Common CODE VIOLATIONS RESIDENTIAL PV SYSTEM

By Ryan Mayfield

Ever-increasing code complexity red tags some installations.

The first residential PV projects were installed in locations far from the long arm of the building code establishment. As a consequence, many of the early PV installers were not familiar with or held to the standards set by the *National Electrical Code*, the *International Building Code* (*IBC*) and local jurisdictions. As the PV industry has grown, so has the need for strict compliance with these codes. Today's PV installations often require multiple permits and inspections. Installation techniques and practices have evolved accordingly. In addition, many traditional ac electricians are entering the PV field and implementing electrical trade practices during installations.

The PV, building and electrical industries are constantly evolving as new equipment and methodologies are developed and released. Consequently, the governing codes are also constantly being updated to meet the requirements of their respective industries. This requires contractors to stay abreast of new information and requirements as they are released. Many new—and sometimes some old—issues about code compliance surface during PV system installation and inspection. To add to that difficulty, depending on the jurisdiction you work in, you may be held to current code cycles or sometimes to previous versions. This ultimately leads to confusion among contractors, PV installers, and enforcement and inspection officials, especially as these groups communicate with peers in other states and jurisdictions.

GENERAL CODE VIOLATIONS

The *NEC* is the guiding document for the electrical portion of PV installations. Some jurisdictions have specialty code requirements, but most are based on the *NEC*. While the *NEC* is considered the premier document guiding electrical installations, its acceptance and interpretation is determined by the AHJ, as outlined in Article 90.4.

Sloppy workmanship. One of the first requirements in the *NEC* appears in Article 110.12, which states, "Electrical equipment shall be installed in a neat and workmanlike manner." While the *Code* does not and inspectors cannot define neat and workmanlike, they will know it when they see it. When work is neither neat nor workmanlike, it is a cue to inspectors to look even harder for additional *Code* violations. A National Electrical Installation Standard—*Standard for Good Workmanship in Electrical Contracting* published by the National Electrical Contractors Association—defines this requirement. (See Resources.)

Wire management is one critical issue to consider during installation. Since most PV modules come with factory installed quick connect plugs, it is not easy to use conduit to protect and manage the array wiring. The installer must properly support the wiring to prevent it from being damaged, especially where it could be exposed to physical harm. Jim Dunlop of Jim Dunlop Solar, and author of *Photovoltaic Systems* says, "One of the areas that I think can use some improvement is in the management of the PV source circuit conductors." Most installers protect wiring from damage caused by roofing and racking. While rodents are not a widespread problem, some installers in the northeastern US also install guards along the array edges to discourage varmints from chewing on the wires and causing failures.

Not installed to listing. Another general *NEC* requirement is found in Article 110.3(B), which reads: "Listed or labeled equipment shall be installed and used in accordance with any instructions included in the listing or labeling." This covers a large number of considerations, from mechanical to electrical.

A common electrical mistake is to install an overcurrent protection device (OCPD), such as a circuit breaker or fuse, in a manner that violates the ampere rating specified by the inverter manufacturer. This can result in the conductors being inadequately protected or in nuisance tripping, which ultimately reduces energy production. While this problem may have been more prevalent in the early days of grid-direct installations, it still comes up today.

Improperly sized fuses or circuit breakers for PV source circuits present another issue. All PV modules come with a series fuse rating that should be used to determine the overcurrent protection size for the PV source circuits. It may be possible to use smaller fuses, but this generally does not benefit the installer. The bottom line is that the OCPD used to protect PV power circuits needs to be sized based on *NEC* Article 690.8, not based on what is on the truck that day.

Typically, most of the components used in a PV installation will be installed outdoors. This requires that individual components be listed for outdoor use and exposure to the elements. Many of the enclosures used, for example, will carry a National Electrical Manufacturers Association (NEMA) rating of at least 3R. This indicates that an enclosure is weather resistant when mounted in a vertical orientation. Most of these boxes are not considered weather resistant when mounted at any other angle. Therefore, using a NEMA 3R junction box or disconnect mounted parallel to a roof surface is a direct violation of *Code,* unless additional testing was performed by a Nationally Recognized Testing Laboratory (NRTL). It is possible to use a NEMA 4 enclosure where the location requires mounting the box on an incline or even on its back. Although several combiner box manufacturers use NEMA 4 enclosures, most disconnects must be mounted on a vertical surface.

