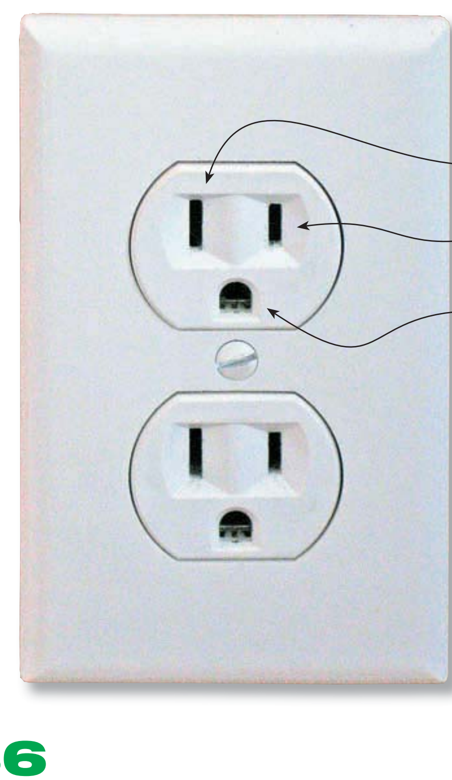
GET GROUNDED

Renewable Energy System Grounding Basics

by Christopher Freitas

ASK TEN RENEWABLE ENERGY INSTALLERS ABOUT SYSTEM GROUNDING and you'll likely get ten different opinions as to what the *National Electrical Code (NEC)* requires, and what the correct methods are to meet those requirements.



After installing dozens of systems and teaching hundreds of classes about solar-electric (photovoltaic; PV) products and systems, I finally figured out the problem—grounding involves three different purposes and three major parts. If that weren't bad enough, the same terms are often used when describing these multiple purposes and parts. No wonder people find grounding so confusing! But it doesn't have to be that way. Here's a simple guide to help you understand the basics of grounding.

Three Purposes

The primary purpose of a grounding system is to reduce the risk of shock (and possible electrocution)—and there's nothing confusing about why we want to do that. Electrocution or shock occurs when electricity flows through your body instead of through the normal electrical wiring system. Proper wiring and grounding will prevent this from occurring.

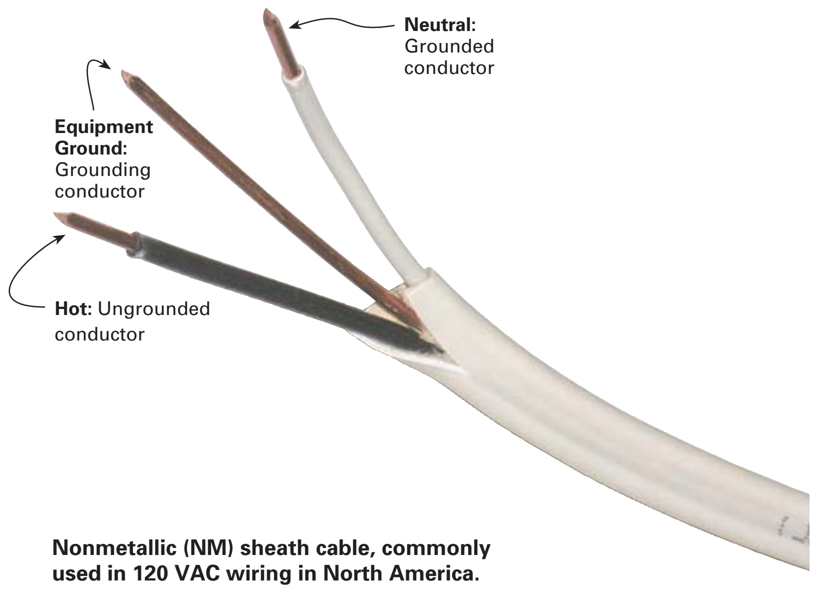
To protect against this risk, the standard, code-compliant practice is to connect all of the exposed metal parts of an electrical system together and then tie this system to the "ground" or earth. If two metal enclosures are electrically connected together with a wire, there will be no voltage difference (potential) between them. If the ground you are standing on is at the same voltage level as the metal enclosures, there won't be a shock hazard if the enclosures become energized due to faulty wiring and you happen to touch them, since there will be no voltage difference to push the electricity through your body.

