

(8) panelboard busbars shall be permitted to be sized in accordance with 705.12(B)(3) (1) through 705.12(B)(3) (3).

(9) Connections shall be permitted on switchgear, switchboards, and panelboards in configurations other than those permitted in 705.12(B) (3)(1) through (B)(3)(5) where designed under engineering supervision that includes available fault-current and busbar load calculations.

Additional Proposed Changes

File Name	Description	Approved
705.12-B-3_correct_text.pdf	Correct legislative text	

Statement of Problem and Substantiation for Public Input

When this new text was introduced into the 2020 NEC, it was written such that the power production source was assumed to be connected ahead of the initiation point of the feed-through conductors, and not interconnected at a subpanel after the termination point of the feed- through conductors. However this assumption was not clearly stated in the text nor was it made clear to enforcement or system designers. The revision to this section clarifies that the connection may made prior to the initiation or the at the termination point of the feed-through conductors without affecting the safety of the installation or conductor sizing provisions.
List items 5 and 6 are also flipped in order along with the reference added in old 6 to also include old 5, which was an oversight from the 2020 cycle that should have permitted engineering supervision for all the relevant options within the list of this section.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public

Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI's submitted.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain, P.E., SEIA; Bill Brooks, PVICC; John Berdner, PVICC, Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing, Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower; Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

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Submittal Date: Thu Sep 10 04:39:05 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9389-NFPA 70-2021

Statement: This revision edits the opening paragraph for clarity. Unnecessary language was deleted from the second sentence for simplicity. A third sentence is added to clarify the currents referred to in this section which were formerly in Section 705.12(B). The sentence relating to Section 705.13 is clarified, and the last sentence is added due to moving Sections 705.12(B)(4) through (6) to the overcurrent section.

Section 705.12(A) is deleted as the requirements for disconnection are adequately covered in Section 705.20 and the overcurrent protection is adequately covered in Section 705.30. The heading of 705.12(B) is deleted in the simplification and reorganization of the overall section.

The title of Section 705.12(B)(1) is changed to 705.12(A) Feeders and Feeder Taps in the section reorganization and pulls Section 705.12(B)(2) into this section as it relates to feeder taps. The language is turned into a list to match the NEC Style Manual and the section related to feeder taps becomes Item 3 on the list. Minor editorial changes are made for clarification.

The revision to 705.12(B)(2) clarifies the only tap calculations impacted by the tap rules in Section 240.21(B) by focusing on Sections 240.21(B)(2) and (4) and specifically addressing that the minimum ampacity calculation in those sections should be increased based on the additional fault current available from the power source overcurrent devices.

The revision to 705.12(B)(3) becomes 705.12(B) and exempts specifically listed equipment from the requirements of 705.12(B)(3) as those issues are covered by the product listing and instructions. The informational note is added to help enforcement better differentiate this specific equipment from equipment with no specific listing for the purpose of interconnecting sources. Minor editorial changes are made for clarity. Unnecessary words are eliminated from two marking requirements.

Former Section 705.12(B)(3)(5) is moved to (6) and edits the existing 705.12(B)(3)(6) for clarity since the overcurrent device could be on either end of the feed-through conductors and have the same result for how the busbars are treated. This added language helps to clarify that as long as an overcurrent device is on either end of feed-through conductors, such as conductors terminating at a main breaker in a subpanel, the busbar rules apply.

The reorganization of Section 705.12 is completed by deleting the three items formerly 705.12(C), (D), and (E) and inserting them into Section 705.30. The language in marking is simplified in the new 705.30(C) for clarity.

(~~6~~5) Connections shall be permitted on busbars of panelboards that supply lugs connected to feed-through conductors or are supplied by feed-through conductors. The feed-through conductors shall be sized in accordance with 705.12(B)(1). Where an overcurrent device is installed at either ~~the supply~~ end of the feed-through conductors, ~~the busbar in the supplying~~ panelboard busbars shall be permitted to be sized in accordance with 705.12(B)(3)(1) through 705.12(B)(3)(3).

(~~5~~6) Connections shall be permitted on switchgear, switchboards, and panelboards in configurations other than those permitted in 705.12(B)(3)(1) through (B)(3)(~~4~~5) where designed under engineering supervision that includes available fault-current and busbar load calculations.

Public Input No. 4689-NFPA 70-2020 [Section No. 705.12(B)(3)]

(3) Busbars.

One of the following methods shall be used to determine the ratings of busbars:

(1) The sum of 125 percent of the power source(s) output circuit current and the rating of the overcurrent device protecting the busbar shall not exceed the ampacity of the busbar.

Informational Note: This general rule assumes no limitation in the number of the loads or sources applied to busbars or their locations.

(2) Where two sources, one a primary power source and the other another power source, are located at opposite ends of a busbar that contains loads, the sum of 125 percent of the power-source(s) output circuit current and the rating of the overcurrent device protecting the busbar shall not exceed 120 percent of the ampacity of the busbar. The busbar shall be sized for the loads connected in accordance with Article 220. A permanent warning label shall be applied to the distribution equipment adjacent to the back-fed breaker from the power source that displays the following or equivalent wording:

WARNING:

POWER SOURCE OUTPUT CONNECTION—

DO NOT RELOCATE THIS OVERCURRENT DEVICE.

The warning sign(s) or label(s) shall comply with 110.21(B).

(3) The sum of the ampere ratings of all overcurrent devices on panelboards, both load and supply devices, excluding the rating of the overcurrent device protecting the busbar, shall not exceed the ampacity of the busbar. The rating of the overcurrent device protecting the busbar shall not exceed the rating of the busbar. Permanent warning labels shall be applied to distribution equipment displaying the following or equivalent wording:

WARNING:

THIS EQUIPMENT FED BY MULTIPLE SOURCES.

TOTAL RATING OF ALL OVERCURRENT DEVICES

EXCLUDING MAIN SUPPLY OVERCURRENT DEVICE

SHALL NOT EXCEED AMPACITY OF BUSBAR.

The warning sign(s) or label(s) shall comply with 110.21(B).

(4) A connection at either end of a center-fed panelboard in dwellings shall be permitted where the sum of 125 percent of the power-source(s) output circuit current and the rating of the overcurrent device protecting the busbar does not exceed 120 percent of the current rating of the busbar.

(5) Connections shall be permitted on switchgear, switchboards, and panelboards in configurations other than those permitted in 705.12(B)(3)(1) through (B)(3)(4) where designed under engineering supervision that includes available fault-current and busbar load calculations.

(6) Connections shall be permitted on busbars of panelboards that supply lugs connected to feed-through conductors. The feed-through conductors shall be sized in accordance with 705.12(B)(1). Where an overcurrent device is installed at the supply end of the feed-through conductors, the busbar in the supplying panelboard shall be permitted to be sized in accordance with 705.12(B)(3)(1) through 705.12(B)(3)(3).

(7) Where all power production sources for a premises are connected on the load side of feed-through conductors, the busbar in the supplying panelboard shall be permitted to be sized not less than the sum of all power production overcurrent device ratings plus the sum of all load overcurrent devices located in the supply panelboard, excluding the rating of the overcurrent device protecting the busbar and, if present, the rating of the overcurrent device protecting the feed-through conductors. The feed-through conductors shall be sized in accordance with 705.12(B)(1). Permanent warning labels shall be applied to distribution equipment displaying the following or equivalent wording: WARNING: THIS EQUIPMENT FED BY MULTIPLE SOURCES. TOTAL RATING OF ALL OVERCURRENT DEVICES EXCLUDING MAIN SUPPLY OVERCURRENT DEVICE SHALL NOT EXCEED AMPACITY OF BUSBAR. The warning sign(s) or label(s) shall comply with 110.21(B).

Statement of Problem and Substantiation for Public Input

Many residential dwellings use a meter combination panel which includes a meter, service disconnect, small distribution busbar, and feed through lugs. The feed through lugs often feed both loads and power production sources in one or multiple downstream subpanels. When applying 705.12 (B)(3)(3) to the main panel in this condition, it is unclear what value should be used for the feed through conductors because there may be no overcurrent device at either the supply or load end of the feed through conductors. Based on ambiguity, different interpretations arise. The language in (B)(3)(6) does not clarify this condition, as it points back to (B)(3)(3) to size the supplying busbar. The suggested addition clarifies exactly how to interpret this conduction. When all power production sources are backfeeding the supplying busbar through the feed through conductors, then any load overcurrent devices connected to the feed through conductors can be ignored in the sum of overcurrent device calculation.

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Submittal Date: Thu Sep 10 16:48:24 EDT 2020

Committee: NEC-P04

Committee Statement

Resolution: FR-9389-NFPA 70-2021

Statement: This revision edits the opening paragraph for clarity. Unnecessary language was deleted from the second sentence for simplicity. A third sentence is added to clarify the currents referred to in this section which were formerly in Section 705.12(B). The sentence relating to Section 705.13 is clarified, and the last sentence is added due to moving Sections 705.12(B)(4) through (6) to the overcurrent section.

Section 705.12(A) is deleted as the requirements for disconnection are adequately covered in Section 705.20 and the overcurrent protection is adequately covered in Section 705.30. The heading of 705.12(B) is deleted in the simplification and reorganization of the overall section.

The title of Section 705.12(B)(1) is changed to 705.12(A) Feeders and Feeder Taps in the section reorganization and pulls Section 705.12(B)(2) into this section as it relates to feeder taps. The language is turned into a list to match the NEC Style Manual and the section related to feeder taps becomes Item 3 on the list. Minor editorial changes are made for clarification.

The revision to 705.12(B)(2) clarifies the only tap calculations impacted by the tap rules in Section 240.21(B) by focusing on Sections 240.21(B)(2) and (4) and specifically addressing that the minimum ampacity calculation in those sections should be increased based on the additional fault current available from the power source overcurrent devices.

The revision to 705.12(B)(3) becomes 705.12(B) and exempts specifically listed equipment from the requirements of 705.12(B)(3) as those issues are covered by the product listing and instructions. The informational note is added to help enforcement better differentiate this specific equipment from equipment with no specific listing for the purpose of interconnecting sources. Minor editorial changes are made for clarity. Unnecessary words are eliminated from two marking requirements.

Former Section 705.12(B)(3)(5) is moved to (6) and edits the existing 705.12(B)(3)(6) for clarity since the overcurrent device could be on either end of the feed-through conductors and have the same result for how the busbars are treated. This added language helps to clarify that as long as an overcurrent device is on either end of feed-through conductors, such as conductors terminating at a main breaker in a subpanel, the busbar rules apply.

The reorganization of Section 705.12 is completed by deleting the three items formerly 705.12(C), (D), and (E) and inserting them into Section 705.30. The language in marking is simplified in the new 705.30(C) for clarity.

Public Input No. 92-NFPA 70-2019 [Section No. 705.12(B)(3)]

(3) Busbars.

One of the following methods shall be used to determine the ratings of busbars:

(1) The sum of 125 percent of the power source(s) output circuit current and the rating of the overcurrent device protecting the busbar shall not exceed the ampacity of the busbar.

Informational Note: This general rule assumes no limitation in the number of the loads or sources applied to busbars or their locations.

(2) Where two sources, one a primary power source and the other another power source, are located at opposite ends of a busbar that contains loads, the sum of 125 percent of the power-source(s) output circuit current and the rating of the overcurrent device protecting the busbar shall not exceed 120 percent of the ampacity of the busbar. The busbar shall be sized for the loads connected in accordance with Article 220. A permanent warning label shall be applied to the distribution equipment adjacent to the back-fed breaker from the power source that displays the following or equivalent wording:

WARNING:

POWER SOURCE OUTPUT CONNECTION—

DO NOT RELOCATE THIS OVERCURRENT DEVICE.

The warning sign(s) or label(s) shall comply with 110.21(B).

(3) The sum of the ampere ratings of all overcurrent devices on panelboards, both load and supply devices, excluding the rating of the overcurrent device protecting the busbar, and excluding one overcurrent device of the smallest size present, shall not exceed the ampacity of the busbar. The rating of the overcurrent device protecting the busbar shall not exceed the rating of the busbar. Permanent warning labels shall be applied to distribution equipment displaying the following or equivalent wording:

WARNING:

THIS EQUIPMENT FED BY MULTIPLE SOURCES.

TOTAL RATING OF ALL OVERCURRENT DEVICES

EXCLUDING MAIN SUPPLY OVERCURRENT DEVICE

AND EXCLUDING ONE OVERCURRENT DEVICE OF THE SMALLEST SIZE PRESENT

SHALL NOT EXCEED AMPACITY OF BUSBAR.

The warning sign(s) or label(s) shall comply with 110.21(B).

(4) A connection at either end of a center-fed panelboard in dwellings shall be permitted where the sum of 125 percent of the power-source(s) output circuit current and the rating of the overcurrent device protecting the busbar does not exceed 120 percent of the current rating of the busbar.

(5) Connections shall be permitted on switchgear, switchboards, and panelboards in configurations other than those permitted in 705.12(B)(3)(1) through (B)(3)(4) where designed under engineering supervision that includes available fault-current and busbar load calculations.

(6) Connections shall be permitted on busbars of panelboards that supply lugs connected to feed-through conductors. The feed-through conductors shall be sized in accordance with 705.12(B)(1). Where an overcurrent device is installed at the supply end of the feed-through conductors, the busbar in the supplying panelboard shall be permitted to be sized in accordance with 705.12(B)(3)(1) through 705.12(B)(3)(3).

Statement of Problem and Substantiation for Public Input

The current language is unnecessarily restrictive and the proposed limited expansion provides an additional allowance of practical use. For example, in a solar combiner panel, this change would allow the addition of a single extra breaker for the connection of solar monitoring equipment.

To start, consider an arrangement allowed by the current section: a panel with a 100A busbar, a 100A main breaker, and (5) 20A breakers. At any given time, each breaker may be a supply or a load, but not both. Physics requires that the sum of the load currents equals the sum of the supply currents; this sum is the busbar current. Then as long as each breaker's current does not exceed its rating, there is no way for the busbar current to exceed the busbar rating. The highest achievable bubar current would be 100A, for the case of a 100A supply and (5) 20A loads, or vice versa. A supply current exceeding 100A would require the 100A breaker and at least one 20A breaker to be supplies; but that leaves only (4) 20A breakers to be loads, meaning the bubar current would actually be limited to 80A.

This argument extends to the case of (6) 20A breakers in the panel, rather than (5), which is the point of my proposed change. There are only two ways to reach a supply current above 100A: (a) all (6) 20A breakers are supplies, or (b) the 100A breaker and one 20A breaker are supplies. In case (a), the load current is limited to 100A by the 100A breaker. In case (b), the load current is limited to 100A by the (5) 20A breakers. Thus in both cases the busbar current is limited to 100A, and the busbar is protected.

While this is just one example, it illustrates the general argument. Relative to the configurations currently allowed, adding one additional breaker, not larger than any of the other breakers, can not overload the bus, as that breaker can only be a supply or a load, not both. So with just one additional breaker, there is no avenue to also increase the complementary load or supply, respectively, that would be necessary to actually increase the busbar current.

Finally, for the case of a panel with just 3 breakers (including the main breaker), the proposed change brings this section in line with section 705.12(B)(1)(b) on feeders. Consider for example a 100A feeder supplied by a 100A breaker from the utility; having a 100A connection from a second power source in the middle of the feeder; and terminating on a 100A main breaker protecting a panelboard with loads. This arrangement is electrically equivalent to a 100A panelboard with (3) 100A breakers in it, with the busbar being the feeder. The current language of 705.12(B)(3)(3) prohibits the arrangement for a busbar, while the language of 705.12(B)(1)(b) allows the arrangement for a feeder. My proposed change eliminates

this logical inconsistency by allowing the arrangement for a busbar.

