Application Paper **AP01200008E** Effective February 2010

UL listed 100%-rated molded case circuit breakers

Introduction

Reducing overall costs is a goal of every project. 100%-rated circuit breakers can help achieve this objective. This paper discusses the proper application of 100%-rated circuit breakers to aid in choosing the right product solution for protecting a distribution system.

Requirements

Before addressing the 100%-rated topic, we should start with a basic understanding of the requirements set forth by the National Electrical Code® (NEC®) and Underwriters Laboratories® (UL®) for rating overcurrent devices. It is important to know that all overcurrent devices are designed and tested at 100% of their nameplate current rating in open air (ref. UL 489 for MCCB). As a result, that continuous current rating is printed on the device nameplate.

When an overcurrent device such as a molded case circuit breaker (MCCB) or fuse is applied in an assembly, it must be sized at 125% of the continuous load per NEC 210.20(A). This results in an overcurrent device being applied at 80% of its nameplate rating. This application sizing rule accounts for the resulting higher ambient temperatures found when an overcurrent device is contained within an enclosure. For the sake of this paper, the balance of the discussion will be focused on MCCBs only, recognizing that the same overcurrent device rules also apply to fuses.

When considering the total cost of a distribution system, a brief analysis shows that size and ratings of components within the system contribute heavily to the overall cost. If a breaker is applied at 100% of its nameplate rating, there is a potential to reduce not only the breaker size, but also the conductor size and the size of the enclosure. This size reduction may result in a less expensive distribution system. Where continuous loads force the selection of a larger frame breaker, 100%-rated breakers may allow the user to remain in a smaller frame breaker.

It is worth noting that thermal-magnetic and electronic trip MCCBs can both be tested for 100% ratings. Since a breaker's main function is to protect the conductors, even though the trip characteristics of an electronic breaker are not as sensitive to elevated temperatures, the conductors are impacted by temperature, thus requiring the special test for 100% rating.

Evaluation

The first step in evaluating the potential use of 100%-rated devices requires an understanding of how the NEC addresses the rating of the overcurrent device.

NEC 210.20(A): *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% of the continuous load.*

Exception: Where the assembly, including the overcurrent devices protecting the branch circuit(s), is listed for operation at 100% 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.

Note: A continuous load as defined by NEC Article100 is "a load where the maximum current is expected to continue for three hours or more."

This exception can be expressed using the following formulas:

Standard 80%-rated design

Noncontinuous load + 125% of continuous load = total minimum load

Special 100%-rated design

Noncontinuous load + continuous load = total minimum load

Notice that the exception refers not only to the breaker, but also to the entire assembly. Since most manufacturers do not label their enclosures at 80% or 100%, the enclosures must either meet the minimum enclosure size and ventilation requirements spelled out by the overcurrent device manufacturer or have the system tested by UL for 100%-rated breaker operation.

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Next, the NEC addresses the rating of the conductor size for the feeder-circuit.

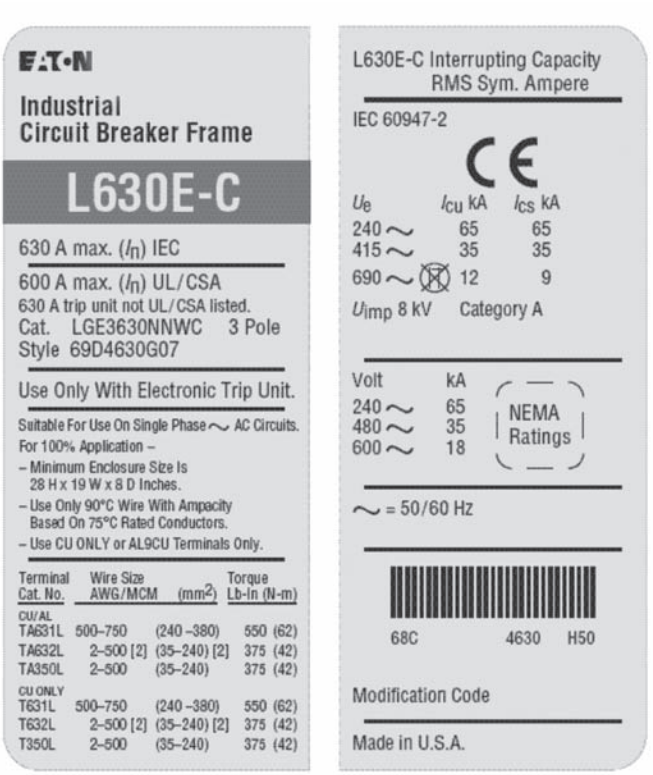
NEC 215.2(A): *The minimum feeder-circuit conductor size, before the application of any adjustment or correction factors, shall have an allowable ampacity not less than the noncontinuous load plus 125% of the continuous load.*

Exception: Where the assembly, including the overcurrent devices protecting the feeder(s), is listed for operation at 100% of its rating, the ampacity of the feeder conductors shall be permitted to be not less than the sum of the continuous load plus the noncontinuous load.

