Our energy working for you.™

Power Generation

Power topic #9005 | Technical information from Cummins Power Generation

Hidden dangers when applying 30-cycle rated transfer switches

White Paper

By Ken Box, P.E., Southeast Regional Manager, Power Electronics

The National Electrical Code (NEC) provides the electrical designer with minimum installation requirements for protecting electrical components against the damaging effects of short circuit currents. Components such as automatic transfer switches can be subjected to potentially damaging short circuit currents during high fault conditions. In addition, the NEC provides the electrical designer with minimum installation requirements for providing selective coordination between overcurrent protective devices. Nevertheless, there are system designs that present a dilemma for the electrical designer when component protection and selective coordination appear to be mutually unachievable.

Withstand current ratings and transfer switches

The Underwriters Laboratory standard for safety covering automatic transfer switches is UL 1008. This standard defines the test requirements for short circuit and fault closing ratings for transfer switches. A transfer switch must withstand a designated level of fault current until its upstream overcurrent protective device opens, unless an overcurrent protective device is integral to the transfer switch.

Along the same lines, NEC 110-10 states that electrical components such as transfer switches shall be protected against extensive damage from short circuits:

110.10 Circuit Impedance and Other Characteristics: *The overcurrent protective devices, the total impedance, the component 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 components 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 grounding conductor or enclosing metal raceway. Listed products applied in accordance with their listing shall be considered to meet the requirements of this section.*

Since transfer switches are not overcurrent protective devices except where integral protection is provided, they must be protected by upstream overcurrent protective devices that are capable of safely opening under short circuit conditions and protecting the downstream transfer switch.

Transfer switch withstand ratings involve two key factors. The first factor is the transfer switch's ability to safely survive its rated level of fault circuit. The second factor involves the element of time. How long can the switch safely withstand the fault current until the upstream overcurrent device opens and clears the fault?

The time factor used in the UL 1008 short circuit withstand and close test has historically been 3 cycles for switches larger than 400 A. These 3-cycle withstand ratings served the industry reasonably well for many years, because older molded-case circuit breakers had slower, short circuit interrupting times. Historically, the older molded case took about 3 cycles to interrupt short circuit currents. Vintage molded-case breakers have significantly slower interrupting times compared with circuit breakers manufactured today. In addition, the UL 1008 standard allows transfer switch manufacturers the option of testing with specific circuit breakers. Either method of testing is acceptable according to the UL 1008 standard. The specific breaker method results in transfer switches having higher withstand and close ratings than when short circuit tested for a duration of 3 cycles.

Modern molded-case circuit breakers with microprocessor trip units open and clear faults in significantly less than 3 cycles. The faster interrupting time provides higher short circuit withstand and close ratings for the transfer switch under short circuit conditions. Ultimately, the end user benefits because the transfer switch has a higher withstand and close rating as the result of being tested with specific circuit breakers.

Prior to 2007, UL 1008-listed transfer switches had to be tested and protected by molded-case circuit breakers listed to the UL 489 standard. The duration of the short circuit test is 1.5 cycles for transfer switches smaller than 400 A, and 3 cycles for switches larger than 400 A. Molded-case circuit breakers listed to the UL 489 standard incorporate instantaneous trip elements that open and clear faults "instantaneously" at or near the breaker's maximum interrupting rating. The clearing time of modern, UL 489-listed molded-case circuit breakers can be at fast as 20 msec or 1.2 cycles.

Some molded-case circuit breakers approach current-limiting status by clearing in a half-cycle or less. When current-limiting fuses are used as the overcurrent protective device, its total clearing time is less than a half-cycle. The current-limiting device's ability to open and clear the fault faster than it takes for the short circuit to reach its peak value reduces the amount of thermal and mechanical energy unleashed upon downstream components. Consequently, transfer switches protected by current-limiting protective devices have significantly higher WCR ratings because these overcurrent devices interrupt short circuits in less than a half-cycle.

Figure 1 compares the different WCR ratings for several transfer switch frame sizes:

Typical ATS UL 1008 Withstand and Close-On Ratings							
Transfer Switches	Current-Limiting Fuse Rating	Max Fuse Amps	Max Fuse Type	Specific Breaker Rating	3-Cycle Rating	Short-Time Withstand Rating	Short-Time Duration (Cycles)
125, 150, 225, 260	200,000	400	Class J, T	42,000 30,000	25,000 18,000	25,000 N/A	10 N/A
300, 400 600	200,000	1200	Class L, T	65,000 50,000	35,000 22,000	30,000 N/A	30 N/A
800	200,000	2000	Class L, T	85,000 65,000	65,000 65,000	42,000 N/A	30 N/A

Figure 1 - Withstand and close-on ratings.

