Code Curveball—*Safe vs. Silly*

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Once again, I find myself having to take umbrage at the author of Code Corner for his unreasonably restrictive opinions concerning the proper installation of PV modules. In Coder Corner *HP* #60, Mr Wiles, along with some unidentified electrical inspector, is of the opinion that flexible nonmetallic conduit should not be used with PV modules. He would prefer instead that we use liquidtight flexible metal conduit. Failing that we should use rigid PVC or metal conduit which renders most commercially available adjustable mounts and trackers less than useless.

Let's look at the facts. I called two major electrical distributors and a giant electrical mail order outfit regarding the temperature ratings of flexible nonmetallic conduit (fnc) and liquidtight flexible metal conduit. All the suppliers carried a different brand name. All the fnc they carry (Alflex, Carlon, and Kaftech) is rated at 80°C Dry and 60°C Wet, none are rated 70°/60° as Mr. Wiles states. Interestingly, all the liquidtight metal flex offered (Alflex, Kaftech, and Electroflex) is rated only from -10°C to +60°C. One manufacturer claimed their liquidtight is "suitable" to 80°C and one even claimed a 90°C rating for "intermittent use". I don't think we can categorize 20 years on a PV array as intermittent use.

80°C = 176°F. The junction boxes for a PV module are located on the back of the module and are always made from plastic. Since the front of the module must face the sun in order to work, the wiring is–by definition–in the shade. Not that the back of a PV module doesn't get warm, it does–just not that warm. During the hot weather tests at Home Power central (HP#49, pg28) where the ambient temperature was 31°-35°C/88°-94°F in the shade, we measured temperatures from 49°-55°C/120°-131°F with a probe directly on the PV's back. Any fnc connecting those modules would have been connected between junction boxes in free air and NOT in actual contact with the PV back. Simple logic tells us that if anything, the fnc would be subjected to less, not more heat. Of course, there are hotter places in North America than Agate Flat, OR during August. But even in the worse case scenario of the deserts of the SouthWest, the air temperature doesn't get above 49°C / 120°F. Assuming a corresponding temperature on the back of the PV, we MIGHT get to 70°C. That's directly on the back of the module, mind you, not on or in the fnc in free air between modules.

Where There Is Error

I think where Mr Wiles goes wrong is in his interpretation of 351-23(b)(2) and the fact that the PV manufacturers suggest using wire with insulation rated to 90°C. The NEC reads "Where any combination of ambient and conductor temperature is in excess of that for which the liquidtight nonmetallic conduit is approved." By the way, the exact same language is used to describe conditions unsuitable for liquidtight metal flex as well. Apparently Mr Wiles surmises that you either "add" the ambient to the conductor rating, or we assume the wire is running at full rating and the ambient only makes things worse. Neither is the case. Taking a common sense approach to the letter and spirit of the NEC, my interpretation is this: Current flowing in a wire causes a certain amount of heat. If the ambient temperature causes the wire temperature to increase past the temperature rating of the conduit, you have a possible problem.

No competent electrician or PV system designer would EVER waste expensive photovoltaic delivered watts by sizing PV interconnect and feed wires anywhere CLOSE to the current rating of the wire. It's just plain foolish. Barring conditions found near an active volcano or in a certain air-conditioned office somewhere in New Mexico, I believe using fnc rated to 80° is not only safe, but NEC compliant with all temperatures found in the natural or concrete jungles of North America.

The Wet Real World

So much for dry conditions, now let's take a real world look at that 60°C Wet rating. PVs make electricity, not hot water. Any wet conditions the fnc would be subjected to would be caused by rain. 60°C=140°F. I submit to you, that if you are experiencing a 140°F rainstorm, the possibility of your conduit failing would be of very little consequence indeed. End of story.

These are my own thoughts and opinions based on my interpretation of the NEC guided by common sense and many years of hands-on experience installing PV systems. For another opinion, I consulted with Mr Redwood Kardon. Mr Kardon is the author of Code Check-A Field Guide to Building a Safe House (see HP#56,pg 92) and an electrical inspector for the city of Oakland, CA.

