Inverter Grounding

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Safely grounding inverters poses some unique problems. A photovoltaic (PV) power system with a standby inverter, a backup generator, and an ac load center is a very complex system of neutral conductors and equipment grounds. Similarly, all ac systems using generators or uninterruptible power systems pose similar problems. This article will highlight the problem areas, and will provide answers for some installations.

The Problem

The equipment grounding conductors in a system are normally uninsulated (bare) conductors that are grounded. They are intended to carry currents only during fault conditions and are the last line of defense to protect the user from short circuits in equipment. When these equipment grounding conductors are improperly connected, currents can and do flow in these bare conductors (during non-fault conditions) posing a safety problem. When currents flow in these conductors, shock hazards can exist and equipment damage is possible. At the very least, electronic equipment such as TVs, stereos, computers, radio telephones, and PV instrumentation and control systems may not work properly.

PV systems are easy to connect, but they can also be connected in a manner that allows currents to flow in these equipment grounding conductors. With the presently available equipment, it is sometimes difficult to avoid the currents. The National Electrical Code (NEC) specifically prohibits connections which result in these currents and requires that actions be taken to eliminate them.

The Equipment — Load centers

An uninsulated copper or aluminum bus bar is installed in most standard ac residential load centers (circuit breaker box). This bus bar is fastened (electrically connected) to the load center enclosure. All neutral (white insulation) conductors and all equipment grounding (bare) conductors are connected to the bus bar, and it is connected to the ground rod. This load center internal connection represents one connection between the neutral and equipment grounding (grounding for short) conductors. If this was the only such connection, no problems could exist.

Inverters

The PV inverter with hard-wired and receptacle outlets must have the neutral connected to the grounding conductor to provide safety for plug-in loads. This represents a second connection between the neutral and grounding conductors. If the inverter is connected to the load center described above, there will be two connections between the neutral and the grounding conductors. These two connections place the wires in parallel and allow currents to flow through both, a decidedly unsafe situation.

Some inverters have no receptacle outlets and have a floating neutral which is not connected to the grounding conductor. When connected to the load center, they work properly and no objectionable currents flow in the grounding conductor.

Standby inverters with receptacles should supply the internal connection when operating as the ac source in the inverting mode. When wheeling ac power through the inverter (internal transfer switch) from a backup source (such as the grid or an ac generator) to the load, the connection may pose problems. In either case, the internal connection will create parallel paths if the inverter is connected to the load center with the bus bar.

Still other inverters have an internal relay that opens the connection between the neutral and grounding conductors when an external power source is used for battery charging. This presumes that the external generator or power source has the necessary connection. It also presumes that there is no load center connected which has the internal connection. Underwriters Laboratories allows this relay and may even require it although it may not be the best solution.

Generators

Most standby generators used in PV systems are less than 6 kW and have receptacle outlets and sometimes hard-wired outputs. For safe use of plug-in loads, the neutral and grounding conductors are connected internally. This third connection provides another parallel path when the generator is connected to either the load center or the inverter. Generators with only hard-wired outputs may have an optional connection at the wiring panel. Some generators do not connect the neutral to the grounding conductor, and the neutral floats all of the time.

Solutions — maybe

Because the equipment that is used in PV systems is not standardized and frequently is designed for other purposes (construction generators), it will be difficult to generalize about possible solutions.

If a stand-alone PV system provides ac power to a residence, the most durable hardware will be the ac load center. The load center is most likely to be the piece of equipment that will not break and will always be in the system when generators or inverters are down, disconnected, or otherwise not available to the system.

Because the load center is the most durable unit in the system, it should be the single piece of equipment that contains the single connection between the neutral and equipment grounding conductor. If the connection in the load center is used, there should be no connection in the inverter or in the backup generator. This may require equipment modification of existing inverters and generators.

Precautions

The following modifications should only be attempted by the technically qualified person. These modifications will void any warranties on the modified equipment, and some factories may refuse to service modified equipment. Factory service departments and service manuals should be consulted to determine if proper operation can be obtained after the modifications. The factory may be the best place to have the modification made. In new systems, the equipment may be ordered in the modified form with a standard warranty. In no case should the modified equipment be used when not connected to the PV system and the standard ac load center.

Inverters and Generators

The basic concept is to convert the inverter and generator to hardwire outputs only and to remove any internal connection between the neutral and grounding conductors. These devices become part of a permanent installation and the generator and inverter lose any portable, stand-alone capability they may have had. They should not be used by themselves after the modifications.

Remove the receptacle outlets, if any, and block the remaining access holes with metal cover plates. Some inverter manufacturers have a hard-wire conversion kit available or can make the conversions at the factory. Using flexible conduit, hardwire the inverter or generator ac output to the transfer switch or the load center as appropriate. The flexible conduit can be attached to the metal plate covering the holes where the receptacles were located. Find the connection in the inverter or generator between the neutral and grounding conductors. Break that connection and carefully tape and shrink wrap any cut wires.

Connect the inverter to a load center which has the necessary internal connection. Since the ac branch circuit needs overcurrent protection, this load center may be only a single circuit breaker in small systems. The ac system is also grounded in this load center.

There is now only one connection between the neutral and grounding conductors. That connection is in the load center where it normally resides and where the inspector expects to find it. The inverter and generator are hardwired into the system and can no longer be safely used by themselves. The load center makes the safety connection for the entire system. The ac system grounding conductor for the ground rod goes from the load center bus bar to the ground rod just as it does in a conventional ac-only system. If either the inverter or generator is removed for repairs, the ac system remains safely grounded.

Alternatives

If the choice is made not to modify the inverter or the generator, then the neutral-grounding conductor connection could be severed in the load center. Actually, the neutral conductors should be connected to an insulated terminal strip so they do not contact the bare grounding conductors or the enclosure. The single connection will now have to be made in either the generator or the inverter. Also, the connection between the neutral conductor and the ground rod will now have to be made somewhere other than the load center. At all times, under all operating conditions, there should be one and only one connection between the neutral conductor and the equipment grounding conductor.

For safety, consult the factory before making these modifications and have them made by only a qualified person.

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