Issue 6.2, Feb/Mar '13

PV Array Wire Management

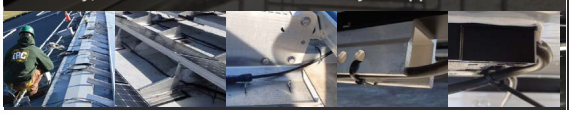
Securing, Supporting and Protecting Conductors within the PV Array

By: Tommy Jacoby,

Racking

m Email | o Share | d Print

Cable trays - Before specifying and using cable trays to protect and manage conductors within the PV array, check with your local AHJ. Currently, the NEC does not allow cable trays in applications...



Inside this Article

PV systems are expected to have a 25-year lifespan, and array wire management solutions should match this expectancy. However, designers and installers face persistent challenges to managing free-air conductors within the PV array.

Ongoing Discussions

5 days 1 hour ago *by RFLOYD11*
Power-Conditioning Equipment for Residential Battery-Backup PV Systems
(1) replies to this post

1 week 1 day ago *by SolarPro*
odd fault voltages
(3) replies to this post

Log In to Discuss

Implementing a safe, reliable and *Code*-compliant wire management system for exposed PV conductors is not an easy task. PV module leads can be too long or sometimes too short, requiring site-specific solutions for supporting and interconnecting the cables. Equipment grounding, PV source-circuit and inverter-output conductors from microinverters and ac modules must also be managed to ensure protection from potential damage. Within the PV array, these various conductors are often secured to module frames, support rails and other racking system components. While securing array wiring seems like it should be a straightforward exercise, the reality is that integrators continue to face numerous challenges.

UV-rated plastic wire ties provide a flexible, convenient and low-cost solution for bundling and fastening array conductors, but they are not a permanent answer and require regular inspection and replacement. Stainless steel cable clips work well for attaching conductors to the module frame, but this solution is often limited to supporting only one or two conductors at a time, and not all modules have frames. Structural channels or integrated cable management solutions within the module support rails assist with protecting and routing conductors, yet precautions must be taken where conductors enter and exit the channels to protect them from sharp edges that may compromise their insulation. In addition, module rails tend to run either east-west or north-south, so they may not provide support where conductors run perpendicular to the rail alignment.

Unfortunately, the PV industry lacks consistent, standardized wire management solutions for free-air conductors within the array. Coupled with the harsh environmental conditions that PV array conductors are exposed to—UV radiation, high winds and extreme ambient temperatures, and ice, snow and other debris—wire management continues to be the Achilles heel of the majority of PV installations. In this article, I check in with several PV industry experts—from *Code* gurus and inspectors to installers and O&M providers—to better understand the industry's current challenges, considerations, *Code* requirements and needs when it comes to managing and protecting exposed conductors within the PV array.

The Importance of Wire Management

The majority of PV systems have integrated leads, or wires, used for making electrical connections between modules. The module leads and the associated homerun conductors are often installed in free air within the PV array—meaning they are not in conduit. These exposed circuits contain potentially lethal voltages and currents that could electrocute someone, or cause a fire, in a faulted condition. As a result, we need wire management solutions that can endure the extreme environments in which PV arrays are installed while ensuring the systems are safe and reliable.

The Consequences of Poor Wire Management

I have done quite a few fire investigations. While the specifics of many of these investigations are confidential, there are several types of problems where poor wire management contributed to failures. All of the following practices have caused fires in the field:

- Putting USE-2 string conductors in contact with sharp edges, creating undetected ground faults that end up short-circuiting the array
- Not properly identifying conductors and incorrectly polarizing combiner boxes, creating array short circuits and combiner box fires
- Improperly installing thermal expansion fittings, especially in runs that require multiple fittings
- Not properly accounting for thermal expansion and conductor weight, causing damage at roof edge fittings and boxes
- Not properly addressing thermal expansion of conductors inside raceways, causing damage at box fittings
- Improperly using stainless steel wire ties, putting too much stress on conductor insulation
- Not fully seating plug connectors
- Putting stress on junction box and plug connectors, causing them to fail and separate (which can cause an arc if under load)
- Using improper torque procedures on combiner box terminals (It is common for combiner box terminals to loosen over time due to improper torquing or thermal cycling and vibration on rooftops.)

New mistakes are invented every day.

