Short Circuit Current Rating
White Paper

Current-limiting devices:
Strengthening the weakest SCCR link

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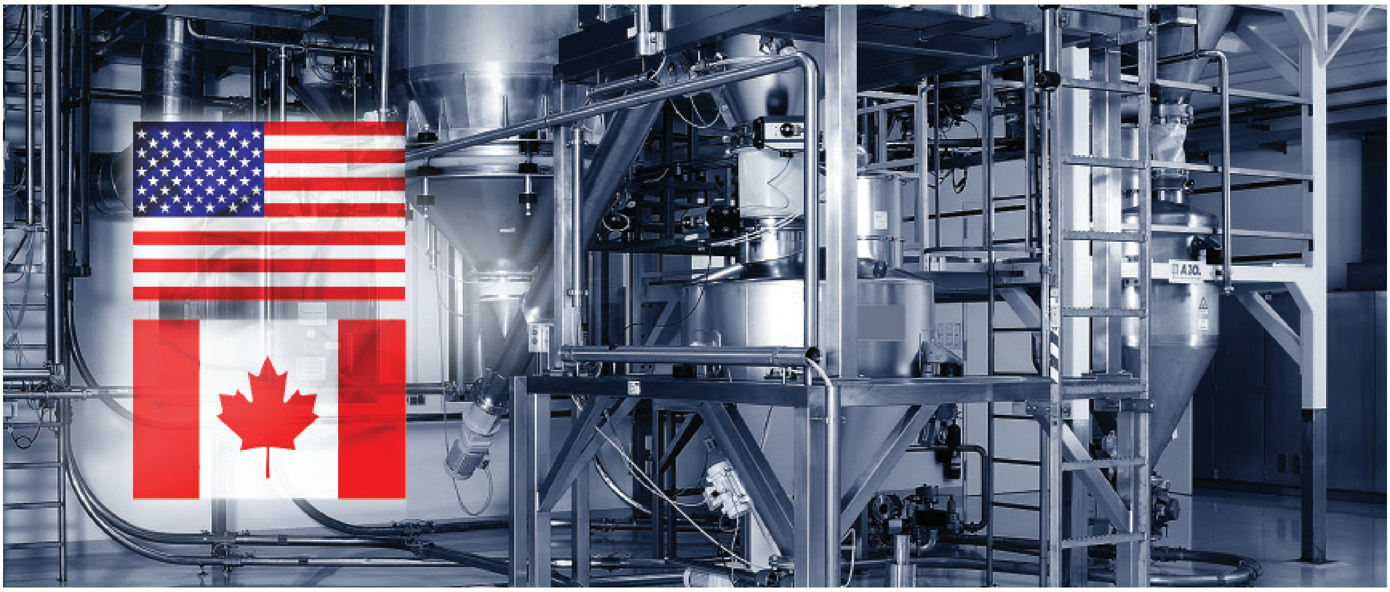
1st Edition

Powering Business Worldwide



Introduction

Equipment with insufficient short-circuit current rating (SCCR) can pose a risk to personnel, equipment or create a fire hazard. Original equipment manufacturers (OEMs) and machine builders often struggle with developing an equipment SCCR, an SCCR plan or solution for their panels and assisting end users with equipment SCCR specifications that will help support electrical code compliance.

In 2017 the North American National Electrical Code (NEC) will include several new short-circuit protection requirements. The most significant changes will require that the available fault current¬ (also referred to as available short-circuit current) at the location where the equipment is installed is marked or documented (depending on the equipment type) and dated. These changes will allow installers, inspectors and approvers to verify that the installed equipment SCCR is equal to or greater than the available fault current, and compliant with the other code sections dealing with equipment installations.
The available fault current (also known as available short-circuit current) is the amount of current that is available during a short-circuit event and is unique to the installed equipment's location.

Research indicates that more than half of OEMs design to a typical minimum equipment SCCR of 5 kA. However, with the new code requirements to mark or document available fault current and mark equipment with its SCCR, there is the increased chance many equipment installations will not be code compliant or approved. Designing an equipment SCCR plan or implementing an SCCR solution can be difficult, but it doesn't have to be.

