HOW TO SIMPLIFY ELECTRICAL DISTRIBUTION DESIGNS AND ENABLE SELECTIVE COORDINATION STRATEGIES WITH TRANSFER SWITCH HIGH WITHSTAND AND CLOSING RATINGS (WCR)

White paper by Hassan Obeid, Global Technical Advisor

When designing a power system, sizing the electrical distribution to handle the available fault current is critical. A major challenge design engineers face when specifying transfer switches is that the available fault current and the overcurrent protection devices, specifically circuit breakers, are not known at the time specifications are written. This paper discusses how design engineers can take advantage of the high withstand and closing rating and short-time rating of transfer switches to simplify circuit breaker selection and enable effective selective coordination schemes.

Since transfer switches are applied in mission-critical and life-safety applications, superior reliability is paramount. Therefore, transfer switches are subjected to the most stringent testing requirements outlined by the leading standard in North America: UL 1008 “Standard for Safety – Transfer Switch Equipment” (UL 1008 is harmonized with Canadian standard CSA 22.2 178).

UL 1008 specifies robust testing requirements for verifying manufacturer ratings, including the Withstand and Closing Ratings (WCR).

The tests specified by UL 1008 are:

- Temperature rise test
- Dielectric voltage-withstand test
- Overload test
- Contact opening test
- Endurance test
- Short-circuit test
- Dielectric voltage-withstand test (following short-circuit withstand/closing test)
- Short-time current test (optional)

Most transfer switches don't experience the extreme UL 1008 testing requirements during their life span. However, the positive outcome is that robust and highly reliable transfer switches are then deployed to mission-critical and life-safety applications.

Per UL 1008, transfer switches are not intended to interrupt fault current, and therefore, they don't have an Ampere Interrupting Capacity (AIC) rating. Overcurrent Protection Devices (OCPDs), such as fuses and circuit breakers, clear faults and therefore have an Ampere Interrupting Capacity (AIC) rating. The AIC rating is the maximum available fault current that an OCPD will safely clear when a fault is applied at the load side of the OCPD.

Transfer switches have short-circuit Withstand and Closing Rating (WCR): a level of fault current which the transfer switch can withstand and close onto without creating a hazardous condition. For a safe installation, the WCR of the transfer switch must be equal or higher than the available fault current at the point in the circuit where the transfer switch is installed. The WCR presumes that each source of the transfer switch is protected by OCPDs — so that the fault current persists for a limited period of time.

UL 1008 SHORT-CIRCUIT WCR TEST REQUIREMENTS

Table-01 lists the minimum current, power factor and time duration to which the transfer switch must be tested.

Note that the current can be higher, the power factor can be lower, and the time durations can be different. However, the accepted RMS symmetrical fault currents and durations that are recognized by UL 1008 are listed in Tables 02 & 03. Data is from Tables 1 & 27 of UL 1008 8th edition.

After a fault (short-circuit) is cleared by the OCPD, the transfer switch must remain operable so that it can restore power to the critical loads from the alternate power source.

TABLE-02 ACCEPTED FAULT CURRENTS

AVAILABLE FAULT CURRENT RATING – RMS SYMMETRICAL AMPERES
5,000
7,500
10,000
14,000
18,000
22,000
25,000
30,000
35,000
42,000
50,000
65,000
85,000
100,000
125,000
150,000
200,000

TABLE-03 ACCEPTED TIME DURATIONS

SHORT-CIRCUIT CURRENT TIME DURATIONS IN SECONDS
0.008
0.017
0.025
0.033
0.050
0.067
0.083
0.100

TABLE-01 SHORT-CIRCUIT TEST

Data from Table-25 of UL 1008 8th Edition

SWITCH RATING (A)	CURRENT(A)	POWER FACTOR	TIME DURATION (s), MINIMUM
100 or less	5,000	0.40 - 0.50	0.008
101 - 400	10,000	0.40 - 0.50	0.025
401 - 1000	20x rating but not less than 10,000	0.25 - 0.30	0.050
1001 and greater	20x rating	0.20 or less	0.050

TRANSFER SWITCH SHORT-CIRCUIT WCR TESTING

Transfer switches are subjected to a withstand test and a closing test.