Industry PR

Released Jun 11, 2013

By: Yes! Solar Solutions

NABCEP Announces Accredited PV Installation Company

Released Jun 10, 2013

By: CSP Today

CSP Today LATAM 2013 has confirmed a site visit to Minera El Tesoro CSP Plant

More Industry PR

Training & Events

June 13, 2013

Fronius Service Provider Certification Training for Fronius...

By: Fronius USA, LLC

June 13, 2013

Free Webinar: Alpha on-roof system - The total residential...

By: Mounting Systems, Inc.

More Training & Events

—Bill Brooks, president, Brooks Engineering

The harsh environment. John Wiles, senior research engineer at the Institute for Energy and the Environment (IEE) at New Mexico State University, provides an important background perspective on the fundamental challenges of PV array wire management in terms of the environmental conditions the materials are exposed to. He notes, "Before we even start with *NEC* requirements of array wire management, we must address the fact that the outdoor environment that exposed PV conductors must survive is one of the most difficult environments that any electrical system will face outside of utility transmission systems.

"The temperatures may range from -60°C (-76°F) to +90°C (+194°F). UV irradiance may exceed 2,000 hours per year. Winds and gusts of 90–130 mph are not uncommon. And then there is the physical abuse of wind-driven sleet, snow, rain, hail and sand. The environment also includes Mother Nature's living creatures, such as squirrels, rats, rabbits and birds, who all like the warm, secure areas behind PV modules and may even enjoy a meal of conductor insulation from time to time.

"PV modules will be producing dangerous levels of voltage and current—30 volts and greater is a shock hazard, and 30–50 milliamps can stop a heart—for at least 40–50 years, and probably longer. The exposed PV conductors, and even those in raceways, must survive the severe environment for that length of time without posing a safety risk, while retaining the initial levels of performance.

"I have witnessed USE-2 conductors that are still in good condition after 33 years in the sun, yet poorly secured loose USE-2 module interconnection cables rubbing against racks and abrading halfway through the insulation due to wind motion in only 3 months."

The risk of ground faults. Exposed conductors within the PV array are particularly vulnerable to coming in contact with module frames and support rails. Conductors should be installed and dressed so that they are protected from physical damage to avoid compromising the insulation, because damaged insulation can result in a ground fault. Ground faults may not be detected until too late, as we have recently learned from two widely publicized PV system fires in Bakersfield, California, and Mount Holly, North Carolina. (See "The Bakersfield Fire," *SolarPro* magazine, February/March 2011, and *The Ground-Fault Protection Blind Spot: A Safety Concern for Larger Photovoltaic Systems in the United States*, Solar America Board for Codes and Standards, January 2012.)

Undetected ground faults due to blind spots in the groundfault protection system can result in arcing and fires when a second ground fault occurs. Alternatively, when a ground fault is detected, Paul Mync and John Berdner point out: "A ground fault not only causes PV system shutdown and energy loss, but also presents a safety concern that all designers, electricians, installers and service technicians need to be aware of. … Proper wire management is essential to avoiding ground faults, especially at the array where conductors are installed in free air and more easily damaged." (See "PV System Ground Faults," *SolarPro* magazine, August/September 2009.)

Industry Input and Best Practices

In an effort to communicate best practices in array wire management and related challenges that PV integrators may face, I asked several industry colleagues to share their experience and expertise in PV wire management.

What are common wire management mistakes?

"The most common issue we see with wire management involves pinched wires leading to ground faults in the PV array. Often, when a PV module is mounted, the module output wire gets pinched between the module frame and the metal mounting system, giving the current an easy path to ground.

“Another issue we have seen involved the use of metal wire ties to bundle array conductors. The goal was to increase the life of the wire management system, assuming that UV-rated plastic wire ties would degrade over time and need to be replaced. However, the metal wire ties ended up cutting into the conductor insulation, causing multiple faults throughout the array. This problem was exacerbated when [the ties were] installed on a tracker, on which the conductors were moving throughout the day. In fact, the ground faults were intermittent and occurred only when the tracker was in certain positions, making them very difficult to locate and repair.”
—Adam Burstein, president, Next Phase Solar

“Common mistakes with regard to wire management include installing conductors in contact with sharp edges, allowing conductors to touch abrasive roofing materials, laying homerun source-circuit conductors on membrane roofs, not observing the specified bending radius for conductors per *NEC* Article 338.24, insufficient support of conductors and stress on junction box and plug connections.”
—Bill Brooks, president, Brooks Engineering

“As a third-party inspector, Cadmus typically sees more than 100 PV installations in the Northeast each year consisting of the good, the bad and the ugly. One of the most common issues we observe is the lack of protection and wire management beneath pitched-rooftop arrays. Although conductors may not necessarily be readily accessible or easy to see, they are still in danger of damage from ice, debris and animals.”
—Matt Piantedosi, associate engineer and master electrician, The Cadmus Group

What wire management challenges has your company encountered?

