Understanding the Withstand and Close-On Ratings for TRANSFER SWITCHES

AUTHOR
MIKE LITTLE
Principal Engineer

Kohler Co.
Power Systems Division

INTRODUCTION

Numerous short circuit current ratings and references exist for transfer switches that are often confusing and seemingly contradictory. This paper provides some explanation and clarification to help engineers specify the proper equipment to meet local and national regulations.

For an electrical system to operate safely, the design should consider a variety of scenarios where things do not go as planned. One of those scenarios is when a short circuit occurs in the system and causes extremely high currents. An electrical system needs to be designed to safely react to these extreme conditions and, ideally, to continue to function afterwards. This article looks at automatic transfer switches (ATS) which are integral pieces of the power distribution system that help ensure power for home, office, factory or process, when served by an emergency or standby generator in addition to the local utility.

This paper also aims to help engineers understand what the withstand and close-on ratings (WCR) means and provide background information to allow the proper sizing and selection of the transfer switch. Two key abilities of the transfer switch are tested under the WCR: the quantified ability to withstand fault currents for a specified period of time while maintaining functionality; and the ability to close into a fault current and continue to operate. Both abilities are critical to allow the electrical system to sustain a fault current with minimal impact.

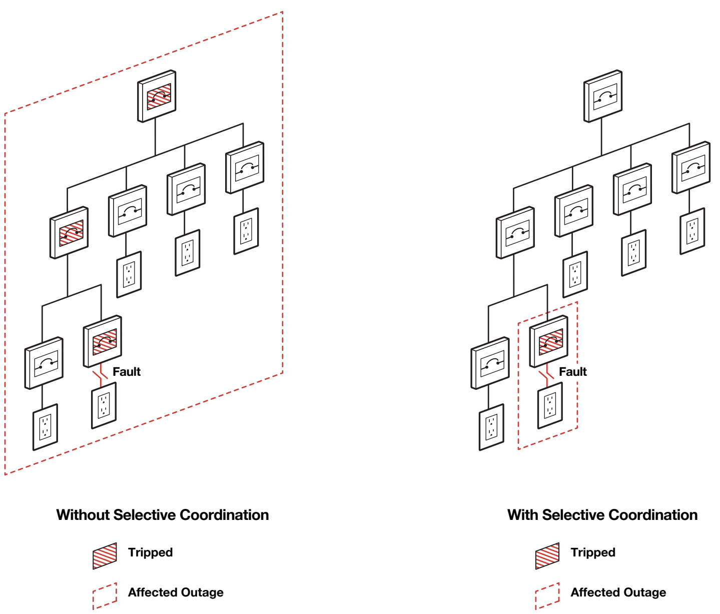
SELECTING AN ATS

I. UNDERSTAND DAMAGES CAUSED BY HIGH FAULT CURRENTS

Prior to selecting an ATS, it is important to understand how high fault currents can damage an electrical system's functionality. High fault currents flowing through power system components can create significant heat over the duration of the fault, which can cause damage to the insulation on conductors and transformers, as well as to the overcurrent protective devices and switch contacts.

Fault currents can also create significant mechanical stress, as they produce high magnetic forces that can bend bus structures, separate switch contacts, or cause power cables to pull out and energize surrounding structures or circuits. All these factors should be taken into consideration during the electrical system's design phase in conjunction with the power system study and proper selective coordination.

Figure 1



II. STUDY THE POWER SYSTEM

Detailed knowledge is required about the section of the power system where the ATS will be connected. Modern power system studies are performed by engineers who build models of power systems using computer software. The study covers all system parameters including the sizes, conductors' quantities and lengths, transformer ratings and impedances, overcurrent protective devices and related Time-Current Curves (TCC), and other relevant data.

Through a power system study, engineers compute fault currents at each system bus for normal, contingency and future system configurations and evaluate capability of upstream and downstream protective devices. Additionally, engineers provide computations on subjects such as available arc-fault energies at each bus along with analysis and recommendations on device coordination. Based on the study results, the specifier can then make an intelligent ATS selection.

III. APPLY SELECTIVE COORDINATION AND FAULT ISOLATION

As part of the power system study, it is important to understand the concept of selective coordination with overcurrent protective devices. Proper selective coordination ensures that an electrical fault will be cleared as close to the point of occurrence as is practical.

The National Electrical Code (NEC), in the 2017 standard, defines selective coordination as the following in Article 100:
"Localization of an overcurrent condition to restrict outages to the circuit or equipment affected, accomplished by the selection and installation of overcurrent protective devices and their ratings or settings for the full range of available overcurrents, from overload to the maximum available fault current, and for the full range of overcurrent protective device opening times associated with those overcurrents."

