Code Q & A

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Q **I'm working on a large grid-tied PV installation and could use some advice on connecting the system to the utility. It's too large to connect via a backfed breaker on the existing 200-amp load center, so what other options exist? I have read the Code Corner in HP112 about supply-side taps, but I could use some additional guidance. I am a master electrician, and have installed few PV systems.**

A Existing load centers may not have enough room to make the necessary connections. The *National Electrical Code (NEC)* limits the number of conductors and splicing devices that can be in any space (Articles 312 and 408). The photo below shows an overcrowded disconnect enclosure that does not meet *NEC* requirements. Even when the conductors between a separate meter and the main disconnect enclosure are accessible, they should not be tapped there unless an enclosure is added to hold the tap device.

In places where net-metering laws are in effect, the utility-side (supply-side) interconnection will be made between the meter and the main service disconnect. In that case, the utility will need to remove the meter from the socket (meter base) to de-energize the service entrance conductors.

If the point of connection is to be the load-side terminals of the meter socket (only when double conductors on these terminals are allowed by the socket listing), extreme caution must be exercised when connecting the new conductors to these terminals. The utility-energized ("hot") input terminals and meter socket jaws are in the same socket and are only a few inches away from each other. Those energized terminals should be covered with a heavy, insulated, protective shield so that they cannot be touched accidentally. Because high torque is needed to loosen and tighten large terminals, slipping screwdrivers and wrenches are possible. Tools should be insulated, and insulated gloves (lineworker's gloves) and a protective face shield should be worn while working in the meter socket. Touching those "hot" input meter jaws could electrocute you.

The maximum output current from the PV system should be no greater than the rating of the service entrance. Careful consideration should be given to conductor sizes if the PV AC output current approaches the rating of the service entrance. Table 310.15(B)(6) for reduced conductor sizes may no longer apply to a very large PV system. For larger systems, the basic ampacities found in Table 310.16 may have to be used. Since these service-entrance tap conductors have no overcurrent protection, they should be as short as possible and be installed in a metal conduit (RMC, EMT, or IMC). The local jurisdiction may have requirements for protecting the service-entrance conductors that need to be followed for these tap conductors. I do not believe the "tap rules" in Article 240 apply to service-entrance taps since these taps are fully addressed in Article 230.

As for other locations, some existing service-entrance disconnects and meter cabinets have an additional set of terminals that are in parallel with the input connections to the main breaker. These are located to allow the main disconnect enclosure to be easily fed from either the top or bottom of the enclosure.

Some combination meter socket/main disconnect enclosures have the meter socket on one side and the disconnects on the other side of the enclosure. Busbars or cables connect the meter socket to the main breaker. After getting the approval of the enclosure manufacturer and the local inspector, it may be possible to tap these circuits with either bolt-on terminals for the busbars or splicing blocks for the cables. However, normally, busbars may not be drilled and tapped to add terminals for a tap.

Safety for ourselves as installers, for the utility, and for the system owner/operator should be primary considerations. Any work on electrical service-entrance conductors *must* be done only when those electrical conductors are de-energized. That usually involves notifying the utility and having them turn off all power to the building or structure. Although some electricians will work with "hot" (energized) conductors, this procedure is *strongly* discouraged. As the old saying goes, *"There are old electricians. There are bold electricians. But there are no old, bold electricians."*

Q **What is the best way to ground the frame of a photovoltaic module?**

A This is an apparently simple question, with a complex answer. When exposed to sunlight, PV arrays can generate dangerous levels of voltage (up to 600 volts) and current. The frames of these modules must be effectively and continually grounded to earth to prevent electrical shocks and to reduce fire hazards from stray ground-fault currents.

When ground faults occur in a PV system, these currents may circulate indefinitely under certain conditions. Unlike a ground fault in an AC power system, which is interrupted immediately, a DC ground fault may exist whenever the module is illuminated. In larger commercial (nonresidential) systems, the ground-fault detection system does not interrupt these currents. The connections that are used for grounding PV modules may have to be as robust as those used for the circuit conductors.

Grounding PV modules is complicated by several factors. A typical aluminum-framed PV module has a clear or colored anodizing on its surface that must be removed or breached for good electrical contact. When these coatings are removed, the bare aluminum will oxidize very quickly (in seconds) and build up an insulating film that also prevents good electrical contacts. Plus, the copper equipment-grounding conductor must not come directly into contact with the aluminum surface, since galvanic corrosion between these two dissimilar metals will occur, eventually resulting in a failed connection.

Unfortunately, although inspectors have been providing examples of failed grounding methods and devices, the grounding hardware and instructions provided by PV module manufacturers have not yet been tested and evaluated by Underwriters Laboratories (UL). Under pressure from the PV industry and the electrical inspection community, UL now has undertaken a major investigation of PV module grounding. However, the results of the UL investigation are not yet known.

Based on discussions with grounding-lug manufacturer FCI–Burndy and using utility company procedures to connect copper wires to aluminum busbars in an outdoor environment, I'm employing the following procedure to make equipment-grounding connections to module frames. These procedures are used only when they do not directly contradict manufacturer's instructions provided with the listed module.

At one of the marked grounding points on the module frame, an abrasive material like emery cloth is used to remove the clear coat, anodizing, and aluminum oxide from the surface where the ground lug will contact the aluminum surface. Immediately, a thick layer of antioxidant compound is applied to the exposed aluminum surface. Any excess compound will be squeezed out when the lug is bolted in place. A tin-plated, solid-copper, direct-burial-rated lay-in lug is used to connect a copper conductor to the exposed aluminum frame.

A bolt, nut, two flat washers, two split-lock washers and a Belleville (cupped spring) washer are used to bolt the lug to the frame. The flat washers are used to prevent the hard

steel split-lock washers and Belleville washers from digging into the relatively soft copper and aluminum. The split-lock washers and the Belleville washer are used to maintain the assembly under the correct tension. Use a calibrated torque screwdriver set to 12 to 15 inch–pounds (depending on the type of bolt) to ensure a reliable connection. A copper conductor (generally from #12 to #4) is attached to this lug. The size of the conductor depends on the electrical grounding requirements, the need for physical protection, and the requirements of the local inspecting agency.

Other 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 me at the location below. See the SWTDI Web site (below) for more detailed articles on these subjects. The U.S. Department of Energy sponsors my activities in this area as a support function to the PV industry under Contract DE-FC 36-05-G015149.

Access

John Wiles (jwiles@nmsu.edu) works at the Southwest Technology Development Institute, which provides engineering support to the PV industry and provides industry, electrical contractors, electricians, and electrical inspectors with information on code issues related to PV systems. An old solar pioneer, he lives in his utility-interactive PV-powered home in the suburbs.

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