

# ARTICLE 250

## GROUNDING AND BONDING

### Introduction to Article 250—Grounding and Bonding

No other article can match Article 250 for misapplication, violation, and misinterpretation. Terminology used in this article has been a source for much confusion, but that's improved during the last few *NEC* revisions. It's very important to understand the difference between grounding and bonding in order to correctly apply the provisions of Article 250. Pay careful attention to the definitions that apply to grounding and bonding both here and in Article 100 as you begin the study of this important article. Article 250 covers the grounding requirements for providing a path to the earth to reduce overvoltage from lightning, and the bonding requirements for a low-impedance fault current path back to the source of the electrical supply to facilitate the operation of overcurrent protection devices in the event of a ground fault.

Over the past several *Code* cycles, this article was extensively revised to organize it better and make it easier to understand and implement. It's arranged in a logical manner, so it's a good idea to just read through Article 250 to get a big picture view—after you review the definitions. Next, study the article closely so you understand the details. The illustrations will help you understand the key points.

### Part I. General

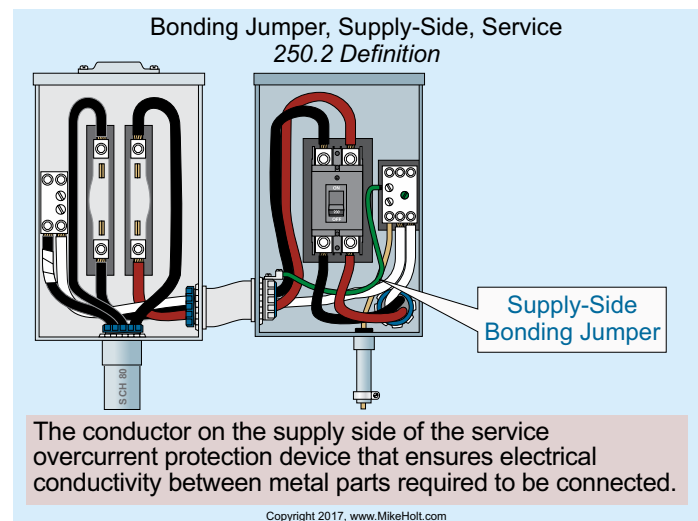
#### 250.1 Scope

Article 250 contains the following grounding and bonding requirements:

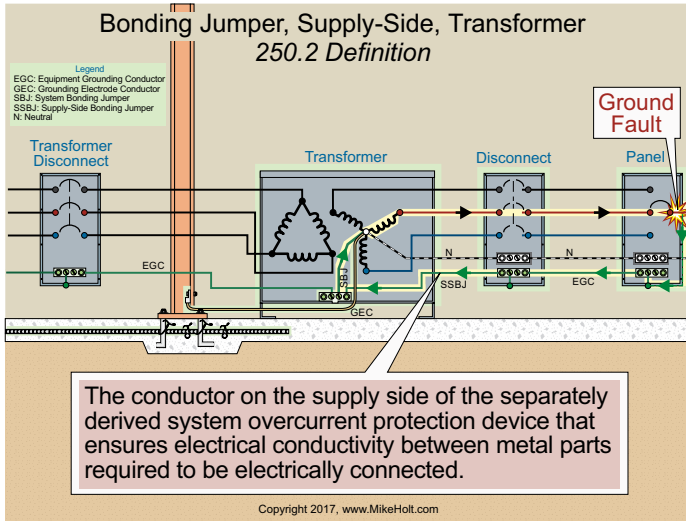
- (1) What systems and equipment are required to be grounded.
- (3) Location of grounding connections.
- (4) Types of electrodes and sizes of grounding and bonding conductors.
- (5) Methods of grounding and bonding.

#### 250.2 Definition

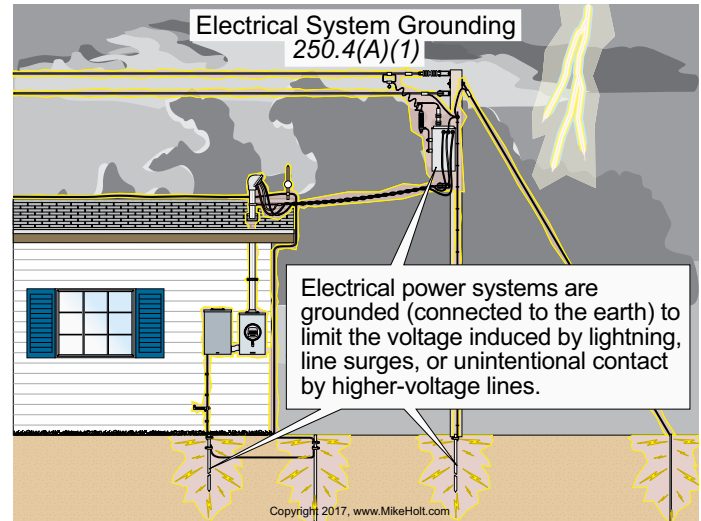
**Bonding Jumper, Supply-Side.** The conductor on the supply side of the service or separately derived system overcurrent protection device that ensures electrical conductivity between metal parts and the grounded conductor. ▶[Figure 250-1](#), ▶[Figure 250-2](#), and ▶[Figure 250-3](#)



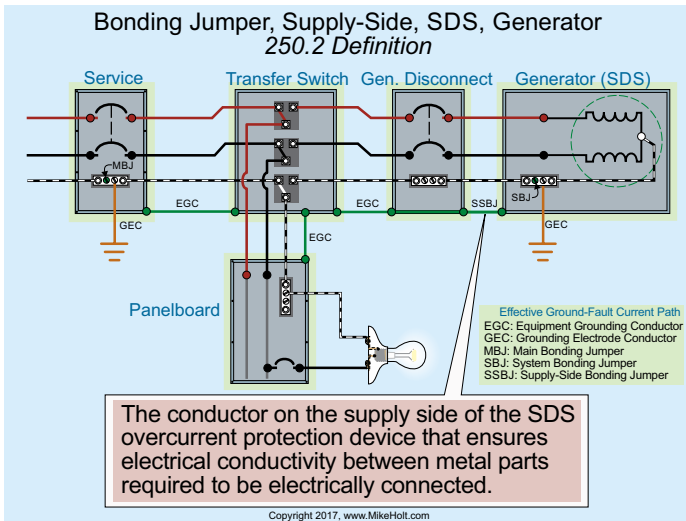
▶[Figure 250-1](#)



▶Figure 250-2



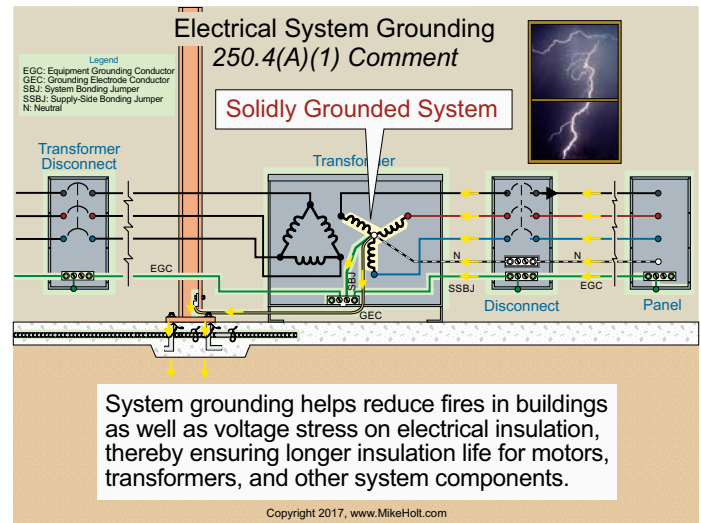
▶Figure 250-4



▶Figure 250-3

**Author's Comment:**

- System grounding helps reduce fires in buildings as well as voltage stress on electrical insulation, thereby ensuring longer insulation life for motors, transformers, and other system components. ▶Figure 250-5