“Besides squirrels, the biggest issue we face is a ‘recreate the wheel’ approach at every site as we strive to meet *NEC* requirements while installing systems that will last 25 years. With racking and modules evolving almost monthly, it is hard to stick to any one approach. Different techniques and materials are needed. Some good wire management materials, like stainless steel cable clips and coated steel cable ties, are readily available, though expensive. We need new approaches to this problem, and we need module manufacturers to work with racking manufacturers to come up with easy-to-implement solutions. I do not believe it should be up to installers to solve the problem.

“*NEC* Article 392.3(B)(1)(a) says single-conductor cable must be 1/0 or larger and marked for use in cable tray. Obviously source-circuit conductors, whether PV Wire or USE-2, are much smaller than 1/0 and do not meet this requirement. So it is up to the AHJ whether it supports a cable tray wire management solution. This can lead to some uncertainty in design and possible inspection issues.

“Another issue is the length of module leads. Depending on the orientation of the module—two in portrait versus four in landscape being the most common options on large ground-mount systems—the module leads may or may not easily reach the cable tray, and cable clips or wire ties may be needed to secure these conductors to the module frame or support rails. Note that if the module leads can be secured in the cable tray, fill calculations must be done to figure out what width of cable tray is necessary.”
—Rebekah Hren, director of implementation, O2 Energies

“The largest issue for us is interrow wiring on ballasted flat-roof systems. Most racking manufacturers do not provide an integrated solution, but a few are starting to come onboard. Installing rigid or intermediate metal conduit is time-consuming, and PVC does not age well in the rooftop environment. Strut is not UL listed for the application, and other industry raceways can be cost prohibitive or are not UL listed for the application.

“Another problem with using conduit for interrow wire management is roof clearance. Once properly installed and supported, the installed height of the raceway may be as high as 6 inches above the roof deck. At this height, there may not be adequate clearance to route the conduit underneath the southern edge of the module or racking system.”

—Geoff Greenfield, president, Third Sun Solar

“Wire management can be one of the most labor-intensive tasks on an installation. It can also be tedious and frustrating, especially if you do not have a clear, sensible wire management plan heading into the installation, and subsequently lack the appropriate materials or tools to securely and safely manage conductors within the array. In such cases, it can be tempting for installers to take shortcuts, especially with a flush-mount array on a 105°F roof in June. It takes a vigilant and experienced lead installer to properly train new installers and ensure wire management details are not overlooked.

“Modules installed in the landscape orientation can present a beast of a wire management situation, especially if you intend to adhere to the securing and supporting requirements specified in *NEC* Article 334.30. In particular, I am referring to the requirement that conductors be secured within 12 inches of each box, cabinet, conduit body or other termination, which in this application is the module junction box. If modules within the same row are installed in the landscape orientation with the junction boxes facing the same direction, it is usually impossible to connect the module leads and adhere to this requirement without creating some sort of series jumper because the module leads are too short. This can add significant time and material costs to an installation.”
—Conor Black, field manager, Positive Energy, Las Cruces Branch

What factors do you consider when selecting a wire management solution?

“Key factors include code compliance, ease of installation and cost— both upfront and labor. For large ground-mount arrays, the selection gets folded into the racking system selection, and any additional costs for wire management solution add-ons are factored in accordingly.”
—Rebekah Hren, O2 Energies

“We consider the application, location, *NEC* requirements relative to the AHJ’s interpretation and cost, labor usually more so than material.”
—Geoff Greenfield, Third Sun Solar

“In no particular order, we consider the following factors: code compliance; acceptance by the specific AHJ; effectiveness of the method for actually protecting the wires, as determined by our engineers and experience; long-term durability; ease of installation; and cost.”
—Blake Gleason, director of engineering, Sun Light & Power

“We consider the expected lifetime of the wire management products and whether they offer a 25-year solution. This includes their UV rating and if they might become brittle or breakable when exposed to sunlight or high ambient temperatures. We also assess if the solution will protect wires from sharp edges within the mounting structure and keep conductors off the roof surface. We want a solution that can be installed in a manner that does not create future problems, such as ground faults.”
—Conor Black, Positive Energy

Do you consider wire management features when selecting racking systems and modules? If so, what factors do you consider?

