Questions Questions

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Every week, I get calls from around the country from electrical inspectors, electricians, PV dealers and installers, PV manufacturers, and PV users. These calls cover a wide range of subjects related to the installation of PV systems and how they are to comply with the requirements of the National Electrical Code® (NEC®). Here are some of the more common questions and the best answers that I have.

Where can I find large, flexible cables for inverter and battery connections?
Automobile battery cables and welding cables do not meet NEC requirements and, while readily available, are not suitable for inverter-to-power center and power center-to-battery connections. What is needed is a flexible cable that is UL-Listed and is marked as a building-type of cable such as USE, THW, RHW, XHHW, etc.

For the individual installing a single PV system, many of the PV Dealers and Distributors are stocking the appropriate cables. For the dealer who installs a lot of systems, the major cable distributors like Anixter can get the proper cable. Cobra Wire and Cable also makes an appropriate cable and will accept orders of at least $250.00 (see access).

What can I use for conduit between modules?
In the last Code Corner, I pointed out that non-metallic flexible conduit did not have the proper temperature range needed for connections to modules where a 90°C wet rating was required. The non-metallic flexible conduit is rated for only 60°C wet.

Unfortunately, the metallic flexible liquid-tight conduit that I suggested using in the last Code Corner may have this same limitation, but I have not been able to complete the research in this area. For now, it appears that we are limited to rigid electrical PVC conduit. It can be bent when heat is applied with a heat gun so it is possible to connect adjacent modules even though there is frame structure between them. Of course, metal conduit can be used if you are a professional and have that experience.

There are some types of metal covered cables that could be used.

Where conduit is not required, the single-conductor USE-2 cables are permitted by the NEC as is tray cable and other wiring methods.

Where can I get Ground-Fault Protection Equipment?
Section 690-5 of the NEC requires that PV systems installed on the roofs of dwellings have a device that detects ground faults in the PV array, interrupts the ground fault current, and disables the array. This requirement has been in the NEC since 1987 and electrical inspectors are beginning to require it.

Such devices are available as an integral part of listed, utility-interactive inverters from Trace Engineering and Omnion Power Engineering. Both Trace Engineering and Alternative Power Technologies (APT) are working on ground-fault units that will be listed and that can be used with stand-alone PV systems (see access).

Where can I get a copy of the National Electrical Code?
Most electrical supply houses and some major bookstores have the NEC for sale. It is also available directly from the National Fire Protection Association (see access).

What is a current-limiting fuse?
By definition, a current-limiting fuse limits the short-circuit current flowing in a faulted circuit to a level that is significantly below the short-circuit current that would be flowing in the same circuit without the fuse under the same fault conditions.

Don't all fuses limit current by blowing?
In a given circuit without a fault, the current is at zero or some nominal low value (e.g. 20 amps). When a fault occurs in a circuit without a current-limiting fuse, the current increases very rapidly from the initial value to a maximum determined by the system voltage, the available current from the source, and the circuit resistance. The fault current may increase to 10,000 amps or more in a battery circuit. The current-limiting fuse senses the rapidly increasing fault current and opens the circuit so rapidly that the current never reaches the maximum, but is limited at the 2,000-4,000 amp level by the opening fuse. Fuses that are not

designed as current-limiting fuses may let the current reach the maximum value before opening the circuit.

While the current-limiting fuse limits the fault current, it may also be designed so that it has a time delay that allows it to carry normal surge currents from motor starting actions without opening. These currents may be 4-10 times the rating of the fuse (e.g. 600 amps for a 100 amp fuse).

What is the relationship between the current rating and the interrupt rating of a fuse?
The current rating (e.g. 100 amps) is the current that the fuse can carry continuously. The fuse is required to open for currents above 110% of rating, but there is a time dependent function involved that is different for each fuse. The interrupt rating (e.g. 20,000 amps) is the maximum short-circuit that the fuse can interrupt under fault conditions. Both the current rating and the interrupt rating are given with an associated voltage rating (e.g. 125 volts direct current (DC)).

While the current rating of a fuse may be the same for ac and DC use, the interrupt ratings and the voltage ratings for ac and DC circuits may be considerably different. For example, a 100-amp fuse may have a 300-volt , 200,000-amp interrupt rating for use in ac circuits. The DC rating for the same fuse may be 125 volts and 20,000 amps - both of which are significantly lower than the ac ratings.

Is a current-limiting fuse necessary in all systems?
If the PV system does not have a battery or other source of high short-circuit currents, then a current-limiting fuse is not necessary. Non-current-limiting fuses or circuit breakers may be necessary, however, for proper conductor protection.

If the overcurrent device, either a fuse or a circuit breaker, has sufficient interrupt rating for the circuit, then a current-limiting fuse is not required. For example, the Heinemann circuit breakers used in Trace and APT products have an interrupt rating of 25,000 amps at 65 Volts DC and this is in excess of the available fault current in most battery systems.

However, if Square D QO breakers are used, they have an interrupt rating of only 5,000 amps at 48 volts dc and require the use of a current-limiting fuse between the circuit breaker and the battery. The current-limiting fuse limits the current under fault conditions to 3,000-4,000 amps which is within the interrupt capability of the circuit breaker.

Are there current-limiting circuit breakers?
I have not yet seen a DC-rated, UL-Listed circuit breaker that meets the definition of current limiting. Some circuit breakers are advertised as current limiting, but they are either rated only for ac or are rated by European Standards that are not the same as the US UL Standards.

Why don't you use more diagrams and pictures in Code Corner?
I am only partially computer literate and am just exploring the capabilities of Word 6, Excel 5, Mac Draft, Power Point, and the Power Mac 7300/200 64 Meg 12 x CD ROM/166 Pentium 48 Meg computer that I use for the Code Corner columns. Maybe next issue.

Questions or Comments?
If you have questions about the NEC or the implementation of PV systems following the requirements of the NEC, feel free to call, fax, email, or write me at the location below. Sandia National Laboratories sponsors my activities in this area as a support function to the PV Industry. This work was supported by the United States Department of Energy under Contract DE-AC04-94AL8500. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy.

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