The 2008 National Electrical Code Part 2

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Proposals for the 2008 *National Electrical Code (NEC)* are due to the National Fire Protection Association (NFPA) in early November 2005. Last issue, half of the current proposals were presented in this column. The remaining proposals and their edited substantiations are outlined below. To see the entire list and keep abreast of any changes, the current proposals may be downloaded from the SWTDI Web site (see Access).

690.33(C) Type (Revised)

Proposal: Add a second sentence to this section as follows: Connectors that are readily accessible in circuits operating at over 50 volts (maximum system voltage for DC circuits or nominal voltage for AC circuits) shall require a tool to open and shall not present a shock hazard when opened under load.

Substantiation: Circuits with operating voltages above 50 volts (either DC maximum system voltages or AC nominal voltages) pose shock hazards when the energized conductors are exposed. Note the grounding requirement established at this voltage limit in 690.41. Connectors are allowed in PV systems (690.33) and they are commonly used in PV source circuits where the voltages typically range from 27 volts to 600 volts.

Most of the currently used connectors are of the latching type and may be opened by just pulling them apart. Although these existing connectors are manufactured as "touch safe," they are not designed to be opened under load. If inadvertently opened under load, the resulting arc (particularly on DC circuits) may disable the "touch-safe" feature by carbonizing the insulation.

Where these connectors are installed in readily accessible locations, they should be of a type that requires a tool to open. The "tool" may be a connector-specific opening device or merely the blade of a screwdriver or other pointed instrument. In some cases, the connector may consist of a latching connector with a locking shell that prevents the connector from being pulled apart. The connector must remain "touch safe" after opening under load and not present a shock hazard.

690.35(C)(3) (Revised)

Proposal: Revise the section as follows:
(3) Automatically disconnects the conductors or causes the inverter or charge controller connected to that portion of the faulted array to automatically cease exporting power.

Substantiation: Aligns the text for these ungrounded systems with the text in 690.5 dealing with grounded PV systems. Establishes that the faulted array may be isolated by disconnecting the conductors (typically done on low-voltage systems—12, 24, and 48 V) or by causing the connected inverter or charge controller to cease exporting power (typically done on higher voltage systems). Either of these methods serves the purpose of ceasing power production and providing an additional indication that something has happened that needs attention.

690.35(D) (New)

Proposal: Add the new exception as follows:
Exception: Conductors listed and identified as photovoltaic (PV) conductors may be installed as exposed, single-conductor cables in PV source circuits as permitted by 690.31(B).

Substantiation: UL has developed a new cable specification/standard for a cable type specifically designed for PV installations where exposed single-conductor cable is used. The cable is intended to meet the safety requirements associated with cables used in ungrounded PV installations permitted by 690.35. See the substantiation for the proposed revision to 690.31 in *HP108*.

690.35(F) Ungrounded Photovoltaic Power Systems (Revised)

Proposal: Revise the section as follows:
(F) The photovoltaic power source shall be labeled with the following warning at each junction box, combiner box, disconnect, and device where energized, uninsulated terminals or connections may be exposed during service:

WARNING: ELECTRIC SHOCK HAZARD. THE DC CONDUCTORS ARE UNGROUNDED BUT MAY BE ENERGIZED WITH RESPECT TO GROUND DUE TO LEAKAGE PATHS AND/OR GROUND FAULTS.

Substantiation: The section is modified to indicate that the label shall be required only where there are exposed, uninsulated, energized terminals. Pull boxes where there are no exposed, energized terminals would not require the label. The wording of the warning is simplified.

690.42 Point of System Grounding Connection (Revised)

Proposal: Add the new exception as follows:
Exception: Systems with a 690.5 ground-fault protection device, either as a separate device or built into the inverter, shall have the required grounding point (bond) made by the ground-fault protection device.

Substantiation: Section 690.5 ground-fault protection devices actually make the grounded conductor-to-ground bond for the entire DC system. It is important that no additional bond (as required by 690.42) be made in a system employing one of these devices. While many PV systems employ such a device, there are still numerous ground-mounted PV systems that do not require them. A proposal (690.5) has been submitted to require a ground-fault protection device on all PV systems.

690.43 Equipment Grounding (Revised)

Proposal: Add a second paragraph to the existing section as follows:

Equipment-grounding conductors for the PV array and structure (where required) shall be contained within the same raceway or cable, or otherwise run with the PV array circuit conductors where conductors leave the vicinity of the PV array.

Substantiation: This proposal is required because Section 250.134(B), Exception 2, allows DC equipment-grounding conductors to be routed separately from the circuit conductors. A proposal has been submitted to remove this exception, but there is no guarantee that it will be accepted.