“Yes, but I believe the industry currently has a problem with the serious disconnect between installation methods and module manufacturers. In general, module leads are too long for portrait installations and too short for landscape installations. In portrait orientation, many inches of copper conductor are wasted for each module installed, creating a cost burden for the manufacturer and an installation headache for the installer who has to manage extra wire. In landscape orientation, very few modules have leads long enough to meet *NEC* requirements. Good wire management means that the bending radius requirements of at least five times the wire diameter are met; there is not a lot of stress or tension at the module junction box when the module leads are pulled to clipping points on the frame or racking system; and the securing requirements of within 12 inches of a box or enclosure are met. It can be physically impossible to meet these three requirements with module leads that are too short.”
—Rebekah Hren, O2 Energies

“Absolutely. Many racking systems have evolved to be very fast to install, and many have addressed automatic module grounding, but very few have sufficiently addressed wire management. For now, when evaluating new racking systems, we usually have to imagine what kind of wire management solution we would use and determine the amount of cost and complexity it adds to the base racking cost. Module manufacturers are usually similar with respect to wire management, but occasionally leads are too short to adequately provide strain relief for module-to-module landscape connections without adding a jumper. Modules with built-in lead management, such as durable clips built into the frame, are fantastic.”
—Blake Gleason, Sun Light & Power

What are some of the wire management solutions your company employs?

“I have worked only on ground-mounted arrays for the last 3 years. Currently, we employ several different techniques, depending on which manufacturer’s racking product we use. For example, Schletter’s racking system (schletter.us) has an integrated tray and thus does not require a cable tray system. Some racking systems do not have an integrated raceway, in which case we use a Legrand Cablofil cable tray (legrand.us) attached to the back of the racking system.”
—Rebekah Hren, O2 Energies

“On pitched roofs, we use SnapNrack’s Pitched Roof PV Mounting System (snapnrack.com) because we can place the array conductors inside the rail channels. For flat-roof applications, conduit is installed wherever possible, using conduit blocks to keep it elevated above the roof. This decreases the required ambient temperature adjustment per *NEC* Table 310.15(B)(2)(c) and provides adequate clearance for general roof maintenance.

“On pole- and ground-mount systems, we secure the conductors to the module frames with cable clips. Sometimes we wrap the exposed conductors in split, flexible corrugated-plastic conduit to provide additional protection.”
—Ken Gardner, owner, Gardner Engineering

“For many years we used UV-rated wire ties to manage conductors on pitched-roof systems, but we have seen a lot of failures with this approach, even on those ties shaded from direct sunlight by the modules. Now we use stainless steel cable clips and Heyco’s (heyco.com) SunBundler product to secure conductors within the PV array. We typically use this approach on pole- and ground-mount systems as well.

“On flat roofs, we like the PanelClaw (panelclaw.com) Grizzly Bear ballasted mounting solution because it has integrated conduit pipes cast into the ballast blocks that protect the conductors as they are routed between rows. For similar reasons, we also like Ecolibrium Solar’s (ecolibriumsolar.com) Ecofoot2 product, which offers integrated wire management clips both within and between the rows.”
—Geoff Greenfield, Third Sun Solar

“On pitched roofs, we use Wiley Electronics’ (we-llc.com) Acme Cable Clip ACC—which is compatible with PV Wire and USE-2 wire types— to secure conductors to module frames. PV source-circuit conductors are routed in Professional Solar Products’ (prosolar.com) module support rails within the array and in EMT between and beyond it. We utilize the same approach on flat roofs, but we switch to a cable tray system when managing a large number of conductors. We do not have a specific wire management solution for ground-mount applications— it really depends on the racking system being used.”
—Blake Gleason, Sun Light & Power

“In general, we never use wire ties to secure PV array conductors— conductors are either fastened to modules using cable clips or run alongside the module support rails and secured at approximately 3-foot intervals with EPDM collar clamps. For a while, we allocated a couple of staff members to auditing old systems, and we found that some of the EPDM collar clamps were slowly deteriorating, but it always seemed to be the clamps that were overfilled.”
—Conor Black, Positive Energy

Wire Management and the *NEC*

NEC Section 690.31(B) allows the use of single-conductor types USE-2 and PV Wire "in exposed outdoor locations in photovoltaic source circuits for photovoltaic module interconnections within the photovoltaic array." In addition, Section 690.31(D) permits the use of 16 AWG and 18 AWG conductors for module interconnections, although the majority of installations these days use a 10 AWG or 12 AWG conductor.