This white paper explores the standards and best practices for determining equipment SCCR and approved methods to increase ratings. Current-limiting devices can be used, but the rules involved are often unclear or difficult to apply. Eaton provides a range of solutions that helps machine builders achieve equipment SCCR code compliance easily and efficiently. This is especially important for equipment manufacturers that export worldwide. Understanding the different regional legislations can often be complex and this is where working with trusted partners can be a real advantage. Suppliers such as Eaton that operate globally are fully aware of regulation updates, enabling OEMs to build equipment with enhanced safety and reliability, and for a larger range of available fault currents, so they can in turn better support their end user customers.

Timing the implementation of SCCR into a machine is also an important consideration. As OEMs are under pressure to make efficiencies and cost savings in their businesses, it is important to plan in advance versus devising a resolution to inadequate equipment SCCR in the field. There is no guaranteed quick or easy solution to address inadequate SCCR once equipment is installed, so manufacturers can avoid further costs and delays by planning prior to installation.

Why SCCR is important

Fire hazards, equipment damage, and personnel safety are key concerns in any manufacturing facility. Should electrical faults and short circuits occur, manufacturers need to be certain their equipment and staff are fully protected. SCCRs are a key consideration for the safety of commercial and industrial equipment, and to minimize the risks associated with a fault. These ratings identify the highest level of short-circuit current that a component or equipment can safely withstand. If correctly applied, the control panel should safely withstand a short-circuit condition without exposing personnel to fire hazard, flying debris, or shock.

What standards apply?

The North American National Electrical Code (NEC®), the Occupational Safety and Health Administration (OSHA) and Underwriters Laboratories (UL) provide guidelines related to SCCR. They have recognised the risk of faults and added SCCR requirements to their standards to increase workplace safety, establishing equipment SCCR requirements for industrial control panels and other equipment. The main purpose of the SCCR standards is to prevent the installation of equipment with an SCCR that is lower than the available fault current at the point of installation, a condition that could cause a shock or fire.

- SCCR is defined by the NEC as the maximum short-circuit current a component or assembly can safely withstand
- OSHA regulations require all electrical equipment (for both existing and new equipment) to have adequate SCCR
- The NEC (Section 409.22) prohibits installing equipment in locations where available fault current exceeds the equipment's SCCR
- The NEC requires control panels to be marked with SCCR

When it comes to control panels, UL 508A Supplement SB establishes an approved method that defines how equipment SCCR is determined. UL 508A allows for current-limiting fuses or current-limiting circuit breakers to increase component SCCR. However, the rules surrounding the application of current-limiting devices can be confusing.

While marked current-limiting devices do limit the available fault current, they do not guarantee proper protection of downstream overcurrent protective devices unless they are tested together (called series rating). UL 508A prohibits the use of series ratings within the control panel, hence any overcurrent protective device in the panel must have a sufficient interrupting rating for the available fault current. In cases where the fault current exceeds the interrupting rating of an overcurrent protective device in the power circuit of a control panel, using the current-limiting properties of a marked current-limiting device will not be acceptable or provide the control panel with an adequate SCCR.

What is expected to change

The anticipated 2017 NEC changes include marking and documenting requirements that will make it easier for OEMs, industrials and inspectors to verify proper equipment SCCR protection.

Marking - The available fault current must be marked at the location where the following equipment types will be installed:

- Machinery
- HVAC equipment
- Elevator control panels
- Generator equipment
- Transfer equipment
- Energy storage equipment
- Battery systems equipment

Documenting - The available fault current must also be documented for the location where the following equipment types are located:

- Motor control centers
- Any other equipment with an industrial control panel

Determining equipment SCCR

Two basic types of devices are used in control panels: components that do not provide overcurrent protection, and overcurrent protective devices.

Devices that do not provide overcurrent protection, such as motor starters, distribution blocks, and switches, have a component rating known as SCCR that defines the level of short-circuit current the device can safely withstand when protected by the specified overcurrent protective device as indicated on its SCCR marking. Devices that provide overcurrent protection, such as breakers and fuses, have an interrupting rating that indicates the amount of fault current they can safely interrupt. Some overcurrent protective devices are marked current-limiting and may be used to improve the SCCR of a branch circuit component. In the event of a fault, current-limiting devices will react faster than typical (non-current-limiting) overcurrent protective devices.