The second purpose of a grounding system is to provide a way to trip a circuit breaker if a ground fault in the system occurs. A "ground fault" occurs when the electricity flows through objects not intended to carry current, such as an enclosure or a person. When the system is properly grounded, the ground wires will provide an easy, low-resistance path for the fault currents, allowing high enough currents to trip a breaker.

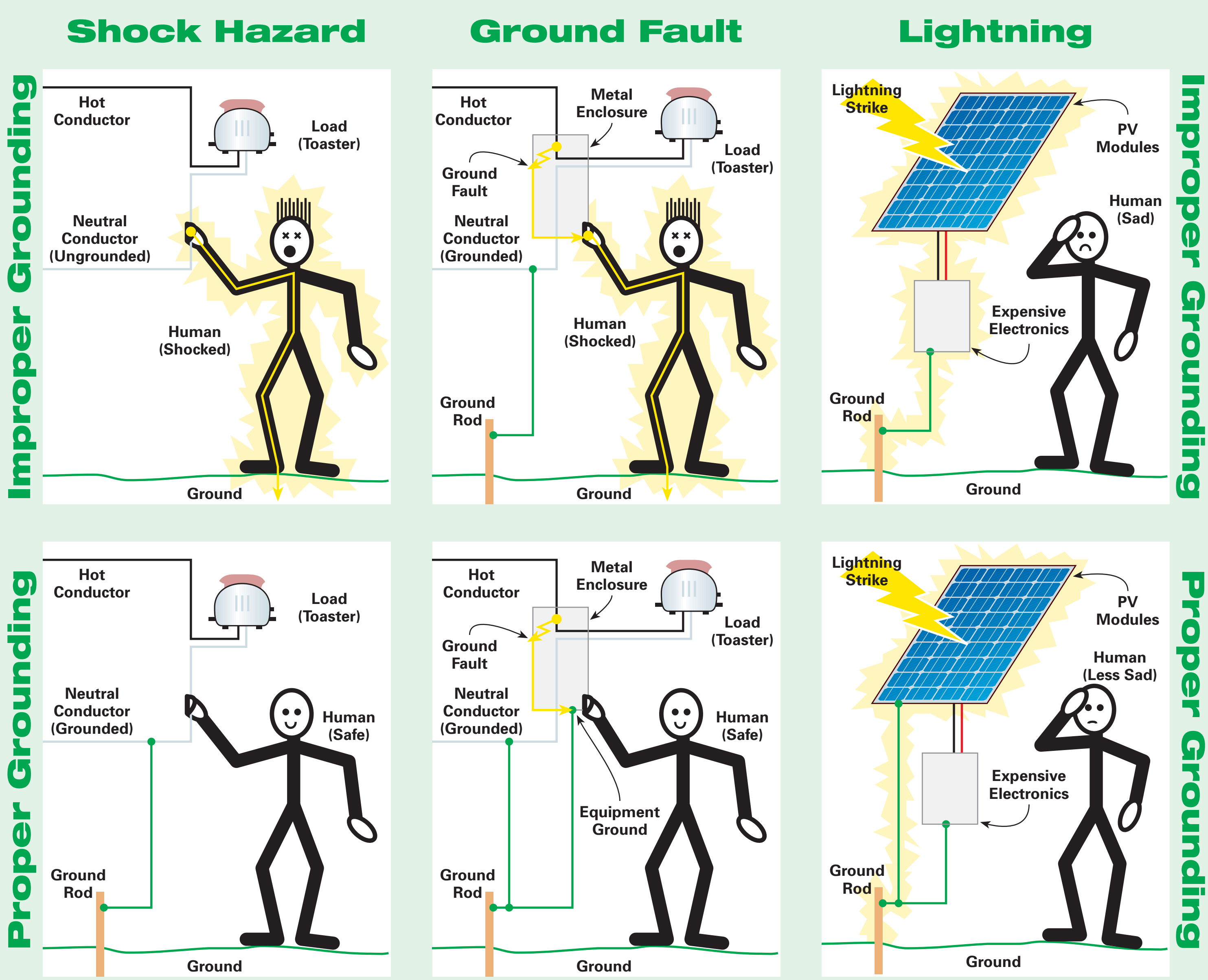
Tripping the breaker reduces the risk of electrocution, protects the circuit's electrical wiring from overheating (and possible fire) due to overcurrent conditions, and also makes it easier to identify the location of the hazard. The grounding system becomes a temporary path for the electric fault long enough to cause the circuit's breaker to trip or fuse to blow. Having individual circuit breakers on each circuit in your home helps you or your electrician isolate the fault, find the problem, and fix it.

