Grounding and bonding portable generators and stages

Sometimes, writing books and magazine articles feels like living in a vacuum. You pour your efforts into a couple thousand words, launch it into the cybersphere, and...nothing happens. Other times, you get a ping back from the darkness. A couple of issues ago, I wrote about the reasons for grounding an electrical system, and Ron Dahlquist, owner of Dadco and instructor for the IATSE Local 728 Safety Training Program, sent me an email that read:

“I enjoyed reading your article in the Summer 2011 edition of Protocol on grounding. As your article indicates, grounding is a confusing and controversial issue. To ground or not to ground; that is the question. The truth is that proper grounding does not necessarily involve the earth as a grounding plane. And, in some instances, grounding to earth can create a hazard.

“Your article deals mainly with venues in buildings with existing grounded systems; I deal mainly with portable power systems in temporary situations, such as motion picture and television productions on location.

“I have been heavily involved with grounding portable power systems in Los Angeles since the 1984 Olympics, when the old two-wire, ungrounded, direct-current system was used on alternating current systems involving the public in the Olympic venues. In order to provide a safe system for AC use, a complete new portable power distribution system needed to be designed to replace the DC system.

“For more than 25 years, the motion picture and television industry, through the combined efforts of the L.A. City Department of Building and Safety, The AMPTP, and IATSE Local 728 have established safe working standards for grounding portable power systems used on locations.

“We have found that grounding portable generators to earth is ineffective for the most part and usually impractical, due to the short duration of filming using multiple locations on any given day; as many as 100 productions can be working at the same time in the generic ‘Hollywood’ film community.

“A proper earth ground for portable generators depends on the condition of the soil, the length of the grounding rod and the placement of the grounding rod. In most cases, a grounding rod needs to be driven 8’ into the ground to provide a good ground; this also requires a permit from the department of building and safety, a dig alert to determine what lies underground (such as water lines, gas lines, electrical lines, and other obstructions), and an inspector to verify the ground with a megger device and other requirements. As you can see, this is impractical for this application.

“As your article indicates, in order for a person to be shocked you must complete the circuit; if the system is isolated above earth, a person cannot complete the circuit by standing on the earth.

“The National Electrical Code addresses portable and vehicle-mounted generators in Article 250.34, and states, among other things, that, under certain conditions, the frame of a portable generator shall not be required to be grounded (earth ground) and the frame of the generator shall be permitted to serve as the grounding electrode for a system supplied by the generator.”
“In order to provide a safe system for the end-user (the lighting technician), all non-current carrying metal parts of the system and equipment grounding conductor terminals of the receptacles are bonded to the frame of the generator, and the neutral terminal of the generator is bonded to the ground terminal and the frame of the generator.

“When two or more generators are used on the same location and the equipment is within 20’ of each other, the generator grounds must be bonded (connected) together, forming a zero potential between systems. Also, when generators are combined with venue or building premises electrical systems, the generator ground must be bonded to the premises, grounding the electrode at the power source.

“All of the aforementioned is subject to the local authority having jurisdiction (AHJ), which is the electrical inspector. Even though an electrical inspector may require a grounding rod be used on portable power generators, it may have the same effect as grounding your washing machine to a flower pot in your kitchen. But remember, arguing with an electrical inspector is like wrestling with a pig in the mud; you soon find out the pig likes it. So abide by the local AHJ requirements.”

“To ground or not to ground” certainly makes for better prose than “to use a grounding electrode or not to use a grounding electrode,” so I’m with Dahlquist there. But, strictly speaking, to ground or not to ground is spelled out in Article 250.20 of the NEC. For the record, there are systems that must be grounded, may be grounded, and must not be grounded. The exceptions to the requirements for grounding an AC system typically don’t apply to the live entertainment industry, so all of our systems should be grounded, as I’m sure the reader will agree.

The question of what to use as a grounding electrode is a valid point. There are many acceptable instances where driving a grounding rod or earthing rod 8’ into the ground is not only impractical, but also not a very good idea. If you pick any downtown location in any heavily populated metropolitan area like Los Angeles, Chicago, or New York, and drive a stake 8’ into the ground, chances are that you will hit a water, sewer, gas, or electrical line. In other locations, such as Vancouver, I’m told that the soil is not particularly conducive to making a good, solid connection between the earth and a driven rod, so they often use grounding plates, which must be buried at least 30” below grade.

In some cases, it is more appropriate, as Dahlquist points out, to use the frame of a portable generator as the grounding electrode. This is allowed by the NEC as spelled out in Article 250.34:

Article 250.34 Portable and Vehicle-Mounted Generators.

(A) Portable Generators. The frame of a portable generator shall not be required to be connected to a grounding electrode as defined in 250.52 for a system supplied by the generator under the following conditions:

(1) The generator supplies only equipment mounted on the generator, cord-and-plug-connected equipment through receptacles mounted on the generator, or both, and

(B) Vehicle-Mounted Generators. The frame of a vehicle shall not be required to be connected to a grounding electrode as defined in 250.52 for a system supplied by a generator located on this vehicle under the following conditions:

(1) The frame of the generator is bonded to the vehicle frame, and

(2) The normally non-current-carrying metal parts of equipment and the equipment grounding conductor terminals of the receptacles are connected to the generator frame.