Figure 1 on the left shows an electrical system without selective coordination. Without selective coordination, when a fault occurs at a particular load, several levels of overcurrent protective devices (even the main disconnect) may see the fault and react, or trip. When this happens, it may potentially impact the entire facility.

Figure 1 on the right illustrates proper selective coordination, which is equipped with properly timed overcurrent protective devices. When a fault current happens, the upstream breakers from the fault "withstand" the current long enough that only the nearest overcurrent protective device will open and clear the fault. In this way, most of the distribution circuit remains unaffected and operational.

IV. IDENTIFY THE REQUIRED WCR FOR THE ATS

Engineers need to identify the required WCR for the point of installation. To ensure safety, the ideal WCR should be high enough that the transfer switch can handle available fault currents. At the same time, the WCR should not be overrated, which may result in a higher cost and larger switch, contributing to a lack of space in the electrical room.

For example, two identical 200 A-rated ATS installed at different parts of a facility may require different WCR levels. If a specifier installs a 200 A-rated ATS close to the utility service entrance, it may need to withstand a 35-kA available fault current as determined by the power system study. To achieve the required WCR, the ATS may be upsized or may require specific upstream overcurrent protection. Meanwhile, the same 200 A ATS installed in a branch circuit on the other side of the facility may only need to withstand a 10 kA available fault current, therefore requiring a much smaller WCR which allows more flexibility regarding selection of overcurrent devices and ATS model.

V. CONCLUSION

Engineers should conduct a comprehensive power system study prior to installing an ATS. The study would help determine available fault currents from sources present or considered for future installation and recommend appropriate WCRs for the ATS in Figure 1. Only with an accurate understanding of the electrical system and its design implications, can a proper ATS be selected to provide safe, robust and cost-effective solutions. This prestudy will also help avoid problems that can occur during the commissioning phase, such as impermissible disconnect and ATS combinations, incorrect switch purchase or failure to satisfy a specification.

UNDERSTANDING THE FOUR WCR TYPES

WCR are fundamentally the short-circuit ratings of a transfer switch. Various standards, such as UL 1008, define the methods and criteria for testing and reporting the WCR levels. The four main types of WCR (Figure 2) are specific breaker ratings, time-based ratings, short-time ratings and fuses. The categorization is based on how the overcurrent protection of the transfer switch is accomplished and tested.

The WCR for any KOHLER® ATS is found in the model's specification sheet and near the contactor inside the enclosure.

Figure 2

Typical contactor rating nameplate:

SUITABLE FOR CONTROL OF MOTORS, ELECTRIC DISCHARGE AND TUNGSTEN LAMPS, ELECTRIC HEATING EQUIP. WHERE THE SUM OF MOTOR FULL LOAD AMPS AND AMPS OF OTHER LOADS DOES NOT EXCEED THE SWITCH AMP RATING AND THE TUNGSTEN LOAD DOES NOT EXCEED 30 PERCENT OF THE SWITCH RATING.

SHORT-CIRCUIT WITHSTAND/CLOSING AND SHORT-TIME CURRENT RATINGS

WHEN PROTECTED BY A CIRCUIT BREAKER, THISTRANSFER SWITCH IS SUITABLE FOR USE IN A CIRCUIT CAPABLE OF DELIVERING THE SHORT-CIRCUIT CURRENT FOR THE MAXIMUM TIME DURATION AND VOLTAGE MARKED BELOW.

THE CIRCUIT BREAKER MUST INCLUDE AN INSTANTANEOUS TRIP RESPONSE UNLESS THE AVAILABLE SHORT-CIRCUIT CURRENT IS LESS THAN OR EQUAL TO THE SHORT-TIME RATING OF THE TRANSFER SWITCH AND THE CIRCUIT BREAKER INCLUDES A SHORT-TIME TRIP RESPONSE.

THE MAXIMUM CLEARING TIME OF THE INSTANTANEOUS TRIP RESPONSE MUST BE LESS THAN OR EQUAL TO THE TIME DURATION SHOWN FOR THE MARKED SHORT-CIRCUIT CURRENT.

