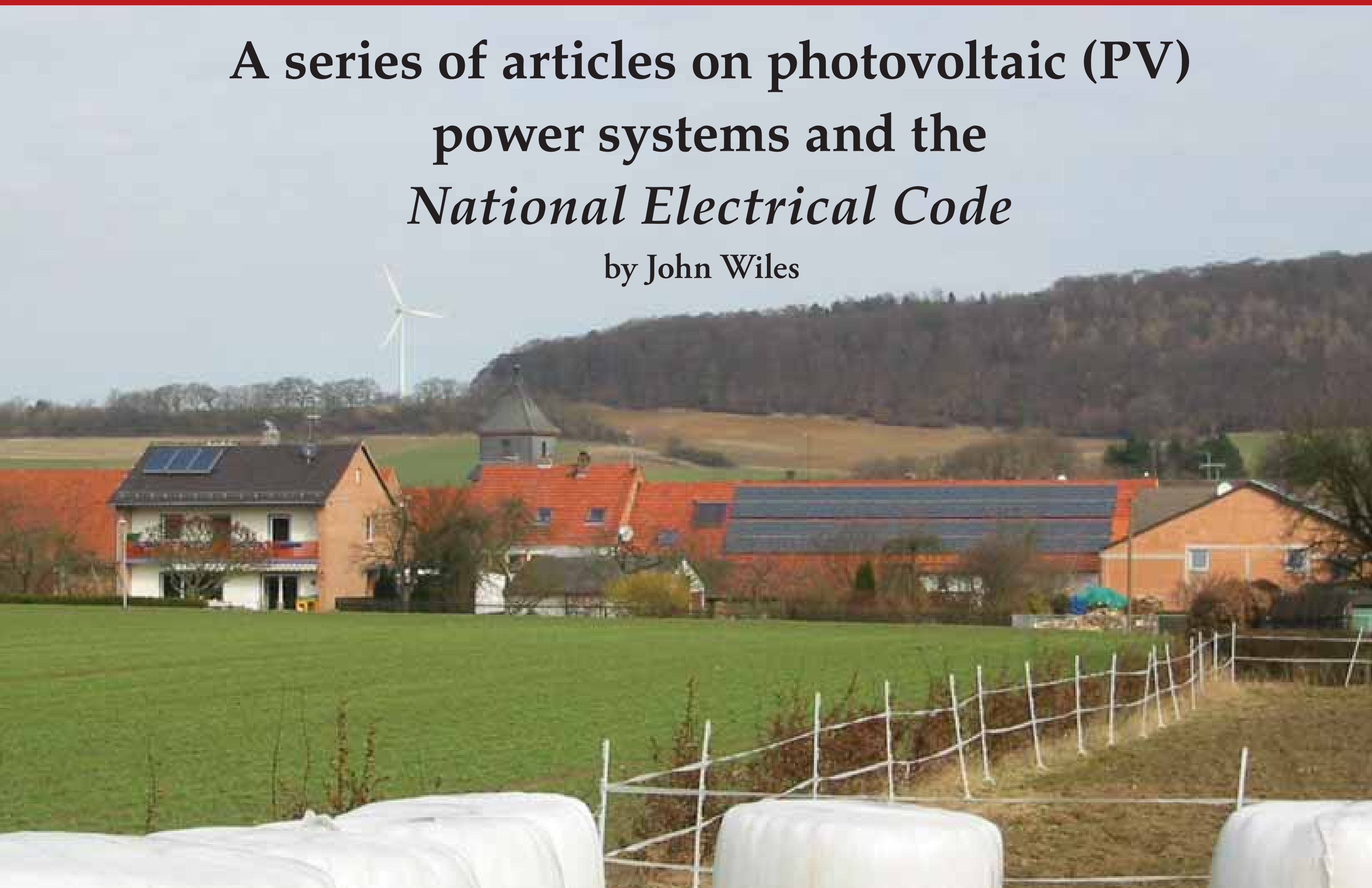
Perspectives on PV

A series of articles on photovoltaic (PV) power systems and the *National Electrical Code*

by John Wiles



Updates: Grounding PV and Systems Fine Stranded Conductors

Grounding

In the "Perspectives on PV" article in the September-October 2004 issue of the *IAEI News*, the subject of grounding PV systems was covered in some detail. In the March-April 2005, *IAEI News*, we discussed the changes to Article 690 that appear in the *2005 National Electrical Code*. As normally happens over the three-year code development cycle, new thoughts and ideas come to the forefront about how things should be done. Here are some of those thoughts as they apply to grounding smaller PV systems with single inverters sized below about 10 kW. Figure 1 shows the dc grounding for a PV system as spelled out in Section 690.47 of *NEC*-2005 and as described in the above-mentioned article. Inspector Russ Coombs of Bakersfield, California, suggested that if the ac ground rod cannot be found, then the dc grounding electrode conductor might be spliced (irreversibly) to the ac grounding electrode conductor. I think this is a good suggestion because in many older buildings, the ac grounding electrode is buried in non-accessible locations.

