BY RICHARD CADENA

Grounding and bonding

LAST YEAR I WAS WORKING as an electrician on a large corporate event, when I overheard someone tell the production manager that when you touch one of stages, you can feel a tingle. The production manager sent another electrician to the stage, which was in a building across the street, to investigate. He grabbed his voltmeter, hopped in a golf cart, and off he went. When he returned, he said he eventually found that a carpenter had driven a nail through a set piece, inadvertently piercing a hot conductor, which came in contact with the metal structure of the stage, putting voltage on the entire stage structure. He pulled the nail—problem solved. Or was it?

> "... the EGC's ... connection to the neutral conductor at the supply is the only reason it trips the circuit breaker in the event of a ground fault."

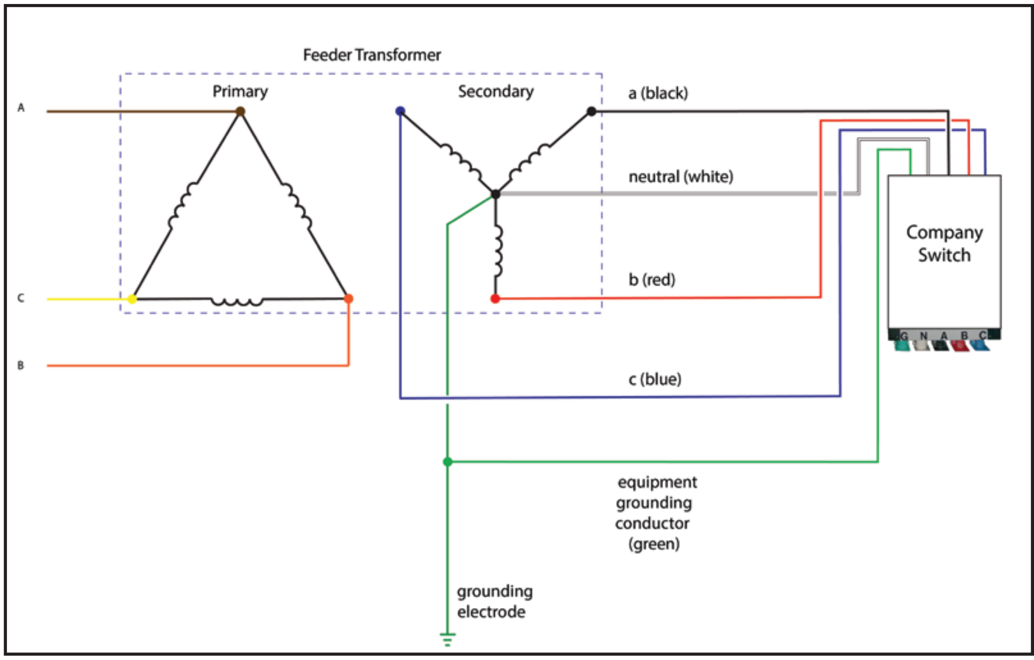
Removing the nail certainly removed a symptom of the problem, but it didn't address the real problem, which was that the stage was not bonded. Had it been properly bonded, then as soon as the carpenter drove the nail and shorted the conductor to the stage structure, a circuit breaker would have tripped.

What is grounding? What is bonding?

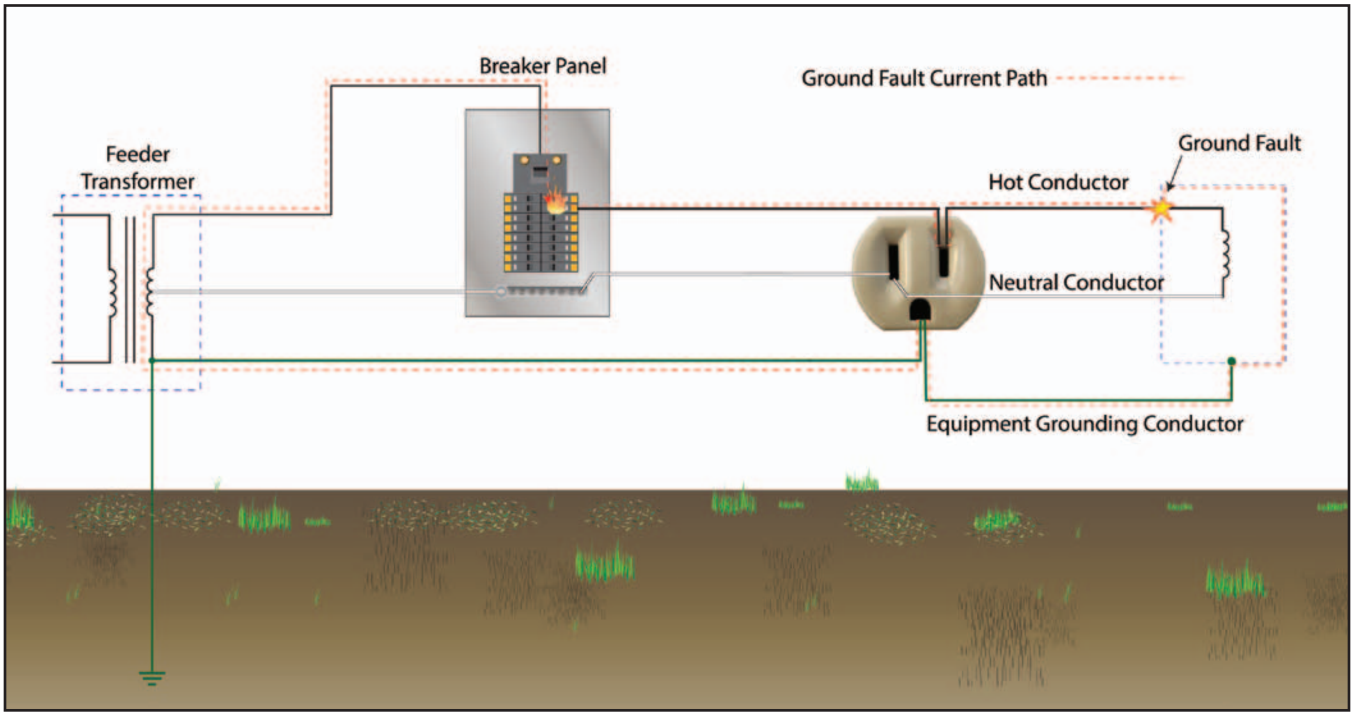
Bonding the conductive parts of a stage structure that has power distribution is mandated by the *National Electrical Code* (*NEC*). Article 250.4(A)(4) says, "*Normally, non-current-carrying electrically conductive materials that are likely to become energized shall be connected together and to the electrical supply source in a manner that establishes an effective ground-fault current path.*"