SHORT-CIRCUIT CURRENT (RMS SYM AMPS)	VOLTAGE (VOLTS AC) MAX	TIME DURATION (SEC) MAX
65,000	600	0.050

WHEN PROTECTED BY A CIRCUIT BREAKER WITH A SHORT-TIME TRIP RESPONSE, THE SHORT-TIME RESPONSE OF THE CIRCUIT BREAKER MUST BE COORDINATED WITH THE SHORT-TIME CURRENT RATING OF THE TRANSFER SWITCH AS MARKED BELOW.

SHORT-TIME CURRENT (RMS SYM AMPS)	VOLTAGE (VOLTS AC) MAX	TIME DURATION (SEC) MAX
42,000	600	0.5

SPECIFIC CIRCUIT BREAKER MANUFACTURER AND TYPE LISTING

WHEN PROTECTED BY A CIRCUIT BREAKER OF THE SPECIFIC MANUFACTURER, TYPE, AND AMPERE RATING AS MARKED BELOW, THIS TRANSFER SWITCH IS SUITABLE FOR USE IN CIRCUITS CAPABLE OF DELIVERING THE SHORT-CIRCUIT CURRENT AT THE MAXIMUM VOLTAGE MARKED.

VOLTAGE (VOLTS AC MAX): 480

SHORT-CIRCUIT CURRENT (RMS SYM RATING AMPS)	CIRCUIT BREAKER MANUFACTURER	BREAKER MODEL/TYPE	BREAKER RATING (AMPS)
85,000	MFG ‘A’	TB8	800
		TKL	1200
	MFG ‘B’	CMD6	800
		HMD6	
		SCMD6	
		SHMD6	
		CND6	1200
		HND6	
		SCND6	
		SHND6	
		CPD6	1600
	MFG ‘C’	MH SER 2	1000
		PJ, PL	1200
		RJ, RL	1600
		SE LS TRIP	2500
		SEH LS TRIP	
	MFG ‘D’	HLD	600

SHORT-CIRCUIT WITHSTAND/CLOSING RATING WHEN PROTECTED BY FUSES

WHEN PROTECTED BY A FUSE OF THE SPECIFIC FUSE CLASS AND MAXIMUM AMPERE RATING AS MARKED BELOW, THIS TRANSFER SWITCH IS SUITABLE FOR USE IN A CIRCUIT CAPABLE OF DELIVERING THE SHORT-CIRCUIT CURRENT AT THE MAXIMUM VOLTAGE MARKED.

SHORT-CIRCUIT CURRENT (RMS SYM AMPS)	VOLTAGE (VOLTS AC) MAX	FUSE CLASS	RATING (AMPERES)
200,000	600	L	1600

Time based

Short time

Specific breaker

Fuses

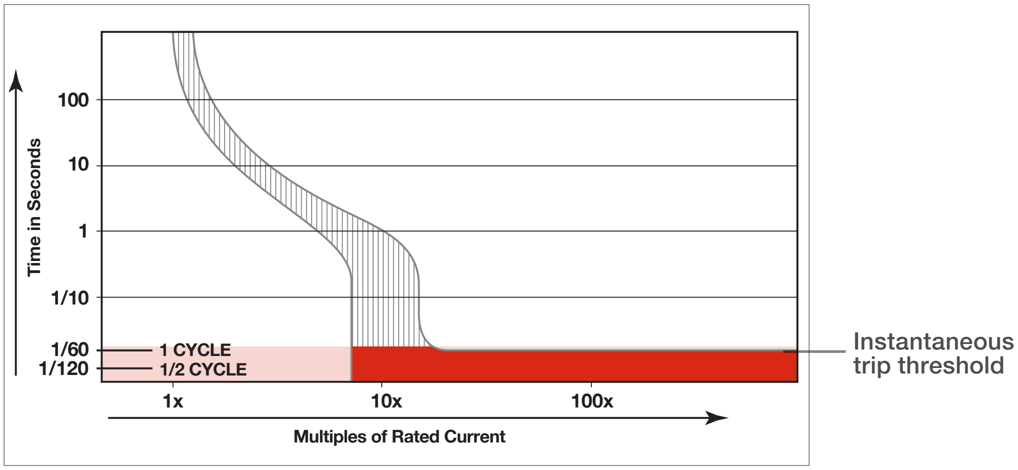
I. SPECIFIC BREAKER RATINGS

Sometimes referred to as series ratings, specific breaker ratings are just as they sound. For an ATS to receive a specific breaker rating, it should be short-circuit current tested with a specific molded-case circuit breaker between the ATS and the test source. Under the current UL 1008 standard, only the breakers that are listed on the contactor rating labels or in the ATS specification sheet can be used for specific breaker rating coordination Figure 2.

