This article provides the requirements for sizing branch circuits, feeders, and services, and for determining the number of receptacles on a circuit and the number of branch circuits required. It consists of five parts:

- Part I. General
- Part II. Branch-Circuit Load Calculations
- Part III. Feeder and Service Calculations
- Part IV. Optional Calculations
- Part V. Farm Load Calculations

Part I describes the layout of Article 220 and provides a table of where other types of load calculations can be found in the NEC. Part II provides requirements for branch-circuit calculations and for specific types of branch circuits. Part III provides requirements for feeder and service calculations. Part IV provides shortcut calculations in place of the more complicated calculations provided in Parts II and III—if an installation meets certain requirements. Part IV provides calculations that apply only to farms.

Electricians should focus on Parts I, II, and III. Whether to do the optional calculations in Part IV is typically a decision made by the project manager or design engineer. You need to be aware that there can be two right answers when doing the calculations because the NEC allows two different methods.

The cost of improperly applying Article 220 can be staggering. In the best case, making a mistake just involves an expensive call-back and some rework. But the costs can easily involve catastrophic destruction and loss of human life.

**PART I. GENERAL**

**220.1 Scope.** This article contains the requirements necessary for sizing branch circuits, feeders, and services. In addition, this article can be used to determine the number of receptacles on a circuit and the number of general-purpose branch circuits required.

**220.3 Application of Other Articles.** Other articles contain calculations that are in addition to, or modify those, contained within Article 220. Take a moment to review the following additional calculation requirements:

- Air-conditioning and refrigeration equipment, 440.6, 440.21, 440.22, 440.31, 440.32, and 440.62
- Appliances, 422.10 and 422.11
- Branch Circuits, 210.19 and 210.20(A)
- Computers (Data Processing Equipment), 645.4 and 645.5(A)
- Conductors, 310.15
- Feeders, 215.2(A) and 215.3
- Fire Pumps, 695.7
- Fixed Electric Space-Heating Equipment, 424.3(B)
- Marinas, 555.12, 555.19(A)(4), and 555.19(B)
- Mobile Homes and Manufactured Homes, 550.12 and 550.18
- Motors, 430.6(A), 430.22(A), 430.24, 430.52, and 430.62
- Overcurrent Protection, 240.4 and 240.20
- Refrigeration (Hermetic), 440.6 and Part IV
- Recreational Vehicle Parks, 551.73(A)
220.5 Calculations.

(A) Voltage Used for Calculations. Unless other voltages are specified, branch-circuit, feeder, and service loads must be calculated on nominal system voltage, such as 120V, 120/240V, 120/208V, 240V, 277/480V, or 480V. Figure 220–1

(B) Fractions of an Ampere (Rounding Amperes). Calculations that result in a fraction of less than one-half of an ampere can be dropped.

AUTHOR’S COMMENT: When do you round—after each calculation, or at the final calculation? The NEC isn’t specific on this issue, but I guess it all depends on the answer you want to see!

Question: According to 424.3(B), the branch-circuit conductors and overcurrent protection device for electric space-heating equipment must be sized no less than 125 percent of the total load. What size conductor is required to supply a 9 kW (37.5A), 240V single-phase fixed space heater with a 3A blower motor, if equipment terminals are rated 75°C? Figure 220–2

Answer: (c) 6 AWG

Step 1: Determine the total load.

\[ I = \frac{VA}{E} \]
\[ I = \frac{9,000 \text{ VA}}{240\text{V}} \]
\[ I = 37.5\text{A} \]

Step 2: Conductor size at 125% of the load.

Conductor Size = \((37.5\text{A} + 3\text{A}) \times 1.25\)

Conductor Size = 50.63A, round up to 51A

If we rounded down, then 8 AWG rated 50A at 75°C could be used, but since we have to round up, 6 AWG rated 65A at 75°C is required.

PART IV. OPTIONAL CALCULATIONS FOR COMPUTING FEEDER AND SERVICE LOADS

220.82 Dwelling Unit—Optional Load Calculation.

(A) Feeder/Service Load. The 3-wire feeder/service load for a dwelling unit can be calculated by adding the calculated loads from 220.82(B) and (C). The feeder/service neutral calculated load must be determined in accordance with 220.61.

(B) General Loads. The feeder/service calculated load must not be less than 100 percent of the first 10 kVA, plus 40 percent of the remainder of the following:
1 General Lighting. 3 VA per sq ft for general lighting and general-use receptacles. The floor area must be calculated from the outside dimensions of the dwelling unit, not including open porches, garages, or unused or unfinished spaces not adaptable for future use.

2 Small-Appliance and Laundry Circuits. A load of 1,500 VA for each 20A small-appliance and laundry branch circuit. Since two small-appliance circuits and a laundry circuit are required, the minimum will be 4,500 VA.

3 Appliances. The nameplate rating of all appliances fastened in place, permanently connected or located to be on a specific circuit must be included.

4 Motor VA. The VA nameplate rating of all motors.

C Air-Conditioning and Heating Equipment. The largest of (1) through (6):

1 Air-Conditioning Equipment. 100 percent of the nameplate rating(s).

2 Heat-Pump Compressor without Supplemental Heating. 100 percent of the nameplate rating(s).

3 Thermal Storage Heating. 100 percent of the nameplate rating(s).

AUTHOR’S COMMENT: One form of thermal storage heating involves heating bricks or water at night when the electric rates are lower. Then during the day, the building uses the thermally stored heat.

4 Heat-Pump Compressor and Supplemental Heating. 100 percent of the nameplate rating(s) of the heat-pump compressor and 65 percent of the supplemental electric heating for central electric space-heating systems. If the heat-pump compressor is prevented from operating at the same time as the supplementary heat, it can be omitted in the calculation.