This exception tells us that an assembly listed for operation at 100% of its rating will also carry the full rating of the overcurrent device *and* conductor. Therefore, the same formula that applies to breakers can also be used for the conductors. UL provides additional explanation about the conductor sizing in Section 9.1.2.14 where it says that the conductor must be applied using 90°C wire based on the ampacity of 75°C-rated conductors when used with a 100%-rated circuit breaker. In other words, 90°C wire must be sized with the same circular mils as the associated 75°C wire for a required ampacity. An example of this would be a required conductor ampacity rating is 380A. In a 100%-rated application, the choice of conductor would be 90°C 500 kcmil conductor, not 90°C 400 kcmil (NEC Table 310.16). The last detail for conductors is the connectors or terminals that must be used. Per UL 489 9.2.14(b), they shall either be provided on the circuit breaker by the manufacturer or if the conductors are aluminum or copper-clad aluminum, connectors shall be identified as AL9, CU9AL, or AL9CU.

Now that we have defined the rules for applying breakers and conductors, we must understand how to determine the difference between a standard breaker and one rated for 100% of its name-plate current. As required by UL and shown in the example label at right, a breaker manufacturer must include information on the enclosure size that was used to achieve 100% rating during testing.

UL 489 9.1.4.4 *A circuit breaker, having a frame size of 250A or greater, or a multi-pole type of any ampere rating rated over 250V; and intended for continuous operation at 100% of rating, shall be marked: Suitable for continuous operation at 100% of rating only if used in a circuit breaker enclosure Type (Cat. No.) ____ or in a cubicle space ___ by ___ by ___ mm (inches). Equivalent wording shall be permitted. The blanks are to be filled in with the minimum dimensions.*



Application

We can now evaluate the steps to determine if 100%-rated breakers provide an economic benefit.

Enclosure Size

This information is provided on the breaker label as seen above and in Table 1, which is based on testing that was performed with UL. If the enclosure that will house this breaker meets the minimum dimensions and/or the ventilation requirements listed, proceed to the load calculation.

Load Calculation

1. Examine each load in the system and determine if they are primarily continuous (three hours or more) or noncontinuous loads. If all of the loads are noncontinuous, both the standard-rated and 100%-rated breaker can be size at 100% of the load, so the standard-rated breaker would be the most economical option.
2. If continuous loads are part of the system, a simple calculation (formulas above) must be done to determine if using a 100%-rated breaker will result in a financial benefit for the customer.
3. One consideration that should always be weighed is the amount of future growth anticipated for the system. Load calculations can be modified to simulate potential growth, which will help improve the accuracy of estimating such expansions. Keeping an eye on this detail will maximize savings over the life of the system.

The example in Table 2 on Page 3 will best illustrate this calculation and clarify the decision point, keeping in mind that the financial savings could be found in the breaker, conductors, equipment, or any combination of these places.

Table 1. Available 100%-Rated Circuit Breakers

Frames	Amperes	Minimum Enclosure Size—In (mm)	Rating at 480V		Trip Units
JG-Frame	250A	26.00 x 18.00 x 8.00 (660.4 x 457.2 x 203.2 mm)	JGE-C, JGS-C, JGH-C, JGC-C	25 kA, 35 kA, 65 kA, 100 kA	Thermal-magnetic, Digitrip™ 310+
K-Frame	125/250/400A	24.00 x 15.00 x 6.00 (609.6 x 381.0 x 152.4 mm)	CKD, CHKD	35 kA, 65 kA	Digitrip 310
L-Frame	600A	24.00 x 15.00 x 6.00 (609.6 x 381.0 x 152.4 mm)	CLD, CHLD, CLDC	35 kA, 65 kA, 100 kA	Digitrip 310
LG-Frame	600A	28.00 x 19.00 x 8.00 (711.2 x 482.6 x 203.2 mm) ①	LGE-C, LGS-C, LGH-C, LGC-C	35 kA, 50 kA, 65 kA, 100 kA ④	Thermal-magnetic, Digitrip 310+
M-Frame	800A	42.00 x 18.00 x 7.50 (1066.8 x 457.2 x 190.5 mm)	CMDL, CHMDL	50 kA, 65 kA	Digitrip 310
N-Frame	800/1200A	42.00 x 22.75 x 11.50 (1066.8 x 577.9 x 292.1 mm) ②	CND, CHND, CNDC	50 kA, 65 kA, 100 kA	Digitrip 310, Digitrip OPTIM™
R-Frame	1600/2000A	21.50 x 18.00 x 13.00 (546.1 x 457.2 x 330.2 mm) ②③	CRD, CRDC	65 kA, 100 kA	Digitrip 310, Digitrip OPTIM, Digitrip 510/610/810/910

① Thermal-magnetic LG requires venting 7 square inches above and 7 square inches below on the front face of enclosure.

② 100%-rated NG-C and RG-C will be available soon.

③ Use with 9-inch (228.6 mm) Tee connector.

④ Contact Eaton for 100 kA applications.