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Submittal Date: Mon Nov 11 12:16:48 EST 2019
Committee: NEC-P04

Committee Statement

Resolution: Adding additional features to this very simple rule creates unnecessary confusion for the enforcement and marking requirements.

Public Input No. 4201-NFPA 70-2020 [Section No. 705.12 [Excluding any Sub-Sections]]

The output of an interconnected electric power source shall be permitted to be connected to the load side of the service disconnecting means of the other source(s) at any distribution equipment on the premises. Where distribution equipment or feeders are fed simultaneously by a primary source of electricity and one or more other power source and are capable of supplying multiple branch circuits or feeders, or both, the interconnecting equipment shall comply with 705.12(A) through (E). Where a power control system (PCS) is installed in accordance with 705.13, the setting of the PCS controller shall be considered the power-source output circuit current in 705.12(A) through (E). Equipment listed for the purpose is permitted to be installed in accordance with its ratings and installation instructions.

Statement of Problem and Substantiation for Public Input

An allowance for equipment listed specifically for the purpose of interconnecting interactive power production equipment has been added to recognize that equipment may have ratings or other features that could differ from the general rules contained within this section.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI's submitted.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain, P.E., SEIA; Bill Brooks, PVICC; John Berdner, PVICC, Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing, Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower; Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

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Submittal Date: Thu Sep 10 04:36:09 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9389-NFPA 70-2021

Statement: This revision edits the opening paragraph for clarity. Unnecessary language was deleted from the second sentence for simplicity. A third sentence is added to clarify the currents referred to in this section which were formerly in Section 705.12(B). The sentence relating to Section 705.13 is clarified, and the last sentence is added due to moving Sections 705.12(B)(4) through (6) to the overcurrent section.

Section 705.12(A) is deleted as the requirements for disconnection are adequately covered in Section 705.20 and the overcurrent protection is adequately covered in Section 705.30. The heading of 705.12(B) is deleted in the simplification and reorganization of the overall section.

The title of Section 705.12(B)(1) is changed to 705.12(A) Feeders and Feeder Taps in the section reorganization and pulls Section 705.12(B)(2) into this section as it relates to feeder taps. The language is turned into a list to match the NEC Style Manual and the section related to feeder taps becomes Item 3 on the list. Minor editorial changes are made for clarification.

The revision to 705.12(B)(2) clarifies the only tap calculations impacted by the tap rules in Section 240.21(B) by focusing on Sections 240.21(B)(2) and (4) and specifically addressing that the minimum ampacity calculation in those sections should be increased based on the additional fault current available from the power source overcurrent devices.

The revision to 705.12(B)(3) becomes 705.12(B) and exempts specifically listed equipment from the requirements of 705.12(B)(3) as those issues are covered by the product listing and instructions. The informational note is added to help enforcement better differentiate this specific equipment from equipment with no specific listing for the purpose of interconnecting sources. Minor editorial changes are made for clarity. Unnecessary words are eliminated from two marking requirements.

Former Section 705.12(B)(3)(5) is moved to (6) and edits the existing 705.12(B)(3)(6) for clarity since the overcurrent device could be on either end of the feed-through conductors and have the same result for how the busbars are treated. This added language helps to clarify that as long as an overcurrent device is on either end of feed-through conductors, such as conductors terminating at a main breaker in a subpanel, the busbar rules apply.

The reorganization of Section 705.12 is completed by deleting the three items formerly 705.12(C), (D), and (E) and inserting them into Section 705.30. The language in marking is simplified in the new 705.30(C) for clarity.

Public Input No. 4108-NFPA 70-2020 [Section No. 705.13(E)]

(E) Access to Settings.

The access to settings of the PCS shall be restricted to qualified personnel in accordance ~~with the requirements of~~ with 240.6(C).

Statement of Problem and Substantiation for Public Input

Deleting the words "the requirements of" does not change the meaning of the section.

Submitter Information Verification

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Submittal Date: Wed Sep 09 21:02:30 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9391-NFPA 70-2021

Statement: Power control systems do not only control power sources, some also interface with energy management systems for load management. By recognizing this interface within the language in this section, it is made clearer that the compatibility of these two systems needs to be evaluated through the listing of the PCS, to ensure that functional safety is maintained throughout the operation of both systems. The word “ampere” was added to clarify which busbar rating is related to the control current of the PCS. Editorial change is made to Section 705.13(B) to refer to “ratings” of busbars and ampacity of conductors since busbars have ratings rather than ampacities. This revision deletes words in 705.13(E) which does not alter the meaning and is concise.

Public Input No. 3959-NFPA 70-2020 [Section No. 705.13 [Excluding any Sub-Sections]]

A power control system (PCS) shall be listed and evaluated to control the output of one or more power production sources, energy storage systems (ESS), energy management system, and other equipment. The PCS shall limit current and loading on the busbars and conductors supplied by the PCS.

For the circuits connected to a PCS, the PCS shall limit the current to the ampacity of the conductors or the ratings of the busbars to which it is connected in accordance with 705.13(A) through (E).

Statement of Problem and Substantiation for Public Input

Power control systems do not only control power sources, some also interface with energy management systems for load management. By recognizing this interface within the language in this section, it is made clearer that the compatibility of these two systems needs to be evaluated through the listing of the PCS, to ensure that functional safety is maintained throughout the operation of both systems.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI's submitted.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain, P.E., SEIA; Bill Brooks, PVICC; John Berdner, PVICC, Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing, Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower; Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Ben Chamberlain, Olivewood Energy; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar;

Jason Smolko, Copperweld;

Submitter Information Verification

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Submittal Date: Wed Sep 09 16:19:44 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9391-NFPA 70-2021

Statement: Power control systems do not only control power sources, some also interface with energy management systems for load management. By recognizing this interface within the language in this section, it is made clearer that the compatibility of these two systems needs to be evaluated through the listing of the PCS, to ensure that functional safety is maintained throughout the operation of both systems. The word “ampere” was added to clarify which busbar rating is related to the control current of the PCS. Editorial change is made to Section 705.13(B) to refer to “ratings” of busbars and ampacity of conductors since busbars have ratings rather than ampacities. This revision deletes words in 705.13(E) which does not alter the meaning and is concise.

Public Input No. 4046-NFPA 70-2020 [New Section after 705.14]

TITLE OF NEW CONTENT

705.15 Interconnection or Transfer Equipment.

705.15(A) General.

Interconnection or transfer equipment shall be listed, suitable for the intended use, and shall prevent the inadvertent interconnection of sources of supply not designed to operate in parallel with one another.

Exception: Temporary connection of a portable generator without transfer equipment shall be permitted where conditions of maintenance and supervision ensure that only qualified persons service the installation and where the normal supply is physically isolated by a lockable disconnecting means or by disconnection of the normal supply conductors.

705.15(B) Transfer Switches.

(1) Reconditioned. Transfer switches shall not be permitted to be reconditioned.

(2) Meter-Mounted Transfer Switches. Transfer switches installed between the utility meter and the meter enclosure shall be listed meter-mounted transfer switches.

Informational Note: For more information, see UL 1008M, *Transfer Switch Equipment, Meter Mounted* .

Statement of Problem and Substantiation for Public Input

The requirements in this new section of Article 705 are to parallel to the requirements in Article 702 for consistency. This section provides for the use of transfer equipment and interconnection equipment necessary to prevent the inadvertent interconnection of sources is a key safety factor when supplying loads during an interruption of the normal source. These functions are often found in multimode inverters or microgrid interconnect devices, but standard transfer switch may also be used to perform this function. Systems which meet the appropriate code requirements for paralleling of sources typically refer to the equipment which separates or isolates the connection to the normal source as interconnection equipment rather than transfer equipment. This change would make this section apply generally and maintain the safety requirement for inadvertent source interconnection.

The addition of 705.15(B) groups the existing requirements for transfer switches in Article 702 into the same section in Article 705 for ease of use.

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Committee: NEC-P04

Committee Statement

Resolution: FR-9374-NFPA 70-2021

Statement: The first sentence is deleted as this is already covered in Section 110.2. The section was reorganized for clarity. An informational note provides similar information as is found in Article 710 and points to the standard found in the annex that is used to evaluate interactive equipment.

Public Input No. 3850-NFPA 70-2020 [Section No. 705.14]

705.14 Output Characteristics.

The output of a power production source operating in parallel with an electrical supply system shall be compatible with the voltage, wave shape, and frequency of the system to which it is connected. ~~Synchronous~~ Each power source shall be marked with the rated output current and the nominal operating voltage at a readily visible location. Synchronous generators operating in parallel with an electrical supply system shall be provided with the necessary equipment to establish and maintain a synchronous condition.

~~Informational Note: The term *compatible* does not necessarily mean matching the primary source wave shape.~~

Statement of Problem and Substantiation for Public Input

There are marking requirements for PV systems included in Section 690.54 that relate to the compatibility and ratings of a PV system's interconnection with other systems. These requirements should be a requirement for any interconnected power systems, not just PV. Since Article 705 is the Article that is used to where different sources will interconnect, this is a more appropriate location. These requirements should be able to be met by manufacturer's markings, and not require field markings in all cases. A requirement that any markings be readily visible ensures that where it is not possible to use a nameplate etc., a field marking would be needed.

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This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI's submitted.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain, P.E., SEIA; Bill Brooks, PVICC; John Berdner, PVICC, Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing, Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower; Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Ben Chamberlain, Olivewood Energy; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener,

SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

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Committee: NEC-P04

Committee Statement

Resolution: FR-9392-NFPA 70-2021

Statement: This revision clarifies the language related to output characteristics so that it is related to compatibility with the primary source which is most often the serving utility.

The requirements are split into an (A) and (B) to match the NEC Style Manual. It adds the marking requirements for PV systems included in Section 690.54 that relate to the compatibility and ratings of a PV system's interconnection with other systems. These requirements should be a requirement for any interconnected power systems, not just PV. Since Article 705 is the article where different sources will interconnect, this is a more appropriate location. These requirements should be able to be met by manufacturer's markings, and not require field markings in all cases. A requirement that any markings be readily visible ensures that where it is not possible to use a nameplate etc., a field marking would be needed. The last sentence related to synchronous machines is simplified for clarity and enforceability.

The informational note is changed to refer to the relevant standards for interconnection requirements including power quality. There are over 3000 electric utilities in the USA and most make use of UL1741 certified equipment that are evaluated and tested using the IEEE 1547 performance standards

Public Input No. 2536-NFPA 70-2020 [Section No. 705.16]

~~**705.16** Interrupting and Short-Circuit Current Rating.~~

~~Consideration shall be given to the contribution of fault currents from all interconnected power sources for the interrupting and short-circuit current ratings of equipment on interactive systems.~~

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

Interrupting rating requirements and SCCR requirements are handled as part of 110.9 and 110.10 of the NEC. All equipment must be able to either interrupt or withstand maximum available fault current as required by the NEC.

The definitions of fault current and fault current, available add the clarity necessary for proper application of electrical equipment in any system.

712.72 is also being deleted for same reasons.

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Submittal Date: Mon Aug 24 12:18:20 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9394-NFPA 70-2021
Statement: Section 705.16 is deleted as this section contains unenforceable language, “consider” and refers to the interrupting rating requirements and SCCR requirements that are handled as part of Sections 110.9 and 110.10. All equipment must be able to either interrupt or withstand maximum available fault current as required by the NEC. This section is not necessary since it does not modify Article 110.

Public Input No. 4681-NFPA 70-2020 [Section No. 705.16]

705.16 Interrupting and Short-Circuit Current Rating.

Consideration shall be given to the contribution of fault currents from all interconnected power sources for the interrupting and short-circuit current ratings of equipment on interactive systems.

Exception: Systems engineered to be interconnected for less than 100ms.

Statement of Problem and Substantiation for Public Input

If a system, like a closed-transition ATS, is engineered to be interconnected with two sources of power for a very brief amount of time, it should not be required to be sized to account for both power sources' fault currents.

Submitter Information Verification

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Submittal Date: Thu Sep 10 16:44:54 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9394-NFPA 70-2021

Statement: Section 705.16 is deleted as this section contains unenforceable language, “consider” and refers to the interrupting rating requirements and SCCR requirements that are handled as part of Sections 110.9 and 110.10. All equipment must be able to either interrupt or withstand maximum available fault current as required by the NEC. This section is not necessary since it does not modify Article 110.

Public Input No. 2537-NFPA 70-2020 [Section No. 705.20]

705.20 Disconnecting Means, Source.

Means shall be provided to disconnect power source output circuit conductors of electric power production equipment from conductors of other systems. ~~The disconnecting means shall comply with the following:~~

- ~~Be one of the following types:~~
  - (1) ~~A manually operable switch or circuit breaker~~
  - (2) ~~A load-break-rated pull-out switch~~
  - (3) ~~A power-operated or remote-controlled switch or circuit breaker that is manually operable locally and opens automatically when control power is interrupted~~
  - (4) ~~A device listed or approved for the intended application~~
- ~~Simultaneously disconnect all ungrounded conductors of the circuit~~
- ~~Located where readily accessible~~
- ~~Externally operable without exposed live parts~~
- ~~Enclosures with doors or hinged covers with exposed live parts when open that require a tool to open or are lockable where readily accessible to unqualified persons~~
- ~~Plainly indicate whether in the open (off) or closed (on) position~~
- ~~Have ratings sufficient for the maximum circuit current, available fault current, and voltage that is available at the terminals~~

~~Be~~ Where the line and load terminals are capable of being energized in the open position, the disconnect shall be marked in accordance with the warning in 690.13(B) ~~, where the line and load terminals are capable of being energized in the open position~~ .

Informational Note: With interconnected power sources, some equipment, including switches and fuses, is likely to be energized from both directions. See 240.40 .

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

As a general requirement, it is stated here that a means must be provided to disconnect power source output circuit conductors from the conductors of other systems.

The specific requirements for this disconnect are found in the specific Articles focused on various alternative sources of power. These sections include the following:

ARTICLE 445 Generators, 445.18 Disconnecting Means and Emergency Shutdown.

ARTICLE 625 Electric Vehicle Power Transfer System, Part III. Installation, 625.43 Disconnecting Means.

ARTICLE 690 Solar Photovoltaic (PV) Systems Part III. Disconnecting Means

ARTICLE 692 Fuel Cell Systems, Part III. Disconnecting Means

ARTICLE 694 Wind Electric Systems, Part III. Disconnecting Means

ARTICLE 706 Energy Storage Systems, Part II. Disconnecting Means

As a result, the language being deleted is not required as part of the general requirements as the specifics may vary based upon the supply. While there may be installations that require multiple disconnects, it is important that this section not imply that this is a requirement, or that it modifies other article in this area. The language addressing disconnects that may have load terminals energized when open has been kept since this language is not consistently addressed in the other power source articles

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Committee: NEC-P04

Committee Statement

Resolution: FR-9395-NFPA 70-2021

Statement: As a general requirement, it is stated here that a means must be provided to disconnect power source

output circuit conductors from the conductors of other systems.

A sentence is added to the opening paragraph to clarify that this disconnecting means may separate multiple power sources from other systems. Also, this disconnect need not be duplicated if the disconnect required in one of the source articles (Articles 690, 692, 694, and 706) meet the list of requirements in Section 705.20.

The language of item (5) is edited for clarity. The term, lockable is unchanged as it automatically invokes Section 110.25.

The marking requirement of Section 705.20(8) is revised and the language of Section 690.13(B) is extracted rather than referenced so the language is located in one place for consistent reference.

The informational note is revised for clarity and to remove an unnecessary reference.

Public Input No. 2810-NFPA 70-2020 [Section No. 705.20]

705.20 Disconnecting Means, Source.

(A) General. _ Means shall be provided to disconnect power source output circuit conductors of electric power production equipment from conductors of other systems.

