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Technology • Development • Installation

March 2015

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3 POINTS OF common code confusion

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Despite improvements, provisions for PV systems in the 2014 NEC are still confusing, which can lead to installations that don't meet regulations.

You might think

that most solar power systems erected by qualified installers and inspected by local wiring inspectors would be pretty much free of major operational problems. But that hasn't been the experience of the Cadmus Group, an energy and environmental services consulting firm based in Waltham, Mass. Cadmus examines PV installations funded by state programs and other sponsoring agencies. The inspections include comprehensive reviews of such aspects as available solar resources to compliance with codes and standards. Out of 1,758 recent inspections, Cadmus has found major or critical issues in 28% of them. Another 47% had either minor or incidental issues. Only 25% were problem free.

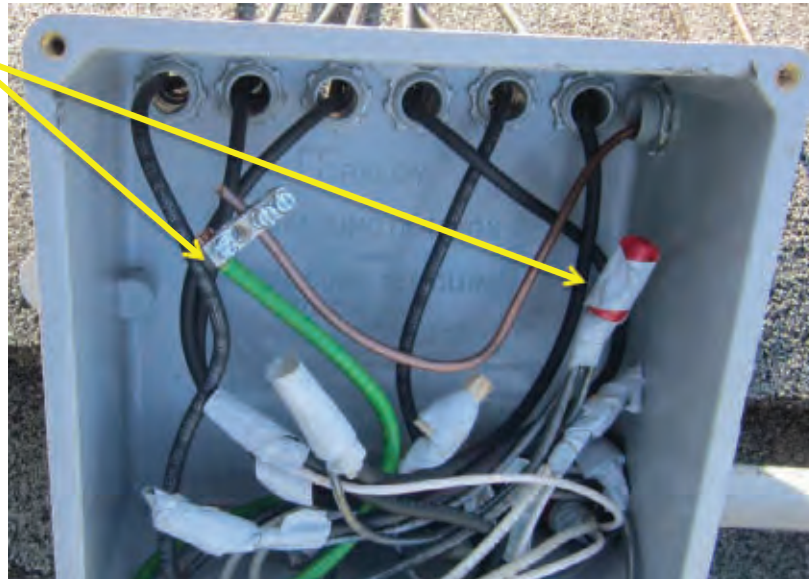
One of the unsettling things about problems found during the Cadmus inspection is that many of them violate provisions of the National Electrical

Code (NEC). Yet these difficulties got past installers, utilities and electrical inspectors.

For example, more than half the sites Cadmus inspects are not grounded properly. More than 20% have violations because conductors weren't protected properly or were improperly sized. A whopping 70% of systems inspected lack the proper labels.

Some of the problems uncovered by Cadmus are simply due to sloppy work. But a significant portion arise because both installers and inspectors have trouble interpreting NEC solar provisions. "Ultimately we hope the PV industry doesn't need engineers and consultants inspecting every PV system," said Cadmus Senior Associate Shawn Shaw, who

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Here are a few examples of code-related problems noted by Cadmus during its inspections of PV arrays. Enclosure sealing is one bugaboo. Cadmus notes that NEC 300.9 defines outdoor raceways as wet locations. NEC 110.14(B) says splices must be listed for use or equivalent to insulation of conductors being spliced and that all splices must be insulated (not like those called out in this photo taken during a Cadmus inspection). NEC 300.7 dictates sealing conduits penetrating from unconditioned into conditioned space (far left). Otherwise condensation can build up, even in otherwise perfectly sealed conduit runs.

These labels are pasted over manufacturer-applied labels, a practice which does not meet code. Cadmus also frequently finds instances where installers have not checked NEC 690.7 and 690.8 before marking labels with ratings, or have somehow miscalculated the ratings.



leads the firm's Solar Quality Assurance practice. "Right now, we see ourselves as helping the industry bridge the gap while municipal inspectors get up to speed understanding the technology and how to apply the code."

Grounding

Shaw explains that a lot of the grounding issues Cadmus finds aren't straightforward. "It takes experience to wrap your head around some of these practices," he said. Typical grounding problems include equipment partly or completely ungrounded. "Sometimes module frames are not properly bonded together so you lack a good low-impedance connection from one module frame to the next," said Shaw. "That's not an uncommon problem when there can easily be hundreds of WEEBs (a commonly used device for bonding PV module frames) installed. You need to ensure you have the right number of them and that they are properly engaged."

