Executive summary

Learn how to apply multiple branches and multi-wire terminals with circuit breakers in industrial control panels in accordance with Underwriters Laboratories® (UL®) standard 508A and the National Electrical Code® (NEC®), National Fire Protection Association (NFPA® 70-2011).

Molded-case circuit breakers are used for the main overcurrent protective device (OCPD) and the main disconnecting means for an industrial control panel, or as a main or feeder application. If branch circuits need to emanate from the main OCPD, this can be accomplished with:

- Power distribution blocks
- Multi-wire terminals
- Standard breaker terminals

Introduction

Typically, power terminal blocks are used in UL 508A–listed industrial control panels and NEC installations for tapping circuits. They provide the widest range of configurations for distributing loads within a panel. However, most power distribution blocks are unmarked components that carry a maximum short-circuit current rating (SCCR) of 10 kA, which can be limiting. To achieve a panel SCCR above 10 kA, power distribution blocks must be applied in combination with circuit breakers that are tested and listed for the higher rating.

An alternative to power distribution blocks are circuit breaker terminals. These space-saving accessories mount directly to the breaker’s load-side terminals, saving panel space, mounting time, and wiring expense. Multi-wire circuit breaker terminals provide a means to make more than one load-side termination while maintaining the circuit breaker’s UL listing and applying the breaker’s SCCR rating to the terminals. For larger circuit breakers, standard terminals can be applied to provide multiple load-side terminations.

For many configurations, using breaker terminals (versus power distribution blocks) can provide overall efficiencies when distributing loads in a control panel. Standard circuit breaker terminal offerings are somewhat limited in range of number and size of conductors when compared to power distribution blocks; however, they may offer economic and technical advantages, as will be shown later.

Proper application is essential to ensure that the circuit breaker (OCPD) is sized and applied so it can perform its main function: protecting wire. The NEC and UL 508A prescribe maximum length and ampacity for tap conductors. This article references these requirements and highlights examples of both correct and incorrect methods of distributing loads within an industrial control panel.

You can expect to gain an understanding of the options available for distributing loads in an industrial control panel and for safely applying them to achieve an optimized panel design.

Notes:

1. All references to “conductors” are for materials made of copper.
2. Note to the National Electrical Code (NEC): the 2011 edition of the NEC changed the designation for Table 310.16 for conductor ampacities to Table 310.15(B)(16).
Tap conductor, defined
A tap conductor has an overcurrent protective device ahead of its point of supply that exceeds the value normally allowed by ampacity tables in the NEC or UL 508A.

Rules for tapping

NEC requirements
NEC, Sections 240.21(B)(1), 240.21(B)(2), and 430.28, address the topic of feeder taps. Feeder tap conductors must have an ampacity not less than that required by Part II (the sub-section addressing the sizing of conductors for specific loads), terminate in a branch-circuit protective device, and must meet one of the following:

1. Be enclosed by a controller or a raceway not more than 10 feet (3.0 meters) long and—for field installation—be protected by an overcurrent device on the line side of the tap conductor, the rating or setting of which should not exceed 1000 percent of the tap conductor ampacity;
2. Have an ampacity of at least one-third that of the feeder conductors, suitably protected from physical damage or enclosed in a raceway, and not more than 25 feet (7.5 meters) long.

UL 508A requirements
UL 508A, Section 31.4.3, addresses the issue using similar language. The ampacity of the tap conductors, which are the internal conductors to the individual loads, should be:

1. Not less than one-third of the ampacity of the branch circuit conductor, calculated as in 28.3.3 (28.3.3 addresses the sizing of field wiring conductors for specific loads); or
2. Not less than one-tenth the ampere rating of the branch circuit protection for the group for each motor circuit provided with a manual motor controller marked “Suitable as tap conductor protection in group installations” and complies with the Standard for Industrial Control Equipment, UL 508. The conductors on the load side of the manual motor controller should have an ampacity not less than that which is calculated in 28.3.2 (28.3.2 addresses the sizing of field wiring conductors for motor loads; consult UL 508A for details).

Note: Note that the rules outlined above, whether from the NEC or from UL 508A, are also known as the 10-foot tap rule and the 25-foot tap rule.

Applications complying with the 10-foot tap rule
The ampacity for a conductor not exceeding 25 feet (7.5 meters) in length must be at least one-third the ampacity of the circuit breaker’s trip rating. The ampacity for a tap conductor applied to a 300A circuit breaker must be equal to 100A or greater. Referring to Table 28.1 in UL 508A, the conductor would have to be at least 3 AWG. The conductor must terminate in an appropriately sized overcurrent protective device.

Conductor temperature ratings
UL 508A, Table 28.1, and NEC Table 310.15(B)(16) list temperature ratings, wire sizes and conductor ampacity requirements. Terminals on starters, circuit breakers, and other devices are rated for a maximum temperature of 75ºC. It is important to pay close attention to conductor temperature ratings and the corresponding ampcapilities tabulated in the appropriate standard.

The NEC has columns for 90ºC and higher. Conductors with higher temperature ratings, such as 90ºC, may be used. Ampacities, however, must be the values shown in the 75ºC column.

