A young girl with dark hair in pigtails, wearing a pink long-sleeved shirt, is looking intently at a large array of solar panels on a roof. The scene is set during sunset or sunrise, with a warm orange and yellow glow in the sky and silhouettes of trees in the background. The solar panels are the dominant feature, filling most of the frame.

The 15-minute PV System Inspection Can You? Should You?

by John Wiles

**That PV system
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Perspectives on PV

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

As I make presentations on photovoltaic power systems and the *National Electrical Code* around the country, I frequently talk to inspectors who have as little as 15 minutes to make a residential electrical inspection. A common question is, “Can I inspect a residential PV system in 15 minutes?” This article will examine that question and also take up the question, “Should only 15 minutes be allocated for inspecting a residential PV system?”

Let’s start with an ideal situation. The inspector is familiar with PV systems in general and has inspected quite a few. He or she receives an application for a permit for a PV system, and that application is accompanied by all of the material outlined in the “PV Plan Check” article in *IAEI News*, March/April 2006. A review of the supplied material shows no major problems in code compliance, and the installer quickly rectifies the few minor problem areas found. A team consisting of a PV vendor with a history of good PV installations and an electrical contractor/electrician who has a commercial electrical license and some PV experience has done the design of the system and the installation.

Here are some of the items that an inspector should verify during the site visit. They are listed in order of importance and in order of safety for the inspector. For a more complete list, see “Perspectives on PV,” in *IAEI News*, May/June 2005.

Grounding and Bonding

Proper grounding of the PV system is extremely important because the PV modules will be generating hazardous amounts of energy for the next fifty years or more. Proper grounding is the first, the last, and most important area (in my mind) that requires code compliance in a PV system. Proper grounding of all exposed metal surfaces that may become energized as the system ages or as accidents happen will provide the highest levels of protection against shock and fires. Proper grounding will also facilitate the action of the ground-fault detection system that most of these systems will have. As the inspector moves through the PV system, grounding will be a critical inspection item in several locations.

Many residential PV systems (6 kW and below) have all of the PV equipment, both ac and dc, grounded by a single equipment grounding conductor connected from the modules to the grounding bus bar in the residential ac load center. The module frames, the PV array mounting rack, the dc disconnect, the inverter, and the one or more ac disconnects are all grounded by the single equipment grounding conductor routed to the ac load center. The first item a careful inspector should verify is that the equipment grounding conductor from the PV system inverter has been connected properly in the ac load center grounding bus bar and that the ac load center has a proper connection to ground (earthed). If this equipment grounding has not been done properly, a ground fault in the PV array or elsewhere in the system may put several hundred volts on the ungrounded exposed metal surfaces of any PV equipment.

As PV systems mature and UL standards and the *Code* evolve, it is hoped that the grounding of PV systems will become more robust. Even now, some systems will be installed with a dc grounding electrode conductor connected to a dc grounding electrode or to the ac grounding electrode.

If the backs of the PV modules can be closely observed, proper grounding of the modules should be checked. The use of the hardware and instructions supplied by the module manufacturer should have been followed as shown in the instruction manual that was delivered, hopefully, with the permit request. See “Perspectives on PV” in the September/October 2004 issue of the *IAEI News* for more details on grounding PV systems.

AC Point of Connection to the Utility

While the residential ac load center is open to check the grounding connection, the value of the backfed PV circuit breaker can be noted. It should match the value on the permit application and not be generally greater than 20% of the load center rating. This assumes that the main breaker and the load center have the same rating [See *NEC 690.64*]. This requirement limits the backfed PV breaker to a maximum of 20 amps on a 100-amp load center and to a maximum of 40 amps on a 200-amp panel. Breakers larger than this indicate that the utility connection should have been made on the supply side of the service disconnect. See “Perspectives on PV” in the January/February

2005 issue of the *IAEI News* for supply-side connection requirements.

Inverters

The inverter should be opened to check the field-installed connections. Some inverters will require metric hex socket drivers (or Allen wrenches) to open. One manufacturer makes a sealed inverter with permanently attached cables for connections to the adjacent ac and dc disconnects.

