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Short-Circuit Current Rating Update

Short-Circuit Current Rating (SCCR) is not a new topic, but recent changes to the Underwriters Laboratories (UL) safety standard for heating and cooling equipment, UL 1995[1], could result in a significant increase in SCCR design issues. As of July 30, 2012, listed HVAC equipment with Maximum Over-Current Protection (MOP) greater than 60 amps will include an SCCR on or near the nameplate, making it much easier for code officials to check compliance.

This EN provides an overview of industry terminology while offering practical solutions to SCCR design challenges.

The issues surrounding short-circuit current ratings were covered in an earlier newsletter[2] published in August of 1998. Back then the rating was called short-circuit withstand rating. Because the terminology can be confusing, let's start with a review of the key terms surrounding this issue: *fault current*, *interrupt rating*, *short-circuit current rating*, and *current-limiting*. Knowing what these terms mean and applying them correctly is fundamental to designing safe, reliable electrical distribution systems.

Fault Current, n. Imagine a wiring error that inadvertently connects one phase directly to another or a phase to ground. When the circuit is energized, this mistake results in a potentially dangerous situation or "fault condition" caused by the low-impedance, phase-to-phase or phase-to-ground connection—a "short circuit."

Fault current, also called "short-circuit current" (I_{SC}), describes current flow during a short. It passes through all components in the affected circuit. Fault current is generally very large and therefore hazardous. Only the combined impedance of the object responsible for the short, the wire, and the transformer limit its magnitude.

One objective of electrical distribution system design is to minimize the effect of a fault, i.e., its extent and duration, on the uninterrupted part of the system. Coordinating the sizes of circuit breakers and fuses ensures that these devices isolate only the affected circuits. Put simply, it prevents a short at an outlet from shutting down power to the entire building.

Calculating the magnitude of the fault current is prerequisite to selecting appropriate breakers, fuses, and equipment. If the transformer and unit are in close proximity, the calculation can be simplified by ignoring the impedance of the interconnecting wiring—a simplification that errs on the side of safety. We can also assume that the source of the fault has zero impedance, i.e., a "bolted" short. Given these assumptions, the only impedance left to consider is that of the transformer. (Impedance upstream of the transformer is usually negligible.)

Suppose a rooftop with a minimum circuit ampacity (MCA) of 80 amps is supplied by a 500-kVA, 480-V transformer with an impedance of 2.5 percent. With this value and the equation below, we can determine how much fault current a short circuit will produce.

$$I_{sc} = \frac{500\ kVA \cdot 1000}{480\ V \cdot 1.73 \cdot 0.025}$$

$$= (24,100\,amps)$$

As you can see, a short-circuit would force our wiring to carry more than 20,000 amps (until the fault was cleared), when it was designed to handle approximately 80 amps!

Short-circuit current is often two orders of magnitude greater than normal operating current. Unless a circuit breaker or fuse successfully interrupts the fault, this enormous amperage rapidly heats components to temperatures that destroy insulation, melt metal, start fires—even cause an explosion if arcing occurs. The inherent likelihood of severe equipment and property damage, as well as the risk of personal injury or death, underscores the importance of sufficient electrical distribution system protection.

Interrupt Rating, n. Determined under standard conditions, the "interrupt rating" specifies the maximum amount of current a protective device can cut off safely—i.e., without harm to personnel, damage to equipment, the premises, or the device itself. For example, a circuit breaker that trips "safely" successfully interrupts the fault, can be reset and will function properly afterward. To safely stop the fault current calculated for our rooftop unit scenario, the interrupt rating of the circuit breaker or fuses selected must be at least 24,100 amps.

A common misconception. Before leaving this topic, let's dispel a common misconception: "Using an overcurrent protection device with an interrupt rating greater than the fault current is all that is required to satisfy the short-circuit code requirements." Not so—not unless it's also a true current-limiting device as described in the "Current Limiting" section of this newsletter. Even though the device successfully breaks the circuit, all components in the circuit will be exposed to the full magnitude of the let-through current (as well as the severe thermal and magnetic stresses that accompany it) for the time it takes the device to clear the fault current.

