Bob-O Schultze, Don Loweburg,
Wes Edwards, and Redwood Kardon

This month's column is written by three Wrenches with over 500 installed systems under our collective belt. Over the years, we've discovered a few realities about PV systems that can't be learned by studying theory or demonstrated under laboratory conditions. This is real world information. Why the NEC, Sandia, and Mr. Wiles continue to ignore it in favor of their own untested theories is beyond us.

Safety

Why is is that every time Mr. Wiles comes up with a scheme for doing any part of a PV installation, it adds yet another layer of complexity and cost to the project? Most engineers and theorists strive to simplify an application or technique. Sometimes, we Wrenches just have to wonder what his motives really are. A healthy respect for the power of electricity is a good thing, but I get the feeling that Mr. Wiles is basically scared of it.

It's really difficult to knock someone or something touting safety. No one wants to give the impression of being cavalier about it, especially when it comes to electricity. So, if a little safety is a good thing, more must be better, right? Not necessarily. There are acceptable levels which make good sense for the protection of personnel and property. Beyond that lies needless extra expense and complexity in ever increasing spirals.

For example, most of us will agree that seat belts in vehicles are a good thing. They save lives. So many of us agree, in fact, that wearing seat belts is mandated in most states. It can also be statistically proven that wearing crash helmets and fire resistant clothing in addition to seat belts will save even more lives. Therefore, we should mandate them as well, right? You see the point.

Grounding

The easiest explanation of grounding I've seen is written by Redwood Kardon, author of *Code Check: A Field Guide to Building a Safe House*. Rather than try to paraphrase it and inadvertently make it more confusing than it already is, here are Mr Kardon's words:

> Grounding is probably the source of the greatest confusion in the understanding of electrical power distribution. The National Electric Code does little to clear this fog of misunderstanding. It lists the purpose of grounding as:
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> 1) "To limit voltages due to lightning, line surges, or unintentional contact with higher voltage lines and to stabilize the voltage to ground during normal operation"
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> These three sources of dangerous overvoltage are provided with an alternative path around the electrical system of your home or workplace by intentionally connecting the system to the earth.
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> In practice, this proviso of the code only minimizes damage from such occurrences. If lightning is a common occurrence in your area, additional provisions must be made to protect your property.
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> 2) "To stabilize voltages"
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> This is a difficult concept. There are many sources of electricity. Every transformer can be considered a separate source. If there were not a common reference point for all these voltage sources it would be extremely difficult to know their relationships to each other. The earth, of course, is the most omnipresent conductive surface, and so it was adopted in the very beginnings of the National Electric Code as a nearly universal standard for all electric systems. (There are a few exceptions where ungrounded systems are permitted, as in direct current systems operating at 50 Volts or less between conductors).

3) "To provide a low impedance path…that will facilitate the operation of overcurrent devices."

From a day-to-day point of view this last purpose of grounding is the most important one to understand.

Most PVs get installed as 12 or 24 VDC systems. The DC charging and direct use parts of these systems are exempt from the grounding requirements of the NEC. For some inexplicable reason, the NEC requires that while the conductors of a PV system less than 50 VDC need not be electrically grounded, any metal frames, boxes, etc. in that system still do. Frankly, I don't understand the need for it.

To Ground or Not to Ground

NEC section 250-42 states that "Exposed noncurrent-carrying metal parts of fixed equipment likely to become energized shall be grounded…". The explanation in the NEC handbook states that "Exposed noncurrent-carrying metal parts of fixed equipment not likely to become energized are not required to be grounded." When we look at the typical PV module, we see a metal frame which is not connected in any way to the PV cells themselves. We see a non-metallic junction box fully insulated from the frame where the wire connections take place. Is any of this "likely" to become energized? I don't think so.

By the way, the 1996 Code states that "in a photovoltaic power source and its direct-current circuits, the voltage considered shall be the rated open circuit voltage." It also details that "for a photovoltaic power source, one conductor of a two-wire system rated over 50 Volts…shall be solidly grounded." Notice the word 'rated' in both quotes? Look on the back of your PV module. Look at the 1996 NEC. Do the math. Never mind Mr. Wiles interpretation or someone's explanation in the NEC handbook (After all, that handbook is not the Code, and I'm guessing that Wiles had his hand in it as well).

We can debate whether this grounding is really necessary to insure safety. However, the question of whether the PV equipment ground needs to be electrically bonded to any other parts of the system still remains.