- Withstand Test (starts with contacts closed):
- A specified fault current is applied for either a specific duration or until a specific OCPD trips
- Closing Test (starts with contacts open then closes):
  - The same transfer switch must close onto the fault current under the same conditions used in the withstand test
    Note: The same set of contacts are used for both tests: withstand and closing

The short-circuit passing criteria defined by UL 1008 are:

- Ability to operate the switch and close to the opposite source
- No breakage of switch base or any other internal parts
- Door must stay secure
- Cables stay connected to lugs without insulation damage
- No continuity between the normal and alternate source terminals
- Pass a dielectric voltage-withstand test

GUIDELINES FOR APPLYING WCR

If a transfer switch does not have a sufficient WCR, severe damage and a potential fire hazard could result from the fault current. One possible solution is to oversize the transfer switch to a larger frame to achieve sufficient WCR. However, this solution could lead to a larger footprint and possibly higher cost.

Good engineering practice requires adequately rated devices in the power distribution system. Therefore, the specified WCR for the transfer switch should be equal to or greater than the available fault current at the location of the transfer switch.

Listed below are three quick steps to apply the WCR rating of a transfer switch in the power system:

STEP 1
Determine the Available Fault Current (AFC) at the switch location from the short-circuit analysis

STEP 2
Select transfer switches with appropriate short-circuit WCR

- Transfer switches must be rated for the available fault current at their line side terminals and protected by an OCPD selected appropriately

STEP 3
Select appropriate OCPD

- Time Based: generic UL 489* circuit breaker
- Specific Breaker: tested with the transfer switch

Figure-01 shows the available fault currents at the different busses in the distribution system along with the minimum WCR of each transfer switch:

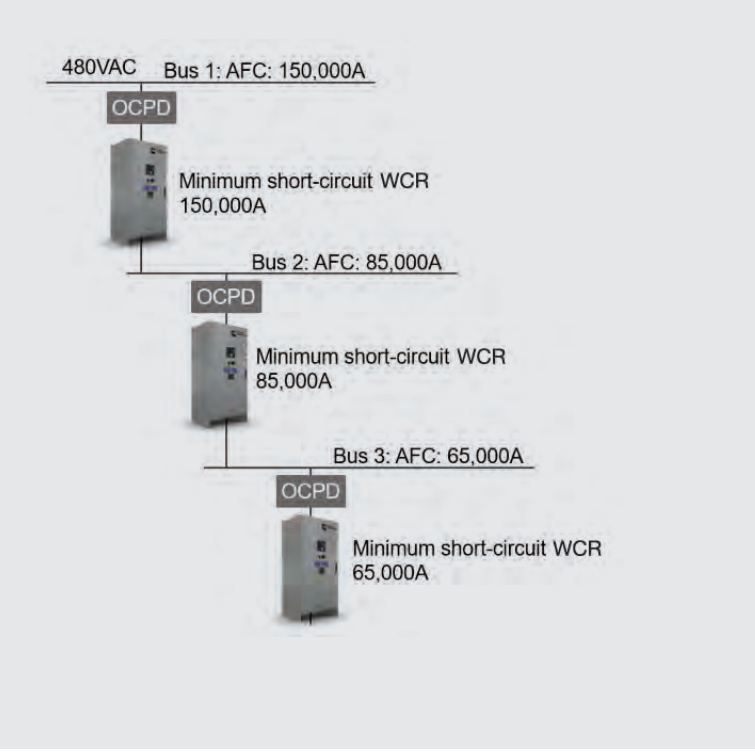


Figure-01 Transfer Switch WCR

***UL 489 requires Molded Case Circuit Breakers above 400 amps to clear a fault in no more than 0.050s**

APPLYING A SPECIFIC BREAKER TO PROTECT THE TRANSFER SWITCH

Effective November of 2014, UL changed the requirements for adding circuit breakers to transfer switches' specific breaker file without running additional short-circuit tests (UL 1008 7th edition). In earlier versions of UL 1008, a new breaker could be added by comparing its maximum published trip time with the maximum published trip time of a previously tested breaker at the rated short-circuit current. If the trip time of the new breaker was less than or equal to the previously tested breaker, the new breaker could be added to the list.

