Significant Code Changes in 2014 NEC Articles 690 and 705 affecting the installation of Solar Photovoltaic (PV) Systems

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When looking at any premises power production system, such as solar photovoltaic (PV) systems, that are going to operate in parallel with a utility supplied source, the requirements of Article 705 need to be complied with to make the system safe. Section 705.4 states that all equipment shall be approved for the intended use and specifically requires utility-interactive inverters used for interconnection systems be listed and identified for interconnection service. Section 705.10 requires a permanent plaque or directory noting all electric power sources on or in the premises. This plaque or directory must be installed at each location of service equipment and at locations of all electric power production sources capable of being interconnected.

The heart of Article 705 is section 705.12 which lays out the requirements for where and how the interconnection of systems can occur. When talking about PV systems, we would want to look at 705.12(D) because more than likely a utility interactive inverter will be used. Section 705.12(D) has been reorganized for the 2014 NEC to provide better clarity. Section 705.12(D)(1) requires that the source interconnection point for inverter(s) installed in a system shall be made at a dedicated circuit breaker or fusible disconnecting means. Section 705.12(D)(2) adds requirements for sizing ampere rating for buses and conductors and was broken up into three parts for the 2014 NEC (Feeders, Taps, and Busbars). It tells us that 125 percent of the inverter output circuit current shall be used in ampacity calculations for 705.12(D) and lays out requirements for four different situations:

Item one tells us how to size feeders where the inverter output connection is made to a feeder at a location other than the opposite end of the feeder from the primary source overcurrent device. The NEC gives a choice of having the feeder sized not less than the sum of the primary source overcurrent device and 125 percent of the inverter output circuit current or having an overcurrent device on the load side of the inverter connection rated no more than the ampacity of the feeder.

Item two tells us how to size conductors that are tapped to a feeder connected to the inverter output. The taps are to be sized per 240.21(B) plus 125 percent of the inverter output circuit current.

Item three gives us four methods for determining the ratings of busbars in panelboards. This is a very common way to tie in PV systems' inverters into a premises wiring system. The first and most common option is that the busbar of the panel be rated for the sum of 125 percent of the inverter(s) output circuit current and the rating of the overcurrent device protecting the busbar. The second method allows for the sum of 125 percent of the inverter(s) output circuit current and the rating of the overcurrent device protecting the busbar to exceed of the ampacity of the busbar but not more than 120 percent of the busbar's rating. It also requires that the two sources, one a utility and the other an inverter, are located at opposite ends of a busbar where the busbar also serves loads. If you are using this option, a permanent warning label shall be applied to the distribution equipment adjacent to the backfed breaker from the inverter that stating "WARNING: INVERTER OUTPUT CONNECTION; DO NOT RELOCATE THIS OVERCURRENT DEVICE." The third method requires that rating of the overcurrent device protecting the busbar not exceed the rating of the busbar and 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. If using the third method a permanent warning label must be applied to the panel that displays: "WARNING: THIS

EQUIPMENT FED BY MULTIPLE SOURCES. TOTAL RATING OF ALL OVERCURRENT DEVICES, EXCLUDING MAIN SUPPLY OVERCURRENT DEVICE, SHALL NOT EXCEED AMPACITY OF BUSBAR." Or similar wording.

Item four allows the inverter output connected to multiple-ampacity busbars or center-fed panelboards where the design is under engineering supervision that includes fault studies and busbar load calculations.

Previous requirements in 705.12(D)(3) Ground Fault Protection were deleted and a renumbering occurred, because they were redundant to what is required in 705.32. The 2014 NEC 705.12(D)(3) now lays out the marking requirements for 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. Please keep in mind this article is talking about parallel power production sources.

Because it is so common for these systems to be fed into distribution equipment through backfed breakers 705.12(D)(4) and (5) lays out requirements for circuit breakers being back-fed, (D)(4) requires that backfed breakers must be suitable for such operation. This means they cannot be marked with line and load connections. The Informational Note was rewritten to explain that "Fused disconnects, unless otherwise marked, are suitable for back-feeding." Please keep in mind section 240. 40 and 690.16 which requires a disconnecting means shall be provided to disconnect a fuse from all sources of supply. Section 705.12(D)(5) allows the fastener that is required by 408.36(D) to be omitted where a listed plug-in-type circuit breaker is backfed from listed utility-interactive inverters.

A new list item in 705.12(D)(6) was added in the 2014 NEC adding arc fault protection requirements to utility-interactive inverter output(s) that have a wire harness or cable output circuit rated 240 V, 30 amperes, or less, that are not installed within an enclosed raceway.