30-cycle rated transfer switches

In 2007, the UL amended the 1008 standard for short circuit test criteria. Transfer switches were allowed to be protected with circuit breakers incorporating short-time ratings as long as the transfer switch was tested for the longer duration of time, i.e., longer than 3 cycles. Low-voltage power circuit breakers listed to the UL 1066 standard can incorporate short-time delay settings up to 30 cycles (0.5 seconds). Articles 700.27 and 701.18 of the 2008 National Electrical Code (NEC) state that “overcurrent devices shall be selectively coordinated with all supply side overcurrent selective devices.” While it is relatively simple to selectively coordinate overcurrent devices in the short-time region, challenges frequently arise in the instantaneous region of the time/current curve (see Figure 2).

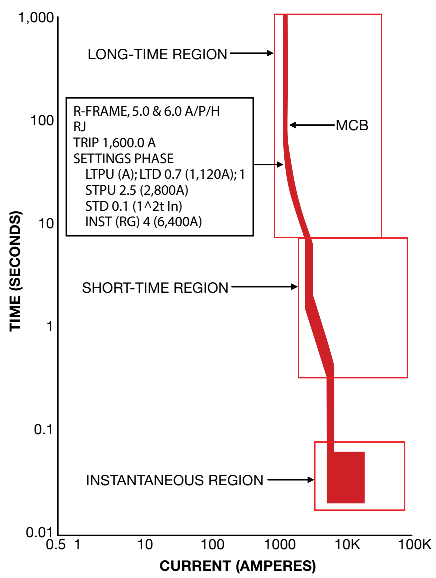

Figure 2

Transfer switches with extended withstand and close ratings (longer than 3 cycles) give the electrical designer the ability to adjust and coordinate the trip settings for upstream power circuit breakers with downstream circuit breakers incorporating instantaneous trip elements. Unfortunately, the use of short-time rated trip units in low-voltage power circuit breakers can potentially allow fault currents to flow for as long as 30 cycles (0.5 seconds). This results in the need for the designer to evaluate the impact of utilizing short-time delays in several additional areas:

- The impact of the additional duration of current flow on devices and equipment downstream from the ATS.
- The impact of greater arc flash energy in downstream devices and personnel.

Electrical conductors and short circuit withstand ratings

The chart in Figure 3, published by the Insulated Cable Engineers Association (ICEA), provides an illustration of the amount of short circuit energy (proportional to I^2t) that will generate the maximum temperature in a particular size of cable.

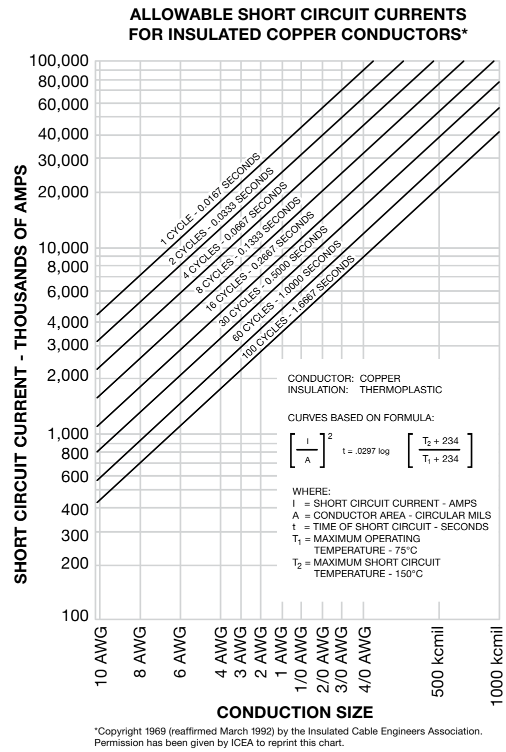

Figure 3

According to the ICEA chart, 500 kcmil cable can withstand about 39,000 A of fault current for 30 cycles. As many systems have much higher levels of available fault current, it would not be acceptable to protect this cable with a breaker with a 30-cycle time delay setting. We can also see from this chart that if the 500 kcmil cable is protected by a device that trips in 3 electrical cycles, it can withstand well over 100,000 A.

An 800 A automatic transfer switch is commonly supplied with two 500 kcmil conductors per phase fed from 800 A low-voltage power circuit breakers. The load conductors from the transfer switch are also commonly sized using 2 – 500 kcmil per phase and neutral. Assume copper conductors in both cases. Let’s also assume 82,000 A RMS symmetrical of fault current is potentially available at the line side lugs of the transfer switch. We can select an 800 A low-voltage power circuit breaker rated 100 kaic at 480 V. We are using short-time delays to achieve selectivity with downstream devices.