With the introduction of the UL 1008 7th edition, manufacturers are now required to compare the published trip time of the new breaker with the actual trip time of the breaker from a previous short-circuit test.

For example, if a tested breaker has a maximum published trip time 0.05 seconds, under the earlier versions of UL 1008, any breaker that has a maximum published trip time of 0.05 seconds or less could be added to the list regardless of how long it took that breaker to trip during the test. Under the UL 1008 7th edition, if the tested breaker actually tripped in 0.03 seconds during the test, only the circuit breakers that have a maximum published trip time of 0.03 seconds or less can be added to the list *without* an additional test.

This change resulted in the removal of some listed breakers from the file and has made it more difficult to add new breakers to lists without performing additional short-circuit tests. Such tests are difficult to complete due to the limited number of facilities that are capable of performing short-circuit testing and the high cost associated with it.

This breaker qualification challenge may limit the OEM's ability to provide a full range of breakers approved and listed to protect the transfer switch.

UTILIZING TRANSFER SWITCH HIGH TIME DURATION WCR TO SIMPLIFY BREAKER SELECTION

Since it is difficult to have all the variables needed to calculate the fault current, design engineers often take a conservative approach and specify high fault clearing time-based ratings.

Another major challenge engineers are faced with during the design phase is unknown switchgear/switchboard OEMs and therefore unknown breaker selections that will be used to protect the transfer switch. Therefore, transfer switches with high time duration based WCR will present a perfect solution to these issues and speed up the design cycle.

SHORT-CIRCUIT WITHSTAND/CLOSING RATINGS

When protected by a circuit breaker, this transfer switch is suitable for use in a circuit capable of delivering the short-circuit current for the maximum time duration and voltage listed below.

The circuit breaker must include an instantaneous trip response and shall not include a short-time trip response.

The maximum clearing time of the instantaneous trip response must be equal to or less than the time duration shown for the listed short-circuit current.

Short-Circuit Current (RMS Symmetrical Amperes)	AC Voltage (Maximum)	Time Duration (Maximum Seconds)
150000	600	0.050

Figure-02 Transfer Switch Short-Circuit WCR Label

In addition, by utilizing the high WCR, which is time duration based, it drastically simplifies the issues presented by UL1008 7th Edition of needing to pre-select the appropriate breakers. Figure-02 shows an example of a Cummins transfer switch label with short-circuit withstand and closing rating.

In Figure-03, different size frame transfer switches with high time duration WCRs are applied to the example shown in Figure-01 to simplify selecting the breakers ahead of the transfer switches.

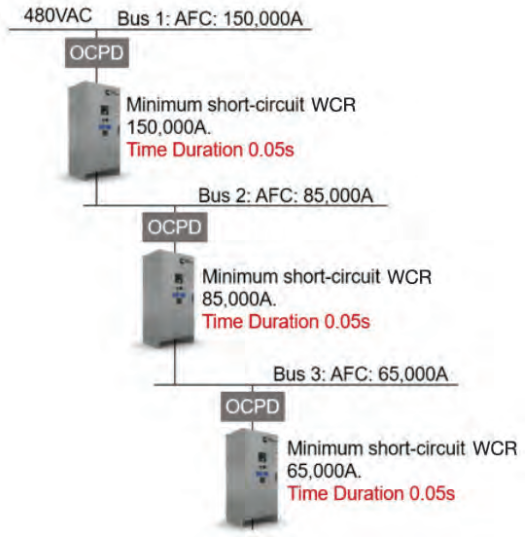


Figure-03 Applying Time Duration Based WCR

SHORT-TIME WITHSTAND/ CLOSING RATING

Transfer switch manufacturers can take the extra step and perform the UL 1008 optional short-circuit short-time withstand and closing test and subject the transfer switch to fault currents for durations longer than what is listed in Table-03. The passing criteria for the short-time rating are similar to the short-circuit passing criteria outlined before. However, there is an additional test that the manufacturer must pass: a temperature rise test. Passing this test demonstrates that the transfer switch can still carry the rated current after a short-circuit occurs in the distribution system.

