



# GROUNDING AND BONDING

## Using the Tables in Article 250 of the NEC®

Article 250 is a foundational pillar of NFPA 70®, *National Electrical Code*® (NEC®), and the tables within Article 250 are critical resources for sizing the wiring for the grounding and bonding of an electrical system. Becoming more familiar with the proper use of these tables can help installers ensure effective grounding and bonding on their projects and, in turn, help ensure the safety of those within the building.

### Essential NEC Terms for Understanding Article 250

Having a good understanding of the terms used within Article 250 is critical to understanding the grounding and bonding requirements within the NEC®. The following definitions are commonly used throughout Article 250, and knowing them is essential to installing an effectively grounded and bonded electrical system.

**Ground** — The earth.

**Grounded (Grounding)** — Connected (connecting) to ground or to a conductive body that extends the ground connection.

- ▶ An example of a conductive body that extends the ground connection is the first 5 feet of a water pipe entering a building. It is permitted to connect at this point even though it is not a grounding electrode, as the first 5 feet of the pipe is not physically in contact with the earth.

**Grounded Conductor** — A system or circuit conductor that is intentionally grounded.

- ▶ These are often regarded as “neutral” conductors in the trade. Section 200.6 requires these conductors to be identified as continuous white, continuous gray, or having three continuous white or gray stripes along the conductor’s entire length on other than green insulation. Be mindful that grounded conductors can also be phase conductors in certain applications.

**Grounding Conductor, Equipment (EGC)** — The conductive path(s) that provides a ground-fault current path and connects normally non-current-carrying metal parts of equipment together and to the system grounded conductor or to the grounding electrode conductor, or both.

- ▶ These are often called “ground” conductors in the trade. Section 250.119 requires these conductors to be bare, covered, or insulated. Covered or insulated equipment grounding conductors shall have a continuous outer finish that is either green or green with one or more yellow stripes.

**Grounding Electrode** — A conducting object through which a direct connection to the earth is established.

- ▶ Section 250.52(A)(1–8) lists the permissible grounding electrode options. While all the available grounding electrodes are required to be bonded per 250.50, it’s fair to say the most common are typically rod and pipe electrodes (i.e., ground rods), which are listed in 250.52(A)(5), and concrete-encased electrodes, which are listed in 250.52(A)(3). Often, concrete-encased electrodes consist of rebar that is embedded in the concrete footings of a building.

**Grounding Electrode Conductor** — A conductor used to connect the system grounded conductor or the equipment to a grounding electrode or to a point on the grounding electrode system.

- ▶ This is the conductor that connects the grounding electrodes to the electrical system.

**Ground-Fault Current Path** — An electrically conductive path from the point of a ground fault on a wiring system through normally non-current-carrying conductors, equipment, or the earth to the electrical supply source.

**Effective Ground-Fault Current Path** — An intentionally constructed, low-impedance electrically conductive path designed and intended to carry current under ground-fault

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conditions from the point of a ground fault on a wiring system to the electrical supply source and that facilitates the operation of the overcurrent protective device or ground-fault detectors.