During the agency certification test, a fault current is applied to the ATS and prospective breaker. The selected circuit breaker clears the test current. The test procedures are described in the text box on Page 9.

Ideally, all breakers listed should be short circuit tested to determine their acceptability, even though it is expensive to do so. Alternatively, a proposed breaker can go through an evaluation of its published trip curve compared to the tested withstand and close-on clearing times of included breakers. If the entire instantaneous trip portion of the proposed breakers' characteristic trip curve is below the actual clearing time of the tested breaker(s), it can be included in the specific breaker list. See Figure 3. Additionally, the proposed breaker must meet the required fault current rating level at the tested voltage.

Figure 3



A BRIEF HISTORY: WHERE DID THIS UL CHANGE COME FROM?

The stricter qualification of specific breakers was enforced on November 1, 2014, as UL implemented the 7th edition of the UL 1008 standard. The new evaluation criteria resulted in shorter lists of specific breakers for many contactor manufacturers Figure 4.
Previously, the ATS manufacturer would compare the two published trip curves of the tested breaker and the proposed, untested breaker. As the published characteristic trip curve of a breaker accounts for tolerances and variation in the breaker family, they tend to be conservative and have wide trip bands. Therefore, if a tested breaker had a published instantaneous trip level of 25 milliseconds—even though it actually tripped at 13 milliseconds under the short circuit test—manufacturers could add any proposed breakers that had maximum instantaneous trip levels of 25 milliseconds to the breaker list, despite the fact the ATS never saw the fault current longer than 13 milliseconds. This could lead to unsafe coordination pairings with slower, untested breakers.

Now, many electrical system designers are being forced to migrate to the time based or "any breaker" ratings whenever possible due to the truncated specific breaker lists. For a given frame size, the "any breaker" ratings are typically lower than the specific breaker ratings, therefore, to reach a required calculated fault level under the specific breaker ratings, the ATS frame size may need to be upsized.

Figure 4

Circuit Breaker Manufacturer	Breaker Rating (Amps)	Breaker Model/Type
Mfg 'A'	250	FEH, FEL, FEN, SFL, SFP
	400	FGH4, FGL4, FGP4, SGLA, SGP4, TB4, THLC4, TJL4, TLB4
	600	FGH6, FGL6, FGN6, FGP6, SGL6, SGP6, TB6, TJL6
	800	SKH8, SKL8, SKP8, TB8
Mfg 'B'	250	CFD6, HFD6, HFXD6, HHFD6, HHFXD6
	400	CJD6, HHJD6, HHJXD6, HJD6, HJXD6, SCJD6, SHJD6
	600	CLD6, HHLD6, HHLXD6, HLD6, HLXD6, SCLD6, SHLD6
	800	CMD6, HMD6, HMXD6, MD6, MXD6, SCMD6, SHMD6, SMD6
Mfg 'C'	250	JJ, JL, JR
	400	LJ, LL, LR
	600	LJ, LL, LR
	800	MJ, PJ, PK, PL, RJ, RK, RL
Mfg 'D'	250	HJD, JDC, JGC, JGH, JGU, JGX
	400	CHKD, CHLD4, CHMDL4, CLDC4, CMDL4, HKD, HLD4, HMDL4, KDC, LDC4, MDL4, NB Tri-Pac
	600	CHLD6, CHMDL6, CMDL6, HLD6, HMDL6, LCDC6, LDC6, MDL6, NB Tri-Pac
	800	CHMDL8, CMDL8, HMDL8, MDL8, NB Tri-Pac

Example: Original 600A Specific Breaker List

Circuit Breaker Manufacturer	Breaker Rating (Amps)	Breaker Model/Type
Mfg 'A'	250	SFL, SFP
	600	FGL, FGP
Mfg 'B'	250	CFD6, HFD6, HFXD6, HHFD6, HHFXD6
Mfg 'C'	600	LJ, LL, LR
Mfg 'D'	250	HJD, JDC, JGC, JGH, JGU, JGX
	400	CHLD4, CLD, HLD4, CLDC, LDC, KDC, HKD, CHMDL4, CMDL4
	600	CHLD6, HLD6, CHMDL6, CMDL6, CLDC, CLDC6, LDC6, CLD6
	800	CHMDL8, CMDL8, HMDL8, MDL8

Example: Final 600A Specific Breaker List after UL 1008 standard added requirements for breaker approval in 2014

II. TIME-BASED (“ANY BREAKER”) RATINGS

If an ATS can pass the UL 1008 WCR test under a fault current of a given magnitude for 0.050 seconds—or 0.025 seconds for transfer switches with a continuous current rating smaller than 400 A—it obtains a time-based rating. Note that these are typical values. UL 1008 also allows alternate time values to be used. Formerly known as "any breaker" or 3-cycle ratings, time-based ratings allow an ATS to be used with any molded case circuit breaker that has an instantaneous trip function, which means all breakers listed under UL 489. Using time- based ratings simplifies the process for ordering and installing ATS and upstream circuit breakers.