An even less well-understood area concerns grounding electrodes. "For example, a lot of installers don't understand the requirement to bond ferrous metallic enclosures and raceways

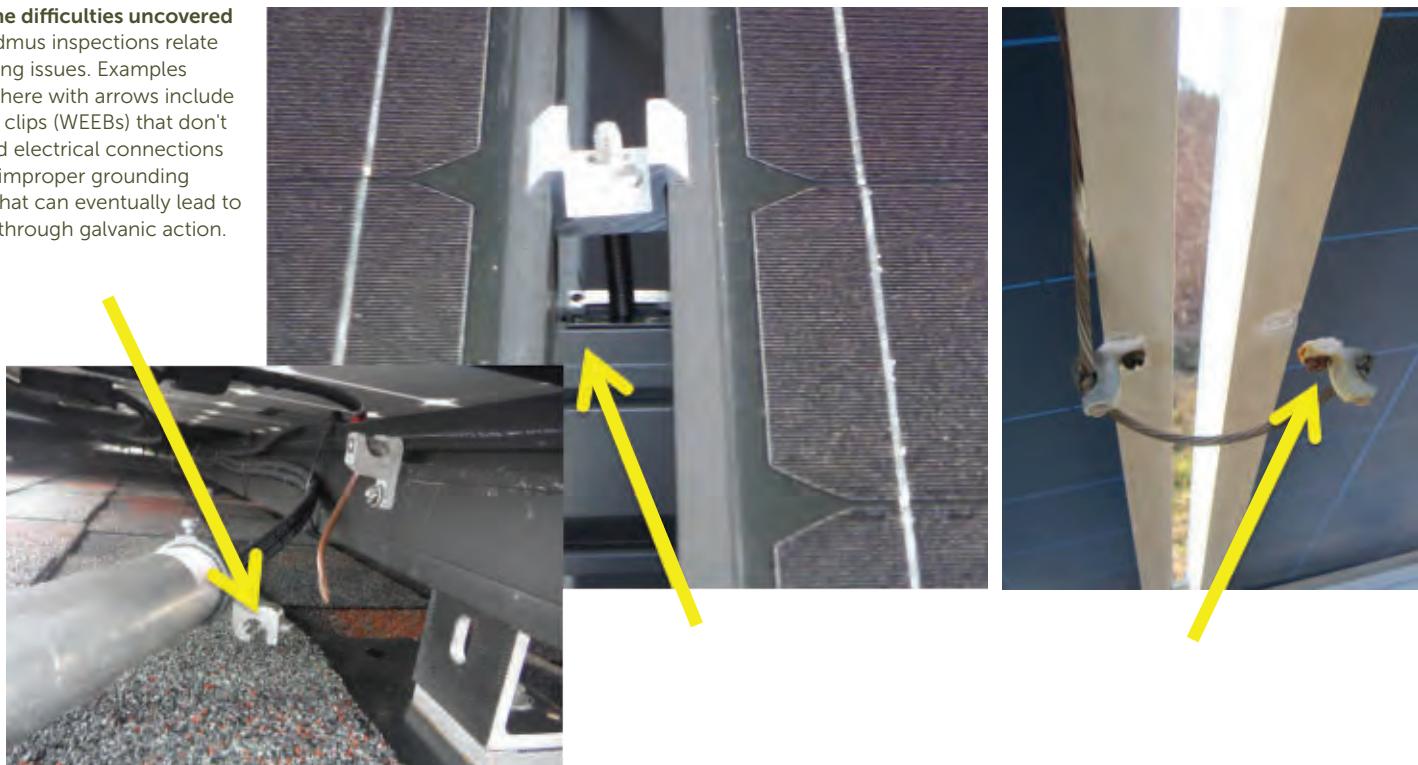
to the grounding electrode conductor," said Shaw. "You do this to reduce inductive choking if there is a lightning strike, but it is an NEC requirement that is often overlooked."

Interconnection

Cadmus sees numerous problems associated with interconnecting PV systems. Part of the problem seems to be an unfamiliarity with NEC requirements that differ depending on whether PV is installed on the load side or the supply side of the main disconnect. "There are pros and cons for each approach," said Shaw. "On the load side we tend to see issues of locating and labeling the backfeed breaker properly. In most cases you should locate the backfeed breaker at the end of the panel opposite from the main breaker to balance the heat distribution on the bus bar. Having all the current entering the bus bar at the same place tends to let heat build up," he explained.

The sizing of back-feed breakers is another point of difficulty. "The NEC allows adding a back-feed breaker so that the current supply is up to 120% of the rating of the bus bar. If a 200-A busbar has a 200-A main breaker, the code

Many of the difficulties uncovered during Cadmus inspections relate to grounding issues. Examples called out here with arrows include grounding clips (WEEBs) that don't make good electrical connections and using improper grounding materials that can eventually lead to corrosion through galvanic action.



allows adding a up to a 40-A backfeed breaker. We sometimes see people adding a 60 or 80-A breaker instead. That could cause the bus bar to overheat, even though the current supplied would not trip any of the breakers," Shaw said.

Cadmus reports that supply side connections are becoming more widely used, partly because they let home owners install more PV capacity than would be the case if connections were on the load side. But the NEC proscribes several requirements for supply side connections that installers and inspectors often miss. "The PV disconnect is now essentially a service disconnect, so it must be grouped with the main breaker under some editions of the NEC and must have a new connection to the grounding electrode system. That is something a lot of installers miss," said Shaw. "It is also common to see new PV service disconnects that are not rated

properly. The Code mandates a 60-A minimum rating but we sometimes see, for example, 30-A disconnects installed by mistake."

