THE SHOCKING STORY OF GROUNDING

John Wiles

The subject of grounding is one of the more confusing issues in the installation of PV systems. Even the word grounding has different meanings for different people. The National Electric Code® (NEC®) has specific definitions and requirements in this area--requirements that must be followed in order to have a relatively safe PV system. There are also some recommendations on grounding that should be followed to enhance system performance.

Definitions

The word GROUNDED means connected to the earth. The GROUNDED CONDUCTOR is a system conductor that normally carries current and is intentionally grounded. In PV systems, the NEC requires one conductor (normally the negative except for telephone systems) of a two conductor PV system, with an array open circuit voltage over 50 volts, to be grounded. Any PV system with three conductors--positive, negative, and neutral or array center tap--must have the neutral/center tap grounded. The GROUNDING CONDUCTOR is 1) a conductor that does not normally carry current and is used to connect all exposed, noncurrent-carrying metal surfaces of PV equipment to earth--also known as the Equipment Grounding Conductor or 2) a conductor that does not normally carry current and is used to connect the grounded conductor to the grounding electrode (rod) or grounding electrode system--also known as the Grounding Electrode Conductor.

The Requirements

All PV systems must have an equipment grounding system whether or not one of the current-carrying conductors is grounded. Grounding all exposed metal surfaces creates a barrier between the live conductors and the user. Since all surfaces are connected together and to earth, the voltage between them and earth even when a fault occurs, remains near zero. This minimizes the shock potential and is a requirement for any PV system. In a system with the proper overcurrent devices, the equipment grounding system also provides a mechanism to trip or blow over-current devices when a ground fault occurs. If this provision were not present, a faulty PV module or appliance, for instance, might have the frame or case connected to the positive conductor. The fault would not be noticed until a second fault occurred or the first came into contact with a water pipe or sink or, worse yet, someone made skin contact with a grounded surface and the faulty appliance.

Twelve and twenty four volt PV systems have open circuit voltages less than 50 volts and therefore are not required to have one conductor grounded. They must, however, have exterior metal surfaces of equipment grounded to comply with the NEC. This means three wire cables and three wire plugs and sockets for plug-in appliances so that the equipment grounding conductor connection can be made. Sorry, cigar lighter plugs and sockets do not qualify.

Any system with an open circuit voltage greater than 50 (i.e. 36, 48 and above systems) must have one conductor grounded in addition to the equipment grounding system.

Because DC fluorescent lights and inverters make less radio frequency noise when grounded and the lights seem to start a little easier, it is suggested that even 12 and 24 volt systems have one current carrying conductor grounded. This should provide extra protection in the event electromagnetic and electrostatic surges get into the system, since the grounded conductor stabilizes the system voltage with respect to ground and bleeds off such surges. Also, if you are using short wave radio equipment or other radio systems requiring outside antennas, they may already be grounding your PV system in a manner that does not provide the safest system.

Color Codes

Red is positive and black is negative and it always has been--right? WRONG! Ever since the beginning of time (1900 or so) the only color codes that have been approved for residential and commercial power wiring -no matter whether it is ac or DC are the following: The grounded conductor, if any, shall be white or a natural gray rubber color. The equipment grounding conductor shall be bare, green, or green with a yellow stripe. No other colors are specified, but power wiring has for years been: Black is the hot (nongrounded) conductor, white is the grounded neutral conductor, and bare or green is the grounding conductor. In 240/120 volt ac systems, the additional hot conductor is usually red but this color is not required by the code. In industrial dc systems, the center tap or neutral which is grounded is white and here at last the positive cable may be marked red and the negative cable marked black. The local inspector will be looking for that green or bare grounding conductor in all PV systems and a white grounded conductor in those over 50 volts or those which are grounded below 50 volts.

Equipment Grounding

The size of the green or bare equipment grounding wire must be at least as big as the current carrying conductors between the two pieces of equipment being connected. It can have a current-carrying capacity (ampacity) no less than the ampacity of the overcurrent device protecting the circuit. This is easy to do if 10-2 (American Wire Gauge-AWG) with ground, or 12-2 AWG with ground nonmetallic cable is used and the fuses or circuit breakers are rated at 30 amps (10-2 cable) or 20 amps (12-2 cable). If you have a metallic battery box to ground or an inverter chassis and have used 4/0 AWG conductors between the battery and the inverter, then the grounding conductor must be as large as the current-carrying conductors - in this case 4/0.

The equipment grounding conductors must at some point be connected directly to the grounding electrode which must be a 5/8" metal rod driven at least 8 feet into the earth. This grounding electrode conductor should be the same size as the largest equipment grounding conductor in the system even if this is 4/0 AWG between the battery and the inverter as used in the example.

The frames of the PV arrays must be connected to the equipment grounding system with a green insulated or bare conductor. For additional protection against lightning strikes, it is suggested that a separate ground rod be used as near the array frames as possible and a large (at least number 6 AWG) conductor be connected between the frames and the grounding rod with no splices and a minimum number of bends.

System Grounding

For grounded systems, the grounded conductor must also be connected to the grounding rod. Again, the grounding electrode conductor must be as large as the largest current-carrying conductor in the system. This conductor should be attached to the end of the largest negative conductor nearest the PV array. In most cases this will be either the negative battery terminal or the negative inverter terminal. There must be only one connection between the negative current-carrying conductor and the grounding electrode. Failure to adhere to this requirement will result in hazardous currents flowing in the grounding conductor. Furthermore, there can be no splices in the grounding electrode conductor.

All grounding rods in the system must be bonded (connected) together with conductors equal to the size of the largest grounding electrode conductor. Because of the high cost of large cable, it is suggested that with careful planning, the ac and DC ground rods can be one and the same and for roof mounted arrays, this might also be the same rod used to ground the array frame.

Now that we are connected, the next step is to be able to disconnect--the subject of the next Code Corner.

Access

John Wiles, SouthWest Technology Developemnt Institute, Las Cruces, NM.