The disconnecting means shall comply with the following:

(1) Be one of the following types:

(2) _ A manually operable switch or circuit breaker

(3) _ A load-break-rated pull-out switch

(4) _ A power-operated or remote-controlled switch or circuit breaker that is manually operable locally and opens automatically when control power is interrupted

(5) _ A device listed or approved for the intended application

(6) Simultaneously disconnect all ungrounded conductors of the circuit

(7) Located where readily accessible

(8) Externally operable without exposed live parts

(9) Enclosures with doors or hinged covers with exposed live parts when open that require a tool to open or are lockable where readily accessible to unqualified persons

(10) Plainly indicate whether in the open (off) or closed (on) position

(11) Have ratings sufficient for the maximum circuit current, available fault current, and voltage that is available at the terminals

(8) Be marked in accordance with the warning in 690.13(B) , where the line and load terminals are capable of being energized in the open position

Informational Note: With interconnected power sources, some equipment, including switches and fuses, is likely to be energized from both directions. See 240.40 .

(B) Labeling. The disconnecting means for the power source output circuit conductors from a multimode inverter shall be field labeled "INTERCONNECTED ELECTRIC POWER PRODUCTION SOURCE DISCONNECT". The label shall not be handwritten and shall comply with 110.21(B).

Additional Proposed Changes

File Name	Description	Approved
705.20_B_2023_NECdocx.docx	Clean Word doc version of the proposed PI	

Statement of Problem and Substantiation for Public Input

This PI seeks to add a new labeling requirement in a new (B). Any language that has been underlined in (A) is a glitch in Terra View.

With the increased installations of smart multimode inverters there needs to be additional requirements for the labeling of the inverters ac output power source disconnecting means. These types of disconnecting means only isolate the multimode inverter connection to the normal power source, and do not serve as a PV System or ESS disconnect. When the ac output power source disconnect is opened, the multimode inverter will switch to island mode and will allow an ESS or PV system to remain operational. The improper labeling of this ac output power source disconnect can lead to safety issues

with first responders trying to remove all sources of power to a building.

Submitter Information Verification

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Committee: NEC-P04

Committee Statement

Resolution: The marking requirements are covered by their respective articles. Section 705.10 requires a directory of all sources. Section 702.7(A) requires a sign at the service entrance denoting the location of the disconnecting means for an optional standby system which is the subject of this public input.

705.20 Disconnecting Means, Source.

(A) General. Means shall be provided to disconnect power source output circuit conductors of electric power production equipment from conductors of other systems.

The disconnecting means shall comply with the following:

1. Be one of the following types:
    a) A manually operable switch or circuit breaker
    b) A load-break-rated pull-out switch
    c) A power-operated or remote-controlled switch or circuit breaker that is manually operable locally and opens automatically when control power is interrupted
    d) A device listed or approved for the intended application
2. Simultaneously disconnect all ungrounded conductors of the circuit
3. Located where readily accessible
4. Externally operable without exposed live parts
5. Enclosures with doors or hinged covers with exposed live parts when open that require a tool to open or are lockable where readily accessible to unqualified persons
6. Plainly indicate whether in the open (off) or closed (on) position
7. Have ratings sufficient for the maximum circuit current, available fault current, and voltage that is available at the terminals
8. Be marked in accordance with the warning in 690.13(B), where the line and load terminals are capable of being energized in the open position

Informational Note: With interconnected power sources, some equipment, including switches and fuses, is likely to be energized from both directions. See 240.40.

(B) Labeling. The disconnecting means for the power source output circuit conductors from a multimode inverter shall be field labeled "INTERCONNECTED ELECTRIC POWER PRODUCTION SOURCE DISCONNECT". The label shall not be handwritten and shall comply with 110.21(B).

Public Input No. 3866-NFPA 70-2020 [Section No. 705.20]

705.20 Disconnecting Means, Source.

Means shall be provided to disconnect power source output circuit conductors of electric power production equipment from conductors of other systems.

The disconnecting means shall comply with the following:

(1) Be one of the following types:

(2) A manually operable switch or circuit breaker

(3) A load-break-rated pull-out switch

(4) A power-operated or remote-controlled switch or circuit breaker that is manually operable locally and opens automatically when control power is interrupted

(5) A device listed or approved for the intended application

(6) Simultaneously disconnect all ungrounded conductors of the circuit

(7) Located where readily accessible

(8) Externally operable without exposed live parts

(9) Enclosures with doors or hinged covers with exposed live parts when open that require a tool to open or are lockable where readily accessible to unqualified persons

(10) Plainly indicate whether in the open (off) or closed (on) position

(11) Have ratings sufficient for the maximum circuit current, available fault current, and voltage that is available at the terminals

(12) Be marked in accordance with the warning in 690.13(B), where the line and load terminals are capable of being energized in the open position

(13) Be lockable

Informational Note: With interconnected power sources, some equipment, including switches and fuses, is likely to be energized from both directions. See 240.40 .

Statement of Problem and Substantiation for Public Input

In our area, the utility companies do not use production meters and as such the PV companies are using the breaker in the panel as a disconnecting means. The breaker needs to be lockable in emergency situations, as well as for use by the utility to service their equipment if they do have production meters. Currently some jurisdictions are allowing a locking means on an external panel to serve as a means to lock out the PV breaker, however by placing a lock on the entire panel, you now eliminate the access for use of the rest of the breakers. The locking means should be a separate method than locking the entire panel such as a breaker or disconnect that is not located in the main panel, or a permanent locking means on the breaker itself.

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Submittal Date: Wed Sep 09 14:20:30 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: Lockable requirements are found in each article that controls each power source. The intent is to make Section 705.20 a general requirement and that specific attributes for specific technologies be covered by their respective articles.

Public Input No. 3942-NFPA 70-2020 [Section No. 705.20]

705.20 Disconnecting Means, Source.

Means shall be provided to disconnect power source output circuit conductors of electric power production equipment from conductors of other systems. ~~The disconnecting means shall comply with the following:~~

- ~~Be one of the following types:~~
  - (1) ~~A manually operable switch or circuit breaker~~
  - (2) ~~A load-break-rated pull-out switch~~
  - (3) ~~A power-operated or remote-controlled switch or circuit breaker that is manually operable locally and opens automatically when control power is interrupted~~
  - (4) ~~A device listed or approved for the intended application~~
- ~~Simultaneously disconnect all ungrounded conductors of the circuit~~
- ~~Located where readily accessible~~
- ~~Externally operable without exposed live parts~~
- ~~Enclosures with doors or hinged covers with exposed live parts when open that require a tool to open or are lockable where readily accessible to unqualified persons~~
- ~~Plainly indicate whether in the open (off) or closed (on) position~~
- ~~Have ratings sufficient for the maximum circuit current, available fault current, and voltage that is available at the terminals~~

~~Be marked in accordance with the warning in 690.13(B) , where the line and load terminals are capable of being energized in the open position A single handle or other action is permitted to operate multiple disconnecting means from a single source or multiple sources. Circuit breakers not marked "line" and "load" shall be considered suitable for backfeed. Circuit breakers marked "line" and "load" shall be considered suitable for backfeed or reverse current if specifically rated.~~

Where the line and load terminals are capable of being energized in the open posi tion the device shall be marked with the following words or equivalent:

WARNING

ELECTRIC SHOCK HAZARD

TERMINALS ON THE LINE AND LOAD SIDES MAY BE

ENERGIZED IN THE OPEN POSITION

The warning sign(s) or label(s) shall comply with 110.21(B).

Informational Note: With interconnected power sources, some equipment, including switches and fuses, is likely to be energized from both directions. See 240.40 .

Statement of Problem and Substantiation for Public Input

Note that the informational note is not new despite the appearance of the legislative text.

Several requirements are removed from this section since they are not necessary as the unique requirements for each power source disconnect(s) are addressed in the specific source articles, not in 705. The presence of these requirements here are not only duplicative, but cause confusion or create conflicts since in some cases it will be unclear which article modifies which.

Clarification is added to allow a single handle or throw to operate multiple disconnecting means where applicable.
Language addressing backfed circuit breakers is revised for clarity. The warning label from 690.13 has been added instead of a pointer to better convey the requirement.
The requirement to secure hinged covers and doors has been deleted since 110.27 should provide requirements for guarding of all electrical equipment. See related PI.

See the following sections for disconnection requirements for each source:
ARTICLE 445 Generators, 445.18 Disconnecting Means and Emergency Shutdown.
ARTICLE 625 Electric Vehicle Power Transfer System, Part III. Installation, 625.43 Disconnecting Means.
ARTICLE 690 Solar Photovoltaic (PV) Systems Part III. Disconnecting Means
ARTICLE 692 Fuel Cell Systems, Part III. Disconnecting Means
ARTICLE 694 Wind Electric Systems, Part III. Disconnecting Means
ARTICLE 706 Energy Storage Systems, Part II. Disconnecting Means

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI's submitted.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain, P.E., SEIA; Bill Brooks, PVICC; John Berdner, PVICC, Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing, Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower; Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Ben Chamberlain, Olivewood Energy; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3926-NFPA 70-2020 [New Section after 110.27(C)]	Guarding of certain equipment
Public Input No. 3926-NFPA 70-2020 [New Section after 110.27(C)]	

Submitter Information Verification

Submitter Full Name: Evelyn Butler
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Submittal Date: Wed Sep 09 16:00:56 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: The proposed definition does not add clarity to the term "Termination Point", “Tubing Termination" or "Conduit Termination". “Termination” is used throughout the code and is not accurately define in the proposed text. The proposed definition combines multiple terms for a single definition and does not comply with the format identified in Section 2.2.2.5 of the 2020 NEC Style Manual.

Public Input No. 4006-NFPA 70-2020 [Section No. 705.20]

705.20 Disconnecting Means, Source.

Means shall be provided to disconnect power source output circuit conductors of electric power production equipment from conductors of other systems.

The disconnecting means shall comply with the following:

(1) Be one of the following types:

(2) A manually operable switch or circuit breaker

(3) A load-break-rated pull-out switch

(4) A power-operated or remote-controlled switch or circuit breaker that is manually operable locally and opens automatically when control power is interrupted

(5) A device listed or approved for the intended application

(6) Simultaneously disconnect all ungrounded conductors of the circuit

(7) Located where readily accessible

(8) Externally operable without exposed live parts

(9) Enclosures with doors or hinged covers ~~with~~ containing exposed live parts when ~~open that~~ the door or cover is open, shall require a tool to open or ~~are lockable~~ shall be locked where readily accessible to unqualified persons

(10) Plainly indicate whether in the open (off) or closed (on) position

(11) Have ratings sufficient for the maximum circuit current, available fault current, and voltage that is available at the terminals

(12) Be marked in accordance with the warning in 690.13(B), where the line and load terminals are capable of being energized in the open position

Informational Note: With interconnected power sources, some equipment, including switches and fuses, is likely to be energized from both directions. See 240.40.

Statement of Problem and Substantiation for Public Input

Substantiation – This proposal is intended to provide similar electric shock protection as required by 690.13(A). The existing 705.20 (5) text mentions that the enclosure is to be lockable, but as it is written it does not require it to be locked, which is different from 690.13(A). “Shall” was introduced to make this list item a requirement.
It is important to note that utility interactive inverter outputs are not evaluated for touch safety when in a grid interactive output current cessation condition, such as when a inverter output disconnect is open. In this case, if the inverter is energized from its input source, the grid interactive output is paused from exporting current. Grid interconnection performance standards only require a cessation of current during abnormal grid events, and do not require a touch safe output evaluation, which has a significantly different criteria and safety evaluation.
As indicated by the inverter warning markings, an inverter that has been disconnected from all of it input and output power sources, (including the AC grid terminals/conductors), may take up to 5 minutes to discharge to levels that are safe to touch.

Please note that I did not modify (a-d) under item (1). Terraview underlined that text for some unknown reason to show it as modified or added.

Submitter Information Verification

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Submittal Date: Wed Sep 09 17:06:49 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9395-NFPA 70-2021

Statement: As a general requirement, it is stated here that a means must be provided to disconnect power source

output circuit conductors from the conductors of other systems.

A sentence is added to the opening paragraph to clarify that this disconnecting means may separate multiple power sources from other systems. Also, this disconnect need not be duplicated if the disconnect required in one of the source articles (Articles 690, 692, 694, and 706) meet the list of requirements in Section 705.20.

The language of item (5) is edited for clarity. The term, lockable is unchanged as it automatically invokes Section 110.25.

The marking requirement of Section 705.20(8) is revised and the language of Section 690.13(B) is extracted rather than referenced so the language is located in one place for consistent reference.

The informational note is revised for clarity and to remove an unnecessary reference.

Public Input No. 4076-NFPA 70-2020 [Section No. 705.20]

705.20 Disconnecting Means, Source.

Means shall be provided to disconnect power source output circuit conductors of electric power production equipment from conductors of other systems.

The disconnecting means shall comply with the following:

(1) Be one of the following types:

(2) A manually operable switch or circuit breaker

(3) A load-break-rated pull-out switch

(4) A power-operated or remote-controlled switch or circuit breaker that is manually operable locally and opens automatically when control power is interrupted

(5) A device listed or approved for the intended application

(6) Simultaneously disconnect all ungrounded conductors of the circuit

(7) Located where readily accessible

(8) Externally operable without exposed live parts

(9) Enclosures with doors or hinged covers with exposed live parts when open that require a tool to open or are lockable where readily accessible to unqualified persons

(10) Plainly indicate whether in the open (off) or closed (on) position

(11) Have ratings sufficient for the maximum circuit current, available fault current, and voltage that is available at the terminals

(12) ~~Be marked in accordance with the warning in~~ 690.13(B) ~~, where the~~ Where the line and load terminals are capable of being energized in the open position, shall be marked with the following words or equivalent:
WARNING ELECTRIC SHOCK HAZARD TERMINALS ON THE LINE AND LOAD SIDES MAY BE ENERGIZED IN THE OPEN POSITION

Informational Note: With interconnected power sources, some equipment, including switches and fuses, is likely to be energized from both directions. See 240.40.

Statement of Problem and Substantiation for Public Input

With the proposed placement of Article 705 as the new Article 689, a reference to the Solar PV article 690 seems unnecessary. In this case, 690 should now reference the new Article 689.

Submitter Information Verification

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Submittal Date: Wed Sep 09 20:12:45 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9395-NFPA 70-2021

Statement: As a general requirement, it is stated here that a means must be provided to disconnect power source

output circuit conductors from the conductors of other systems.

A sentence is added to the opening paragraph to clarify that this disconnecting means may separate multiple power sources from other systems. Also, this disconnect need not be duplicated if the disconnect required in one of the source articles (Articles 690, 692, 694, and 706) meet the list of requirements in Section 705.20.

The language of item (5) is edited for clarity. The term, lockable is unchanged as it automatically invokes Section 110.25.

The marking requirement of Section 705.20(8) is revised and the language of Section 690.13(B) is extracted rather than referenced so the language is located in one place for consistent reference.

The informational note is revised for clarity and to remove an unnecessary reference.

Public Input No. 2946-NFPA 70-2020 [Section No. 705.25]

705.25 Wiring Methods.

(A) General.

All raceway and cable wiring methods ~~included in Chapter~~ that comply with either (1) or (2) shall be permitted:

(1) raceway and cable wiring methods found in Chapter 3 of this *Code* ~~and other wiring systems and~~

(2) wiring methods and fittings specifically listed, ~~intended,~~ and identified for use with power production systems and equipment ~~shall be permitted~~ .

Where wiring devices with integral enclosures are used, sufficient length of cable shall be provided to facilitate replacement.

Information Note: See 300.15 (E)

(B) Flexible Cords and Cables.