PV system designers, PV integrators and installers are always looking for ways to meet the code safety requirements, install the system at the lowest cost, and make the system look good. The grounding system shown in figure 2 has been proposed as an alternate grounding system to meet most of the *NEC* requirements for grounding these systems. There is no dc grounding electrode (ground rod) located at the inverter. An unspliced 8 AWG (if allowed, based on the type of existing ac grounding electrode) bare or insulated

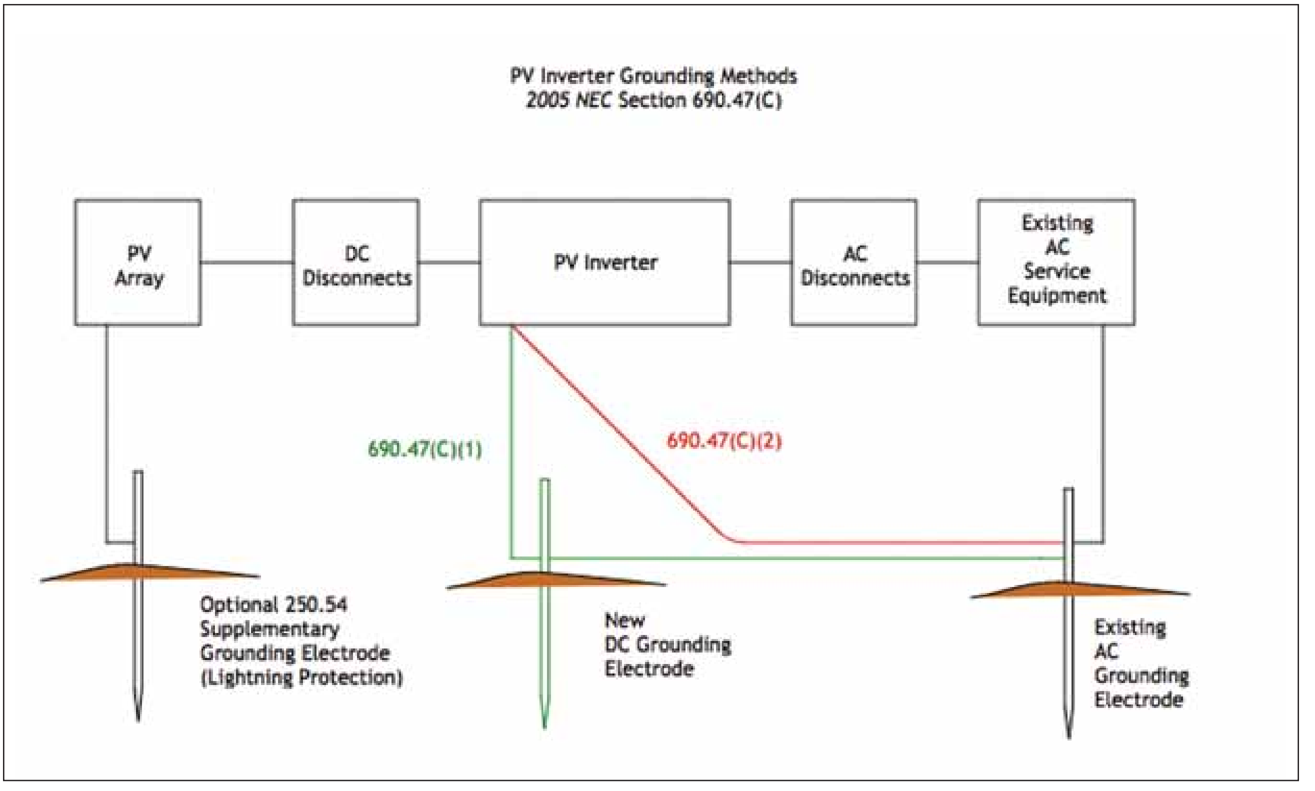


Figure 1. Grounding amall PV inverters per NEC-2005

conductor (marked green) is routed from a grounding terminal in the inverter along with the ac inverter output circuit conductors to and through (no stopping) to the ac ground rod. In this example, the 8 AWG conductor serves as both the dc grounding electrode conductor (unspliced, minimum size) and the ac equipment-grounding conductor. It should be noted that all grounding terminals and lugs (equipment-grounding and grounding electrode conductor) are electrically connected together in the inverter and may generally be used interchangeably depending on the size of the conductors they will accept.