5 Space-Heating Units (three or fewer units). 65 percent of the nameplate rating(s).

6 Space-Heating Units (four or more units). 40 percent of the nameplate rating(s).

Question: Using the optional calculation method, what size 3-wire, single-phase, 120/240V feeder/service conductor is required for a 1,500-sq ft dwelling unit that contains the following loads?

- Dishwasher 1,200 VA
- Water heater 4,500 VA
- Disposal 900 VA
- Dryer 4,000 VA
- Cooktop 6,000 VA
- Oven 3,000 VA

- Heat pump 5 hp compressor, a with a 7 kW supplemental electric heat that operates with the heat pump

(a) 100A (b) 110A (c) 125A (d) 150A

Answer: (c) 125A

Step 1: Determine the total feeder/service calculated load.

Lighting, receptacles, and appliance calculated load (220.82(B)):

<table>
<thead>
<tr>
<th>Component</th>
<th>VA</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small appliance</td>
<td>1,500</td>
<td>1,500 VA x 2</td>
</tr>
<tr>
<td>Laundry</td>
<td>1,500</td>
<td>1,500 VA x 1</td>
</tr>
<tr>
<td>General lighting</td>
<td>1,500</td>
<td>(1,500 sq ft x 3 VA/sq ft)</td>
</tr>
<tr>
<td>Dishwasher</td>
<td>1,200</td>
<td>1,200 VA x 1</td>
</tr>
<tr>
<td>Water heater</td>
<td>4,500</td>
<td>4,500 VA x 1</td>
</tr>
<tr>
<td>Disposal</td>
<td>900</td>
<td>900 VA x 1</td>
</tr>
<tr>
<td>Dryer</td>
<td>4,000</td>
<td>4,000 VA x 1</td>
</tr>
<tr>
<td>Cooktop</td>
<td>6,000</td>
<td>6,000 VA x 1</td>
</tr>
<tr>
<td>Oven</td>
<td>3,000</td>
<td>3,000 VA x 1</td>
</tr>
</tbody>
</table>

Total calculated load 220.82(B) = 28,600 VA

Step 2: Feeder/service calculated load in amperes:

\[ I = \frac{VA}{E} \]

\[ I = \frac{28,430}{240} = 119A, 2 AWG [215.2(A)(3) and 310.15(B)(6)] \]

220.84 Multifamily—Optional Load Calculation.

(A) Feeder or Service Load. The feeder/service calculated load for a building with three or more dwelling units equipped with electric cooking equipment, and either electric space heating or air-conditioning, can be in accordance with the demand factors of Table 220.84 based on the number of dwelling units. The feeder/service neutral calculated load must be determined in accordance with 220.61.
(B) **House Loads.** House loads are calculated in accordance with Part III of Article 220 and then added to the Table 220.84 calculated load.

**AUTHOR’S COMMENT:** House loads are those not directly associated with the individual dwelling units of a multifamily dwelling. Some examples of house loads could be landscape and parking lot lighting, common area lighting, common laundry facilities, common pool and recreation areas, etc.

(C) **Connected Loads.** The connected loads from all of the dwelling units are added together, and then the Table 220.84 demand factors are applied to determine the calculated load.

(1) 3 VA per sq ft for general lighting and general-use receptacles.
(2) 1,500 VA for each small-appliance circuit (minimum of 2 circuits [220.52(A)], and 1,500 VA for each laundry circuit.

**AUTHOR’S COMMENT:** A laundry circuit isn’t required in an individual unit of a multifamily dwelling if common laundry facilities are provided.

(3) The nameplate rating of all appliances.
(4) The nameplate rating of all motors.
(5) The larger of air-conditioning load or space-heating load.

**Question:** What size 120/208V three-phase service is required for a multifamily building with twenty 1,500 sq ft dwelling units, where each unit contains the following loads?

- Dishwasher 1,200 VA
- Water heater 4,500 VA
- Disposal 900 VA
- Dryer 4,000 VA
- Cooktop 6,000 VA
- Oven 3,000 VA
- Heat 7,000 VA
- A/C, 5 hp compressor 6,440 VA

(a) 400A  (b) 600A  (c) 800A  (d) 1,200A

**Answer:** (c) 800A, 240.4 and 240.6(A)

---

**Step 1:** Determine the dwelling unit connected load:
- General lighting 1,500 sq ft x 3 VA/sq ft = 4,500 VA
- Small appliance 1,500 x 2 = 3,000 VA
- Laundry = 1,500 VA
- Dishwasher = 1,200 VA
- Water heater = 4,500 VA
- Disposal = 900 VA
- Dryer = 4,000 VA
- Cooktop = 6,000 VA
- Oven = 3,000 VA
- A/C 5 hp (omit) = 0 VA
- Heat = + 7,000 VA
- Total Dwelling Unit Load = 35,600 VA

**Step 2:** Determine the calculated load for the multifamily building:

35,600 VA x 20 x 0.38 = 270,560 VA

**Step 3:** Determine feeder/service conductor size:

\[
I = \frac{VA}{E \times \sqrt{3}}
\]

\[
I = \frac{270,560 \text{ VA}}{208 \text{V} \times 1.732}
\]

\[I = 751 \text{A}
\]

\[I \text{ of each conductor parallel set} = 751 \text{A/2 conductors}
\]

\[I \text{ of each conductor parallel set} = 376 \text{A}
\]

Conductor = 500 kcmil, rated 380A x 2
\[= 760 \text{A, Table 316.16}
\]

---

**220.85 Optional Calculation—Two Dwelling Units.**

Where two dwelling units are supplied by a single feeder and where the standard calculated load in accordance with Part II of this article exceeds that for three identical units computed in accordance with 220.84, the lesser of the two calculated loads may be used.

**220.87 Determining Existing Loads.** The calculation of a feeder or service load for existing installations can be based on:

(1) The maximum demand data is available for a 1-year period. 