Flexible cords and cables, where used to connect the moving parts of a power production system or where used for ready removal for maintenance and repair, shall comply with Article 400 and shall be listed and identified as DG Cable, Distributed Generation Cable, hard service cord, or portable power cable, shall be suitable for extra-hard usage, shall be listed for outdoor use, and shall be water resistant. Cables exposed to sunlight shall be sunlight resistant. Flexible, fine-stranded cables shall be terminated only with terminals, lugs, devices, or connectors in accordance with 110.14(A).

(C) Multiconductor Cable Assemblies.

Multiconductor cable assemblies used in accordance with their listings shall be permitted.

Informational Note: See UL 3003, *Distributed Generation Cables*, for additional information on DG Cable, Distributed Generation Cable. An ac module harness is one example of a multiconductor cable assembly.

Statement of Problem and Substantiation for Public Input

705.25(A) was revised for clarity and for usability.

Submitter Information Verification

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Submittal Date: Thu Sep 03 13:27:49 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9397-NFPA 70-2021

Statement: This revision adds a sentence before the first level subdivision to ensure it is clear that the requirements within this section apply to the power source output conductors only, and are not intended to apply to other circuits within the power source systems. The sentence addressing integral enclosures was deleted as these requirements are addressed in the respective articles.

Public Input No. 3825-NFPA 70-2020 [Section No. 705.25]

705.25 Wiring Methods.

Power Source Output Circuit conductors shall comply with 705.25 (A) through (C).

(A) General.

All raceway and cable wiring methods included in Chapter 3 of this *Code* and other wiring systems and fittings specifically listed, intended, and identified for use with power production systems and equipment shall be permitted. Where wiring devices with integral enclosures are used, sufficient length of cable shall be provided to facilitate replacement.

(B) Flexible Cords and Cables.

Flexible cords and cables, where used to connect the moving parts of a power production system or where used for ready removal for maintenance and repair, shall comply with Article 400 and shall be listed and identified as DG Cable, Distributed Generation Cable, hard service cord, or portable power cable, shall be suitable for extra-hard usage, shall be listed for outdoor use, and shall be water resistant. Cables exposed to sunlight shall be sunlight resistant. Flexible, fine-stranded cables shall be terminated only with terminals, lugs, devices, or connectors in accordance with 110.14(A).

(C) Multiconductor Cable Assemblies.

Multiconductor cable assemblies used in accordance with their listings shall be permitted.

Informational Note: See UL 3003, *Distributed Generation Cables*, for additional information on DG Cable, Distributed Generation Cable. An ac module harness is one example of a multiconductor cable assembly.

Statement of Problem and Substantiation for Public Input

This proposed text simply adds a sentence before the first level subdivision to ensure it is clear that the requirements within this section apply to the power source output conductors only, and are not intended to apply to other circuits within the power source systems.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI's submitted.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain, P.E., SEIA; Bill Brooks, PVICC; John Berdner, PVICC, Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing, Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower; Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural

Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Ben Chamberlain, Olivewood Energy; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

Submitter Information Verification

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Submittal Date: Wed Sep 09 13:42:52 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9397-NFPA 70-2021

Statement: This revision adds a sentence before the first level subdivision to ensure it is clear that the requirements within this section apply to the power source output conductors only, and are not intended to apply to other circuits within the power source systems. The sentence addressing integral enclosures was deleted as these requirements are addressed in the respective articles.

Public Input No. 1869-NFPA 70-2020 [Section No. 705.28]

705.28 Circuit Sizing and Current.

(A) Calculation of Maximum Circuit Current.

~~Where not elsewhere required or permitted in this *Code* , the maximum current for the circuit~~ The maximum current for the circuit, at the circuit nominal system voltage, shall be the continuous output current rating of the power production equipment.

(B) Conductor Ampacity.

Where not elsewhere required or permitted in this *Code*, the circuit conductors shall be sized to carry not less than the largest of the following:

(1) The maximum currents in 705.28(A) multiplied by 125 percent without adjustment or correction factors

(2) The maximum currents in 705.28(A) with adjustment and correction factors

(3) Where connected to feeders, if smaller than the feeder conductors, the ampacity as calculated in 240.21(B) based on the over-current device protecting the feeder

(C) Neutral Conductors.

Neutral conductors shall be permitted to be sized in accordance with either 705.28(C)(1) or (C)(2).

(1) Single-Phase Line-to-Neutral Power Sources.

Where not elsewhere required or permitted in this *Code*, the ampacity of a neutral conductor to which a single-phase line-to-neutral power source is connected shall not be smaller than the ampacity in 705.28(B).

(2) Neutral Conductor Used Solely for Instrumentation, Voltage, Detection, or Phase Detection.

A power production equipment neutral conductor used solely for instrumentation, voltage detection, or phase detection shall be permitted to be sized in accordance with 250.102.

Statement of Problem and Substantiation for Public Input

I deleted the leading text since it is too vague and I suggest adding the text about the current based on the circuit nominal system voltage, since power production equipment often has multiple output currents listed, based on the output nominal system voltage to which it is connected.

Submitter Information Verification

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Submittal Date: Mon Jul 13 10:11:35 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9399-NFPA 70-2021

Statement: The phrase, “power source output…” is added to clarify the circuits being described by this section. The nominal voltage is added to clarify the voltage at which the current is rated. The language related to “Where not elsewhere required or permitted…” is retained as it was specifically chosen as there are power sources that may have very different power ratings than a 3-hour continuous rating. Generators are one example.

Changes are made to 705.28(B) to align conductor ampacity with language found in Articles 210 and 215. Similar exceptions and language to that found in Articles 210 and 215 are added for clarity and consistency with the Code. References to “feeders” are changed to circuit conductors as not all of these conductors are feeders nor are they branch circuits

Public Input No. 201-NFPA 70-2019 [Section No. 705.28(B)]

(B) Conductor Ampacity.

Where not elsewhere required or permitted in this *Code*, the circuit conductors shall ~~be sized to carry~~ have an ampacity not less than the ~~largest of the following:The~~ larger of 705.28(B)(1), (B)(2), or (B)(3) and shall comply with 110.14(C).

(1) The minimum circuit conductor size shall have an ampacity not less than t he maximum currents in 705.28(A) multiplied by 125 percent without adjustment or correction factors.

Exception No. 1: If the assembly, including the overcurrent devices protecting the circuit, is listed for operation at 100 percent of its rating, the ampacity of the conductors shall be permitted to be not less than calculated maximum current of 705.28(A).

Exception No. 2: Where a portion of a circuit is connected at both its supply and load ends to separately installed pressure connections as covered in 110.14(C)(2), it shall be permitted to have an ampacity not less than the calculated maximum current of 705.28(A). No portion of the circuit installed under this exception shall extend into an enclosure containing either the circuit supply or the circuit load terminations, as covered in 110.14(C)(1).

Exception No. 3: Grounded conductors that are not connected to an overcurrent device shall be permitted to be sized at 100 percent of the calculated maximum current of 705.28(A).

The minimum feeder conductor size shall have an ampacity not less than the maximum load to be served after the application of any adjustment or correction factors in accordance with 310.14.

(2) The minimum circuit conductor size shall have an ampacity not less than the calculated maximum currents in 705.28(A)

~~with adjustment and correction factors~~
after the application of any adjustment or correction factors in accordance with 310.14.

(3) Where connected to feeders, if smaller than the feeder conductors, the minimum conductor size with an ampacity as calculated in 240.21(B) based on the over-current device protecting the feeder

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

Changes made to align conductor ampacity with language found in Articles 210 and 215 focused on the same. Allowances for similar exceptions and language format to that found in Articles 210 and 215 help add clarity and consistency with the Code.

Submitter Information Verification

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Submittal Date: Sun Dec 22 18:30:55 EST 2019

Committee: NEC-P04

Committee Statement

Resolution: FR-9399-NFPA 70-2021

Statement: The phrase, “power source output…” is added to clarify the circuits being described by this section. The nominal voltage is added to clarify the voltage at which the current is rated. The language related to “Where not elsewhere required or permitted…” is retained as it was specifically chosen as there are power sources that may have very different power ratings than a 3-hour continuous rating. Generators are one example.

Changes are made to 705.28(B) to align conductor ampacity with language found in Articles 210 and 215. Similar exceptions and language to that found in Articles 210 and 215 are added for clarity and consistency with the Code. References to “feeders” are changed to circuit conductors as not all of these conductors are feeders nor are they branch circuits

Public Input No. 4380-NFPA 70-2020 [Section No. 705.30(A)]

(A) Circuit and Equipment.

Power source output circuit conductors and equipment shall be provided with overcurrent protection. Circuits connected to more than one electrical source shall have overcurrent protective devices located to provide overcurrent protection from all sources. Electronic power converters that are capable of operating in island mode and connected to the premises wiring system by flexible cords and cables or multiconductor cable assemblies not protected by a raceway shall be provided with listed electronic overcurrent and ground fault protection for the circuit connected to each electronic power converter.

Statement of Problem and Substantiation for Public Input

Added the word “protective” between overcurrent and device to align with the terms in Article 100 since these devices are not overcurrent devices, but rather overcurrent protective devices. Added a new sentence to clarify overcurrent protection needs for the output of electronic power converters that can operate in island mode versus interactive equipment. Other sections of the code, such as 690.8(A)(1)e, rely on the output rating of the listed electronic power converter for circuit sizing. Section 690.9(A)(1) even identifies where “overcurrent protection” for circuits is not required. Section 690.9(A)(2) specifies where overcurrent protection is only required at one end, which assumes the system is also connected to a primary source. The new sentence clarifies protection needs for power cords or multiconductor cables not protected by a raceway and are connected to the output of electric power production equipment that can operate in island mode. For these systems, the high fault currents from the grid and the utility interactive function of interactive electronic power converters will not work together to quickly remove ground faults since the grid is not present and the inverter does not have this interactive function in island mode. When the power production equipment is operating in island mode, the output current will be limited to its rating, which protects the wiring from overload but could allow continual sourcing of current to ground faults. Therefore, listed electronic ground fault detection and protection is needed to mitigate the fire risk from cable systems not installed in raceways. The term raceway was purposely chosen since the protection could be accomplished by non-metallic conduit, metallic conduit or a wire protection system as part of the equipment.

Submitter Information Verification

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Submittal Date: Thu Sep 10 11:33:19 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: The term overcurrent device is used synonymously with overcurrent protective device nearly 100 times in the NEC. The language regarding electronic power converters is also problematic as it focuses on protection of specific premises wiring requirements that are handled elsewhere in the Code. The public input is unclear as to whether a GFCI or another device would be necessary.

Public Input No. 3409-NFPA 70-2020 [Section No. 705.30(C)]

(C) Power Transformers.

Transformers with sources on each side shall be provided with overcurrent protection in accordance with 450.3. The primary shall be the side connected to the largest source of available fault current. ~~Secondary protection~~ Transformer secondary conductors shall ~~not be required for a transformer secondary that has a current rating not less than the sum of the rated continuous output currents of the power sources connected to that secondary.~~ be protected in accordance with 240.21(C).

Statement of Problem and Substantiation for Public Input

Transformer secondary conductors require overcurrent protection per 240.21(C) even when the only source of potential fault current is the utility supply to the primary. Why would the addition of a second supply of potential fault current to the secondary (the inverter) alter the general rule of Article 240? A line-to-line or line-to-ground fault between the conductors from the transformer secondary to the inverter would be supplied by both the inverter and the utility.

The basis for the current requirement was established in the 1984 NEC with the following substantiation: This requirement is necessary to ensure that proper overcurrent protection is provided for power transformers where sources of supply are connected to both sides.

The primary and secondary windings of a transformer are required to be identified by the manufacturer through the UL product standard XQNX - Power and General-purpose Transformers, Dry Type. Step-up and step-down transformers are available and some manufacturers permit transformers to be reverse connected within certain operational limitations in accordance with installation instructions.

Identification of what constitutes the primary is needed clarification but substantiation for modification of Article 240 rules has not been provided. The existing language references overcurrent protection of the transformer (450.3) but not overcurrent protection for transformer secondary conductors [240.21(C)].

Providing all required Article 450 and 240 transformer related overcurrent protection is not a hardship because overcurrent protection for the utility supplied primary conductors and overcurrent protection for the inverter output conductors is already required. If rated and located properly, these overcurrent devices will also provide the protection required by 450.3 and 240.21(C).

The suggested revision would provide the necessary clarity for proper enforcement of all applicable transformer circuit rules.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3408-NFPA 70-2020 [Section No. 690.9(D)]	
Public Input No. 3408-NFPA 70-2020 [Section No. 690.9(D)]	

Submitter Information Verification

Submitter Full Name: Rudolph Garza
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Submittal Date: Tue Sep 08 14:07:34 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9402-NFPA 70-2021

Statement: Sections 705.12(C), (D), and (E) are deleted and inserted as 705.30(C), (D), and (E). Editorial changes are made to the marking section.

This revision makes power transformers Section 705.30(F) and moves the overcurrent protection requirements for transformers into a list. It combines the first two sentences into a single statement about which side is the primary for transformers with power sources on both sides. It removes the reference to Section 450.3 as the statement does not modify any requirements. Lastly, the revision replaces the text of the last sentence with a reference to Section 240.21(C) where the requirements for transformer secondary conductor overcurrent protection is covered.

Item 3 is added to power transformers as it modifies the overcurrent protection requirements where a zig-zag connected transformer only provides a neutral reference point for inverter controls and there is no neutral current flow.

The generators overcurrent section is deleted as it does not modify the generator requirements.

Public Input No. 4354-NFPA 70-2020 [Section No. 705.30(C)]

(C) Power Transformers.

Transformers with sources on each side shall be provided with overcurrent protection in accordance with 450.3. The primary shall be the side connected to the largest source of available fault current. Secondary protection shall not be required for a transformer secondary that has a current rating not less than the sum of the rated continuous output currents of the power sources connected to that secondary.

Exception: Where the only purpose of installating the transformer is to provide a neutral reference point for inverter controls, the requirements in 450.5(A)(2) shall not be required.

Statement of Problem and Substantiation for Public Input

The proposed new exception is intended to address situations where a zig-zag connected transformer has been installed only to provide a neutral reference point for inverter controls and there is no neutral current flow. Because there is no amendment in Articles 690 or 705, per 90.3, 450.5(A)(2) applies.

Submitter Information Verification

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Submittal Date: Thu Sep 10 11:04:48 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9402-NFPA 70-2021

Statement: Sections 705.12(C), (D), and (E) are deleted and inserted as 705.30(C), (D), and (E). Editorial changes are made to the marking section.

This revision makes power transformers Section 705.30(F) and moves the overcurrent protection requirements for transformers into a list. It combines the first two sentences into a single statement about which side is the primary for transformers with power sources on both sides. It removes the reference to Section 450.3 as the statement does not modify any requirements. Lastly, the revision replaces the text of the last sentence with a reference to Section 240.21(C) where the requirements for transformer secondary conductor overcurrent protection is covered.

Item 3 is added to power transformers as it modifies the overcurrent protection requirements where a zig-zag connected transformer only provides a neutral reference point for inverter controls and there is no neutral current flow.

The generators overcurrent section is deleted as it does not modify the generator requirements.

Public Input No. 2538-NFPA 70-2020 [Section No. 705.32]

705.32 Ground-Fault Protection.

Where ground-fault protection of equipment is installed ~~in accordance with~~ ~~230.95~~ as required elsewhere in this Code , the output of ~~an interactive system~~ interconnected power production equipment shall be connected to the supply side of the ground-fault protection.

Exception: Connection shall be permitted to be made to the load side of ground-fault protection, if there is ground-fault protection for equipment from all ground-fault current sources.

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

Added “of Equipment” to align with other areas in the NEC where this terminology is used.

Minor changes to add clarity. Removed the reference to 230.95 an made a general reference to where GFPE is provided regardless.