The main idea is to have as large a mass as possible to absorb any energy that may go astray, and to build a grounding plane that bonds all of the metal parts together.

The requirement for supplying cord-and-plug-connected equipment means that this exception does not apply to hard-wired equipment, which is typical not how we in the live event production industry do things. We typically use cord-and-plug connected equipment through a combination of multi-core cables and circular multi-pin connectors, and feeder cable connected with camlock connectors in a temporary situation, so we usually meet the requirements.

Dahlquist also correctly points out that all non-current carrying metal parts of the system should be bonded together. If the portable power is feeding a portable stage, that also goes for the metal parts of the stage.

Since a portable power generator is a separately derived system (SDS), the requirements for bonding an SDS apply. According to NEC Article 250.104 (D)(2), Structural Metal, “Where exposed structural metal that is interconnected to form the building frame exists in the area served by the separately derived system, it shall be bonded to the grounded conductor of each separately derived system. This connection shall be made at the same point on the separately derived system where the grounding electrode conductor is connected.” Most of the time, in our world, “where the grounding electrode conductor is connected” is on the portable power generator.

A stage is not a building, but its metal parts are structural and they can be dangerous if they are not bonded to the power system feeding it and become energized. That could happen should the insulation of any of the current-carrying power cables fail and come in contact..."
with the stage metal. In that case, there would be no path for ground-fault current back to the source, unless we bond it for that purpose.

Also, if we fail to make sure the metal parts of the stage are bonded to each other, then the stage, or parts of it, could be at a different potential than other parts of the stage. That could lead to a dangerous situation if someone comes in contact with both at the same time.

It’s worth mentioning that there are times when a grounding or earthing rod is appropriate. For example, if the metal parts of the stage are in direct contact with the earth, then the electrical system is not isolated from the earth. In that case, there should be a grounding or earthing rod, plate, or ring, which meets regulatory compliance.

How do we properly bond the metal parts of the stage to the grounding system? The key is to do it in a way that “establishes an effective ground-fault current path.” That means that we need to create a low-impedance path for fault current to insure that the circuit breaker will trip in the event of a ground fault. The other stipulation is that this ground-fault circuit “shall be capable of safely carrying the maximum ground-fault current likely to be imposed on it from any point on the wiring system where a ground fault may occur to the electrical supply source,” and “the earth shall not be considered as an effective ground-fault current path.”

Typically, we run a grounding conductor (marked by a green connector) from the generator to a portable power distribution rack. Since the conductors are normally connected using a camlock connector, those connectors should be listed devices. Any camlock listed with a nationally recognized testing laboratory (NRTL) should do.

The grounding conductor should be sized according to NEC Table 250.66, Grounding Electrode Conductor for Alternate-Current Systems. For example, under normal circumstances, when we run a 4/0 feeder cable system to a portable stage, the green grounding conductor needs to be at least #2 wire. Typically, we use the same size grounding conductor as the phase conductors for simplicity.

The reason it can be sized smaller than the phase conductors is that it only has to safely carry fault current for a very brief time, just long enough to cause the overcurrent protection to trip. What’s just as important is having low enough impedance to do so. Remember, fuses and circuit breakers are inverse time-related devices, meaning the higher the overcurrent the faster they trip, and the faster they trip the more quickly they clear a potentially disastrous problem.

When we connect that feeder cable to a portable power distribution system with multi-core cable outputs, the green grounding wire inside the cable eventually connects to the grounding terminal of the luminaire, which is bonded to the metal chassis (if it has one). The metal chassis is bonded to the metal yoke (again, if there is one), and the yoke is bonded to the C-clamp, which is normally clamped to the truss. Unless someone has placed plastic or PVC protection sleeves over the aluminum truss (which is sometimes done to protect the truss from getting scarred or damaged) then the truss is bonded to the equipment ground of the electrical system through multiple bonds.

Sometimes the truss is dead-hung or rigged on chain hoists using insulating roundslings, then the metal structure could be isolated from the electrical system, in which case we need to take steps to remedy the situation. Wherever there is isolated structural metal, it should be bonded to the system ground. According to the NEC, you are allowed to use listed pressure connectors, terminal bars, exothermic welding, machine screw-type fasteners, thread-forming machine screws, or other listed means for bonding. You can use a grounding connector like the Harting Han GND connector (http://bit.ly/H8ywg8) or another listed connector to make it quick and easy for temporary installations.
distribution panel, it creates a parallel path for normal return current through the neutral and the grounding conductor. That is what is known as “objectionable current.”

The green grounding conductor is not normally a current-carrying conductor. It is there only as a safety valve to conduct fault current in the event that something goes wrong. Allowing current to flow through it under normal circumstances is dangerous, because it can energize everything that is bonded to it, including the metal parts of the system.

How to create a safe working environment using portable generators and portable stages is really the question. The main idea is to have as large a mass as possible to absorb any energy that may go astray, and to build a grounding plane that bonds all of the metal parts together. It is a complex subject but one that we must get right. Thanks to your experience and expertise, Ron, it’s a bit easier. Thanks for writing.