**Exception:** The maximum power demand over a 15-minute period continuously recorded over a minimum 30-day period using a recording ammeter or power meter connected to the highest loaded phase, based on the initial loading at the start of the recording. The recording must be taken when the building or space is occupied based on the larger of the heating or cooling equipment load.
This article covers installation requirements for service conductors and equipment. It consists of seven parts:

- Part I. General
- Part II. Overhead Service-Drop Conductors
- Part III. Underground Service-Lateral Conductors
- Part IV. Service-Entrance Conductors
- Part V. Service Equipment
- Part VI. Disconnecting Means
- Part VII. Overcurrent Protection

The requirements for service conductors differ from those for other conductors. For one thing, service conductors for one structure cannot pass through the interior of another structure, and different rules apply depending on whether a service conductor is inside or outside a structure. When are they “outside” as opposed to “inside?” The answer may seem obvious, but isn’t.

It’s usually good to start a service installation by deciding which conductors are actually parts of the service. What’s decided here determines how to do the rest of the job. To identify a service conductor, first determine whether you’re dealing with a service (line side) or a premises (load side) distribution point.

The following definitions in Article 100 help explain when the requirements of Article 230 apply:

- **Service Point**—The point of connection between the facilities of the serving utility and the premises wiring.
- **Service Conductors**—The conductors from the service point to the service disconnecting means (service equipment, not meter). Service-entrance conductors may be either overhead (service drop) or underground (service lateral).
- **Service Equipment**—The necessary equipment, usually consisting of circuit breakers or fused switches, connected to the load end of service conductors in a building or other structure (or an otherwise designated area), and intended to constitute the main control and cutoff of the electricity supply. Service equipment doesn’t include the metering equipment, such as watthour meters and enclosures.

These definitions make it clear that service conductors originate at the serving utility (service point) and terminate on the line side of the service disconnecting means (service equipment). Conductors and equipment on the load side of service equipment are considered feeder conductors, which must be installed in accordance with Articles 215 and 225. Feeders include:

- Secondary conductors from customer-owned transformers.
- Conductors from generators, UPS systems, transformers, batteries, phase converters, or photovoltaic systems.
- Conductors to remote buildings or structures.
PART I. GENERAL

230.7 Service Conductors Separate from Other Conductors. Service conductors cannot be installed in the same raceway or cable with feeder or branch-circuit conductors. Figure 230–5

WARNING: Overcurrent protection for the feeder conductors could be bypassed if service conductors were mixed with nonservice conductors in the same raceway and a fault occurred between the service and nonservice conductors.

AUTHOR’S COMMENTS:
- This rule doesn’t prohibit the mixing of service, feeder, and branch-circuit conductors in the same “service equipment enclosure.” Figure 230–6

230.8 Raceway Seals. Underground raceways (used or unused) must be sealed or plugged to prevent moisture from contacting energized live parts [300.5(G)].

AUTHOR’S COMMENT: Sealing can be accomplished with the use of a putty-like material called duct seal or a fitting identified for the purpose. A seal of the type required in Chapter 5 for hazardous (classified) locations isn’t required.
PART V. SERVICE EQUIPMENT—GENERAL

230.66 Identified as Suitable for Service Equipment.
The service disconnecting means must be identified as suitable for use as service equipment.

AUTHOR’S COMMENT: Suitable for use as service equipment means that the service disconnecting means is supplied with a main bonding jumper so that a neutral-to-case connection can be made, as permitted in 250.32(B)(2) and 250.142(A).

Figure 230–22

PART VI. SERVICE EQUIPMENT—DISCONNECTING MEANS

230.70 General. The service disconnecting means must open all service-entrance conductors from the building or structure premises wiring.

(A) Location.

(1) Readily Accessible. The service disconnecting means must be placed at a readily accessible location either outside the building or structure, or inside nearest the point of service conductor entry.

WARNING: Because service-entrance conductors do not have short-circuit or ground-fault protection, they must be limited in length when installed inside a building. Some local jurisdictions have a specific requirement as to the maximum length permitted within a building. Figure 230–23

(2) Bathrooms. The service disconnecting means is not permitted to be installed in a bathroom. Figure 230–24
AUTHOR’S COMMENT: Overcurrent protection devices must not be located in the bathrooms of dwelling units, or guest rooms or guest suites of hotels or motels [240.24(E)].

(3) Remote Control. Where a remote-control device (shunt-trip) is used to actuate the service disconnecting means, the service disconnecting means must still be at a readily accessible location either outside the building or structure, or nearest the point of entry of the service conductors as required by 230.70(A)(1). Figure 230–25

AUTHOR’S COMMENTS:
• See the definition of “Remote Control” in Article 100.
• The service disconnecting means must consist of either a manually operated switch, or a power-operated switch or circuit breaker also capable of being operated manually [230.76].

(B) Disconnect Identification. Each service disconnecting means must be permanently marked to identify it as part of the service disconnecting means. Figure 230–26

AUTHOR’S COMMENT: When a building or structure has multiple services and/or feeders, a plaque is required at each service or feeder disconnect location to show the location of the other service or feeder disconnect locations. See 230.2(E).

230.71 Number of Disconnects.

(A) Maximum. There must be no more than six service disconnects for each service permitted by 230.2, or each set of service-entrance conductors permitted by 230.40, Exceptions Nos. 1, 3, 4, or 5.
The service disconnecting means can consist of up to six switches or six circuit breakers mounted in a single enclosure, in a group of separate enclosures, or in or on a switchboard. **Figure 230–27**

**CAUTION:** The rule is six disconnecting means for each service, not six service disconnecting means per building. If the building has two services, then there can be a total of twelve service disconnects (six disconnects per service). **Figure 230–28**

The disconnecting means for power monitoring equipment, transient voltage surge suppressors, the control circuit of the ground-fault protection system, or power-operable service disconnecting means is not considered a service disconnecting means. **Figure 230–29**

### 230.72 Grouping of Disconnects.

**A** Two to Six Disconnects. The service disconnecting means for each service must be grouped.

**B** Additional Service Disconnecting Means. To minimize the possibility of accidental interruption of power, the disconnecting means for fire pumps [695], and emergency [700], legally required [701], or optional standby [702] systems must be located remote from the one to six service disconnects for normal service.