The work of this task group included modifying the definition of interactive system such that the term no longer exists. The modification made removes the conflict should the public input that modifies the term be accepted.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2684-NFPA 70-2020 [Definition: Interactive System.]	Definition change / term

Submitter Information Verification

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Submittal Date: Mon Aug 24 12:28:18 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9404-NFPA 70-2021

Statement: This revision provides editorial changes for clarity and adds “of equipment” to align with other areas in the NEC where this terminology is used.

This also removes the reference to Section 230.95 and makes a general reference to where GFPE is provided in the NEC.

The exception includes the installation of systems in accordance with 705.11

Public Input No. 4056-NFPA 70-2020 [Section No. 705.40]

705.40 Loss of Primary Source.

The output of interactive electric power production equipment shall be automatically disconnected from all ungrounded conductors of the ~~interconnected systems~~ primary source when one or more of the phases of the primary source to which it is connected opens. The electric power production equipment shall not be reconnected until all the phases of the ~~interconnected system~~ primary source to which it is connected are restored. This requirement shall not be applicable to electric power production equipment providing power to an emergency or legally required standby system.

Exception: A listed interactive inverter shall trip or shall be permitted to automatically cease exporting power when one or more of the phases of the ~~interconnected system~~ primary source opens and shall not be required to automatically disconnect all ungrounded conductors from the primary source. A listed interactive inverter shall be permitted to automatically or manually resume exporting power to the interconnected system once all phases of the source to which it is connected are restored.

Informational Note No. 1: Risks to personnel and equipment associated with the primary source could occur if an interactive electric power production source can operate as an intentional island. Special detection methods are required to determine that a primary source supply system outage has occurred and whether there should be automatic disconnection. When the primary source supply system is restored, special detection methods are typically required to limit exposure of power production sources to out-of-phase reconnection.

Informational Note No. 2: Induction-generating equipment connected on systems with significant capacitance can become self-excited upon loss of the primary source and experience severe overvoltage as a result.

Interactive power production equipment shall be permitted to operate in island mode to supply loads that have been disconnected from the electric power production and distribution network.

Statement of Problem and Substantiation for Public Input

The way this section is written, it is not clear that the intent is related to the loss of phase or phases from the primary source. The title is "Primary Source" but the language talks about interconnected sources as if there were only one primary source and one interactive source. By changing interconnected source to primary source in the proper locations, the intent is clarified.

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Committee: NEC-P04

Committee Statement

Resolution: FR-9407-NFPA 70-2021

Statement: This revision clarifies that it is the loss of the primary source, as the title suggests, that is the key concern of this section. By changing interconnected source to primary source in the proper locations, the intent is clarified.

In the last sentence “electric utility and other” was added to emphasize was added that the electric utility is often the electric power production and distribution network to which this is connected.

Public Input No. 4392-NFPA 70-2020 [Section No. 705.40]

705.40 Loss of Primary Source.

The output of interactive electric power production equipment shall be automatically disconnected from all ungrounded conductors of the interconnected systems when one or more of the phases to which it is connected opens. The interactive electric power production equipment shall not be reconnected until all the phases of the interconnected system to which it is connected are restored. This requirement shall not be applicable to interactive electric power production equipment providing power to an emergency or legally required standby system.

Exception: A listed interactive inverter shall trip or shall be permitted to automatically cease exporting power when one or more of the phases of the interconnected system opens and shall not be required to automatically disconnect all ungrounded conductors from the primary source. A listed interactive inverter shall be permitted to automatically or manually resume exporting power to the interconnected system once all phases of the source to which it is connected are restored.

Informational Note No. 1: Risks to personnel and equipment associated with the primary source could occur if an interactive electric power production source can operate as an intentional island. Special detection methods are required to determine that a primary source supply system outage has occurred and whether there should be automatic disconnection. When the primary source supply system is restored, special detection methods are typically required to limit exposure of power production sources to out-of-phase reconnection.

Informational Note No. 2: Induction-generating equipment connected on systems with significant capacitance can become self-excited upon loss of the primary source and experience severe overvoltage as a result.

Interactive power production equipment shall be permitted to operate in island mode to supply loads that have been disconnected from the electric power production and distribution network.

Statement of Problem and Substantiation for Public Input

The word “interactive” was added to the first paragraph to align with the statement in the last paragraph and make it clear that only interactive equipment is required to meet this requirement. Equipment operating in island mode is not required to meet this requirement.

Submitter Information Verification

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Submittal Date: Thu Sep 10 11:46:15 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9407-NFPA 70-2021

Statement: This revision clarifies that it is the loss of the primary source, as the title suggests, that is the key concern of this section. By changing interconnected source to primary source in the proper locations, the intent is clarified.

In the last sentence “electric utility and other” was added to emphasize was added that the electric utility is often the electric power production and distribution network to which this is connected.

Public Input No. 3456-NFPA 70-2020 [New Section after 705.45]

705.46 Energy Management Systems (EMS)

Where a listed energy management system that controls multiple loads up to a maximum total ampere rating is connected to a feeder or service, a single value equal to the maximum ampere setpoint of the EMS shall be permitted to be used in load calculations for all loads controlled by the EMS where the following conditions are met:

(1) The EMS shall include monitoring and controls that disconnect the managed loads upon system malfunction

(2) The access to settings of the EMS shall be restricted to qualified personnel in accordance with the requirements of 240.6(C)

(3) The setpoint value of the EMS shall be considered a continuous load for the purposes of load calculations

(4) Loads not controlled by the EMS connected to the same feeder or service shall be included in load calculations for that feeder or service

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

The electrification of homes and businesses is dramatically increasing the loads that must be served from electrical distribution systems. Widespread adoption of electric vehicles chargers, conversion of heating and cooling systems from oil and gas to heat pumps, and the adoption of onsite power sources such as solar and energy storage continues at a rapid pace. As these loads are connected to electrical distribution systems, the capacity of these distribution systems is becoming a barrier toward this electrification progress. Technologies in energy management systems are being developed, listed, and installed to help address these challenges. Advanced systems from large microgrids serving multiple buildings to residential systems supplying a single home are being built today with advanced load management functions to ensure that conductors and distribution equipment are used within their ratings, and that owners of these systems benefit from a reliable and efficient supply of power when it is needed. Increasingly these load management systems are adding features not only to prevent operation in different system states (i.e. backup priority), but also to schedule loads (i.e. for time of use) or to make loads non-coincident (i.e. optimize backup capacity). Additionally, energy management systems are increasingly being used for demand response programs in concert with utilities to support a smart grid. Historically this Code has provided allowances for alternative equipment sizing where our buildings are built to energy codes (220.12(B)), or when sizing an optional standby system (702.4(B)(2)(b)), or when adding some types of EV chargers (625.42). There is also a recognition of loads that are “unlikely” to be in use simultaneously (220.60) along with an allowance for power source control where the output of multiple power sources connected in parallel are controlled to a specified total output limit (705.13).

This public input seeks to build upon those specific allowances to provide a new option in Part I of Article 705 for any load connected to a feeder or service conductor where those loads are controlled to a maximum limit that effectively restricts the total loads operated at one time. Inputs addressing this issue in Article 220 are also being submitted in Parts 3 and 4 of that article. If the technical committees decide that those locations are more appropriate for this language then this new section in 705 is not necessary (though would not conflict, only duplicate).

Providing this option is important to allow electric distribution systems to be utilized, in a safe and effective manner, in order to provide reasonable accommodation for property owners to further pursue electrification without requiring extensive electrical system equipment upgrades that are not necessary in

all use cases. For those cases where loads do not need to be operated at the same time, load management will likely be preferred to equipment replacement to save costs and downtime of existing equipment.

Since safety is critical to ensure overcurrent does not occur, requiring that such a system be listed and that loads are disconnected during any malfunction will ensure fail-safe operations. To ensure that the setpoints for the EMS are protected, the same requirements for adjustable-trip circuit breakers is included. The current limit of the EMS is treated as continuous for the purposes of conductor sizing to recognize the connection of continuous and non-continuous duty loads is not restricted in this section. If other loads not controlled by the EMS are connected to the same feeder or service, a requirement to ensure those are also included in the load calculations is included here without any novel adjustments.

This public input does not modify Article 750 so restrictions on specific loads such as for emergency systems and fire pumps still apply as called out in Article 750.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3448-NFPA 70-2020 [New Section after 220.80]	EMS additions to 220
Public Input No. 3454-NFPA 70-2020 [New Part after IV.]	EMS additions to 220

Submitter Information Verification

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Submittal Date: Tue Sep 08 15:34:33 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9410-NFPA 70-2021

Statement: This revision adds specific requirements for the use of energy management systems to control loads connected to systems with on-site generation. It accommodates property owners who seek to further pursue electrification using on-site sources without requiring extensive electrical system equipment upgrades that are not necessary in all use cases. For those cases where loads do not need to be operated at the same time, load management will likely be preferred to equipment replacement to save costs and downtime of existing equipment.

Since safety is critical to ensure overcurrent does not occur, this requires that such a system be listed and that loads are disconnected during any malfunction which will ensure fail-safe operations. To ensure that the setpoints for the EMS are protected, the same requirements for adjustable-trip circuit breakers is included. The current limit of the EMS is treated as continuous for the purposes of conductor sizing to

recognize the connection of continuous and non-continuous duty loads is not restricted in this section. If other loads not controlled by the EMS are connected to the same feeder or service, a requirement to ensure those are also included in the load calculations is included here without any novel adjustments.

This does not modify Article 750 so restrictions on specific loads such as for emergency systems and fire pumps still apply as called out in Article 750.

Public Input No. 769-NFPA 70-2020 [New Section after 705.45(B)]

TITLE OF NEW CONTENT

Type your content here ...

705.46 Electromagnetic Pulse (EMP) Protection. Protection for interconnected electric power production sources against the effects of electromagnetic pulses shall be provided at a minimum of Level 2. See 709.7 for levels of electromagnetic pulse protection.

Exception: The requirements of 709.7(A)(5) and 709.7(B)(3) shall not apply.

This requirement shall become effective January 1, 2026.

Statement of Problem and Substantiation for Public Input

A devastating electromagnetic pulse (EMP), caused by a sun-spot or a nuclear bomb exploded high in the atmosphere, can impress 50,000 volts per meter on unprotected electrical and electronic equipment. It is similar to a radio wave impressing a very small voltage on a radio antenna, only orders of magnitude larger. The problem is that a significant EMP will fry every electrical/electronic component or piece of equipment that is not protected.

The EMP won't directly harm or injure people, but because there is no longer a working electrical infrastructure, which may take years to repair/rebuild, people will die from the lack of clean water, medicine, food, fuel, and eventual rioting due to the breakdown of society. Unclassified studies, referenced at the end of this substantiation, have estimated from 66% to 90% of the US population will die within one year if a significant sun spot were to occur or if a nuclear explosion were to occur 25 to 250 miles over the Midwest.

Our US military already "hardens" systems/buildings so that our country's critical defensive capabilities are not completely destroyed. There are two major methods of protecting electrical/electronic systems. The first is that surge protective devices are installed on all "incoming" power and communications cables, shunting overvoltages to ground. The second is that Faraday cages are installed around equipment/rooms, preventing the EMP from reaching critical equipment/components.

The NEC® needs to address EMP protection for equipment, systems and special occupancies that are critical to our survival. Electrical and electronic equipment can and must be protected, as has been achieved by our military. Unfortunately, there are no requirements to protect civilian electrical and electronic equipment/systems from EMPs.

The NEC Correlating Committee has informally advised that an EMP Protection Article, if passed and adopted into the NEC®, would be most appropriately located after Article 708 (COPS). Thus, Public Input 756 has suggested a new Article 709 under jurisdiction of CMP 13, which already has purview over Emergency Systems (Article 700), Legally Required Standby Systems (Article 701), Optional Standby Systems (Article 702), and Critical Operations Power Systems (Article 708).

Levels of protection and associated protection requirements listed in the Public Input(s) are based upon the unclassified National Cybersecurity and Communications Integration Center report "Electromagnetic Pulse (EMP) Protection and Resilience Guidelines for Critical Infrastructure and Equipment". This study explains electromagnetic pulses and provides the necessary protective measures. It also contains estimates of the costs associated with properly protecting our electrical infrastructure.
The following table contains critical infrastructure components/special occupancies and the maximum time for outages caused by an EMP. Electrical components/infrastructure that is not functioning for periods longer than shown in this table may begin to cause injury or death to people and harm to society/economy.
Critical Infrastructure Component/Special Occupancy Permitted Outage Time
Branch banking facilities 10 hours

Critical Operations Power Systems 10 minutes
Data centers 10 minutes
Direct current microgrids 10 hours
Drug stores/distribution centers 10 hours
Electrically driven or controlled irrigation machines 1 week
Elevators, dumbwaiters, escalators, moving walks, platform lifts, and stairway chairlifts See facility requirements
Emergency systems 10 hours
Energy storage systems 10 hours
Fire alarm systems 1 week
Fire houses/stations 10 hours
Fire pumps 10 hours
Food processing and storage facilities 10 hours
Fuel cell systems 10 hours
Generators 10 hours
Grocery stores 10 hours
Hardware stores/home centers 10 hours
Healthcare facilities See NFPA 99
Information technology equipment 10 minutes
Interconnected electric power production sources 10 minutes
Jails and prisons 10 minutes
Large-scale photovoltaic (PV) electric supply stations 10 hours
Legally required standby systems 10 hours
Modular data centers 10 minutes
Motor fuel dispensing facilities 1 week
Motors, motor circuits, and controllers See facility requirements
Nuclear reactors 10 seconds
Optional standby systems 1 week
Petrochemical plants/facilities 10 hours
Pharmaceutical plants/facilities 10 hours
Police stations 10 minutes
Solar photovoltaic (PV) systems 10 hours
Stand-alone systems 10 hours
Storage batteries See facility requirements
Transformers See facility requirements
Waste water treatment facilities 10 minutes
Water supply facilities 10 hours
Wind electric systems 10 hours

An effectivity date of January 1, 2026 is chosen to allow time for engineering and industry to adequately pan and prepare for the required changes.

Opponents of EMP protection requirements will likely charge that it is too costly to protect our critical infrastructure, and that the NEC® is not a war-time document. A close reading of 90.1 reveals that there is no mention of the “cost” of safeguarding persons and property. Neither does 90.1 mention that safeguarding persons and property is only required during peacetime. Additionally, a significant EMP event, caused by a sunspot, would be an act of God, not an act of war.

The novel, “One Second After”, provides an understanding of what happens when the majority of all unprotected electrical and electronic equipment/systems is destroyed during an EMP event. An audio version of this book is available in two parts, for free, on YouTube.

This link provides the unclassified report “Electromagnetic Pulse (EMP) Protection and Resilience Guidelines for Critical Infrastructure and Equipment”
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&ved=2ahUKEwjQhp2-77DoAhXBHM0KHboOB2QQFjACegQIBRAC&url=https%3A%2F%2Fwww.cisa.gov%2Fsites%2Fdefault%2Ffiles%2Fpublications%2F19_0307_CISA_EMP-Protection-Resilience-Guidelines.pdf&usg=AOvVaw2n7jLtJAUJtOJKHPMqWsTE

This link provides the study predicting up to 90% of our population could die from an EMP event
http://www.firstempcommission.org/uploads/1/1/9/5/119571849

/nuclear_emp_attack_scenarios_and_combined-arms_cyber_warfare_by_peter_pry_july_2017.pdf

This link provides unclassified guidelines for facility EMP protection
https://info.publicintelligence.net/DHS-FacilitiesGuidelinesEMP.pdf

These links provide Parts 1 and 2 of a national plan for EMP protection.
https://interferencetechnology.com/a-national-plan-for-emp-protection-part-1/
https://interferencetechnology.com/national-plan-emp-protection-part-2-protection-buildings/

We have all just witnessed the chaos and pain caused by not having the “protections” in place to quickly defeat the Covid-19 virus. As unfortunate, costly, painful, and deadly as Covid-19 was, it would be child’s play when compared to a significant EMP event if our critical electrical/electronic infrastructure remains unprotected. Quite simply, NEC® requirements to protect electrical and electronic equipment from an EMP event, could literally save millions of American lives.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 756-NFPA 70-2020 [New Section after 708.64]	
Public Input No. 756-NFPA 70-2020 [New Section after 708.64]	

Submitter Information Verification

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Submittal Date: Mon Mar 23 14:03:21 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: EMP protection, in much the same way as lightning protection, should not be a requirement for all electrical systems. EMP protection is a design issue and the safety hazard of not having EMP has not been adequately provided in the substantiation.