Article 690.4(D), an addition to the 2008 *NEC,* requires that equipment used in PV systems, including source-circuit combiner boxes, "shall be identified and listed for the application." This addition to *Code* restricts the use of on-site manufactured combiner boxes. While it is possible to individually purchase the components used in a listed combiner box, if these are assembled in the field the final product is not identified and listed for the application. This requires that a NRTL evaluate the product and components used. The NRTL verifies proper construction and checks that the

Wire management Conductors need to be properly supported and protected from damage to ensure system longevity, performance and safety. Here is one of the worst examples we have come across.

Equipment locations Verify that the installed equipment carries proper NEMA ratings and listings for the location. NEMA 3R boxes, like the one pictured here, require additional testing if mounted in any position other than vertical.

accompanying documentation is sufficient for field personnel to properly install the unit.

PV combiner boxes now need to be listed to UL 1741. Installers can choose among several types of combiner boxes, from simple junction boxes to large multiple string combiners, that incorporate fusing. (See "Pulling It All Together," April/May 2009, *SolarPro* magazine.) Article 690.4(D) should eliminate the use of non-listed combiners, but John Hardwick, training manager for Sharp Solar, notes: "I am still seeing installations where the installer has used indoor-rated wire nuts inside a NEMA 3R junction box on the rooftop. We encourage installers in our trainings to use listed junction boxes that are properly flashed at the roof penetration to ensure a proper electrical connection and a weather-tight junction on the roof."

WIRING METHODS

PV systems present their own set of challenges when it comes to wiring. Source-circuit wiring is often exposed to sunlight and extreme temperatures, while output circuits are often run at very high dc voltages inside hot conduit. The inverter output circuit for utility interactive inverters sends electricity into the grid—the wrong direction for current to flow, in the minds of many inspectors. Live dc circuits on the roof always cause inspectors grave concern, even though these are inherently current limited. These are all legitimate concerns that system designers and installers need to account for and be prepared to explain to permit and inspection officials.

Temperature correction. One of the first *Code* requirements that PV installers need to review is Article 110. This article specifically addresses temperature limitations associated with conductor ampacity. Since PV systems operate at excessive temperatures, this section can have major implications.

Article 310 in the 2008 *NEC* now includes Table 310.15(B)(2)(c), "Ambient Temperature Adjustment for Conduits Exposed to Sunlight On or Above Rooftops." The adjustments in this table "shall be added to the outdoor temperature to determine the applicable ambient temperature for application of the correction factors in Table 310.16 and Table 310.18." Such an adjustment can require significantly larger wire sizes, depending on the local temperatures and the height of the conduit off the roof.

According to Brian Crise, lead instructor at the Portland, Oregon, NECA/IBEW training facility: "This is one of the areas that catches some traditional electricians. Many of them do not estimate rooftop temperatures as high as they can actually get." Crise also sits on Code Making Panel number four, which includes purview of Article 690. "One of [the panel's] big concerns," he explains, "is equipment installed outside of its temperature range. This includes using properly rated conduit, wiring and enclosures. In addition to applying the new temperature adjustment table, installers also need to be aware of the temperature effects on the conduit. Both PVC and metallic conduit have large expansion coefficients when placed on rooftops. Therefore, the conduit runs need to be installed with expansion couplings and proper support."

Article 310.15(A)(2) includes an exception allowing for a less restrictive calculation. This exception applies where the conduit along the rooftop is less than 10 feet in length or less than 10% of the total circuit length, whichever is less. If the conduit is minimally exposed, the balance of the conduit length is able to dissipate the heat effectively, thereby reducing the heating impact. This exception may allow installers of residential PV to avoid upsizing conductors and conduit.

Color coding. A longstanding convention in PV installation is to mark the positive dc circuit conductor red and the negative conductor black. While this may be recognizable to PV professionals, it is not a correct method per the *NEC* nor is it safe. It may lead to confusion. Article 200.6(A) dictates that grounded current-carrying conductors smaller than 6 AWG "shall be identified by a continuous white or gray outer finish or by three continuous white stripes on other than green insulation along its entire length." There is an exception to the size restraint in 200.6(A)(2). This allows PV source conductors to be installed and marked at their terminations. The use of white tape, for example, can identify a PV source conductor as grounded.

When describing and calling out conductors, it is more appropriate to refer to *nongrounded current-carrying conductors* and *grounded current-carrying conductors.* The former is typically the positive conductor, and the CONTINUED ON PAGE 76

Not UV rated Not only are these conductors not rated for the environment in which they are installed, but they are also exposed to potential physical damage.