Inverters with a 120-volt output should have line, neutral (grounded), and equipment grounding conductors between the load center and the inverter. Inverters made outside the U.S. may have the equipment grounding terminals marked PE for “Protective Earth.” Some 240-volt inverters have only line 1, line 2, and equipment grounding conductors with no neutral (grounded) conductor, while others will have line 1, line 2, neutral, and equipment grounding conductors. The inverter manual (submitted with the permit request) will show the proper connections. Inverters requiring no neutral connection must not have the neutral conductor attached to anything, particularly an equipment grounding terminal,

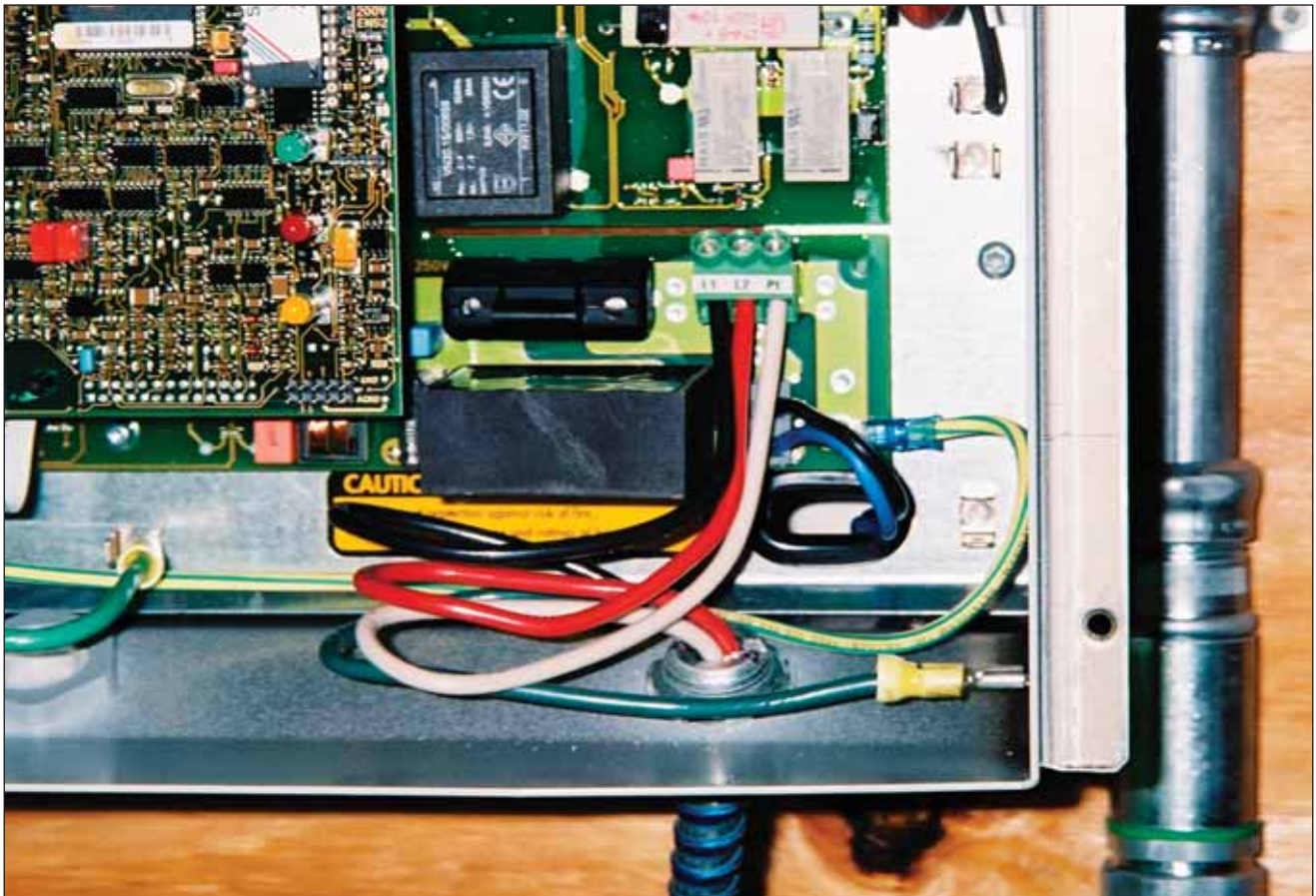


Photo 1. Improperly wired 240-volt inverter; neutral wired to PE terminal



Photo 2. Inverter with three DC inputs

because such a connection would establish a connection between ground and the neutral conductor that is prohibited by *NEC* Section 250.6 and 250.24(A)(5).

The dc input connections to the inverter may include one or more sets of positive and negative conductors as well as at least one dc equipment grounding conductor routed to either an external dc disconnect or to the PV array (see photo 2).

AC and DC Disconnects

Each disconnect should be properly grounded. Following and verifying the equipment grounding conductors backwards from the ac load center through the system to the PV modules is important to ensure that each ex-



Photo 3. Improperly grounded dc disconnect; violates 250.8, 110.3(3), 250.96(A), and 250.4(A)(5)

posed metal surface that may be energized is grounded. Grounding using sheet metal screws is prohibited by the *Code* and the use of “tech screws” and aluminum lugs is questionable (photo 3). Most listed fused disconnects and circuit breaker enclosures have ground-bar kits with specific mounting instructions and locations that should be used to maintain the listings of the devices and to provide the highest quality grounding connection (photo 4).