Labeling

Similarly, labeling requirements are spread around in different parts of the NEC so they can easily confuse installers. One of the most common issues concerns labeling and marking material. "The code could do more here," said Shaw. "The 2014 version makes labeling easier to understand, but it can be a challenge to apply requirements spelled out in the 2008 edition. In general, you can't mark up a piece of tape with a Sharpie pen and call it a label. It should be UV stabilized plastic or an engraved placard. You want to make sure the label is legible for as long as possible."

Another common shortcoming in the labeling category is the proper marking of disconnects, especially to

indicate the system voltage and current levels. "The NEC lays out a process for calculating these currents but we often find mistakes in voltage and current labels. You have to be on your toes or you can end up putting down the wrong values," said Shaw.

Cleaning up for clarity in 2017

Some of these issues can be attributed to the fact that provisions for PV installations reside in different sections of the NEC. Indications are that the upcoming 2017 edition of the code will try to address these difficulties. "There is some clean-up coming in Article 690. There are a lot of proposals related to grounding, and there will be a lot of provision moved out of 690 into other sections for the sake of clarity," said Matt Paiss, a fire captain with the San Jose, Calif. fire department and the primary NEC representative for the International Association of Fire Fighters.

Arc-fault detection in the 2011 NEC and the rapid shut-down provision for PV that came out in the 2014 NEC both came from proposals by a task group that included the IAFF, fire marshals, other fire fighting organizations and the insurance industry. "We are seeking the ability to shut down PV generators to voltages lower than existing string voltages of up to 1,000 Vdc. But the final result did not go as far as the group wanted. The rapid shut down takes place at the array level. It doesn't address voltages on the roof. Our proposal for the 2017 NEC is a rapid shutdown that will lower the voltage on the roof," said Paiss.

Basically, IAFF's proposal for the 2017 Code is for a shut-off control at the module rather than an array level. "The shut-off could be a junction box-embedded switch or it could be at the dc optimizer or microinverter. It doesn't specify the technology, Paiss said. "Our proposal simplifies things to some degree because just shutting off the power at the main service will accomplish the shut down. For example, shutting down the main power will shut down an array using microinverters. Ditto for arrays with dc optimizers and junction box-embedded switches. These both require ac power to operate. The wording in the 2017 proposal fills in gaps associated with shut-down initiating devices and where they need to be."

Paiss and the IAFF are well aware of the confusion surrounding rapid-disconnect in the 2014 code. Much of the confusion centers on where the disconnect should physically reside. Paiss said the module-level disconnect would usually reside at the

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service panel. "Suppose you have a roof with three modules," he said. "The physical shutoff will be at main electrical panel. The PV breaker will serve as the initiating device. Or in the case of a large PV system with a line side tap, the disconnect would have to be in sight of the main service panel. In 90% of all situations the module-level disconnect would be close to the main service panel." The rapid-disconnect proposal is for a PV disconnect that kicks in on the loss of ac mains power, Paiss explained. It also specifies control of conductors at the module level at 80 Vdc max. "The requirement states that the maximum voltage in the conductors can be 80 V if it is within five feet of a junction box, and 30V for conductors farther away. It is written to accommodate the input leads to microinverters or dc optimizers higher than 30V. The 80V is the highest voltage that a standard module could put



Here is graphic evidence of why fire fighting organizations lobbied for arc fault protection in the 2011 NEC. San Jose Calif. Fire Captain Matt Paiss photographed these melted connectors are from a residential PV installation. The connectors were improperly crimped and got hot. In another case, a similar problem with a faulty field-made connector resulted in an attic fire. Fire Captain Paiss investigated the blaze and reports that the array was installed to 2008 Code three months before the municipality adopted the 2011 NEC mandating arc fault protection at the inverter. Paiss said arc fault protection would have prevented this fire.



out in the coldest environment. Ideally, the PV system could be shut down to a touch-safe level of 30 Vdc, but that would require getting into intermodule strings and we acknowledge the standard is just not there yet.

The IAFF has also suggested adding provisions to the 2017 Code for external utility disconnects. "There are large areas of the country where the utility meter is on the exterior of the building but the service panel is inside," said Paiss. "First responders wanting to shut off the power can't do it from the outside. An external disconnect at the point of entry of the service conductors would address that. The outside meter socket would go into a lockable knife-blade disconnect

so firefighters can secure the power without having to pull the meter, something they are not equipped to do it. The arguments against this idea center on security and possible corrosion, but there are NEMA enclosures that address this."

Of course, module-level disconnect and utility disconnects are just proposals at this point. There's still a possibility they will be revised before wording in the 2017 Code is finalized. That will happen after a public comment period that ends this summer and then the second draft hearings in November. **SPW**

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