The third purpose of a grounding system is to reduce the potential for damage from lightning. Lightning can damage your renewable energy (RE) equipment or household appliances by forcing high currents and voltages through electrical equipment or causing arcs between a product's electronic components that were not designed to handle these high-level voltages.

By providing a separate path for the flow of the lightning's energy, and a way for it to dissipate back to the earth, sensitive electronics can be "shielded" from damage. Without a proper grounding system, your expensive inverter or charge controller can become the route for this energy, with unfortunate results.



Nonmetallic (NM) sheath cable, commonly used in 120 VAC wiring in North America.



A ground rod (grounding electrode) keeps all grounding system components at the same voltage level relative to the earth.

Equipment grounds prevent a potentially shocking electrical imbalance between any and all metal parts in both AC and DC systems. Shown: A ground lug on a PV module frame.

Three Parts

All grounding systems can be divided into three different parts:

- Grounding electrode
- Equipment grounds
- Grounded conductor

Too often these three parts get confused, the different terms are used interchangeably, or each part is just called "ground." It's much easier to discuss the topic of grounding if we use the proper terms for each part or function involved.

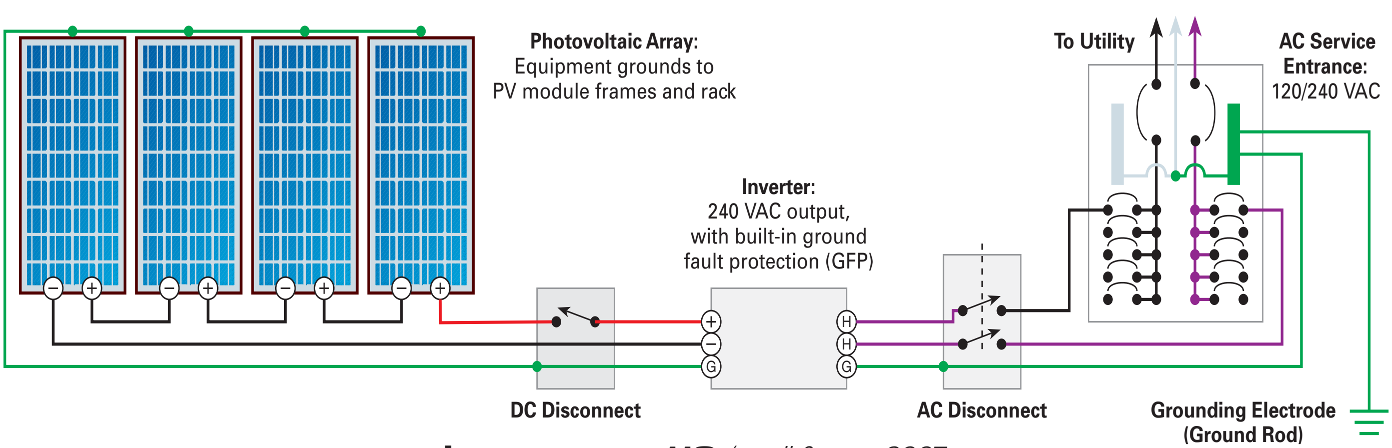
Grounding Electrode. A typical grounding electrode is the common ground rod—a length of metal rod, 5/8-inch or greater in diameter, and sometimes copper-plated, that is driven about 6 feet (2 meters) into the earth. Since moist earth creates a better ground than dry earth does, multiple ground rods are often needed in typically dry climates like the Southwest. Grounding can also be done with a copper wire or the appropriate length of properly connected coated steel reinforcing bars (rebar) installed inside a concrete foundation; this is known as a Ufer ground (named after H.G. Ufer, an Army consultant in the 1940s) and is said to offer better performance, especially in dry soil locations.