Transfer switches and component protection

The short-time rating of the power circuit breaker is 85 kA for 30 cycles. Consequently, we must select an automatic transfer switch capable of carrying the 800 A load and listed to withstand 82,000 A for 30 cycles. The component protection problem occurs at the conductors. Each individual 500-kcmil conductor is capable of withstanding 39,000 A RMS symmetrical. Together, the conductors can theoretically withstand 78,000 A.

However, we have 82,000 A RMS symmetrical available at the transfer switch. Consequently, we have not complied with the minimum requirements of NEC 110-10. We could alleviate the problem by oversizing the conductors or increasing the size of the switch. Typically, an 800 A transfer switch will not have sufficient space for three sets of conductors per phase. But besides increasing the cost of the switch, oversizing conductors or increasing the ampacity of the switch doesn't address the issue of exposing personnel to high levels of short circuit energy.

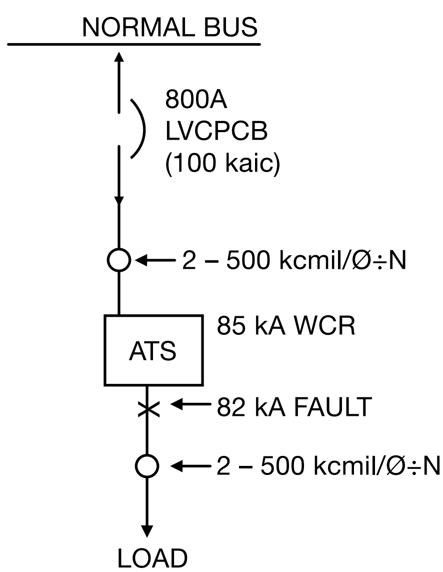

Figure 4

One could argue that the above example is "splitting hairs" just to prove a point. How many short circuits result in nice, clean interruptions without damage to components? There is always damage after a high-level short circuit as seen in Figure 5. The transfer switch shown here was subjected to its maximum withstand rating for a duration of 3 cycles. The switch shown in the photo passed the test. Obviously, there is damage. UL 1008 test procedures don't require the switch to carry rated load after a fault. Since safety, not performance, is the intent of the UL short circuit test, one should avoid stressing the device to its limits.

Figure 5

What purpose did it serve to achieve selectivity when the end result required replacing the circuit conductors? The NEC mandates selectivity, component protection and arc flash protection. Safety is the ultimate issue, not convenience. The amount of energy released during a 30-cycle interruption is shown in Figure 6.

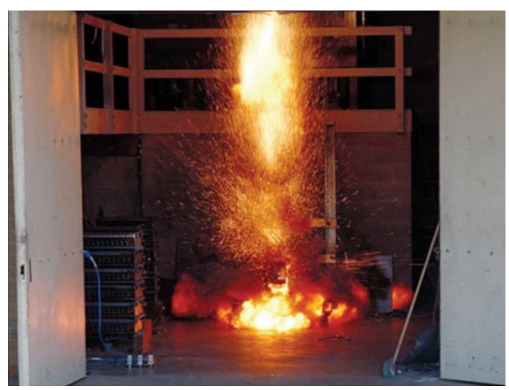

Figure 6

Current-limiting devices reduce the destructive energy effects of short circuits

The concept of current limitation is illustrated in Figure 7, where the prospective available fault current is shown in conjunction with the limited let-through current associated when a current-limiting cable limiter clears. The area under the current curve is representative of the amount of short circuit energy let through prior to interruption of the circuit. Since thermal and magnetic forces are proportional to the square of the current, it is critically important to limit the amount of current to as small a value as possible for protection of downstream components.

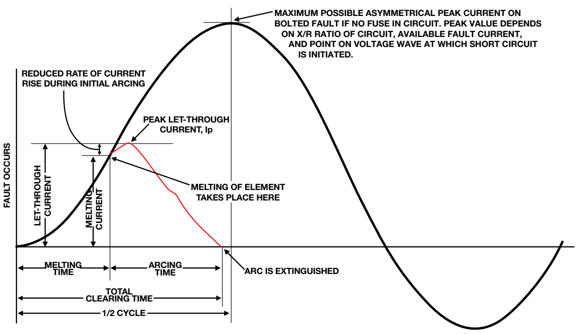

Figure 7

Keep in mind that the maximum magnetic forces vary as the square of the peak current, as Figure 8 illustrates, whereas thermal force energy varies as the square of the RMS current.