**AUTHOR'S COMMENT:** Because emergency systems are just as important, if not more so, than fire pumps and standby systems, they should have the same safety precautions to prevent unintended interruption of the supply of electricity.

**C** Access to Occupants. In a multiple-occupancy building, each occupant must have access to his or her service disconnecting means.
Exception: In multiple-occupancy buildings where electrical maintenance is provided by continuous building management, the service disconnecting means can be accessible only to building management personnel.

230.76 Manual or Power Operated. The service disconnecting means can consist of either a manually operated or a power-operated switch, or a circuit breaker that is capable of being operated manually. Figure 230–30

230.79 Rating of Disconnect. The service disconnecting means for a building or structure must have an ampere rating not less than the calculated load according to Article 220, and in no case less than:

(A) One-Circuit Installation. For installations consisting of a single branch circuit, the disconnecting means must have a rating not less than 15A.

(B) Two-Circuit Installation. For installations consisting of two 2-wire branch circuits, the disconnecting means must have a rating not less than 30A.

(C) One-Family Dwelling. For a one-family dwelling, the disconnecting means must have a rating not less than 100A, 3-wire.

(D) All Others. For all other installations, the disconnecting means must have a rating not less than 60A.

230.82 Equipment Connected to the Supply Side of the Service Disconnect. Electrical equipment must not be connected to the supply side of the service-disconnect enclosure, except for:

(2) Meters and meter sockets are permitted ahead of the service disconnecting means.

(3) Meter disconnect switches that have a short-circuit current rating equal to or greater than the available short-circuit current can be installed ahead of the service disconnecting means. Figure 230–31

Figure 230–30

AUTHOR’S COMMENT: A shunt-trip button does not qualify as a service disconnect because it does not physically interrupt the service conductors.

Figure 230–31

AUTHOR’S COMMENT: Electric utilities often require a meter disconnect switch for 277/480V services to enhance safety of utility personnel when they install or remove a meter.

(5) Tap conductors for legally required [701] and optional standby [702] power systems, fire-pump equipment, fire and sprinkler alarms, and load (energy) management devices are permitted ahead of the service disconnecting means.

AUTHOR’S COMMENT: Emergency standby power cannot be connected ahead of service equipment. Figure 230–32

(6) Solar photovoltaic systems, fuel cell systems, or interconnected electric power production sources are permitted ahead of the service disconnecting means.
(7) Control circuits for power-operable service disconnecting means, if suitable overcurrent protection and disconnecting means are provided, are permitted ahead of the service disconnecting means.

(8) Ground-fault protection systems or transient voltage surge suppressors, where installed as part of listed equipment, are permitted ahead of the service disconnecting means if suitable overcurrent protection and disconnecting means are provided.

PART VII. SERVICE EQUIPMENT
OVERCURRENT PROTECTION

AUTHOR’S COMMENT: The NEC doesn’t require service conductors to be provided with short-circuit or ground-fault protection, but the feeder protection device provides overload protection.

230.90 Overload Protection Required. Each ungrounded service conductor must have overload protection at the point where the service conductors terminate [240.21(D)]. Figure 230–33

(A) Overcurrent Protection Size. The rating of the protection device must not be greater than the ampacity of the conductors.

Exception No. 2: Where the ampacity of the ungrounded conductors doesn’t correspond with the standard rating of overcurrent protection devices as listed in 240.6(A), the next higher protection device can be used, if it doesn’t exceed 800A [240.4(B)].

Example: Two sets of parallel 500 kcmil THHN conductors (each rated 380A at 75°C) can be protected by an 800A overcurrent protection device. Figure 230–34

Figure 230–33

Figure 230–34
Exception No. 3: The combined ratings of two to six service disconnecting means can exceed the ampacity of the service conductors provided the calculated load, in accordance with Article 220, doesn’t exceed the ampacity of the service conductors. Figure 230–35

Exception No. 5: Overload protection for 3-wire, single-phase, 120/240V dwelling unit service conductors can be in accordance with 310.15(B)(6). Figure 230–36

230.95 Ground-Fault Protection of Equipment.
Ground-fault protection of equipment is required for each service disconnecting means rated 1,000A or more supplied by a 4-wire, three-phase, 277/480V wye-connected system.

The rating of the service disconnecting means is considered to be the rating of the largest fuse that can be installed or the highest continuous current trip setting for which the actual overcurrent protection device installed in a circuit breaker is rated or can be adjusted.

Exception No. 2: The ground-fault protection provision of this section does not apply to fire pumps.

AUTHOR’S COMMENTS:
• Article 100 defines “Ground-Fault Protection of Equipment” as a system intended to provide protection of equipment from ground faults by opening the circuit-protection device at current levels less than those required to protect conductors from damage. This type of protective system isn’t intended to protect people, only connected utilization equipment. See 215.10 for similar requirements for feeders.
• Ground-fault protection of equipment isn’t required for emergency power systems [700.26] or legally required standby power systems [701.17], because the goal is to have the alternate power supply operating as long as possible. Ground fault protection of equipment is required to be tested when first installed, and a record is required to be made available to the AHJ [230.95].
This article provides requirements for selecting and installing overcurrent protection devices. Overcurrent exists when current exceeds the rating of conductors or equipment. This can be due to overload, short circuit, or ground fault. Article 240 consists of nine parts:

Part I. General
Part II. Location
Part III. Enclosures
Part IV. Disconnecting and Guarding
Part V. Plug Fuses, Fuseholders, and Adapters
Part VI. Cartridge Fuses and Fuseholders
Part VII. Circuit Breakers
Part VIII. Supervised Industrial Installations
Part IX. Overcurrent Protection Over 600 Volts, Nominal