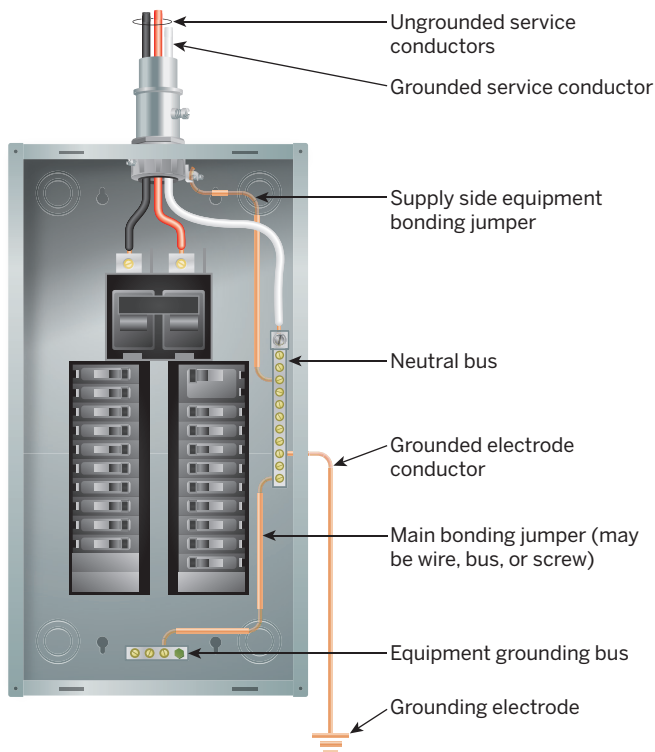
- ▶ An effectively designed ground-fault current path will allow for circuit breakers, fuses, and ground-fault detectors to open properly when ground-fault conditions arise within the electrical system.

**Bonded (Bonding)** — Connected to establish electrical continuity and conductivity.

**Bonding Conductor or Jumper** — A reliable conductor to ensure the required electrical conductivity between metal parts required to be electrically connected.

**Bonding Jumper, Equipment** — The connection between two or more portions of the equipment grounding conductor.

**Bonding Jumper, Main** — The connection between the grounded circuit conductor and the equipment grounding conductor at the service.



A main bonding jumper installed at the service between the grounded service conductor and the equipment grounding conductor.

**Bonding Jumper, System** — The connection between the grounded circuit conductor and the supply-side bonding jumper, or the equipment grounding conductor, or both, at a separately derived system.

### Sizing Grounding Electrode Conductors Using Table 250.66

Table 250.66 of the NEC is used to size grounding electrode conductors for alternating-current systems located at the service, at each building or structure where supplied by a feeder(s) or branch circuit(s), or at a separately derived system, such as on the load side of transformers.

This table shows you how to use the size of your largest ungrounded (hot) conductor to determine the necessary size of your grounding electrode conductor. Where you have two or more sets of service-entrance conductors run in parallel, the

**Table 250.66 Grounding Electrode Conductor for Alternating-Current Systems**

|                       | Size of Largest Ungrounded Conductor or Equivalent Area for Parallel Conductors (AWG/kcmil) |                                  | Size of Grounding Electrode Conductor (AWG/kcmil) |                                  |
|-----------------------|---|----------------------------------|---|----------------------------------|
|                       | Copper  | Aluminum or Copper-Clad Aluminum | Copper  | Aluminum or Copper-Clad Aluminum |
| 2 or smaller          | 1/0 or smaller  | 8                                | 6   |                                  |
| 1 or 1/0              | 2/0 or 3/0  | 6                                | 4   |                                  |
| 2/0 or 3/0            | 4/0 or 250  | 4                                | 2   |                                  |
| Over 3/0 through 350  | Over 250 through 500  | 2                                | 1/0   |                                  |
| Over 350 through 600  | Over 500 through 900  | 1/0                              | 3/0   |                                  |
| Over 600 through 1100 | Over 900 through 1750   | 2/0                              | 4/0   |                                  |
| Over 1100             | Over 1750   | 3/0                              | 250   |                                  |

Notes:

1. If multiple sets of service-entrance conductors connect directly to a service drop, set of overhead service conductors, set of underground service conductors, or service lateral, the equivalent size of the largest service-entrance conductor shall be determined by the largest sum of the areas of the corresponding conductors of each set.
2. Where there are no service-entrance conductors, the grounding electrode conductor size shall be determined by the equivalent size of the largest service-entrance conductor required for the load to be served.
3. See installation restrictions in 250.64.

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grounding electrode conductor must be sized according to the largest sum of the corresponding conductors of each set. (See the Application Example that follows the Table Tips.)

