Code Q&A

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Sponsored by the U.S. Department of Energy

Q I want to give my customers the best possible system for the least cost. Since time is money, I worked up a couple of shortcuts that will save me some time on solar-electric (photovoltaic; PV) installations. I usually mount my modules in rows, in a portrait configuration. The module manufacturers place the grounding points on the long sides of the modules, where they are difficult to reach to connect wires. I have been drilling holes in the short sides of the modules and installing lay-in lugs, which are very easy (and fast) to wire. At the end of each module string, I switch to a THHN conductor in a junction box, and use conduit through the attic and down to the DC disconnect. I usually just cut off the Multi-Contact (MC) connector from the first and last modules in the string, and use a split bolt or a crimp-on connector to connect the bare module wire to the THHN. What's your view on this?

A I applaud your desire to make a quality installation and keep the costs as low as possible. Unfortunately, some problems arise from your time-saving techniques.

First, drilling the module frames may void the manufacturer's warranty. This is especially problematic if you are drilling a new hole at a location other than the marked grounding point. Underwriters Laboratories (UL) has evaluated the module grounding *only* at the marked points, and other points may not provide adequate grounding. Furthermore, other points on the module frames may not be thick enough to provide the required two full-contact threads for a good electrical connection. For those rare instances where the module grounding hardware and/or instructions prove difficult to use, you might want to review the *Code Corner* on PV module grounding in *HP102*. In all cases, please contact the module manufacturer and see what their position is on module modifications, grounding, and warranties. Some of them have technical notes on this subject.

I am working with Underwriters Laboratories (as a member of the Standards Technical Panel) on UL Standard 1703 for PV modules to clarify the requirements and methods for PV module grounding, and to encourage module manufacturers to give installers more and better options for module grounding. For example, modules with conduit-ready junction boxes could have a third, copper-compatible terminal in the J-box for grounding, just like most other electrical devices. Modules with pigtail leads and MC connectors could have a third lead added for the equipment-grounding conductor, and studs or nuts that are copper compatible could be pressed into the module frames. As a minimum, module grounding points could be provided on both the short and long sides of the module frame. If these options appeal to you, write to the module manufacturers. There is nothing to prevent them from offering these options today.

Cutting off the MC connectors is also a warranty issue for some module manufacturers. When the manufacturer objects to cutting off the connectors, the easiest thing to do is buy pre-made cables with MC connectors attached. Another option is to buy an MC connector tool, take the factory training, and make your own connector–cable assemblies.

Several effective splicing devices can be used where proper strain-relief has been provided for each cable. They include wet-rated, twist-on connectors; split bolts (heavily taped); and several other types of insulated splicing blocks made by various manufacturers.

Any and all exposed metal, including junction boxes, must be properly grounded, and all metal conduits must be properly terminated and grounded at each end to other grounded equipment.

Q I have, on previous PV installations, connected the MC cables continuous from the last module in the string, through the J-box on the roof to the DC disconnect. I do this to avoid having a connection at the J-box (less chance of failure), but it means that I am running the USE-2 wire in conduit (usually 3/4 inch) to the disconnect. Is this a "proper use" of USE-2 wire? If not, what is your preferred method for splicing in the J-box and should the grounding wire be landed there?

A Type-MC cable in the *National Electrical Code (NEC)* refers to metal-clad cable; this may be an indoor- or outdoor-rated cable depending on the actual construction and marking on the specific product. If you mean single-conductor cables with MC connectors, that is something entirely different. Cables with only the USE-2 marking may *not* be run inside any building (even in conduit) because they have no flame retardant. Cables marked USE-2/RHW-2 have the proper flame retardants and can be exposed in outdoor locations for module interconnections, as well as run in conduits, both outdoors and indoors.

Any conduit in the building must be a metal conduit like EMT, not a plastic conduit, and that use is permitted only under the 2005 *NEC*, not the 2002 *NEC*, which is still in effect in many areas.

Q I have read through the section on string fusing in your *Photovoltaic Power Systems and the 2005 National Electrical Code: Suggested Practices* manual, but am still a bit confused about this topic. I tried to draw a diagram showing the various scenarios, but still did not totally understand the theory. I have tried to find diagrams illustrating this, but have been unsuccessful. Do you know of any? Also, isn't it possible that the faulted string could add backcurrent, depending on the fault location in that string? I would like to understand the theory behind this.

A Fusing of any PV module or conductor is required when potential backfed currents from all *external* sources exceed the reverse current rating of the module (listed on the back of the module as the maximum protective fuse) or the ampacity of the conductor. Currents generated *in* a string of modules are not counted in this calculation, since both the module and the conductors are, by design, capable of handling all forward currents. In the simple case, the sum of all external currents (typically 1.25 Isc from each external string with no feedback from the inverter) must be less than the module maximum protective fuse. If the external currents are larger than the fuse rating, a series fuse will be required on each string of modules. For more details and theory, see Appendix J in the newest version (1.3) of the *Manual* (see Access and the SWTDI Web site).

Q I used a braided tinned copper (flat) grounding wire on a system a couple of years ago and found it very nice to work with. I am unsatisfied with the typical ground method (clamps and #6 bare), as I feel that there are too many connections to come loose (especially at the clamp). When fastened directly to the module with a stainless steel #10-32 screw and a stainless steel star washer, the braided wire is superior. Do you have any experience with this? How should I size this wire? This type of wire has an AWG "size" and an ampacity rating, but the corresponding size to #6 does not have the ampacity of #6.

A I have no experience with tinned braided conductors and do not know if they are suitable for use in contact with aluminum module frames, nor do I know if the material is suitable for outdoor applications. These braided grounding straps are used to ground electronic equipment and are usually installed in a dry, indoor environment. While some inspectors require #6 equipment-grounding conductors for physical strength, the code requirement is usually a smaller conductor sized at 1.25 Isc. These smaller conductors, such as #12 or #10, can usually be adequately attached to the module using the hardware provided. Uninsulated conductors don't have ampacity calculated in the same manner as insulated conductors because there is no insulation to worry about overheating. However, the *NEC* requires that you use the ampacity associated with the same-size insulated conductor.

A Question for You

Have you ever had any electrical or electronic device or appliance damaged when connected to a modified square wave inverter (also called a modified sine wave inverter)? Such devices or appliances might include light dimmers, laser printers, copiers, and battery chargers for power tools.

If so, please send me the manufacturer and model number of the inverter, and as much information as you can provide about the damaged device or appliance (name, model number, date, damage, etc.). I will forward the information to Underwriters Laboratories (UL). UL is concerned about listed PV inverters damaging other listed equipment in common use. They may consider tightening the specifications and requirements on these inverters to reduce the possibility of equipment damage.

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 SDTI 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.

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The 2005 *National Electrical Code* and the *NEC Handbook* are available from the National Fire Protection Association (NFPA) • 800-344-3555 or 508-895-8300 • www.nfpa.org

Photovoltaic Power Systems & the 2005 National Electrical Code: Suggested Practices, a downloadable 144-page PDF manual • www.nmsu.edu/Research/tdi/public_html/Photovoltaics/Codes-Stds/PVnecSugPract.html

2008 *NEC* Proposals PDF • www.nmsu.edu/~tdi/pdf-resources/2008NECproposals2.pdf

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