

Best Practices

The Quagmire of Electrical System Grounding

The subject is complex. NEC Article 694 tries to clarify it.

By MICK SAGRILLO with technical review by Roy Butler, Four Winds Renewable Energy

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As originally envisioned, grounding electrical systems in the United States was quite simple. Over the years, however, grounding has become increasingly complex and more confusing.

The rules for grounding electrical equipment are laid out in Article 250 of the National Electrical Code (NEC). In addition, the new Article 694 on small wind turbines in the 2011 NEC covers a few of the differences unique to wind systems and clarifies a few additional considerations about grounding and lightning protection.

Before delving into these, we need to differentiate between grounding for electrical faults and grounding for lightning protection.

Lightning Protection

Imagine this: It's a cold, snowy Sunday morning, and with a fire going in the woodstove, you head over to your favorite chair with cup of coffee in hand and the Sunday paper under your arm. But wait! That darned cat has already settled into your chair. Shuffling your feet on the carpet as you approach the chair, you stick your finger out toward the cat's nose and ZAP! A spark flies and the cat flees. You have the chair all to yourself.

What happened during the ZAP portion of this drama?

We all remember from grade school science the "experiment" where we rubbed rabbit fur on a piece of plastic and created some static electricity that we could discharge on the ear of an unsuspecting classmate. That same experiment was just conducted with your cat. Stocking feet on the carpet, dissimilar materials, static buildup: It's got to equalize somehow. All you did was simply provide a discharge path through the cat's nose.

The same thing happens as the air masses roll across the planet: A static charge builds between ground and atmosphere, creating a giant capacitor (not unlike the capacitor in the flash on your camera). At some point, that static builds to a point where it has to discharge to equalize itself. This is what we call lightning, and it occurs several thousand times a minute at locations scattered around the planet.

Understanding how to dissipate that static buildup between the atmosphere (with winds blowing across your wind turbine blades) and the earth (what your tower is attached to) will go a long way toward understanding how to minimize the attraction between lightning and your tower, and subsequent damage. By connecting wires from the tower structure to ground rods in the earth, you are able to dissipate the static charge that builds up on the

tower and turbine, thereby making the tower less attractive to lightning strikes.

In addition, should it strike, ground wires and rods give lightning a quick route to get from the tower to the earth. Although your tower is built on a concrete foundation embedded in the earth, the concrete is not necessarily a desirable path for lightning to get to the earth. Imagine the problem that would occur if lightning came down your tower and into the metal anchors embedded in the concrete. Depending on the conductivity and moisture content of the concrete, the lightning could shatter the foundation. However, the damage would remain completely unseen, buried below the ground, until a high wind event toppled the system over. Not good.

Ground rods ... dissipate the static charge that builds up on the tower and turbine ... making the tower less attractive to lightning strikes.

Equipment Grounding

A second type of grounding, called bonding, includes connecting all metal components together electrically. This is required by the NEC so that no one component is isolated in such a way that it might carry a fault current that could harm someone. More importantly to a small wind system is the fact that bonding assures that all components of the system are at the same electrical potential should lightning strike and set up transient voltage on the wiring from the tower to the controls in the house. Equalizing such voltage potentials by bonding all metal components together will not eliminate lightning damage, but it often minimizes it.

Grounding plays another role with wind systems. Just as with any electrical generating device, the metal components of a wind system need to be grounded to protect service personnel and the public from a shock caused by an electrical fault. Since alternators and wires carry an electrical current, and since they can short to the tower or wind turbine, it is prudent to make sure that this equipment is protected by proper grounding.

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Article 694

Although all metal components that can potentially be energized are required to be grounded, Article 694 exempts the blades and tail from this requirement, as there is no electrical energizing source associated with them. In

It should always be assumed that a spinning turbine is generating electricity.

addition, since the guy cables on a guyed tower are physically connected to the tower, these are assumed to be grounded through the tower per Article 694. Regardless, for lightning protection purposes, most installers will ground the guy cables to a dedicated ground rod at each respective anchor. Another best practice is to bond all guy anchor ground rods together with a ground

wire, then run this wire back to the tower and on into the house where the system electronics are housed. Again, this puts everything at the same electrical potential.

Since guy cables are usually made of galvanized steel, and since grounding components are usually copper wires and ground rods, a problem surfaces having to do with connecting dissimilar metals. Technically, galvanic action could take place between copper and the zinc in the galvanizing, creating a weak current flow that would move ions from one metal to the other. The worst-case scenario is that a galvanized guy cable would fail, resulting in the tower buckling. While it doesn't appear as though this type of failure of a small wind system has ever been documented, Article 694 prudently specifies that contact between dissimilar metals must be avoided. This means sourcing connectors, ground wires and rods that are acceptable to the NEC to ground the guy cables.

Not addressed in Article 694 (but on the docket for consideration next time) is grounding the output of the alternator. Wind system alternators are somewhat unique. Unless they are a standard AC voltage and frequency, as is

found in the induction generator of some systems, permanent magnet alternators generate 3-phase wild AC, meaning the AC voltage, current and frequency varies continually with the wind speed; it is not stable like utility-provided AC power. Such systems operate as "floating" systems, and the output is ungrounded until it reaches the controller or inverter where it is converted to utility-grade electricity. While AC induction generators must have their neutral conductor grounded just as is done with any other AC system, permanent-magnet wind AC alternators do not have a neutral conductor and will not operate if grounded.

This means that service personnel must be cautious when working around permanent magnet wild AC wind turbines. It should always be assumed that a spinning wind turbine is generating electricity, and that a potentially hazardous voltage is present on the wind turbine conductors. Coming in contact with the wires of any small wind turbine can be extremely dangerous. Never work on one unless you have personally shut it off, verified that the blades are no longer turning, and the electrical disconnect has been locked out on the utility AC side of the system. **ST**

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