3-phase

One Issue—Three Viewpoints

Module Grounding Clips and the *NEC*

Language in Article 690.43 of the 2008 *NEC* allows the use of new array grounding methods and hardware typically referred to as *module grounding clips*. The article states, "Devices identified and listed for bonding the metallic frames of PV modules shall be permitted to bond the exposed metallic frames of PV modules to the metallic frames of adjacent PV modules." In addition, several module and rack manufacturers and system integrators have developed system kits that utilize grounding clips as well as lug sets to bond between mounting rails. What's your take on this new language in the 2008 *NEC*? What are the implications for these grounding methods with regard to safety and the long-term integrity of these electrical bonding methods?

IEC 61730 Will Test and Document Module Grounding

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Article 110.3(B) of the *National Electrical Code* requires that the instructions and labels provided with a listed product be followed. PV modules are marked for grounding at specific points. Installation instructions specify grounding at the marked points and do not generally address grounding the module at mounting holes or at other locations.

A few manufacturers have published technical bulletins that show other grounding methods. These bulletins may or may not have been reviewed by UL where they differ from the listed grounding points. Also, even if reviewed, they may not be in compliance with all *NEC* requirements or might describe grounding techniques that have not withstood the test of time.

I have been making formal and informal inputs to UL for several years concerning module grounding and requiring manufacturers to tighten up documentation and procedures. In addition, I have been encouraging manufacturers to have their modules tested with new grounding products and to include this information in their instruction manuals. This way, the AHJs will not have any questions, and the installation will be code compliant.

The PV team at UL has stated that it is not sure that the UL grounding standard, UL 467, is suitable for evaluating devices and methods used for grounding PV modules. A UL task group, of which I am a member, is developing a change to the module standard UL 1703 (soon to be IEC 61730) that will test and evaluate new grounding devices with actual PV modules during the module listing process.

UL issued an interpretation of UL 1703 in August 2007 that says that manufacturers must specify, in the module instruction manual, the grounding method(s) and materials that must be used to establish the external field-made grounding connections. These methods *and* materials will be evaluated as part of the module listing process and will apply to all existing listed modules and their instructions as they come up for review. For example, any threaded connection used for grounding must be capable of being torqued and loosened 10 times without damage to the connecting parts. This requirement will probably end the practice of driving a thread cutting/thread forming screw into the module frame for grounding.

Finally, when using a new grounding method that does not result in an electrically continuous wire to each PV module, grounding continuity must be addressed. One of the oldest requirements in the *Code* is to make a grounding connection first and break it last (250.124(A)). Consider a module with an internal ground fault to the frame. If the circuit conductors are left connected, and the module is unbolted from the grounded rack—disconnecting the frame grounding first rather than last—the module frame may be energized with up to 600 volts to the grounded rack.

For the grounding method we currently use at the Southwest Technology Development Institute, see Appendix G in the latest version (1.6) of the PV/NEC Suggested Practices manual, available here: nmsu.edu/~tdi/Photovoltaics/Codes-Stds/Codes-Stds.html

New Test Standard for Modules Will Speed Acceptance

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Much controversy has surrounded the little stamped stainless steel clips used for grounding PV modules since their introduction a few years back. Basically, they were created to resolve the problem that simply clipping or bolting anodized aluminum PV module frames to their support racks is insufficient to produce an electrical bond between two anodized surfaces.

The Wiley Electronics Equipment Bond clip, commonly called a WEEB, addresses the concern over making an electrical bond to the rail and makes it simple to bond the rail to

the equipment-grounding conductor. Since the clip is made of stainless steel, it is not subject to corrosion and dissimilar-metal issues, and it creates an oxygen-free connection without antioxidant compound or labor intensive grinding.

So why does controversy surround the WEEB? The problem lies in the test standard for PV modules known as UL 1703, which has no provisions for such equipment. To date UL has not tested grounding methods for PV modules. The only test required is to verify that the module has sufficient conduction so that a ground can be taken off any grounding point on the module. This test involves testing the frame screws or other attachment elements that hold the frame together; it has nothing to do with any attachments to a module.

To remove all doubt about the WEEB product, an additional step was needed. The solution was to come up with new language in UL 1703 that would address how to allow new grounding methods without having to individually test each method. This language specifies the characteristics of the module frame, including cross-sectional area and coating thicknesses, so that products can be developed and tested on a generic frame. The revision was sent to the UL Standards Testing Panel in December for final approval, with the hope that this new language will be in the standard soon.

So where does that put us now? I have been encouraging jurisdictions around the US to allow the use of grounding clips based upon their merit shown in the testing done by the listing agency. WEEBs pass UL 467, which requires that the grounding connection stay intact when enough current passes through the connection to fuse the wire connected to it. Since a 6 AWG wire can be connected to the outgoing lug on the support rail, over 1,000 amps could be passed through this connection for up to 4 seconds. That is enough current to burn a 6 AWG copper wire apart and will easily melt a lay-in lug off a PV module.

A few module manufacturers have provided documentation to local jurisdictions stating that they allow the use of WEEBs for bonding their modules. This has helped many installers overcome specific permitting or inspection issues. As a rule, we can use whatever grounding methods are stated in the listing literature from the module manufacturers. Much of this information has been recently updated and several manuals now allow multiple methods when previously none were mentioned.

Bonding Modules to Rails Improves System Grounding

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Prior to 2008, Article 250.136 of the *NEC* described a method of grounding equipment to a mounting structure, thus allowing these new grounding methods. Additional language in Article 690.43 of the 2008 *NEC* makes this explicit, stating: "Devices listed and identified for grounding the metallic frames of PV modules shall be permitted to bond the exposed metallic frames of PV modules to grounded mounting structures."

In the past, it was common for installers to ground only module frames and not the mounting structure. In my opinion, this neglects the most common failure mechanism, a pinched wire between module frame and mounting rail that could just as easily energize the rail as energize the frame. When bonding the frames to the mounting rails, one is forced to also ground the mounts, and the resulting system is safer.

The older method of grounding an array generally used a wire strung between each element of the array. It was common to use wires as small as 10 AWG and—where inspectors deemed that the equipment ground was subject to physical damage—as large as 6 AWG. Compare this to some mounting rails I have measured, which are 263 mm^2, or approximately equivalent to a 500-kcmil wire. The rail has almost 20 times the cross-sectional area of a 6 AWG wire. As a result, resistance in the rail is an order of magnitude lower than in the wire. It therefore provides a much safer ground. It is worth noting that module frames typically have similar cross-sectional areas and should provide an equally effective ground.

Another factor to remember in transient faults is that the overall impedance—inductance combined with resistance—of the conductor may limit the effectiveness of a ground. Large conductors have lower inductance than small conductors. Straight mounting rails have a lower inductance than a meandering loop of wire. Where there are a number of mounting rails in parallel, the impedance is reduced proportional to that number. Again, newer grounding equipment will have lower impedance and therefore be safer. This also applies for protection against lightning.

The long-term integrity of all methods of grounding arrays is a big question. There is anecdotal evidence that older methods of grounding that are still being accepted by inspectors do not hold up well; but there is not yet an accepted standard for testing grounding methods. This means that individual manufacturers can evaluate their own products, but the Nationally Recognized Testing Laboratories cannot evaluate all grounding methods in a consistent way. Until agreed upon standards are published, inspectors and installers can use the *NEC* as a guideline but will have to use their common sense, experience and good judgment to decide what grounding methods are acceptable. ⏚