He writes: " I think your approach is lent credence by the industry trend toward 'performance driven' criteria. You can present performance criteria that shows ambient temps below 60 degrees C. The Authority Having Jurisdiction can buy into this and do whatever they feel like.

Important NEC Article

Article110-14 says: 'Temperature Limitations. The temperature rating associated with the ampacity of a conductor shall be so selected and coordinated as to not exceed the lowest temperature rating of any connected termination, conductor, or device (I would add conduit to the intent here-rk). Conductors with temperature ratings higher than specified for terminations shall be permitted to be used for ampacity adjustment, correction, or both.' Playing it conservative, I would say size the wire for the lowest rated portion of the system, the fnc. Figure the wire from the 60 degree column and there shouldn't be any argument."

The Problem, The Solution

The problem, as I see it, is Mr Wiles unbelievably strict interpretation of the minutia of the letter of the NEC and his disregard of the intent or "spirit" of the Code. One does not stand alone without the other. Fortunately, on the other side of the table sit the vast majority of electrical inspectors and industry professionals who work on and with actual PVs systems every day. The furtherance, rather than the hamstringing, of PVs and the existing PV industry as a significant part of the energy supply for North America is our goal. Toward that end, safety is always on our collective minds. Happily, these experienced industry professionals know the difference between safety and silliness.

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Response to Code Corner— HP #60

David Katz

I think John Wiles' conclusion that fuses or blocking diodes should be placed in every series string of photovoltaic modules in an array to prevent excessive reverse current in the event of a wiring fault is carrying code issues too far.

While it is true that connecting a 24 volt battery to a 12 volt module will cause damage to the module, I do not think it should be the user's job to install fuses in each module. Requiring this protection would be the same as requiring everyone in utility powered homes to put a small fuse on every radio, television, lamp and appliance to protect them in case of a "loss of neutral" fault that could subject each 120 volt appliance to up to 240 volts. Since overcurrent protection is usually provided for the conductors in the system, the ratings of these overcurrent devices, usually 15 to 20 amps is many times the value needed to protect a light bulb, fax machine, computer or television.

In a 12 Volt system, there is no wiring fault possible between a 12 Volt battery and 12 volt modules that would cause an over current situation in the module, unless, as John pointed out, there was a short circuit in a bypass diode connected across 18 cells of the 36 cells in the module. Fortunately, there is no reason to have blocking diodes in modules in a 12 Volt system. If you have a 12 Volt system using modules with blocking diodes wired across 18 cells, such as in a Siemens M55 or M75 or BP 275 or 590, it would be far easier to remove the diodes than to install fuses or diodes. The only other possibility for over current in a 12 Volt system would be in the case that there was a short circuit inside the module. This type of fault could cause overcurrent in the module, but at this point the module is beyond repair anyway.

In 24 Volt and 48 Volt systems, there is more room for damage from incorrect wiring by people who know only enough to be dangerous, but asking the same people who cannot wire modules correctly to install fuses in each one will probably not make things safer or better protected. Using the 6 Amp, 400 Volt diodes that John suggested would cause nearly 1 Volt of drop from the output of the module. At a typical operating temperature of 47° C, this would cause a 10% loss of output amperage in a module operating near the peak power point in a system with only 2% wiring loss between the modules and batteries and as much as a 20% amperage loss in a poorly wired system. Since PV modules cost about $100 per Amp (in a 12 Volt system) using this 65 cent diode may cost $40 to $100 in lost output power, because it would require more modules to do the same job.

If John Wiles thinks there should be a fuse installed in each module junction box, it should be done by the manufacturer, where the cost would be very low, since it could be done when the junction boxes are molded.

Don’t require everyone who installs an off-grid PV system to spend more money because a few people may make stupid mistakes in wiring. The current requirement to provide overcurrent protection for conductors is adequate to prevent fires. If all PV systems are installed according to code by trained and qualified installers, there will very few system problems that will be prevented by blocking diodes and individual module fuses. If John Wiles manages to get these devices required by code the installation cost and the added module cost will be much higher than the cost of the few modules lost to damage from high voltage backfeed. I have been selling PV modules for 18 years and have sold many millions of dollars worth of modules. I can count the modules that have been damaged this way on one hand.

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