



Neither Sleet
nor Snow

nor Rain
nor the Dark
of Night ...



Perspectives on PV

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

Well, not exactly. Yes, all of those things will usually keep a photovoltaic (PV) system from generating power, but that is to be expected when your power system uses sunlight for fuel. However, these and other weather conditions also affect how a PV system is designed and installed to comply with the requirements of the *National Electrical Code*. With a PV power system lifetime exceeding 40 years, Mother Nature is going to use every trick in the book to make that system fail before its time. PV designers, installers, and inspectors need to devote significant attention to the weather-related safety requirements for PV systems to help ensure long-lived, hazard-free electrical installations.

Intense Solar Radiation and High Temperatures

Before we look at the dark side of PV, let's examine hot and sunny. PV modules are designed to operate in sunlight and the more sunlight they get, the more power and energy they will produce. The "Perspectives on PV" article in the July-August 2004 *IAEI News* (available on the SWTDI web site) addressed how the PV module's electrical output is affected by the intensity of the solar radiation. But what about the related issues of the effects of temperature and ultra-violet radiation on the other equipment? Any equipment exposed to the sunlit

environment should be rated for the exposure. Exposed conductors and cables must be marked sunlight resistant (UF and TC cables) or be tested during the listing process for UV exposure (USE and SE) cables. Using the wrong conductors can lead to failures (photo 1). Conductors (both in and out of conduit) should also be listed for use in wet environments and for at least 90°C. Conductor designations that include the -2 marking meet these requirements.

Underwriters Laboratory is releasing a specification for a new "PV" cable. Cables meeting this specification will have to pass a 700-hour accelerated UV exposure test, be rated for wet locations, have at least a 90°C rated insulation, have a flame retardant compound, and have a physically tougher insulation than type USE cable. Although the intent of the specification was that compliant cables would now meet the requirements for use in ungrounded PV systems as permitted by Section 690.35 of the *NEC*, it has yet to be determined how the "PV" cable will be used, given the existing code language in 690.35(D). The issue will hopefully be clarified in the *2008 NEC* and the PV industry is looking at ways to use this cable long before the *2008 Code* is enacted. Enlightened electrical inspectors who may see the new cable as an acceptable alternative to USE-2 may be the key to early its adoption.



Photo 1. THHN conductors exposed to sunlight



Photo 2. Pipe clamps with inserts holding cables securely

Cord grips and cable clamps used on outdoor junction boxes should be UV rated. In some cases, metal cord grips have been used, and while metal is resistant to UV, these generally have not been listed for outdoor use because they can corrode rapidly. Nylon cable ties are frequently used to tie conduits and exposed cables to module racks. The white cable ties have no UV0 resistance, and even some of those that are black fail in a few months. The use of listed cable ties specifically marked (at least on the package) for outdoor use and sunlight resistance should be encouraged. Even better is the use of stainless steel pipe clamps with neoprene rubber inserts to firmly secure exposed single conductor cables to racks and frames (photo 2).

The Fine Print Note No. 2 in 310.10 of the *2005 NEC* points out that conduits on buildings in sunlight operate at temperatures of 17°C above the ambient temperatures. Because conduits in PV systems are exposed to sunlight for decades, the raceways many times become discolored or darken with age (photo 3). Therefore, I suggest to the PV installers that 20°C be added to the highest ambient temperature when doing ampacity calculations, to account for the higher solar energy absorption of the aged materials. With PV module junction boxes operating in the 65–75°C (and hotter) ranges and

conduits in sun in ambient temperatures of 40–50°C plus the added 20°C for solar heating, it becomes evident that 310.15 temperature corrections are critical in calculating ampacities of wiring for PV systems.

PV combiner boxes that combine the outputs of strings of PV modules are also mounted in the sun. These devices (photo 4) usually contain overcurrent devices, and most overcurrent devices are rated for operation in ambient temperatures up to 40°C. With ambient temperatures in many locations of 40°C (45–50°C in the Southwest), solar heating of these enclosures pushes the internal temperature well above 40°C. The overcurrent device manufacturer must be consulted for appropriate temperature corrections. After applying the corrections by increasing the rating of the overcurrent device, the installer must then go back and verify that conductors and modules are properly protected from fault currents.