Table 2. Illustrative Example

Selection of either a 100%-rated design or standard design must result from a system analysis beginning with the lowest feeder and concluding with the system's main device. For this system example, assume that all assembly testing has been successfully completed and either the 100%-rated design or the standard design can be selected. Each system is hypothetical, and either approach will meet safety requirements. Loads were arbitrarily selected. The load table includes the calculations for minimum total loads in conformance with NEC Section 210.20(A).

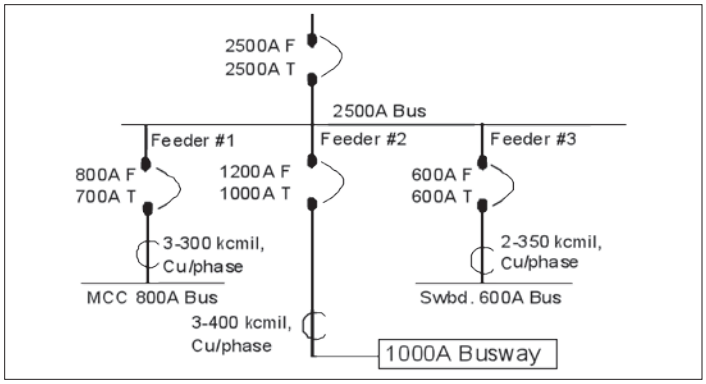
Load	Feeder #1	Feeder #2	Feeder #3	Main	Description
Noncontinuous Continuous	200A 400A	0 800A	600A 0	1000A 1000A	Three-phase distribution system line diagrams
Standard 80%-Rated Design—Noncontinuous Load + 125% of the Continuous Load = Total Minimum Load					See line-diagram 1, below
Calculation per NEC of minimum total load ①	200 + (1.25)(400) = 700A	0 + (1.25)(800) = 1000A	600 + 0 = 600A	1000 + (1.25)(1000) = 2250A ①	
Breaker frame (F), trip (T) rating	800A (F) ④ 700A (T)	1200A (F) ④ 1000A (T)	600A (F) 600A (T)	2500A (F) ④ 2300A (T)	
Bus/cable rating	800A ④	1000A	600A	2500A ④	
100%-Rated Design—Noncontinuous Load + Continuous Load = Total Minimum Load					See line-diagram 2, below
Calculation per NEC of minimum total load ②	200 + 400 = 600A	0 + 800 = 800A	600 + 0 = 600A	2000A ③	
Breaker frame (F), trip (T) rating	600A (F) 600A (T)	800A (F) 800A (T)	600A (F) 600A (T)	2000A (F) 2000A (T)	
Bus/cable rating	600A	800A	600A	2000A	

① (Noncontinuous Load) + (125%)(Continuous Load) per NEC Section 210.20(A).

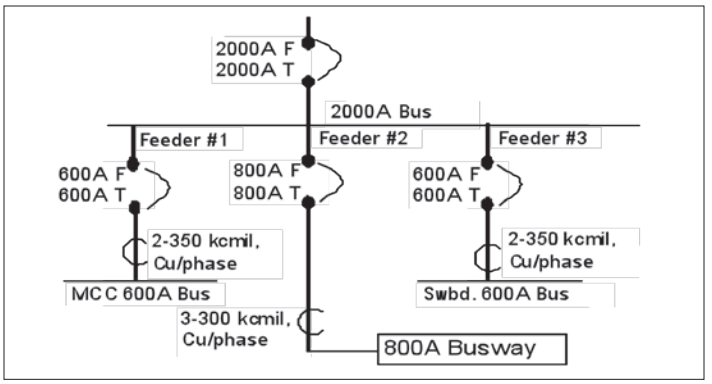
② (Noncontinuous Load) + (Continuous Load) per NEC Section 210.20(A) Exception.

③ Sum of all NEC calculated minimum feeder loads.

④ Nearest standard size, not less than calculated value.



Line-diagram 1



Line-diagram 2

Table 3. The Results

Design	Minimum Total Load (Amperes)			
Standard load	700	1000	600	2250
100%-rated load	600	800	600	2000
Results	Economic advantages are achieved by using the 100%-rated design. Savings result from a smaller frame breaker (M-Frame to L-Frame), smaller bus requirement, and reduced cable size.	Economic advantages are achieved by using the 100%-rated design. Savings result from a smaller frame breaker (N-Frame to M-Frame), smaller bus requirement, and reduced cable size.	Calculations indicate that either approach results in the same size breaker and hardware. The final decision could rest on whether or not future load growth is anticipated.	The 100% approach results in the same frame size breaker with a savings in conductor material cost. Eaton offers a 2000A frame 100%-rated breaker, which is less expensive than the 2500A frame 80%-rated.

With the proper understanding of 100%-rated circuit breakers and knowledge of a particular application, a simple evaluation can help point to the right solution. Advantages to a 100%-rated solution may include lower rated and smaller sized circuit breakers, less cable, and a potential to reduce equipment floor and wall space. Additional foresight about future expansion could also weigh heavily on the final decision. An understanding of all these facts will help in choosing those components that provide the greatest economic benefit.

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