Common PV Code Violations

by John Wiles

As we move into 2008, the PV industry continues to grow by leaps and bounds. New module and inverter manufacturers are entering the industry, and the number of individuals and organizations installing PV systems is growing right along with the demand. Numerous small 2 kW residential and large megawatt commercial PV systems are being installed in many states, and all need to be inspected for code-compliance. With new people entering the industry every day, the common code violations we have seen in the past will continue. Here are some of the most prominent ones that have been repeatedly observed throughout the country.

DC Module Wiring Color Codes

Back in '97—that is 1897—when the first edition of the *Code* was being drafted, Thomas A. Edison was generat-

ing power. And it was direct current (dc) power, not that alternating current (ac) stuff with those heavy, costly transformers developed by Westinghouse and/or Tesla. AC came later, and the early *Code* dealt with direct current, including color codes for that dc power. 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 stripe insulation or be bare.

Those color codes apply to both ac and dc electrical systems. There is no special 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 back to their *electronics* workbenches where such color codes originated.

Yes, in the future, we will see the installation of ungrounded PV arrays (see 690.35) that will be used with transformerless inverters, and those systems will not have a grounded PV dc conductor. Then red and black conductors may become more common; but on the current grounded systems, they are incorrect. (See photo 1).

Photo 1. 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 the PV installers attempt to take time and materials short cuts when grounding modules. (See photos 2a and 2b). Underwriters Laboratories (UL) has issued an Interpretation of the UL Standard 1703 for PV modules in September 2007 that requires that the module manufacturer identify the grounding method and materials to be used in grounding the module. UL will then test and evaluate those methods and materials during the listing of new modules and the periodic recertification of exist-

Photo 2a. Improper module grounding—dissimilar metals

Photo 2b. Dry location lug in wet location

ing 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 instructions start appearing, *NEC* 110.3 requires that the labels and instructions provided with the listed/certified modules be followed. That usually means attaching a conductor or 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 new procedures and materials are approved quickly. (See photo 3).

Enclosure and Conduit grounding

Most utility-interactive PV systems operate at dc voltages between 300 and 600 volts. The metallic enclosures used for dis-

Photo 3. Module grounding hardware and tools

connects and source-circuit combiners must be properly grounded. The *NEC* does not recognize the use of sheet metal screws to ground enclosures (250.8), but PV installers and electricians continue to use them. (See photo 4). In listed safety disconnects, there is usually a label requiring the use of the appropriate listed, ground-bar kit to ground the enclosure. There are designated areas of the enclosure where the metal has been swaged thicker to allow two full threads of the thread cutting screw provided with the ground-bar kit to be cut into the enclosure. (See photo 5). 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.

Photo 4. Improper grounding of enclosure; wrong device, wrong location

Typical, residential, utility-interactive PV systems operate at voltages up to 600 volts. *NEC* 250.97 requires that metal conduits operating over 250 volts be properly bonded to the enclosures, particularly when concentric and eccentric knockouts are involved. The large enclosures used for disconnects have not be evaluated for grounding/bonding where concentric or eccentric knockouts are used. (See photo 6).

Disconnect Connections

The typical fused and unfused disconnects (a.k.a. safety switches) usually have the *line terminals* (usually the top set of terminals) shielded by an insulator so that these terminals, when energized by the source, cannot be easily touched when the cover or door is open. These disconnects normally have a mechanical interlock between the handle and door that re-