There are two ways to determine equipment SCCR: testing or analysis. Because testing is often cost prohibitive, analysis is the most common method to determine the equipment SCCR. The UL 508A Supplement SB provides an analysis method that considers the "weakest link" as the basis for the determining equipment SCCR; the equipment SCCR is limited to the lowest rated component SCCR or lowest rated overcurrent protective device interrupting rating in the control panel.

There are three key considerations to determining equipment SCCR: component SCCRs, the interrupting rating of the overcurrent protective devices, and the effect of current-limiting devices in the feeder circuit. Product markings or manufacturer's installation instructions provide component SCCR, while the interrupting ratings are found on the overcurrent protective device markings.

According to UL 508A SB4.3, current-limiting devices in the feeder circuit can be used to increase branch-circuit component ratings, but not for components in the feeder circuit. The peak let-through current of a current-limiting overcurrent protective device in the feeder circuit is compared to the downstream branch circuit component SCCR. If the peak let-through at a selected prospective short-circuit current is less than or equal to the component SCCR, then the component SCCR can be raised to the selected prospective short-circuit current.

Fuse class	Fuse amp rating	Between threshold and 50 kA		100kA	200kA			300kA† (Class J Only)	
		I^2t x 103	1p x 103 (kA)	I^2t x 103	1p x 103 (kA)	I^2p x 103	Ip x 103 (kA)	I^2t x 103	Ip x 103 (kA)
Class CF. J and 600V*	1	–	–	0.8	1	–	–	–	–
	3	–	–	1.2	1.5	–	–	–	–
	6	–	–	2	2.3	–	–	–	–
	10	–	–	3	3.3	–	–	–	–
	15	–	–	4	4	–	–	–	–
	20	–	–	5	5	–	–	–	–
	25	–	–	5.5	6	–	–	–	–
	30	7	6	7	7.5	7	12	8.4	18.5
	35	–	–	12	7.5	–	–	–	–
	40	–	–	17	8	–	–	–	–
	45	–	–	18	8.5	–	–	–	–
	50	–	–	22	0	–	–	–	–
	60	30	8	30	10	30	16	38	24.4
	70	–	–	50	11.5	–	–	–	–
	80	–	–	60	12.5	–	–	–	–
	90	–	–	75	12.5	–	–	–	–
	100	60	12	80	14	80	20	96	28.4
	110	–	–	100	14.5	–	–	–	–
	125	–	–	150	15.5	–	–	–	–
	150	–	–	175	17	–	–	–	–
	175	–	–	225	18.5	–	–	–	–
	200	200	16	300	20	300	30	360	42.4
	225	–	–	350	22.5	–	–	–	–
	250	–	–	450	24	–	–	–	–
	300	–	–	600	26	–	–	–	–
	350	–	–	800	29	–	–	–	–
	400	1000	25	1100	30	1100	45	1320	66.4
	450	–	–	1500	36	–	–	–	–
	500	–	–	2000	42	–	–	–	–
	600	2500	35	2500	45	2500	70	3000	101.4
	700**	–	–	3500**	50**	–	–	–	–
	800**	4000**	60**	4000*	55**	4000**	75**	–	–
Class L	800	10,000	80	10,000	80	10000	80	12000	79
	1200	12,000	80	12,000	80	15000	120	18000	108
	1600	22,000	100	22,000	100	30000	150	36000	143
	2000	35,000	110	35,000	120	40000	165	48000	158
	2500	–	–	75,000	165	75000	180	90000	171
	3000	–	–	100,000	175	100000	200	120000	226
	4000	–	–	150,000	220	150000	250	180000	286
	5000	–	–	350,000	–	350000	300	420000	288
	6000	–	–	350,000	–	600000	350	600000	399

Note: These values are UL umbrella limits.
* When values at 50kA and 200kA are needed, the standard case size shall be used
** Value applies to Class T fuses. Values at 700A are included per UL 248, but have not been added to UL 508A Supplement 5B
t 300kA values are in 248 Standard, but are not yet in UL 508A Standard

Fig. 1: Peak let-through value for current-limiting fuses (Class CF, J, T and L); UL 508A, Table SB 4.2

For current-limiting fuses, the value for the peak let-through must be determined from Table SB4.2 in UL 508A (see Figure 1). Manufacturers' published let-through data for specific fuses cannot be used, as fuses are interchangeable and there is no guarantee that a fuse will be replaced with the same fuse from the same manufacturer following installation of the equipment. However, for circuit breakers marked as current-limiting, manufacturers' let-through data is used (Figure 2).