▶Figure 250-5

**2017 CC 250.4 Performance Requirements for Grounding and Bonding**

**(A) Solidly Grounded Systems.**

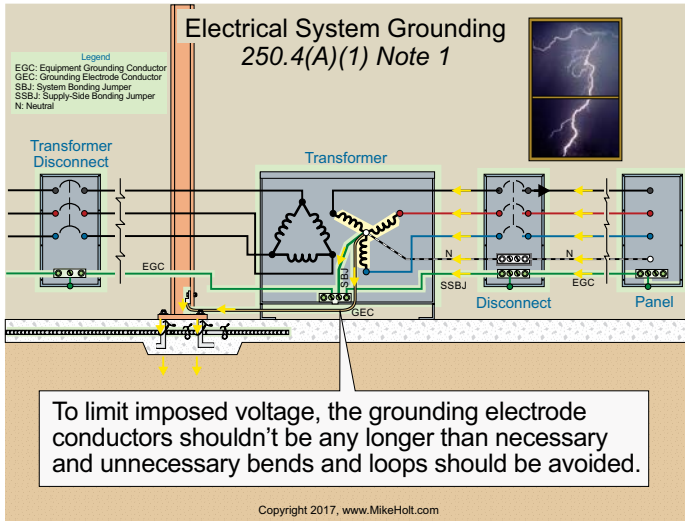


Scan this QR code for a video of Mike explaining this topic; it's a sample from the DVDs that accompany this textbook.

**(1) Electrical System Grounding.** Electrical power systems are grounded (connected to the earth) to limit the voltage induced by lightning, line surges, or unintentional contact by higher-voltage lines. ▶Figure 250-4

**Note 1:** To limit imposed voltage, the grounding electrode conductors shouldn't be any longer than necessary and unnecessary bends and loops should be avoided.

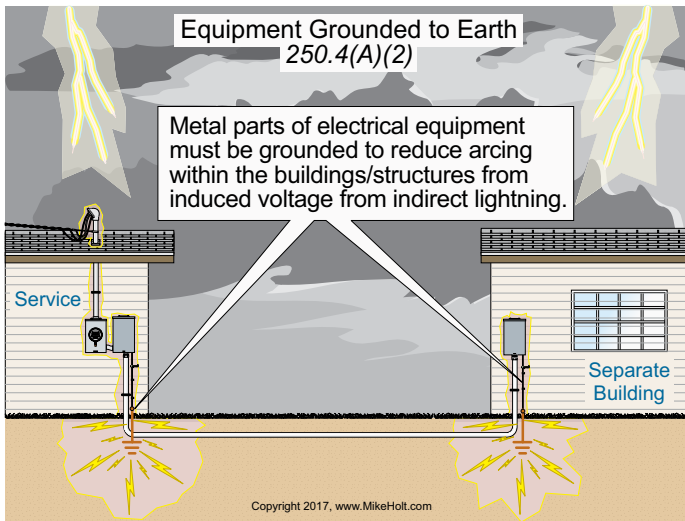
▶Figure 250-6



▶Figure 250-6

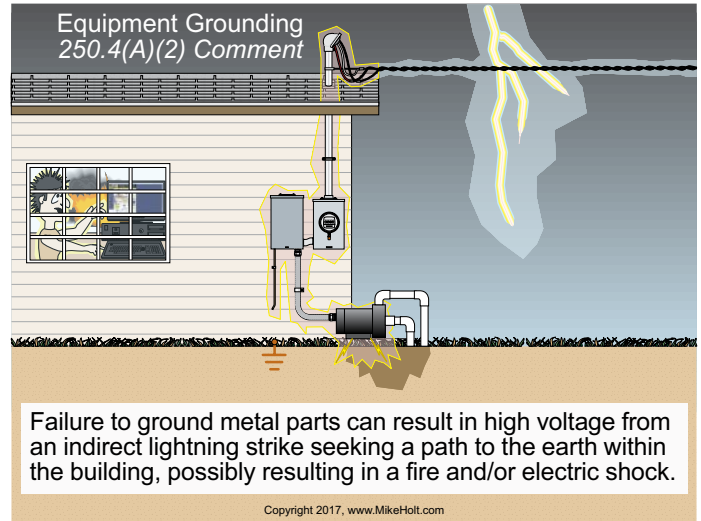
**Note 2:** See NFPA 780, *Standard for the Installation of Lightning Protection Systems* for grounding and bonding of lightning protection systems.

**(2) Equipment Grounding.** Metal parts of electrical equipment are grounded to reduce arcing within the buildings/structures from induced voltage from indirect lightning strikes. ▶Figure 250-7



▶Figure 250-7

**DANGER:** Failure to ground metal parts to earth can result in induced voltage on metal parts from an indirect lightning strike seeking a path to the earth within the building—possibly resulting in a fire and/or electric shock from a side flash. ▶Figure 250-8

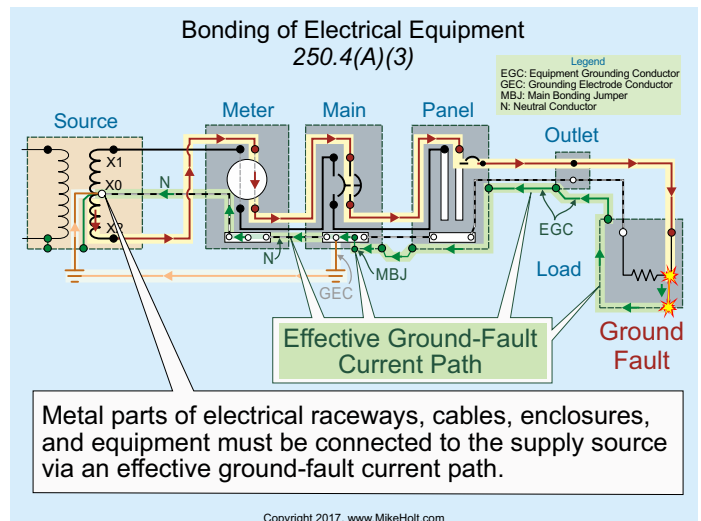


▶Figure 250-8

**Author's Comment:**

- Grounding metal parts helps drain off static electricity charges before flashover potential is reached. Static grounding is often used in areas where the discharge (arcing) of the voltage buildup (static) can cause dangerous or undesirable conditions [500.4 Note 3].