Basic concepts of overcurrent protection include the following:

- **Overload.** An overload is a condition where conductors carry current exceeding their rated ampacity. An example of an overload is plugging two 12.5A (1,500W) hair dryers into a 20A branch circuit.
- **Ground Fault.** A ground fault is an unintentional, electrically conducting connection between an ungrounded conductor of an electrical circuit and the normal noncurrent-carrying conductors, metallic enclosures, metallic raceways, metallic equipment, or earth. During the period of a ground fault, dangerous voltages and higher than normal currents exist.
- **Short Circuit.** A short circuit is an unintentional electrical connection between any two conductors of an electrical circuit, either line-to-line or line-to-neutral. Overcurrent protection devices protect conductors and equipment. But it’s important to note that they protect conductors differently than equipment.

An overcurrent protection device protects a circuit by opening when current reaches a value that would cause an excessive temperature rise in conductors. Using a water analogy, current rises like water in a tank—at a certain level, the overcurrent protection device shuts off the faucet. Think in terms of normal operating conditions that just get too far out of normal range.

Section 240.6 lists standard ratings for fuses and fixed-trip circuit breakers. Overcurrent protection devices are also required to have interrupting ratings sufficient for the maximum possible fault current available on the line-side terminals of the equipment, according to 110.9.

An overcurrent protection device protects equipment by opening the circuit when it detects a short circuit or ground fault. Short circuits and faults aren’t normal operating conditions. Thus, the overcurrent protection devices for equipment will have different characteristics than overcurrent protection devices for conductors.

Every piece of electrical equipment must have a short-circuit current rating that permits the overcurrent protection devices (for that equipment) to clear short circuits or ground faults without extensive damage to the electrical components of the circuit, according to 110.10.
PART I. GENERAL

240.1 Scope. Article 240 covers the general requirements for overcurrent protection and the installation requirements of overcurrent protection devices. Figure 240–1 This article is divided into seven parts:

- Part I. General
- Part II. Location
- Part III. Enclosures
- Part IV. Disconnecting and Grounding
- Part V. Plug Fuses, Fuseholders, and Adapters
- Part VI. Cartridge Fuses and Fuseholders
- Part VII. Circuit Breakers

AUTHOR’S COMMENT: Overcurrent is a condition where the current exceeds the rating of conductors or equipment due to overload, short circuit, or ground fault [Article 100]. Figure 240–2

FPN: An overcurrent protection device protects the circuit by opening the device when the current reaches a value that will cause excessive or dangerous temperature rise (overheating) in conductors. Overcurrent protection devices must have an interrupting rating sufficient for the maximum possible fault current available on the line-side terminals of the equipment [110.9]. Electrical equipment must have a short-circuit current rating that permits the circuit’s overcurrent protection device to clear short circuits or ground faults without extensive damage to the circuit’s electrical components [110.10].

240.2 Definitions.

Current-Limiting Overcurrent Protective Device. An overcurrent protective device (typically a fast-acting fuse) that reduces the fault current to a magnitude substantially less than that obtainable in the same circuit if the current-limiting device was not used. See 240.40 and 240.60(B). Figure 240–3

AUTHOR’S COMMENT: A current-limiting fuse is a type of fuse designed for operations related to short circuits only. When a fuse operates in its current-limiting range, it will clear a bolted short circuit in less than half a cycle. This type of fuse limits
the instantaneous peak let-through current to a value substantially less than what would occur in the same circuit if the fuse were replaced with a solid conductor of equal impedance. If the available short-circuit current exceeds the equipment/conductor short-circuit current rating, then the thermal and magnetic forces can cause the equipment circuit conductors, as well as the equipment grounding (bonding) conductors, to vaporize. The only solutions to the problem of excessive available fault current are to:

(1) Install equipment with a higher short-circuit rating, or
(2) Protect the components of the circuit by a current-limiting protection device such as a fast-clearing fuse, which can reduce the let-through energy.
(3) Install series rated components, in accordance with 240.86.

A breaker or a fuse does limit current, but it may not be listed as a current-limiting device. A thermal-magnetic circuit breaker will typically clear fault current in less than three to five cycles when subjected to a short circuit or ground fault of twenty times its rating. A standard fuse would clear the fault in less than one cycle and a current-limiting fuse should clear the same fault in less than one-quarter of one cycle.

**Tap Conductors.** A conductor, other than a service conductor, that has overcurrent protection rated greater than the ampacity of a conductor. See 240.21 for details. **Figure 240–4**

### 240.3 Protection of Equipment

The following equipment and their conductors are protected against overcurrent in accordance with the article that covers the type of equipment:

- Air-conditioning and refrigeration equipment, 440.22
- Appliances, Article 422
- Audio Circuits, 640.9
- Branch Circuits, 210.20
- Class 1, 2, and 3 Circuits, Article 725
- Feeder Conductors, 215.3
- Flexible Cords, 240.5(B)(1)
- Fire Alarms, Article 760
- Fire Pumps, Article 695
- Fixed Electric Space-Heating Equipment, 424.3(B)
- Fixture Wire, 240.5(B)(2)
- Panelboards, 408.36(A)
- Service Conductors, 230.90(A)
- Transformers, 450.3

### 240.4 Protection of Conductors

Except as permitted by (A) through (G), conductors must be protected against overcurrent in accordance with their ampacity after ampacity adjustment, as specified in 310.15.

(A) Power Loss Hazard. Conductor overload protection is not required, but short-circuit protection is required where the interruption of the circuit would create a hazard; such as in a material-handling electromagnet circuit or fire pump circuit.

(B) Overcurrent Protection Not Over 800A. The next higher standard rating overcurrent device (above the ampacity of the ungrounded conductors being protected) is permitted, provided all of the following conditions are met:

(1) The conductors do not supply multioutlet receptacle branch circuits.