This method only works on the smaller string inverters where the ac equipment grounding conductor is 8 AWG or less and the ac grounding electrode is not something like a UFER (concrete-encased electrode) that may require a 4 AWG grounding electrode conductor. It is usually not appropriate for the 10 kW and larger three-phase inverters.

Multiple, Small String Inverters

Where multiple small inverters are installed in a single location, it is probably best to install a 6 AWG (if allowed based on the type of grounding electrode) bare, grounding electrode conductor from the first inverter in the set to a dc grounding electrode, which is then bonded to the ac grounding electrode. As allowed by *NEC*-2005, this dc grounding electrode conductor may also be routed and connected directly to the ac grounding electrode. If the ac ground rod cannot be found, then this conductor might be spliced (irreversibly) to the ac grounding electrode conductor. This dc grounding electrode conductor is routed beneath each of the other inverters in the set. A short, 6 AWG grounding electrode conductor is connected to a grounding terminal in each of the other inverters and then irreversibly spliced to the dc grounding electrode conductor running beneath each inverter (see figure 3). In this manner, only one dc grounding electrode conductor is required for the entire set. This is similar to the way multiple service disconnects are grounded in an apartment complex as shown in Exhibit 250.28 in the *2002 NEC Handbook.*

Lightning Surge Protection

PV installers should note that the single-inverter grounding method runs the dc negative grounding system and the dc equipment-grounding conductors all the way back to the ac grounding electrode along with the ac output conductors from the inverter. Lightning induced surges may also travel this path and this may increase the possibility of lightning-induced surge damage to the PV equipment with this method of grounding