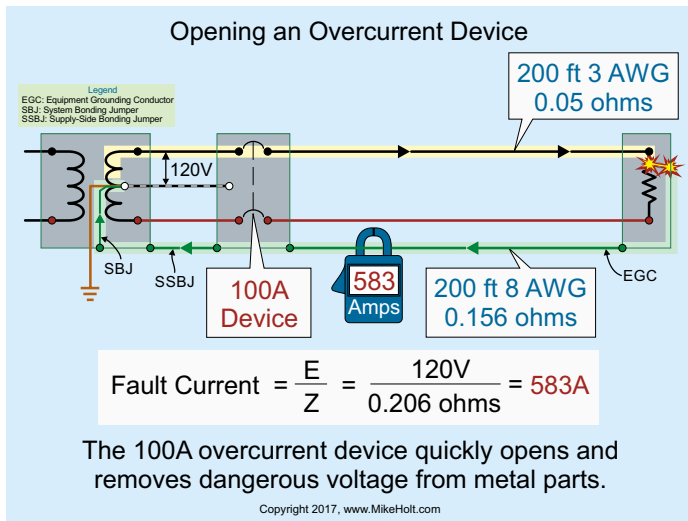
**(3) Equipment Bonding.** Metal parts of electrical raceways, cables, enclosures, and equipment must be connected to the supply source via an effective ground-fault current path. ▶Figure 250-9



▶Figure 250-9

**Author's Comment:**

- To quickly remove dangerous voltage on metal parts from a ground fault, the effective ground-fault current path must have sufficiently low impedance to the source so fault current will quickly rise to a level that will open the branch-circuit overcurrent protection device. ▶ [Figure 250-10](#)



▶ [Figure 250-10](#)

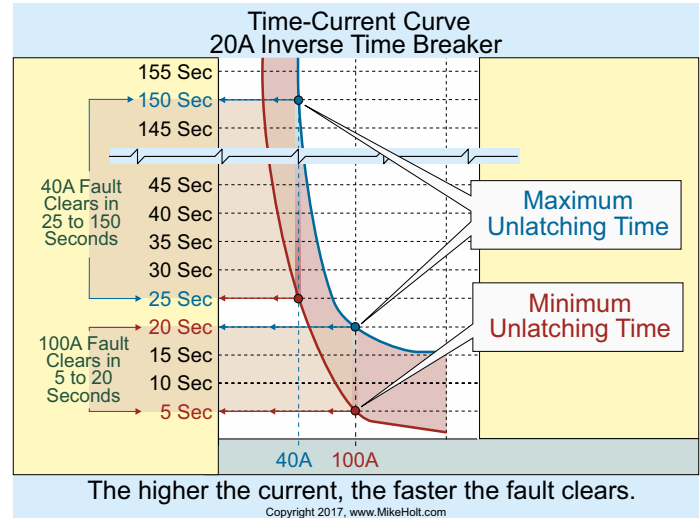
- The time it takes for an overcurrent protection device to open is dependent on the magnitude of the fault current. A higher fault current value will result in a shorter clearing time for the overcurrent protection device. For example, a 20A overcurrent protection device with an overload of 40A (two times the 20A rating) takes 25 to 150 seconds to open. The same device at 100A (five times the 20A rating) trips in 5 to 20 seconds.

▶ [Figure 250-11](#)

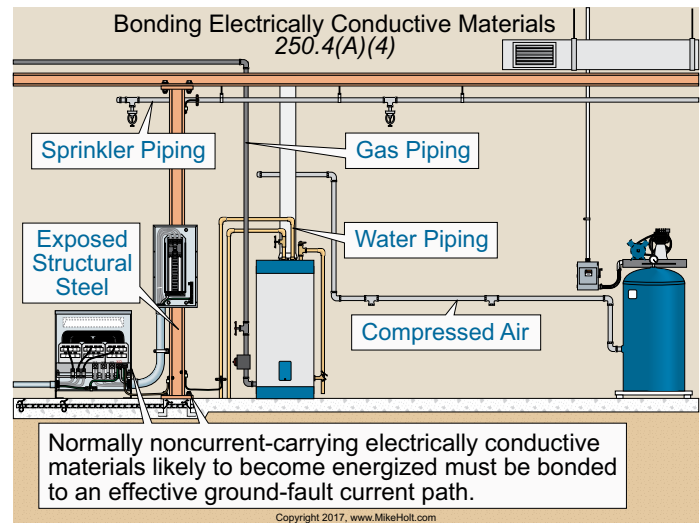
**(4) Bonding Conductive Materials.** Electrically conductive materials likely to become energized, such as metal water piping systems, metal sprinkler piping, metal gas piping, and other metal-piping systems, as well as exposed structural steel members, must be connected to the supply source via an effective ground-fault current path. ▶ [Figure 250-12](#)

**Author's Comment:**

- The phrase “likely to become energized” is subject to interpretation by the authority having jurisdiction.



▶ [Figure 250-11](#)



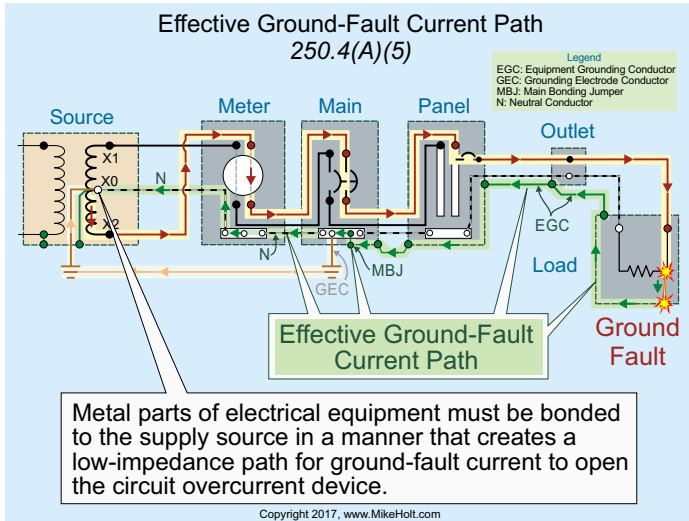
▶ [Figure 250-12](#)

**(5) Effective Ground-Fault Current Path.** Metal parts of electrical raceways, cables, enclosures, or equipment must be bonded together and to the supply source in a manner that creates a low-impedance path for ground-fault current that facilitates the operation of the circuit overcurrent protection device. ▶ [Figure 250-13](#)

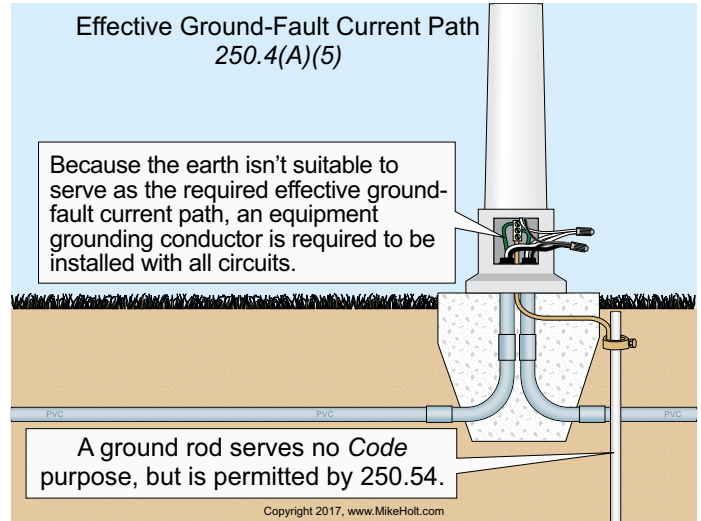
**Author's Comment:**

- To ensure 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)].

