code corner

Common Questions about Grid-Tied Systems

by John Wiles

In the course of helping the PV industry with *NEC* issues and questions, I get some that are repeated many times. There are always a few that need clarification or repeating.

Inverter DC Grounding-Electrode Conductor

In *HP133*, 690.47(C) in both the 2005 and 2008 editions of the *NEC* was discussed. Since this section is permissive in both codes, either the 2008 or 2005 requirements may be applied in jurisdictions using either edition. Everyone using the *NEC* should at least read Article 90 Introduction—where in Section 90.5 it is explained that the *NEC* has permissive (optional) requirements and mandatory requirements. Sections 690.47(C) in both editions are based on requirements found in Article 250, which is unchanged. For 690.47(C), then, these permissive requirements can be applied in jurisdictions using either edition. As always, the inspector has the final say.

It should be clarified that the combined conductor permitted by 690.47(C)(3) in the 2008 *NEC* originates at the inverter and runs to the first grounding bar in a panel where a grounding electrode conductor is attached. It should be noted that *this* combined DC inverter grounding-electrode conductor/AC inverter equipment-grounding conductor does not originate at the PV array. The PV array is normally grounded with an equipment-grounding conductor routed with the DC circuit conductors, per 690.43. Additional grounding of the PV array may be required by 690.47(D) when the array is ground- or pole-mounted, or mounted on a separate structure from the inverter.

Main AC Service Disconnect Ground-Fault Protection

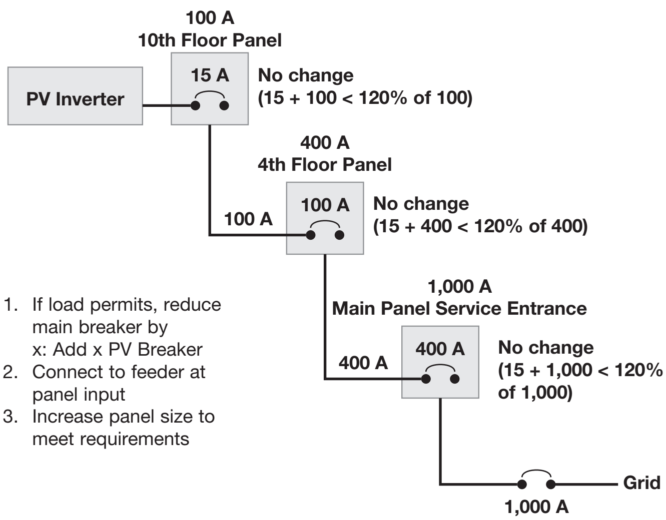
NEC Section 230.95 requires that solidly grounded wye services be provided with ground-fault protection for services rated at 1,000 amps or more, with a line-to-ground voltage

With increasing numbers of PV installations, the same questions about how to meet specific *NEC* requirements often arise.

John Wiles

Commercial Utility-Interactive Systems

690.64(B)(2)
PV + Main ≤ Panel



After applying 690.64(B)(2) to all panels and feeders, it may be cheaper and easier to add a second service to the building.

of more than 150 volts, but not exceeding 600 volts phase-to-phase. This protection is generally provided by a main disconnect, consisting of a circuit breaker with an attached or included ground-fault protection device (GFPD). How should the PV designer, installer, or inspector proceed where a utility-interactive PV system connection could backfeed this GFPD breaker? The answer: With a great deal of caution.

First, Underwriters Laboratory (UL) standards state that if a circuit breaker is *not* marked "line" and "load," it has been evaluated for current/power flow in both directions—and is suitable for backfeeding—which is the case with most new, smaller, molded-case circuit breakers. However, retrofit situations may have main disconnect circuit breakers that are 40 or 50 years old—these may have "line" and "load" markings, indicating that the breaker should *not* be backfed.

Let's assume that we have a main disconnect breaker that is suitable for backfeeding and is also equipped with a GFPD as required by the 2008 *NEC* and earlier editions. Discussions with engineers at UL and with circuit breaker manufacturers reveal that the GFPD may not have been tested for backfeeding in a method that duplicates the utility-interactive PV situation. When a ground-fault trips a GFPD breaker that is being backfed by a PV inverter, both the line and load terminals may be energized at the same time for up to 2 seconds as the inverter shuts down. Many older GFPD devices could be damaged when this happens. Some of the newer GFPD breakers are not susceptible to this kind of damage, but no one seems to have a universal answer that covers all GFPD breakers in all installations. So, the first hurdle is to get the design engineer at the breaker/GFPD manufacturer to provide written statements that the GFPD device will not be damaged when tripped while being backfed by a utility-interactive inverter.