Courtesy nmsu.edu/~tdi

One of the first *Code* requirements that PV installers need to review is Article 110. This article specifically addresses temperature limitations associated with conductor ampacity.

latter typically the negative. This is more descriptive and identifies the conductor's role in the circuit to qualified personnel. Under this nomenclature, color coding is also clarified.

The nongrounded current-carrying conductor may be any color other than white, gray, green or green with yellow stripes. Typically, this conductor is red, which is acceptable per the *NEC* and stands out to a technician servicing the system. When a positively grounded PV system is employed, it may be in the installer's best interest to use both proper color coding and additional labeling to identify the system as positively grounded.

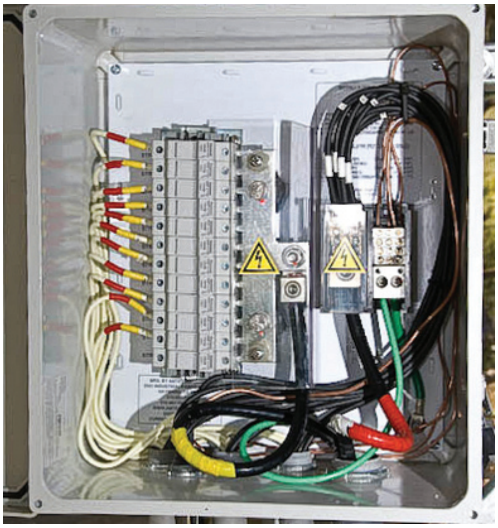
Readily accessible conductors. *NEC* Article 690.31(B) allows for the installation of unprotected current-carrying conductors in PV systems. This is one of the only places in the *NEC* where such conductors are allowed. In the 2008 *NEC,* however, there is an addition to 690.31(A) that states: "Where photovoltaic source and output circuits operating at maximum system voltages greater than 30 volts are installed in readily accessible locations, circuit conductors shall be installed in a raceway." This requirement is problematic for ground mounted or other PV arrays that are considered "readily accessible" per *NEC* Article 100 and use modules with the quick connect cables attached to the junction boxes. These modules do not have a method for conduit attachment and make it difficult to comply with this article.

The integrator is left with the dilemma of how to best install the system and comply with the *NEC.* The easy answer is to make the array not readily accessible, and this generally translates into "build a fence." This is an additional expense, and it has a visual impact that the system owner may not want. Another method is to create a wiring chase that integrates with the racking system and renders the wires inaccessible. In this scenario, it is best to work closely with the AHJ to determine what it will accept.

Article 690.31(E) appeared in the 2005 *NEC.* This addition allows dc conductors from the PV array to run through a structure before being terminated at a readily accessible disconnect, as long as the conductors are located in metallic raceway. It is now generally accepted that *metallic raceway* includes conduits such as EMT and flexible metallic conduit—but not metal clad cable, which is technically a cable assembly. The Article also includes language that refers specifically to utility interactive inverters, so depending on your AHJ's interpretation, the method outlined in Article 690.31(E) may not be acceptable for off-grid installations.

Point of connection. One of the new requirements in the 2008 *NEC* means that a common practice under the 2005 *Code* is now considered a violation. Article 690.64(B) now requires that the inverter output connection for utility interactive systems be made at the *opposite end* of the busbar from the main circuit breaker location, unless the sum of these two breakers is less than the busbar rating. Per this language, in typical residential installations the inverter connection must be located at the opposite end of the panel from the main breaker, with the PV breaker labeled, "Do not relocate."

Fine-stranded cables. Article 690.31(F), added in the 2008 *NEC,* specifically requires the use of fine-stranded cables only with terminals or lugs identified and listed for such use. In battery based systems, it is common to use fine-stranded cables for the battery interconnects and the battery to inverter connection. In addition to making sure that conductors are appropriate for the location, the installer needs to verify that connections are made properly. When fine-stranded cables are used in connections not specifically listed for that use, the conductors will expand and contract within the connection, eventually causing a high-resistance connection and possibly leading to the failure of the CONTINUED ON PAGE 78


shawnschreiner.com

Color coding While an exception to *NEC* 200.6(A)(2) allows for reidentifying PV source conductors at their terminations, this photo shows a poor example. Since white and black USE-2 were both available, the black conductor should have been dedicated to the fused nongrounded current-carrying conductors and the white conductor to the unfused grounded conductors.

connection. Therefore, it is important that contractors properly source and attach any connectors used with fine-stranded cables. Manufacturers such as Burndy and Ilsco make appropriate lugs and corresponding crimping tools for fine-stranded conductors.