A section 705.31 was added to the 2014 NEC which requires that if electric power production source conductors connected to the supply side of the service disconnecting means in accordance with 705.12(A), the overcurrent protection shall be located within 10 feet of the point where the electric power production source conductors are connected to the service. This overcurrent protection protects against short-circuit current supplied from the primary source(s) of electricity. Keep in mind the requirement of Article 230 still apply to these conductors and this is not giving you an exception to section 230.70 or any other requirement in 230.

Article 690

NEC 2014, Section 690.2 has two new definitions added. "DC to DC converter" is a device that is installed in either the PV source circuit or PV output circuit that will provide an output dc voltage and current at a higher or lower value than the input dc voltage and current. A "direct current (dc) combiner" is a device used in the PV source and PV output circuits to combine two or more dc circuit inputs, providing one dc circuit output. These definitions should make it clear that the PV source or output circuit ends at the input to the device by defining it as dc utilization equipment. In the PV industry, several different names are used to refer to what is defined as dc combiners such as source circuit combiners, recombiners, and subcombiners just to name a few.

Section 690.5 was revised because the code making panels had recent information on existing ground fault protection techniques that indicated that additional protection is necessary to provide protection from high impedance and multiple ground faults on PV systems. The first of these revisions were the deletion of exception 2 in the 2011 NEC which allowed for the omission of ground fault protection for

DC grounded PV arrays where the equipment grounding conductor was sized at twice the required size for the equipment grounding conductor. The code making panel had research that indicated that oversizing the equipment grounding conductor would not reduce the potential fire hazard. Section 690.5(A) was revised and reorganized into a list format. A new requirement was added to the last item that the equipment providing the PV ground-fault protection be listed.

Section 690.9 “Overcurrent Protection.” was revised for the 2014 NEC. There was an effort to in 2014 NEC Article 690 to group similar requirements together in to make Article 690 more user friendly. Requirements were added requiring listed equipment for equipment that provides overcurrent protection of PV source and output circuits. This will ensure that devices are specifically designed for these systems. New language was added to Section 690.9(A) to clarify that circuits of either ac or dc connected to current-limited supplies (such as PV modules, ac output of utility-interactive inverters), and also connected to sources having significantly higher current availability (such as, parallel strings of modules and utility power), shall be protected at the source from overcurrent. Also newly revised language in section 690.9(E) distinguishes the differences in the requirements for overcurrent protection between grounded and ungrounded PV source circuits.

A new section 690.12 titled "Rapid Shutdown of PV Systems on Buildings" was added to the 2014 NEC. This new section applies to PV systems installed on or in buildings and would require that PV source circuits be de-energized from all sources within 10 seconds of when the utility supply is de-energized or when the PV power source disconnecting means is opened.

This new rapid shutdown provisions were incorporated into the 2014 NEC as a result of combined efforts from three different groups; 1) CMP4 Firefighter Safety Task Group, 2) the SEIA Codes and Standards Working Group, and 3) the PV Industry Forum., all with concerns for safety of emergency responders at buildings or structures with PV systems involved. This is consistent with international standards including IEC 61730, Photovoltaic (PV) Module Safety Qualification, which establish safety procedures for PV modules.

United States Department of Homeland Security (DHS) Assistance to Firefighter grant program requested that, Underwriters Laboratories (UL) examined concerns of PV systems and potential impacts on firefighting operations. One of the key concerns included firefighter vulnerability to electrical and casualty hazards when attempting to extinguish a fire involving a PV system. This research project by UL provided evidence of the need for the ability to disconnect PV-power sources in the event of an emergency. The rapid increased rate of PV systems installations is has resulted in a traditional firefighter tactics for suppression, ventilation, and overhaul have been complicated, leaving firefighters vulnerable to severe hazards.

This new section addresses the disconnecting of rooftop wiring, leaving only the module wiring and internal conductors of the module still energized. The requirement leaves no more than 5 feet of energized controlled conductors inside of a building and/or no more than 10 feet of energized controlled conductors from a PV array within 10 seconds of rapid shutdown initiation. In order to meet these new requirements, an electronic means will be necessary to shut down the module at the source circuit level. This shutdown must coincide with a utility outage, or manual inverter shutdown. A single-module micro-inverter, and ac module can all meet this requirement at the module end of the circuit. Simple remotely controlled electronic switches can also meet this requirement. A voltage limit of 30-volts and a power limit of 240 volt/amperes (watts) were established as a safe power limited environment. This also allows for 24-volt control circuits throughout the array that are currently used in

products that employ contactors for shutting down combiner boxes. Voltage and power shall be measured between any two conductors and between any conductor and ground.