We also have to deal with those often overlooked terminal temperature limitations in *NEC* 110.14(C) because the high PV module temperatures require the PV installer to use 90°C rated conductors. While the modules all have terminals rated for use with 90°C conductors, the combiner boxes and most of the other fused disconnects and overcurrent devices have terminals that are restricted to use with 60°C or 75°C rated conduc-



Photo 3. PVC conductor, darkened with age

tors. Some of the combiner boxes do not have temperature markings, and since the overcurrent devices are usually below 100 amps, a conductor temperature limitation of 60°C must be assumed. Things get pretty complex when we deal with a fused combiner box, for example, with unmarked terminal temperature limitations. Consider one operating in the sun in Phoenix, Arizona, where the ambient temperature may be 45°C for weeks at a time. The box temperature could be 55–60°C (requiring 90°C insulated conductors), the fuse rating must be temperature corrected for the 55–60°C operating temperature, and then the operating temperature of the conductor/terminal at these elevated temperatures must be estimated to be less than 60°C. Obviously, if the internal temperature of the enclosure is near 60°C, it is going to be difficult to have fuse terminals operating below 60°C with any appreciable current in the terminals. In this case, the prudent path would be to replace this PV combiner with one that is marked for use with 75°C insulated conductors. At the very least, any enclosure containing overcurrent devices installed in the hot Southwest (and other hot locations) should be mounted in the shade where it will be subjected to no more than the high ambient temperatures (photo 5).

Wind, Sleet, Snow and Rain

Moving from the hot summer Southwest (and other parts of the country) to winter and the colder locations, we see other weather related issues. Equipment has to be able to withstand wind-driven rains. The use of appropriate types of NEMA enclosures will generally ensure that the internal equipment will not be subject to direct water spray. The use of listed devices will ensure that the internal connections are also generally immune to the effects of wind-driven rain. However, some custom, field-assembled enclosures may have been made with materials that are not well designed for even a little moisture. Rust may form when the internal components have not been properly specified for outdoor/damp areas (see photo 6).

High winds are an issue in coastal areas where hurricanes are common as well as in many other areas of the country. Building codes in these areas generally specify how items on the roof and on the ground are to be fastened down to resist the lifting forces of the wind. The *Study Guide* for the North American Board of Certified Energy Practitioners (NABCEP) has some guidance for PV installers in this area that is based on information in the *National Design Specification* for wood construction and on roofing manuals. The *Study Guide* may be downloaded from the Resources section of the NAB-



Photo 4. PV combiner in the sun

CEP web site (www.nabecp.org).

In areas of the country where there is snow buildup on roofs, attention must be directed to securely fastening all conductors and cables to the module racks or mounts and to the roof. Otherwise, sliding snow can rip wires loose and pull conduits loose. Similar attention to these workmanship details should be applied to windy areas and in all installations, a neat, workman-like installation will usually be safer than a messy installation (photo 2).

The PV designer/installer will usually be required to make a tradeoff between the best tilt angle for PV array performance and the angle that will best shed snow. Fortunately, as the installation location moves farther north (into snow country), the tilt angle for best performance gets greater and even assists in shedding snow. However, these higher tilt angles usually result in the PV modules being subjected to higher wind loading, so secure mounting is a must.

At very low temperatures, snow, sleet and freezing rain may adhere to the PV modules and must be removed if full output from the PV system is desired (photo 7). Obviously rooftop installations may make this more difficult. On the other hand, ground-mounted arrays must be high enough to avoid deep snow and drifts.

Hail? Usually, hail doesn't pose too much of a problem. The PV modules are made with tempered glass and the modules are tested with impacts simulating hailstones.

Summary

Yes, sleet, snow, rain, and the dark of night will prevent a PV system from producing energy. But when the snow melts and the sun comes up, that PV system will again be generating power for a very, very long time. The wide range of environmental conditions in which PV systems are installed impose significant design and installation requirements. The *NEC* has been addressing such requirements for many years. The long life of these systems points to the need for durable hardware and high level of workmanship. The equipment is up to the task. Installers and inspectors are too.

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 previous "Perspectives on PV" articles. 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.

Draft proposals for the 2008 *NEC* being developed 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 profes-