LABELING

When I surveyed industry professionals about common *Code* compliance issues, they almost universally mentioned labeling system components.

Required labels. Article 690 lists numerous requirements for labeling equipment, with more requirements added each *Code* cycle. For proper signage, installers must refer specifically to Articles 690.17, 690.53, 690.54 and 690.64. Labeling equipment is an extremely important yet commonly overlooked requirement in PV installation. It is one of the final steps in an on-site installation, but the labeling requirements should be identified before the first module even shows up on site.

One of the labels required in *NEC* 690.53, for example, is "Direct-Current Photovoltaic Power Source." This requires applying a permanent label to the dc disconnecting means that specifies the PV system voltage and current characteristics. These characteristics include the maximum system voltage, the short-circuit current and the rated maximum power point voltage and current. It is far too common to see installations where this is either missing entirely, erroneously reported or else presented in a fashion that makes the information difficult to decipher.

The following calculations for a typical residential system illustrate how to obtain the values for specific label requirements.

Assume the following PV system characteristics:

- **PV array capacity:** 3,328 W STC; 16 Sharp 208 W modules
- **Module specifications:** Sharp ND-208UCI, 36.3 Voc, 28.7 Vmp, 8.35 Isc, 7.53 Imp, -0.131 V/C° temperature coefficient
- **Array configuration:** Eight modules per series string with two strings paralleled in a roof mounted combiner box
- **Site temperature:** Record low -10°C
- **Inverter:** Kaco 2901xi, 2.9 kW, 400 Vdc maximum input, 125–300 Vdc MPPT range

The rated maximum power point voltage and current values are rather straightforward; they are determined by the module manufacturer's specifications at STC. The 2005 *Code* requires listing the operating current and voltage, and the 2008 *Code* helps clarify that language. The number of modules per string and the number of strings in parallel makes this value a variable from job to job.

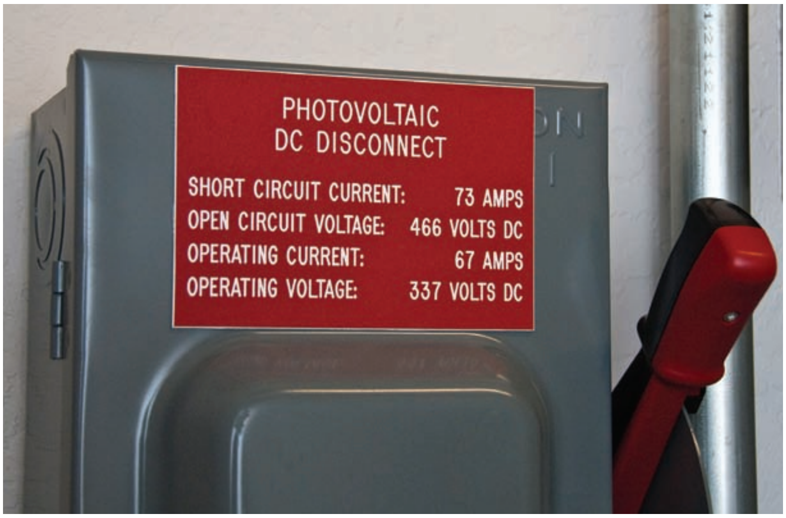
Imp = Module rated Imp x strings in parallel
= 7.53 A x 2 = 15.06 A

Vmp = Module rated Vmp x number of modules per string
= 28.7 V x 8 = 229.6 V

Article 690.53(3) in the 2008 *Code* has a fine print note (FPN) that directs you to list the maximum voltage as calculated in Article 690.7. Therefore, depending on the *Code* cycle you are working with, this value may be the array's open circuit voltage value at STC multiplied by the correction factor listed in 690.7, or it may be calculated from data that the module manufacturer supplies.

Max Voc = (36.3 V + ((T_min - T_STC) x coeff)) x 8
= (36.3 V + ((-10ºC - 25ºC) x -0.131 V/ºC)) x 8
= (36.3 V + (-35ºC x -0.131 V/ºC)) x 8
= (36.3 V + 4.6 V) x 8
= 40.9 V x 8
= 327.2 V

The fourth piece of information required is the array's short-circuit current. Again, the 2008 *NEC* has added a FPN to clarify this calculation. The FPN refers you back to Article 690.8(A) for



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Clear labeling In order to comply with the *NEC,* a system's electrical parameters need to be clearly labeled for future reference, as shown here.

the calculation, which requires that you multiply the array's short-circuit current by 1.25 to determine the value to list on the label.