Selective coordination strategies may require transfer switches to withstand fault current for longer durations than what is shown in Table-03. UL 1008 thus specifies testing measures to verify short-time ratings. The short-time current rating test applies a current equaling the manufacturer's short-time rating at the maximum rated voltage of the switch at the same power factors used for the WCR tests. Under this test, manufacturers can verify that a switch can hold a current for durations of their choosing. For example, Cummins PowerCommand® transfer switches short-time WCR are rated to the maximum duration accepted in the industry, which is 0.5 seconds.

It is important to note that the short-time rating must be withstand and closing rating. Transfer switches listed as withstand rating only violate UL 1008 - as the rating is not a true short-time rating and shall not be accepted. Figure-04 shows an example of Cummins transfer switch short-time rating label.

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

When protected by a circuit breaker, this transfer switch is suitable for use in a circuit capable of delivering the short-circuit current for the maximum time duration and voltage listed 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 response.

The maximum clearing time of the instantaneous trip response must be equal to or less than the time duration shown for the listed short-circuit current.

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 listed below.

Short-Circuit Current (RMS Symmetrical Amperes)	AC Voltage (Maximum)	Time Duration (Maximum Seconds)
150000	600	0.050

Short-Time Current (RMS Symmetrical Amperes)	AC Voltage (Maximum)	Time Duration (Maximum Seconds)
125000	600	0.500

Figure-04 Transfer Switch Short-Time WCR Label

CIRCUIT BREAKER SHORT-TIME PICKUP

There are at least six basic adjustable trip functions on sophisticated circuit breakers that shape the time-current characteristic curve, allow proper protection, and enable selective coordination (see Figure-06). Short-time pickup and short-time delay determine the amount of current the breaker will carry for a short period of time, allowing downstream protective devices to clear faults without tripping the breaker.

When a breaker with short-time trip response element (such as UL 1066 breakers) is feeding a transfer switch, the transfer switch must have a short-time WCR rating. The short-time response of the circuit breaker must be coordinated with the short-time current rating of the transfer switch as listed on the transfer switch label.

For example, a transfer switch is fed by a UL 1558 switchgear and the breakers feeding the transfer switch are UL 1066 breakers equipped with a short-time element (see Figure-07). In this case, the transfer switch must have a short-time rating, and the short-time response of the circuit breaker must be coordinated with short-time current rating of the transfer switch (listed on the transfer switch nameplate) (See Figure-08).

