TECHNICAL PAPER

MCCB applications

When to use a 100% rated circuit breaker

There are widespread misconceptions around the topic of 80% and 100% rated circuit breakers. In this technical paper, we will examine the NEC rules and how they impact circuit breaker selection.

Proper circuit breaker selection is not an easy task especially when the subject of “80% rated” versus “100% rated” circuit breakers comes up. Always sizing the circuit breaker at 125% of load, means that a larger, more expensive circuit breaker will always be required. There are widespread misconceptions around this topic of 80% and 100% rated circuit breakers which we will try to clarify. In this technical paper we will examine the NEC rules and how they impact circuit breaker selection. The emphasis will be on using the rules to your advantage and explaining how to save money on an installation whenever possible.

National Electrical Code® (NEC)

The NEC recognizes that the operation of overcurrent protective devices may be affected by the heat in a system. Because of this, it defines the concept of continuous loads and the 80% limitation in order to try and offset the effects of heat in the system when sizing a circuit breaker. This is where we find an instance of an electrical code rule that describes how to size the circuit breakers current rating based on the amount of load current and how long the load will be running at full capacity.

Article 240.20 (A) of the National Electrical Code (NEC), 2014 Edition states: (A) Continuous and Noncontinuous Loads. Where a branch circuit supplies continuous loads or any combination of continuous and noncontinuous loads, the rating of the overcurrent device shall not be less than the noncontinuous load plus 125 percent of the continuous load.

Exception: Where the assembly, including the overcurrent devices protecting the branch circuit(s), is listed for operation at 100 percent of its rating, the ampere rating of the overcurrent device shall be permitted to be not less than the sum of the continuous load plus the noncontinuous load.

Definition from Article 100 of the National Electrical Code (NEC), 2014 edition

Before we can apply the electrical code rule, we must know what constitutes a continuous load which the NEC defines as:

“A continuous load is defined as a load where the maximum current is expected to continue for 3 hours or more.”

If we have to size the circuit breaker rating to 125% of the continuous load current then it stands to reason that we are only utilizing 80% of the circuit breaker's current carrying capacity. Since 80% is the inverse of 125% (0.80 = 1 divided by 1.25), this is the source of the common terminology "80% rated circuit breaker". This does not mean that the circuit breaker is only good for 80% of its rating but rather this is an application restriction imposed by the NEC to not exceed 80% of the circuit breaker's rating if it is being used on a continuous load. If however, the circuit breaker is only supplying noncontinuous loads, those where the maximum current is expected for less than 3 hours, then the NEC rule does not impose this limitation and the circuit breaker can be sized at 100% of its current rating.

As with many rules, there are exceptions that can be made and this NEC code article has the specific exception that says the circuit breaker may be used at 100% of its rating if it is "listed" for operation at 100%. Many circuit breaker manufacturers have gone through the process of testing and obtaining UL certifications which enables them to advertise their products as UL Listed 100% rated.

This additional testing establishes that the correct operation of the circuit breaker can carry the full rated current without tripping and that it does not exceed temperature limits that could render it unsafe.

Circuit breaker testing requirements

UL 489, the UL Standard for Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures, requires all circuit breakers to carry 100% of their current rating when tested in an open air environment. These tests are performed without an enclosure, but they are typically inside a thermal chamber where the ambient temperature is held at a constant 40ºC (approx. 104ºF). The circuit breaker is designed to carry 100% of its rated current indefinitely without tripping under these standard test conditions. Since the wire size attached to the circuit breaker terminals can in some cases make a difference in the tripping characteristics of the circuit breaker, UL specifies what size and type of wire is to be used during the test. In order to be third party certified by UL as a 100% rated circuit breaker, there are additional testing requirements that must be met. The circuit breaker must undergo thermal testing inside an enclosure of minimum size/volume without tripping until it reaches temperature stabilization; the temperature is monitored on various parts of the circuit breaker to make sure the breaker does not exceed the temperature rise limits set forth in the standard. When the temperature at the circuit breaker terminals exceeds 50ºC during the 100% rating test, but remains below 60ºC, UL requires the use of wire with 90ºC insulation, but sized at 75ºC ampacity. Both thermal-magnetic and electronic trip circuit breakers can be tested for 100% ratings. Although the trip characteristics of an electronic trip circuit breaker are not affected by ambient temperatures, the conductors are impacted by the temperature, thus the need for a special test for the 100% rating. If these additional tests are successful, then the circuit breaker is allowed to be marked as a 100% rated circuit breaker and can be used in an installation under the exception of NEC 240.20 (A).