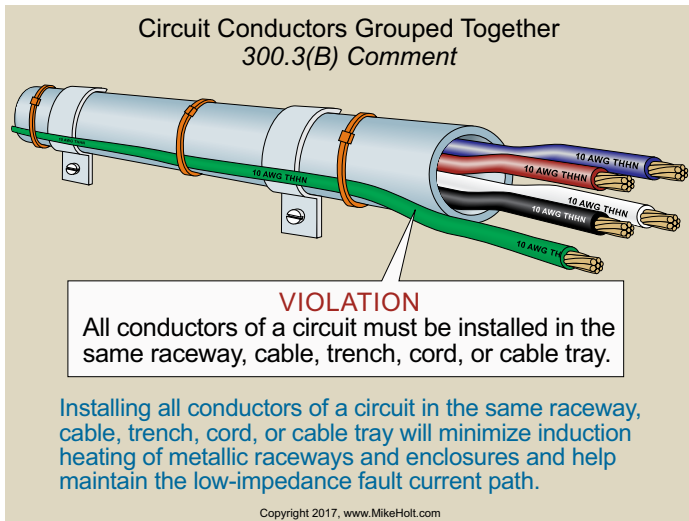
▶ [Figure 250-14](#)



▶Figure 250-13

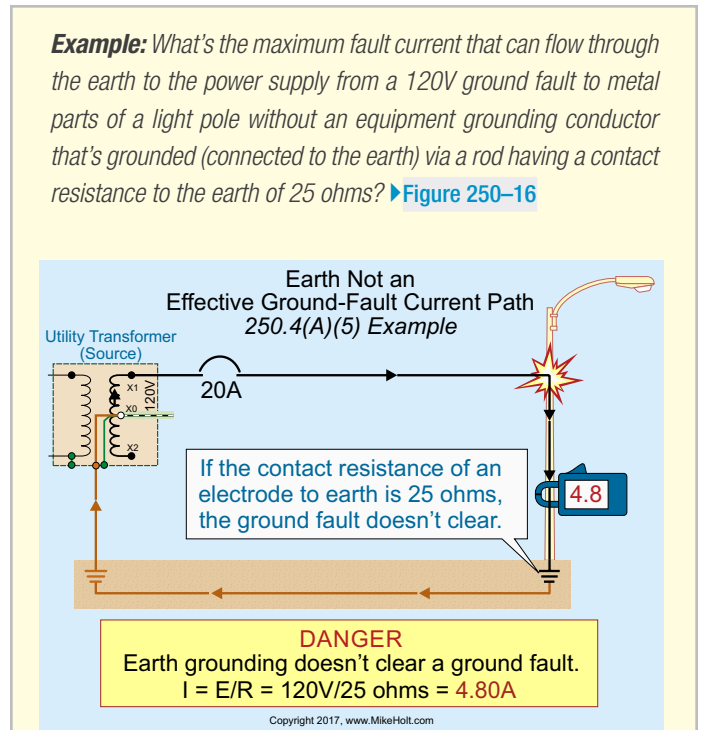


▶Figure 250-15



▶Figure 250-14

Because the earth isn't a low impedance path for fault current, it isn't suitable to serve as the required effective ground-fault current path, therefore an equipment grounding conductor of a type recognized in 250.118 is required to be installed with all circuits. ▶Figure 250-15



▶Figure 250-16

**Solution:**

$$I = E/R$$

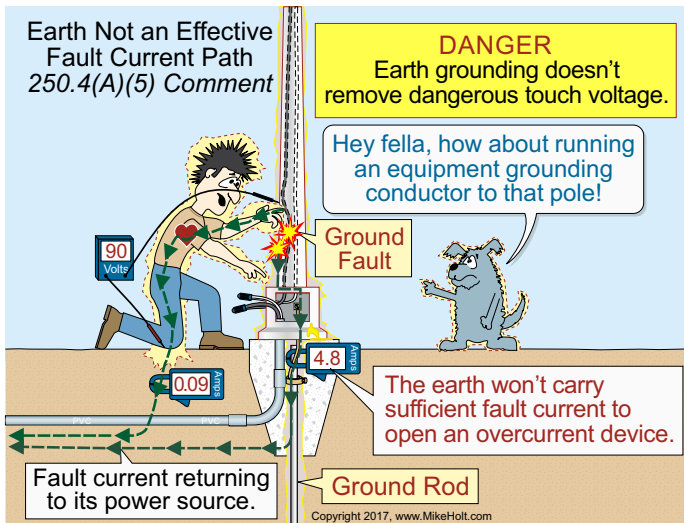
$$I = 120V/25 \text{ ohms}$$

$$I = 4.80A$$

**Answer: 4.80A**

**DANGER:** Because the contact resistance of an electrode to the earth is so high, very little fault current returns to the power supply if the earth is the only fault current return path. ▶Figure 250–17

Result—the circuit overcurrent protection device won't open and all metal parts associated with the electrical installation, metal piping, and structural building steel will become and remain energized.



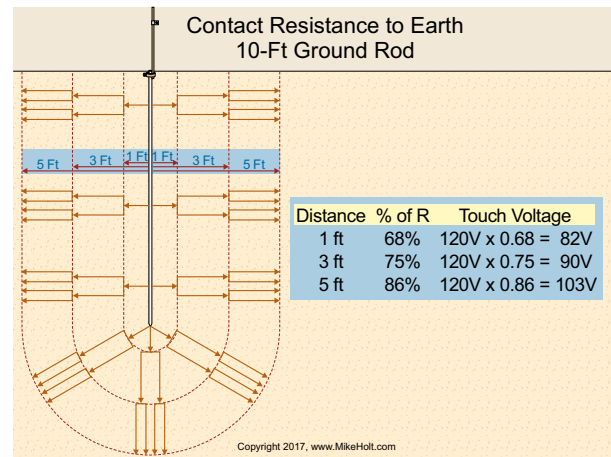
▶Figure 250–17

### Earth Shells

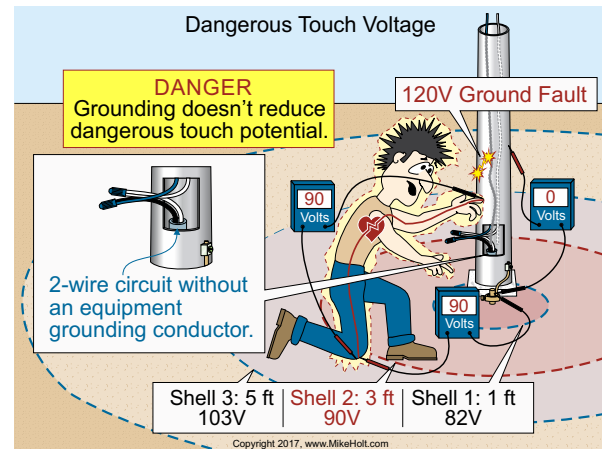
According to ANSI/IEEE 142, *Recommended Practice for Grounding of Industrial and Commercial Power Systems* (Green Book) [4.1.1], the resistance of the soil outward from a rod is equal to the sum of the series resistances of the earth shells. The shell nearest the rod has the highest resistance and each successive shell has progressively larger areas and progressively lower resistances. Don't be concerned if you don't understand this statement; just review the table below.