Public Input No. 2884-NFPA 70-2020 [New Section after 705.50]

705.55 Microgrid Commissioning.

Microgrid systems shall be commissioned upon installation per 110.17 to confirm system operation.

Statement of Problem and Substantiation for Public Input

Common requirements for device and system commissioning are being proposed to Article 110 in PI 2844 that will help drive consistency in the actions necessary prior to devices and systems being placed into service. This public input is part of a series of revisions proposed throughout the code to include commissioning where system verification is warranted.

Microgrid systems require setup and initial performance verification for devices and equipment necessary for proper system operation and safety to confirm the installation. In addition to verifying operational controls and sequence of operation, this revision also adds clarity that overcurrent and protective devices must have settings that have been adjusted and verified when inspected by the AHJ. The requirement to include as-built documentation and a record of the actions taken to correct any shortcomings will enhance the safety of those who will operate, maintain, and service the equipment.

The term commissioning is defined in 708.2 and applies throughout the code.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2844-NFPA 70-2020 [New Section after 110.16]	
Public Input No. 2894-NFPA 70-2020 [New Section after 712.4]	
Public Input No. 2887-NFPA 70-2020 [Definition: Commissioning.]	
Public Input No. 2894-NFPA 70-2020 [New Section after 712.4]	

Submitter Information Verification

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Submittal Date: Thu Sep 03 08:14:52 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: Since microgrids can vary dramatically in size and complexity, a broad requirement for commissioning is problematic for enforcement of this code. The better place for this requirement is in the installation instructions which are required to be followed by 110.3(B). The proposed language will likely result in a wide variety of interpretations that will not address the perceived issue.

Public Input No. 2539-NFPA 70-2020 [Section No. 705.50]

705.50 System Operation.

~~Microgrid~~ Microgrid systems shall be ~~permitted to disconnect from the~~ interconnected to and capable of operating in interactive mode with a primary source of power or ~~other interconnected~~ an electric power production and distribution network. Microgrid systems shall be permitted to disconnect from other sources and operate ~~as an isolated microgrid system operating~~ in island mode.

Informational Note: Microgrid systems often include a single or a compatible interconnection of sources such as engine generators, solar PV, wind, ESS, or batteries

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

Requirements in 705 Part 1 still apply. See 705.6 for listing of equipment. 705.14 for compatibility of parallel sources, 705.16 for SCC rating etc., 705.20 for disconnects, 705.28 for ampacities, 705.40 for loss of primary source, etc.

Submitter Information Verification

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Submittal Date: Mon Aug 24 12:29:48 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9411-NFPA 70-2021

Statement: This revision rewords the opening paragraph of microgrid systems to better reflect how these systems are operated. The revision clarifies that the intention of a microgrid to operate in interactive mode in general and is permitted to operate in island mode. “Electric utility and other” was added to emphasize that the electric utility is often the electric power production and distribution network to which this is connected.

The informational note is added to clarify that microgrids often include multiple interconnected sources.

Public Input No. 899-NFPA 70-2020 [Section No. 705.50]

705.50 System Operation.

Microgrid systems shall be permitted to disconnect from the primary source of power or other interconnected electric power production sources and operate as an isolated microgrid system operating in island mode.

Informational Note: For additional information about microgrids see NECA 417-2019, *Recommended Practice for Designing, Installing, Operating and Maintaining Microgrids.*

Statement of Problem and Substantiation for Public Input

The proposed informational note provides users with a reference that assists with increasing understanding of microgrid installations and how they work. Many in the electrical field are not very familiar with these systems. As these installations become more common, this quality performance standard provides valuable insight that assists with this understanding.

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Submittal Date: Tue Apr 21 13:29:39 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: The referenced document is not necessary to enforce the requirements in this section. This is only one of many documents that may assist on this complex issue.

Public Input No. 2540-NFPA 70-2020 [New Section after 705.70]

705.75 Direct-Current Ground-Fault Detection

In addition to the requirements of 250.167, functionally grounded power source output circuit conductors in microgrids operating at greater than 60 volts dc to ground shall have ground fault detection that indicates that a fault has occurred. The ground fault equipment shall be marked in accordance with 250.167(C).

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

The requirements found in 712.55 was moved to new article 705. The language was modified slightly recognizing that there is an additional expanded requirement beyond that which is a part of 250.167 requiring ground-fault current detection on grounded systems greater than 60V where as 250.167 only recognizes a permission for this detection and not a requirement for this detection. Furthermore, the specific circuit conductors are now referenced to ensure this requirement is applied to the correct portions of the microgrid, which also contain circuits within any connected sources (i.e. battery circuits within an ESS that would be covered in Article 480 or 706).

The references to Ungrounded and reference grounded dc microgrids which are a part of the original 712.55 are not included here because ground fault detection equipment is included for the different types of sources covered in other articles related to those sources. Part VIII of Article 250 addresses the other dc sources / applications.

Submitter Information Verification

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Submittal Date: Mon Aug 24 12:33:18 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9412-NFPA 70-2021

Statement: This revision duplicates the requirements found in Section 712.55 to Article 705. The language was modified recognizing that there is an additional expanded requirement beyond that which is a part of Section 250.167 requiring ground-fault current detection on grounded systems greater than 60V whereas Section 250.167 only recognizes a permission for this detection and not a requirement for this detection.

Furthermore, the specific circuit conductors are now referenced to ensure this requirement

is applied to the correct portions of the microgrid, which also contain circuits within any connected sources (i.e. battery circuits within an ESS that would be covered in Article 480 or 706).

The references to ungrounded and reference grounded dc microgrids which are a part of the original Section 712.55 are not included here because ground fault detection equipment is included for the different types of sources covered in other articles related to those sources. Part VIII of Article 250 addresses the other dc sources / applications.

Public Input No. 2541-NFPA 70-2020 [New Section after 705.70]

Part III Systems Operating in Island Mode

705.8 0 Power Source Capacity.

The sum of all sources capable of parallel operation in island mode shall have a capacity complying with 705.80(A), (B) or (C) in accordance with Article 220 or by another approved method.

I nformational Note: For general-use loads the system capacity can be calculated using the sum of the capacity of the firm sources, such as generators and ESS inverters. For specialty loads intended to be powered directly from a variable source, the capacity can be calculated using the sum of the variable sources, such as PV or wind inverters, or the combined capacity of both firm and variable sources.

(A) Automatic Load Management.

Where load management is controlled automatically, the system shall have adequate capacity and rating sufficient to supply the maximum load that will be connected by the load management system at one period of time.

(A) Manual Load Management.

Where load management is controlled manually, the system shall have adequate capacity and rating for the supply of all equipment intended to be operated at one time. The user of the system shall be permitted to select the load connected to the system.

A permanent label shall be applied to the distribution equipment containing branch circuit overcurrent protection devices supplied by the system operating in island mode that states the total system capacity available to supply loads continuously and contains the following or equivalent wording:

NOTICE: Equipment is supplied by a power system incapable of operating all loads at one time. Manual disconnection of loads is required for system to operate independent of a utility source.

Informational Note: The opening of switches or circuit breakers to select loads is a common method of controlling loads manually.

(C) No Load Management .

Where load management is not used, the system shall have adequate capacity and rating equal to or greater-than the full load that is connected when the system is operating in island mode.

705.81 Circuit Sizing and Protection.

The circuit conductors between a source capable of operating in island mode and a building or structure disconnecting means shall be sized based on the sum of the output ratings of the stand-alone source(s). For three-phase interconnections, the phase loads shall be controlled or balanced to be compatible with specifications of the sum of the power supply capacities.

705.82 Stand-Alone Systems with 120-Volt Supply.

Stand-alone systems shall be permitted to supply 120 volts to single-phase, 3-wire, 120/240-volt service equipment or distribution panels where there are no 240-volt outlets and where there are no multiwire branch circuits. In all installations, the sum of the ratings of the power sources shall be less than the rating of the neutral bus in the service equipment. This equipment shall be marked with the following words or equivalent:

WARNING:

SINGLE 120-VOLT SUPPLY. DO NOT CONNECT MULTIWIRE BRANCH CIRCUITS!

The warning sign(s) or label(s) shall comply with 110.21(B).

705.83 Energy Storage or Standby Power System Requirements.

Energy storage or standby power supplies shall not be required except where otherwise required in this Code.

705.84 Back-fed Circuit Breakers.

Plug-in-type back-fed circuit breakers connected to an interconnected supply shall be secured in accordance with 408.36(D). Overcurrent devices shall comply with 705.12(D).

705.85 Voltage and Frequency Control.

Power sources operating in island mode shall be controlled so that output voltage and frequency remain within suitable limits for the connected loads.

Statement of Problem and Substantiation for Public Input

This public input was prepared by the correlating committee task group focused on alternative energy requirements. This task group consisted of the following members: Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Thomas Domitrovich (CMP 2, CMP 10), Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

This new Part III is a part of the effort to merge the requirements of Article 710 with Article 705.
705.80:
The changes in 705.80 include new language to replace the previous 710.15(A) and is largely based on 702.4(B)(1)&(2). The creation of the three options of automatic load management, manual load management, and no load management establish important options that provide flexibility for the designer and transparency for the owner. For systems operating in Island Mode, this new Section builds upon the base established in Article 702 while maintaining flexibility without losing transparency as to what methods have been selected. The IN was moved from 710.15(A).

705.82:
The language in 705.82 is the same as that found in 710.15(B).

705.83:
Langauge from 710.15(C) was moved over with some minor changes to account for its new location within Article 705. The title was changed and there was a removal of isolated microgrid. Isolated microgrid is not a defined term nor system. This allowance has historically only been applied to small stand-alone systems.

705.84:
Language from 710.15(E) was moved here with a minor change. added end of sentence to recognize applications like emergency systems where this may be a requirement.

705.85:
Language from 710.15(F) was moved here.

705.86:
Language from 710.15(G) was moved here. Minor modifications were made to apply to all sources in island mode, not just stand-alone.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3012-NFPA 70-2020 [Section No. 702.4]	

Submitter Information Verification

Submitter Full Name: Thomas Domitrovich
Organization: Eaton Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Mon Aug 24 12:35:36 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9414-NFPA 70-2021

Statement: This revision creates a new Part III for systems operating in island mode. The power source capacity requirements are divided into three categories: automatic, manual, and no load management. Each of these categories have unique requirements for capacity of power sources. Power sources operating in island mode systems must operate within proper voltage and frequency for loads or cease to operate (Section 705.81). Section 705.82 is copied from 710.15(C) which deals with 120-volt supplies.

Public Input No. 2566-NFPA 70-2020 [New Section after 705.70]

Part IV. Systems Over 1000 Volts ac, or 1500 Volts dc.

705.100 General.

Power source output circuits with a maximum voltage between conductors of over 1000 volts ac shall comply with the requirements in this Code applicable to installations rated over 1000 volts. Power source output circuits with a maximum voltage between conductors of over 1500 volts dc shall comply with the requirements in this Code applicable to installations rated over 1500 volts dc.

705.101 Wiring Systems.

All raceway and cable wiring methods shall be installed according to the applicable Chapter 3 requirements. Other wiring systems and fittings specifically listed for use in microgrid or stand-alone systems, and wiring as part of a listed system shall be permitted. Where wiring devices with integral enclosures are used, sufficient length of cable shall be provided to facilitate replacement.

Statement of Problem and Substantiation for Public Input

This Public Input is submitted on behalf of two correlating committee task groups, (Medium Voltage Task Group and Alternative energy Task Group. These two task groups consist of the following members:

Medium Voltgage Task Group: Robert Osborne (Chair), Paul Barnhart, Lou Grahor, David Temple, Donny Cook, Dean Hunter, Mike Querry, Roger McDaniel, Dave Burns, Rod Belisle, and Kevin Rogers.

Alternative Energy Task group: Thomas Domitrovich (Chair), Derrick Atkins (CMP 5), Greg Ball (CMP 13)
Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

This Public Input, along with other companion Public Inputs, was developed with the goal of improving usability and providing a platform to increase the focus on requirements associated with Medium or High Voltage.

Submitter Information Verification

Submitter Full Name: Thomas Domitrovich
Organization: Eaton Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Mon Aug 24 17:55:58 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9417-NFPA 70-2021
Statement: This revision creates a new Part IV to provide increased focus on the parts of the Code that address these higher voltage circuits.

Public Input No. 2828-NFPA 70-2020 [Article 710]

~~**Article 710** Stand-Alone Systems~~

~~**710.1** Scope.~~

~~This article covers electric power production systems that operate in island mode and installations not connected to an electric power production and distribution network.~~

~~Informational Note: These systems are capable of operating in island mode, independent from an electric power production and distribution network, and include isolated microgrid systems or interactive with other power sources. Stand-alone systems often include a single or a compatible interconnection of sources such as engine generators, solar PV, wind, ESS, or batteries.~~

~~**710.6** Equipment Approval.~~

~~All equipment shall be approved for the intended use in accordance with one of the following:~~

(1) ~~Be listed for the application~~

(2) ~~Be evaluated for the application and have a field label applied~~

~~Informational Note: Inverters identified as "multimode" and "stand-alone" are specifically identified and certified to operate in this application. Stand-alone inverters operate in island mode. Multimode inverters operate in either island mode (previously called "stand-alone mode") or interactive mode, if it has been installed with the optional utility grid connection. A multimode inverter will only operate in island mode if it is never connected to an electric utility supply. Stand-alone inverters are not evaluated for and are not intended for connection to export power in parallel with an electric utility.~~

~~**710.10** Identification of Power Sources.~~

~~A permanent plaque or directory shall be installed at a building supplied by a stand-alone system at each service equipment location, or at an approved readily visible location. The plaque or directory shall denote the location of each power source disconnecting means for the building or be grouped with other plaques or directories for other on-site sources. Where multiple sources supply the building, the plaque or directory shall be marked with the wording "CAUTION: MULTIPLE SOURCES OF POWER." The marking shall comply with 110.21(B) .~~

~~*Exception: Installations with multiple co-located power production sources shall be permitted to be identified as a group(s). The plaque or directory shall not be required to identify each power source individually.*~~

~~**710.12** Stand-Alone Inverter Input Circuit Current.~~

~~The maximum current shall be the stand-alone continuous inverter input current rating when the inverter is producing rated power at the lowest input voltage.~~

~~**710.15** General.~~

~~Premises wiring systems shall be adequate to meet the requirements of this *Code* for similar installations supplied by a feeder or service. The wiring on the supply side of the building or structure disconnecting means shall comply with the requirements of this *Code* , except as modified by 710.15(A) through (G).~~

~~**(A)** Supply Output.~~

~~Power supply to premises wiring systems fed by stand-alone or isolated microgrid power sources shall be permitted to have less capacity than the calculated load. The capacity of the sum of all sources of the stand-alone supply shall be equal to or greater than the load posed by the largest single utilization equipment connected to the system. Calculated general lighting loads shall not be considered as a single load.~~