It also allows more flexibility when designers coordinate the transfer switch installation with other over current devices in the system. This is especially true for retrofit applications.

As mentioned earlier, an ATS typically obtains a lower WCR level under the time-based ratings when compared with the specific breaker ratings. Even though a typical circuit breaker can clear a fault in approximately one cycle (~0.017 seconds @ 60 Hz) or less, this test makes the ATS pass the full 0.050 seconds of fault current. Figure 5 outlines the ratings difference between specific breaker and time based tests. Figure 2 illustrates how the time based ratings information is shown on the rating label.

Figure 5

Switch Rating, Amps	Withstand Current Ratings in RMS Symmetrical Amperes	
	Specific Breaker Rating	Time-Based Rating (Any Breaker)
	Amps @ 480 V	Amps @ 480 V
30	22,000	10,000
70–100	22,000	10,000
150	25,000	10,000
200-230	25,000	10,000
260	42,000	35,000
400	42,000	35,000
600	50,000	42,000
800-1200	65,000	50,000
1600-2000	125,000	100,000
2600-3000	100,000	100,000
4000	100,000	100,000

III. SHORT-TIME RATINGS

Short-time ratings—sometimes known as "30-cycle" ratings—are optional ratings that a transfer switch manufacturer may obtain. The short-time ratings require longer duration application of fault current and are intended for selective coordination purposes, where an extended delay is needed to allow for downstream protective devices to clear a fault closer to its source. Because the tested ATS needs to carry the fault energy over an extended period, the WCR level that a given switch obtains under short-time ratings is the lowest among the four rating types.

The short-time test subjects an ATS to a given fault current for up to 30 cycles, or 0.5 second. To withstand currents in such long duration, the ATS and entire electrical distribution system should be braced for much higher fault energies. Wire selection and derating should also be taken into consideration. For example, a single 500-kcmil cable can only handle about 39,000 A of fault current for 0.500 seconds, while the same wire can handle over 100,000 A for 0.050 seconds.

Reaching 30 cycles also pushes the application out of the normal range of UL 891 switchgear or UL 489 breakers into the much higher cost of UL 1558 switchgear and UL 1066 breakers. Thus, extreme care is needed when specifying short-time rated units. While it may seem to be the easiest option for selective coordination—or indeed the safest option for 0.30-second or 0.50-second short-time ratings—the unintended consequences may be enormous.

If a 30-cycle requirement is written into a specification, make sure it is truly required for the application and the entire electrical system matches the requirement. For example, a short-time-rated switch installed in a system with a UL 489 breaker, would not be utilizing the short-time ratings. Figure 2 illustrates the short-time ratings information found on the rating label.

Due to these circumstances, a short-time rated ATS can be two to three times more expensive than a typical specific breaker or any breaker switch for a given amperage.

IV. FUSES

The use of current-limiting fuses is the final over current protection type under UL 1008. Fuses can typically clear a fault within 0.008 seconds.

Moreover, they also have the benefit of limiting the amount of current that passes through the ATS during a fault. With the ability of limiting current and interrupting the fault current quickly, fuses protect the downstream components by limiting the energy to which they are exposed. This leads directly to the highest WCR levels for an ATS, which, in many cases, are up to 200 kA.

A drawback of fuses, however, is that they are neither resettable nor adjustable for selective coordination purposes. They are also subject to the qualification restrictions that specific circuit breakers face—only the fuse classes listed on the rating decal or specification sheet are allowed. Figure 2 shows an example of the fuse information on the rating label.

Figure 6 Fuse Rating Chart

HOW IS A WCR OBTAINED?

The UL 1008 Standard for Automatic Transfer Switch Use in Emergency Standby Systems is the main certification authority for transfer switches. Other relevant standards include CSA C22.2 No. 178.1, IEC 60847-6-1, NEMA Standard ICS 10-2005, NFPA 70 National Electrical Code, and NFPA 110 Essential Electrical Systems for Health Care Facilities. While each of these standards has unique aspects, they closely mirror the UL 1008 standard with regards to switch performance.