(2) The ampacity of a conductor, after ampacity adjustment and/or correction, doesn’t correspond with the standard rating of a fuse or circuit breaker in 240.6(A).

(3) The protection device rating doesn’t exceed 800A.

**Example:** A 400A protection device can protect 500 kcmil conductors, where each conductor has an ampacity of 380A at 75°C, in accordance with Table 310.16. **Figure 240–5**

**AUTHOR’S COMMENT:** This definition is needed so that we can properly apply the tap rules in 240.21.
AUTHOR’S COMMENT: This rule “next size up” doesn’t apply to feeder tap conductors [240.21(B)], or secondary transformer conductors [240.21(C)].

(C) Overcurrent Protection Over 800A. If the circuit’s overcurrent protection device exceeds 800A, the conductor ampacity, after ampacity adjustment and/or correction, must have a rating not less than the rating of the overcurrent device.

Example: A 1,200A protection device can protect three sets of 600 kcmil conductors per phase, where each conductor has an ampacity of 420A at 75°C, in accordance with Table 310.16. Figure 240–6

(D) Small Conductors. Unless specifically permitted in 240.4(E) or (G), overcurrent protection must not exceed 15A for 14 AWG, 20A for 12 AWG, and 30A for 10 AWG copper, or 15A for 12 AWG and 25A for 10 AWG aluminum, after ampacity adjustment and/or correction. Figure 240–7

(E) Tap Conductors. Tap conductors must be protected against overcurrent as follows:

1. Household Ranges and Cooking Appliances and Other Loads, 210.19(A)(3) and (4)
2. Fixture Wire, 240.5(B)(2)
3. Location in Circuit, 240.21
4. Reduction in Ampacity Size of Busway, 368.17(B)
5. Feeder or Branch Circuits (busway taps), 368.17(C)
6. Single Motor Taps, 430.53(D)

(F) Transformer Secondary Conductors. The primary overcurrent protection device sized in accordance with 450.3(B) can protect the secondary conductors of a 2-wire system or a 3-wire, delta/delta-connected, three-phase system, provided the primary protection device does not exceed the value determined by multiplying the secondary conductor ampacity by the secondary-to-primary transformer voltage ratio.
**Question:** What is the minimum size secondary conductor required for a 2-wire 480V to 120V transformer rated 1.5 kVA? Figure 240–8  
(a) 16 AWG  
(b) 14 AWG  
(c) 12 AWG  
(d) 10 AWG

**Answer:** (b) 14 AWG

Primary Current = \( \frac{VA}{E} \)

\[ \text{VA} = 1,500 \text{ VA} \]
\[ E = 480 \text{V} \]

Primary Current = 3.13A

Primary Protection \( \{450.3(B)\} = 3.13 \times 1.67 \)

Primary Protection = 5.22A or 5A Fuse

Secondary Current = \( \frac{VA}{120} \text{V} \)

Secondary Current = 12.5A

Secondary Conductor = -14 AWG, rated 20A at 60C, Table 310.16

The 5A primary protection device can be used to protect 14 AWG secondary conductors because it doesn’t exceed the value determined by multiplying the secondary conductor ampacity by the secondary-to-primary transformer voltage ratio (5A = 20A x 120V/480V)

**Author's Comment:** Typically, the branch-circuit ampacity and protection size is marked on the equipment nameplate [440.4(A)].

**Question:** What size branch-circuit protection device is required for an air conditioner when the nameplate indicates that the minimum circuit ampacity (MCA) is 23A, and the running load is 18A? Figure 240–9  
(a) 12 AWG, 40A protection  
(b) 12 AWG, 50A protection  
(c) 12 AWG, 60A protection  
(d) 12 AWG, 70A protection

**Answer:** (a) 12 AWG, 40A fuses

**Step 1:** Branch-Circuit Conductor Size [440.32]

\[ 18A \times 1.25 = 22.5A, \text{ 12 AWG rated 25A at 60C} \]

**Step 2:** Branch-Circuit Protection Size [440.22(A)]

\[ 18A \times 2.25 = 40.5A, \text{ 40A maximum fuse size (fuses in accordance with the manufacturer’s instructions) [110.3(B) and 240.6(A)]} \]

**Motors [Article 430].** Motor circuit conductors must be protected against short circuits and ground faults in accordance with 430.52 and 430.62 [430.51].
Question: What size branch-circuit conductor and protection device (circuit breaker) is required for a 7½ hp, 230V three-phase motor?

Figure 240–10

(a) 10 AWG, 50A breaker  
(b) 10 AWG, 60A breaker  
(c) a or b  
(d) none of these

Answer: (c) 10 AWG, 50A or 60A breaker

Step 1: Branch-Circuit Conductor Size [Table 310.16, 430.22, and Table 430.250]

22A x 1.25 = 28A, 10 AWG, rated 30A at 60°C

Step 2: Branch-Circuit Protection Size [240.6(A), 430.52(C)(1) Exception No. 1, Table 430.250]

Inverse Time Breaker: 22A x 2.5 = 55A

Next size up = 60A

Motor Control [Article 430]. Motor control circuit conductors must be sized and protected in accordance with 430.72.

Remote-Control, Signaling, and Power-Limited Circuits [Article 725]. Remote-control, signaling, and power-limited circuit conductors must be protected against overcurrent according to 725.23 and 725.41.

AUTHOR’S COMMENT: Fuses rated less than 15A are sometimes required for the protection of fractional horsepower motor circuits [430.52], motor control circuits [430.72], small transformers [450.3(B)], and remote-control circuit conductors [725.23].

(B) Adjustable Circuit Breakers. The ampere rating of an adjustable circuit breaker is equal to its maximum long-time pickup current setting.