Isc = Module Isc rating x strings in parallel × 1.25
= 8.35 A × 2 × 1.25
= 20.88 A

Rounding to the nearest whole numbers, the label applied at this site should read:

DC PV POWER SOURCE
Imp: 15 A
Vmp: 230 V
Max Voc: 327 V
Isc: 21 A

One final piece of information required is the "Maximum rated output current of the charge controller (if installed)." Where applicable, this value is determined by the charge controller manufacturer and is included in its specifications.

The items just described are all required for a single label in a single location. Articles 690 and 705 require additional labels. One of the most commonly overlooked labels is the one required in Article 690.56(B), which specifies "a permanent plaque or directory providing the location of the service disconnecting means and the photovoltaic system disconnecting means if not located at the same location." As Crise points out, "This isn't so much a label as it is a map." It is possible that two directory labels will be needed to identify the locations of the disconnecting means for both the PV system and the service.

Label material and attachment. The label's physical integrity is a major consideration. David Devir, vice president of technology at SunCentric, has trained PV installers and inspected many systems across the nation. "I have seen labeling methods that cover the spectrum: nonexistent labels to well made engraved placards; labels made with magic markers to labels made with spray paint," Devir says.

While the 2008 *NEC* now requires permanent labels, this is a reasonable expectation for any label added to a PV system under any *Code* cycle. The method and material used to make the label will be determined in large part by the environment in which it will be sited for the next 25 to 40 years. Many installers use plastic or metal engraved signs that are applied to the required equipment. When plastic is used, it

Courtesy millersolar.com

Service disconnect? Not only is the dc power source label missing here, but the integrated dc disconnect has also been questioned by some AHJs. Most inverter manufacturers now include disconnects that are easily accessible and can separate from the inverter if service is required.

should not be placed in direct sunlight, unless the plastic is specifically manufactured as sunlight resistant. Where a label is installed in direct sunlight, a metallic engraved sign is generally more appropriate.

Another dilemma for installers is the method for attachment. There are reports from the field of jurisdictions not passing installations until the signs were mechanically attached to the equipment; there are also contrary reports of jurisdictions not passing installations because labels were mechanically attached. In the latter case, the argument is made that pop riveting a label to equipment violates the product's UL listing. Generally, the most accepted practice is to install the labels with an adhesive that is rated for outdoor locations and high temperatures.

In an effort to supply the industry with properly manufactured and worded signage, Tyco Electronics is manufacturing labels for dc disconnects and combiner boxes. These labels are advertised as "manufactured from a combination of ultraviolet (UV) resistant ink, permanent acrylic adhesive and base material designed to withstand environmental elements." These labels meet *Code* requirements in general and are often accepted in residential applications, but they may not meet all *Code* requirements and interpretations.

GROUNDING

Grounding PV arrays is probably the most discussed topic when it comes to *Code* compliance. PV systems introduce a complex problem for installers and inspectors alike. The grounding requirements imposed from one jurisdiction to the next can make it difficult for installers to keep their methods consistent. In addition, the requirements for equipment grounding and system grounding are separate and need to be evaluated separately. If you were to get 10 inspectors or installers in the same room to discuss grounding, inevitably you would walk away with 11 different opinions on the subject.

Equipment grounding. PV modules and associated racking aside, equipment grounding is generally the least divisive of all the grounding subjects. The *NEC* is very clear: "Exposed non–current-carrying metal parts of module frames, equipment and conductor enclosures shall be grounded…regardless of voltage." For equipment and conductor enclosures, this is very straightforward: A grounding conductor is used to bond all pieces of equipment in order to keep them all at the same potential.

Unfortunately, using an equipment grounding conductor (EGC) to bond PV modules and racks has never been simple or straightforward. While module manufacturers provide a location on their frames for the bonding hardware, that location is generally midway along the bottom of the frame's long edge. This is not the most convenient place, especially if the modules are mounted flush to a roof with minimal clearance. In addition, the approved method of attaching the bonding hardware is not always well documented, and the appropriate hardware is not always included. As far as bonding the racks to the EGC, installers have historically had to develop techniques

Make Your Voice Heard

The *National Electrical Code* is revised and released every three years. Individuals representing various groups make up a number of Code Making Panels. The process used to make changes to the *NEC* is complex and time consuming. Suggested changes must be received nearly three full years before the release of the next *Code* cycle; for example, suggested changes for the 2011 *NEC* were due in October 2008. The proceedings regarding these suggestions are detailed online at the National Fire Protection Association (NFPA) Web site (see Resources).