The four item listed in the new section 690.12 is a labeling requirement and references 690.56(C). Section 690.56(C) requires that buildings or structures with both utility service and a PV system, complying with 690.12, shall have a permanent signage that includes the verbiage “PHOTOVOLTAIC SYSTEM EQUIPPED WITH RAPID SHUTDOWN”. Also, the signage shall be reflective, with all letters capitalized and having a minimum of 3⁄8 of an inch height and be white on red background.

The fifth and final item listed in the new section 690.12 is a requirement that the equipment that performs the rapid shutdown be listed and identified. Although, there is a lot of ways to accomplish the intended goal of 690.12, the requirement is still new and there is no way to comply with the fifth item as of yet. The author knows of one product that has been submitted for testing and is out on market anticipating its listing.

CMP-4 has taken a huge step to reduce hazards for first and second responders by accepting these new rapid shutdown provisions into 690.12 of the 2014 NEC.

A revision to NEC 690.31 brought clarity and organization and also was an effort to bring PV system wiring method requirements into one location. In the 2011 NEC PV source and output circuits operating at more than 30 volts that are installed in readily accessible locations, circuit conductors were to be installed in a raceway. The revision in 2014 NEC 690.31(A) now, also allows them to be guarded. A revision in 690.31(B) now includes “inverter output circuits” to the circuit’s conductors that cannot be contained in the same raceway, cable tray, cable, outlet box, junction box, or similar fitting with PV source circuits and PV output circuits. This is important revision because otherwise the listed utility interactive device could be bypassed by damaged or comprised conductors and DC currents could be present on inverter output circuits even if the inverter has shut down. NEC 690.31(D) had new provision added pertaining to multi-conductor cable Type TC-ER or Type USE-2 to allow them in outdoor locations in PV inverter output circuits where used with utility interactive inverters mounted in locations that are not readily accessible. The cable must be secured at intervals not exceeding 6 feet. Equipment grounding conductor for grounding the utilization equipment has to be provided within the cable.

Ungrounded PV systems are allowed as long as they comply with NEC section 690.35 which includes 690.35(C). Section 690.35 is now requiring a ground fault protection system or device that complies with four requirements. The requirement was rewritten to make clear that the device or system must detect ground faults in the DC current carrying conductors and components. These devices are also required to indicate that a ground fault has occurred, and automatically disconnects all conductors or causes the inverter or charge controller connected to the faulted circuit to automatically cease supplying power to output circuits. A new forth item was added to require the equipment providing this function to be listed for providing PV ground-fault protection.

Section 690.41 “System Grounding” has been revised into a list format to make it more user friendly. The revision included the deletion of the “with voltages over 50 volts” so now all PV systems must have one conductor grounded and have ground fault protection in compliance with 690.5. Please keep in mind that the system grounded conductor must be white or gray to comply with Article 200 of the NEC. However systems that comply with Section 690.35 or systems that use other methods that accomplish

equivalent system protection in accordance with 250.4(A) with equipment listed and identified for the use can remain ungrounded.

690.47(D) was inadvertently removed from the 2011 NEC and was placed back into the 2014 NEC. This section requires an auxiliary grounding electrode system be installed in accordance with 250.52 and 250.54 at the location of all ground- and pole-mounted PV arrays and as close as practicable to the location of roof-mounted PV arrays. This electrode shall be directly connected to the array(s) This DC grounding electrode conductor is to be sized per section 250.166. Also, this is in addition to any equipment grounding conductor or bonding conductor required by this code.

These provisions had been in the code since the 1996 NEC. When installing a PV system a lot of conductive material is being added to the roof top which increases the likelihood of a lighting strike. There are two reasons for this grounding electrode. The first is to maintain the frames of the PV system to as close possible to the voltage potential of earth surrounding the structure. This is preferred over relying on what could be an extremely long equipment grounding conductor serpentine through the structure. The second purpose of the PV Grounding Electrode is to provide a direct path for any static charge to drain during a storm or lighting activity. Section 690.47(D) was revised to include “Auxiliary” in the title and the body of the text was revised to include a reference to section 250.54. These new references make it clear that the grounding electrode for the array is consider being an auxiliary electrode for the array grounding and is not required to be tied into the grounding electrode system for the buildings electrical system. There are also two exceptions that are allowed to omit the required auxiliary electrode of 690.47(D).

A new part X was added to Article 690 to clarify the requirement for PV systems used directly to charge electrical vehicles and states that these PV systems must comply with the requirements of both Articles 690 and 625.