(C) Restricted Access, Adjustable-Trip Circuit Breakers. The ampere rating of adjustable-trip circuit breakers that have restricted access to the adjusting means is equal to their adjusted long-time pickup current settings.

PART II. LOCATION

240.20 Ungrounded Conductors.

(B) Circuit Breaker as an Overcurrent Device. Circuit breakers must open all ungrounded conductors of the circuit, unless otherwise permitted in 240.20(B)(1), (B)(2), and (B)(3).

(1) Multiwire Branch Circuit. Except where limited by 210.4(B), individual single-pole breakers can be installed on each ungrounded conductor of a multiwire branch circuit that supplies only line-to-neutral loads. Figure 240–13
AUTHOR'S COMMENTS:

- Multiwire branch circuits that supply switches, receptacles, or equipment on the same yoke must be provided with a means to disconnect simultaneously all ungrounded conductors that supply those devices or equipment at the point where the branch circuit originates [210.4(B) and 210.7(B)]. This can be accomplished by single-pole circuit breakers with handle ties identified for the purpose or a 2- or 3-pole breaker with common internal trip. Figure 240–14

- Single-pole AFCI or GFCI circuit breakers are not suitable for protecting multiwire branch circuits. AFCI or GFCI circuit breakers for multiwire branch circuits must be of the 2-pole type.

2) Single-Phase, Line-to-Line Loads. Individual single-pole circuit breakers with handle ties identified for the purpose are permitted on each ungrounded conductor of a branch circuit that supplies single-phase, line-to-line loads. Figure 240–15

(3) Three-Phase, Line-to-Line Loads. Individual single-pole circuit breakers with handle ties identified for the purpose are permitted on each ungrounded conductor of a branch circuit that serves three-phase, line-to-line loads. Figure 240–16

AUTHOR'S COMMENT: Handle ties must be identified for the purpose. This means that handle ties made from nails, screws, wires, or other nonconforming methods are not permitted. Figure 240–17

240.21 Overcurrent Protection Location in Circuit

Except as permitted by (A) through (G), overcurrent protection devices must be placed at the point where the branch or feeder conductors receive their power.

A tap conductor cannot supply another tap conductor. In other words, you cannot make a tap from a tap.
(A) **Branch-Circuit Taps.** Branch-circuit taps installed in accordance with 210.19 are permitted.

(B) **Feeder Tap Conductors.** Conductors can be tapped from a feeder if they are installed in accordance with (1) through (5). The “next size up protection rule” for conductors contained in 240.4(B) is not permitted to be used for feeder tap conductors.

**Question:** What size tap conductor would be required for a 150A circuit breaker if the calculated continuous load was 100A?  

(a) 3 AWG, rated 100A  
(b) 2 AWG, rated 115A  
(c) 1 AWG, rated 130A  
(d) 1/0 AWG, rated 150A

**Answer:** (d) 1/0 AWG tap conductors would be required to supply the circuit breaker.

**AUTHOR’S COMMENT:** 1 AWG conductor, which is rated 130A [Table 310.16], can be protected by a 150A circuit breaker [240.4(B)].

1. **10-Foot Feeder Tap.** Feeder tap conductors up to 10 ft long are permitted without overcurrent protection if installed as follows: Figure 240–19

   (1) The ampacity of the tap conductor must not be less than:

   a. The calculated load in accordance with Article 220, and

   b. The rating of the device supplied by the tap conductors or the overcurrent protective device at the termination of the tap conductors.

   (2) The tap conductors must not extend beyond the equipment they supply.

   (3) The tap conductors must be installed in a raceway if they leave the enclosure.
(4) The tap conductors must have an ampacity not less than 10 percent of the ampacity of the overcurrent protection device that protects the feeder.

(2) **25-Foot Feeder Tap.** Feeder tap conductors up to 25 ft long are permitted without overcurrent protection if installed as follows: Figure 240–20

(1) The ampacity of the tap conductors must not be less than one-third the ampacity of the overcurrent protection device.

(2) The tap conductors terminate in a single circuit breaker or set of fuses rated no greater than the tap conductor ampacity in accordance with 310.15 [Table 310.16].

(3) The tap conductors must be protected from physical damage by being enclosed in a manner approved by the authority having jurisdiction, such as within a raceway.

(3) **Taps Supplying a Transformer.** Feeder tap conductors that supply a transformer must be installed as follows:

(1) The primary tap conductors must have an ampacity not less than one-third the ampacity of the overcurrent protection device.

(2) The secondary conductors must have an ampacity that, when multiplied by the ratio of the primary-to-secondary voltage, is at least one-third the rating of the overcurrent device that protects the feeder conductors.

(3) The total length of the primary and secondary conductors must not exceed 25 ft.

(4) Primary and secondary conductors must be protected from physical damage by being enclosed in a manner approved by the authority having jurisdiction, such as within a raceway.

(5) Secondary conductors terminate in a single circuit breaker, or set of fuses rated no greater than the tap conductor ampacity in accordance with 310.15 [Table 310.16].

(4) **100 Ft Tap.** Feeder tap conductors in a high bay manufacturing building (over 35 ft high at walls) can be run up to 100 ft without overcurrent protection if installed as follows:

(1) Supervision ensures that only qualified persons service the systems.

(2) Tap conductors aren’t over 25 ft long horizontally and not over 100 ft in total length.

(3) The ampacity of the tap conductors must not be less than one-third the ampacity of the overcurrent protection device that protects the feeder.

(4) The tap conductors terminate in a single circuit breaker or set of fuses rated no greater than the tap conductor ampacity in accordance with 310.15 [Table 310.16].

(5) Tap conductors must be protected from physical damage by being enclosed in a manner approved by the authority having jurisdiction, such as within a raceway.

(6) Tap conductors contain no splices.

(7) Tap conductors are 6 AWG copper or 4 AWG aluminum or larger.

(8) Tap conductors do not penetrate walls, floors, or ceilings.