The second hurdle is posed by meeting the exception to 690.64(B)(3). How are the load circuits protected from ground-fault currents from the inverter? An analysis of the various impedances involved (inverter-output-source circuits vs. utility-source circuits) to determine how currents would be shared between the inverter and the utility would not be simple. It may be possible that the inverter can source sufficient fault currents so that the GFPD does not trip. Also, the GFPD has adjustable trip points and the *NEC* provides no guidance on how they should be set in either a non-PV or a PV installation. When the adjustment ranges over several hundred amps on a 1,000 amp GFPD breaker, it is not clear how this adjustment should be made. If a GFPD is put on the output of the inverter, there is the question of how it should be connected and whether it would provide the desired protection.

My opinion is that when the existing installation has a main breaker or any breaker (or any fused disconnect) with a GFPD function, then that device should not have a utility-interactive inverter attached to any circuits that feed the load terminals of the GFPD. Supply-side connections (690.64(A)) are the way to make these PV installations and avoid these problems until they are resolved by a combination of changes to the *NEC* and the UL Standard, and a better understanding of the situation by PV installers, electricians, and the electrical inspectors.

690.64(B) All The Way

Code Corner 134 dealt with load-side connections. However, the proposed changes for the 2011 *NEC* were rejected, so *NEC* 690.64(B) and 705.12(D) will be in force for awhile. These code requirements apply to any bus bar or conductor that has multiple sources of supply (utility and PV inverter outputs) with each supply protected by an overcurrent device (fuse or circuit breaker).

In a typical utility-interactive PV system, the requirement would apply to all bus bars and conductors from the service disconnect (breaker or fused disconnect) to the first dedicated overcurrent device/disconnect on the inverter output circuit. Although the number of subpanels and conductors between the service disconnect and the PV

A modern breaker marked as suitable for backfeeding. Should it be used with a PV system connected to the load terminals or not? Exercise extreme caution!

inverter output may be numerous, and the load on the building large compared with the rating of the PV system, there is always the possibility that any conductor in this path may be subjected to backfed currents from the PV system. Each of those panel bus bars, and the conductors between them, must be sized to meet the requirements of 690.64(B)/705.12(D)—see the diagram above.

If the PV inverter output connection cannot be made at the very last breaker position in the most distant panel from the service disconnect, as required by 690.64(B)(7), then the calculations for ampacity and bus bars must be based on 100% of the total of all overcurrent devices supplying the bus bar or conductor. Without this opposite breaker configuration, it may be possible to overload portions of the bus bar or some conductors with current from both the utility and the PV system. The 120% allowance in *NEC 2008* 690.64(B)(2) cannot be applied, nor can just that first dedicated breaker connected to the PV inverter output be used in the calculations for each conductor and bus bar. Each panel bus bar and conductor segment must be examined to determine which breakers are limiting current to that specific bus bar or conductor. These are usually the main breaker on the panel and the single backfed breaker *in that particular* panel that is handling backfed current from the possibly distant PV inverter—not the dedicated breaker connected directly to the inverter. The 120% allowance has been lost that was allowed when the breakers were positioned at the bottom of the panels, and frequently the ratings of a main breaker and the panel are the same. Therefore it is not possible to have a breaker carrying backfed PV currents connected to this panel or conductor.

In some cases, the main breaker for a panel may be sized below the rating of the bus bar; this can allow a backfed breaker to be connected anywhere on that panel. Load calculations determine if the main breaker size can be reduced. If so, the sum of the rating of the main breaker (supplying utility power) and the rating of the backfed breaker in that panel may not exceed 100% of the bus bar rating for that panel. Plus, upstream panels and circuits toward the service entrance must be analyzed to see if the 100% rule can be met. In many cases, a supply-side connection is the only option available.

Access

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Southwest Technology Development Institute • www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/Codes-Stds.html • PV systems inspector/installer checklist, previous “Perspectives on PV” and *Code Corner* articles, and *Photovoltaic Power Systems & the 2005 National Electrical Code: Suggested Practices*, by John Wiles