The UL 508A standard only permits the branch component SCCR to be raised using a current-limiting device. It does not allow components in the feeder circuit to be raised. Also, the current-limiting overcurrent protective device in the feeder circuit is not permitted to be used to increase the interrupting rating of a downstream branch circuit overcurrent protective device, or the SCCR of a downstream branch circuit combination motor controller. In simple terms, this means that the SCCR of a contactor, overload relay, variable frequency drive, or any other branch component can be improved as prescribed. However, the interrupting rating for circuit breakers and fuses, or the SCCR for Type F Combination Motor Controllers cannot be improved by an upstream current-limiting device, even if they are located in the branch circuit.

Power transformers can also be used to increase branch circuit SCCR. This approach is permissible, but not commonly used within the control panel, because it requires too much space. For that reason, it is not explored in depth here. Outside of the control panel, using a transformer is an option because it lowers available fault current at the location where the equipment is installed. Depending on the transformer and system attributes, the available fault current on the transformer secondary may be less than 5 kA, making the default equipment SCCR of 5 kA acceptable. (This was the approach used for the retailer's refrigeration equipment as outlined in example 2 further in the paper.)

Equipment with control panels that cannot achieve an SCCR suitable for the available fault current at its point of installation may be remedied by lowering the available fault current using an upstream isolation transformer (same primary/secondary voltage), provided the secondary available fault current is not greater than the equipment's SCCR. Lowering the available fault current outside the equipment's panel is typically a last resort.

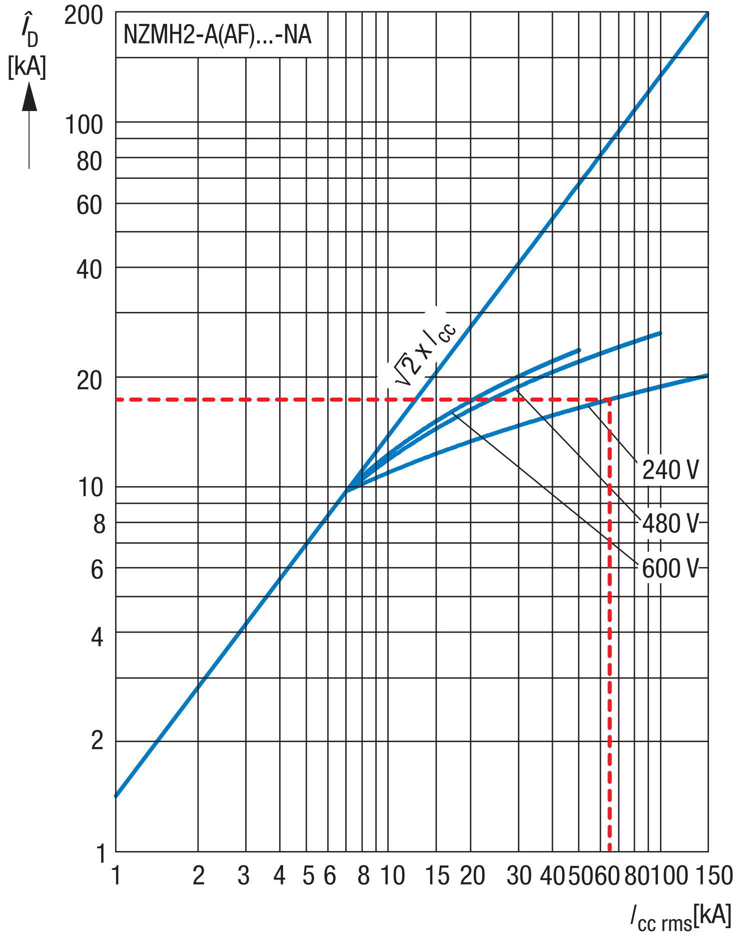


Fig. 2: Manufacturer let-through charts for current-limiting breakers; The example above is for Eaton's Moeller Series NZM breaker, type NZMH2-VE250-NA, molded case circuit breaker - 240V, 480V, 600V.