Photo 5. Listed ground-bar kit in the proper location

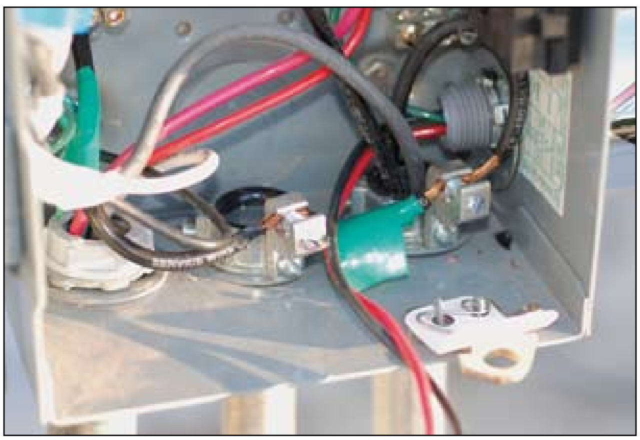

Photo 6. Bonding bushing on 500 VDC conduits

Photo 7. Warning label for PV dc disconnect

quires that the disconnect be turned "OFF" before the door can be opened. With the disconnect "OFF," the blade contacts and the lower set of *load terminals* are supposedly safe and are not energized. They are exposed and not covered with insulation. This works well when the only source of power is connected to the line terminals and loads are connected to the lower load terminals. However, PV systems with multiple sources of power and power flows confuse the issue somewhat.

The dc PV disconnect should have the line terminals connected to the incoming PV output conductors, and the inverter dc input should be connected to the load terminals on the disconnect. However, there are energy storage and filtering capacitors in the inverter that can energize the inverter dc input terminals and the disconnect load terminals up to five minutes after the disconnect is opened. These energized load terminals are the reason for the requirement in 690.17 for a warning label on the disconnect saying that all terminals might be energized when the disconnect is opened. (See photo 7).

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 the service-entrance tap for the PV system. The power flows from the inverter to the utility (usually through a backfed circuit breaker) and 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 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 the temperatures on and near the modules may range from -40 to +80 degrees Celsius. There is always an abundance of ultraviolet (UV) radiation (remember, it comes from sunlight) and wind, rain, snow, and ice depending on location. *NEC* 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 in 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. (See photo 8). Conductors marked USE-2 with or without RHW-2 markings should be used for exposed module interconnections. Newer cables marked "PV Wire," "PV Cable," "Pho-

Photo 8. THHN conductors deteriorating due to outdoor UV exposure

tovoltaic Wire," or "Photovoltaic Cable" are coming to the market, and they too will be acceptable since they have superior sunlight resistance to USE-2 and a thicker jacket, plus some other good features. Where 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.

Summary

Photovoltaic power systems are a mature, but evolving, technology. While seasoned inspectors and PV installers are meeting *Code* requirements, there is a continual influx of new equipment and new, inexperienced installers. Inspectors must keep up with the new equipment installation requirements while maintaining a firm but fair vigilance for the *Code* violations that have been seen in the past and that will continue to be seen. Inspectors should also be vigilant for unexpected hazards—(photo 9).

Photo 9. Unexpected hazard

For Additional Information

If this article has raised questions, do not hesitate to contact the author by phone or e-mail. E-mail: jwiles@nmsu.edu Phone: 575-646-6105

A color copy of the latest version (1.7a) of the 150-page, *Photovoltaic Power Systems and the 2005 National Electrical Code: Suggested Practices*, published by Sandia National Laboratories and written by the author, may be downloaded from this web site: http://www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/PVnecSugPract.html

The Southwest Technology Development Institute web site maintains a PV Systems Inspector/Installer Checklist and all copies of the previous "Perspectives on PV" articles for easy downloading. Copies of "Code Corner" written by the author and published in *Home Power Magazine* over the last 10 years are also available on this web site: http://www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/Codes-Stds.html

The author makes 6–8 hour presentations on "PV Systems and the *NEC*" to groups of 40 or more inspectors, electricians, electrical contractors, and PV professionals for a very nominal cost on an as-requested basis. A schedule of future presentations can be found on the IEE/SWTDI web site.

John Wiles works at the Institute for Energy and the Environment (IEE) (formerly the Southwest Technology Development Institute) at New Mexico State University. IEE has a contract with the US Department of Energy to provide engineering support to the PV industry and to provide that industry, electrical contractors, electricians, and electrical inspectors with a focal point for Code issues related to PV systems. He serves as the secretary of the PV Industry Forum that submitted 42 proposals for Article 690 in the 2008 NEC. He provides draft comments to NFPA for Article 690 in the NEC Handbook. As an old solar pioneer, he lived for 16 years in a stand-alone PV-power home in suburbia with his wife, two dogs, and a cat—permitted and inspected, of course. He has just installed a new PV system on his home that is utility-interactive with a full-house battery back up using a New Mexico Homeowner's Electrical Permit.

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