Distance from Rod	Soil Contact Resistance
1 ft (Shell 1)	68% of total contact resistance
3 ft (Shells 1 and 2)	75% of total contact resistance
5 ft (Shells 1, 2, and 3)	86% of total contact resistance

Since voltage is directly proportional to resistance, the voltage gradient of the earth around an energized rod, assuming a 120V ground fault, will be as follows: ▶Figure 250–18 and ▶Figure 250–19



▶Figure 250–18



▶Figure 250–19

Distance from Rod	Soil Contact Resistance	Voltage Gradient
1 ft (Shell 1)	68%	82V
3 ft (Shells 1 and 2)	75%	90V
5 ft (Shells 1, 2, and 3)	86%	103V

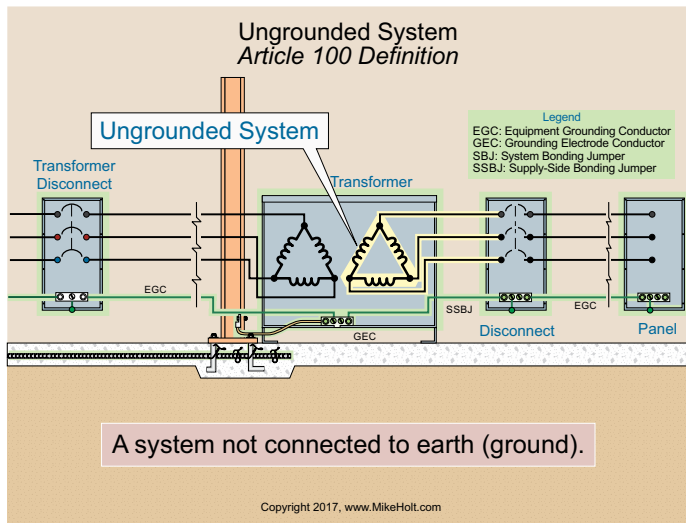
**(B) Ungrounded Systems.**



Scan this QR code for a video of Mike explaining this topic; it's a sample from the DVDs that accompany this textbook.

**Author's Comment:**

- Ungrounded systems are those systems with no connection to the ground or to a conductive body that extends the ground connection [Article 100]. ▶ [Figure 250–20](#)



▶ [Figure 250–20](#)

**(1) Equipment Grounding.** Metal parts of electrical equipment are grounded (connected to the earth) to reduce induced voltage on metal parts from lightning so as to prevent fires from an arc within the buildings. ▶ [Figure 250–21](#)

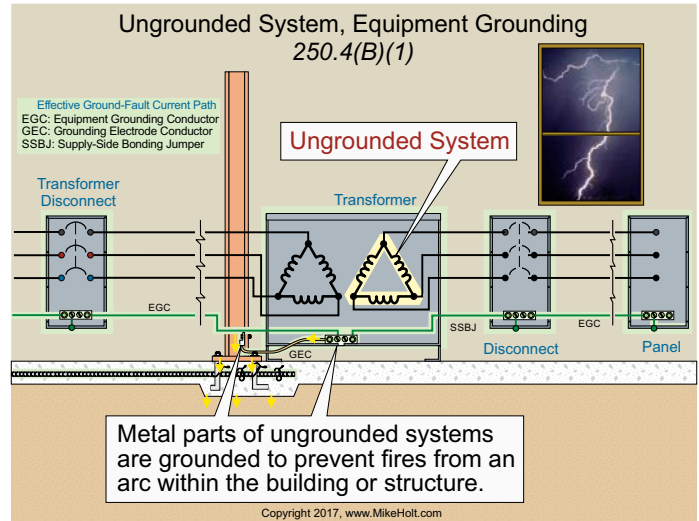
**Note 2:** See NFPA 780, *Standard for the Installation of Lightning Protection Systems* for grounding and bonding of lightning protection systems.

**Author's Comment:**

- Grounding metal parts helps drain off static electricity charges before an electric arc takes place (flashover potential). Static grounding is often used in areas where the discharge (arcing) of the voltage buildup (static) can cause dangerous or undesirable conditions [500.4 Note 3].

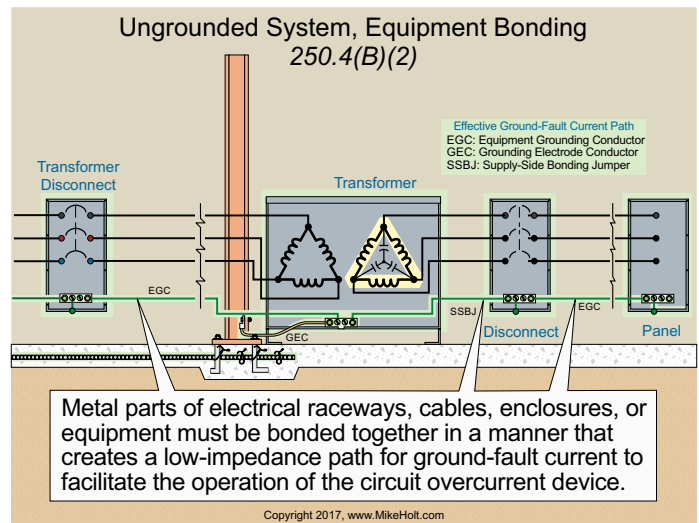


**CAUTION:** Connecting metal parts to the earth (grounding) serves no purpose in electrical shock protection.



▶ [Figure 250–21](#)

**(2) Equipment Bonding.** Metal parts of electrical raceways, cables, enclosures, or equipment must be bonded together in a manner that creates a low-impedance path for ground-fault current to facilitate the operation of the circuit overcurrent protection device. ▶ [Figure 250–22](#)

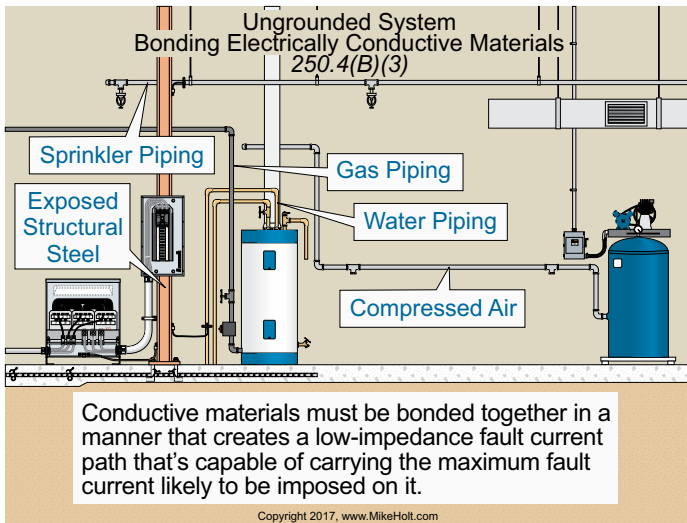


▶ [Figure 250–22](#)

The fault current path must be capable of safely carrying the maximum ground-fault current likely to be imposed on it from any point on the wiring system should a ground fault occur to the electrical supply source.

**(3) Bonding Conductive Materials.** Conductive materials such as metal water piping systems, metal sprinkler piping, metal gas piping, and other metal-piping systems, as well as exposed structural steel members

likely to become energized must be bonded together in a manner that creates a low-impedance fault current path that's capable of carrying the maximum fault current likely to be imposed on it. ▶ [Figure 250–23](#)

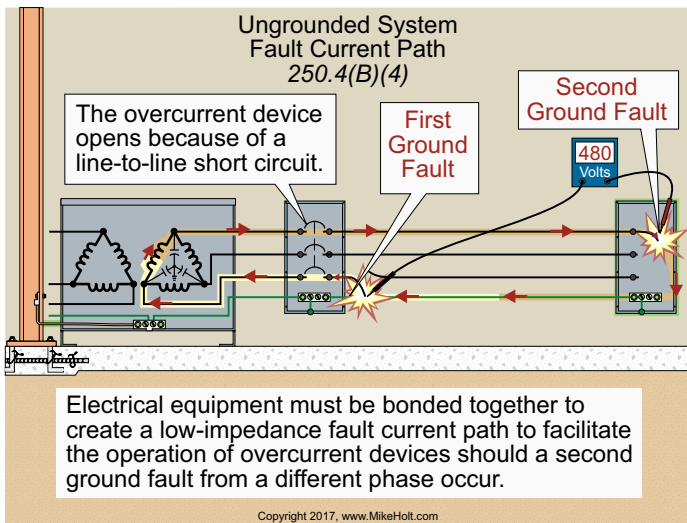


▶ [Figure 250–23](#)

**Author's Comment:**

- The phrase “likely to become energized” is subject to interpretation by the authority having jurisdiction.