Since Article 690.31 does not address how to install and manage these exposed conductors, you must turn to Article 338, "Service-Entrance Cable: Types SE and USE," for installation requirements, such as supporting and securing. Article 338.10(B)(4)(b) directs you to Article 334.30 for securing and supporting requirements in outdoor environments, and Article 338.24 specifies the allowable bending radius for type USE conductors.

Per *NEC* 334.30, type USE conductors "shall be supported and secured by staples, cable ties, straps, hangers, or similar fittings designed and installed so as not to damage the cable, at intervals not exceeding 1.4 m (4.6 feet) and within 300 mm (12 inches) of every outlet box, junction box, cabinet, or fitting." The IEE's Wiles points out that "in windy areas, supports this far apart for exposed USE-2 or PV Wire would be inadequate to prevent conductor motions that would abrade the insulations over time." In addition, conductors may need to be secured more frequently than the minimum requirement to comply with Article 300.4, which requires that conductors be protected against physical damage, and Article 110.12, which requires that they be installed in a neat and workmanlike manner.

Unfortunately, Table 392.3(A) does not include singleconductor cable type USE-2 or listed and labeled PV Wire in the list of wiring types permitted to be installed in cable tray. In addition, in industrial establishments "where conditions of maintenance and supervision ensure that only qualified persons service the installed cable tray system," Section 392.3(B) (1)(a) does not allow single-conductor cables smaller than 1/0 AWG in cable trays. In other words, per the *NEC*, cable tray can be used as a wire management solution in very few PV applications. According to Wiles, "nothing is certain at this time, but there is a proposal to the 2014 *NEC* to allow the use of small conductor cables in cable trays on the roof."

The 2011 version of the *NEC* added wire management requirements in Articles 690.4 and 690.31. Brooks of Brooks Engineering points out, "There are several specific changes related to identification of conductors and raceways and routing of circuit conductors to reduce the likelihood of firefighters coming in contact with energized PV circuits while fighting fires." Some of the changes in Article 690.4 include circuit identification and grouping; requiring qualified persons to install PV system equipment and conductors; routing circuits, both in and out of conduit, when inside a building or structure; and isolating electrical circuits from each monopole of a bipolar PV array. Article 690.31 expanded upon Part (E), elaborating on the requirements and guidelines for installing PV source circuits indoors.

Protecting PV Array Conductors from Pests


Topher Donahue

At SPI 2012 in Orlando, O&M emerged as one of the more-discussed topics. Though much of the focus is on medium- to large-scale PV system O&M, we must keep an eye on the multitude of smaller residential systems. The majority of these systems are installed on shingle or tile pitched roofs and utilize a mounting system that follows the roofline, providing a few inches of clearance between the roof and PV modules. The word on the roof is that squirrels and other small animals like to nest beneath the modules, perhaps for warmth or protection from larger predators. Regardless, squirrel damage is becoming an all-too-common term in our industry, as the animals continue to wreak havoc on the insulation of array conductors, and correspondingly on our PV systems. Animal mitigation is paramount for long-term system performance, return on investment and safety, especially since pitched-roof residential installations, where this damage seems to be most prevalent, are probably the least monitored systems once installed and commissioned. Squirrels, birds, mice, raccoons— you name it, we have seen them trying to nest under rooftop arrays. The latticework of rails and modules makes a very attractive habitat for wildlife, especially in

the spring. Few critters do as much damage as squirrels. They love to chew free-air wires, USE-2 and PV Wire alike. The result of this damage can be extensive. Failing to prevent animal access during the original installation can lead to thousands of dollars in repair costs only a few months or years later. It can mean a complete deinstallation and reinstallation of an array in addition to module lead wire repairs. This can quickly wipe out any financial payback for a customer. We have seen cases where every module in a residential system has had module lead wires completely chewed to the junction box. Losing production due to a chewed wire is one thing, but the biggest risk is to structure and life. A fault within the array can lead to arcing. If there is indeed a nest near the arc, the debris from the nest adds to the list of materials that could easily catch on fire.