With the resurgence of DC power systems (renewable energy systems, fuel cells, uninterruptible power systems, and various industrial processes), the routing of DC equipment-grounding conductors needs to be reconsidered. One of the many issues that *IEEE/ANSI Standard 1375, Guide for the Protection of Stationary Battery Systems* points out is the difficulty in getting proper overcurrent device operation as the circuit time constant goes above 10 milliseconds (the time constant limit of testing in UL Standards 198 and 489). Fuses and circuit breakers may not operate properly when inductance in the circuit results in a time constant exceeding 10 milliseconds.

Calculations shown in the IEEE Standard indicate that the normal circuit inductance in many DC systems results in time constants between 5 and 10 milliseconds. It wouldn't take much spacing between the equipment-grounding conductor and the circuit conductors to increase the fault-circuit time constant to greater than 10 milliseconds. If Exception 2 in 250.134(B) is followed, the routing of the equipment-grounding conductor away from the circuit conductors may allow the time constant under ground-fault conditions to exceed 10 milliseconds. These longer time constants, under ground-fault conditions, could prevent the DC overcurrent devices from functioning properly and possibly affect the operation of 690.5-required DC ground-fault protection equipment.

PV module frames are commonly large rectangles of aluminum that are generally grounded by equipment-grounding conductors at one point on the frame. In PV arrays with modules mounted side by side, the UL-designated grounding points on the modules allow one equipment-grounding conductor to be connected to a number of modules, grounding all at one time. The junction boxes on the modules for the DC power leads are some distance (1–3 ft.) away from the grounding points on the same modules. Since the grounded frames are in proximity to the junction boxes, the equipment-grounding conductors are effectively close to the circuit conductors throughout the array field. However, once the circuit conductors leave the vicinity of the PV array, the equipment-grounding conductor(s) should be routed with the circuit conductors to minimize the time constant described above.

690.45 Size of Equipment-Grounding Conductor (Revised)

Proposal: Revise 690.45 as follows:

690.45 Size of Equipment-Grounding Conductor. Equipment-grounding conductors in photovoltaic source and photovoltaic output circuits shall be sized in accordance with Table 250.122. Where no overcurrent protective device is used in the circuit, an assumed overcurrent device rated at 1.25 times the photovoltaic-originated short-circuit currents shall be used in Table 250.122. Increases in equipment-grounding conductor size to address voltage drop considerations shall not be required. The equipment-grounding conductor shall be no smaller than 14 AWG.

Substantiation: This proposal is a result of the proposed new ground-fault protection limits in 690.5 and 690.5(A). The language simplifies and clarifies the requirement. The ground-fault protective devices will interrupt any DC ground-fault currents that are in excess of a maximum value of 5 amps, no matter how large the PV array. This means that the equipment-grounding conductor will never have to carry more than 5 amps of circulating ground-fault currents on a continuous basis. Requiring the size to be based on Table 250.122 (or an assumed overcurrent device rated at 1.25 times the short-circuit current where there are no overcurrent devices in the circuit) will size the equipment-grounding conductors to an acceptable size that will minimize physical/mechanical abuse when being installed along with circuit conductors sized at 1.56 times the short-circuit current. Because even a 20 AWG conductor can carry the maximum 5 amps, there is no increase in size required by 250.122(B) where circuit conductors have been increased in size for voltage drop. Also, there are no overcurrent devices that need a low-impedance equipment-grounding connection for proper operation because the ground-fault device will activate at a significantly lower current level than any overcurrent device in the circuits. Typically, inverters up to about 10 KW are using 0.5 to 1.0 amp ground-fault trigger levels, and higher power inverters will use up to the 5-amp allowed maximum. Off-grid stand-alone systems are commonly using a 1-amp ground-fault protection device trip level.

690.47(D) Additional Grounding Electrodes (New)

Proposal: Add the new section as follows:

690.47(D) Additional Grounding Electrodes. Additional grounding electrodes for equipment grounding shall be installed in accordance with the methods described in 250.54 as modified by (1) and (2).

(1) A grounding electrode shall be installed at the location of ground-mounted PV arrays.

(2) A grounding electrode shall be installed at the location of any PV array that is mounted on a building or structure that is separate from the building or structure holding other power equipment in the system.

Substantiation: PV arrays may be mounted in locations that are some distance from the structure that holds the other power equipment in the system (inverters, batteries, interface equipment, etc.). To maintain the potential of the exposed metal surfaces as close to the potential of the local earth as possible, supplementary grounding electrodes are required at the remote locations where the PV arrays are located. These grounding electrodes do not have to be bonded directly to other grounding electrodes in the system since the equipment-grounding conductors indirectly connect them. The installation provisions of 250.54 are appropriate, but these grounding electrodes are required, not permissive.

