2023 NEC Study Guide For "Service Grounding Basics"

(This Study Guide was prepared by Gaylord Poe)

Like many code topics, there are numerous NEC rules about the grounding of service installations. As with most of the "complicated" code topics, our problems with these rules begin to disappear as we better understand the basic concepts. Within the numerous NEC rules regarding service grounding, I believe there are three basic concepts that stand out. These concepts apply to all service installations. This study guide will address the three basic concepts. Understand the "Big Three" and the other rules become much easier to understand. *(Note: For the purpose of this study guide the grounded conductor of grounded systems will be referred to as the "neutral".)*

1. **There's a difference between "System Grounding" and "Equipment Grounding".** Don't let a "misread" of the code rules send you down the wrong path. All service installations require a grounding electrode conductor (GEC) and a grounding electrode system. For a grounded system (where a service conductor is intentionally grounded) the GEC is connected to the grounded conductor. For an ungrounded system (a Delta 3ϕ - 3-wire system is the most common example) the GEC is connected to any metal enclosure that contains service conductors. The big difference is an ungrounded system has no "neutral" to connect the GEC to – everything else stays the same.

2. **Everything that's metal and contains service conductors shall be bonded.** How do you determine what is defined as "service" and what is not? Easy. Whatever is going to stay "hot" after you turn off the main(s) is "service". There's a lot of ways to accomplish the required bonding. For example, on a grounded system anything that's directly connected to the neutral is considered to be bonded. Examples of enclosures that are bonded by the neutral are: Service switches (the neutral bonding jumper), and CT cabinets or termination boxes or wireways where the neutral is bolted directly to the enclosure. Because of the neutral connection, whatever is bolted to or connected to these enclosures with bonding fittings is bonded too. Anything that is connected to the neutral through an approved connection is considered to be bonded. What are recognized bonding paths? For grounded systems, paths that provide continuity to the neutral conductor using bonding fittings such as bonding-type locknuts, bonding bushings, and threaded hubs. For ungrounded systems, paths that provide continuity between all enclosures using bonding fittings such as bonding-type locknuts, bonding bushings, and threaded hubs. Look at each individual component in the service scheme and imagine a fault within that component. Will all fault current flow through approved bonding paths?

3. **When a neutral is available in the system, the neutral must be run to and bonded to every service disconnecting means.** This rule recognizes that if a

fault can be disposed of by using the neutral (as opposed to just enclosures and bonding fittings) then the neutral shall be used for that purpose – even if there is no need for the neutral downstream of the service disconnect. Don't worry about multiple disconnects within switchboards, there's a rule covering that. Don't worry about having the neutral bonded more than once either – it's OK on service installations – as a matter of fact, when it's not mandatory it's recommended.

Summary of the "Big Three": The concepts are simple. What we're trying to do here is get rid of a fault quickly before it starts a fire. Service installations often have numerous enclosures containing service conductors located ahead of the main overcurrent device. The main overcurrent device offers no protection for faults in these enclosures. Because of this, a fault in any of these enclosures will continue until it burns clear or burns open or the supply fails. The primary role of the grounding electrode conductor (GEC) during a fault is to keep voltage off of exposed conductive enclosures until the fault clears. *(Note: The GEC only performs this function during a ground fault and even then it will only conduct a very small amount of the fault current.)*

There are two basic kinds of faults encountered ahead of the mains: Line-to-line faults and line-to-ground faults. Direct line-to-line faults are very rare.

Line-to-ground fault, Ungrounded System: A line-to-ground fault on an ungrounded system basically "does nothing" until a second line conductor faults to ground. At that point there is in effect a "short" between the two faulted line conductors with the grounded conductive enclosures serving as the "conductors" between them. The better the bonding path, the lower resistance of the fault path. The lower the resistance of the fault path, the faster the fault will clear.

Line-to-ground fault, Grounded System: Unlike an ungrounded system, a line-to-ground fault on a grounded system instantly causes extreme current flow. Since the system is grounded and the neutral is bonded, a line-to-ground fault is actually a "short" that uses the grounded conductive enclosures between the faulted line conductor and the neutral as "conductors". The better the bonding path, the lower resistance of the fault path. The lower the resistance of the fault path, the faster the fault will clear.

All Faults: Remember, regardless of the type of fault, fault current flows between the fault and the supply. For Services, that supply is the utility transformer. Our job is to make sure that whatever is part of that path is large enough (low resistance) to handle the fault, can do so without failing (main & equipment bonding jumper sizes and connections) and is "tight" enough to eliminate arcs and sparks at all fittings that are conducting the fault for the duration of the fault (bonding fittings).

Example: Let's examine a ground fault on a simple 200A residential service. Suppose the fault is between a line conductor and the service main enclosure: The fault current flows from the utility transformer through the line conductor, through the service enclosure, through the main bonding jumper, through the neutral, and back to the utility transformer. In this example, whatever amount of fault current that is available flows not only though the conductors but also through the enclosure and the main bonding jumper.

On a multiple disconnect grounded service installations this type of fault will use all of the metal enclosures and raceways that are between the fault and wherever the neutral is bonded to work it's way to the neutral and then on to the supply. The quality of that path depends on the quality of the bonding.

The "bottom line" is "get the fault home" as quick as you can (low resistance path) without any arcing or sparking (from loose or non-bonding type fittings) along the way. Accomplish this and the fault won't last long enough to cause a fire. It is really that simple.

The NEC rules that are covered in this study guide are:

RE: "**There's a difference between "System Grounding" and "Equipment Grounding"**
Art. 250.4 (A) & (B), 250.24 (A) (E) & (F), 250.50, 250.64

RE: "**Everything that's metal and contains service conductors shall be bonded."**
Art. 250.92 (A) & (B)

RE: "**When a neutral is available in the system, the neutral must be run to and bonded to every service disconnecting means."**
Art. 250.24 (D) (Note: See *Exception*)

RE: "**Summary of the "Big Three"**
Art. 250.4 (A) (5), 250.4 (B) (4)