> ~~Informational Note: For general-use loads the system capacity can be calculated using the sum of the capacity of the firm sources, such as generators and ESS inverters. For specialty loads intended to be powered directly from a variable source, the capacity can be calculated using the sum of the variable sources, such as PV or wind inverters, or the combined capacity of both firm and variable sources.~~

~~**(B)** Sizing and Protection.~~

~~The circuit conductors between a stand-alone source and a building or structure disconnecting means shall be sized based on the sum of the output ratings of the stand-alone source(s). For three-phase interconnections, the phase loads shall be controlled or balanced to be compatible with specifications of the sum of the power supply capacities.~~

~~**(C)** Single 120-Volt Supply.~~

~~Stand-alone and isolated microgrid systems shall be permitted to supply 120 volts to single-phase, 3-wire, 120/240-volt service equipment or distribution panels where there are no 240-volt outlets and where there are no multiwire branch circuits. In all installations, the sum of the ratings of the power sources shall be less than the rating of the neutral bus in the service equipment. This equipment shall be marked with the following words or equivalent:~~

~~WARNING:~~

~~SINGLE 120-VOLT SUPPLY. DO NOT CONNECT MULTIWIRE BRANCH CIRCUITS!~~

~~The warning sign(s) or label(s) shall comply with 110.21(B) .~~

~~**(D)** Three-phase Supply.~~

~~Stand-alone and microgrid systems shall be permitted to supply three-phase, 3-wire or 4-wire systems.~~

~~**(E)** Energy Storage or Backup Power System Requirements.~~

~~Energy storage or backup power supplies shall not be required.~~

~~**(F)** Back-fed Circuit Breakers.~~

~~Plug-in-type back-fed circuit breakers connected to an interconnected supply shall be secured in accordance with 408.36(D) . Circuit breakers marked “line” and “load” shall not be backfed.~~

~~**(G)** Voltage and Frequency Control.~~

~~The stand-alone or isolated microgrid supply shall be controlled so that voltage and frequency remain within suitable limits for the connected loads.~~

Statement of Problem and Substantiation for Public Input

This Public Input is submitted on behalf of two correlating committee task groups, (Medium Voltage Task Group and Alternative energy Task Group. These two task groups consist of the following members: Medium Voltgage Task Group: Robert Osborne (Chair), Paul Barnhart, Lou Grahor, David Temple, Donny Cook, Dean Hunter, Mike Querry, Roger McDaniel, Dave Burns, Rod Belisle, and Kevin Rogers. Alternative Energy Task group: Thomas Domitrovich (Chair), Derrick Atkins (CMP 5), Greg Ball (CMP 13) Ken Boyce (CMP 1), Bill Brooks (CMP 4), Bruce Campbell, Jason Fisher (CMP 4), Scott Harding (CMP 5), Pete Jackson (CMP 8), David Kendall (CMP 8, CC), Chad Kennedy (CMP 13), Christine Porter (CMP 5, CC), Timothy Windey (CMP 13).

This article is being deleted since the relevant requirements within it are being moved into Article 705, new Part III. The interconnection of power sources has always been covered under Article 705 and many stand-alone systems, and all microgrids, will have multiple power sources interconnected together.

Furthermore, the use of the term stand-alone within this Code has become confusing thus making the application of this Article unclear to many users. By moving this content into Article 705, users of this Code will have greater clarity what requirements should be placed on both stand-alone systems and microgrid systems capable of operating in island mode when their interactive connection to utility sources is not maintained.

The attached word document provides an overview of all of the changes in this effort to assemble a general requirements article for alternative energy applications. Each section in Article 710 was addressed and is shown as such to help the Code Panel account and verify each item being removed here has indeed been addressed by the task group.

Submitter Information Verification

Submitter Full Name: Thomas Domitrovich
Organization: Eaton Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 01 19:01:34 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: The scope of the article is restricted to systems only operating independently from the utility. There is no need to delete the entire article at this time.

Public Input No. 1955-NFPA 70-2020 [Section No. 710.1]

710.1 Scope.

This article covers installations of electric power production systems that operate in island mode and ~~installations~~ are not connected to an electric power production and distribution network.

Informational Note No. 1 : These systems are capable of operating in island mode, independent from an electric power production and distribution network, and include isolated microgrid systems or interactive with other power sources. Stand-alone systems often include a single or a compatible interconnection of sources such as engine generators, solar PV, wind, ESS, or batteries.

Informational Note No. 2 : See Article 702 for more information on electric power production sources that can operate as optional standby systems.

Statement of Problem and Substantiation for Public Input

Clarity needs to be provided to the scope of Article 710 that a stand alone system is an electric power production system that operates 100% of the time in an off-grid application and no component of the system is connected to a utility source. A multimode inverter that can island upon the loss of the normal source of power would be an optional standby system. An optional standby system is defined as "Those systems intended to supply power to public or private facilities or property where life safety is not depend on the performance of the system. These systems are intended to supply on-site generated or stored power to selected loads either automatically or manually." A new informational note will provide guidance for code users that Article 702 has purview for Optional Standby Systems.

Submitter Information Verification

Submitter Full Name: Brian Baughman
Organization: Generac Power Systems Inc.
Street Address:
City:
State:
Zip:
Submittal Date: Tue Jul 21 10:13:56 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9420-NFPA 70-2021

Statement: The scope of Article 710 is recommended to the Correlating Committee to be restricted to only those systems that only operate in island mode and cannot be interconnected to the electric utility or other power production and distribution network. Power sources that operate in island mode and operate interconnected to the electric utility and other power sources are covered in Article 705 and power sources that only operate in standby mode are covered by Article 702.

Informational Note No. 2 and the diagrams are added to Section 710.1 to illustrate various terms used in Article 710 for a variety of power sources.

Public Input No. 2200-NFPA 70-2020 [Section No. 710.1]

710.1 Scope.

This article covers electric power production systems that operate in ~~island mode and~~ installations not connected to an electric utility power production and distribution network.

Informational Note: These systems are capable of ~~operating in island mode,~~ operating independent from an electric utility power production and distribution network, and include isolated microgrid systems or interactive with other power sources. Stand-alone systems often include a single or a compatible interconnection of sources such as engine generators, solar PV, wind, ESS, or batteries.

Statement of Problem and Substantiation for Public Input

Removing Island Mode from the Scope corolates the article for the installation and use. When there is an electric utility -power production connection, it is not possible to operate in Stand Alone Mode. The Grounded Conductor of any Serving Utility annuls the applying Stand Alone. The Grounded Conductor Connection is common to a PV, ESS, Wind or Battery system.

Unless there is a at minimum of a UL 1008 Automatic Transfer Switch that Switches the Grounded Conductor there by creating a Separately Derived System, any interconnection of any other system is not operating independently of the electric serving utility.

Island Mode is not an accurate application for 710.

Submitter Information Verification

Submitter Full Name: James Hathorn
Organization: City Of Irving
Street Address:
City:
State:
Zip:
Submittal Date: Sat Aug 08 22:36:41 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9420-NFPA 70-2021

Statement: The scope of Article 710 is recommended to the Correlating Committee to be restricted to only those systems that only operate in island mode and cannot be interconnected to the electric utility or other power production and distribution network. Power sources that operate in island mode and operate interconnected to the electric utility and other power sources are covered in Article 705 and power sources that only operate in standby mode are covered by Article 702.

Informational Note No. 2 and the diagrams are added to Section 710.1 to illustrate various terms used in Article 710 for a variety of power sources.

Public Input No. 3116-NFPA 70-2020 [Section No. 710.6]

710.6 Equipment Approval.

All equipment shall be approved for the intended use in accordance with one of the following:

(1) Be listed for the application

(2) Be evaluated for the application and have a field label applied

Informational Note: Inverters identified as “multimode” and “stand-alone” are specifically identified and certified to operate in this application. Stand-alone inverters operate in island mode. Multimode inverters operate in either island mode (previously called “stand-alone mode”) or interactive mode, if it has been installed with the optional utility grid connection. A multimode inverter will only operate in island mode if it ~~is never connected to an electric~~ is disconnected from the electric utility supply. Stand-alone inverters are not evaluated for and are not intended for connection to export power in parallel with an electric utility.

Statement of Problem and Substantiation for Public Input

The way the informational note was worded seemed confusing/contradictory to what was stated previously. A better way to word it would be to say that when in island mode, the inverter is always disconnected from the electric utility supply.

Submitter Information Verification

Submitter Full Name: Laurie Florence
Organization: UL LLC
Street Address:
City:
State:
Zip:
Submittal Date: Fri Sep 04 19:02:45 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9421-NFPA 70-2021
Statement: The informational note is edited for clarity and for consistency with the revised scope of the article.

Public Input No. 3820-NFPA 70-2020 [Section No. 710.6]

710.6 Equipment Approval.

All equipment shall be approved for the intended use in accordance with one of the following:

(1) Be listed for the application

(2) Be evaluated for the application and have a field label applied

Informational Note: Inverters identified as “multimode” and “stand-alone” are specifically identified and certified to operate in this application. Stand-alone inverters operate in island mode. Multimode inverters operate in either island mode ~~(previously called “stand-alone mode”)~~ or interactive mode, if it has been installed with the optional utility grid connection. A multimode inverter will only operate in island mode ~~if it is never connected to~~ where not operating in parallel with an electric utility supply. ~~Stand~~ Inverters identified only for stand-alone ~~inverters are~~ applications are not evaluated for and are not intended for connection to export power in parallel with an electric utility.

Statement of Problem and Substantiation for Public Input

This informational note language should be modified to more accurately describe how multimode inverters are certified, installed and operated. The use of the phrase “never connected” in the original text can cause confusion when applied to multimode inverters. Changes to the last sentence are made to further clarify the specific applications these inverters are evaluated for. The parenthetical text was removed as it is unnecessary since it refers to text used in older NFPA-70 revisions.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF’s effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI’s as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI’s submitted.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain, P.E., SEIA; Bill Brooks, PVICC; John Berdner, PVICC, Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing, Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower; Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Ben Chamberlain, Olivewood Energy; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson;

Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.; Michael Heinrich, PanelClaw, Inc.; Steve Wurmlinger, SMA Solar Technology AG; Thomas Wegener, SMA Solar Technology AG; Chris Flueckiger, Key Renewables; Matt Piantedosi, Ridgeline Energy Analytics; Samantha Doshi, Intertek; Kyle Breuning, Tesla; Charles Picard, Tesla; Steve Connolly, Tesla; Greg Ball, Tesla; Jake West, Tesla; Jamie Daggett, DNV GL; MinWah Leung, DNV GL; Bob White, Fimer SpA; Marvin Hamon, Pure Power Engineering; Milton Nogueira, Roof Tech; Peter Seidel, First Solar; Jason Smolko, Copperweld;

Submitter Information Verification

Submitter Full Name: Evelyn Butler
Organization: Solar Energy Industries Assn
Affiliation: PV Industry Forum (PVIF)
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 09 13:39:23 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9421-NFPA 70-2021
Statement: The informational note is edited for clarity and for consistency with the revised scope of the article.

Public Input No. 4100-NFPA 70-2020 [New Section after 710.10]

TITLE OF NEW CONTENT

Type your content here ...

710.11. Emergency Disconnects. For one- and two-family dwellings, each power source including PV systems, wind systems, batteries, energy storage systems, fuel cells, and hydropower systems shall have an emergency disconnecting means or shutdown means meeting (the following:

(A) Be located in a readily accessible and visible location outside the building.

(B) Be located within 1 m (3 ft) of all other emergency disconnecting or shutdown means and the plaque required by 710.10.

(C) If controlled remotely, the control system shall be “fail safe” where disconnects shall automatically open or the power source be automatically disabled on loss or control power or control signal.

Statement of Problem and Substantiation for Public Input

This proposal is one of several related, but separate proposals involving the 2020 NEC requirements for external (outside the building) emergency disconnects on one- and two-family dwellings for energy sources such as the utility service, batteries, energy storage systems (ESS), wind systems and also stand-alone PV systems plus PV rapid shutdown systems. The intent of these proposals is to establish uniform requirements where there is more than one of these emergency disconnects, that all such disconnects be grouped in one location to increase safety for Fire Service first responders.

Also, when remote activation of these disconnects is allowed, the proposal establishes an additional safety requirement that the remote controls be fail safe and in the event of loss of control power or control signal, the emergency disconnect shall automatically be opened. It has been determined that some inverter manufacturers are already starting to put inputs on their products to allow an external remote shutdown control system that is fail safe. Also, it has been determined that adding such a fail-safe remotely controlled emergency disconnect system is relatively inexpensive using voltage-trip circuit breakers and a relay on large battery banks or ESS.

Submitter Information Verification

Submitter Full Name:	John Wiles
Organization:	Southwest Technology Development Institute, New Mexico State University
Street Address:	
City:	
State:	
Zip:	
Submittal Date:	Wed Sep 09 20:41:33 EDT 2020
Committee:	NEC-P04

Committee Statement

Resolution: There is no need to provide an “emergency disconnect” for a stand-alone system connected to a one- and two-family dwelling. The identification of the power source in

710.10 is sufficient. The use of term “emergency” in this Code is inconsistent.

Public Input No. 3792-NFPA 70-2020 [Section No. 710.10]

710.10 Identification of Power Sources.

A permanent plaque or directory shall be installed at a building supplied by a stand-alone system at each service equipment location, or at an approved readily visible location. The plaque or directory shall denote the location of ~~each power~~ the stand-alone power source disconnecting means for the building~~ or be grouped with other plaques or directories for other on-site sources~~ . Where multiple sources supply the building, ~~the plaque or directory shall be marked with the wording "CAUTION: MULTIPLE SOURCES OF POWER." The marking shall comply with 110.21(B)~~ .

~~*Exception: Installations with multiple co-located power production sources shall be permitted to be identified as a group(s). The plaque or directory shall not be required to identify each power source individually.*~~

markings shall comply with 705.10.

Statement of Problem and Substantiation for Public Input

This PI has no impact on installation requirements or enforcement, it is merely a simplification of the text to shorten the Code by redirecting to the requirements of 705.10 instead of replicating the 705.10 language in 710. This avoids the need to duplicate or perfectly synchronize the language as changes occur in 705.10.

The PV Industry Forum (PVIF) is a collaborative initiative of several organizations dedicated to continually improving the installation safety of PV systems in the U.S. The organizations are the Solar Energy Industry Association (SEIA), the PV Industry Codes Council (PVICC), Solar Energy International (SEI), the Interstate Renewable Energy Council (IREC), and the Large-Scale Solar Association (LSA). This coalition has come together to organize, convene, support and mentor solar industry professionals through the NEC public input process, which is open to all solar industry participants.
This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI's submitted.
Evelyn Butler, SEIA; Jason Fisher, SEIA; Ward Bower, Ward Bower Innovations LLC/SEIA; Joseph Cain, P.E., SEIA; Bill Brooks, PVICC; John Berdner, PVICC, Rebekah Hren, Solar Energy International; Brian Mehalic, Solar Energy International; Mark Rodriguez, Sunrun; Paul Joyce, Sunrun; Brian Ewing, Swinerton; Sumana Seshadri, Swinerton; Christian Eder, Fronius USA; Isaac Opalinsky, SunPower; Chris Fox, SunPower; James Cormican, RBI Solar; Dave Compaan, RBI Solar; Shawn Shaw, Natural Power; Cody Oram, Vivint Solar; Greg Elvestad, Vivint Solar; Mike Weimer, Westwood Professional Services; Doug Mutcher, Westwood Professional Services; Jeff Wang, Staubli; Colleen O'Brien, UL; John Doty, UL; Laurie Florence, UL; Tim Zgonena, UL ; Gokul Kalyan, FTC Solar; Ali Sedaghat, FTC Solar; K.C. Radford, Radian Generation; Jan Dominguez, LG Electronics; Ben Chamberlain, Olivewood Energy; Klaus Nicolaedis, Unirac Inc.; Leif Cook, Core Development Group; Martin Herzfeld, Herzfeld; Dave Click, esaSolar; Sean White, principal; Kate Collardson, BayWa r.e. Solar Systems; Bryan Holland, NEMA; Jack Lyons, NEMA; Mike Stone, NEMA; Evan Martin, BURNDY; Terry McKinch, Mortenson; Jason Bobruk, SolarEdge Technologies; Reid ; train, Savion; Charlie Dearie, McCalmont Engineering; Sumanth Lokanath, Ray Illuminati LLC; Yann Schwarz, Esdec Inc.; Joseph Armano, PanelClaw, Inc.;

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Submittal Date: Wed Sep 09 12:55:24 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9422-NFPA 70-2021

Statement: The language is simplified with a reference to 705.10 for buildings with multiple power sources. Also, the reference to service equipment is removed since some stand-alone systems will have no service equipment since they are often installed where there is no utility service. The term “label” is added to the list of options for signage as some may believe that placards are too restrictive of good sign options.

