Sizing a circuit breaker.

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One of the most often asked questions is, "How do I size a circuit breaker?" A commonly misunderstood fact about circuit breakers (CBs) is related to the percentage of loading permitted by the NEC and the CB design, and why the two may be different. Let's investigate both aspects.

CB design

A CB is designed and evaluated to carry 100% of its rated current for an indefinite period of time under standard test conditions. These conditions, per UL 489, Underwriters Laboratories Standard for Safety for Molded-Case Circuit Breakers and Circuit Breaker Enclosures, include mounting the CB in free air (i.e.: with no enclosure) where the ambient temperature is held at 40 [degrees] C (approximately 104 [degrees] F). Under these conditions, molded-case CBs are required not to trip at rated current.

However, a CB most frequently is applied in equipment at 80% of its rated current under NEC Sec. 384-16(c). If you understand why this requirement is in place, you'll be able to apply CBs correctly.

CB characteristic trip curves

CB characteristic trip curves document how long it takes for specific CBs to trip depending upon the level of current. Fig. 1 shows a typical curve for a thermal-magnetic CB. The curved portion at the top represents the time it takes for the CB to trip on overload. An overload condition will cause heat buildup around the current path, within the CB as well as along the power conductors. This heat, which is generated by the current flow, is actually what causes the CB to trip in this region not simply the magnitude of the current flow. This portion of the curve is said to have an inverse time characteristic, which means that the CB will trip in less time at higher levels of current flow.

Since the current path (including both the CB and the conductor) reacts to heat, the overall operating temperature of the equipment becomes a factor in sizing a CB in an enclosure.

Other factors that may affect this equipment operating temperature include:

* Size and location of the enclosure;
* More than one current carrying device housed in the same enclosure;
* Level of current each device is carrying; and
* Environmental conditions in the area of the equipment.

Consequently, simply designing a CB to hold 100% of its rated current only addresses a portion of the concern. The equipment must be able to safely sustain the heat generated by all sources without exceeding the temperature limits in the product test standard. Both of these factors are accounted for by the sizing rules imposed by the NEC.

1996 NEC

The 1996 NEC recognizes that overcurrent protective devices will be affected by heat in the system. As such, it defines the concept of continuous loads and the 80% rule to try and offset the effects of heat in the system when sizing a CB. Continuous loads. To better understand the sizing aspects of a CB, you must first clearly understand the concept of continuous loads.

In Art. 100, the NEC defines a continuous load as "a load where the maximum current is expected to continue for three hours or more."It's critical for you to understand that this is a load at its maximum current uninterrupted for at least three hours. Office lighting typically meets this qualification.

NEC sizing rules. Secs. 210-22(c), 220-3(a), 220-10(b), and 384-16(c) all relate to the sizing rules for overcurrent protective devices (OCPDs). The first three all specify the same requirement:

OCPD size = 100% of noncontinuous load + 125% of continuous load.

Sec. 384-16(c) has the same requirement, except that it's stated in terms of the loading of the OCPD. This rule states that an OCPD can be loaded to only 80% of its rating for continuous loads. Remember that 80% is the inverse of 125% (0.80 = 1 [divided by] 1.25) and, as such, the rules are indeed identical in their end requirement.
Read the rule closely; the 125% sizing of the OCPD (or 80% loading) is only applicable when continuous loads are involved. CBs and other OCPDs can be sized at 100% of their rating for noncontinuous load applications.

100%-rated devices. The NEC does recognize complete assemblies (including the OCPDs) that are listed for operation at 100% of their rating for continuous loads. This means that the equipment has undergone additional testing to verify that it can handle the additional heat rise associated with this level of operation.

A 100%-rated CB and the end use equipment have been tested to verify that the additional heat generated by the 100% continuous loading conditions is safely dissipated. Other equipment specifications also are driven by the need to dissipate the heat associated with the level of heat rise achieved during 100% rated testing. In cases where the temperature at the CB wiring terminals exceeds 50 [degrees] C during 100% rated testing, UL 489 requires the use of 90 [degrees] C insulated wire (sized at the 75 [degrees] C ampacity) with these CBs, and the CB must be marked as such by the manufacturer. UL 489 also specifies minimum enclosure size and venting requirements if needed for heat dissipation. A CB that successfully has passed these additional tests is still not listed for application at 100% of its rating for continuous loading unless it's marked as such by the manufacturer.

In summary, a CB either carries a standard rating (80%) or a 100% rating. The standard rating is subject to the NEC sizing rules we've just discussed. CBs that are 100%-rated are permitted to be loaded continuously at their full rating as long as the assembly is listed and conductors are properly connected.

CB sizing examples

The following are examples of sizing rules.

Example 1: 50A continuous load and 125A non-continuous load.

OCPD = 100% non-continuous load + 125% continuous load = (1.00 x 125A) + (1.25 x 50A) = 187.5A

Therefore, a 200A OCPD is needed. If a 100%-rated CB is chosen, a 175A rating (125A + 50A) is acceptable.

Example 2: 300A non-continuous load.

A 300A device is acceptable; a 100%-rated device is not needed since the load is non-continuous.

Example 3: 200A continuous load.

OCPD = 100% non-continuous load + 125% continuous load = (1.00 x 0A) + (1.25 x 200A) = 250A

Therefore, a 250A device is needed. If a 100%-rated CB is selected, a 200A rating is permitted.

Example 4: 16A continuous and 30A non-continuous.

OCPD = 100% non-continuous load + 125% continuous load = (1.00 x 30A) + (1.25 x 16A) = 50A

Therefore, a 50A device can be selected. Although 100%-rated devices typically are not available in sizes this small, the permitted rating would still be 50A (16A + 30A = 46A; rounded up to 50A).