(9) The tap is made no less than 30 ft from the floor.
(5) **Outside Feeder Tap of Unlimited Length Rule.** Outside feeder tap conductors can be of unlimited length without overcurrent protection at the point they receive their supply if installed as follows: Figure 240–21

1. The tap conductors must be suitably protected from physical damage in a raceway or manner approved by the authority having jurisdiction.
2. The tap conductors terminate at a single circuit breaker or a single set of fuses that limit the load to the ampacity of the conductors.
3. The overcurrent device for the tap conductors must be an integral part of the disconnecting means or it must be located immediately adjacent to it.
4. The disconnecting means must be located at a readily accessible location either outside the building or structure, or nearest the point of entry of the conductors.

(C) **Transformer Secondary Conductors.** Each set of conductors feeding separate loads can be connected to a transformer secondary, without overcurrent protection at the secondary, in accordance with (1) through (6).

The “next size up protection rule” for conductors contained in 240.4(B) is not permitted to be used for transformer secondary conductors. Figure 240–22

3-wire, delta/delta-connected, three-phase system, provided the primary protection device does not exceed the value determined by multiplying the secondary conductor ampacity by the secondary-to-primary transformer voltage ratio.

**Question:** What is the minimum size secondary conductor required for a 2-wire, 480V to 120V transformer rated 1.5 kVA? Figure 240–23

(a) 16 AWG  (b) 14 AWG  (c) 12 AWG  (d) 10 AWG

**Answer:** (b) 14 AWG

(1) **Protection by Primary Overcurrent Device.** The primary overcurrent protection device sized in accordance with 450.3(B) can protect the secondary conductors of a 2-wire system or a
Primary Current = \( \frac{VA}{E} \)

\[ VA = 1,500 \text{ VA} \]

\[ E = 480 \text{V} \]

Primary Current = 1,500 VA/480V

Primary Protection \([450.3(B)]\) = 3.13A

Secondary Current = 1,500 VA/120V

Secondary Current = 12.5A

Secondary Conductor = 14 AWG, rated 20A at 60ºC, Table 310.16

The 5A primary protection device can be used to protect 14 AWG secondary conductors because it doesn’t exceed the value determined by multiplying the secondary conductor ampacity by the secondary-to-primary transformer voltage ratio (5A = 20A x 120V/480V).

(2) 10 Ft Secondary Conductor. Secondary conductors can be run up to 10 ft without overcurrent protection if installed as follows: Figure 240–24

Author’s Comment: Lighting and appliance branch-circuit panelboards must have overcurrent protection located on the secondary side of the transformer \([408.36(D)]\). Figure 240–25

(3) Industrial Installation Secondary Conductors Not Over 25 Ft. For industrial installations, secondary conductors can be run up to 25 ft without overcurrent protection if installed as follows:

(1) The secondary conductor ampacity isn’t less than:

a. The calculated load in accordance with Article 220,

b. The rating of the device supplied by the secondary conductors or the overcurrent protective device at the termination of the secondary conductors, and
c. Not less than one-tenth the rating of the overcurrent device protecting the primary of the transformer, multiplied by the primary-to-secondary transformer voltage ratio.

(2) Secondary overcurrent devices are grouped.

(3) Secondary conductors must be protected from physical damage by being enclosed in a raceway or manner approved by the authority having jurisdiction.

(4) Outside Secondary Conductors of Unlimited Length. Outside secondary conductors can be of unlimited length without overcurrent protection at the point they receive their supply if they are installed as follows: Figure 240–26
(1) The conductors must be suitably protected from physical damage in a raceway or manner approved by the authority having jurisdiction.

(2) The conductors terminate at a single circuit breaker or a single set of fuses that limit the load to the ampacity of the conductors.

(3) The overcurrent device for the ungrounded conductors must be an integral part of a disconnecting means or it must be located immediately adjacent thereto.

(4) The disconnecting means must be located at a readily accessible location that complies with one of the following:
   a. Outside of a building or structure.
   b. Inside, nearest the point of entrance of the conductors.
   c. Where installed in accordance with 230.6, nearest the point of entrance of the conductors.

(5) Secondary Conductors from a Feeder Tapped Transformer. Transformer secondary conductors must be installed in accordance with 240.21(B)(3).

(6) 25-Foot Secondary Conductor. Secondary conductors can be run up to 25 ft without overcurrent protection if they comply with all of the following: Figure 240–27

   (1) The secondary conductors have an ampacity that is not less than the value of the primary-to-secondary voltage ratio multiplied by one-third of the rating of the overcurrent device that protects the primary of the transformer.

   (2) Secondary conductors terminate in a single circuit breaker or set of fuses rated no greater than the tap conductor ampacity in accordance with 310.15 [Table 310.16].

(3) The secondary conductors must be protected from physical damage by being enclosed in a manner approved by the authority having jurisdiction, such as within a raceway.

**Question:** True or False, 500 kcmil conductors can be used for the secondary for a 112.5 kVA, wye-connected, three-phase 120/208V transformer.

   (a) True
   (b) False

**Answer:** (a) False

**Step 1:** Calculate Secondary Current

\[ I = \frac{VA}{E \times 1.732} \]

\[ I = \frac{112,500 \text{ VA}}{208 \times 1.732} \]

\[ I = 313 \text{ A} \]

**Step 2:** Size Secondary Overcurrent Protection Device Size

Secondary Overcurrent Protection Device Size = \( 313 \text{ A} \times 1.25 \) [215.3]

Secondary Overcurrent Protection Device Size = 391A

Secondary Overcurrent Protection Device Size = 400A [240.6]

**Step 3:** Size Secondary Conductor

According to Table 310.16 at 75°C, a 600 kcmil conductor is rated 420A

However, conductors leaving the 400A protection device can be 500 kcmil. See 240.4(B).

(D) Service Conductors. Service-entrance conductors must be protected against overload in accordance with 230.90.