Conductor Sizing and Protection

By Mike Holt, published in EC&M magazine.

Overcurrent Protection

Overcurrent protection devices are intended to open a circuit to prevent damage to persons or property due to excessive or dangerous heat. Overcurrent protection devices have two current ratings, (1) overcurrent and (2) amperes interrupting current (AIC).

Overcurrent Rating. Overcurrent protection has provisions for opening a circuit to protect conductors and its related equipment from excessive heat [240-1 FPN]. If the current flowing through the protection device exceeds the device setting for a significant period, the protection device will open. The overcurrent rating of an overcurrent protection device is the actual ampere; such as 15, 20, or 30 ampere and the National Electrical Code list the standard sizes in Section 240-6(a). They include, but are not limited to: 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 700, 800, 1000, 1200, 1600, 2000, **Figure 1. Graphics not posted on internet.**

Interrupting Rating (Short-circuit) [110-9]. Overcurrent protection devices, such as circuit breakers and fuses are required to have an interrupting rating sufficient for the maximum possible fault-current available on the line side terminals of the equipment [240-1 FPN].

If the overcurrent protection device is not rated to interrupt at the available fault-current, it could explode while attempting to clear the fault, and/or the downstream equipment could suffer serious damage causing possible hazards to persons and property. For more information on calculating available short-circuit current, visit http://www.mikeholt.com/free/free.htm, **Figure 2.**

The NEC states that unless marked otherwise, the amperes interruption current (AIC) rating for circuit breakers is 5,000 ampere [240-83(c)] and 10,000 ampere for fuses [240-60(c)].

> **Author's Comment:** Circuit breakers are typically marked with an AIC rating of 10,000. **Figure 3.**

Overcurrent Protection Of Conductors General Rules [240-3]

There are many different rules for sizing and protecting conductors and equipment. It is not simply No. 12 wire and a 20 ampere breaker or fuse. The general rule is that conductors must be protected in accordance with their ampacity as determined by Section 310-15, except as permitted or required in Sections 240-3(b) through (g).

Continuous Load Factors. Overcurrent protection devices are to be sized no less than 125 percent of the continuous load, plus 100 percent of the noncontinuous load. [210-20(a), and 215-3]. In addition, conductors must have an ampacity (before the application

of any adjustment or correction factors) no less than 125 percent of the continuous load, plus 100 percent of the noncontinuous load [210-19(a) and 215-2(a)] in accordance with the terminal temperature rating limitations of Section 110-14(c).

Example – Branch Circuit Continuous Load
What size protection device and conductor is required for a 100 ampere continuous load, **Figure 4?**
(a) 150 amperes (b) 100 amperes (c) 125 amperes (d) any of these

• Answer: (c) 125 amperes, 100 amperes x 1.25 = 125 amperes [240-6(a)]
Step 1. The branch circuit overcurrent protection device must have an ampacity of not less than 125% of the continuous load [210-20(a)], 100 amperes X 1.25 = 125 amperes = 125 ampere protection.
Step 2. The branch circuit conductor must have an ampacity of not less than 125% of the continuous load before any ampacity adjustment [210-19(a)], 100 amperes X 1.25 = 125 amperes. No. 1 THHN rated 130 amperes at 75°C [110-14(c)(2)(b)].

Section 240-3(b), Next Higher Overcurrent Device Rating. Where the ampacity of a conductor does not correspond with the standard ampere rating of a fuse or circuit breaker as listed in Section 240-6(a), the next size up device (breaker or fuse) can be used. However, this is only permitted if the conductors do not supply multioutlet receptacle branch circuits for portable cord- and plug-connected loads and the next size up does not exceed 800 amperes.

Example – Feeder Continuous Load
What size feeder conductor and protection device is required for a 104 ampere continuous load, **Figure 5?**
(a) 150 A/No. 1/0 (b) 150 A/No. 1 (c) 125 A/No. 2 (d) 125 A/No. 1

• Answer: (b) 150 ampere protection device with No. 1 THHN
Step 1. The feeder overcurrent protection device must have an ampacity of not less than 125% of the continuous load [215-3], 104 amperes X 1.25 = 130 amperes = 150 ampere protection [240-6(a)].
Step 2. The feeder conductor must have an ampacity of not less than 125% of the continuous load before any ampacity adjustment [215-2(a)], 104 amperes X 1.25 = 130 amperes. No. 1 THHN is rated 130 amperes at 75°C [110-14(c)(2)(b)] and the 150 ampere overcurrent protection device can protect it.

Section 240-3(c), Circuits with Overcurrent Protection over 800 Amperes. If the circuit overcurrent protection device exceeds 800 amperes, the circuit conductors must have an ampacity not less than the rating of the overcurrent protection device as listed in Section 240-6(a).