**(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 low-impedance fault current path to facilitate the operation of overcurrent protection devices should a second ground fault from a different phase occur. ▶ [Figure 250–24](#)



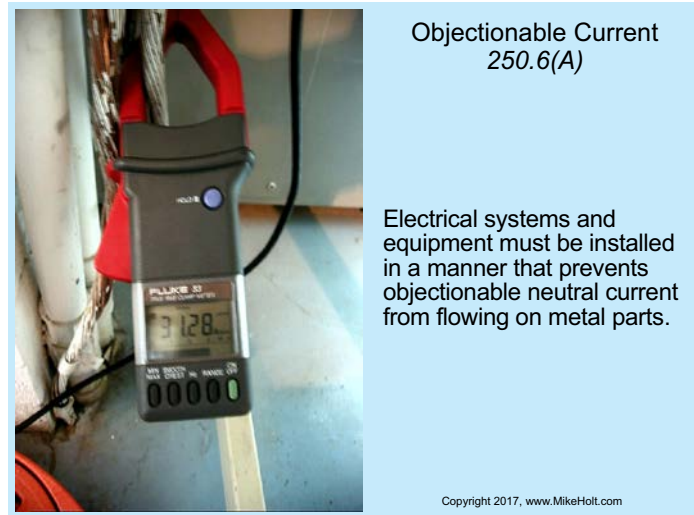
▶ [Figure 250–24](#)

**Author's Comment:**

- A single ground fault can't be cleared on an ungrounded system because there's no low-impedance fault current path to the electric power source. The first ground fault simply grounds the system and initiates the ground detector. However, a second ground fault on a different phase results in a line-to-line short circuit between the two ground faults. The conductive path, between the ground faults, provides the low-impedance fault current path necessary so the overcurrent protection device will open.

**2017 CC 250.6 Objectionable Current**

**(A) Preventing Objectionable Current.** To prevent a fire, electric shock, or improper operation of circuit overcurrent protection devices or electronic equipment, electrical systems and equipment must be installed in a manner that prevents objectionable neutral current from flowing on metal parts. ▶ [Figure 250–25](#)



▶ [Figure 250–25](#)

**(B) Stopping Objectionable Current.** If the use of multiple grounding connections results in objectionable current and the requirements of 250.4(A)(5) or (B)(4) are met, one or more of the following alterations are permitted:

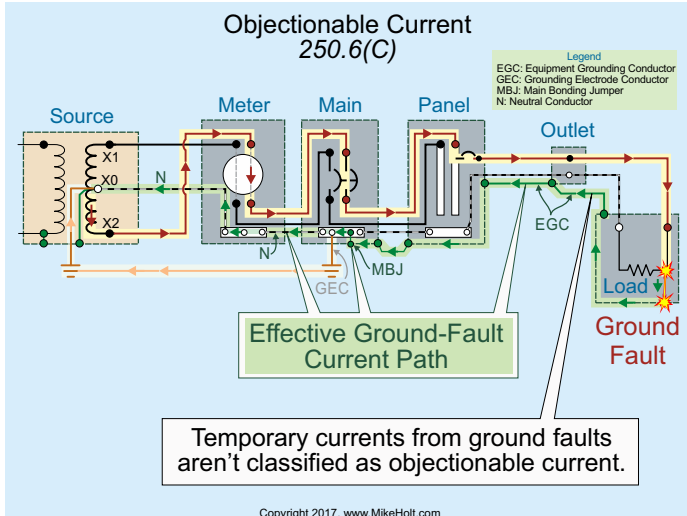
- (1) Discontinue one or more but not all of such grounding connections.
- (2) Change the locations of the grounding connections.
- (3) Interrupt the continuity of the conductor or conductive path causing the objectionable current.



(4) Take other suitable remedial and approved action.

**(C) Temporary Currents Not Classified as Objectionable Currents.**

Temporary currents from abnormal conditions, such as ground faults, aren't to be classified as objectionable current. ▶ **Figure 250-26**



▶ **Figure 250-26**

**Objectionable Current**

Objectionable neutral current occurs because of improper neutral-to-case connections or wiring errors that violate 250.142(B).

**Improper Neutral-to-Case Connection [250.142]**

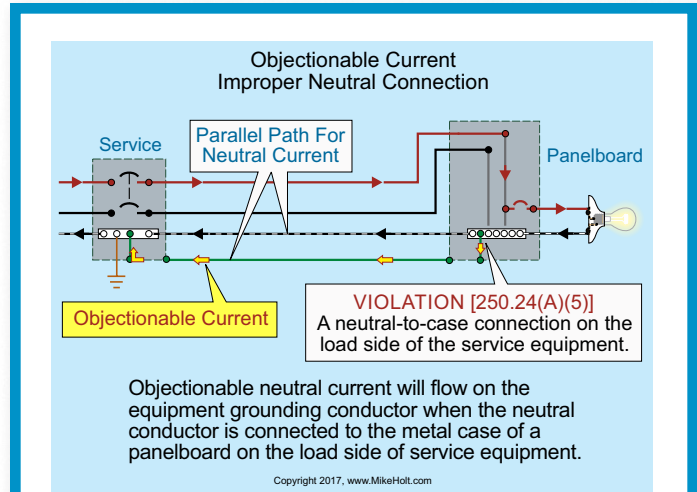
**Panelboards.** Objectionable neutral current will flow on metal parts and the equipment grounding conductor when the neutral conductor is connected to the metal case of a panelboard on the load side of service equipment. ▶ **Figure 250-27**

**Separately Derived Systems.** Objectionable neutral current will flow on metal parts if the neutral conductor is connected to the circuit equipment grounding conductor on the load side of the system bonding jumper for a separately derived system.

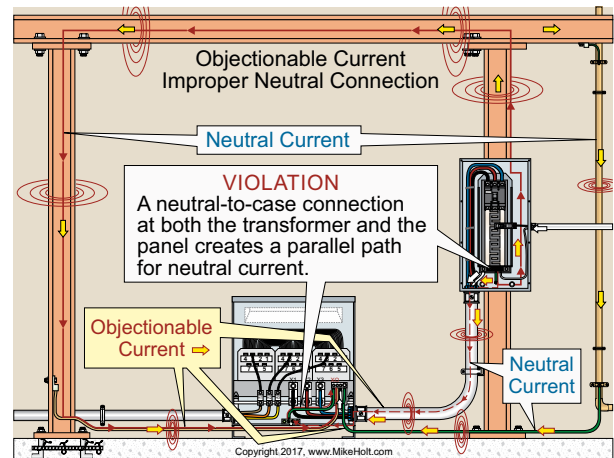
▶ **Figure 250-28**

**Generator.** Objectionable neutral current will flow on metal parts and the equipment grounding conductor if a generator is connected to a transfer switch with a solidly connected neutral and a neutral-to-case connection is made at the generator.

