**Introduction**

When considering protection of conductors, the general rule per NEC® 240.21 is to provide overcurrent protection in each ungrounded circuit conductor at the point where the conductors receive their supply. For branch circuits, the overcurrent protective device must comply with 210.20. For feeder circuits, the overcurrent protective device must comply with 215.3. For service conductors, overcurrent protection is not required at the point where the conductor receives it supply, but overcurrent protection requirements are detailed in Part VII of Article 230. In addition, 240.4 provides additional provisions and requirements for branch, feeder, and service conductors. If a conductor does not adhere to the requirements above, it is then considered a “tap conductor”.

**Tap Conductors**

A Tap conductor is defined in 240.2 as a conductor, other than a service conductor, that has overcurrent protection ahead of its point of supply that exceeds the value permitted for similar conductors that are protected as described in 240.4. Tap conductors are permitted provided they adhere to the requirements of 240.21(A)-(G). In addition, 240.21 prohibits tap conductors from supplying other conductors, except through an overcurrent protective device meeting the requirements of 240.4. This means “you can’t tap a tap”.

One common misconception about tap conductors is that overcurrent protection is not required. However, it should be noted that in most instances, overcurrent protection is required at the termination point of the tap conductor by either 240.21(A)-(G), transformer protection requirements per 450.3, or panelboard protection requirements per 408.16. In addition, the use of tap conductors should be limited where possible since tap conductors have limited short-circuit protection. In fact, besides meeting the requirements of 240.21, a short-circuit protection analysis of the tap conductor should also be done per NEC 110.10. The primary applications of interest to most include feeder taps per 240.21(B) and transformer taps per 240.21(C). This issue will focus on feeder taps, the next issue will focus on transformer taps.

**Feeder Taps**

As stated above, 240.21(B) covers the requirements for feeder taps. Five possibilities exist as listed in 240.21(B)(1) - 240.21(B)(5).

- Feeder Taps Not Over 10’

  Per 240.21(B)(1), feeder taps 10’ or less are permitted provided:
  1. The ampacity is not less than the combined computed loads supplied and not less than the rating of the device or overcurrent protective device supplied.
  2. Does not extend beyond the switchboard, panelboard or control device which it supplies, and
  3. Is enclosed in raceway, except at the point of connection to the feeder, and
  4. For field installed taps, where the tap conductors leave the enclosure, the ampacity of the tap conductor must be at least 10% of the overcurrent device rating.

An example of acceptable application of the 10’ tap rule is shown below:

The example above complies with 240.21(B)(1), but is the tap conductor protected against short circuits? In this example the tap conductor is a 10 AWG conductor. Let’s assume that the available fault current is 10,000A at the location of the tap conductor. The question now is, can the 200A overcurrent protective device protect the 10AWG tap conductor (assuming the fault is ahead of the 30A fuse)?

According to the ICEA (Insulated Cable Engineers Association) protection chart, a 10AWG conductor with 75°C thermoplastic insulation can withstand 6,020 A for ½ cycle or 4,257A for 1 cycle. This represents the amount of current for a given period of time that can begin to damage the conductor insulation (raises the temperature in the conductor from 75°C to 150°C).
Thus, in order to provide short-circuit protection and avoid insulation damage to the tap conductor, the 200A overcurrent protective device must:

- Limit the current to below 6,020A if the device clears the fault in ½ cycle or
- Limit the current to below 4,257A if the device clears in 1 cycle.

If the 200A device is a Bussmann® FRN-R (Class RK5), LPN-RK (Class RK1), LPJ (Class J), or JJN (Class T), all will limit the current below 6,000A in ½ cycle (per the current-limiting effects charts as shown in the Bussmann SPD) and thus protection is assured.

If the 200A device is a standard circuit breaker (non current-limiting), the opening time can be determined. Most likely the opening time will be approximately 1 cycle. However, unless the circuit breaker manufacturer provides let-through data, it must be assumed that the full available fault current could be let through. Thus, the analysis then shows that the standard circuit breaker could potentially let through 10,000A which is greater than the conductor withstand of 4,257A.

Taking it a step further, there is a second and third damage level for conductors that could be explored. The second is the Soares Validity Rating. This represents the amount of current for a given time that can cause the conductor to anneal (raises the temperature in the conductor from 75°C to 250°C). When a conductor becomes annealed, it can loosen in the terminals causing heating issues. The third damage level is given by Onderdonk. This damage level represents the amount of current for a given time that can cause the conductor to melt or vaporize (raises the temperature in the conductor from 75°C to 1,083°C).

For a 10 AWG conductor, the Soares Validity Rating is:
- 8,651A for ½ cycle or
- 6,117A for 1 cycle

For a 10 AWG conductor, the Onderdonk rating is:
- 15,549A for ½ cycle or
- 10,995A for 1 cycle

Again, looking at the example above, the fuses mentioned before will all protect within these levels as well. However, a standard circuit breaker (non current-limiting) potentially could cause the tap conductor to anneal (result in a loose termination and cause heating issues) and be almost enough to vaporize the conductor.

Conclusions
When determining the protection required for conductors, protection must be applied in accordance with branch, feeder, service or tap conductor requirements. When applying tap conductors, care must be taken to not only meet the requirements of the 240.21, but also the requirements of 450.3 and 408.16 if applicable. In addition, additional steps should be taken to assure short-circuit protection of conductors per NEC 110.10.

For more information on tap conductor rules, see the Bussmann NE02 (p. 25-29) at:
http://www.bussmann.com/library/docs/NE02.pdf

For information on short-circuit protection of conductors, see Tech Spec 6 and a white paper on conductor protection at:

Register for the Bussmann® Industrial & Commercial Power System Seminar on Overcurrent Protection October 23-24. Seminar is in St Louis and includes demonstrations in our high power test lab. 1.6 CEUs will be offered for attending the seminar. See informational flyer at:
http://www.bussmann.com/apen/seminars