#### Table Tips

1. Ensure that you are using the proper column(s) based on the wire type you are installing—copper, aluminum, or copper-clad aluminum.
2. Section 250.66(A) references connections to rod, pipe, or plate electrodes. If the connection does not extend on to other types of electrodes that require a larger size conductor, the grounding electrode conductor is not required to be larger than 6 AWG copper or 4 AWG aluminum wire.
3. Section 250.66(B) references connections to concrete-encased electrodes, often referred to in the trade as “Ufer ground.” If the connection does not extend on to other types of electrodes that require a larger size conductor, the grounding electrode conductor is not required to be larger than 4 AWG copper wire.
4. Section 250.66(C) references connections to ground rings. If the grounding electrode conductor or bonding jumper connected to a ground ring does not extend on to other types of electrodes that require a larger size conductor, the grounding electrode conductor is not required to be larger than the conductor used for the ground ring.

#### Application Example: Parallel Conductors

A 3-phase, 800-A service is supplied using two 500 kcmil THWN copper conductors per phase. The parallel conductors are installed in two separate runs of rigid metal conduit. Using Table 250.66, determine the maximum size grounding electrode conductor required for this service.

**STEP 1.** Determine the size of the largest ungrounded conductor in each raceway.

**STEP 2.** Determine the maximum size grounding electrode conductor (GEC) required for this service.

**SOLUTION.** Two parallel 500 kcmil copper conductors:

$$\text{Total equivalent area} = 2 \times 500 \text{ kcmil} = 1000 \text{ kcmil}$$

Then refer to Table 250.66 for the ungrounded conductor and copper column values:

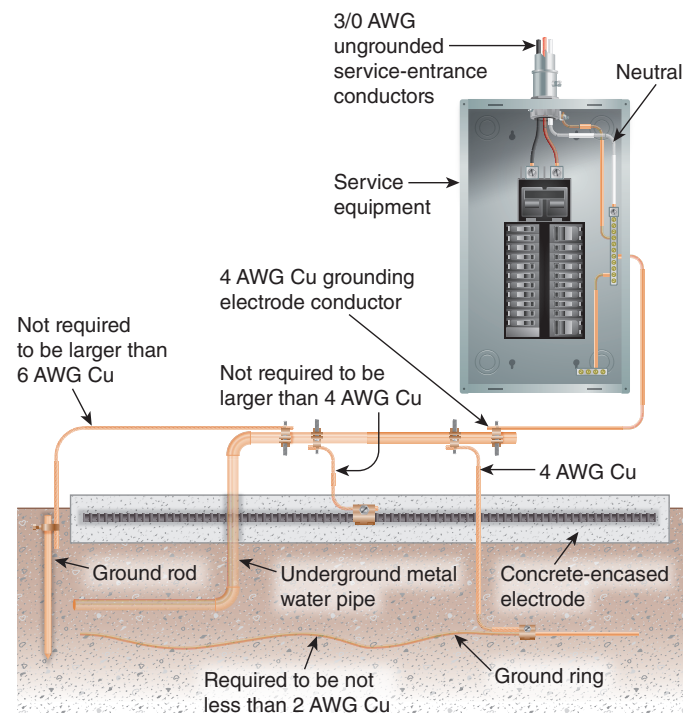
1000 kcmil falls into the “Over 600 through 1100” row = size 2/0 copper GEC.

#### Sizing Grounding Electrode Conductors and Bonding Jumpers

The exhibit below illustrates a grounding electrode conductor (GEC) installed from service equipment or a separately derived system to a water pipe grounding electrode. The GEC is required by 250.66 to be sized based on the size of the ungrounded supply conductors. The supply conductors could be service conductors or, in the case of separately derived systems, feeder conductors from a generator or other power source or transformer secondary conductors.

The bonding jumpers that connect the other grounding electrodes together must be sized using 250.53(C), which refers to 250.66. GECs and bonding jumpers are permitted to be sized based on the electrodes to which they connect, as specified in 250.66(A), (B), or (C). However, if the GEC or bonding jumper extends from this connection to an electrode that is not specified in 250.66(A), (B), or (C), it must be sized per Table 250.66.