4 steps to calculate equipment SCCR

Determine SCCR of components incorporated in the feeder and branch circuits

Determine the potential of current-limiting devices in the feeder circuit to increase the SCCR of branch circuit components

Identify interrupting ratings of all overcurrent protective devices in the feeder and branch circuits, as well as on the primary of control transformers and power supplies

The equipment SCCR is the lowest value of the component SCCRs, raised component SCCRs, or interrupting ratings of the overcurrent protective devices.

Basic guidelines

Marked current-limiting fuses or current-limiting circuit breakers cannot be used to increase component SCCR or the interrupting rating of an overcurrent protective device in the feeder circuit

Branch circuit component SCCR can be raised using a current-limiting overcurrent protective device in the feeder circuit under specified conditions

Marked current-limiting fuses or circuit breakers cannot be used to increase the interrupting rating of a branch circuit overcurrent protective device; only component SCCRs are affected

Branch and feeder circuit overcurrent protective devices must have sufficient interupting rating for the available fault current

Marked current-limiting devices or fuses and circuit breakers cannot be used to increase the SCCR of a branch circuit combination motor controller

Combination motor controllers must have sufficient SCCR for the available fault current

Marked current-limiting fuses and circuit breakers are permitted to be field installed upstream of the control panel. However, the higher resulting SCCR and the specific current-limiting overcurrent protective device must be marked on the panel

When SCCR should be implemented

When building SCCR into a machine it is important to consider it early in the equipment design stage, as this is most efficient. Once equipment is installed, it is difficult to increase the SCCR, and options are limited to equipment modification and recertification, or reducing available fault current at the control panel. Equipment modification may require substitution of components, or adding components (and associated space), and typically causes project delays and added costs. However, reducing the available fault current at the control panel requires a transformer and associated circuit protection, and may not independently solve the inadequate equipment SCCR. Some situations may require both options to resolve. In either case, the solution requires additional cost, time and effort that could be avoided if planned prior to installation.