The most direct way to make your voice heard regarding *Code* changes is detailed in the back of every copy of the *NEC.* There you will find a form that anyone can fill out and submit to the NFPA. In addition, the Solar America Board for Codes and Standards specifically addresses *NEC* changes as they pertain to Article 690 and PV installations. If there is something in *Code* that you think needs attention, you can initiate the process of change. ●

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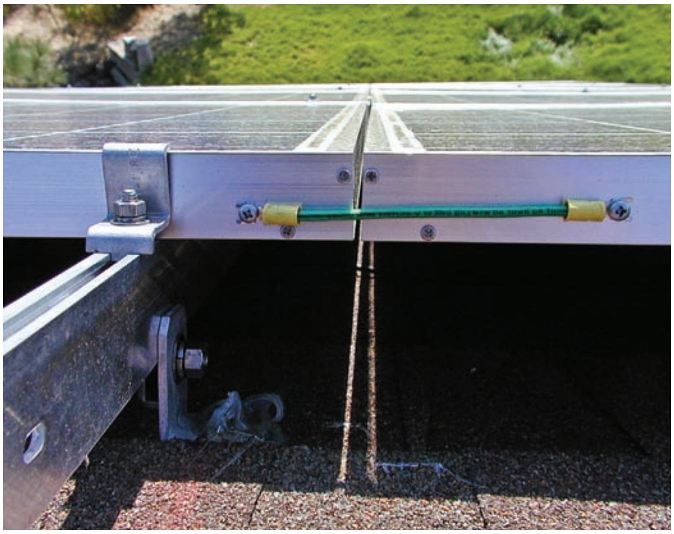
without much guidance from manufacturers. Fortunately this is changing for the better.

Some poor choices were made in past attempts to bond modules together with the EGC. One method, for example, was to use short lengths of THHN wire with a ring terminal attached to each end. The ring terminals were then attached to the module frames via a screw, generally a self-tapping screw that would not provide the proper electrical contact with the PV frame.

The grounding method subsequently accepted industry-wide is to attach a tinned copper lay-in lug to each module and rack member, with an appropriately sized conductor bonding each of the modules and racks together. When installed correctly, this method is undoubtedly superior to many of the methods outlined in some manufacturer's installation instructions. Recently, some PV manufacturers have specifically mentioned this method of grounding in their installation instructions, which is good news for the PV installation community.

The lay-in lugs used for this purpose are solid copper, coated in a tin material to negate the deteriorating effect of having copper and aluminum in contact with each other. These lugs come standard with a stainless steel set screw and are rated for direct burial. There is a very similar looking lug on the market that is made from aluminum and is not outdoor rated; this product does not include a stainless steel set screw and is not appropriate for bonding PV modules.



Continuous ground Equipment grounding conductors need to be installed such that removal of any one panel will not disrupt the module's reference to ground. Properly rated lugs and wire type also need to be employed in a *Code* compliant manner. Here is an example of how not to do it.

In the past couple of years, Wiley Electronics introduced a product designed to help overcome the issue of bonding PV modules and racking structures: the Washer, Electrical Equipment Bond (WEEB) for bonding modules to racks. The racks are then bonded together to create an EGC that is eventually bonded to the other pieces of equipment, generally via a rooftop combiner box. Additional language to Article 690.43 seems to support the use of WEEB grounding clips and the use of the racks as the EGC.

The PV community has overwhelmingly accepted WEEB products, but not necessarily universally. This ambiguity is expected since the subject matter is grounding, but it is also based on legitimate concerns. One question often put forward concerns the appropriateness of the UL listing used to test WEEB products. Another concern is the lack of testing by individual module manufacturers. It is reasonable to expect, however, that just as the lay-in lug was widely accepted despite these same issues, the WEEB grounding method will gain increasing acceptance and approval. Inevitably, the most important question is whether the WEEB grounding solution is acceptable to your AHJ.

System grounding. With the new requirements in the 2008 *Code,* system grounding is one of the most discussed and debated topics within the installer community.

When the first utility interactive inverters were introduced to the US market, it was difficult to make a connection from the inverter to the system ground. Many inverters did not include a lug large enough to connect a grounding electrode conductor (GEC) to it. Almost universally, all utility interactive inverters now have ground lugs large enough to run a GEC to the existing grounding system.