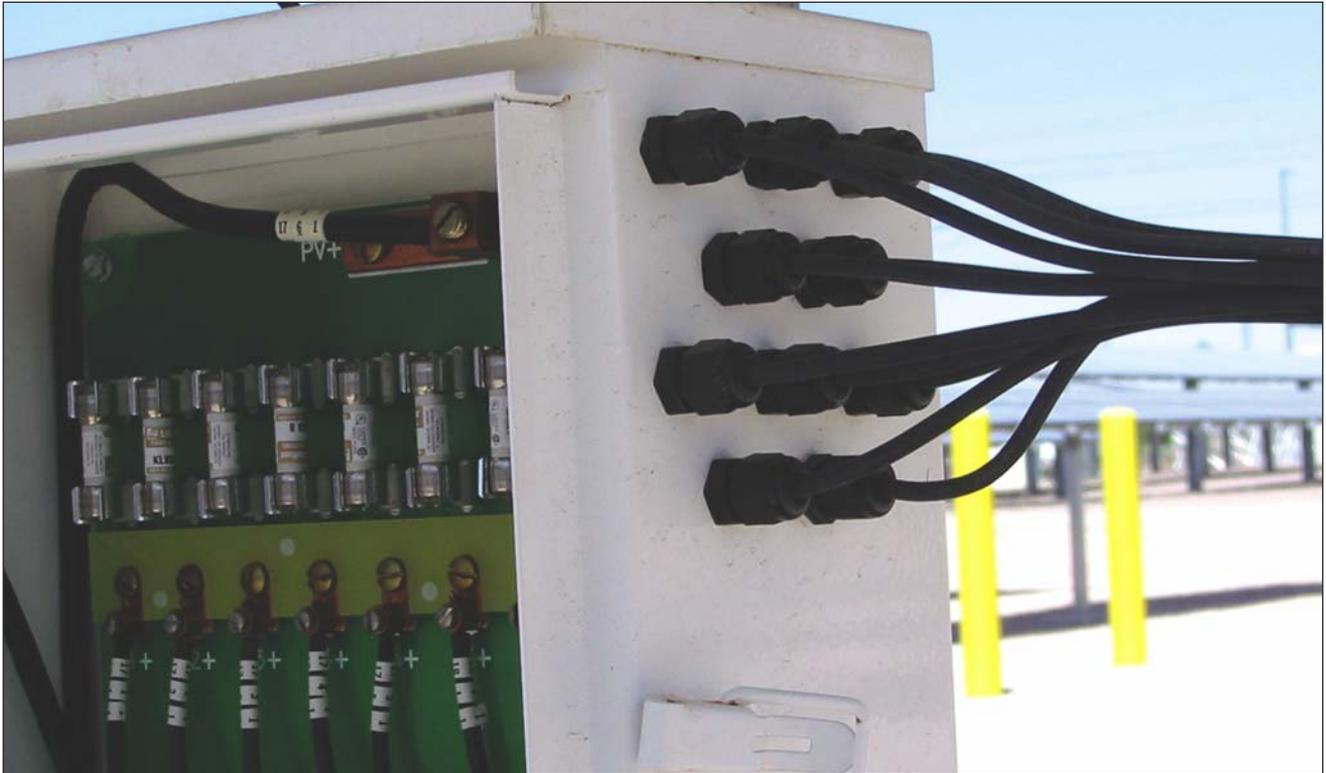


Photo 5. PV combiner in shade

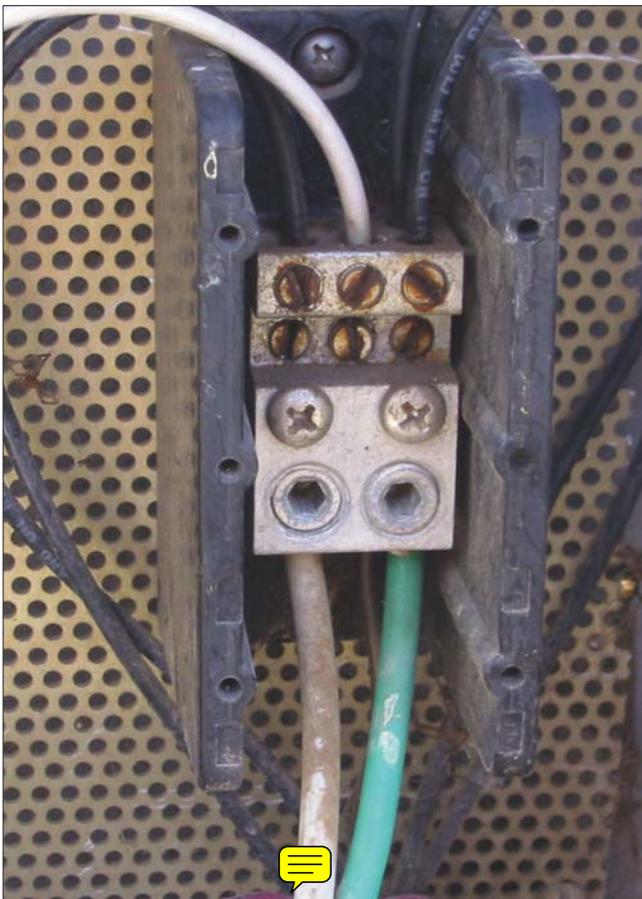


Photo 6. Rust due to improper use of components



Photo 7. Too much snow means no juice Photo courtesy of NREL

sionals 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 will be submitting 30+ 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 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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