690.53 Direct-Current Photovoltaic Power Source (Revised)

Proposal: Revise the section as follows:

690.53 Direct-Current Photovoltaic Power Source. A label for the direct-current power source indicating items (1) through (5) shall be provided by the installer at the PV disconnecting means:

(1) Rated maximum power-point current
(2) Rated maximum power-point voltage
(3) Maximum system voltage
(4) Rated short-circuit current
(5) Maximum rated output current of maximum power-point charge controller (if installed)

Substantiation: The basic paragraph is reworded to indicate that a label is required rather than a marking and to eliminate unnecessary words. The term "rated" is added to items (1), (2), and (4) to clarify exactly what values should be on the label. This term is not required on item (3) because maximum system voltage is defined in 690.7. Item (5) is added to identify the maximum rated output of the maximum power-point charge controller since that device, where installed, may significantly increase the current from the PV array.

690.54 Interactive System Point of Connection (Revised)

Proposal: Revise the section as follows:

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 with the rated AC output current and the nominal operating AC voltage.

Substantiation: Clarifies the required marking to show the rated AC output, which is the current upon which conductors and overcurrent devices are based (690.8, 690.9). The existing text is sometimes interpreted as the maximum operating current for the installed system, which may be considerably less than the rated output current. Some installers were also marking a range of AC voltages. Both changes provide inspectors with better information to use in determining if code requirements have been met.

690.62 Ampacity of Neutral Conductor (New)

Proposal: Add the following second paragraph:

A neutral conductor connection to a single-phase or 3-phase utility-interactive inverter used solely for instrumentation or voltage or phase detection purposes and not for power transmission shall be permitted to be as small as 14 AWG.

Substantiation: Many utility-interactive inverters have a 240 V, 208 V, or 480 V output that requires no connection to a neutral conductor for power transmission. However, due to various IEEE standards and local jurisdiction requirements, a connection to the electrical power system neutral conductor is required to detect a loss of phase and/or to monitor unbalanced line-to-neutral voltages of the inverter. This neutral connection, used only for phase detection or instrumentation, carries no appreciable power and can safely be made very small. A minimum requirement of 14 AWG ensures that this conductor is physically robust enough to be pulled through conduits with the power conductors.

690.64 Point of Connection (Revised)

Proposal: Revise the section as follows:

690.64 Point of Connection. The output of a utility-interactive inverter shall be connected as specified in 690.64(A) or 690.64(B).

Substantiation: Over the evolution of article 690 since 1984, the definition of photovoltaic power source has referred to the DC output of a PV array. All of Part VII in 690 has always referred to the AC output of utility-interactive inverters. The terms "photovoltaic power source" was used incorrectly in this section.

690.64 (A) Supply Side (Revised)

Proposal: Revise the section as follows:

690.64 (A) Supply Side. The output of a utility-interactive inverter shall be permitted to be connected to the supply side of the service disconnecting means as permitted in 230.82(6).

Substantiation: See 690.64.

690.64(B) Load Side (Revised)

Proposal: Revise the first sentence of the section as follows:

690.64(B) Load Side. The output of a utility-interactive inverter 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, provided that all of the following conditions are met.

Substantiation: See 690.64

Proposal: Revise 690.64(B)(2) as follows:

690.64(B)(2). The sum of the ampere ratings of overcurrent devices in circuits supplying power to a busbar or conductor shall not exceed 110 percent of the rating of the busbar or conductor.

Substantiation: Since Section 690.64 was first placed in the 1984 *NEC*, significant changes have been made to the way overcurrent device ratings and conductor ampacities are used in the code. Load calculations including demand factors and other code requirements generally restrict the operation of overcurrent devices and conductors to continuous operation at 80 percent of rating. Therefore, there is 20 percent or more (depending on demand factors) additional capacity in the busbar of a load center than is currently being used. If 10 percent of the load center rating were allowed for a circuit from a PV inverter, there would still be, under the very unlikely, worst-case conditions of high loads on load circuits, a 10 percent safety factor. In nearly all installations under normal operating conditions, the addition of PV power to a load center will reduce the loading on the busbars and the loading on the main circuit breaker to the load center. Only in the unlikely situation where additional load circuits or increased loads were placed on the panel without complying with code requirements, would there be any possibility of even using the 10 percent extra designed allowance.

Proposal: Revise 690.64(B)(2) as follows by adding the following new second paragraph after the exception:

In dwelling units having no single main overcurrent protection device or service disconnect and having up to six main disconnects as allowed by 230.71(A), the sum of the ampere rating of overcurrent devices from the output of utility-interactive inverters supplying the busbar feeding the main disconnects shall not exceed 20 percent of the rating of that busbar.

Substantiation: In many areas of the country, residential service panels are installed that have no single main circuit breaker or disconnect. Up to six disconnects/circuit breakers are used to feed subpanels in other locations. It is not possible to apply the general rule and the exception of this section because a single breaker does not limit the contribution of current from the utility. Allowing a backfed PV breaker or breakers with ratings totaling 20 percent of the panel rating is consistent with safety requirements and the use of the exception in other dwelling unit installations.