Note that the temperature rating in the wire tables refers to insulation temperature, not necessarily the temperature at which it may be terminated. While the insulation may be rated for 90ºC, the conductor must be terminated at the 75ºC rating. Further, the ampacity associated with the free-air rating, as shown in NEC Table 310.15(B)(17), may never be used within an enclosure.

Short-circuit interrupting ratings
Both the NEC (Article 409.110) and UL 508A (Article 49) require supply markings on industrial control panels. The maximum short-circuit rating for the supply circuit to which the panel can be connected must be marked. For a panel to be listed at a particular short-circuit rating, the components within the enclosure must be rated individually or in combinations for the short-circuit rating. The requirement includes those items used to provide branch- or feeder-circuit taps.

There are several devices typically used to create branch and feeder taps, including power terminal blocks; standard, multiple-outlet circuit breaker terminals; and multi-wire circuit breaker terminals. Following are discussions of those components, their uses, and their limitations.

Tap rules illustrated, examples:

Applications complying with the 10-foot tap rule
The ampacity for a tap conductor applied to a 200 ampere (200A) circuit breaker must be equal to or greater than 20A. Referring to Table 28.1 in UL 508A, the conductor would have to be at least 12 American Wire Gauge (AWG) and must terminate in an appropriately sized overcurrent protective device, such as a circuit breaker or fuse.
Power distribution blocks

Power distribution blocks (PDB) are also known as power terminal blocks (PTB).

They serve to distribute circuits within industrial control panels, and provide a means for tapping smaller conductors from a circuit breaker—so long as one follows the tapping rules. Conductors equal to the full ampacity of the circuit breaker must be extended to the power distribution. Properly sized taps may then extend from the PDB to an overcurrent protective device.

Although tapping rules may be followed, the SCCR of the circuit may be limited by the components used. UL 508A, Table SB 4.1, assigns an SCCR of 10,000A to an unmarked, untested PDB. This requirement may severely limit the SCCR for an industrial control panel, but the use of standard, multiple-conductor terminals for circuit breakers can overcome this limitation. Listed terminals take on the same SCCR as the breaker to which they are connected.

Application of multi-wire terminals for molded-case circuit breakers

Multi-wire terminals for molded-case circuit breakers can provide more than one load-side termination while maintaining the circuit breaker’s UL listing. This section explores the application of multi-wire terminals in conjunction with UL 508A and the NEC NFPA 70-2011, and addresses multi-wire terminals used with circuit breakers in industrial control panels as defined in NEC Section 409 and UL 508A. Circuit breakers equipped with multi-wire terminals function as feeder breakers, not branch breakers. Feeder circuits can be tapped, while branch circuits cannot.

Advantages of applying multi-wire terminals

Multi-wire terminals can offer significant advantages in the construction of industrial control panels. Although a combination of a circuit breaker and a power terminal block must be tested for a combined short-circuit current rating, a multi-wire terminal is a listed circuit breaker accessory, carrying the same short-circuit current rating as the breaker.

Additionally, a multi-wire terminal should be mounted on the circuit breaker’s load-side terminals to save expensive panel space, mounting time, and wiring time.

Note: All references to “conductors” are for materials made of copper.

Using standard, multiple-conductor breaker terminals for taps

Although power distribution terminal blocks may be used to distribute branch circuits, an alternative configuration is one that distributes branch circuits directly from the breaker’s terminals, if the terminals have provisions for more than one cable. Terminals for larger breakers may contain one or more conductor openings. That feature is used normally for paralleling cables to feed the breaker’s full ampacity to a load. Multiple terminal openings on the load side of the breaker may also be employed for deriving lower-current branch or feeder circuits from a breaker in accordance with the NEC and UL 508A tap rules.

Although the examples are accurate, they are not the only configurations available. For other terminals, wire sizes, and quantities of wire, you can consult circuit breaker terminal tables.

Notes:

- Conductor ampacities are from Table 310.15(B)(16) in the National Electrical Code (NEC) and Table 28.1 in UL 508A.
- Ampacities used are from the 75°C temperature column in the wire tables. Although conductors with higher-temperature insulation may be used, their ampacities may not exceed those in the 75°C column.
- Unless otherwise stated, cable lengths are assumed to be a maximum of 10 feet.
Application examples

Exclusions
To avoid design and field implementation errors, it is imperative to understand misapplication of the tap rule.

Figure 1 and Figure 2 illustrate a tap not permitted by the NEC or UL 508A. Note that the 4/0 cable is a correct cable size based on the tapping rules (minimum 10 percent of the breaker rating and less than 10 feet in length). The 4/0 cable terminates on a PTB. Then, 1 AWG and 10 AWG wires are tapped from the PTB. These latter taps are not allowed. Instead, the 4/0 cable must terminate on a circuit breaker with the correct ampacity of 225A or less. A tap cannot be made from the 4/0 cable prior to terminating the cable on a properly sized OCPD. That prohibition regards “tapping a tap.” The 4/0 conductor is a tap from the 1200A circuit breaker. Note that connecting the conductor to one terminal of a multi-equipped breaker terminal is the same electrically as if four 350 kcmil conductors were extended from the circuit breaker and the 4/0 cable tapped from those conductors. The 4/0 cable is required to terminate at a circuit breaker of 225A or smaller for the wire to be considered protected. In this example, the 4/0 cable is, instead, tapped further with a conductor as small as 10 AWG. Although the 1 AWG conductor can be tapped from the 1200A circuit breaker, the 10 AWG conductor cannot, and neither conductor can be tapped from the 1200A circuit breaker through the use of a power terminal block. In both of these scenarios, 1 AWG and 10 AWG conductors are not considered to be protected properly.

