Avoiding Common Code Mistakes

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Eight years into the new millennium, the PV industry continues to grow by leaps and bounds. New module and inverter manufacturers are entering the market, and the number of PV system installers is growing right along with the demand. Numerous small residential and large commercial PV systems are being installed in many states, and all need to be in compliance with the *National Electrical Code (NEC)* and any local electrical codes. With new people entering the industry every day, the *NEC* installation mistakes we have seen in the past will likely continue. Here are some of the most common ones that should be avoided.

DC Module Wiring Color Codes

Back in '97—that is, *1897*—when the first edition of the *NEC* was being drafted, Thomas A. Edison was generating electricity. This was direct current (DC), not that AC stuff with its heavy, costly transformers developed by Westinghouse and/or Tesla. So the earliest *NEC* dealt with DC, including color coding for conductors that still holds today. If the conductor is a grounded circuit conductor, the insulation or marking on larger conductors must be white or gray. If the conductor is an equipment-grounding conductor, it must have green or green with yellow-striped insulation—or be bare. Ungrounded conductors may be any color other than the ones listed above, with black and red being the most common in the field.

Those color codes apply to both AC and DC electrical systems. There is no separate color code for DC systems. Nearly all past PV systems and those being currently installed are grounded systems, and one of the conductors in the DC parts of the system should be white. PV installers insisting that red is positive and black is negative are to be relegated to their *electronics* workbenches, where such color codes are common.

In the future, we will see the installation of ungrounded PV arrays that will be used with transformerless inverters, and those systems will not have a grounded PV DC conductor. (See *NEC* Section 690.35.) At that time, the use of red and black conductors may become more common, but, presently, this is incorrect on grounded systems.

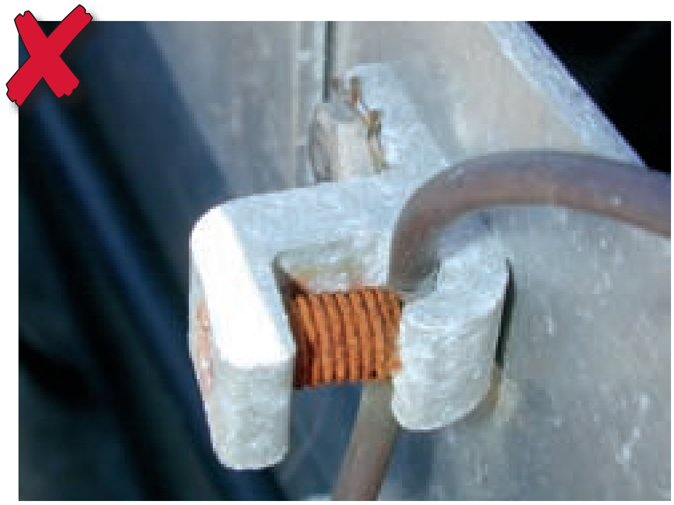
Grounded PV source circuits, but no white conductors.

Module Grounding

Module grounding still continues to be an issue with many inspectors, and rightly so, as PV installers attempt to reduce the time and materials required to ground modules. In September 2007, Underwriters Laboratories (UL) issued an interpretation of the UL Standard 1703 for PV modules requiring that module manufacturers identify the grounding method and materials to be used in grounding the modules. UL will then test and evaluate those methods and materials, both during the listing of new modules and the periodic recertification of existing modules. It is likely that the common use of a thread-cutting screw will not survive these new evaluations, which require that all threaded electrical connections be installed and removed ten times without damage to the threads.

Until those more definitive requirements come into play, *NEC* Section 110.3 requires that the labels and instructions provided with listed/certified modules be followed for proper module grounding. That usually means attaching a conductor or a tin-plated copper direct-burial lug to one of the four grounding points marked on the module frame. Attaching lugs properly is a time- and materials-intensive process, and it is hoped that better procedures and materials are developed and approved quickly.

Improper module grounding with dissimilar metals.



A dry-location lug used in a wet location.

Improper enclosure grounding: wrong device, wrong location.

A listed ground-bar kit in the proper location.

Enclosure & Conduit Grounding

Most utility-interactive PV systems operate at DC voltages between 300 volts and 600 volts, making proper grounding of the metallic enclosures used for disconnects and source-circuit combiners essential. Under *NEC* Section 250.8, using sheet-metal screws to ground enclosures is not allowed, although some PV installers and electricians continue to do so.