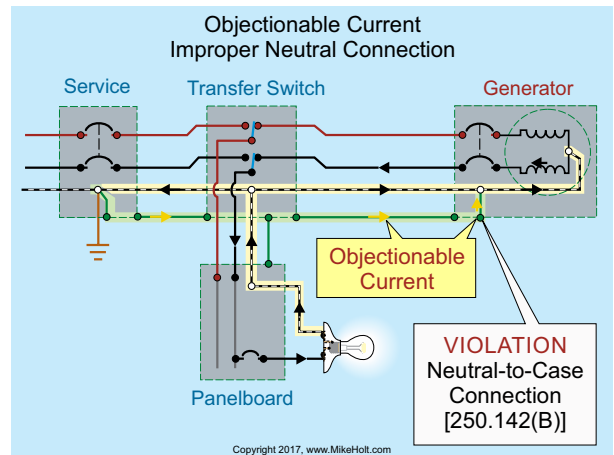
▶ **Figure 250-29**



▶ **Figure 250-27**

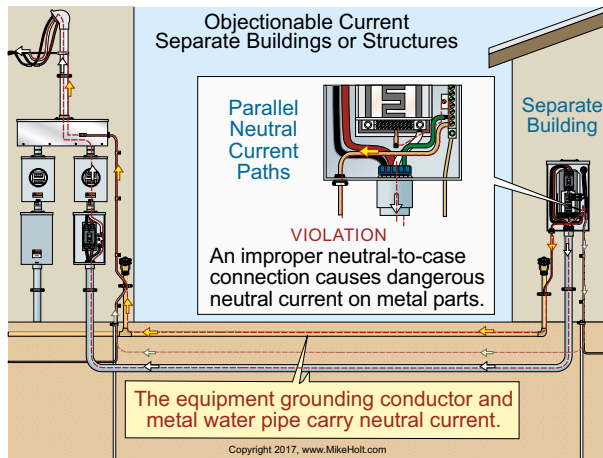


▶ **Figure 250-28**



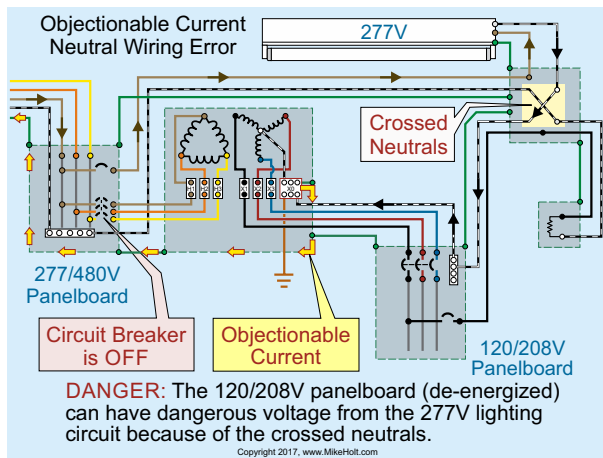
▶ **Figure 250-29**

**Disconnects.** Objectionable neutral current will flow on metal parts and the equipment grounding conductor when the neutral conductor is connected to the metal case of a disconnect that's not part of the service equipment. ▶[Figure 250-30](#)



▶[Figure 250-30](#)

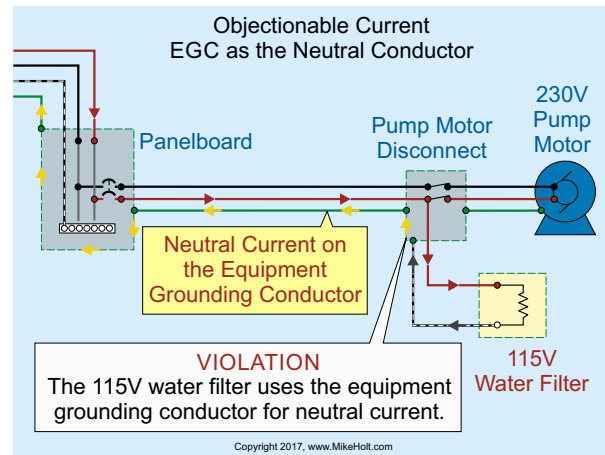
**Wiring Errors.** Objectionable neutral current will flow on metal parts and equipment grounding conductors when the neutral conductor from one system is used as the neutral conductor for a different system. ▶[Figure 250-31](#)



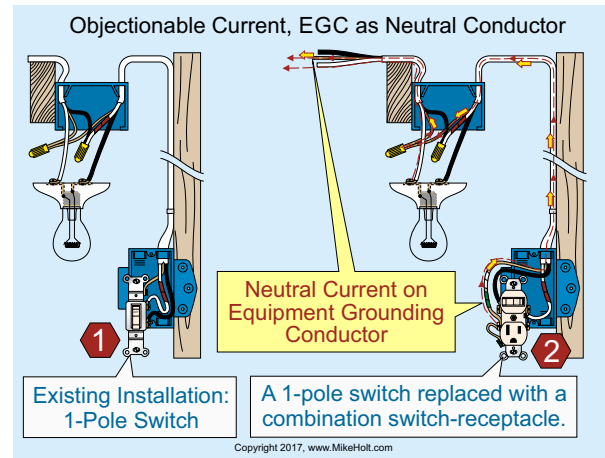
▶[Figure 250-31](#)

Objectionable neutral current will flow on the equipment grounding conductor when the circuit equipment grounding conductor is used as a neutral conductor such as where:

- A 230V time-clock motor is replaced with a 115V time-clock motor, and the circuit equipment grounding conductor is used for neutral return current. ▶[Figure 250-32](#)
- A 115V water filter is wired to a 240V well-pump motor circuit, and the circuit equipment grounding conductor is used for neutral return current. ▶[Figure 250-32](#)
- The circuit equipment grounding conductor is used for neutral return current. ▶[Figure 250-33](#)



▶[Figure 250-32](#)

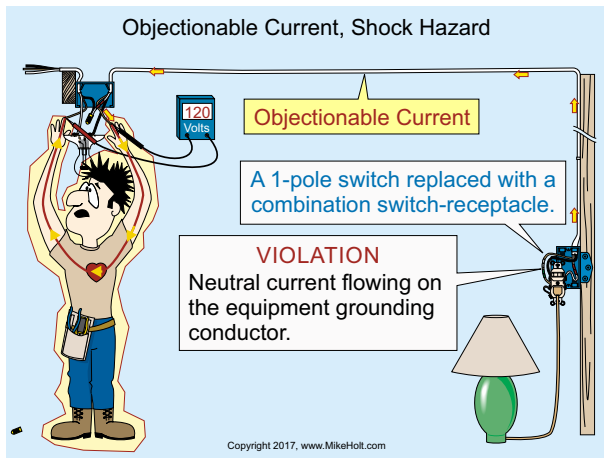


▶[Figure 250-33](#)

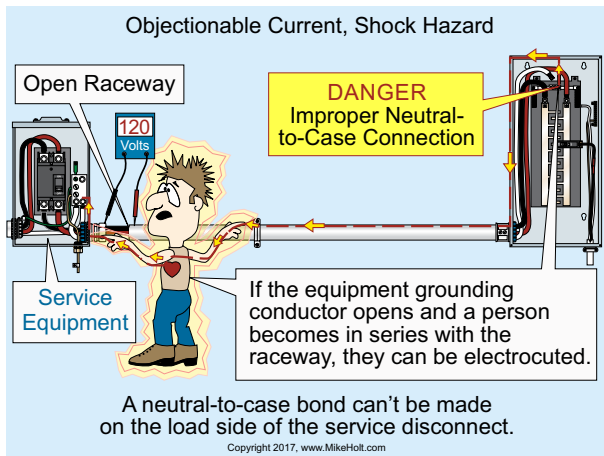
### Dangers of Objectionable Current

Objectionable neutral current on metal parts can cause electric shock, fires, and improper operation of electronic equipment and overcurrent protection devices such as GFPs, GFCIs, and AFCIs.