Example – Feeder Continuous Load
What size feeder conductor is required for a 1200 ampere service/feeder paralleled in three raceways, **Figure 6?**

(a) 400 kcmil (b) 500 kcmil (c) 600 kcmil (d) any of these

• Answer: (c) 600 kcmil
The feeder overcurrent protection device must have an ampacity not less than the rating of the overcurrent device (1200 amperes).
Step 1. Determine ampacity per parallel conductor, = 1200 amperes/ 3 = 400 amperes
Step 2. Select a conductor using table 310-16 that has an ampacity of 400 amperes at 75°C [110-14(c)(2)(b)], = 600 kcmil.

Section 240-3(d), Small Conductors. Unless specifically permitted in 240-3(e) through 240-3(g), overcurrent protection shall not exceed 15 amperes for No. 14, 20 amperes for No. 12, and 30 amperes for No. 10 copper. Also, it should not exceed 15 amperes for No. 12, and 25 amperes for No. 10 aluminum and copper-clad aluminum after ampacity correction, **Figure 7.**

Section 240-3(g), Overcurrent Protection – Specific Requirements
The following rules apply when sizing conductors and overcurrent protection devices for specific equipment:

- Air-Conditioning, Section 440-4(b)
- Appliances, Sections 422-10 and 422-11
- Cooking Appliances, Sections 210-19(c), 210-21(b)(4), Note 4 of Table 220-19
- Electric Heating Equipment, Section 424-3(b)
- Feeder Conductors, Sections 215-2 and 215-3
- Fire Protective Signaling Circuits, Section 760-23
- Motors - Branch-Circuits, Sections 430-22(a), and 430-52
- Motors - Feeders, Sections 430-24, and 430-62
- Motors - Remote Control, Section 430-72
- Neutral Calculations, Section 220-22
- Neutral Service, Section 230-24(b)
- Panelboard, Section 384-16(a)
- Service Conductors, Sections 230-42, and 230-90(a)
- Tap - One hundred foot, Section 240-21(b)(4)
- Tap - Outside Feeder, Section 240-21(b)(5)
- Tap - Ten foot, Section 240-21(b)(1)
- Tap - Twenty-five foot, Section 240-21(b)(2)
- Temporary Conductors, Section 305-4
- Transformer Taps, Sections 240-21 and 450-3

Air-Conditioning, Section 440-4(b)
Air-conditioning equipment shall be provided with a visible nameplate marked with the minimum supply circuit conductor ampacity, and the maximum rating of the branch-circuit short-circuit and ground-fault protective device.

> **Author's Comment:** For more information about this, read Michael J. Johnston's article in the July/August 2000 issue of IAEI.

Example. Air-Conditioning
An air-conditioner nameplate indicates a minimum circuit ampacity of 27.8 amperes with a maximum fuse size of 40 amperes. What is the minimum size branch circuit conductor and the maximum size overcurrent protection device for this equipment, **Figure 8?**
(a) No. 12 with a 40 ampere fuse (b) No. 10 with a 30 ampere fuse
(c) No. 10 with a 40 ampere fuse (d) No. 8 with a 40 ampere fuse

• Answer:(c) No. 10 with a 40 ampere fuse, Section 440-4(b)
Short-Circuit Protection = 40 ampere Fuse. The protection device must not be greater than a 40 ampere fuse, either one-time or dual-element because the nameplate specifies fuses [110-3(b)]. A circuit breaker cannot be used for this application. Conductor Size = No. 10. The conductors must be sized based on the 60ºC column of Table 310-16 [110-14(c)] and they must have an ampacity of not less than 27.8 amperes.

Motor, Sections 430-22(a) and 430-52(c)
Branch Circuit Conductors. According to Section 420-22, branch circuit conductors are sized at no less than 125% of the motor full-load current listed in Tables 430-147 to 430-150, not the motor nameplate amperes [430-6(a)].

Short-Circuit and Ground-Fault Protection. The motor short-circuit ground-fault protection device must be sized at no more than the motor full-load current rating listed in Tables 430-147 to 430-150 multiplied by the percentages on Table 430-152. According to Table 430-152, inverse time circuit breakers are sized at 250% of the motor FLC.

Example – Motor, Sections 430-22(a) and 430-52(c)
What size branch circuit conductor and short-circuit protection (circuit breaker) is required for a 2 horsepower motor rated 230 volts (12 amperes FLC), **Figure 9?**
(a) No. 14 with a 15 ampere breaker (b) No. 12 with a 20 ampere breaker
(c) No. 12 with a 30 ampere breaker (d) No. 14 with a 30 ampere breaker

Answer (d) No. 14 with a 30 ampere protection device.
Short-Circuit Protection: The short-circuit protection (circuit breaker) must be sized at no more than 250 percent of motor full-load current. 12 amperes X 2.5 = 30 amperes [240-6(a) and 430-52(c)(1) Exception No. 1]
Conductors: Conductors must be sized no less than 125 percent of the motor full-load current [430-6(a) and 430-22(a)]. 12 amperes X 1.25 = 15 amperes, Table 310-16, No. 14.