Rules for Backup Power Systems

Part 3 of 4
Article 250
Article 250 covers the requirements for providing paths to divert high voltage to the earth, requirements for the low-impedance fault-current path to facilitate the operation of overcurrent protection devices, and how to remove dangerous voltage potentials between conductive parts of building components and electrical systems.

AUTHOR’S COMMENT: Article 250 is entitled “Grounding and Bonding” and the article text often uses the word “grounding” in two different senses interchangeably (to mean both grounding and bonding, which are two different things). The purpose of this textbook is to clarify and explain the National Electrical Code. For this reason, when the NEC uses the word “ground” or “grounding” where the intent is connecting to the earth, this textbook will add “(earth).” If the NEC uses the word “ground” or “grounding” where the intent is bonding metal parts to the supply source, this textbook will add “(bonding).”

Article 250 consists of ten parts:

Part I. General
Part II. Circuit and System Grounding
Part III. Grounding Electrode System and Grounding Electrode Conductor
Part IV. Enclosure, Raceway, and Service Cable Grounding
Part V. Bonding
Part VI. Equipment Grounding and Equipment Grounding Conductors
Part VII. Methods of Equipment Grounding
Part VIII. Direct-Current Systems
Part IX. Instruments, Meters, and Relays
Part X. Grounding of Systems and Circuits of 1 kV and Over (High Voltage)

PART I. GENERAL

250.1 Scope. Article 250 contains the following grounding and bonding requirements for electrical installations:

(1) Systems and equipment required to be grounded
(2) Circuit conductor to be grounded on grounded systems
(3) Location of grounding connections
(4) Types and sizes of grounding and bonding conductors and electrodes
(5) Methods of grounding and bonding

AUTHOR’S COMMENT: Why is grounding so difficult to understand? One reason is because many do not understand the definition of many important terms. So before we get too deep into this subject, let's review a few important definitions contained in Articles 100 and 250.

Bonding [100]. The permanent joining of metal parts together to form an electrically conductive path that has the capacity to conduct safely any fault current likely to be imposed on it. Figure 250–1
Effective Ground-Fault Current Path [250.2]. An intentionally constructed, permanent, low-impedance conductive path designed to carry fault current from the point of a ground fault on a wiring system to the electrical supply source. Figure 250–3

The effective ground-fault current path is intended to help remove dangerous voltage from a ground fault by opening the circuit overcurrent protective device. Figure 250–4

Equipment Grounding Conductor [100]. The low-impedance fault current path used to bond metal parts of electrical equipment, raceways, and enclosures to the effective ground-fault current path at service equipment or the source of a separately derived system.

AUTHOR’S COMMENTS:

- The purpose of the equipment grounding (bonding) conductor is to provide the low-impedance fault current path to the electrical supply source to facilitate the operation of circuit overcurrent protection devices in order to remove dangerous ground-fault voltage on conductive parts [250.4(A)(3)]. Fault current returns to the power supply (source), not the earth!
- According to 250.118, the equipment grounding (bonding) conductor must be one or a combination of the following: Figure 250–5
  - Wire Type. A bare or insulated conductor [250.118(1)]
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250.2

- Armor of Type AC cable [250.118(8)]
- Armor of Type MC cable as limited by 250.118(10)
- Metallic Cable Trays as limited by 250.118(1) and 392.7
- Electrically continuous metal raceways listed for grounding [250.118(13)]
- Surface Metal Raceways listed for grounding [250.118(14)]

*Ground (Earth)* [100]. Earth or a conductive body that is connected to earth. Figure 250–6

*Grounded* [100]. Connected to earth.

*Ground Fault* [100]. An unintentional connection between an ungrounded conductor and metal parts of enclosures, raceways, or equipment. Figure 250–7

*Ground-Fault Current Path* [250.2]. An electrically conductive path from a ground fault to the electrical supply source.

**AUTHOR’S COMMENT:** The fault current path of a ground fault is not to the earth! It’s to the electrical supply source, typically the $X_0$ terminal of a transformer.

**FPN:** The ground-fault current path could be metal raceways, cable sheaths, electrical equipment, or other electrically conductive materials, such as metallic water or gas piping, steel-framing members, metal ducting, reinforcing steel, or the shields of communications cables. Figure 250–8
AUTHOR’S COMMENT: The difference between an “effective ground-fault current path” and “fault current path” is that the effective ground-fault current path is “intentionally” constructed to provide the low-impedance fault current path to the electrical supply source for the purpose of clearing the ground fault. A ground-fault current path is simply all of the available conductive paths over which fault current flows on its return to the electrical supply source during a ground fault.

Grounded (Neutral) conductor [100]. The conductor that terminates to the terminal that is intentionally grounded to the earth. Figure 250–9

Grounded (Earthed) [100]. Connected to earth.

AUTHOR’S COMMENT: An example would be the conductor used to connect equipment to a supplementary grounding electrode [250.56]. Figure 250–10
**Grounding (Earthing) Electrode [100]**. A device that establishes an electrical connection to the earth. **Figure 250–11**

**AUTHOR’S COMMENT**: See 250.50 through 250.70

**Grounding Electrode (Earth) Conductor [100]**. The conductor that connects equipment grounding (bonding) conductor, the grounded (neutral) conductor, or both, at service equipment [250.24(A)], the building or structure disconnecting means enclosure [250.32(A)], or separately derived systems enclosure [250.30(A)] to an electrode (earth). **Figure 250–12**

**Main Bonding Jumper [100]**. A conductor, screw, or strap that bonds the equipment grounding (bonding) conductor at service equipment to the grounded neutral service conductor in accordance with 250.24(B). **Figure 250–13**

**AUTHOR’S COMMENT**: For more details, see 250.24(A)(4), 250.28, and 408.3(C).

**Solidly Grounded [100]**. The intentional electrical connection of one system terminal to the equipment grounding (bonding) conductor in accordance with 250.30(A)(1).
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AUTHOR’S COMMENT: The system bonding jumper provides the low-impedance fault current path to the electrical supply source for the purpose of clearing the ground fault. For more information see 250.4(A)(5), 250.28, and 250.30(A)(1).

250.4 General Requirements for Grounding and Bonding.

(A) Solidly Grounded Systems.

(1) System Grounding (System Earthing). The secondary winding of a transformer is grounded to the earth to reduce equipment failures due to overvoltages caused by lightning, unintentional contact with high-voltage conductors, primary to secondary faults, static charges, ground fault, line switching, line surges, restriking/intermittent ground faults, capacitive coupling, or ferroresonance. In addition, system grounding reduces the chances of electric shock from lightning as well as interior fires from lightning.

System grounding also reduces voltage stress on electrical insulation, thereby ensuring longer insulation life of motors, transformers and other system components. This is accomplished because system grounding limits the maximum secondary voltage between any ungrounded conductor and the earth during a ground fault.

On a solidly grounded system, in contrast to an ungrounded system, a a high-voltage ground fault should result in sufficient fault current to flow back to the source, thereby permitting the circuit protection device to open quickly and clear the fault.

(2) Equipment Grounding (Equipment Earthing). Metal parts of electrical equipment is grounded to the earth to reduce voltage on the metal parts from lightning so as to prevent fires from a surface arc within the building or structure.