There are a lot of challenges to installing animal guards. Many EPC contractors deploy different materials and methods. Some best practices to consider while addressing this issue are:

Heyco SunScreener Heyco's SunScreener mounts a screen (not included) or other protective guard to the frame of most PV modules, forming a barrier of protection against rodents and birds around the array.

- Use materials properly rated for the installation environment.
- Attach screening barriers to rails and structural members—drilling a module frame may void the manufacturer's warranty.
- Do not block airflow beneath the array.
- Keep in mind that the UL equipment listing and manufacturer warranty may be jeopardized if the module leads are repaired or modified in the field.
- Where metal screening products are used and may become energized, make sure they are properly grounded.
- Anticipate leaf and other material debris buildup to occur over time. Install screens and guards so they can be removed easily for repairs and general maintenance.

I am encouraged to see two recently introduced animal guard products. Heyco's (heyco.com) SunScreener hook helps facilitate attaching screen mesh to framed modules, creating a guard or skirt around the array. Additionally, Spiffy Solar (spiffysolar.com) recently launched its Spiffy Clip squirreland bird-guard system, which includes both clips and black screening at a cost of $1.65 per linear foot. I encourage more manufacturers to develop similar solutions. Until then, it is our duty as PV system designers and installers to provide protection against squirrels and other small critters that may frequent our arrays.

—Stephen Kane, president, Kane Solar

Going beyond the *NEC*

Complying with the *NEC* provides a good baseline for wire management, but you must consider additional steps to provide a safe and reliable installation. Some best practices that may not be directly specified by *Code* include: using drip loops where conductors enter enclosures from free air, protecting and shading conductors from direct sunlight whenever possible, securing exposed conductors more frequently than every 4.5 feet and conducting ongoing inspection and maintenance of the PV array conductors.

Wire management system maintenance should include inspecting and replacing conductor labeling when needed, and verifying the condition and effectiveness of the conductor support and protection systems. Where conductors may be subject to physical damage, conductors should be checked for damaged or discolored insulation. Regular inspections also provide an opportunity to look for signs of pests that may be living within or frequenting the array. Evidence of nests, fur and droppings are telltale signs of unwanted guests.

Since best practices with regard to wire management are constantly evolving, I asked Brooks and Wiles what they suggest. Although their opinions on the use of plastic wire ties differ, they each point out the importance of material selection and addressing the high levels of sunlight and thus damaging UV radiation that can occur in and around the PV array.

What are important considerations and best practices beyond minimum *Code* requirements?

“Best practices are to keep sunlight-resistant materials out of direct sunlight as much as possible.

Most of the materials used in PV systems that are exposed to sunlight experience some degradation over time. Using the available shade of modules and other obstructions simply makes things last longer. Good-quality UV-rated plastic wire ties and stainless steel cable clips are probably best around modules. Plastic wire ties do deteriorate over time, but ongoing operation and maintenance is necessary in all exterior wiring systems—regardless of materials used."
—Bill Brooks, Brooks Engineering

"Both USE-2 and PV Wire are available with colored insulations such as white, red and green, but care should be exercised when considering them. While these colored cables are marked 'Sunlight Resistant' and have passed the 720-hour accelerated UV test, they do not have as much carbon black in them as the black insulated cables. Carbon black is one of the main insulation components that provides a conductor with UV-radiation resistance. Cables with less carbon black may not fare as well over 40–50 years in the extreme PV environment as cables with high levels of carbon black.

"Similarly, PVC- or thermoplastic-insulated cables have passed the 720-hour accelerated UV tests, but PVC-insulated electrical components like jacketed UF cables and liquid-tight nonmetallic conduit (LFNC) have not survived well in the hot, sunny Southwest outdoor environment. As a result, exposed conductors in PV systems should have black thermoset insulations that contain cross-linked polyethylene. These insulations are sometimes marked XLPE or XLP. Remember, PV systems can receive more than 2,000 hours of UV exposure each year for 40–50 years, and the accelerated 720-hour UV tests are equivalent to approximately 1,500–2,000 hours—once.