A ground rod is the simplest grounding component. Its job is to connect the electrical system to earth. This reduces the chance of electrical shock by keeping all grounding system components at the same voltage level relative to the earth, and helps prevent the system from developing a high-voltage static charge. Without grounding to dissipate static buildup, the shock that may result can damage sensitive electrical equipment or, at a minimum, scare people into thinking there is a problem with the system.

The critical idea to remember is that if there is more than one ground rod in a system, they all need to be connected together to keep component-to-component voltage at an equal level. This also applies to parts of the system that are themselves effective ground rods—such as solar-electric array mounting poles or wind turbine tower anchors. These all need to be interconnected with the entire grounding system.

Equipment Grounds. The equipment ground is the second part of a grounding system. Confusingly, the *NEC* refers to the equipment ground simply as "bonding." The idea is to ensure a reliable interconnection of all metal enclosures and metallic components to each other and to the ground rod. Then, any errant current or ground-fault current can be conducted

Grounding in a Grid-Tied PV System



Inverters usually have both AC and DC equipment ground terminals—both should be utilized.

A common AC circuit breaker.

Ground Fault Protection

Photovoltaic (PV) array installations mounted on home rooftops require DC ground fault protection (GFP). A GFP device is a specialized breaker or circuit designed to "monitor" the current between the grounding system and the grounded conductor at the point where they are connected together (or "bonded"). If a voltage imbalance occurs due to a ground fault, the GFP will open the circuit, and prevent the PV array from providing electricity to the rest of the system. In this instance, the GFP will also provide a visible indication that a ground fault has occurred. An installed GFP device typically provides the connection between the negative conductor and the grounding system. Therefore, the DC negative conductor must be kept isolated from the grounding system at other points in the DC circuit wiring. With most GFP systems, multiple PV arrays and inverters will each have their own ground fault protection devices, each with its own connection for the DC negative conductor to the grounding system.

reliably, causing the circuit breaker to trip and protecting the wire or device on that circuit.

The equipment ground also prevents shock if you happen to touch two different parts of an electrical system by ensuring that they are at the same voltage potential. The equipment ground is often accomplished with an additional wire, but in some situations specific grounding screws and even metallic conduit connecting system components are used.

There can (and should) be multiple equipment ground connections of metal enclosures, raceways, and components in a system. The more equipment grounding connections, the better—they will provide redundant paths for a ground-fault current, guaranteeing that a breaker will trip. For example, most inverters used in battery-based systems will have an AC and DC ground terminal—both should be used. Often the inverter will be mounted on a metal rack or panel, which should also be connected to the grounding system. Redundant equipment grounds can also help to reduce radio and TV interference problems by providing more paths to dissipate the radiated and conducted emissions produced by some system components.

The equipment grounding conductors are connected (or bonded) to the grounded AC neutral conductors at only one place in an electrical system—usually in the AC distribution panel (seen here before the installation of the branch circuit breakers).