In this exhibit, the sizes of the GEC and the bonding jumpers are dependent on the electrode to which they are connected.



GEC and bonding jumpers sized in accordance with 250.66 for a service supplied by 3/0 AWG copper ungrounded conductors.



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The illustration is not intended to show a mandatory physical routing and connection order of the bonding jumpers and the GEC, as the NEC does not specify an order or hierarchy for these connections. The sizes of the bonding jumpers to the ground rod and the concrete-encased electrode shown here are the maximum sizes required by the NEC based on 250.66(A) and (B). If the GEC from the service equipment is run to the ground rod first and then to the water pipe, the GEC to the ground rod is required to be sized based on Table 250.66 as if it were run to the water pipe electrode. The use of bonding jumpers or GECs larger than those required by 250.66 is not prohibited.

#### Sizing Grounded (Neutral) Conductors and Bonding Jumpers Using Table 250.102(C)(1)

Table 250.102(C)(1) is used to size the grounded conductor, main bonding jumper, system bonding jumper, and supply-side bonding jumper for alternating-current systems. Keep in mind that this table is for sizing grounded conductors and the bonding jumpers listed, NOT for sizing grounding electrode conductors, which must be done using Table 250.66.

Table 250.102(C)(1) uses the size of the largest ungrounded (hot) conductor to determine the sizes of your grounded (neutral) conductor and bonding jumpers. When sizing the grounded conductor or jumper where two or more ungrounded conductors are connected in parallel and the total equivalent area is larger than 1100 kcmil copper or 1750 kcmil aluminum, Table Note 1 requires the size to be not less than 12½ percent of the area of the largest ungrounded supply conductor or the equivalent area for parallel supply conductors.

#### Table Tips

1. Make sure that you are using the proper column(s) based on the wire type that you are installing—copper, aluminum, or copper-clad aluminum.
2. If your ungrounded conductor or equivalent parallel conductors' area is larger than 1100 kcmil copper or 1750 kcmil aluminum, follow Table Note 1.
3. See the Sizing Supply-Side Bonding Jumpers section and the application example that follows on the next page.
4. See also the Sizing Main and System Bonding Jumpers section on the next page.

**Table 250.102(C)(1) Grounded Conductor, Main Bonding Jumper, System Bonding Jumper, and Supply-Side Bonding Jumper for Alternating-Current Systems**

| Size of Largest Ungrounded Conductor or Equivalent Area for Parallel Conductors (AWG/kcmil) |                                  | Size of Grounded Conductor or Bonding Jumper* (AWG/kcmil) |                                  |
|---|----------------------------------|---|----------------------------------|
| Copper  | Aluminum or Copper-Clad Aluminum | Copper  | Aluminum or Copper-Clad Aluminum |
| 2 or smaller  | 1/0 or smaller                   | 8   | 6                                |
| 1 or 1/0  | 2/0 or 3/0                       | 6   | 4                                |
| 2/0 or 3/0  | 4/0 or 250                       | 4   | 2                                |
| Over 3/0 through 350  | Over 250 through 500             | 2   | 1/0                              |
| Over 350 through 600  | Over 500 through 900             | 1/0   | 3/0                              |
| Over 600 through 1100   | Over 900 through 1750            | 2/0   | 4/0                              |
| Over 1100   | Over 1750                        | See Notes 1 and 2.  |                                  |