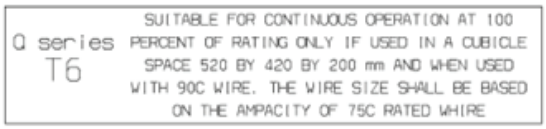
Marking requirements

Distinguishing between a 100% rated circuit breaker and an 80% rated circuit breaker?

A UL 489 100% rated circuit breaker must be marked by the manufacturer with the minimum enclosure size and venting requirements needed for heat dissipation. These markings are present on the device so that a local electrical inspector can verify that all of the installation requirements are being met. These circuit breaker conditions are:

- Minimum enclosure size
- Temperature rating of the wire
- Ventilation requirements (if needed)

Example of a circuit breaker marking:



When a circuit breaker is listed for operation at 100% of its current rating, the requirement to oversize the circuit breaker goes away. Instead, the device simply has to be able to handle the sum of all the continuous and non-continuous loads.

While using a 100% rated circuit breaker may always seem like the best choice, it is not always the case. An determination of whether the load will be continuous or noncontinuous should be made. If the load will be noncontinuous, there is no need for protecting 125% of the load requirement and the breaker size can be selected to meet 100% of the load. In that case, the 80% rated circuit breaker may be the better choice.

With continuous loads, the load current on each branch circuit must be determined in order to calculate the required ampere rating for each circuit breaker type; 100% of load current for 100% rated circuit breakers or 125% of load current for 80% rated circuit breakers. Typically, the greatest cost savings comes when using the 100% rated circuit breaker precludes the need to move up to the next larger frame size circuit

breaker. This often makes the 100% rated circuit breaker the most economical choice.

Total cost of the installation

In making the most cost effective circuit breaker selection, the total cost of the installation should be considered. This evaluation certainly includes the cost of the circuit breaker, but must also take into account the size and cost of the enclosure or equipment that into which the circuit breaker is installed. The installation is not complete until the cable is connected from the circuit breaker to the load. Since the cable size is based on the circuit breaker rating, reducing the circuit breaker size by using a 100% rated circuit breaker results in a reduction in the size of the cable to match the lower circuit breaker rating. Other installation costs will also be reduced such as using smaller diameter conduit and conduit fittings, compression terminals, etc.

Application examples

The following are several application examples for the use of 80% rated circuit breakers and 100% rated circuit breakers to show when it may be advantageous to use one over the other. Many other configurations are possible. Always refer to the manufacturer's published data concerning 100% rated circuit breakers to ensure compliance with all installation requirements for their use.

Notes for application examples:

- All wire size ampacity references are for copper conductors.
- Conductor ampacities were taken from the 75°C column of Table 310.15 (B) (16) in the 2014 Edition of the National Electrical Code®.
- Although some 100% rated circuit breakers require the use of conductors with insulation temperature ratings of 90°C, the ampacities must not exceed those shown in the 75°C temperature column.
- Circuit breakers are used in these examples, but other overcurrent protective devices such as fusible disconnect switches may also be used.
- No adjustments were made to the cable size based on ambient temperature or excessive length, etc.
- The minimum enclosure sizes shown in the table are for three pole circuit breakers.

Example 1

Let's consider the installation of a 300HP, 480V motor with a nameplate full load amp rating of 360 amps. If this is a continuous load the NEC would have us size a standard 80% rated circuit breaker at: 360A * 125% = 450A. This would cause us to use a 600 amp frame circuit breaker with a rating plug or trip threshold setting of 450 amps. If however we were to use a 100% rated circuit breaker we could use a 400 amp frame circuit breaker with its smaller dimensions and lower cost. Now consider the additional costs differences in using cable and conduit sized for 360 amps instead of 450 amps, and you can see that the cost savings can be significant and extend well beyond the cost of the circuit breaker.

Example 2

In this case we have a combination of continuous and non-continuous loads; the non-continuous loads total to 150 amps and the continuous loads are 600 amps. The NEC says we should size the circuit breaker at 100% of the non-continuous loads and 125% of the continuous loads, so we have the equation; (100% * 150) + (125% * 600) = 900A. This means we would use a 1000 amp frame circuit breaker set at 900 amps. Our other option is to use a 100% rated circuit breaker and in this instance the equation becomes; 150 + 600 = 750A. Now we can use an 800 amp frame circuit breaker and as in the previous example, not only is the circuit breaker smaller and less expensive, but the overall installation costs are much less. The 80% rated 900A circuit breaker would need three per phase #350 kcmil cables for an ampacity of 930 amps, while the 100% rated 750A circuit breaker would only need three per phase #250 kcmil cables for an ampacity of 765 amps.