AUTHOR’S COMMENT: Grounding metal parts to the earth helps to drain off static electricity charges before a flash over potential is reached. Static Grounding is often necessary in areas where the discharge (arching) of the voltage buildup (static) could cause dangerous or undesirable conditions. Such an occurrence might be the failure of electronic equipment being assembled on a production line, or a fire and explosion in a hazardous (classified) area. See 500.4 FPN No. 3.

CAUTION: System and equipment grounding serves no purpose in:

- Electrical Shock Protection
- Clearing of Ground Faults
- Electrical Noise and EMI protection

(3) Bonding Electrical Equipment to an Effective Ground-Fault Current Path. To remove dangerous voltage from ground faults, metal parts of electrical raceways, cables, enclosures, and equipment must be bonded to an effective ground-fault current path with an equipment grounding (bonding) conductor of a type specified in 250.118. Figure 250–19

AUTHOR’S COMMENT: To protect against electric shock from dangerous voltages on metal parts, a ground fault must quickly be removed by opening the circuit’s overcurrent protection device. To quickly remove dangerous touch voltage on metal parts from a ground fault, the fault current path must have suf-
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250.4

The time it takes for an overcurrent protection device to open is inversely proportional to the magnitude of the fault current. This means that the higher the ground-fault current value, the less time it will take for the protection device to open and clear the fault. For example, a 20A circuit with an overload of 40A (two times the rating) would take 25 to 150 seconds to open the protection device. At 100A (five times the rating) the 20A breaker would trip in 5 to 20 seconds. Figure 250–20

AUTHOR’S COMMENT: The phrase “likely to become energized” is subject to interpretation by the authority having jurisdiction.

(5) Effective Ground-Fault Current Path. Metal raceways, cables, enclosures, and equipment, as well as other electrically conductive materials that are likely to become energized, must be installed in a manner that creates a permanent, low-impedance fault current path that facilitates the operation of the circuit overcurrent device. Figure 250–22

AUTHOR’S COMMENT: To assure a low-impedance ground-fault current path, all circuit conductors must be grouped together in the same raceway, cable, or trench [300.3(B), 300.5(l), and 300.20(A)]. Figure 250–23

The earth is not considered an effective ground-fault current path.
DANGER: Because the resistance of the earth is so high, very little current returns to the electrical supply source via the earth. If a ground rod is used as the ground-fault current path, the circuit overcurrent protection device will not open and metal parts will remain energized.

Example: The maximum current flow to the power supply from a 120V ground fault through a ground rod that has a contact resistance of 25 ohms would only be 4.8A. Figure 250–24

\[ I = \frac{E}{R} \]
\[ I = \frac{120\text{V}}{25 \text{ ohms}} \]
\[ I = 4.8\text{A} \]

To understand how a ground rod is useless in reducing touch voltage to a safe level, let’s answer the following questions:

- What is touch voltage?

- At what level is touch voltage hazardous?
- How do earth surface voltage gradients operate?

**Touch/Step Voltage.** The IEEE definition of touch/step voltage is “the potential (voltage) difference between a bonded metallic structure and a point on the earth 3 ft from the structure.”

**Hazardous Level.** Death and/or severe electric shock can occur whenever touch/step voltage exceeds 30V in a dry location, 15V in a wet location, and as little as 2V in a body of water such as a pool or lake

**Surface Voltage Gradients.** According to ANSI/IEEE 142, Recommended Practice for Grounding of Industrial and Commercial Power Systems (Green Book) [4.1.1], the resistance of the soil outward from a ground rod is equal to the sum of the series resistances of the earth shells. The shell nearest the rod has the highest resistance and each successive shell has progressively larger areas and progressively lower resistances.

Don’t worry if you don’t understand the above statement; just review the table below with Figure 250–25.

<table>
<thead>
<tr>
<th>Distance from Rod</th>
<th>Resistance</th>
<th>Touch Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Ft (Shell 1)</td>
<td>68%</td>
<td>82V</td>
</tr>
<tr>
<td>3 Ft (Shells 1 and 2)</td>
<td>75%</td>
<td>90V</td>
</tr>
<tr>
<td>5 Ft (Shells 1, 2, and 3)</td>
<td>86%</td>
<td>103V</td>
</tr>
</tbody>
</table>
Many think a ground rod can reduce touch voltage to a safe value. However, as the above table shows, the voltage gradient of the earth drops off so rapidly that a person in contact with an energized object can receive a lethal electric shock one foot away from an energized object that is grounded to the earth.

The generally accepted grounding practice for street lighting and traffic signaling for many parts of the United States is to ground all metal parts to a ground rod as the only fault current return path. Studies by some electric utilities indicate that about one-half of one percent of all their metal poles had dangerous touch voltage.

**AUTHOR’S COMMENT:** The common practice of installing a ground rod at a metal pole supporting a luminaire serves no useful purpose. Figure 250–26

(B) Ungrounded Systems.

**AUTHOR’S COMMENT:** According to IEEE 242, *Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems* (Buff Book), if a ground fault is intermittent, or allowed to continue on an ungrounded system, the system wiring could be subjected to severe system overvoltage, which can be as high as six or eight times the phase voltage. This excessive system voltage can puncture conductor insulation and result in additional ground faults. System overvoltage can be caused by repetitive charging of the system capacitance or by resonance between the system capacitance and the inductances of equipment in the system [7.2.5].

In addition, ANSI/IEEE 142, *Recommended Practice for Grounding of Industrial and Commercial Power Systems* (Green Book) states, “One of the dangers of an ungrounded system is that system overvoltages can occur during arcing, resonant or near-resonant ground faults [1.4.2].”

And, “Field experience and theoretical studies have shown that arcing, restriking, or vibrating ground faults on ungrounded systems can, under certain conditions, produce surge voltages as high as six times normal.

The conditions necessary for producing overvoltage require that the dielectric strength of the arc path build up at a higher rate after each extinction of the arc than it did after the preceding extinction. This phenomenon is unlikely to take place in open air between stationary contacts because such an arc path is not likely to develop sufficient dielectric recovery strength. It may occur in confined areas where the pressure may increase after each conduction period.

Neutral grounding is effective in reducing transient voltage buildup from such intermittent ground faults by reducing neutral displacement from ground potential and reducing destructive effectiveness of any high-frequency voltage oscillations following each arc initiation or restrike [1.2.14].” Figure 250–27

(1) Grounding Electrical Equipment to the Earth. Metal parts of electrical equipment must be grounded to the earth by electrically connecting the building or structure disconnecting means [225.31 or 230.70] with a grounding electrode conductor [250.64(A)] to a grounding electrode [250.52, 250.24(D), and 250.32(A)].
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AUTHOR’S COMMENTS:

- Metal parts of the electrical installation are grounded to the earth to reduce voltage on the metal parts from lightning so as to prevent fires from surface arcs within the building or structure. Grounding equipment to the earth doesn’t provide a low-impedance fault current path to the source to clear ground faults. In fact, the Code prohibits the use of the earth as the effective ground-fault current path [250.4(A)(5) and 250.4(B)(4)].
- Grounding metal parts to the earth doesn’t protect electrical or electronic equipment from lightning voltage transients on the circuit conductors. To protect electrical equipment from high-voltage transients, proper transient voltage surge-protection devices must be installed in accordance with Article 280 at service equipment, and in accordance with Article 285 at panelboards and other locations.