**Notes:**

1. If the ungrounded supply conductors are larger than 1100 kcmil copper or 1750 kcmil aluminum, the grounded conductor or bonding jumper shall have an area not less than 12½ percent of the area of the largest ungrounded supply conductor or equivalent area for parallel supply conductors. The grounded conductor or bonding jumper shall not be required to be larger than the largest ungrounded conductor or set of ungrounded conductors.
2. If the ungrounded supply conductors are larger than 1100 kcmil copper or 1750 kcmil aluminum and if the ungrounded supply conductors and the bonding jumper are of different materials (copper, aluminum, or copper-clad aluminum), the minimum size of the grounded conductor or bonding jumper shall be based on the assumed use of ungrounded supply conductors of the same material as the grounded conductor or bonding jumper and will have an ampacity equivalent to that of the installed ungrounded supply conductors.
3. If multiple sets of service-entrance conductors are used as permitted in 230.40, Exception No. 2, or if multiple sets of ungrounded supply conductors are installed for a separately derived system, the equivalent size of the largest ungrounded supply conductor(s) shall be determined by the largest sum of the areas of the corresponding conductors of each set.
4. If there are no service-entrance conductors, the supply conductor size shall be determined by the equivalent size of the largest service-entrance conductor required for the load to be served.

\*For the purposes of applying this table and its notes, the term *bonding jumper* refers to main bonding jumpers, system bonding jumpers, and supply-side bonding jumpers.



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#### Sizing Supply-Side Bonding Jumpers

Similar to how you size the main bonding jumper per 250.28(D), supply-side bonding jumpers must be sized based on the size of the ungrounded conductors with which they are associated. If the ungrounded conductors are 1100 kcmil copper or 1750 kcmil aluminum or smaller, the supply-side bonding jumper must be selected from Table 250.102(C)(1) based on the size of the largest ungrounded supply conductor. If the ungrounded conductors are larger than 1100 kcmil copper or 1750 kcmil aluminum, the size of the supply-side bonding jumper(s) must be calculated based on 12½ percent of the area of the largest ungrounded supply conductor or the equivalent area of the parallel supply conductors. Where an installation consists of multiple raceways for parallel conductors, an individual supply-side bonding jumper can be installed for each raceway; the jumper must be sized based on the size of the ungrounded conductors in that raceway.

#### Sizing Main and System Bonding Jumpers

In a grounded system, the primary function of the main bonding jumper and the system bonding jumper is to create the ground-fault current link between the EGCs and the grounded conductor. Table 250.102(C)(1) can be used to determine the minimum size of the main and system bonding jumpers. Unlike the GEC, which carries current to the ground

(via connection to a grounding electrode), the main and system bonding jumpers will be placed directly in the supply-side ground-fault current return path.

Where the largest ungrounded supply conductor exceeds the parameters of Table 250.102(C)(1), Note 1 in the table requires you to establish a proportional relationship between the ungrounded conductor and the main or system bonding jumper. Where the service-entrance conductors are larger than 1100 kcmil copper or 1750 kcmil aluminum, the bonding jumper must have a cross-sectional area of not less than 12½ percent of the cross-sectional area of the largest phase conductor or phase conductor set. In equipment such as panelboards or switchboards that are listed for use as service equipment, the manufacturer provides a bonding jumper that can be installed as the main or system bonding jumper. It is not necessary to provide an additional bonding jumper.

#### Main Bonding Jumper for Service with More Than One Enclosure

Where a service consists of more than one disconnecting means in separate enclosures, each enclosure must be treated separately, as depicted in the following exhibit. Based on the 3/0 AWG ungrounded service conductors and Table 250.102(C)(1), the minimum size of the main bonding

#### Application Example

A 3-phase, 1600-A service is supplied using five 400 kcmil THWN conductors per phase. The parallel conductors are installed in five separate runs of rigid metal conduit. In accordance with 300.12, Exception No. 2, a supply-side bonding jumper is needed for each raceway at the point at which it enters the open-bottom switchboard. Using 250.102(C)(2), determine the necessary size of the supply-side bonding jumper.

##### Multiple Supply-Side Bonding Jumpers

**STEP 1.** Determine the size of the largest ungrounded conductor in each raceway.

**STEP 2.** Determine the size of the supply-side bonding jumper for each raceway using Table 250.102(C)(1).

**SOLUTION.** For 400 kcmil supply conductors, use the “Over 350 through 600” row of Table 250.102(C)(1). This leads you to a 1/0 AWG copper or 3/0 AWG aluminum supply-side bonding jumper.