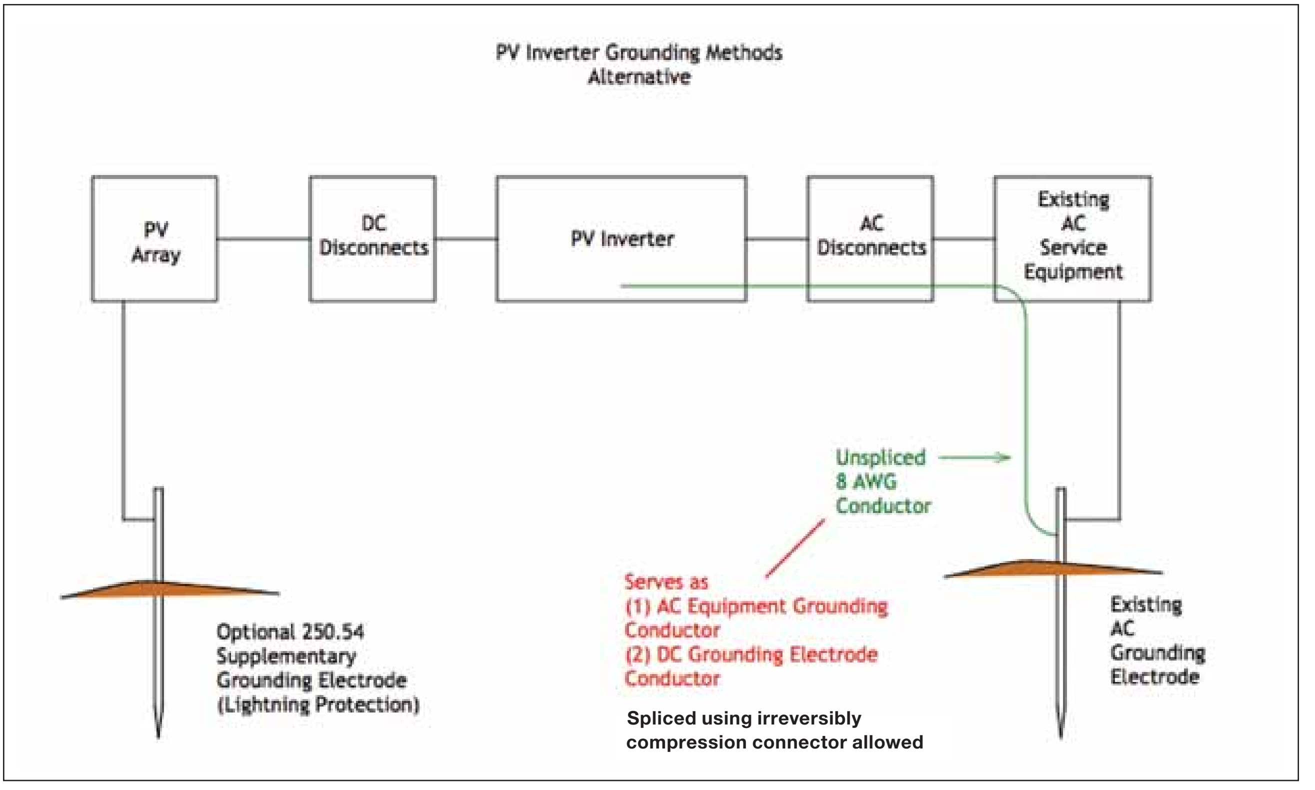


Figure 2. Acceptable alternative grounding method

the dc systems. Placing a dc grounding electrode at the inverter (bonded to the ac grounding electrode) may help to reduce surge damage. Also adding supplementary equipment grounding electrodes for the PV array mounting racks/module frames as shown in figures 1 and 2 and not bonding them to other grounding electrodes may reduce the potential for lightning damage (see *NEC,* 250.54).

Fine Stranded Cables

Since the Perspectives on PV article on fine stranded cables was published in the January-February issue of the *IAEI News*, I have received calls from people in other industries about connections failing where fine stranded cables have been used improperly. These failures have been associated with electric vehicle power cables, motor connections, and a few other high-current applications. At Underwriters Laboratories, the principal engineer for Distributed Energy Resources Equipment and Systems is going to process a bulletin and UL 1741 (*PV Inverters and Charge Controllers*) revision to clarify the use of appropriate connectors and terminals with fine stranded conductors.

If you are in another industry that uses these conductors and associated connectors improperly, or you inspect such equipment, notifying UL might get some additional corrective actions taken. Inspectors can contact UL and