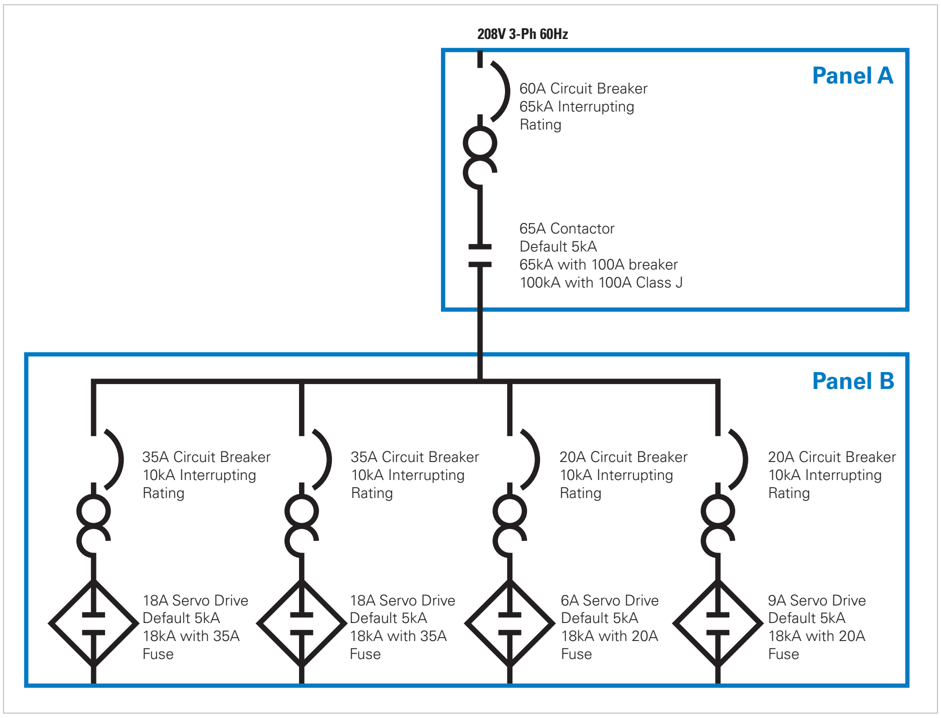


Fig. 3: The original grinding equipment design was rated at 5 kA SCCR

Planning ahead when the available fault current is unknown

Achieving SCCR compliance can be challenging when exporting equipment intended for installation in the US, especially if the equipment is a standard design and not built for a specific customer. In these cases, the actual available fault current can vary, depending on where the equipment is installed. Because it can be very difficult and costly to address inadequate SCCR in the field, it is a best practice to plan for a worst-case condition, or in other words, the largest expected available fault current.

Designing for a worst-case condition can be accomplished by one of two methods:

1. Select components that will result in an overall equipment SCCR sufficient for the worst-case condition. This approach results in a higher equipment SCCR that may be significantly higher than the actual available fault current in a certain installation point, but would cover all installation locations where the available fault current does not exceed the higher equipment SCCR. To realize this solution, all relevant devices in the equipment control panel must have sufficient SCCR or interrupting ratings for the expected worst case available fault current.

2. Design the equipment control panel such that a current-limiting fuse or circuit breaker may be applied upstream of the equipment to achieve a higher SCCR that is sufficient for the worst case available fault current condition. This approach may result in more efficient equipment cost, as well as allow for more flexibility in terms of component selection within the panel. The main advantage in this approach is that installers have an option to apply a feeder device upstream of the panel to raise the equipment SCCR if needed, without the need to consult the manufacturer. However this approach requires the panel be marked so as to define the upstream feeder type and feeder size necessary to realize the raised equipment SCCR (as per UL 508A SB5.1.3).

Example 1: increasing SCCR in semiconductor manufacturing equipment

In another example, Strasbaugh, a leader in precision surfacing technology used in semiconductor devices needed to increase the SCCR for its automated wafer grinding equipment. The Californian company's grinding equipment is used for high-volume production and low-volume research and development applications.

The wafer grinding machine design was rated at 5 kA SCCR (see Figure 3). Yet the available fault currents at the point of installation ranged from 5 kA to 65 kA. Strasbaugh's engineers realized the equipment SCCR issue after the design was specified, but before the grinding equipment was installed. Consequently, it sought an SCCR solution that would meet a range of application requirements with minimal design impact, especially in terms of space requirements and costs.

Strasbaugh's engineers calculated equipment SCCR and identified components to increase its control panels' SCCR. Strasbaugh recognized that the first panel (the feeder panel) already had components that qualified for the 65 kA rating. The main issue involved a second control panel that incorporated servo drives (rated 18 kA with fuses) protected by miniature circuit breakers with a 10 kA interrupting rating. Given the devices used in the panel, it could only achieve a 5 kA rating; since there were no current limiting devices used upstream, the current-limiting rules did not apply. Strasbaugh worked with Eaton's experts to identify a solution to accommodate the required SCCR ratings.

By using compact circuit protectors, disconnect switches containing UL Class CC or CF fuses, the panel rating could be improved to 18 kA SCCR. However, since the servos are 18 kA, the control panel rating would not achieve a higher SCCR unless Strasbaugh used a current-limiting solution, such as a marked current-limiting circuit breaker, fuse or transformer. Replacing the 60 A circuit breaker in the feeder circuit (Panel A) with a current-limiting overcurrent protective device could increase the servo drive SCCR. For example, a marked current-limiting circuit breaker, with a peak let-through of 17 kA at a prospective fault current of 65 kA (Figure 2) – like NZMH2-AF60-NA or Type EGC 60A – would increase the servo drive SCCR to the prospective fault current level of 65 kA. Alternatively, a 60 A Class J fuse in a fusible disconnect could be used in the main, which has a peak let-through current of 10 kA at a fault current of 100 kA. This solution would raise the servo drives SCCR to the prospective fault current, which is 100 kA.