As you can see this is a large difference in cost between the #350 and #250 conductors especially since it takes three cables per phase. Theoretically, the savings are proportional to the length of the cable run with an increase in savings as the cable length increases because a large portion of the savings is the cost difference in the cable and installation products, i.e., the conduit and fittings.

Example 3

In this example we have a 480V 100HP pump motor with a full load current of 124 amps that pumps liquid through pipes as part of a batch process in a food and beverage processing facility. The pump takes two hours to fill the vats to begin the process. Then it turns off until the batch is ready to be bottled. Since the pump motor is only running for two hours at a time, it is a noncontinuous load and can be sized at 100% of the load current and does not require the use of a 100% rated circuit breaker. In this case you should use the standard 80% rated circuit breaker and the extra cost of the 100% rated circuit breaker is not justified.

Example 4
If you have a continuous load with a load current of 80 amps your options are to use an 80A 100% rated circuit breaker or a 100A 80% rated circuit breaker. Since both the 80A and 100A ratings would be the same frame size circuit breaker there is most likely no big price difference between the two choices. Next we need to look at the installation cost; the 80 amp circuit breaker will need #4 AWG copper wires while the 100 amp circuit breaker needs #3 AWG copper wire. Again this is not a huge difference in size, but many times the #3 AWG wire is not readily available which could cause the installer to go up in size to #2 AWG wire. There is not likely to be an advantage to using the 100% rated circuit breaker for this application unless the wire run is long enough that you can realize a savings on the total installation cost of wire, conduit and fittings by using the smaller #4 AWG wire.

Summary
A circuit breaker is designed to carry 100% of its current rating, but the NEC rules limit the application for continuous loads to 80% of the circuit breaker's rating. Manufacturers perform additional testing to be able to offer 100% rated circuit breakers that can be used in accordance with the exception clause of the National Electrical Code. Understanding the difference between 80% and 100% rated circuit breakers and their application requirements can often save the user a substantial amount of money on the total cost of the installation.

With a proper understanding of 100% rated circuit breakers and how they are applied, an evaluation can be made to point us to the best, most economical selection. Advantages to using a 100% rated circuit breaker may include a lower current rating and a smaller physical size circuit breaker, smaller cable, and a potential to reduce the equipment size resulting in a reduction of needed floor and wall space.

References
NFPA 70, The National Electrical Code (NEC), 2014.
UL 489, Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures, Twelfth Edition, Dated January 15, 2013.

UL Listed 100% Rated Molded Case Circuit Breakers

Tmax, Tmax XT Circuit Breakers			
Frame Size (Amps)	Minimum Enclosure Size (mm) (Inches)	90°C Wire Required[1]	Trip Unit Type (T/M, ELT)
XT1 (100A)[4]	370mm H X 216mm W X 72.5mm D 14.6"H X 8.5"W X 2.9"D	Yes	T/M
XT2 (125A)[3]	310mm H X 180mm W X 83.5mm D 12.2"H X 7.1"W X 3.3"D	No	T/M, ELT
XT3 (225A)	370mm H X 217mm W X 72mm D 14.6"H X 8.5"W X 2.8"D	Yes	T/M
XT4 (250A)	380mm H X 195mm W X 83.5mm D 15.0"H X 7.7"W X 3.3"D	Yes	T/M, ELT
T5 (300A, 400A)	506mm H X 381mm W X 153mm D 19.9"H X 15.0"W X 6.0"D	No	T/M, ELT
T6 (600A, 800A)	520mm H X 420mm H X 200mm W 20.5"H X 16.5"W X 7.9"D	Yes	T/M, ELT
T7 (1000A, 1200A)	704mm H X 554mm W X 173mm D 27.7"H X 21.8"W X 6.8"D	Yes	ELT
T8 (1600A, 2000A, 2500A, 3000A)[2]	1016mm H X 608mm W X 615mm D 40.0"H X 24.0"W X 24.2"D	No	ELT

[1] 90°C wire is required for installation but must be sized according to 75°C ampacity tables
[2] T8 1600A, 2000A 80%-100% with front terminals, 2500A 80% with front terminals and 80%-100% with rear vertical terminals, 3000A 80%-100% with rear vertical terminals
[3] Tmax XT2 100% rated up to 125A with electronic trip unit or 100% rated up to 100A with thermal-magnetic trip unit
[4] Tmax XT1 100% rated up to 100A or 80% rated at 125A

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