**Shock Hazard.** When objectionable neutral current flows on metal parts or the equipment grounding conductor, electric shock and even death can occur from the elevated voltage on those metal parts. ▶Figure 250-34 and ▶Figure 250-35



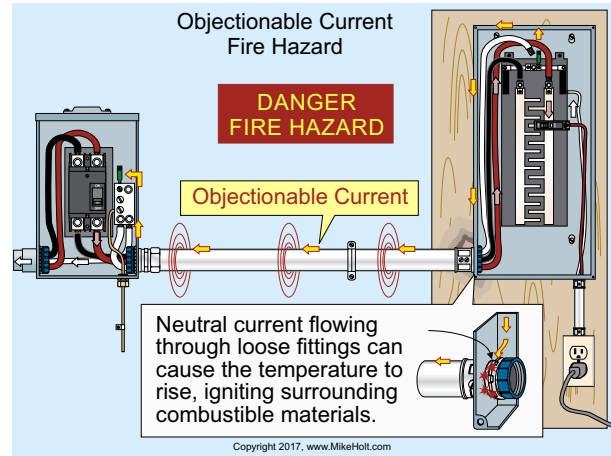
▶Figure 250-34



▶Figure 250-35

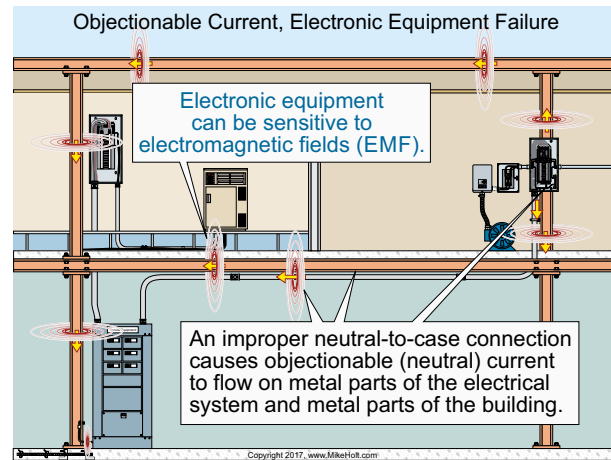
**Fire Hazard.** When objectionable neutral current flows on metal parts, a fire can ignite adjacent combustible material. Heat is generated whenever current flows, particularly over high-resistance parts. In addition, arcing at loose connections is especially

dangerous in areas containing easily ignitable and explosive gases, vapors, or dust. ▶Figure 250-36



▶Figure 250-36

**Improper Operation of Electronic Equipment.** Objectionable neutral current flowing on metal parts of electrical equipment and building parts can cause electromagnetic fields which negatively affect the performance of electronic devices, particularly medical equipment. ▶Figure 250-37



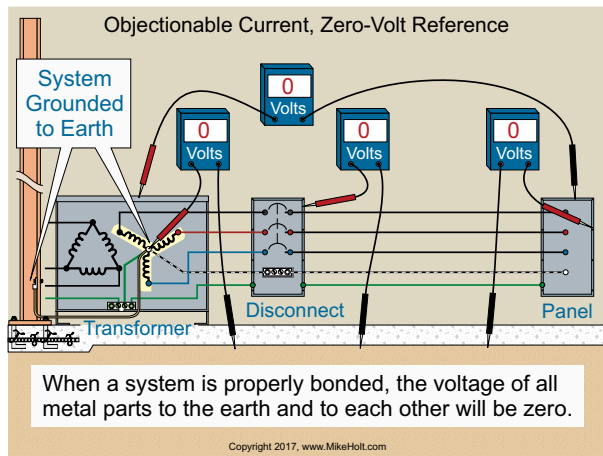
▶Figure 250-37

For more information, visit [www.MikeHolt.com](http://www.MikeHolt.com), click on the “Technical” link, and then on “Power Quality.”

When a solidly grounded system is properly bonded, the voltage of all metal parts to the earth and to each other will be zero.

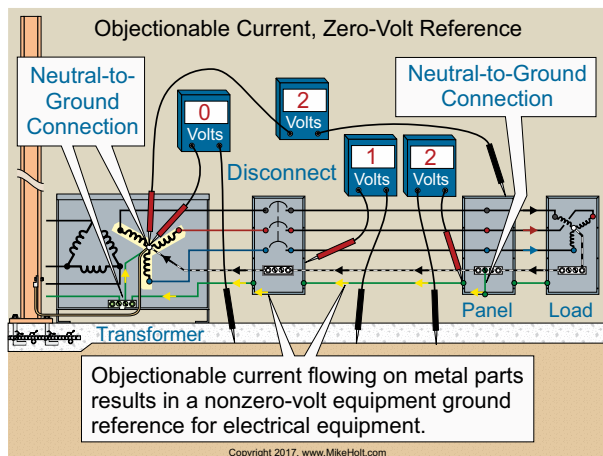
▶Figure 250-38





▶Figure 250-38

When objectionable neutral current travels on metal parts and equipment grounding conductors because of the improper bonding of the neutral to metal parts, a difference of voltage will exist between all metal parts. This situation can cause some electronic equipment to operate improperly. ▶Figure 250-39



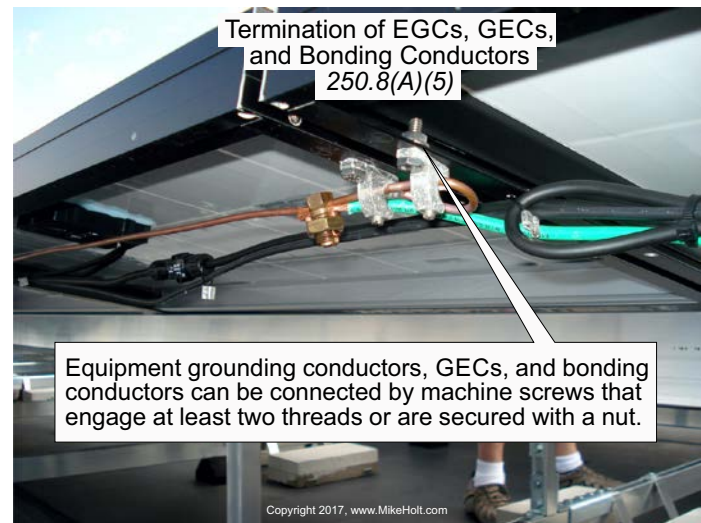
▶Figure 250-39

**Operation of Overcurrent Protection Devices.** When objectionable neutral current travels on metal parts, tripping of electronic overcurrent protection devices equipped with ground-fault protection can occur because some neutral current flows on the circuit equipment grounding conductor instead of the neutral conductor.

## 250.8 Termination of Grounding and Bonding Conductors

**(A) Permitted Methods.** Equipment grounding conductors, grounding electrode conductors, and bonding jumpers must terminate in one or more of the following methods:

- (1) Listed pressure connectors
- (2) Terminal bars
- (3) Pressure connectors listed for grounding and bonding
- (4) Exothermic welding
- (5) Machine screws that engage at least two threads or are secured with a nut, ▶Figure 250-40
- (6) Self-tapping machine screws that engage at least two threads ▶Figure 250-41
- (7) Connections that are part of a listed assembly
- (8) Other listed means



▶Figure 250-40