Refer to the drawing in Code Corner, *HP 64*, p. 73. It shows a PV module grounded to a ground rod which is connected to a grounding bus and hence to the main ac system grounding rod. Let's assume that the PV system operates at less than 50 VDC and is some distance from the house. Let's further assume that at least the ac load center is in the residence. In fact, this is the case with nearly all PV systems. Locating a grounding rod close to the PV array makes good sense for lightning protection. Bonding that ground rod to the ac ground rod serves no good purpose other than inviting lightning induced currents into your house! Is this smart? Is this safe? Is this logical?

Some Field Data

This input comes from Don Loweburg, a fellow Wrench for many years and a licensed electrical contractor:

> I have long doubted the necessity of placing ground jumpers from module to module when they are bolted to a metal frame. In fact, as a matter of personal inquiry, for the last 5 years I have routinely checked ground continuity without the jumper wires on each and every racked system I have installed. In no case was there ever lack of ground continuity for even one module in all those years. I have always found the resistance to be under one ohm. On occasions, I've had the opportunity to return and check the grounding after some number of years. Again, ground continuity has been 100%. I would hope others with field experience might pass on their findings. If, as I suspect, we find ground continuity on metal racks is achieved without the jumper wires, I suggest we drop this nonsense. I suspect that some "expert" made this up and now the gospel is blindly passed on year after year, adding cost but no value to PV systems.
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> Another grounding issue that gets me is the oversize ground requirement if current carrying conductors are oversized. Because the code does make explicit reference here, I'm not ready to take it on. But it does seems like nonsense to me. Especially with array source circuits which are absolutely current limited. Logically, ground wire should be sized according to the maximum fault current possible. We did away with oversize grounds on the inverters. Why must it persist elsewhere?

This long term module to rack continuity has been my experience as well, but it's not universal. The differences seem to be in the initial mounting practices. If a stainless steel lockwasher or star washer (which is even better) is used to get a good "bite" on the module frame or rack from the beginning, little resistance is measured even after many years. I'm thinking of using at least one star washer between each PV module frame and the rack on all my installations. It's cheap, easy, and can't hurt. I believe it will meet both the spirit and letter of the NEC without using all that unneccessary and unsightly ground wire.

Yet Another Wrench Chimes In

This is from Wes Edwards, a long-time RE electrician:

> Like Don, I no longer install jumpers from panel to panel. I have checked resistance between module

frames and the mounting structures and have found no resistance to speak of, even on a seven-year-old array. It makes no sense to add jumpers if they serve no purpose. In fact, the copper jumpers corrode because copper and aluminum are dissimilar metals. Any ham radio operator knows that ground wires will act like an antenna for lightning. If you connect your array back to the house ground, you are in effect adding a large antenna to the solar array. As Bob-O mentioned, the electrical connections and the boxes that contain them are completely isolated from the frames, so the only reason to ground is for lightning protection or static electricity discharge. When I set up a system, I use a separate ground rod connected to the steel structures, not connected to any other grounding system.

Most explanations of grounding the ac neutral and the DC negative are confusing. In fact, an experienced system designer from AEE was totally confused by John Wiles article in the last *HP*. It had to do with grounding the array feed at the disconnect. First of all, it makes perfect sense to ground these conductors at one, and *only* one place. If you don't, current will flow through your ground wires. This can cause big problems. I have seen Trace inverters go up in smoke because the neutral was grounded in two places. Trace claims this is not a problem, but I have seen two inverters smoke at the same residence. I checked the system and found that it was neutral bonded in two places. I corrected that, reinstalled the inverter, and it has been working perfectly for two years now.

On grounding the battery negative, the bottom line is, "Why do we ground it at all?" I would like to hear just one good reason. I do it—but why?

Conclusions

Again, we are talking about 12 and 24 VDC systems. In higher voltage systems where an electrical shock hazard can be demonstrated rather than mostly theoretical, I have to agree that protection is the best policy. In that case, protecting against the potential shock hazard outweighs the possibility of lightning-induced currents trashing your inverter or setting your house on fire. It's a question of risk management and acceptable levels of safety. I wear seat belts and advise you to do so as well. Mr. Wiles, on the other hand, advocates the equivalent of mandating the crash helmet and fire-resistant jump suit.

Calling All Wrenches

A "Wrench" is someone who is actually involved in the installation of RE systems. In other words, them what's doin' as opposed to them what's talkin'. IPP members, folks who have installed their own systems, and many others are mostly Wrenches. It boils down to this: the main depository of the information and data needed to realistically and safely install renewable energy systems is in the memory banks and records of Wrenches who have been doing the actual work for years. Got a gripe or a better idea on how to install a system safely and more simply? Write us about it! A few of us can't do much. If we're to successfully counteract some of the more onerous and unnecessary provisions of the NEC as it applies to RE systems, we'll have to do it together.

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