(2) Bonding Wiring Methods to the Metal Enclosure of the System. To remove dangerous voltage from a second ground fault, metal parts of electrical raceways, cables, enclosures, or equipment must be bonded together and to the metal enclosure of the system.

(3) Bonding Conductive Materials to the Metal Enclosure of the System. Electrically conductive materials that are likely to become energized must be bonded together and to the metal enclosure containing the system.

(4) Fault Current Path. Electrical equipment, wiring, and other electrically conductive material likely to become energized must be installed in a manner that creates a permanent, low-impedance fault current path from any point on the wiring system to the electrical supply source to facilitate the operation of overcurrent devices should a second ground fault occur on the wiring system.

AUTHOR’S COMMENT: A single ground fault cannot be cleared on an ungrounded system because there’s no low-impedance fault current path to the power source. However, in the event of a second ground fault (line-to-line short circuit), the bonding path provides a low-impedance fault current path so that the circuit-protection device will open to clear the fault.

250.6 Objectionable Current.

(A) Preventing Objectionable Current. To prevent a fire, electric shock, or improper operation of circuit-protection devices or sensitive equipment, electrical systems and equipment must be installed in a manner that prevents objectionable current from flowing on conductive materials, electrical equipment, or grounding and bonding paths.

AUTHOR’S COMMENT: Objectionable current occurs because of improper neutral-to-case bonds and wiring errors.

Improper Neutral-to-Case Bond [250.142]

Panelboards. Objectionable current will flow on metal parts when the grounded (neutral) conductor is bonded to the metal case of a panelboard that is not part of service equipment. Figure 250–28
Disconnects. Objectionable current will flow on metal parts when the grounded (neutral) conductor is bonded to the metal case of a disconnecting means that is not part of service equipment. Figure 250–29

Separately Derived Systems. Objectionable current will flow on metal parts when the grounded (neutral) conductor is bonded at the transformer as well as to the metal case on the load side of the transformer. Figures 250–30 and 250–31

Wiring Errors

Objectionable current will flow on metal parts when the grounded (neutral) conductor from one system is connected to a circuit of a different system. Figure 250–32
Objectionable current will flow on metal parts when the equipment grounding (bonding) conductor is used as a grounded (neutral) conductor.

**Example:** A 240V time-clock motor is replaced with a 120V time-clock motor and the equipment grounding (bonding) conductor is used to feed one side of the 120V time clock. Another example is a 120V water filter wired to a 240V well-pump motor circuit, with the equipment grounding (bonding) conductor used for the neutral. **Figure 250–33**

Using the equipment grounding (bonding) conductor for the neutral is also seen in ceiling fan installations where the bare equipment grounding (bonding) conductor is used as a neutral and the white wire is used as the switch leg for the light, or where a receptacle is added to a switch outlet that doesn’t have a neutral conductor. **Figure 250–34**

**AUTHOR’S COMMENT:** Neutral currents always flow on a community metal underground water piping system because the grounded (neutral) conductor from each service is grounded to the underground metal water pipe. **Figure 250–35**

**Dangers of Objectionable Current**

Objectionable current on metal parts can cause electric shock, fires, and improper operation of sensitive electronic equipment and circuit-protection devices.

**Shock Hazard.** When objectionable current flows on metal parts, electric shock and even death can occur (from ventricular fibrillation) from elevated voltage on the metal parts. **Figure 250–36**

**Fire Hazard.** When objectionable current flows on metal parts, a fire could occur because of elevated temperature, which can ignite adjacent combustible material. Heat is generated whenever current flows, particularly over high-resistive parts. In addition, arcing at loose connections is especially dangerous in areas containing easily ignitable and explosive gases, vapors, or dust. **Figure 250–37**
Improper Operation of Sensitive Electronic Equipment. Objectionable current flowing on metal parts of electrical equipment and building parts can cause disruptive as well as annoying electromagnetic fields which can negatively affect the performance of sensitive electronic devices, particularly video monitors and medical equipment. For more information, visit www.MikeHolt.com, click on the Technical link, then on Power Quality. Figure 250–38

In addition, when objectionable current travels on metal parts, a difference of potential will exist between all metal parts, which can cause some sensitive electronic equipment to operate improperly (this is sometimes called a ground loop).

Improper Operation of Circuit-Protection Devices. When objectionable current travels on the metal parts of electrical equipment, nuisance tripping of electronic protection devices equipped with ground-fault protection can occur because some neutral current flows on the equipment grounding (bonding) conductor instead of the grounded (neutral) conductor.

(C) Temporary Currents Not Classified as Objectionable Currents. Temporary fault current on the effective ground-fault current path isn’t classified as objectionable current. Figure 250–39

(D) Electromagnetic Interference (Electrical Noise). Currents that cause noise or data errors in electronic equipment aren’t considered objectionable currents. Figure 250–40

AUTHOR’S COMMENT: Some sensitive electronic equipment manufacturers require isolation between the metal parts of their equipment and the electrical system, yet they require their equipment to be connected to an independent ground (like a ground rod(s)). This practice violates 250.4(A)(5) and is very dangerous because the earth doesn’t provide the low-impedance fault current path necessary to clear a ground fault. Figure 250–41
250.8 Termination of Grounding and Bonding Conductors. The termination of equipment grounding and bonding conductors must be by exothermic welding, listed pressure connectors of the set screw or compression type, listed clamps, or other listed fittings. Sheet-metal screws cannot be used to connect grounding (earthing) or bonding conductors or connection devices to enclosures. Figure 250–42

AUTHOR’S COMMENT: The rule still doesn’t prohibit drywall screws or wood screws from being used for this purpose, just “sheet-metal” screws!

250.10 Protection of Fittings. Ground clamps and other grounding and bonding fittings must be protected from physical damage by:

(1) Locating the fittings so that they aren’t likely to be damaged.
(2) Enclosing the fittings in metal, wood, or equivalent protective covering.

**AUTHOR’S COMMENT:** Grounding and bonding fittings can be buried or encased in concrete if installed in accordance with 250.53(G), 250.68(A) Ex 1, and 250.70.

### 250.12 Clean Surface

Nonconductive coatings, such as paint, must be removed to ensure good electrical continuity, or the termination fittings must be designed so as to make such removal unnecessary [250.53(A) and 250.96(A)].

**AUTHOR’S COMMENT:** The “tarnish” on copper water pipe need not be removed before making a termination.

### PART II. SYSTEM GROUNDING AND BONDING

#### 250.20 Systems Required to be Grounded and Bonded

Alternating-current systems (power supplies) must be grounded and bonded as provided in (A), (B), (C), or (D).

**AUTHOR’S COMMENT:** System grounding, the intentional bonding of the electrical supply source to the metal case, provides the low-impedance fault current path necessary to clear a ground fault. **Figure 250–43**

1. The primary is supplied from a 277V or 480V circuit.
2. The primary is supplied from an ungrounded power supply.
3. Where installed as overhead conductors outside of buildings.

