New Grounding Methods

NEC Compliant or Not?

by John Wiles

PV modules and racks must all be properly grounded.

Many photovoltaic (PV) systems will be producing hazardous voltages and currents for 50 years or more. During that period of time, they may or may not be operational, and they may or may not be maintained. That's why it's important to properly ground all the system's exposed metal surfaces that may be energized by internal faults, poor terminations, or failing conductor insulation. Even in a failed system, maintaining all metal surfaces at ground (or earth) potential will minimize the possibility of electrical shocks.

What's the Problem?

Heating, ventilation, and air conditioning (HVAC) systems are exposed to the same environmental conditions as PV systems, but there are significant differences in the grounding requirements and procedures between the two systems. Yet comparisons between the two systems are sometimes drawn by PV installers.

PV modules, with a life measured in decades, will typically be in place longer than the outdoor unit of a HVAC system. When the performance of an HVAC system deteriorates, it is usually inspected and repaired promptly. PV systems suffer gradual degradation that is often not monitored, and the PV array may remain installed on the roof even after the system is no longer being used.

Although HVAC units have only a few separate pieces, the equipment grounding points are well marked, and the factory-installed bonding jumpers and screws effectively bond all parts of the listed device together. HVAC components are typically made of steel, and the equipment-grounding terminals are electrically and chemically compatible with copper conductors.

On the other hand, PV systems have numerous modules (tens to thousands) and mounting racks that all must be properly grounded. PV modules and mounting racks are

typically made of aluminum and are *not* compatible with copper conductors. (See Access for more information on grounding aluminum-framed PV modules.)

Getting Grounded

Electrical inspectors have been communicating with Underwriters Laboratories (UL) about poor PV module and PV system grounding techniques and equipment that they are seeing in the field. As a result, UL is getting tough on grounding. In the fall of 2007, UL issued an "interpretation" of the existing standard (UL 1703) for PV modules. The grounding problem is in part due to a confusing section in UL 1703 that discusses bonding requirements and instructions (connecting the module frame parts together in the factory) as well as grounding requirements (installing the external equipment-grounding connection in the field). Methods and equipment used in the factory to bond the module frame sections together are evaluated during the listing process. However, the same level of scrutiny cannot be applied to field-installed, equipment-grounding methods, and the same parts and techniques used in the factory are generally not appropriate in the field.

UL's interpretation clarifies the intent of the standard in several areas:

- Dissimilar metals, like copper and aluminum, cannot come into contact with one another at the equipment-grounding connection point. UL provides a chart showing numerous metals and which types can be in contact without galvanic corrosion problems.
- Any threaded fastener used for grounding must pass the same durability tests as any threaded fastener used for other electrical connections. It must be fastened and unfastened ten times without damage to the threads on any part. This requirement will probably result in the demise of using thread-cutting or thread-forming screws for module grounding because screwing them into soft aluminum typically cannot meet this requirement.
- The module manufacturer must provide or designate the specific hardware and methods used to ground the module, and those instructions must be included in the module installation manual. UL will evaluate the grounding hardware and methods throughout the entire testing and listing/certification process on new modules and when existing modules come up for recertification.

UL is also working on changes to UL 1703 that will clarify the requirements, markings, and instructions for grounding PV modules. At some point, they will develop a separate standard that will allow the evaluation and listing of various universal PV module grounding methods and devices that will work with a number of different module frame geometries. The use of this standard will allow grounding-device manufacturers to meet the standard without having to be tested with each and every type of PV module.

As the Code requires, instructions and labels provided with a certified/listed product must be followed (110.3(B)). But the listing and certification process is slow, and modules only come up for review every five years. Therefore, it may be some time before all of the instruction manuals meet the clarified intent of UL 1703.

HVAC grounding is not to be compared with PV system grounding.

