

When is Ground not a Ground?

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Grounding is a term that has many different facets, depending on the application. Some of the reasons for grounding systems and equipment are to: limit the voltage imposed by lightning, line surges, or unintentional contact with higher voltages; stabilize the voltage to earth under normal operation; establish an effective path for fault current that is capable of safely carrying the maximum fault current and with sufficiently low impedance to facilitate the operation of overcurrent devices under fault conditions. In addition, the most important application is to increase the protection people and equipment from shock and/or damage.

In the power quality field, grounding plays an important part in the proper operation of "sensitive" equipment. "Of all the power and grounding problems affecting electronic load equipment, almost 90% are caused by electrical power and grounding conditions inside the facility in which the equipment is used....More importantly, almost 75% of the power quality problems inside the facility relate to grounding, which makes it the single most important factor from a facility standpoint, in having reliable equipment operation." [Warren Lewis, "Quality Grounding and Power Quality: Having Your Cake and Eating It, Too", EC&M Power Quality Advisor, February 1998]

More numerous than the reasons for grounding are the terms related to grounding. The Grounding Subcommittee of NFPA70B Electrical Equipment Maintenance Committee has compiled over fifty related definitions. Article 250 of the National Electric Code is a good source for many of the definitions, though one must remember that the primary purpose of the NEC is to protect life and property, and not necessarily ensure that equipment will run properly in a facility. This does not imply that any of the requirements should be compromised for the sake of improved performance, but rather additional efforts may be required.

A grounding system has several key components: the connection to earth (often the grounding electrodes); the grounding conductor (typically called the green wire); the bonding jumper that connects the grounding conductor to the grounded conductor (often referred to as the neutral); and, the connection of the equipment connected to the grounding system. A few of the definitions from the NEC are listed below, to ensure that we are all speaking the same language.

Bonding Jumper. A reliable conductor to ensure the required electrical conductivity between metal parts required to be electrically connected.

Grounding Conductor. A conductor used to connect equipment or the grounded circuit of a wiring system to a grounding electrode or electrodes.

Grounding Conductor, Equipment. The conductor used to connect the noncurrent-carrying metal parts of equipment, raceways, and other enclosures to the system grounded conductor, the grounding electrode conductor, or both, at the service equipment or at the source of a separately derived system.

Grounded Conductor. A system or circuit conductor that is intentionally grounded.

Grounding Electrode Conductor. The conductor used to connect the grounding electrode to the equipment grounding conductor, to the grounded conductor, or to both, of the circuit at the service equipment or at the source of a separately derived system.

Grounding electrode. A grounding electrode is a conductive body deliberately inserted into earth to make to electrical connection to earth.

The grounding system operates under the same rules as the normal current carrying conductors,

namely Ohm's Law (voltage = current * impedance) and Kirchoff's Laws (sum of the voltage drops around a close circuit equals zero, or the sum of all currents at a node equals zero). For a lightning protection system, the currents involved are tremendous, measured often in tens of thousands of amperes. Obviously, the lowest impedance path possible would be desirable to minimize the voltage rise between different parts of the electrical system when there is a direct strike or induced voltage from lightning. Similarly for the fault protection to work properly, the fault current must travel through an effectively low impedance path to cause the breaker or fuse to operate properly and to reduce the touch potential hazard when equipment insulation failures occur.

For equipment categorized as "sensitive" electronic loads, having an effective grounding system is also important for proper operation. This does not mean that the equipment cannot operate without a very low impedance path to ground. If that was true, then there would have to be very long wires hanging down from every airplane to an earth connection, as airplanes are full of electronics. Many equipment vendors have recommended that the ground impedance should be 5 ohms or less. The NEC states that if the impedance is greater than 25 ohms, then a second grounding electrode should be driven, not that the final impedance must be less than some value. There are many places, such as dry, sandy soil, where it is not possible to achieve such low ground impedances. Rather, it often means having equipment that is interconnected, such as computers and printers, at the same potential (referred to as equipotential bonding). This may mean eliminating ground loops that can result in different voltage potentials, minimizing "noisy" current flowing in the equipment grounding conductor, and providing a lower impedance path to the system ground to reduce disruptive voltages.

Some of the ways that this is accomplished (and most often violated) is to make sure that there is a single, continuous electrical path for the grounding and grounded (neutral) conductors back to the point where they are bonded together. This point is usually at the service entrance. The connection of the grounded (neutral) and grounding wires at distribution panels is a too-often and illegal condition found in facilities unless there is a separately derived system. There are often referred to as "illegal neutral to ground bonds". And the impedance of concern is not just at 60Hz, but also at the harmonic frequencies and even the very high (100K - 10MHz) transient frequencies.

Another problem is the use of the orange colored receptacles typically used in data processing facilities, which are improperly referred to as "isolated ground." An isolated ground is an electrical system where there is no intentional connection between the equipment grounding conductor path and the grounding electrode system, hence, it fails to meet the basic requirements of the grounding system as it does not provide the effective ground path required by NEC and can result in unsafe and hazardous conditions. Such systems should be wired as "insulated ground", which is a circuit where the equipment grounding conductor is run as a separate insulated wire back to the grounding conductor bonding point. It is not connected to other grounding points along the way. Communications equipment from different circuits normally should not have the shield grounds connected on both ends to prevent ground loops.

Use of a power quality monitor can help track down many of these problems. It can be used to monitor the ground current and analyze both the amplitude and frequencies present, as well as transient and noise signals. Monitoring the neutral-to-ground voltage at a distribution panel can indicate that there may be a poor ground path (voltage >3 volts) or illegal bond (voltage <0.2V). Improving the grounding system in the facility may not only provide for more reliable equipment operation, but also a safer environment.