**B** Alternating-Current Systems Over 50V: Alternating-current systems over 50V that require a grounded (neutral) conductor must have the grounded neutral terminal [250.26] of the power supply bonded to the system metal parts in accordance with 250.30(A)(1). Such systems include: **Figure 250–45**

- 2- or 3-wire, single-phase 120V or 120/240V systems
- 4-wire, wye-connected, three-phase 120/208V or 277/480V systems
- 4-wire, three-phase delta-connected 120/240V systems

**D** Separately Derived Systems: Separately derived systems that are required to be grounded (bonded) by 250.20(A) or (B), must be grounded and bonded in accordance with 250.30(A).
AUTHOR’S COMMENTS:

• A separately derived system is a premises wiring system with no direct electrical connection to conductors originating from another system [Article 100 definition of separately derived system and 250.20(D)]. All transformers except autotransformers are separately derived because the primary circuit conductors do not have any direct electrical connection to the secondary circuit conductors. Figure 250–46

FPN No. 1: A generator isn’t a separately derived system if the grounded (neutral) conductor from the generator is solidly connected to the electrical supply source.

AUTHOR’S COMMENT: In other words, if the transfer switch doesn’t open the grounded (neutral) conductor, then the generator isn’t a separately derived system. Therefore, a neutral-to-case bond (system bonding jumper) cannot be made at the generator because it will cause objectionable current to flow on metal parts in violation of 250.6(A) and 250.24(A)(5). Figure 250–48

FPN 2: If a grounded (neutral) conductor is supplied at a transfer switch, and the transfer switch doesn’t open the grounded (neutral) conductor, then the grounded (neutral) conductor must be sized:

• To carry fault current back to the generator in accordance with 445.13. Figure 250–49
• Not smaller than required to carry the unbalanced load in accordance with 220.61.

(E) High Impedance Grounded Neutral Systems. High impedance grounded (bonded) neutral systems must be grounded and bonded in accordance with 250.36.
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250.30 Grounding and Bonding of Separately Derived AC Systems.

AUTHOR’S COMMENT: A separately derived system is a premises wiring system with no direct electrical connection to conductors originating from another system [Article 100 definition of separately derived system and 250.20(D)].

Figure 250–48

Figure 250–49

Figure 250–50

Figure 250–67
Generators that supply a transfer switch that opens the grounded (neutral) conductor would be considered separately derived [250.20(D) FPN No. 1]. Figure 250–68

(A) **Grounded Systems.** Separately derived systems must be system bonded and grounded in accordance with the following:

A neutral-to-case bond must not be on the load side of the system bonding jumper, except as permitted by 250.142(B) or 250.32(B).

(1) **System Bonding Jumper.** Bonding the metal parts of the separately derived system to the secondary grounded neutral terminal by the installation of a system bonding jumper ensures that dangerous voltage from a secondary ground fault can be quickly removed by opening the secondary circuit’s overcurrent protection device [250.2(A)(3)]. Figure 250–69

**DANGER:** During a ground fault, metal parts of electrical equipment, as well as metal piping and structural steel, will become and remain energized providing the potential for electric shock and fire if the system bonding jumper is not installed. Figure 250–70

The system bonding jumper must be sized in accordance with Table 250.66, based on the area of the largest ungrounded secondary conductor [250.28(D)].

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**Question:** What size system bonding jumper is required for a 45 kVA transformer, where the secondary conductors are 3/0 AWG? Figure 250–71

(a) 4 AWG  
(b) 3 AWG  
(c) 2 AWG  
(d) 1 AWG

**Answer:** (a) 4 AWG, Table 250.66

The system bonding jumper can be installed at the separately derived system, the first system disconnecting means, or any point in between the separately derived system and the first disconnecting means, but not at both locations. Figure 250–72
In addition, the system bonding jumper must be installed at the same location where the grounding electrode conductor terminates to the grounded neutral terminal of the separately derived system, which can be at the separately derived system, the first system disconnecting means, or any point in between, but not at more than one location [250.30(A)(3)].

**CAUTION:** Dangerous objectionable current will flow on conductive metal parts of electrical equipment as well as metal piping and structural steel, in violation of 250.6(A), if the system bonding jumper is not located where the grounding electrode conductor terminates to the grounded (neutral) conductor.

Exception No. 2: A system bonding jumper can be installed at both the separately derived system and the secondary system disconnecting means where doing so doesn’t establish a parallel path for neutral current.

**CAUTION:** Dangerous objectionable current will flow on conductive metal parts of electrical equipment as well as metal piping and structural steel, in violation of 250.6(A), if the system bonding jumper is installed at the separately derived system and the secondary system disconnecting means.

**AUTHOR’S COMMENT:** For all practical purposes, this isn’t possible except in a wood frame building that doesn’t have any conductive metal parts.

(2) Equipment Bonding Jumper Size. Where an equipment bonding jumper is run to the secondary system disconnecting means, it must be sized in accordance with Table 250.66, based on the area of the largest ungrounded secondary conductor.
Question: What size equipment bonding jumper is required for a non-metallic raceway containing 500 kcmil secondary conductors? Figure 250–75

(a) 1 AWG  (b) 1/0 AWG  (c) 2/0 AWG  (d) 3/0 AWG

Answer: (b) 1/0 AWG, Table 250.66

(3) Grounding Electrode Conductor, Single Separately Derived System. Each separately derived system must have the grounded neutral terminal grounded (earthed) to a suitable grounding electrode of a type identified in 250.30(A)(7). The secondary system grounding electrode conductor must be sized in accordance with 250.66, based on the total area of the largest ungrounded secondary conductor. Figure 250–76

To prevent objectionable current from flowing onto metal parts of electrical equipment, as well as metal piping and structural steel, the grounding electrode conductor must terminate at the same point on the separately derived system where the system bonding jumper is installed.

Exception No. 1: Where the system bonding jumper [250.30(A)(1)] is a wire or busbar, the grounding electrode conductor can terminate to the equipment grounding terminal, bar, or bus on the metal enclosure of the separately derived system. Figure 250–77

Exception No. 3: Separately derived systems rated 1 kVA (1,000 VA) or less are not required to be grounded (earthed); however, to ensure ground faults can be cleared, a system bonding jumper must be installed in accordance with 250.30(A)(1), if the system is required to be grounded (bonded) by 250.20.
250.30

(4) Grounding Electrode Conductor, Multiple Separately Derived Systems. Where there are multiple separately derived systems, the grounded neutral terminal of each derived system can be grounded (earthed) to a common grounding electrode conductor. The grounding electrode conductor and grounding electrode tap must comply with (a) through (c).

Figure 250–77

Grounding Multiple Separately Derived Systems
Section 250.30(A)(4)

Figure 250–78

Exception No. 1: Where the system bonding jumper [250.30(A)(1)] is a wire or busbar, the grounding electrode tap can terminate to the equipment grounding terminal, bar, or bus on the metal enclosure of the separately derived system.

Exception No. 2: Separately derived systems rated 1 kVA (1,000 VA) or less are not required to be grounded (earthed); however, to ensure ground faults can be cleared, a system bonding jumper must be installed in accordance with 250.30(A)(1).

(a) Common Grounding Electrode Conductor Size. The common grounding electrode conductor must not be smaller than 3/0 AWG copper or 250 kcmil aluminum.

(b) Tap Conductor Size. Each grounding electrode tap must be sized in accordance with 250.66, based on the largest separately derived ungrounded conductor of the separately derived system.

(c) Connections. All grounding electrode tap connections must be made at an accessible location by:

1. Listed connector.
2. Listed connections to aluminum or copper busbars not less than ¼ x 2 in. Where aluminum busbars are used, the installation must comply with 250.64(A).
3. By the exothermic welding process.