New Grounding Devices

With respect to new PV module grounding methods and devices, such as clips and washers, the situation is somewhat murky. Of course, the local authority having jurisdiction (AHJ) can call it as they see it, and some jurisdictions have accepted these new devices.

As mentioned, *NEC* Section 110.3(B) requires that the instructions and labels provided with a listed product be followed. PV modules are marked for grounding at specific points. Hardware (when provided) and these instructions require the use of the marked points. The instructions do not generally address grounding the module at the mounting holes or at other locations.

A few manufacturers may provide tech bulletins that show other methods. These tech bulletins may or may not have been reviewed by UL where they differ from the listed grounding points. UL is attempting to review new manuals and directions submitted by the manufacturer, but at times, the manuals get published without UL review. Also, even if reviewed, they may not be in compliance with all *NEC* requirements or may show grounding techniques that have not withstood the test of time. The future UL Standard for PV Module Grounding Methods/Devices will evaluate the long-term durability and reliability of the various grounding methods and devices.

When using a new grounding method, other than running a separate grounding wire to each PV module, grounding continuity must be addressed. One of the oldest requirements in the *NEC* is to make a grounding connection first and break it last (250.124(A)). Consider a module with an internal ground fault or leakage currents to the frame. If the circuit conductors are left connected and the module is unbolted from the grounded rack (disconnecting the frame grounding

PV modules do occasionally fail and may create hazardous fault conditions in poorly grounded arrays.

first rather than last), the module frame may be energized—providing up to 600 volts between the frame and the grounded rack. Ground-fault protection systems will not respond to ground faults and leakage currents less than about 0.5 amps (they are anti-fire devices, not anti-shock), and only the first ground fault is interrupted when they activate.

A few PV systems integrators have a listed combination—listing the PV modules they use along with proprietary grounding devices and racks. Rack manufacturers also are developing grounding devices, but they are not associated or listed with any particular module at the present time.

See Appendix G in the latest version (1.8) of the *PV/NEC Suggested Practices Manual* for the grounding method we currently use at the Southwest Technology Development Institute. This method can be used only if it does not conflict with the module instructions and when those instructions allow the use of a properly listed lug attached to the marked grounding points after appropriate surface preparation.

I have long encouraged module manufacturers to get their modules tested with new grounding products and integrate that information into the instruction manuals to help ensure a code-compliant installation that doesn't cause headaches for AHJs. Section 690.43 of the *2008 NEC* allows the use of these new devices as soon as they have been listed/certified and identified for that use in the module instruction manuals.

A related question that will eventually have to be addressed is: To what are these new grounding devices attached? It is necessary to first verify that they can make a durable connection with the module frame. Then the device must make a connection to an acceptable grounding electrode (such as building steel) or to an accepted equipment-grounding conductor such as a copper conductor. Aluminum module mounting racks are not currently listed as equipment-grounding conductors, but some of the rack manufacturers are in the process of obtaining such a certification/listing. This is necessary because the racks are typically designed for mechanical durability and not electrical connections. Joints may be designed to allow for thermal expansion and contraction, and with aluminum, such "slop" does not make a good electrical connection. For loosely jointed metal raceways, *NEC* Section 250.98 requires that a provision for electrically bonding the sections of the rack together must be incorporated into the design.

Grounding the Future

In the future, modules will either come with an integral mounting rack (there are a few now) or they will be easily attached to a rack providing robust mechanical and electrical connections. One point on the rack will allow for the connection of the equipment-grounding conductor for all modules and for a grounding conductor routed directly to earth (where required). Installations will take less time, cost less, and will keep those module metal surfaces grounded til the cows come home.

Access

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Photovoltaic Power Systems and the 2005 National Electrical Code: Suggested Practices by John Wiles • www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/PVnecSugPract.html

PV Systems Inspector/Installer Checklist and previous "Code Corner" articles • www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/Codes-Stds.html

"PV Array Grounding," *Code Corner, HP102 & HP103* • Grounding aluminum-framed modules