Figure 2 illustrates the example in Figure 1 taken to the extreme. In Figure 2, one sees that the 4/0 conductor can now be overloaded by the addition of the 250A breaker. By adding this breaker to the circuit, a total load of 405A may be imposed on the 4/0 conductor. Under a full load scenario, the 4/0 conductor would be overloaded, but the 1200A breaker may never see sufficient current to trip, leading to failure of the 4/0 conductor.

Creating branch, feeder circuit taps using circuit breaker terminals

This discussion considers branch circuits or feeder circuits derived from larger circuit breakers. The numbers and sizes of loads in an industrial control panel or NEC installation frequently require a circuit breaker of 800A or greater to be used as a main device, with lower-ampacity circuits tapped from it. Several examples illustrate the correct use of this practice.
Figure 3 illustrates a 2500A breaker frame with a 1600A trip unit. Various breaker sizes are tapped from the breaker. Although breakers with smaller trip units may be used, cable sizes 2/0 AWG and larger must be used to tap from the 2500A breaker. Note that the terminals shown are 2000A because provisions are available to terminate six cables. Terminals for 1600A could be used to achieve cost savings, but they allow termination of only four cables.

Figure 4 illustrates a 1200A breaker frame with an 800A trip unit. The drawing is intended to depict the range of breakers that may be used. Because the minimum cable size for the 1200A frame is 3/0, the 125A breaker is fed with 3/0 AWG, although the trip unit required may be smaller. Alternatively, one may use a 1200A breaker with a 1200A trip unit because the terminals are the same for both kinds of equipment, and the same cable size limitations apply. The 600A circuit breaker contains terminals capable of handling two wires, each for sizes ranging from 2 AWG to 500 kcmil.

Figure 5 illustrates a 400A breaker, as well as a 125A breaker tapped from the 600A circuit breaker. Taps are shown at full capacity for each breaker. Although trip units could be smaller, the smallest cable size that may be used is 2 AWG due to the lower limit of the upstream (main) breaker terminals. In this example, cable size is the limiting feature. In practice, the 600A circuit breaker may contain a lower-ampacity trip unit to avoid the need for an oversized incoming cable. Figure 5 also illustrates two 250A circuit breakers tapped from the 500A breaker. In practice, the 500A circuit breaker is used to avoid the need for oversizing the incoming cable.
Additional examples

Figures 6, 7, and 8 provide additional examples of taps to serve lower-ampacity loads from higher-ampacity circuit breakers, but from a different series of circuit breakers. Although terminal configurations differ from the first series, the rules for tapping remain the same.

The main circuit breaker in Figure 6 has five smaller breakers tapped from its terminals. One may actually tap six breakers because the terminals for the 2500A breaker will accept six conductors. The terminal capacity is for 6-2 AWG to 600 kcmil. Consequently, a circuit breaker as large as 450A can be tapped from the 2500A breaker using a single, 600 kcmil conductor. NEC 240.4 (B) permits sizing to the next higher standard rating shown in 240.6 if the conductor rating is not equal to a standard rating; the maximum OCPD cannot exceed 800A. UL 508A does not offer a similar exemption.

Taps as small as 80A can be made from the 800A circuit breaker in Figure 7 when an 800A trip unit is used. The smallest conductor, however, is limited to 3/0 AWG due to the lower size limit for the terminals. By changing the trip unit to 600A, conductors as small as 1 AWG can be tapped from the breaker.

Figure 8 illustrates a 600A circuit breaker used as a main or feeder breaker. As in Figure 6 with the 2500A breaker, a circuit breaker with a 400A trip unit can be tapped from the 600A circuit breaker by using a single, 500 kcmil conductor. UL 508A does not offer a similar exemption.
PTBs are often used for tapping circuits in UL 508A–listed industrial control panels and NEC installations. Economies of scale can be gained, however, and higher short-circuit ratings achieved, through the use of standard, multiple-conductor terminals on circuit breakers. To ensure that main and branch circuit protection devices are serving their primary function of protecting wires, engineers should review all loads carefully, including tap loads.

Conclusion
For a range of applications, using breaker terminals can provide efficiencies when distributing loads in a control panel. That said, standard terminal offerings are somewhat limited in range of number and size of conductors when compared to power distribution blocks.

References
You can access power distribution block ratings, based on Eaton’s extensive testing program here.

UL 508A, Table 28.1 and NEC Table 310.15(B)(16) list temperature ratings, wire sizes, and conductor ampacity requirements.


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