AUTHOR’S COMMENT: See the definition of “Accessible” as it applies to wiring methods.

Grounding electrode tap conductors must be connected to the common grounding electrode conductor so that the common grounding electrode conductor isn’t spliced.

(5) Installation. The grounding electrode conductor must be installed in accordance with 250.64.

AUTHOR’S COMMENT: The grounding electrode conductor must comply with the following:

- Be of copper where within 18 in. of earth [250.64(A)].
- Securely fastened to the surface on which it’s carried [250.64(B)].
- Adequately protected if exposed to physical damage [250.64(B)].
- Metal enclosures enclosing a grounding electrode conductor must be made electrically continuous from the point of attachment to cabinets or equipment to the grounding electrode [250.64(E)].
(6) **Bonding.** To ensure that dangerous voltage from a ground fault is removed quickly, structural metal and metal piping in the area served by a separately derived system must be bonded to the grounded (neutral) conductor at the separately derived system in accordance with 250.104(D).

(7) **Grounding (Earthing) Electrode.** The grounding electrode conductor must terminate to a grounding electrode that is located as close as possible, and preferably in the same area as the system bonding jumper. The grounding electrode must be the nearest one of the following: **Figure 250–79**


(1) Metal water pipe electrode as specified in 250.52(A)(1).

(2) Structural metal electrode as specified in 250.52(A)(2).

**Exception No. 1:** Where none of the electrodes listed in (1) or (2) is available, one of the following is permitted:

- Concrete-encased electrode encased by not less than 2 in. of concrete, located within and near the bottom of a concrete foundation or footing that is in direct contact with earth, consisting of not less than 20 ft of electrically conductive steel reinforcing bars or rods not less than 1/2 in. in diameter [250.52(A)(3)].

- A ground ring encircling the building or structure, buried not less than 30 in. below grade, consisting of not less than 20 ft of bare copper conductor not smaller than 2 AWG [250.52(A)(4) and 250.53(F)].

**FPN:** To ensure that dangerous voltage from a ground fault is quickly removed, metal water piping (including structural metal) in the area served by a separately derived system must be bonded to the grounded (neutral) conductor at the separately derived system in accordance with 250.104(D).

**AUTHOR’S COMMENT:** This FPN makes no sense, since the requirement is contained in 250.30(A)(6).

(8) **Grounded (neutral) conductor.** Where the system bonding jumper is installed at the secondary system disconnecting means instead of at the source of the separately derived system, the following requirements apply: **Figure 250–80**

(a) **Routing and Sizing.** Because the grounded (neutral) conductor serves as the effective ground-fault current path, the grounded (neutral) conductor must be routed with the secondary conductors, and it must be sized not smaller than specified in Table 250.66, based on the largest ungrounded conductor for the separately derived system.

(b) **Parallel Conductors.** If the secondary conductors are installed in parallel, the grounded neutral secondary conductor in each raceway or cable...
must be sized based on the area of the largest ungrounded secondary conductor in the raceway. But the grounded neutral secondary conductor can not be smaller than 1/0 AWG [310.4].

**PART III. GROUNDING ELECTRODE SYSTEM AND GROUNDING ELECTRODE CONDUCTOR**

Grounding metal parts of the electrical installation to earth is intended to reduce voltage on the metal parts from lightning so as to prevent fires from surface arcing (side-flashes) within the building or structure [250.4(A)(2)].

**250.50 Grounding Electrode System**

All grounding electrodes as described in 250.52(A)(1) through (A)(6) that are present at each building or structure must be bonded together to form the grounding electrode (earthing) system. **Figure 250–91**

- Concrete-encased electrode [250.52(A)(3)]
- Ground ring [250.52(A)(4)]
- Ground rod [250.52(A)(5)]
- Grounding plate [250.52(A)(6)]

*Note: Ground rods are no longer necessary for most new construction*, since virtually all new construction uses concrete encased reinforcing bars or rods in the foundation and since they exist they must be bonded to and used as part of the grounding electrode system.

**Exception**: Concrete-encased electrodes are not required for existing buildings or structures where the conductive steel reinforcing bars aren’t accessible without disturbing the concrete.

Where an underground metal water pipe electrode, metal building or structure frame electrode, or concrete-encased electrode is not present, one or more of the following electrodes specified in 250.52(A)(4) through (A)(7) must be installed to create the grounding electrode (earthing) system. **Figure 250–92**

- Ground rod [250.52(A)(5)]
- Grounding plate [250.52(A)(6)]
- Metal underground systems [250.52(A)(7)]
(A) Electrodes Permitted for Grounding.

(1) Underground Metal Water Pipe Electrode. Underground metal water pipe in direct contact with earth for 10 ft or more can serve as a grounding electrode. **Figure 250–93**

**AUTHOR’S COMMENT:** The grounding electrode conductor to the water pipe electrode must be sized in accordance with Table 250.66.

If the underground metal water pipe electrode is interrupted, such as with a water meter, it must be made electrically continuous with a bonding jumper sized according to 250.66 before it can serve as a grounding (earthing) electrode [250.68(B)].

Interior metal water piping located more than 5 ft from the point of entrance to the building or structure cannot be used to interconnect electrodes that are part of the grounding electrode (earthing) system.

**Exception:** In industrial and commercial buildings where conditions of maintenance and supervision ensure that only qualified persons service the installation, the entire length of the metal water pipe can be used for the grounding, provided the entire length, other than short sections passing through walls, floors, or ceilings, is exposed.

(2) Metal Frame of the Building or Structure Electrode. The metal frame of the building or structure can serve as a grounding electrode, where any of the following apply:

(a) 10 ft or more of a single structural metal member is in direct contact with the earth or encased in concrete that is in direct contact with the earth.

(b) The structural metal is bonded to an electrode as defined in 250.52(A), (3), or (4). **Figure 250–95**

(c) The structural metal is bonded to two ground rods if the ground resistance of a single ground rod exceeds 25 ohms [250.52(A)(5) and 250.56].

(d) Other means approved by the authority having jurisdiction.
AUTHOR’S COMMENTS:

- The intent is that where structural metal is to be used as an electrode, it must be of substantial cross-sectional area.
- The grounding electrode conductor to the metal frame of a building or structure must be sized in accordance with Table 250.66.

(3) Concrete-Encased Grounding Electrode (Ufer). Electrically conductive steel reinforcing bars not smaller than ½ in. in diameter (#4 rebar) or 4 AWG copper conductor can serve as a grounding electrode if the steel or copper conductor:

- Has a total conductive length of 20 ft,
- Is encased in not less than 2 in. of concrete, and
- Is located near the bottom of a foundation or footer that is in direct contact with earth.

The steel rebar isn’t required to be one continuous length and the usual steel tie wires can be used to conductively tie multiple sections together to create a 20 ft concrete-encased grounding electrode. Figure 250–96

AUTHOR’S COMMENTS:

- The concrete-encased grounding electrode is also called a “Ufer Ground,” named after Herb Ufer, the person who determined its usefulness as a grounding electrode in the 1960s. This type of grounding electrode generally offers the lowest ground resistance for the cost and it’s the grounding electrode of choice for many where new concrete foundations are available.
- If a moisture/vapor barrier is installed under a concrete footer, then the steel rebar would not be considered a concrete-encased electrode.

