Grounding Inverters

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Any renewable energy system that employs an inverter to produce 120-volt alternating current must have a grounding system for safety. The National Electrical Code (NEC)®, where applicable, also requires proper grounding. There is no specific standard established by Underwriters Laboratories (UL)® for the manufacture and testing of residential, stand-alone PV inverters and inverters that contain standby battery chargers. With no standard for residential inverters and with several being designed using the UL standard for recreational vehicle or marine inverters, there is variation in the grounding requirements and methods used in each unit.

Underwriters Laboratories — The Standards Maker

The design of UL-listed power-handing equipment (NEMA enclosures, outlet boxes, disconnects, and power contactors), and the existing UL standards for battery chargers, power supplies, uninterruptible power systems, and residential electrical equipment give some indication of the requirements of a possible future UL standard for residential inverters. A future UL standard for residential PV inverters might require that the ac output be isolated from the DC input and the chassis or case be isolated from both. The standard might also require the metal case to be connected to the equipment-grounding system, the green, equipment-grounding conductor on the ac output to be connected to the case, and no other connection be made inside the unit between any of the current-carrying conductors and ground or the case. The standard, to meet the existing NEC requirements, may require the hard-wired ac output to have the white, neutral wire connected to ground in the ac distribution panel. If the open-circuit PV voltage is above 50 Volts, one of the DC input conductors (usually the negative or the center-tap) is required (by the NEC) to be grounded. The standard may require this connection to be made outside the unit. On systems with open-circuit voltages below 50 Volts, the requirement to ground one of the DC conductors is optional in the NEC and the UL standard will have to address this.

Endless Variations

Today, although most inverters provide the isolation between DC inputs and ac outputs, there are numerous variations on the internal connections used to ground the systems. Many of these variations have evolved from inverters used in vehicles where the negative conductor is always grounded and the case is tied to the negative conductor because the metal chassis of the vehicle is the negative conductor. Inverters with ac receptacles nearly always have the white, neutral wire and the green, equipment-grounding wire connected to the case.

The AC Side

If this type of inverter, with multiple ac receptacles, is connected to a distribution panel (circuit breaker load center), some care must be exercised to ensure that the white, neutral wire is not bonded to the bare or green, equipment-grounding conductor in the load center. If this happens, parallel paths will exist for the currents to flow in the neutral circuit and one of these paths will be the bare, uninsulated, equipment-grounding conductor. This represents a safety hazard and is not allowed in installations falling under the NEC. There are several ways to fix this problem. The NEC says to open or remove excess bonding connections between the neutral and grounding conductors until there are no parallel paths. The obvious location is in the inverter.

But opening this connection would not only void the warranty, it might cause the inverter to not operate properly, and it might be hazardous to open even a disconnected inverter. Furthermore, the other ac outlets would not have the proper connection between the white, neutral and green, equipment-grounding conductors.

The other option when using an inverter with ac receptacles is to break the extra connection in the load center. This would require connecting the white, neutral conductors only to other white neutral conductors. The grounded bus bar in the load center would be used only for the bare or green equipment-grounding conductors. For a few white conductors (3-4), an insulated twist wire connector or split bolt could be used. For a larger number of connections, an insulated terminal strip could be used.

Inverters with hard-wired outputs (as opposed to those with multiple ac receptacles) may have the same problem with an internal connection between the neutral and equipment-grounding conductors. The solution outlined above will also work in this case.

Standby Inverters

What about standby inverters with battery chargers working from an external ac power source? The system should be connected so that when operating in either the inverting or in the standby mode, there should be one and only one connection between the neutral and equipment-grounding conductors. Gasoline and diesel engine driven generators usually have the neutral connected to the equipment-grounding conductors and both connected to the frame. When installing such a unit with power transfer relays (either internal or external), the system should be carefully checked to ensure there is no more than one bonding connection in either mode.

Some systems use the utility grid to provide the backup power. If this grid power comes from an ac utility load center, then it will usually have an internal bonding connection. In either the case of the generator or the ac utility load center, it seems best to allow the first piece of power handling equipment or power producer in the string to contain the bonding connection and to break the connections in downstream units. Each operating mode should be checked carefully and the manufacturer of each product consulted when there are any questions. If the PV inverter is located in a different building from the generator or the ac utility load center used for backup, then an electrician should be consulted concerning the proper grounding of separate buildings and separately derived sources.

The DC Side

The NEC requires that the inverter metal case be connected to the equipment ground and for safety, this connection has already been made through the green, equipment-grounding conductor on the ac output. Since the currents on the DC side are higher than the ac side (10 times at 12 Volts, 5 times at 24 Volts), the equipment grounding needs are different. The size of the DC equipment-grounding conductor is related to the size of the overcurrent device protecting the DC conductors. For example, a 400 amp fuse or circuit breaker would require a number 3 AWG equipment-grounding conductor, 200 amps: 6 AWG, 100 amps: 8 AWG, 30-60 amps: 10 AWG. Table 250-95 in the NEC gives the values. Having both an ac and a DC equipment-grounding conductor does not create any parallel path problems.

However, if the case or chassis of the inverter is connected to the DC negative conductor, then the manufacturer has already made the decision that the DC system will be grounded. No option is available for systems with less than 50 volts open-circuit PV voltage. In this case, the conductor between the negative DC input (and the chassis) and the ground rod becomes the system grounding conductor and must be the same size as the largest conductor in the system—probably the conductors between the battery and the inverter. Only one DC grounding conductor is needed and the larger size is the one to use.

On systems where the DC input conductors are isolated from the chassis, the DC equipment-grounding conductor is sized according to Table 250-95 in the NEC and is usually connected to an appropriately marked lug or terminal on the inverter chassis. With this isolated design, the user has the option of grounding the negative conductor on systems less than 50 Volts (nominal 12 and 24 Volt systems). If a system ground is used, then the NEC recommends that it be connected on the PV source circuits as near the modules as possible. Some savings in wire may be realized if the negative inverter input terminal is selected as the system grounding point and the large conductor is connected from here to the ground rod. The equipment-grounding terminal can be connected to this point with a short jumper and all other equipment-grounding conductors can also be connected to this point.

Confused?

Make careful measurements to avoid parallel paths. Contact the inverter manufacturers for full information on their products. Work with a PV professional, a local electrician, and the local electrical inspector. Ask the manufacturers how to install their products and power transfer relays in a system meeting the requirements of the NEC. Ask them if they comply with UL standards for power supplies, battery chargers, and other applicable standards.

Access

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