"Plastic wire ties, even the best ones, should be avoided. The conductors should be secured to module frames and racks with metal cable clips with no sharp edges or pipe clamps with EPDM rubber inserts. The conductors should be fastened at a minimum of every 12 inches to prevent any movement. Lastly, some protection from birds, rodents and other small animals should be considered where these animals are prevalent, but the protection scheme should not inhibit the cooling of the array. A galvanized wire mesh hardware cloth with ½-inch holes has been used successfully in areas where animals present a problem."
—John Wiles, IEE

Final Thoughts

While the challenges related to *Code*-compliant wire management methods, materials and products are numerous, equipment manufacturers have slowly been developing solutions for these issues. Listening to feedback from the field allows some manufacturers to differentiate their products, capture market share and provide the industry with products that will drive down installation costs and increase the safety of PV systems over their 25-year–plus operational lifespans.

When asked about how they would like to see wire management solutions improve, experienced designers and installers from across the country are looking to module, racking and wire management product manufacturers for help. With continued communication and coordination between the various entities involved, we can certainly develop wire management solutions that ensure safe and reliable PV systems.

How would you like to see wire management solutions improve?

"One possible solution to the problems associated with the module leads being too short or too long is junction boxes that come with connectors but no leads, or just one lead and one connector. Another possible solution is modules that can be ordered specifically for portrait or landscape installation, with leads of according lengths. "I believe that module manufacturers need to get out in the field to see the problems that occur on-site. For the most part, installations are similar enough that these should be easy problems to solve if we can get the module manufacturers working in harmony with the racking manufacturers."
—Rebekah Hren, O2 Energies

"It would be great to have a flat-roof, open-top tray system that is UL listed for the application, is easy to install, is inexpensive and complies with *NEC*."
—Geoff Greenfield, Third Sun Solar

"We need a more cost-effective solution for properly managing conductors when modules are configured in landscape orientation. There are several situations in which the design or racking system may call for installing modules in this orientation, but doing so creates a wire management headache."
—Conor Black, Positive Energy

"First of all, we should clear up confusion in the *Code* regarding wire trays versus cable trays versus auxiliary gutters. We need a longlasting, practical lay-in wire management solution for handling a lot of small conductors in a rooftop environment.

"Also, I have recently seen way too many commercial rooftop systems with PV source-circuit wiring 'installed' by pulling out a couple hundred feet of it and laying it on the roof—no strain relief, no mechanical protection and no attempt to get it away from the hot roof. Presumably, if we had readily available practical wire management solutions, we would see fewer installations with bad practices and resulting fires."
—Blake Gleason, Sun Light & Power

CONTACT

Tommy Jacoby / Jacoby Solar Consulting / Austin, TX / jacobysolar.com

CONTRIBUTORS

Conor Black / Positive Energy / Santa Fe, NM / positiveenergysolar.com

Bill Brooks / Brooks Engineering / Vacaville, CA / brooksolar.com

Adam Burstein / Next Phase Solar / Berkeley, CA / nextphasesolar.com

Ken Gardner / Gardner Engineering / Ogden, UT / gardnerengineering.net

Blake Gleason / Sun Light & Power / Berkeley, CA / sunlightandpower.com

Geoff Greenfield / Third Sun Solar / Athens, OH / thirdsunsolar.com

Rebekah Hren / O2 Energies / Cornelius, NC / o2energies.com

Stephen Kane / Kane Solar / Lyons, CO / kanesolar.com

Matt Piantedosi / The Cadmus Group / Waltham, MA / cadmusgroup.com

John Wiles / Institute for Energy and the Environment, New Mexico State University / Las Cruces, NM / ieenmsu.edu

RESOURCES

The Ground-Fault Protection Blind Spot: A Safety Concern for Larger Photovoltaic Systems in the United States, Solar America Board for Codes and Standards, January 2012, solarabcs.org/about/publications/reports/blindspot/pdfs/BlindSpot.pdf

view article discussion.

Articles

Snake Tray Provides Wire Management
Snake Tray offers two products specifically for the PV market. Solar Snake Tray options are...

Greaves Offers Wire Termination Solutions for PV Applications
Greaves, a supplier to the US electrical industry since 1947, offers an extensive range of...

Basics of Medium-Voltage Wiring
We provide an introduction to some common components used in medium-voltage circuits, including...