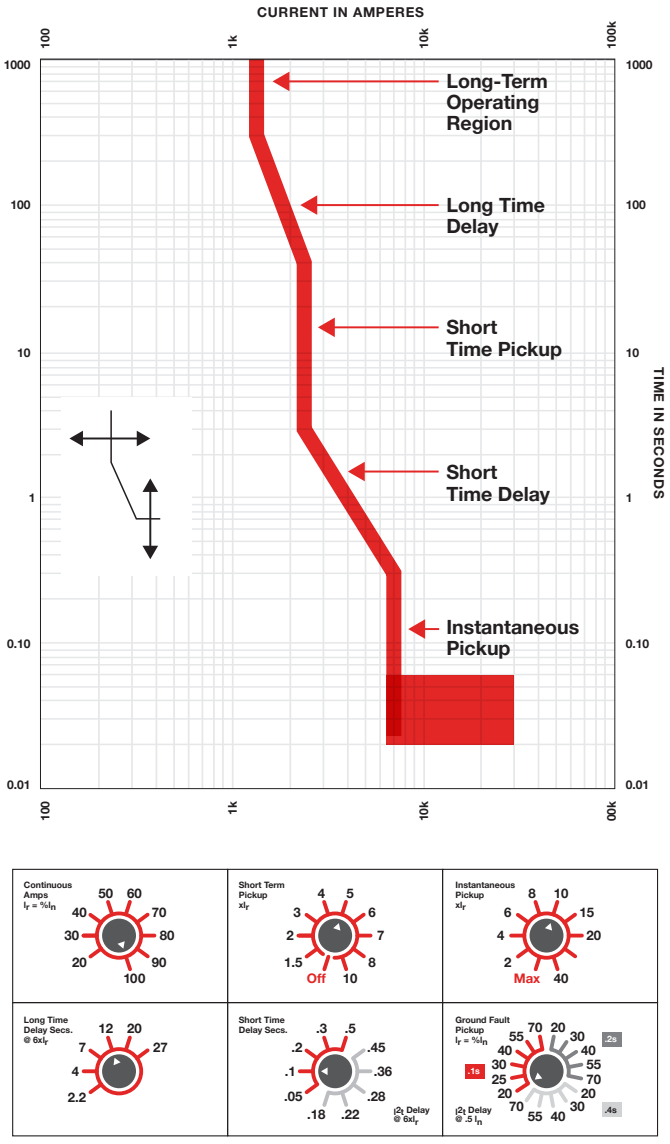


Figure-06 Typical LSIG Breaker Time-Current Curve & Trip Dials

Figure-07 UL1558 Switchgear With UL1066 Breakers Feeding Transfer Switches

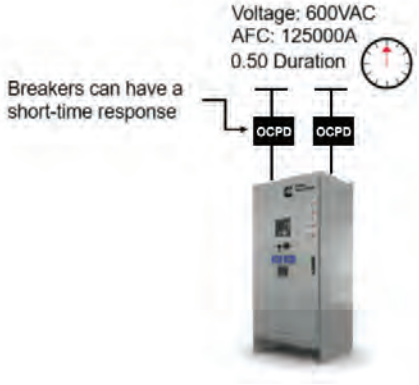


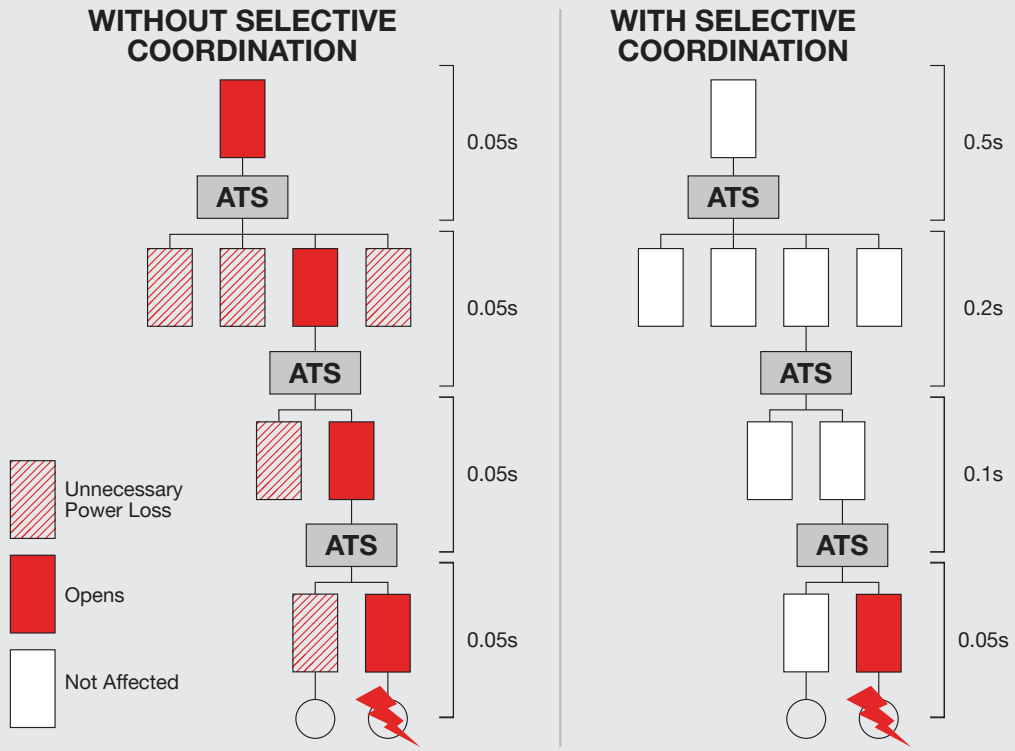
Figure-08 Transfer Switch With Short-Time Rating