(4) Ground Ring Electrode. A ground ring encircling a building or structure, in direct contact with earth consisting of not less than 20 ft of bare copper conductor not smaller than 2 AWG copper, can serve as a grounding (earthing) electrode.

AUTHOR’S COMMENT: The ground ring must be buried at a depth below the earth’s surface of not less than 30 in. [250.53(F)]. The grounding electrode conductor for the ground ring isn’t required to be larger than the conductor used for the ground ring [250.66(C)].

(5) Ground Rod Electrodes. Ground rod electrodes must not be less than 8 ft long and must have not less than 8 ft of length in contact with the soil [250.53(G)].

(b) Rod. Unlisted ground rods must have a diameter of at least ¾ in. Nonferrous ground rods smaller than ¾ in. must be listed and must not be less than ½ in. in diameter. Figure 250–97
Understanding the NEC Rules for Backup Power Systems

AUTHOR’S COMMENT:
- The grounding electrode conductor that is the sole connection to a ground rod isn’t required to be larger than 6 AWG copper [250.66(A)].
- The diameter of a ground rod has an insignificant effect on the ground resistance of the ground rod. However, larger diameter ground rods (¾ in. and 1 in.) are sometimes installed where mechanical strength is required or where necessary to compensate for the loss of the electrode’s metal due to corrosion.

(6) Ground Plate Electrode. A buried iron or steel plate with not less than ¼ in. of thickness, or a nonferrous (copper) metal plate not less than 0.06 in. of thickness, with an exposed surface area not less than 2 sq ft can be used as a grounding electrode.

AUTHOR’S COMMENT: The grounding electrode conductor that is the sole connection to a ground plate electrode isn’t required to be larger than 6 AWG copper [250.66(A)].

(7) Metal Underground Systems Electrode. Metal underground systems such as piping systems, underground tanks, or an underground metal well casing that isn’t effectively bonded to a metal water pipe system, can be used as a grounding electrode.

AUTHOR’S COMMENT: The grounding electrode conductor to the metal underground systems must be sized in accordance with Table 250.66.

(B) Electrodes Not Permitted.

(1) Underground Metal Gas Piping System. Underground metal gas piping systems and structures cannot be used as a grounding electrode. Figure 250–98

FPN: See 250.104(B) for the bonding requirements for gas piping.

AUTHOR’S COMMENT: According to 250.104(B), metal gas piping that is likely to become energized must be bonded to the service equipment enclosure, the grounded neutral service conductor, or the grounding electrode or grounding electrode conductor where the grounding electrode conductor is of sufficient size [250.104(B)]. The equipment grounding (bonding) conductor for the circuit that may energize the piping can serve as the bonding means. So effectively, this means that no action is actually required by the electrical installer!

(2) Aluminum Electrodes. Aluminum cannot be used as a grounding electrode because it corrodes more quickly than copper.

250.53 Installation of Grounding Electrode System.

(A) Ground Rod Electrodes. Where practicable, ground rods must be embedded below permanent moisture level and must be free from nonconductive coatings such as paint or enamel [250.12].
Author’s Comment: See 250.53(G) for more information.

(B) Electrode Spacing. Where more than one ground rod or ground plat exists at a building or structure, they must be separated by at least 6 ft.

(C) Grounding Electrode Bonding Jumper. Where within 18 in. of earth, the conductor used to bond grounding electrodes together to form the grounding electrode system must be copper [250.64(A)], securely fastened to the surface on which it’s carried, and be protected if exposed to physical damage [250.64(B)]. The bonding jumper to each electrode must be sized in accordance with 250.66.

In addition, the grounding electrode bonding jumpers must terminate to the grounding electrode by exothermic welding, listed lugs, listed pressure connectors, listed clamps, or other listed means [250.8]. When the termination is encased in concrete or buried, the termination fittings must be listed and identified for this purpose [250.70].

(D) Underground Metal Water Pipe Electrode.

(1) Continuity. The bonding connection to the interior metal water piping system, as required by 250.104(A), must not be dependent on water meters, filtering devices, or similar equipment likely to be disconnected for repairs or replacement. When necessary, a bonding jumper must be installed around insulated joints and equipment likely to be disconnected for repairs or replacement to assist in clearing and removing dangerous voltage on metal parts because of a ground fault. Figure 250–99

Author’s Comment: See 250.68(B) and 250.104 for more information.

(2) Underground Metal Water Pipe Supplemental Electrode Required. The underground metal water pipe grounding electrode, if present [250.52(A)(1)], must be supplemented by one of the following electrodes:

- Metal frame of the building or structure [250.52(A)(2)]
- Concrete-encased electrode [250.52(A)(3)] Figure 250–100
- Ground ring [250.52(A)(4)]

Figure 250–100

Where none of the above electrodes are available, one of the following electrodes must be used:

- Ground rod in accordance with 250.56 [250.52(A)(5)]
- Grounding plate [250.52(A)(6)]
- Metal underground systems [250.52(A)(7)]

The underground water pipe supplemental electrode must terminate to one of the following: Figure 250–101

- Grounding electrode conductor
- Grounded neutral service conductor
- Metal service raceway
- Service equipment enclosure

(E) Underground Metal Water Pipe Supplemental Electrode Bonding Jumper. Where the supplemental electrode is a ground rod, that portion that is the sole connection to a ground rod isn’t required to be larger than 6 AWG copper.

Figure 250–99
AUTHOR'S COMMENT: The bonding jumper for the underground metal water pipe supplemental electrode is sized in accordance with 250.66, including Table 250.66, where applicable.

(F) Ground Ring. A ground ring encircling the building or structure, consisting of at least 20 ft of bare copper conductor not smaller than 2 AWG, must be buried at a depth of not less than 30 in. See 250.52(A)(4) for more information.

(G) Ground Rod Electrodes. Ground rod electrodes must be installed so that not less than 8 ft of length is in contact with the soil. Where rock bottom is encountered, the ground rod must be driven at an angle not to exceed 45 degrees from vertical. If rock bottom is encountered at an angle up to 45 degrees from vertical, the ground rod can be buried in a minimum 30 in. deep trench. Figure 250–102

The upper end of the ground rod must be flush with or underground unless the grounding electrode conductor attachment is protected against physical damage as specified in 250.10.

AUTHOR’S COMMENTS:
- See 250.52(A)(6) and 250.53(A) for more information.
- When the grounding electrode attachment fitting is located underground, it must be listed for direct soil burial [250.68(A) Ex 1, and 250.70].

(H) Ground Plate Electrode. A plate electrode with not less than 2 sq ft of surface exposed to exterior soils must be installed so that it’s at least 30 in. below the surface of the earth [250.52(A)(6)].

250.54 Supplementary Electrodes.

A supplementary electrode is an electrode that is not required by the NEC. This electrode is not required to be bonded to the building or structure grounding electrode (earthing) system. Figure 250–103

A supplementary electrode is not required to be sized to 250.66, and it is not required to comply with the 25 ohm resistance requirement of 250.56. Figure 250–104
The earth cannot be used as an effective ground-fault current path as required by 250.4(A)(4).

**AUTHOR’S COMMENT:** Because the resistance of the earth is so high, very little current will return to the electrical supply source via the earth. If a ground rod is used as the ground-fault current path, the circuit overcurrent protection device will not open and metal parts will remain energized.