##### Single Supply-Side Bonding Jumper

**STEP 1.** Determine the equivalent area of parallel supply conductors.

**STEP 2.** Determine the size of the supply-side bonding jumper using Table 250.102 (C)(1), Note 1.

**SOLUTION.** Five parallel 400 kcmil conductors:

$$\text{Total equivalent area} = 5 \times 400 = 2000 \text{ kcmil}$$

This total exceeds 1100 kcmil; therefore, the total must be multiplied by 0.125 (12.5 percent).

$$2000 \text{ kcmil} \times 0.125 = 250 \text{ kcmil copper}$$

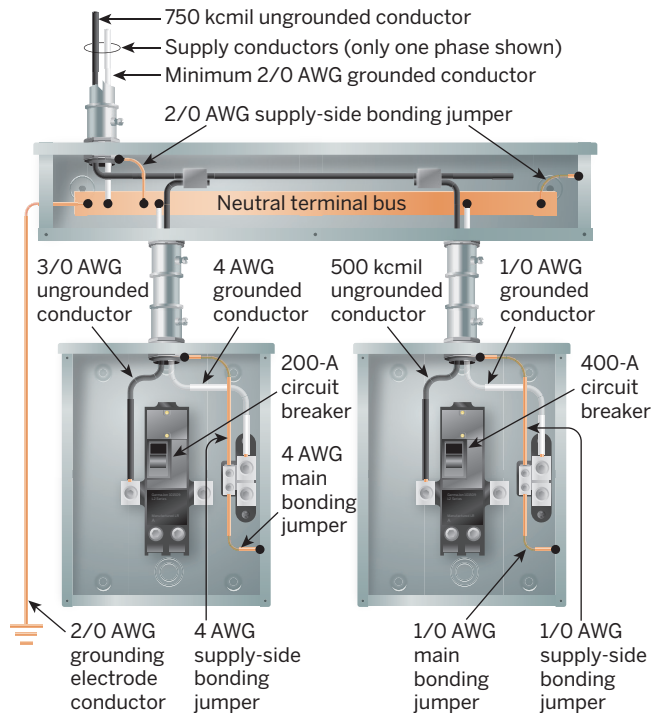
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jumper for the enclosure on the left is 4 AWG copper. The 1/0 AWG main bonding jumper for the enclosure on the right must be derived from Table 250.102(C)(1) based on the 500 kcmil ungrounded service conductors. The bonding jumper provided by the manufacturer for listed service equipment provides the equivalent current capacity to that of a field-fabricated bonding jumper sized per Table 250.102(C)(1).

### Separately Derived System with More Than One Enclosure

To prevent parallel neutral current paths in raceways and enclosures, the system bonding jumper can be either be internal to the panelboards or installed at the separately derived system enclosure so that it connects any supply-side bonding jumpers to the system grounded conductor terminal. The system bonding jumper cannot be installed at both locations.



An example of the bonding requirements for service equipment.

### Sizing Equipment Grounding Conductors Using Table 250.122

Table 250.122 is used to size the equipment grounding conductor (EGC) for grounding raceways and equipment. Unlike Table 250.66 and Table 250.102(C)(1), which both utilize the size of the ungrounded conductor as the determining factor for sizing, Table 250.122 uses the rating of the overcurrent protective device (OCPD) ahead of the equipment or load that is being supplied to properly size the EGC.