Public Input No. 4184-NFPA 70-2020 [Section No. 710.15(A)]

(A) Supply Output.

Power supply to premises wiring systems fed by stand-alone or isolated microgrid power sources ~~shall be permitted to have less capacity than~~ shall have capacity to meet the calculated load ~~.~~ ~~The capacity of the sum of all sources of the stand-alone supply shall be equal to or greater than the load posed by the largest single utilization equipment connected to the system. Calculated general lighting loads shall not be considered as a single load.~~

~~Informational Note: For general-use loads the system capacity can be calculated using the sum of the capacity of the firm sources, such as generators and ESS inverters. For specialty loads intended to be powered directly from a variable source, the capacity can be calculated using the sum of the variable sources, such as PV or wind inverters, or the combined capacity of both firm and variable sources.~~

in accordance with Article 220.

.

Statement of Problem and Substantiation for Public Input

Any system sizing must be based upon the calculated loads of a system. Sizing a Power Supply system based upon a single load of a premises wiring system is inadequate and problematic. There are not any permissions for under sizing a power supply. Optional Stand By Systems must be sized using Full Load Scenarios with an Automatic Transfer.

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Committee: NEC-P04

Committee Statement

Resolution: The sizing of a power source for a stand-alone system need only be large enough to operate all the loads intended to be run at one time. It must be large enough to run the largest single load, but there is no safety issue involved if it is only large enough for that one load if the user only decides to run that single largest connected load. Article 220 is not necessary for these types of systems and often causes significant oversizing of power systems making the application uneconomical without providing additional safety. Article 220 is for sizing systems for loads, not for power sources.

Public Input No. 4382-NFPA 70-2020 [Section No. 710.15(A)]

~~**(A)** Supply Output.~~

~~Power supply to premises wiring systems fed by stand-alone or isolated microgrid power sources shall be permitted to have less capacity than the calculated load. The capacity of the sum of all sources of the stand-alone supply shall be equal to or greater than the load posed by the largest single utilization equipment connected to the system. Calculated general lighting loads shall not be considered as a single load.~~

~~Informational Note: For general-use loads the system capacity can be calculated using the sum of the capacity of the firm sources, such as generators and ESS inverters. For specialty loads intended to be powered directly from a variable source, the capacity can be calculated using the sum of the variable sources, such as PV or wind inverters, or the combined capacity of both firm and variable sources.~~

Statement of Problem and Substantiation for Public Input

Delete this section. Sizing loads should be governed by Article 220 and not by this section. In addition the code text as presently written is unclear about its overall intent. What does it mean when the calculated "general lighting loads shall not be considered as a single load." Why is this important? Why is lighting not to be considered a single load and not other equipment? Why should the "capacity of the sum of all sources of the stand-alone supply shall be equal to or greater than the load posed by the largest single utilization equipment connected to the system"? This language should be rewritten to its clear intent.

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Committee: NEC-P04

Committee Statement

Resolution: The sizing of a power source for a stand-alone system need only be large enough to operate all the loads intended to be run at one time. It must be large enough to run the largest single load, but there is no safety issue involved if it is only large enough for that one load if the user only decides to run that single largest connected load. Article 220 is not necessary for these types of systems and often causes significant oversizing of power systems making the application uneconomical without providing additional safety.

Public Input No. 3847-NFPA 70-2020 [Section No. 710.15(F)]

~~(F)~~ ~~Back-fed Circuit Breakers.~~

~~Plug-in-type back-fed circuit breakers connected to an interconnected supply shall be secured in accordance with 408.36(D) . Circuit breakers marked "line" and "load" shall not be backfed.~~

Statement of Problem and Substantiation for Public Input

The requirements in 408.36(D) may apply to some breakers in a stand-alone system (i.e. a back-fed breaker supplying a load center), but not to others (i.e. the connection of a utility interactive inverter). Deleting this section does not alter the requirements in the Code but does remove potential confusion as-to when the retainer in 408.36(D) must be used. Language addressing when circuit breakers are suitable for reverse current is included in 705.12(D), which is the correct Article for this requirement as it applies where there are interactive sources.

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This collaborative effort has resulted in the consensus development of numerous solar-related Public Input proposals for consideration. The list of task group members indicates those individuals who have contributed to the development of various Public Inputs in nine different tasks groups. A consensus process was used to develop each Public Input, therefore this list does not necessarily indicate that each individual or their representative organization participated in or has agreed with every proposed Public Input submitted under the PVIF effort. Each participant has agreed that any original proposal that they submitted and which was subsequently improved by our process is assigned as original and / or improved work to PVIF for submittal and release to NFPA as a proposed Public Input.
Members of the PVIF's effort include the following representatives. Note that those noted below participated in specific task groups and not necessarily all task groups on specific items proposed. Each member is at their discretion to individually comment on PI's as they deem appropriate and their inclusion here is not necessarily an endorsement of all the PI's submitted.
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Committee: NEC-P04

Committee Statement

Resolution: FR-9424-NFPA 70-2021
Statement: The section is deleted as it does not modify the requirements of Section 408.36(D).

Public Input No. 777-NFPA 70-2020 [New Section after 710.15(G)]

TITLE OF NEW CONTENT

Type your content here ...

710.20 Electromagnetic Pulse (EMP) Protection. Protection for stand-alone systems against the effects of electromagnetic pulses shall be provided at a minimum of Level 2. See 709.7 for levels of electromagnetic pulse protection.

Exception: The requirements of 709.7(A)(5) and 709.7(B)(3) shall not apply.

This requirement shall become effective January 1, 2026.

Statement of Problem and Substantiation for Public Input

A devastating electromagnetic pulse (EMP), caused by a sun-spot or a nuclear bomb exploded high in the atmosphere, can impress 50,000 volts per meter on unprotected electrical and electronic equipment. It is similar to a radio wave impressing a very small voltage on a radio antenna, only orders of magnitude larger. The problem is that a significant EMP will fry every electrical/electronic component or piece of equipment that is not protected.

The EMP won't directly harm or injure people, but because there is no longer a working electrical infrastructure, which may take years to repair/rebuild, people will die from the lack of clean water, medicine, food, fuel, and eventual rioting due to the breakdown of society. Unclassified studies, referenced at the end of this substantiation, have estimated from 66% to 90% of the US population will die within one year if a significant sun spot were to occur or if a nuclear explosion were to occur 25 to 250 miles over the Midwest.

Our US military already "hardens" systems/buildings so that our country's critical defensive capabilities are not completely destroyed. There are two major methods of protecting electrical/electronic systems. The first is that surge protective devices are installed on all "incoming" power and communications cables, shunting overvoltages to ground. The second is that Faraday cages are installed around equipment/rooms, preventing the EMP from reaching critical equipment/components.

The NEC® needs to address EMP protection for equipment, systems and special occupancies that are critical to our survival. Electrical and electronic equipment can and must be protected, as has been achieved by our military. Unfortunately, there are no requirements to protect civilian electrical and electronic equipment/systems from EMPs.

The NEC Correlating Committee has informally advised that an EMP Protection Article, if passed and adopted into the NEC®, would be most appropriately located after Article 708 (COPS). Thus, Public Input 756 has suggested a new Article 709 under jurisdiction of CMP 13, which already has purview over Emergency Systems (Article 700), Legally Required Standby Systems (Article 701), Optional Standby Systems (Article 702), and Critical Operations Power Systems (Article 708).

Levels of protection and associated protection requirements listed in the Public Input(s) are based upon the unclassified National Cybersecurity and Communications Integration Center report "Electromagnetic Pulse (EMP) Protection and Resilience Guidelines for Critical Infrastructure and Equipment". This study explains electromagnetic pulses and provides the necessary protective measures. It also contains estimates of the costs associated with properly protecting our electrical infrastructure.
The following table contains critical infrastructure components/special occupancies and the maximum time for outages caused by an EMP. Electrical components/infrastructure that is not functioning for periods longer than shown in this table may begin to cause injury or death to people and harm to society/economy.
Critical Infrastructure Component/Special Occupancy Permitted Outage Time
Branch banking facilities 10 hours

Critical Operations Power Systems 10 minutes
Data centers 10 minutes
Direct current microgrids 10 hours
Drug stores/distribution centers 10 hours
Electrically driven or controlled irrigation machines 1 week
Elevators, dumbwaiters, escalators, moving walks, platform lifts, and stairway chairlifts See facility requirements
Emergency systems 10 hours
Energy storage systems 10 hours
Fire alarm systems 1 week
Fire houses/stations 10 hours
Fire pumps 10 hours
Food processing and storage facilities 10 hours
Fuel cell systems 10 hours
Generators 10 hours
Grocery stores 10 hours
Hardware stores/home centers 10 hours
Healthcare facilities See NFPA 99
Information technology equipment 10 minutes
Interconnected electric power production sources 10 minutes
Jails and prisons 10 minutes
Large-scale photovoltaic (PV) electric supply stations 10 hours
Legally required standby systems 10 hours
Modular data centers 10 minutes
Motor fuel dispensing facilities 1 week
Motors, motor circuits, and controllers See facility requirements
Nuclear reactors 10 seconds
Optional standby systems 1 week
Petrochemical plants/facilities 10 hours
Pharmaceutical plants/facilities 10 hours
Police stations 10 minutes
Solar photovoltaic (PV) systems 10 hours
Stand-alone systems 10 hours
Storage batteries See facility requirements
Transformers See facility requirements
Waste water treatment facilities 10 minutes
Water supply facilities 10 hours
Wind electric systems 10 hours

An effectivity date of January 1, 2026 is chosen to allow time for engineering and industry to adequately pan and prepare for the required changes.

Opponents of EMP protection requirements will likely charge that it is too costly to protect our critical infrastructure, and that the NEC® is not a war-time document. A close reading of 90.1 reveals that there is no mention of the “cost” of safeguarding persons and property. Neither does 90.1 mention that safeguarding persons and property is only required during peacetime. Additionally, a significant EMP event, caused by a sunspot, would be an act of God, not an act of war.

The novel, “One Second After”, provides an understanding of what happens when the majority of all unprotected electrical and electronic equipment/systems is destroyed during an EMP event. An audio version of this book is available in two parts, for free, on YouTube.

This link provides the unclassified report “Electromagnetic Pulse (EMP) Protection and Resilience Guidelines for Critical Infrastructure and Equipment”
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&ved=2ahUKEwjQhp2-77DoAhXBHM0KHboOB2QQFjACegQIBRAC&url=https%3A%2F%2Fwww.cisa.gov%2Fsites%2Fdefault%2Ffiles%2Fpublications%2F19_0307_CISA_EMP-Protection-Resilience-Guidelines.pdf&usg=AOvVaw2n7jLtJAUJtOJKHPMqWsTE

This link provides the study predicting up to 90% of our population could die from an EMP event
http://www.firstempcommission.org/uploads/1/1/9/5/119571849

/nuclear_emp_attack_scenarios_and_combined-arms_cyber_warfare_by_peter_pry_july_2017.pdf

This link provides unclassified guidelines for facility EMP protection
https://info.publicintelligence.net/DHS-FacilitiesGuidelinesEMP.pdf

These links provide Parts 1 and 2 of a national plan for EMP protection.
https://interferencetechnology.com/a-national-plan-for-emp-protection-part-1/
https://interferencetechnology.com/national-plan-emp-protection-part-2-protection-buildings/

We have all just witnessed the chaos and pain caused by not having the “protections” in place to quickly defeat the Covid-19 virus. As unfortunate, costly, painful, and deadly as Covid-19 was, it would be child’s play when compared to a significant EMP event if our critical electrical/electronic infrastructure remains unprotected. Quite simply, NEC® requirements to protect electrical and electronic equipment from an EMP event, could literally save millions of American lives.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 756-NFPA 70-2020 [New Section after 708.64]	
Public Input No. 756-NFPA 70-2020 [New Section after 708.64]	

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Submittal Date: Mon Mar 23 16:11:09 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: EMP protection, in much the same way as lightning protection, should not be a requirement for all electrical systems. EMP protection is a design issue and the safety hazard of not having EMP has not been adequately provided in the substantiation.

Public Input No. 3915-NFPA 70-2020 [Section No. 710.15(G)]

(G) Voltage and Frequency Control.

The stand-alone or isolated microgrid supply shall be controlled so that voltage and frequency ~~remain within suitable limits for the~~ operate within limits compatable with the connected loads and sources .

Informational Note: Electric power production systems generally operate within +/-10% for voltage and +/-2 Hz for frequency under normal operating conditions.

Statement of Problem and Substantiation for Public Input

This IN provides additional guidance if an AHJ wished to validate the base functionality of the assembled system in the field to ensure it maintains appropriate voltage and frequency levels for common loads.

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Committee: NEC-P04

Committee Statement

Resolution: FR-9425-NFPA 70-2021
Statement: Section is edited for clarity and for consistency with the constrained scope. The word “remain” is changed to “operate” to clarify that the need to stay in the proper range is only necessary when operating. An option of a stand-alone power source is to cease to operate.

Public Input No. 3348-NFPA 70-2020 [Definition: Grounded, Functionally.]

This definition shall be relocated to Article 100. This identical definition is also found in Article 690. The revised Style Manual requires panel action to only have one definition.

Grounded, Functionally.

A system that has an electrical ground reference for operational purposes that is not solidly grounded.

Informational Note: Examples of operational reasons for functionally grounded systems include ground-fault detection and performance-related issues for some power sources.

Statement of Problem and Substantiation for Public Input

The identical definition for "Grounded, Functionally" is also used in Article 690.
This term may not be used elsewhere in the code and could apply for the entire document.
Review the Style Manual revisions for definitions and acronyms. 2.2.2.4 Terms with Multiple Definitions.

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Submittal Date: Tue Sep 08 08:59:24 EDT 2020
Committee: NEC-P04

Committee Statement

Resolution: FR-9324-NFPA 70-2021

Statement: This revision moves all definitions previously in Section 2 of Articles 690, 692, 694 and 705 to Article 100.

The NEC Style Manual also requires that for definitions that apply in only one article, the article number in parentheses shall follow the definition.

CMP-4 identified the following definitions that apply to only one article:

690: AC Module System, AC Module, Array, Direct-Current Combiner, Module, Monopole Circuit, PV Output Circuit, PV Source Circuit, PV System DC Circuit.

692: Fuel Cell Output Circuit

694: Maximum Output Power, Maximum Voltage, Nacelle, Rated Power, Tower, Wind Turbine Output Circuit.

These have been moved to Article 100 with the relevant article number appended. All other definitions have been moved with no article number identified.

All definitions were moved with the annotation (CMP-4) appended to indicate the code

panel responsible for the definition in accordance with NEC Style Manual Section 2.2.2.3.3.