Short-Circuit Current Rating, n.
Though often used as such, "interrupt rating" and "short-circuit current rating" are not interchangeable terms. Unlike the interrupt rating, which defines the performance limit of an overcurrent protection device (e.g., circuit breaker or fuse), the "short-circuit current rating" identifies the maximum short-circuit amperage (fault current) a component, enclosure, or unit can experience without injuring personnel or damaging the premises.

UL defines the methods for determining the short-circuit current rating. A standard short-circuit current rating can be determined if all of the individual components in the power circuit have a short-circuit current rating. Essentially the component with the lowest rating sets the rating for the assembly. A higher rating can be given by testing a current-limiting short-circuit interrupt device (e.g., a current-limiting breaker or fuse) in combination with the panel components or by using pretested combinations of components. Due to the high cost of testing HVAC equipment, manufacturers commonly use pretested combinations to provide higher short-circuit current ratings.

Recall that when a fault occurs, all components in the circuit experience the brunt of the short circuit until it's stopped. Therefore, it's important to ensure that all components "at risk" can withstand a fault condition without causing injury or damaging the surroundings. The 2011 National Electrical Code® (NEC)[3] states this requirement in Section 110-10, "Circuit Impedance, Short-Circuit Current Ratings, and Other Characteristics":

> The overcurrent protective devices, the total impedance, the equipment short-circuit current ratings, and other characteristics of the circuit to be protected shall be selected and coordinated to permit the circuit protective devices used to clear a fault to do so without extensive damage to the electrical equipment of the circuit. This fault shall be assumed to be either between two or more of the circuit conductors or between any circuit conductor and the equipment grounding conductor(s) permitted in 250.118. Listed equipment applied in accordance with their listing shall be considered to meet the requirements of this section.

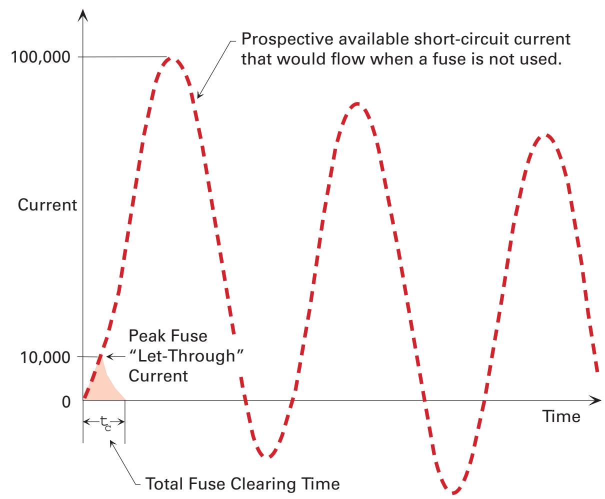
Commentary in the *2011 National Electrical Code Handbook*[4] further explains Section 110-10:

> Wire, bus structures, switching, protection and disconnect devices, and distribution equipment all have limited short-circuit ratings and would be damaged or destroyed if those short-circuit ratings were exceeded. Merely providing overcurrent protective devices with sufficient interrupting ratings would not ensure adequate short-circuit protection for the system components. When the available short-circuit current exceeds the short-circuit current rating of an electrical component, the overcurrent protective device must limit the let-through energy to within the rating of that electrical component.
>
> Overcurrent protective devices (such as fuses and circuit breakers) should be selected to ensure that the short-circuit current rating of the system components is not exceeded should a short circuit or high-level ground fault occur.

To comply with this section of the NEC, the nameplate on our example unit must have short-circuit current rating of at least 24,100 amps indicating that the rooftop power circuit would be able to safely clear the fault and withstand the let-through current.

Current Limiting, n. All components and wiring in an electrical distribution system offer some degree of resistance to current flow. Under normal conditions, the heat produced when current flows against this resistance readily dissipates to the surroundings. However, the enormous current generated during a short circuit produces damaging heat at a much faster rate than can be safely dispersed. Interrupt the current and you stop adding heat to the system.

Figure 1.