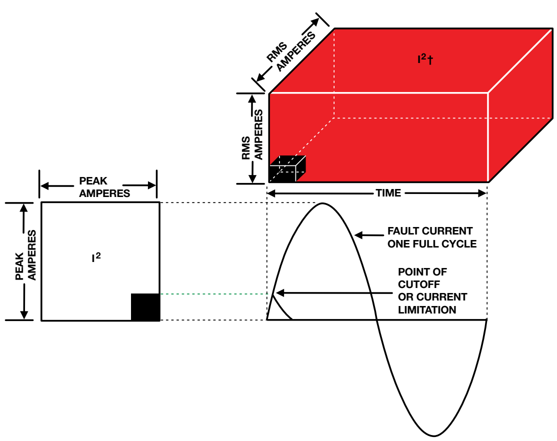

Figure 8

Current-limiting cable limiter devices can clear short circuits before they reach their maximum possible peak current as shown in the figures above.

Figure 8a - Current-limiting cable limiter

In Figure 9, note that the cable limiters installed at the transfer switch "see" the prospective 82,000 A RMS symmetrical short circuit. Since there are two cable limiters, the fault current is divided in half. In other words, each limiter sees 41,000 A. Since the cable limiters are current-limiting devices and will clear fault levels of this magnitude in less than a half-cycle, the resulting let-through current for each limiter is approximately 14 kA RMS and 35 kA peak. The resulting effect is that potentially damaging thermal and mechanical energy is reduced by more than 65%. The reduced let-through energy resulting from the cable limiter's clearing the short circuit protects the conductor and transfer switch from high levels of short circuit damage.

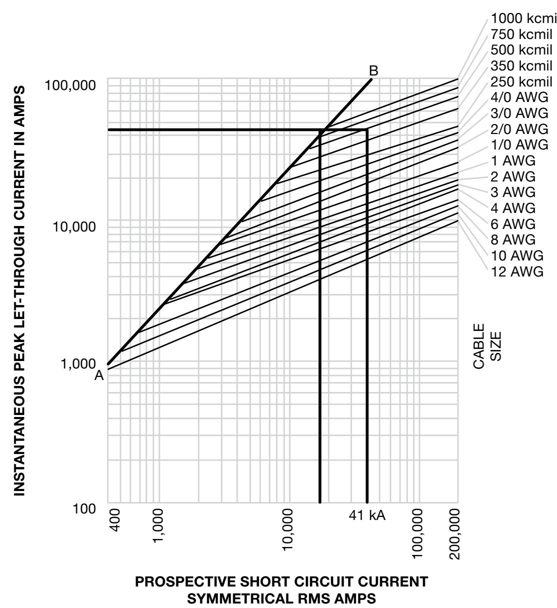

Figure 9

About the author

Ken Box is employed by Cummins Power Generation as the Southeast Regional Sales Manager for Power Electronics. Previously, Ken was the Director of Sales for Cummins Power South in Atlanta, Georgia. Ken's professional career spans over 30 years and includes positions with Westinghouse, Bussmann, McNaughton-McKay Electric, IEM, and Shallbetter, Inc. Ken holds a bachelor's degree in electrical engineering from the Georgia Institute of Technology. His current responsibilities include providing application engineering support for power generation products to customers in the healthcare, wastewater and data center markets. Ken is a published author, an active IEEE member and a licensed professional engineer.

Recommendations

So how does one achieve selectivity, reduce the arc flash hazard to personnel and protect downstream components? With respect to transfer switches, the following actions are suggested:

1. Analyze and compare the conductor withstand ratings, the transfer switch withstand (WCR) ratings and the ANSI breaker short-time rating against the available fault current at the transfer switch.
2. Make sure transfer switches and their conductors can survive the duration of the fault based upon the devices' listed ratings.
3. Reduce fault current and arc flash energy levels by installing current-limiting cable limiters with the transfer switch conductors.
4. Reduce arc flash energy levels by utilizing arc-reducing maintenance switches upstream on the normal and emergency side of the transfer switch.
5. Locate transfer switches close to the loads that they serve. When possible, avoid feeding transfer switches directly from large-ampacity power circuit breakers. This recommendation makes the overall system more reliable, since it is then less likely that a fault on one load will interrupt power to other loads on the system.

References

NFPA-70 2008 – The National Electric Code, National Fire Protection Association, Inc, One Batterymarch Park, Quincy, Massachusetts.

Application Manual for Transfer Switches – T-011a, July 2002, Cummins Power Generation.

Applying Low Voltage Fuses – Class & Characteristics Figures 6 & 7 by Hermann W. Reichenstein, 1979, An EC&M Publication of McGraw-Hill, New York, New York.

Selecting Protective Devices – SPD, Cooper Bussmann, 2008, St. Louis, Missouri.

Cummins Power Generation

Our energy working for you.™
www.cumminspower.com

PT-9005 (08/10)