**CAUTION:** The requirements contained in 250.54 for a “supplementary” electrode should not be confused with the requirements contained in 250.53(D)(2) for the underground metal water pipe “supplemental” electrode.

**AUTHOR’S COMMENT:** Typically, a supplementary electrode serves no useful purpose, and in some cases it may actually create equipment or performance failure. However, in a few cases, the supplementary electrode is used to help reduce static charges on metal parts. For information on protection against static electricity in hazardous (classified) locations, see NFPA 77, Recommended Practice on Static Electricity.

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**250.56 Resistance of Ground Rod Electrode**

When the resistance of a single ground rod is over 25 ohms, an additional electrode is required to augment the ground rod electrode, and it must be installed not less than 6 ft away.

**Figure 250–105**

**AUTHOR’S COMMENT:** No more than two ground rods are required, even if the total resistance of the two parallel ground rods exceeds 25 ohms.

### Measuring the Ground Resistance

A ground resistance clamp meter, or a three-point fall of potential ground resistance meter, can measure the resistance of a grounding electrode.

**Ground Clamp Meter.** The ground resistance clamp meter measures the resistance of the grounding (earthing) system by injecting a high-frequency signal via the grounded (neutral) conductor to the utility ground, and then measuring the strength of the return signal through the earth to the grounding electrode being measured. **Figure 250–106**

**Fall of Potential Ground Resistance Meter.** The three-point fall of potential ground resistance meter determines the ground resistance by using Ohm’s Law: R=E/I. This meter divides the voltage difference between the electrode to be measured and a driven potential test stake (P) by the current flowing between the electrode to be measured and a driven current test stake (C). The test stakes are typically made of ¼ in. diameter steel rods, 24 in. long, driven two-thirds of their length into earth.

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The distance and alignment between the potential and current test stakes, and the electrode, is extremely important to the validity of the ground resistance measurements. For an 8 ft ground rod, the accepted practice is to space the current test stake (C) 80 ft from the electrode to be measured. The potential test stake (P) is positioned in a straight line between the electrode to be measured and the current test stake (C). The potential test stake should be located at approximately 62 percent of the distance that the current test stake is located from the electrode. Since the current test stake (C) is located 80 ft from the grounding (earthing) electrode, the potential test stake (P) will be about 50 ft from the electrode to be measured.

**Question:** If the voltage between the ground rod and the potential test stake (P) is 3V and the current between the ground rod and the current test stake (C) is 0.2A, then the ground resistance is _____. **Figure 250–107**

(a) 5 ohms  
(b) 10 ohms  
(c) 15 ohms  
(d) 25 ohms

**Answer:** (c) 15 ohms

\[
\text{Resistance} = \frac{\text{Voltage}}{\text{Current}} = \frac{3V}{0.20A} = 15\Omega
\]

**AUTHOR’S COMMENT:** The three-point fall of potential meter can only be used to measure one electrode at a time. Two electrodes bonded together cannot be measured until they have been separated. The total resistance for two separate electrodes is calculated as if they were two resistors in parallel. For example, if the ground resistance of each electrode were 50 ohms, the total resistance of two electrodes bonded together is about 25 ohms.

**CAUTION:** If the electrode to be measured is connected to the electrical utility ground via the grounded neutral service conductor, the ohmmeter will give an erroneous reading. To measure the ground resistance of electrodes that aren’t isolated from the electric utility (such as at industrial facilities, commercial buildings, cell phone sites, broadcast antennas, data centers, and telephone central offices), a clamp-on ground resistance tester would better serve the purpose.

**AUTHOR’S COMMENT:** The resistance of the grounding electrode can be lowered by bonding multiple grounding (earthing) electrodes that are properly spaced apart or by chemically treating the earth around the grounding (earthing) electrode. There are many readily available commercial products for this purpose.

**Soil Resistivity**

The earth’s ground resistance is directly impacted by the soil’s resistivity, which varies throughout the world. Soil resistivity is influenced by the soil’s electrolytes, which consist of moisture, minerals, and dissolved salts. Because soil resistivity changes with moisture content, the resistance of any ground-
Wiring (earthing) system will vary with the seasons of the year. Since moisture becomes more stable at greater distances below the surface of the earth, grounding (earthing) systems appear to be more effective if the grounding electrode can reach the water table. In addition, having the grounding electrode below the frost line helps to ensure less deviation in the system’s resistance year round.

250.58 Common Grounding (Earthing) Electrode.
Where a building or structure is supplied with multiple services or feeders as permitted by 225.30 and 230.2, the same electrode must be used to ground enclosures and equipment in or on that building.

AUTHOR’S COMMENTS:
- Metal parts of the electrical installation are grounded to the earth to reduce voltage on the metal parts from lightning so as to prevent fires from a surface arc within the building or structure. Grounding electrical equipment to earth doesn’t serve the purpose of providing a low-impedance fault-current path to clear ground faults.
- The most practical method of meeting this requirement is to ground each of the disconnecting means to a common concrete-encased grounding electrode (250.52(A)(3)).

250.60 Lightning Protection System Grounding (Earthing) Electrode. The grounding electrode for a lightning protection system cannot be used for the building or structure grounding electrode system as required by 250.50.

**CAUTION:** Potentially dangerous objectionable current flows on the grounding electrode conductor when multiple service disconnecting means are grounded to the same electrode. This is because neutral current from each service can return to the utility via the common grounding electrode and its conductors. This is especially a problem if one of the grounded neutral service conductors is opened. Figure 250–109
AUTHOR’S COMMENTS:

- Where a lightning protection system is installed, it must be bonded to the building or structure grounding electrode (earthing) system [250.106].
- A lightning protection system installed in accordance with NFPA 780, Standard for the Installation of Lightning Protection Systems, is intended to protect the building structure from lightning damage. It isn’t intended to protect the electrical wiring or equipment within the structure from lightning damage. To protect from high-voltage transients, proper transient voltage surge-protection devices must be installed in accordance with Articles 280 and 285.

The grounding electrode conductor, or its jumpers, can be solid or stranded, insulated or bare, and it must be copper, except aluminum is permitted if it is not subjected to corrosive conditions and not within 18 in. of the earth [250.64(A)].

![Figure 250–111](image)

**AUTHOR’S COMMENT:** The NEC doesn’t require the identification of the grounding electrode conductor or grounding electrode bonding jumpers. Common practice is to either not identify the conductor at all, or to apply green marking tape.

![Figure 250–111](image)

**250.64 Grounding Electrode Conductor Installation.**

(A) Aluminum Grounding Electrode Conductor. Aluminum grounding electrode conductors cannot be in contact with earth, masonry, or subjected to corrosive conditions. When used outdoors, the termination to the electrode must not be within 18 in. of earth.

(B) Grounding Electrode Conductor Protection. Where exposed, grounding electrode conductors sized 8 AWG and smaller must be installed in rigid metal conduit, intermediate metal conduit, rigid nonmetallic conduit, or electrical metallic tubing.

**AUTHOR’S COMMENT:** Ferrous metal raceways containing the grounding electrode conductors must be made electrically continuous by bonding each end of the ferrous metal raceway to the grounding electrode conductor [250.64(E)].