SELECTIVE-COORDINATION

The National Electrical Code (NEC-2020) Article 100 defines Selective Coordination as "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."

Selective coordination is required for emergency, legally required standby and critical operations power systems circuits per NEC-2020, 700.32, 701.32, and 708.54 "…over-current devices shall be selectively coordinated…"

In Figure-09, without selective coordination, unnecessary power loss can take place throughout the distribution system. However, selective coordination can be achieved by adjusting the time delays or choosing breakers that coordinate.



Figure–09 Faults With and Without Selective Coordination

UTILIZING TRANSFER SWITCH HIGH SHORT-TIME WCR TO ENABLE SELECTIVE COORDINATION

Since selective coordination is achieved using fuses and circuit breakers, the transfer switches placed in these systems must support a selective coordination scheme by withstanding the full fault current for the duration of the fault.

Cummins PowerCommand® transfer switches have the highest short-time ratings currently in the industry with the with the highest duration of 0.5 seconds. Design engineers can take advantage of these high ratings to simplify selective coordination schemes.

For example, Figure-10 shows the RMS symmetrical short-time current rating of 125,000 Amperes at 600VAC for a duration of 0.5 seconds. The design engineer can utilize these ratings to enable selective coordination throughout the distribution system, (see Figure-11).

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

When protected by a circuit breaker, this transfer switch is suitable for use in a circuit capable of delivering the short-circuit current for the maximum time duration and voltage listed 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 response.

The maximum clearing time of the instantaneous trip response must be equal to or less than the time duration shown for the listed short-circuit current.

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 listed below.

Short-Circuit Current (RMS Symmetrical Amperes)	AC Voltage (Maximum)	Time Duration (Maximum Seconds)
150000	600	0.050

Short-Time Current (RMS Symmetrical Amperes)	AC Voltage (Maximum)	Time Duration (Maximum Seconds)
125000	600	0.500