Proposal: Delete the exception for 690.64(B)(3)

Substantiation: Ground-fault protection devices (5 mA GFCI receptacle outlets and circuit breakers, 30 mA equipment protection breakers, and 100–600 amp feeder protection equipment) will generally be damaged if tripped by a ground fault while being backfed. This damage will disable the ground-fault protection mechanism of the device while still allowing normal operation (circuit breaker operation and current flow). The damage may not be visible or obvious. Ground-fault protection equipment should never be backfed under any circumstances.

Proposal: Revise 690.64(B)(5) and add the Fine Print Note (FPN) as follows:

(5) Circuit breakers, if backfed, shall be identified for such operation. Dedicated circuit breakers backfed from listed utility-interactive inverters complying with 690.60 shall not be required to be individually clamped to the panelboard busbars. A front panel shall clamp all circuit breakers to the panelboard busbars. Main circuit breakers connected directly to energized feeders shall be individually clamped.

FPN: Circuit breakers that are not marked “Line” and “Load” are identified as suitable for backfeeding.

Substantiation: UL Standard 489 is the reference for testing and marking molded-case circuit breakers suitable for backfeeding. The limited distribution of the standard and the allowance for backfeeding based on the absence of a marking is resulting in many circuit breakers being used improperly for backfeeding. Conversely, the absence of the marking causes many inspectors to not allow backfed circuit breakers. Also see UL’s *Molded Case Circuit Breaker Marking Guide.*

690.74 Battery Interconnections (Revised)

Proposal: Add the following second paragraph to the section: Flexible, fine-stranded cables shall only be used with terminals, lugs, and connectors that are listed and marked for such use.

Substantiation: UL Standard 486 A and B requires that connectors, lugs, and terminals that are intended for use with flexible, fine-stranded cables be so marked for use with such cables. Very few connectors and terminals have been listed for such use and few are so marked. The vast majority of connectors, lugs, and terminals are unsuitable for use with flexible, fine-stranded cables. However, the limited distribution and wording of the standard has resulted in flexible, fine-stranded cables being used improperly with these nonmarked connectors, lugs, and terminals. Failures in several widely different industries have been reported.

250.134(B) Grounding with Circuit Conductors (Revised)

Proposal: Delete Exception No. 2.

Substantiation: When this exception was added to the code, the drafters correctly realized that pure DC does not have any oscillatory tendencies like AC does that would cause transformer-like heating in metal when the equipment-grounding conductor is separated from the circuit conductors. They likewise realized that there is no frequency-dependent impedance factor associated with DC that might cause higher than desired reactance in the DC circuits that could prevent the operation of overcurrent devices.

A second issue is that DC is not always pure. Any single-phase DC-to-AC power inverter will have a 120 Hz sine wave imposed on the DC that may have an rms value greater than the average DC value. In a similar manner, battery chargers that rectify the AC line to get DC to charge batteries will have 120 Hz ripple currents. Under fault conditions, these DC ripple currents act just like AC currents in that they may cause metal heating if the two (or three) circuit conductors are not routed together. Excess separation leading to increased inductance will also lead to increased impedance in the fault circuit and may not allow overcurrent devices to function properly. The impedance is a function of the frequency, and at 120 Hz, the increased impedance will be higher than at 60 Hz. Also see 690.43.

110.14(A) Terminals (New)

Proposal: Add a third paragraph as follows:

Terminals, lugs, or connectors intended for use with flexible, fine-stranded cables (other than Class B & C stranding) shall be marked and listed for such use.

Substantiation: See 690.74.

250.166 Size of the Direct-Current Grounding Conductor (Revised)

Proposal: Revise 250.166 as follows so that 250.166 (C), (D), and (E) are clearly exceptions to 250.166 (A) and (B) as they were in the 1996 *NEC.*

250.166 Size of the Direct-Current Grounding Conductor. The size of the grounding electrode conductor for a DC system shall be as specified in 250.166 (A) and (B), except as permitted by 250.166 (C) through (E).

Substantiation: As Sections 250.166(C), (D), and (E) are currently written, they are in direct conflict with sections 250.166(A) and (B). Many electricians and inspectors are not able to determine which section takes precedence. For example, many DC systems are not as described in Section 260.166(A), so section 250.166(B) applies. However, a ground rod electrode connection would require Section 250.166(C) to be applied. Sections 250.166 (B) and (C) dictate two different sizes of grounding electrode conductors. This language parallels the language in 250.66 for AC grounding-electrode conductors.

Questions or Comments?

If you have questions about the *NEC* or the implementation of PV systems that follow the requirements of the *NEC*, feel free to call, fax, e-mail, or write to me.

Access

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