Grounding electrode conductors 6 AWG copper and larger can be run exposed along the surface if securely fastened to the construction and not subject to physical damage.

(C) Continuous Run. The grounding electrode conductor, which runs to any convenient grounding electrode [250.64(F)], must not be spliced, except as permitted in (1) through (3): **Figure 250–112**

![Figure 250–112](image)
(1) Splicing is permitted by irreversible compression-type connectors listed for grounding or by exothermic welding.

(2) Sections of busbars can be connected together to form a grounding electrode conductor.

(3) Bonding and grounding electrode conductors are permitted to terminate to a busbar that is sized not smaller than \( \frac{1}{2} \times 2 \) in., and the busbar must be securely fastened in place at an accessible location. Connections must be made by a listed connector or by the exothermic welding process. Figure 250–113

**Figure 250–113**

**D) Grounding Electrode Tap Conductors.** When a service consists of multiple disconnecting means as permitted in 230.71(A), a grounding electrode tap from each disconnect to a common grounding electrode conductor is permitted.

The grounding electrode tap must be sized in accordance with 250.66, based on the largest ungrounded conductor serving that disconnect.

The common grounding electrode conductor for the grounding electrode taps is also sized in accordance with 250.66, based on the service conductors feeding all the service disconnects.

Each grounding electrode tap must terminate to the common grounding electrode conductor in such a manner that there will be no splices or joints in the common grounding electrode conductor. Figure 250–114

**Figure 250–114**

**E) Enclosures for Grounding Electrode Conductor.** Ferrous (iron/steel) raceways, boxes, and enclosures containing the grounding electrode conductors must have each end of the ferrous metal raceway, box, and enclosure bonded to the grounding electrode conductor [250.92(A)(3)]. Figure 250–115

**Figure 250–115**
AUTHOR'S COMMENT: “Nonferrous” metal raceways, such as aluminum rigid metal conduit, enclosing the grounding electrode conductor aren’t required to meet the “bonding each end of the raceway to the grounding electrode conductor” provisions of this section.

The bonding jumper must be sized no smaller than the enclosed grounding electrode conductor.

CAUTION: The effectiveness of the grounding electrode can be significantly reduced if a ferromagnetic raceway containing a grounding electrode conductor isn’t bonded to the grounding electrode conductor at both ends. This is because a single conductor carrying high-frequency lightning current in a ferrous raceway causes the raceway to act as an inductor, which severely limits (chocks) the current flow through the grounding electrode conductor. ANSI/IEEE 142, Recommended Practice for Grounding of Industrial and Commercial Power Systems (Green Book) states, “An inductive choke can reduce the current flow by 97 percent.”

AUTHOR'S COMMENT: To save a lot of time and effort, simply run the grounding electrode conductor exposed if not subject to physical damage [250.64(B)], or enclose it in a nonmetallic conduit that is suitable for the application.

(F) To Electrode(s). The grounding electrode conductor can be run to any convenient grounding electrode available in the grounding electrode (earthing) system. The grounding electrode conductor must be sized for the largest service-entrance conductor or equivalent area for parallel conductors in accordance with Table 250.66.

Question: What size grounding electrode conductor is required for a 1,200A service that is supplied with three parallel sets of 600 kcmil conductors per phase? Figure 250–116

Answer: (d) 3/0 AWG

The equivalent area of three parallel 600 kcmil conductors is 1,800 kcmil per phase [Table 250.66].

Table 250.66—Grounding Electrode Conductor

| Ungrounded Conductor or Copper Grounding Area of Parallel Conductors Electrode Conductor |
|---------------------------------|---------------------------------|
| 12 through 2 AWG                | 8 AWG                           |
| 1 or 1/0 AWG                   | 6 AWG                           |
| 2/0 or 3/0 AWG                 | 4 AWG                           |
| Over 3/0 through 350 kcmil     | 2 AWG                           |
| Over 350 through 600 kcmil     | 1/0 AWG                          |
| Over 600 through 1,100 kcmil   | 2/0 AWG                          |
| Over 1,100 kcmil               | 3/0 AWG                          |

Where the service equipment is located outside and is fed from a service lateral, there might not be any service entrance conductors.

Question: If a service to a single family dwelling contains no service entrance conductors and has a calculated load of 183 amps, what size grounding electrode conductor would be required for a water pipe electrode?

Answer: (a) 8 AWG

Figure 250–116
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Answer: c. 4 AWG

Table 310.15(B)(6) requires a service entrance conductor sized no smaller than 2/0 AWG for 183 amps. Table 250.66 requires 4 AWG for the grounding electrode conductor.

FPN: Because the grounded neutral service conductor is required to serve as the low-impedance ground-fault current path back to the source, it must be sized no smaller than that shown in Table 250.66 [250.24(C)(1)]. Of course, it must be sized to carry the maximum unbalanced load as calculated by 220.61.

(A) Ground Rod. Where the grounding electrode conductor is connected to a ground rod, that portion of the grounding electrode conductor that is the sole connection to the ground rod isn’t required to be larger than 6 AWG copper. Figure 250–117

AUTHOR’S COMMENT: See 250.52(A)(5) for the installation requirements of a ground rod electrode.

(B) Concrete-Encased Grounding Electrode (Ufer Ground). Where the grounding electrode conductor is connected to a concrete-encased electrode, that portion of the grounding electrode conductor that is the sole connection to the concrete-encased electrode isn’t required to be larger than 4 AWG copper. Figure 250–118

AUTHOR’S COMMENT: See 250.52(A)(3) for the installation requirements of a concrete-encased electrode.

(C) Ground Ring. Where the grounding electrode conductor is connected to a ground ring, that portion of the conductor that is the sole connection to the ground ring isn’t required to be larger than the conductor used for the ground ring.

AUTHOR’S COMMENT: A ground ring encircling the building or structure in direct contact with earth must consist of not less than 20 ft of bare copper conductor not smaller than 2 AWG [250.52(A)(4)].

250.68 Grounding Electrode Conductor Termination.

(A) Attachment Fitting. The grounding electrode attachment fitting must be accessible.

Exception No. 1: The grounding electrode attachment fitting to an encased or buried grounding electrode isn’t required to be accessible. Figure 250–119

AUTHOR’S COMMENT: When the grounding electrode attachment fitting is encased in concrete or buried, it must be listed and identified for this purpose [250.70].

Exception No. 2: An exothermic or irreversible compression connection to fireproofed structural metal isn’t required to be accessible.
250.70 Grounding Electrode Conductor Termination Fitting. The grounding electrode conductor must terminate to the grounding electrode by exothermic welding, listed lugs, listed pressure connectors, listed clamps, or other listed means. In addition, termination fittings must be listed for the materials of the grounding electrode.

When the termination to a grounding electrode is encased in concrete or buried, the termination fitting must be listed and identified for this purpose. No more than one conductor can terminate on a single clamp or fitting unless the clamp or fitting is listed for multiple connections. Figure 250–121

(B) Effective Ground-Fault Current Path. To ensure a permanent and effective grounding path for an underground metal water pipe electrode, a bonding jumper must be installed around insulated joints and equipment likely to be disconnected for repairs or replacement. Figure 250–120

AUTHOR’S COMMENT: Continuity of the conductive bonding path for metal water piping as required by 250.104(A) cannot rely on water meters, filtering devices, or similar equipment [250.53(D)(1)].