#### Table Tips

1. In the first column, select the rating that matches the OCPD protecting the circuit. If the rating of the OCPD that is protecting the circuit is not shown, the next higher rating should be chosen. For example, if the OCPD protecting the circuit is rated at 30 A, which is not included in the table, the

**Table 250.122 Minimum Size Equipment Grounding Conductors for Grounding Raceway and Equipment**

| Rating or Setting of Automatic Overcurrent Device in Circuit Ahead of Equipment, Conduit, etc., Not Exceeding (Amperes) | Size (AWG or kcmil) |                                   |
|---|---------------------|-----------------------------------|
|   | Copper              | Aluminum or Copper-Clad Aluminum* |
| 15  | 14                  | 12                                |
| 20  | 12                  | 10                                |
| 60  | 10                  | 8                                 |
| 100   | 8                   | 6                                 |
| 200   | 6                   | 4                                 |
| 300   | 4                   | 2                                 |
| 400   | 3                   | 1                                 |
| 500   | 2                   | 1/0                               |
| 600   | 1                   | 2/0                               |
| 800   | 1/0                 | 3/0                               |
| 1000  | 2/0                 | 4/0                               |
| 1200  | 3/0                 | 250                               |
| 1600  | 4/0                 | 350                               |
| 2000  | 250                 | 400                               |
| 2500  | 350                 | 600                               |
| 3000  | 400                 | 600                               |
| 4000  | 500                 | 750                               |
| 5000  | 700                 | 1250                              |
| 6000  | 800                 | 1250                              |

Note: Where necessary to comply with 250.4(A)(5) or (B)(4), the equipment grounding conductor shall be sized larger than given in this table.

\*See installation restrictions in 250.120.



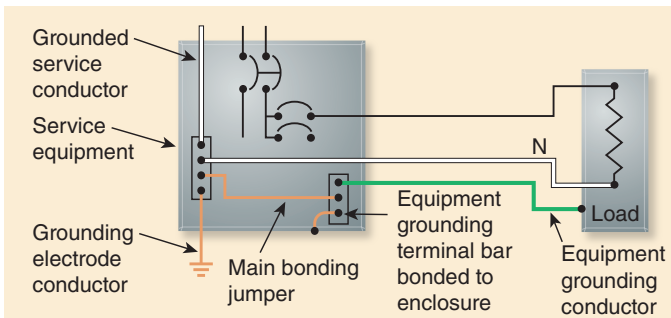
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next higher size, which is 60 A, should be selected, resulting in a 10 AWG copper EGC for this circuit.

- If the ungrounded circuit conductors are increased in size for any reason other than temperature correction or due to the number of current-carrying conductors in a raceway, the EGC must be increased proportionally. For more details, see the following section and its associated Application Example.

Generally, the minimum-sized EGC is selected from Table 250.122 based on the rating or setting of the feeder or branch-circuit OCPD(s). Where the ungrounded circuit conductors are increased in size to compensate for voltage drop, the EGCs must be increased proportionately. This will lower the overall impedance of the ground-fault current return path, which will facilitate the operation of the OCPD in the event of a line-to-ground fault.



Grounding and bonding arrangement for grounded systems, per 250.130(A), illustrating connection of the EGC (bus) to the enclosures and to the grounded service conductor

### Application Example

A 240-V, single-phase, 250-A load is supplied by a 300-A breaker located in a panelboard 500 ft away. The conductors are 250 kcmil copper installed in rigid nonmetallic conduit with a 4 AWG copper EGC. If the conductors are increased to 350 kcmil, what is the minimum required size of the EGC based on the proportional increase requirement?

**STEP 1.** Calculate the size ratio of the new conductors to the existing conductors:

$$\text{Size ratio} = \frac{350,000 \text{ circular mils}}{250,000 \text{ circular mils}} = 1.4$$

**STEP 2.** Calculate the cross-sectional area of the new EGC:

$$41,740 \text{ circular mils} \times 1.4 = 58,436 \text{ circular mils}$$

According to Table 8 of Chapter 9, the size of the existing grounding conductor, 4 AWG, has a cross-sectional area of 41,740 circular mils.

**STEP 3.** Determine the size of the new EGC. Again, referring to Chapter 9, Table 8, we find that 58,436 circular mils is too large for a 3 AWG EGC. The next larger size is 66,360 circular mils, which converts to a 2 AWG copper EGC.

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