It's understandable that the electrician on that job was not well-versed in bonding stages because it's not a common practice in our industry in North America. There are at least two reasons for this: confusion about the purposes of grounding and bonding, and the lack of enforcement.

Grounding and bonding are not well understood in live event production, and it doesn't help that electricians use the same terminology to describe very different functions of a power distribution system. Grounding is the practice of connecting the neutral point of the electrical system to the earth through a grounding electrode, but we also use the same or similar terminology to describe the green (or green with a yellow stripe) conductor found in the power cable of all of our equipment. The purpose of that green equipment grounding conductor (EGC) is to establish "an effective ground-fault current path" in the event of a short circuit to the chassis of the equipment, which we call a "ground fault" even though it's completely unrelated to the earth. The



Grounding is the practice of connecting the neutral point of the electrical system to the earth through a grounding electrode. The same or similar terminology (ground or grounding) is used to describe the green (or green with a yellow stripe) conductor found in the power cable of all of our equipment.



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EGC is required by *NEC* Article 250.4(A)(3): "*Normally, non-current-carrying conductive materials enclosing electrical conductors or equipment, or forming part of such equipment, shall be connected together and to the electrical supply source in a manner that establishes an effective ground-fault current path.*"

That green wire is a bonding conductor really, but we in North America all call it "ground." (In other parts of the world, particularly the UK, it's called the circuit protective conductor, or CPC, which is much more aptly named.) Yes, the EGC eventually connects to the earth through the grounding electrode conductor at the supply, but it works with or without a connection to the earth. Its connection to the neutral conductor at the supply is the only reason it trips the circuit breaker in the event of a ground fault. That's what completes the circuit, not the connection to the earth. Whether or not there is a grounding electrode has nothing whatsoever to do with it, thus the confusion. I've actually had people ask me what happens to the electricity after it goes into the ground (meaning the earth)! The answer is, it never goes into the earth unless something is really wrong.

Earthing the neutral conductor

The practice of connecting the neutral conductor to the earth at the supply dates back to the 1890s. Before there was an NFPA there was the New York Board of Fire Underwriters, and according to David Dini, the author of a paper titled *Some History of Residential Wiring Practices in the US*, they "condemned" the practice of earthing the neutral conductor because they thought it was dangerous. That's because it can create a path for fault current through the earth in the event that someone comes in contact with a live conductor or an energized conductive part. It's safer, they reasoned, to leave electrical systems ungrounded because someone would have to touch both a live conductor and the neutral conductor at the same time in order to get shocked.

But that changed in 1903. By that time, the *NEC* recommended, but didn't strictly require, electrical systems to be earthed. It changed again in 1913 when they mandated the earthing of the neutral point of residential electrical systems. That's likely because there were a number of fires caused by lightning.

> **"If it was 'equipment bonding conductor,' then there might be less confusion about its purpose and perhaps more attention paid to the proper bonding of staging structures and anything else that is likely to become energized."**

Lightning is an enormous amount of energy, and it has been known to strike tall structures like transmission lines and buildings. When it does, that energy is carried into the building either via the electrical system or the building steel. What it does from there determines whether or not there will be a fire in the building. If the energy stays concentrated, it converts to heat energy and becomes destructive, either in the form of a fire or an explosion or both. On the other hand, if it has an easy path to the earth, which is really where it wants to go, then it will take it. Since the earth is such a large mass, it can absorb a great deal of energy like lightning, and it then converts to heat and spreads out so far as to become much less destructive.