Article 690.47 deals specifically with system grounding. *NEC* 690.47(C) is the section used by most PV installers, as most systems have ac and dc grounding requirements. This section was completely rewritten in the 2008 *Code,* resulting

Courtesy nmsu.edu/~tdi (2)

Aluminum lug This aluminum lay-in lug closely resembled the tin plated copper lay-in lug that is appropriate for use in PV applications. Unlike the direct burial lug, however, the aluminum lug is not rated for outdoor use and does not include a stainless steel set screw.

Dissimilar metals Another common *Code* violation regarding equipment grounding occurs when dissimilar metals are installed in direct contact with one another. The result is galvanic corrosion, which over time causes a loss of the bond to ground.

in a number of differing opinions and methodologies.

In residential systems, the grounding conductor is commonly sized equal to the current-carrying conductors, which for many residential systems is smaller than the GEC requirement per *Code*. For example, one of the requirements in 690.47(C) is to size dc GEC according to Article 250.166, which results in a conductor not smaller than 8 AWG. The type of grounding electrode and the size of the system conductors must both be considered when determining the GEC size.

Flash roof penetrations Unlike the poor workmanship shown here, roof penetrations need to be properly flashed. Follow the manufacturer's instructions during installation to avoid code violations.

It is common to see grounding conductors serve as both the EGC and the GEC. This is allowable as long as the conductor is sized appropriately. For example, if a 7,000 W inverter is connected to a 40 A breaker within a main service panel, a minimum 10 AWG copper EGC is required per Article 250.122. However, the GEC must not be smaller than 8 AWG per 250.166. Therefore, for a single conductor to serve both purposes, it needs to be a continuous conductor no smaller than 8 AWG. Any EGCs connected to this conductor may not break the continuous GEC. In situations where this is not possible, it is necessary to run two separate conductors, one for the EGC and one for the GEC.

STRUCTURAL CODES

Electrical code violations receive the most attention when it comes to PV systems, but structural issues deserve attention as well. This requires examining the method of physically attaching PV arrays to roofs, to poles or to the ground.

International Building Code. Building departments most commonly use the *IBC* reference book. Like the *NEC,* it is published on a three year cycle. The *2009 International Building Code* is the most recent release. You must examine attachment methods for modules to racks in order to verify compliance with *IBC* requirements as well as with equipment installation instructions.

Aesthetics Matter

The way an array looks when installed is not referenced in any structural or electrical code requirements. Nevertheless, aesthetics are important. Installers' desire for an array to operate optimally can cloud their judgment on its final appearance. The most common scenario along these lines is when a PV array is mounted on a roof surface that is not pointing south, and the installer decides to orient the array to the south by tilting it off of the roof plane. Granted, PV arrays need to perform well, but this should not come at the cost of creating an absolute eyesore.

This also presents a problem: Once a PV array is elevated off the roof surface, there are no universal standards for structural support methods. Tilting an array off of a residential roof surface requires consulting a structural engineer to evaluate the attachment method. Assuming this is done, the costs associated with the structural engineering process in conjunction with the additional racking materials will very likely negate the overall benefit provided by the moderate increase in energy harvest.

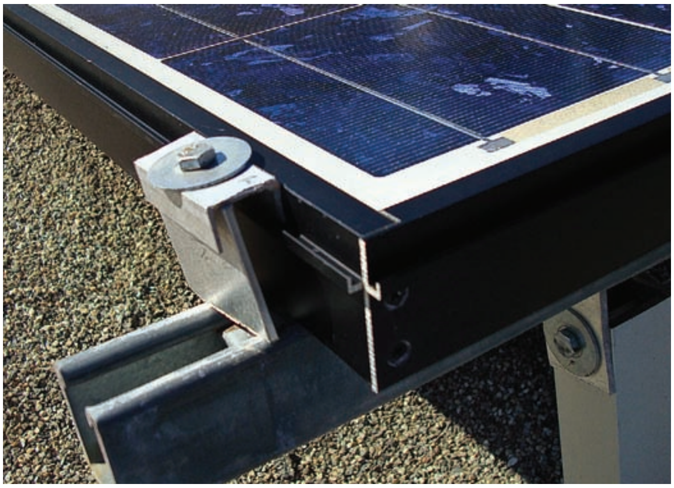
Remember, the PV array you place on a client's home becomes an advertisement for your business. In some cases passing on a job may be better for business in the long run than installing an array that is an eyesore. Take the time to analyze the visual impact of a custom mounting solution versus the energy output, and discuss this with your client. PV systems still hold the stigma of being unsightly, and installers need to keep that in mind, especially when designing and installing residential arrays. ●


Courtesy millersolar.com (2)

Eyesore with increased wind exposure Installing a PV array beyond or off the plane of a residential roof not only perpetuates negative stereotypes about solar technologies, but it also exposes the installer to increased liability. Whenever a custom racking solution is employed—such as tilting an array off a residential roof or, as shown here, installing the array beyond the ridge line—a structural engineer needs to certify the integrity of the mounting and attachment solution. In this case, the undersupported top row of modules blew off the roof during a predictable wind event.