The list of UL tests to certify a transfer switch mechanism includes:

- Normal operation
- Overvoltage
- Under voltage
- Overload
- Temperature rise
- Endurance
- Dielectric voltage-withstand
- Short-circuit (withstand)
- Short-circuit (close-on)
- Short-circuit (short-time current rating—optional)
- Dielectric voltage-withstand

When looking specifically at the short-circuit requirements, testing involves both a withstand test and a close-on test. During the withstand portion, a fault current is applied to a closed switch, either for a set period (time-based or short-time ratings), at which point the lab circuitry interrupts the current, or until the fault current is cleared by an upstream overcurrent protective device (specific breaker or fuse ratings).

The close-on test requires the contactor to close into a fault. Again, this is done for either a predetermined period or until an upstream overcurrent protective device interrupts the circuit.

The two tests are done on the same set of contacts, and the contactor should be able to operate electrically and pass a dielectric test after completion. This ensures the tested switch can safely transfer to an alternate source after a fault current event has occurred. Standard fault current levels are defined in UL 1008. WCR values are listed on the rating label of the contactor or the ATS nameplate. Figure 2 illustrates the typical verbiage and how the ratings are shown.

WCR Milestone Timeline	
	UL 1008 Specific breaker and fuse ratings
1989	UL 1008 3-cycle ratings added
1993	NEC selective coordination for elevator circuits added
2002	UL 1008 adds optional short-time rating
2005	NEC adds stronger selective coordination requirements for legally required standby units
2008	NEC adds stronger selective coordination requirements for critical operations power systems
2014	UL 1008 adds stronger specific breaker rating requirements

FOUR WCR TYPES:

SPECIFIC BREAKER RATING

Specific breaker rating is also referred to as series rating. This type of rating will yield the highest WCR value for an ATS with a breaker due to the instantaneous trip functionality of the upstream circuit breaker. The main limitation for this rating type is that the breaker choices are confined to the published list supplied by the manufacturer. Substitutions can only be considered if actual test trace data is available to use for comparison with a prospective breaker.

TIME-BASED ("ANY BREAKER") RATINGS

Time based ratings, also known as any breaker, 3-cycle or umbrella ratings, allow the use of any UL 489-listed breaker with instantaneous trip function to be coordinated with the ATS. The main drawback is that the WCR level obtained under this rating type is lower than under specific breaker ratings, due to the longer short circuit durations that the switch sees. If a fault current study shows a higher WCR level than a switch has for a given amperage, the specifier will need to either look at different overcurrent protection (breakers from the specific breaker list or fuses) or upsize the ATS frame to achieve the desired WCR.

SHORT-TIME RATINGS

Short-time ratings, commonly referred to as 18-cycle or 30-cycle ratings, allow longer coordination times to work with air circuit breakers or breaker types that can turn the instantaneous trip function off. Due to the very long fault duration, the WCR levels under this rating type are the lowest among the four for a given switch. This type of rating is optional and not available on all switch types or amperages. If short-time ratings are written into a specification without proper understanding of the impact to the other electrical components and wiring in the system, it could increase the cost and size of an ATS. This type of transfer switch could cost two to three times more than an "any breaker" or time-based switch for a required WCR level; the footprint will also be larger as manufacturers should increase the unit's frame size to achieve longer fault durations.

FUSES

Fuses provide the highest possible WCR level for an ATS due to its current-limiting characteristics and extremely fast-tripping threshold. With fuses, an ATS sees less power for a shorter duration during a fault current event. Fuses, however, are not resettable or adjustable for selective coordination purposes. Moreover, a specifier can only choose from fuse types that are listed by the ATS manufacturer, and substitutions are not permitted.

CONCLUSION

There are many factors to consider when conducting a thorough power system study. Fault current calculations and selective coordination of all devices and equipment are essential to design a reliable, cost-effective and safe electrical system.

The WCR of the ATS is an important part of this analysis. Knowing how to evaluate the multitude of ratings supplied for each switch, and how these values are attained, is a basic requirement for a specifying engineer. Failure to do so can lead to costly project delays, unusable equipment or system redesign.

ABOUT THE AUTHOR

Mike Little is a Principal Engineer with Kohler Power Systems-Americas. He holds a B.S.M.E from Marquette University and has been with Kohler in the ATS and controls engineering groups since 2005. He has 15 years prior experience designing and developing commercial and industrial controls including contactors, overload relays, soft-starters and switches.

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