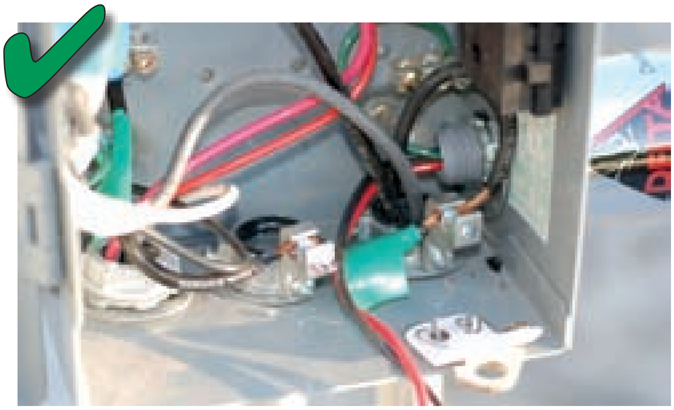
In listed safety disconnects, there is usually a label requiring the use of an appropriate, listed, ground-bar kit to ground the enclosure, and designated areas of the enclosure where the metal has been swaged thicker. This allows two full threads of the ground-bar kit's thread-cutting screw to cut into the enclosure. Failure to use the proper ground-bar kit would appear to violate 110.3(B) and could result in an enclosure that is not properly grounded.

NEC 250.97 requires that metal conduits containing circuits operating at more than 250 volts be properly bonded to the enclosures, particularly when concentric and eccentric knockouts are involved in the large enclosures used for disconnects.

Disconnect Connections

Typical fused and unfused disconnects (a.k.a. safety switches) usually have their "line" terminals (usually the top set of terminals) shielded by an insulator. This prevents these terminals, when energized by a source, from being easily touched when the cover or door is open. Normally, a mechanical interlock between the handle and door requires the disconnect to be turned off before the door can be opened. With the disconnect in the off position, the blade contacts and the lower set of "load" terminals, which are exposed and not covered with insulation, are not energized—and supposedly safe. This setup works well when the only source of power is connected to the line terminals and loads are connected to the lower load terminals.

PV systems with multiple sources of power and power flows confuse the issue somewhat. A PV system's DC disconnect should have the line terminals connected to the incoming PV output conductors. The inverter DC input should be connected to the load terminals on the disconnect. However, energy storage and filtering capacitors in the inverter can energize the inverter DC input terminals and



Bonding bushings on 500 VDC conduits.

Deterioration of THHN conductors due to outdoor UV exposure.

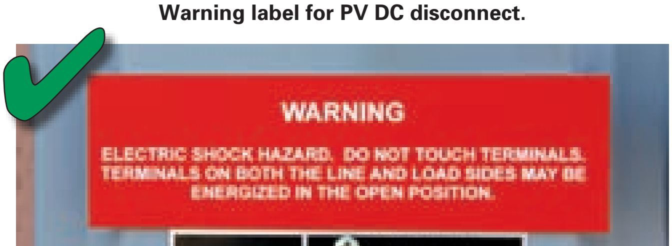
the disconnect load terminals up to five minutes *after* the disconnect is opened. These energized load terminals are the reason for Section 690.17's requirement that a warning label, stating that all terminals might be energized, even when the disconnect is opened, be placed on the disconnect.

Sometimes, installers (and inspectors) get confused when a safety switch is used as the AC inverter disconnect. These disconnects are frequently required by the local electric utility or may be part of a service-entrance tap for the PV system. Electricity flows from the inverter to the utility, usually through a backfed circuit breaker. Some installers and inspectors want the upper line-side terminals of the disconnect to be connected to the source of energy, the inverter. However, the normally energized conductors from the utility are the most dangerous and should be connected to the upper or line terminals of the disconnect. When the disconnect is opened, the inverter immediately ceases producing power, and the load terminals and the exposed blades of the disconnect have no voltage on them. Because the load terminals are de-energized when the disconnect is opened, there is no requirement for a 690.17 warning label on this disconnect when it is connected properly.

Improper Conductors

PV modules operate in extreme outdoor conditions, where temperatures on and near the modules may range from -40°F to 176°F. There is always an abundance of ultraviolet (UV) radiation (remember, it comes from sunlight) and wind, rain, snow, and ice depending on location. *NEC* Section 690.31 allows single-conductor, insulated cables to be installed as connections between PV modules and from the modules to a transition box under the PV array, where a more conventional wiring system starts. The use of the wrong conductors for exposed locations, such as THHN/THWN, RHW, THW, or others that are intended for use in conduit, will result in rapid deterioration of these conductors that have no UV resistance. Conductors marked USE-2, with or without RHW-2 markings, should be used for exposed module interconnections. Newer cables marked "PV Wire," "PV Cable," "Photovoltaic Wire," or "Photovoltaic Cable" are coming to the market, and they too will be acceptable since they have a thicker jacket and superior sunlight resistance compared to USE-2. Where this new cable is used in conduit (it has the necessary properties for that application), the conduit fill will have to be calculated manually because of the thicker jacket.

Warning label for PV DC disconnect.



Best PV Practices

PV systems are a mature, but evolving, technology. While seasoned PV installers are meeting *NEC* requirements, there is a continual influx of new equipment and new, inexperienced installers. Installers must keep up with the new equipment installation requirements while remaining vigilant for the mistakes that will inevitably continue to plague future installations.

Access

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

The Southwest Technology Development Institute • www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/Codes-Stds.html • PV systems inspector/installer checklist & previous *Code Corner* articles