One important structural compliance issue is the need to properly flash all roof penetrations. Several manufacturers have recently addressed this need in residential applications. (See "Pitched Roof Racking," October/November 2008, *SolarPro* magazine.) Not only is flashing at all roof penetrations, including structural attachments, required to fully comply with *IBC,* but it is also a best practice among roofing contractors.

The *IBC* covers most of the structural issues that relate to PV installation, but many local jurisdictions have specialty codes that go beyond these requirements. Environmental effects on structures and attached components are extremely variable. In areas with heavy snow loading, for example, many building departments require that installers evaluate the potential effects of snow drift and the additional dead load imposed by the PV array. In areas of high wind, the dynamic effect of wind needs to be evaluated and properly mitigated. Dunlop notes that some installations in the Southeast that utilize tilt-up racks are suspect in terms of their structural integrity. Engineering documentation



Courtesy millersolar.com

Homemade racking This ad hoc mounting system appears to put dissimilar metals in direct contact with one another. Sloppy mechanical work is often an invitation to inspectors to look even harder for other *Code* violations.

provided by racking manufacturers generally assumes that modules are mounted flush with the roof.

Module to rack attachment. It is also important to consider the acceptable location of support rails as specified by the module manufacturer. For example, multiple module manufacturers specifically disallow mounting their modules with the support rails attached only to the short edges of the frames. Designers and installers need to ensure that supports and attachments meet the manufacturer's requirements in order to maintain the product warranty.

The method of handling the modules on the job site is yet another issue. It is not uncommon to see work crews grabbing a module by one side and carrying it to the final location. While this is not necessarily a *Code* violation, Diana Buttz of Equinox Solar and a former PV module engineer, points out that "carrying the module in this fashion puts an enormous amount of pressure and torque on that edge and can lead to seal failure." The correct way to carry modules, she explains, is to support both sides of the frame in order to minimize that stress.

The placement of modules is another critical and often overlooked point. In the sales process, it is often desirable to fill up the entire roof with modules. When the modules are installed on a roof, however, it is best to leave some roof surface available for the installation crew and for service access in the future. In its trainings, Sharp Solar recommends a minimum 12 inches of clear space around the array perimeter; when the modules approach the roof eaves, 16 inches of clear space is recommended. Hardwick explains, "This is to allow for future service, as well as to reduce the impact of wind uplift around the roof edges."

To determine the exact requirements for your location, work with representatives for both the racking manufacturer and the local building department. They can verify clearances as well as dynamic load allowances like wind, snow, seismic activity and so forth.

CONCLUSION

As the PV industry continues to grow and mature, AHJs are scrutinizing installations for compliance with national electrical and structural codes, as well as ensuring compliance with local codes. It is essential for PV installers to be able to identify relevant code requirements and to consistently adhere to them. Individual businesses, as well as the broader industry, depend on this compliance for long-term success.

I encourage you to read additional references on this subject. Brooks Engineering, for example, has recently prepared a document titled "Expedited Permit Process for PV Systems" as well as an associated generic PV system drawing for the Solar America Board for Codes and Standards and New Mexico State University. Additionally, John Wiles has developed a document entitled "Photovoltaic Power Systems and the *National Electrical Code:* Suggested Practices," which is available through the Southwest Technology Development Institute. (See Resources.)

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Manufacturers:

Burndy Products / 800.346.4175 / burndy.com
Ilsco / 800.776.9775 / ilsco.com
Sharp Solar / 800.765.2706 / solar.sharpusa.com
Tyco / 610.893.9800 / tycoelectronics.com
Wiley Electronics / 845.247.3852 / we-llc.com

Resources:

Brooks Engineering / 707.332.0761 / brooksolar.com
National Fire Protection Association (*NEC*) / 617.770.3000 / nfpa.org
Solar America Board for Codes and Standards / solarabcs.org
Southwest Technology Development Institute / 575.646.1049 / nmsu.edu/~tdi

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