As Figure 1 suggests, time is a critical determinant of the amount of heat (energy) added. An electrical short that lasts three cycles, for example, adds six times the energy of one lasting just one-half of a cycle. It's in this sense that all circuit breakers and fuses "limit" current. Figure 1 also shows the effect of a current-limiting device. To be truly current-limiting, the interrupting device must open the circuit within one-quarter cycle (1/240 second), i.e., before the fault current peaks.

Remember our rooftop scenario? If there isn't a unit available with a short-circuit current rating greater than 24,100 amps, compliance with NEC Section 110-10 requires that we either:

- Add a current limiting device, i.e., usually a fuse, but sometimes a circuit breaker and fuse in series, that restricts the fault current to a value less than the unit's short-circuit current rating. Or …
- Redesign the electrical distribution system to reduce the fault current. Choosing this approach warrants a more detailed fault-current analysis.

UL 1995 Requirements Changed

As of July 30, 2012, all equipment listed under UL 1995 is required to include an SCCR on the nameplate with the following exceptions as noted in section 37.3 (y):

"Equipment intended for use in one- and two-family dwellings, cord-and-attachment plug connected equipment, or equipment supplied from a branch circuit protected at 60 A or less is not required to be marked with a short-circuit current rating."

Listed equipment cannot be assumed to comply with the NEC SCCR requirement by virtue of its listing. Code compliance for all equipment not specifically exempted above will require a fault current calculation and that the available fault current at the unit not exceed the nameplate SCCR.

Summary

Protecting HVAC equipment is a critical element of electrical distribution system design. Proper selection and coordination of overcurrent protection devices should occur early in the design process, and should address both normal operation and fault conditions.

Occasionally, the calculated fault current exceeds the short-circuit current rating listed on the nameplate of the equipment. Such cases require adding an appropriate current limiting device or redesigning the electrical system to reduce fault current.

The fault-current analysis in the rooftop unit scenario consisted of a simplified, worst-case calculation. While this is often sufficient to select system components, a more detailed analysis may be justified.

To learn more, refer to The IEEE Buff Book: *Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems*[5] published by The Institute of Electrical and Electronics Engineers, Inc.

By Dave Guckelberger, applications engineer, Trane. You can find this and previous issues of the Engineers Newsletter at www.trane.com/engineersnewsletter. To comment, e-mail us at comfort@trane.com.

References

[1] Underwriters Laboratories Inc. 2011. UL 1995. *Standard for Safety: Heating and Cooling Equipment*. 4th ed. Northbrook, IL: UL.

[2] Guckelberger, D. and Bradley, B. 1998. "Protecting the Electrical Distribution System… Short-Circuit Withstand Ratings Demystified." Trane Engineers Newsletter, 27-3.

[3] National Fire Protection Association. 2010. NFPA 70. *National Electrical Code*. 2011 ed. Quincy, MA: NFPA.

[4] National Fire Protection Association. 2011. NFPA 70. *National Electrical Code Handbook*. 2011 ed. Quincy, MA: NFPA.

[5] The Institute of Electrical and Electronics Engineers. 2001. IEEE Standard 242-2001. *The IEEE Buff Book: IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems*. New York, NY: IEEE.

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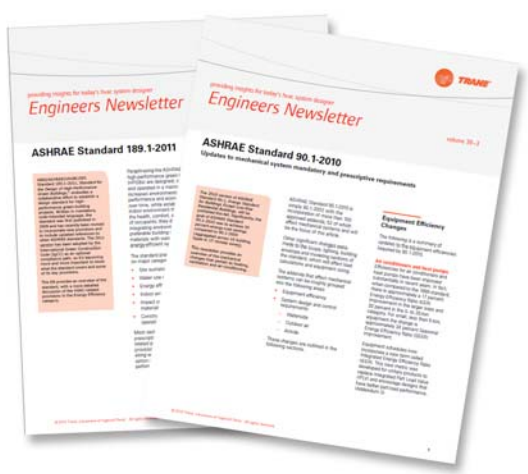

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(SYS-APM008-EN, updated May 2012)

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(SYS-APM010-EN, November 2011)

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