Photo 1. Residential PV installation

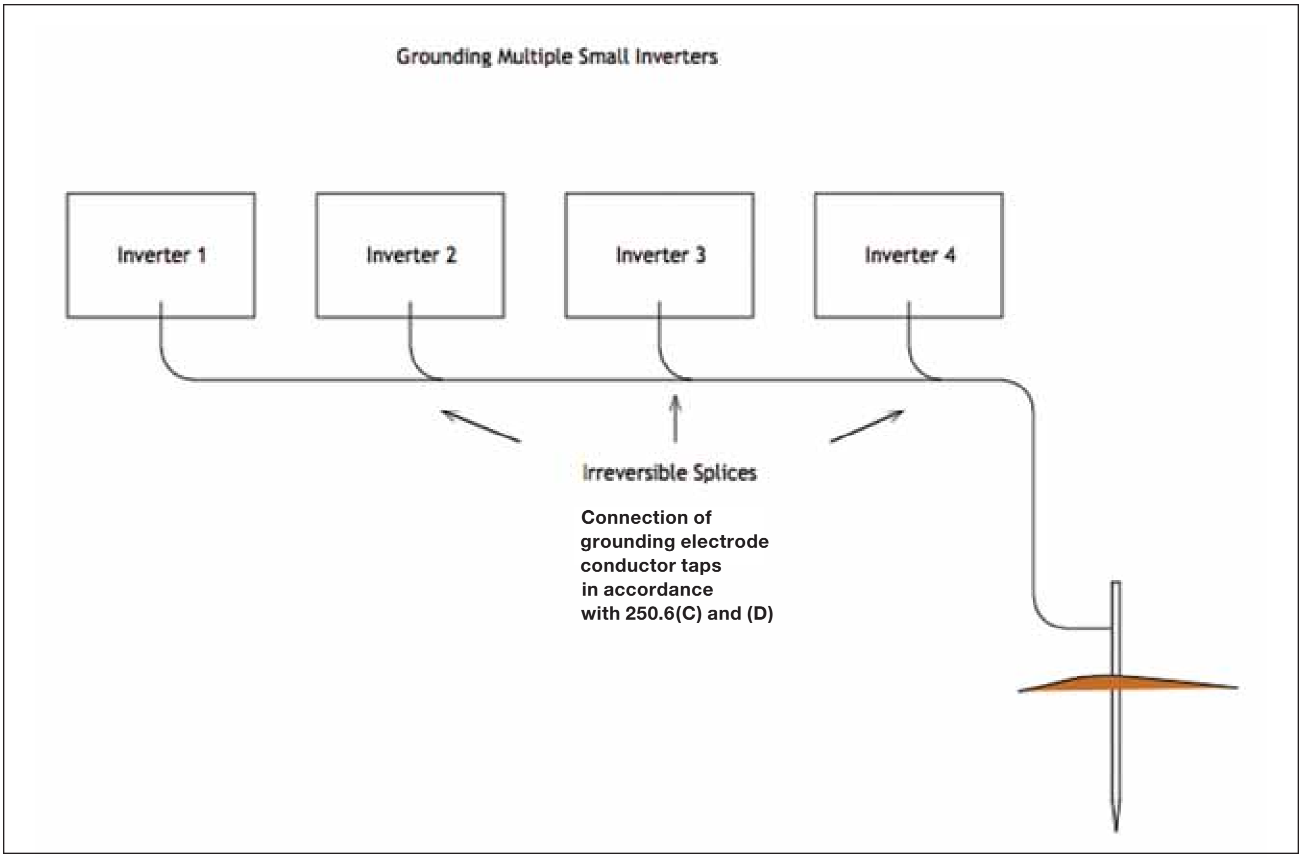


Figure 3. Grounding Multiple Small Inverters

file a field report at the following UL web site: (https://www.ul.com/regulators/ahjprod.cfm). Others can file a report to UL at this site: (https://www.ul.com/consumers/conproddb.cfm). I can supply a PDF of the original article, if needed.

Photo 2. PV system being installed

Photo 3. Ferrules on the shelf

Germany Does It Right

I spent ten days in Germany in early March visiting PV equipment manufacturers, looking at PV installations (photo 1) and touring residential construction projects (photo 2). I was pleasantly surprised to find that trained electricians are installing most PV systems in Germany. Germany is second only to Japan in the number of PV installations.

Photo 4. Fine stranded cables used for residential wiring

The electricians that I talked with were familiar with the use of fine stranded conductors and the equipment-production facilities I visited used them regularly. All locations had a wide range of crimp-on wire-end ferrules and sleeves available, and they also had the proper crimping tools for placing these devices on fine stranded cables before inserting them into terminals. Even the building supply stores (equivalent to Home Depot and Lowes) had these ferrules readily available (photo 3).

I discovered that the typical residential and commercial wiring in Germany is accomplished with a jacketed, sheathed, three-four conductor cable where each of the main conductors consists of flexible, fine stranded wires (photo 4). These types of cables have been used for decades. Where our type NM cables typically have solid conductors up to 10 AWG, the German equivalents use fine stranded flexible conductors. The German electric dryer and range cords use fine stranding like ours do, but theirs have ferrules attached (photo 5).

It appears that the lack of familiarity with the proper use of fine-stranded cables here in the U.S. can possibly be traced to the fact that the typical electrician (and home owner) rarely deals with these cables. In Germany, where these cables are used daily, everyone seems to know how to properly install them. I wish we could import that knowledge base to the U.S. (along with the excellent German rail system).

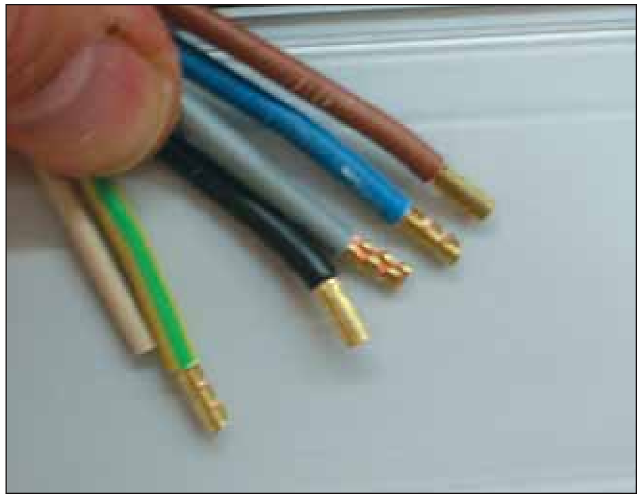


Photo 5. Ferrules installed on dryer cord

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: 505-646-6105

A PV Systems Inspector/Installer Checklist will be sent via e-mail to those requesting it. A color copy of the 143-page, 2005 edition of the *Photovoltaic Power Systems and the 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/roswell-8opt.pdf.). A black and white printed copy will be mailed to those requesting a copy via e-mail if a shipping address is included. The Southwest Technology Development web site http://www.nmsu.edu/~tdi) maintains all copies of the "Code Corner Columns" written by the author and published in *Home Power Magazine* over the last 10 years. Copies of previous "Perspectives on PV" are also available on this web site.

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.

John Wiles works at the Southwest Technology Development Institute (SWTDI) at New Mexico State University. SWTDI 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 30 proposals for Article 690 in NEC-2005. He provides draft comments to NFPA for Article 690 in the NEC Handbook. As an old solar pioneer, he lives in a stand-alone PV-power home in suburbia with his wife, two dogs and a cat—permitted and inspected, of course.

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