Grounding Variations

Positive Ground

Some systems require the DC positive conductor to be connected to the grounding system. This is referred to as a "positive ground system." It's a common grounding approach in telecommunication installations, and is required by one manufacturer of solar-electric modules (SunPower). In a positive ground system, the breakers or fuses are installed in the negative wires (not the positives), since the negative is now the "ungrounded" conductor.

Regardless of whether the system is positive or negative ground, all the metallic enclosures and components still must be connected together to the same grounding system. This also applies to PV module frames, mounting racks, and wind turbine towers and anchors. All of the electrical systems (AC and DC) must share the same grounding system to be code compliant.

Ungrounded Systems

After finally getting a handle on what grounding means, you find out the *NEC* allows ungrounded systems as well! In the past, ungrounded systems were generally limited to small solar-electric systems operating at less than 50 VDC, but ungrounded systems are becoming more common with specific high-voltage, batteryless grid-tie systems. What's the deal?

An *NEC*-compliant "ungrounded" system only eliminates the DC negative or DC positive (in positive ground systems) conductor's connection to the grounding system. Instead, both conductors are considered "hot" and must include overcurrent protection and a means for disconnection, so breakers are commonly used, and installed in each conductor. This doubles the number of overcurrent protection devices, which means higher costs and somewhat lower performance for low-voltage battery systems. Reduced system performance is not an issue for a high-voltage, batteryless grid-tie systems since the currents are generally low. In all ungrounded systems, the PV module frames, the mounting structure, and all electrical enclosures and components must still be connected together and to a grounding electrode—just like with any normally grounded system.

RE equipment used in an ungrounded system should be specifically designed and listed for being installed in this application. The installation of products that require grounding in an ungrounded system can result in hazards to the installer or to the system user, and can damage devices connected to the system.

Grounded Conductor. In the United States, the *NEC* requires nearly all systems to have one of the current-carrying conductors connected to the grounding system. This conductor is then typically called the "neutral" in an AC system and the "negative" in a DC system. Because this conductor is connected to the grounding system, it will be at the same electrical potential in reference to ground if the system is properly wired.

The immense voltage and current in a lightning strike turn silicon inside a lightning arrestor from insulator to conductor, creating a direct path to ground.

These AC neutral and DC negative wires are called the *grounded* conductor, and they are not the same as the *grounding* conductor. The *grounded* conductor normally carries current, while the *grounding* conductor only carries current when a problem occurs, which results in a ground fault situation.

In an AC electrical system, the entire grounding system must only be connected to one of the current-carrying conductors at a single point. If an installation has both AC and DC systems, the AC neutral and the DC negative conductors will each be connected to the grounding system at separate points. Under *NEC* regulations, the AC and DC systems are considered to be separate electrical systems even though they are interconnected. Incorrectly connecting the grounded conductor at two separate points will result in the grounding system carrying current under normal operation. This is referred to as a "ground fault" and can cause equipment failure or damage, and hazards such as energized metallic surfaces and possible electric shock.

There isn't any special location in, or name for where the grounding system and the current-carrying conductor should be connected. In most AC systems, the connection between the current-carrying conductor and the grounding system is made between the neutral and ground bus bars in the AC breaker panel. In a DC system, it's usually located in the DC disconnect enclosure or factory-made inside the inverter itself. This connection should not be made at a backup generator or a battery. These are serviceable parts of a system that may be removed or reinstalled improperly, creating a potential fire or electric shock hazard if the system becomes ungrounded as a result.

Getting Grounded

The next time you discuss the ins and outs of grounding, be sure you don't confuse the purposes and terms—it's easy to do! If you first clarify which of the three parts of the grounding system is involved, and if you use the proper terms, I think you'll find discussing grounding much easier—even productive—for a change. Who knows, you might even find that you can agree with other RE nerds when the topic of grounding comes up, yet again, around the campfire.

Access

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