While the dc PV disconnect enclosure is opened, the color coding of the conductors should be checked. Most current PV systems use a negative ground and the negative conductor should be colored white and should *not* be switched or fused by the disconnect. There are a few positive grounded PV systems being installed, and in this case, the positive conductor is now colored white and is not switched. Section 690.35 of *NEC-2005* permits the use of ungrounded systems (neither of the circuit conductors is grounded) and these will be showing up. These ungrounded systems must meet several additional requirements including switching both of the ungrounded circuit conductors with neither conductor colored white [see *NEC* 690.35]. The inverter or the system should be clearly marked (not yet a *Code* requirement) showing the type of grounding (negative ground, positive ground, or ungrounded) to allow easy determination of the proper color codes.

There is no specified color code for the ungrounded conductors, and any color is permitted as long as gray, white, green, and green and yellow are not used. Typical conductor insulations are shown in table 1.



Photo 4. Properly installed, listed ground bar kit

Both circuit conductors (positive and negative) should be routed through the disconnect enclosure even though only the ungrounded conductor is switched. Avoiding a “switch loop” configuration ensures that both circuit conductors are always in close proximity for best functioning of overcurrent devices and to allow a bolted connection point for the grounded conductor on an isolated “neutral bus” in the enclosure, if required.

In the dc PV disconnect, the always “hot” conductors from the PV array wiring should be connected to the top (covered) “Line,” terminals on the switch while the lower, exposed, “Load” terminals should be connected to the inverter. On the ac disconnect, the upper “Line” terminals should be connected to the utility power conductors that come from the backfed ac load center. The lower “Load” terminals should be connected to the inverter.

Workmanship and the Roof

The equipment used and the workmanship on most residential PV systems will more closely resemble the

equipment and workmanship on a commercial electrical installation than those items in a residential electrical system. There will usually be surface-mounted disconnects and much of the wiring will be in exposed, surface-mounted conduit.

The installer should have a ladder on site the day of the inspection to facilitate examining the installed PV array. A quick look at the PV array on the roof should verify that any exposed wiring is firmly secured to the PV modules or the mounting structure and is not dangling down where it would be subject to physical damage (photo 5).

If the backs of the PV modules can be closely observed, proper grounding of the modules should be checked. The hardware supplied by the module manufacturer should have been used as shown in the instruction manual delivered with the permit application. Each PV module must be grounded, and if exposed, single conductor cables touch the mounting racks or a metal roof, those objects should also be grounded. See “Perspectives on PV” in the September/October 2004 issue of the *IAEI News* for more details on grounding PV systems.

The conductors used for module interconnections

System Type	Negative Conductor	Positive Conductor
Negative Ground	White or Gray *	Black or Red
Positive Ground	Black	White or Gray *
Ungrounded	Black	Red

* Code requirement, others optional

Table 1. Typical DC Wiring Conductor Colors

should be as specified in the permit application with respect to size (AWG), insulation type, and temperature rating. Any PV combiners containing overcurrent devices exposed to sunlight should be noted and the plans and technical data reviewed to determine if adequate temperature deratings were applied. Conduits in sunlight will also be exposed to higher-than-ambient temperatures.

Inspect in 15 Minutes?

Yes, it might be possible to perform the above inspections in 15 minutes if the inspector has spent some time at the plan-check stage and is experienced in PV systems employing this inverter and the installer is there to answer questions, open the inverter and other equipment as necessary and to provide a ladder for roof access. However, any problems found in the above areas should warrant a closer look at the entire system; and when more details are examined, the inspection time can grow. A lack of familiarity with either PV in general, the equipment being installed, or the installer would normally dictate that the inspection take more time. How much? Some residential PV inspections for new inspectors are somewhat of a training session and with a knowledgeable installer, examining and discussing all of the details relating to a durable, safe (for 50 years) installation might take two or more hours.



Photo 5. Module wiring properly secured

Should We Do 15-Minute Inspections?

See the little girl in the lead-in photo? That PV system she is touching will still be producing power when her grandchildren are her age. It will take more than a 15-minute inspection to ensure that the PV system will be as safe then as it is now. Fifteen minutes is probably insufficient time to ensure

the public safety over a 40–50 year period.

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 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>.) The Southwest Technology Development Institute web site <http://www.nmsu.edu/~tdi> 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.

Proposals for the 2008 NEC that were submitted by the PV Industry Forum may be downloaded from this web site: <http://www.nmsu.edu/~tdi/pdf-resources/2008NECproposals2.pdf>

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 SWTDI web site.✍

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 40+ 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.

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