Figure-10 Short-Time Withstand/Closing Rating Label

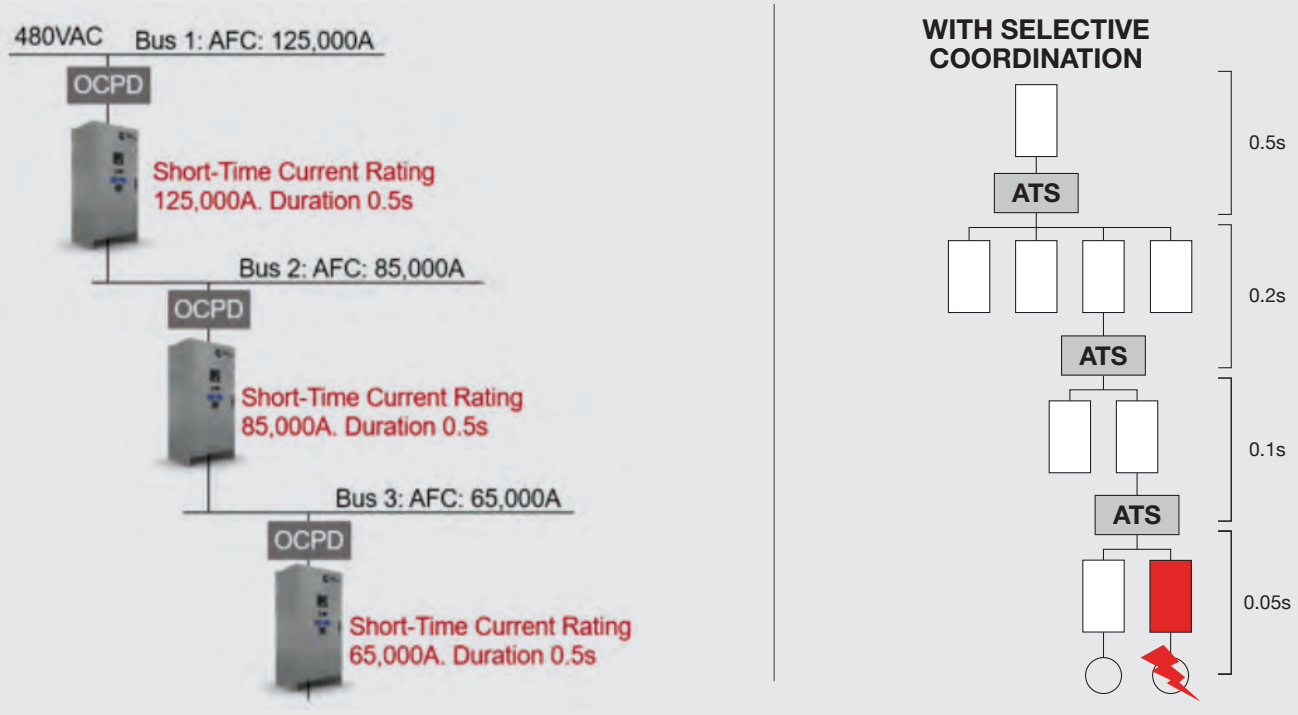


Figure-11 High Short-Time WCR Simplifies Selective Coordination Strategies

SPECIFICATION RECOMMENDATION FOR WITHSTAND AND CLOSING RATINGS

A consultant engineer can utilize the specification language from the AIA Masterspec® 263600 – Transfer Switches.

Fault-Current Withstand and Closing Ratings (WCR): UL 1008 WCR must be listed as meeting the requirements for use with protective devices at installation locations, under specified fault conditions. WCR shall be based on use of the same set of contacts for the withstand test and the closing test. WCR shall be adequate for duty imposed by protective devices at installation locations in project under the fault conditions indicated, based on testing according to UL 1008.

- Transfer switches shall have a time duration Withstand and Closing Rating (WCR) of at least 0.05 seconds (3 cycles at 60 Hz).
- Short-time WCR shall be rated for a duration of 0.5 seconds (30 cycles at 60 Hz).
- Transfer switches with Withstand Ratings only and without Closing Rating shall not be acceptable. This applies for Short-time and Time Duration WCR Ratings.

CONCLUSION

Transfer switches must be designed, built and tested to an upmost standard of reliability due to their crucial role in a power system. For applications where human lives depend on infallible power, transfer switches that are built to include a high Withstand and Close Rating are paramount for ensured power reliability.

UL 1008 specifies robust testing requirements for verifying manufacturer ratings, including the Withstand and Closing Ratings (WCR). Designing around and specifying transfer switches with high time duration WCR drastically simplifies the selection of breakers to protect the transfer switches.

With Cummins PowerCommand® transfer switches, design engineers can take advantage of high short-time WCR to simplify selective coordination schemes and offer reliable cost-effective solutions.

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Hassan Obeid is a Global Technical Advisor for Systems and Controls – Critical Protection at Cummins Power Generation focusing on technical vision, business strategy, and solving a wide range of complex problems. Hassan has been with Cummins since 2007 in a variety of roles: power systems design engineering, project engineering and application engineering.

Hassan has designed power systems involving switchgear, controls, microgrids, paralleling, transfer switches, generator sets and digital solutions. He has developed and conducted numerous technical power seminars to consultant engineers across the globe on several topics and products involving paralleling, grounding, power systems and controls. Hassan received his bachelor's degree in Computer Science and master's degree in Electrical Engineering from Minnesota State University, Mankato.

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