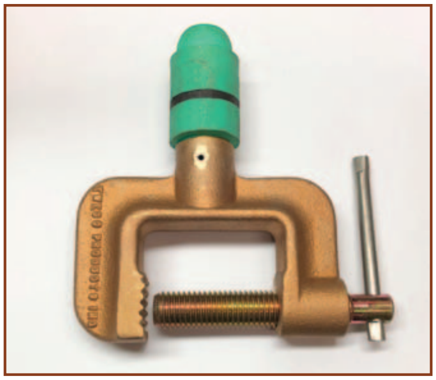
> “. . . we can avoid accidents, and that means we need to anticipate them and be proactive about our safety practices, including taking steps to ensure that conductive materials are properly bonded.”

So, the practice of connecting the neutral point of an electrical system is really all about lightning protection and to protect against voltage surges. According to the *NEC*, it also serves to “. . . stabilize the voltage to earth during normal operation.”

I like that they used the word “earth” instead of “ground” because it avoids confusion. If that word was applied more liberally, as in “earthing electrode” or “earthed conductor,” then I think a lot more electricians would understand the functions of the electrode. The same goes for the use of the term “equipment grounding conductor.” If it was “equipment bonding conductor,” then there might be less confusion about its purpose and perhaps more attention paid to the proper bonding of staging structures and anything else that is likely to become energized.

Tools for bonding a structure

People often ask how to properly bond a stage structure, truss, or other conductive materials. It starts at the generator or distro, and you can use a Camlock tee-connector

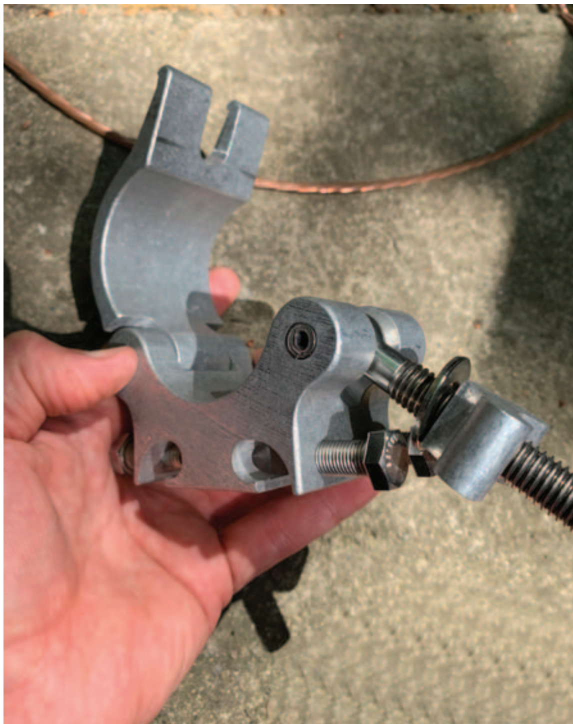


The KRE grounding clamp makes it easy to bond stages and structures.

to tap off of the grounding terminal either at the generator connection panel or the distro, then run a conductor to the structure to be bonded. This conductor should be as short as possible to ensure the impedance is low. From there, you can use any number of methods to bond the structure, including some custom brass C-clamps with Camlock connectors. There are two companies that I know of who make them, and those are Dadco Power and Light and KRE. These C-clamps cost a couple of hundred dollars (in very round numbers).

There is another option for bonding structures that is offered by The Light Source, the same company that makes Mega-Couplers. Their new Grounder is a modified Mega-Coupler with two channels that will accept bare copper or aluminum wire from #14AWG to #1/0AWG. It fits pipes and truss with chords ranging from 1-5/8" O.D. to 2" O.D., and it’s ETL listed to UL standard 467 in the USA and Canada. It’s also corrosion-resistant, and it’s made with 6061 aluminum and stainless-steel bolts. It retails for $55.

It’s rare that we see an electrical inspector on our entertainment stages, which is why the bonding of stages is not strictly enforced. That’s not necessarily a bad thing as long as we can avoid accidents, and that means we need to anticipate them and be proactive about our safety practices, including taking steps to ensure that conductive materials are properly bonded.■



The Light Source Mega-Coupler Grounder allows you to bond pipe, truss, scaffold, and other conductive structures with a clamp that accepts #14AWG to 1/0AWG conductor.

Richard Cadena has worked as a production electrician, lighting designer, and lighting consultant for more than 33 years in theatre, concert/touring, television, corporate events, sporting events, houses of worship, and more. He is the author of *Electricity for the Entertainment Electrician & Technician* (Second Edition, Focal Press, 2015) and *Automated Lighting: The Art and Science of Moving and Color-Changing Light* (Third Edition, Focal Press, 2018). Richard is also an ETCP Certified Entertainment Electrician and an ETCP Recognized Trainer. His websites include www.rcad.me, www.automatedlighting.pro, www.electrics.tech, and www.APTXL.com .