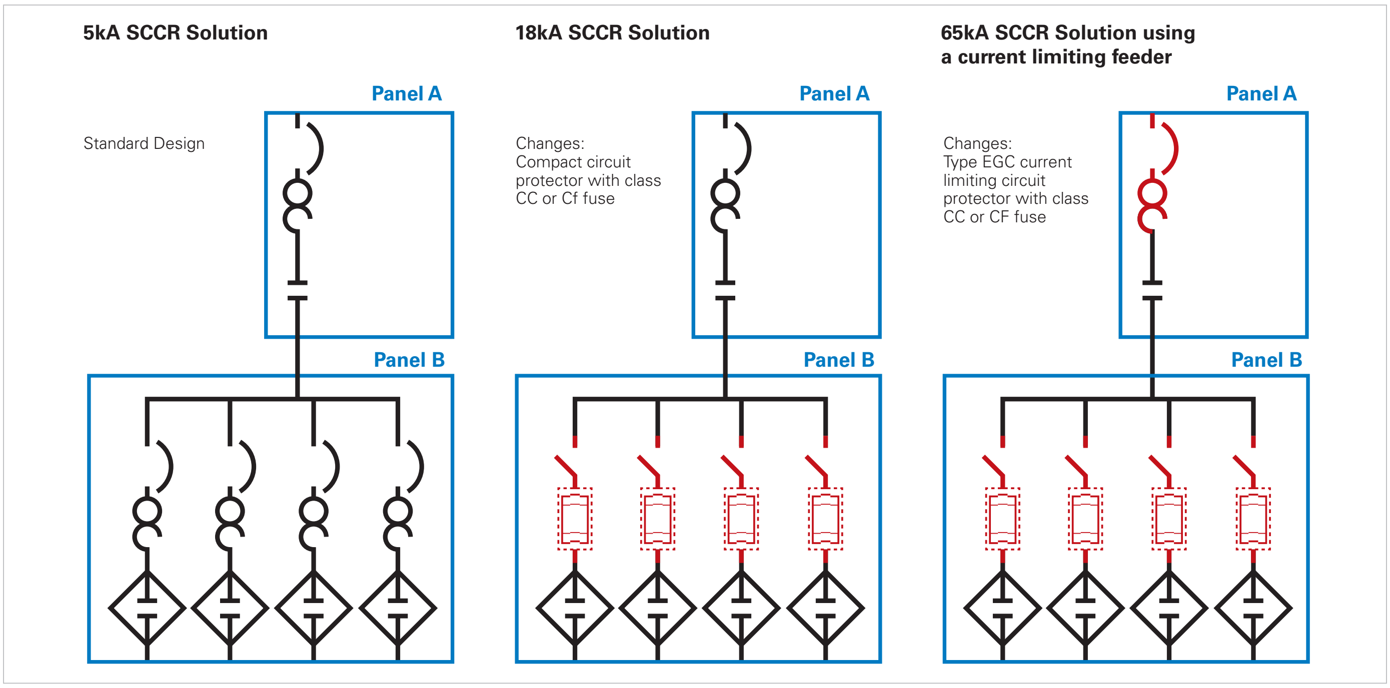


Fig. 4: A menu of design options meets the range of SCCR requirements

Strasbaugh developed designs that offered three different equipment SCCR options for its customers (see Figure 4):

- The original or standard design, with a 5 kA rating
- A modified design that achieved an 18 kA rating by replacing miniature circuit breakers with UL Class CC or CF fuses
- A further modified design that achieved the 65 kA SCCR solution by replacing the miniature breaker and the upstream overcurrent protection solution with a marked current-limiting overcurrent protective device.

Strasbaugh's 7AF-II is fully automated grinding equipment designed to remove extra steps in water processing

Photo courtesy of Strasbaugh

Lessons learned

Understanding equipment SCCR requirements during the design phase provides OEMs with the flexibility to cost effectively achieve the SCCR required by their customers. Strasbaugh was able to provide tiered SCCR solutions that involved minimal changes to components and no additional space requirements. Further, Strasbaugh engineers were able to achieve the range of equipment SCCR its customers required.

In an ideal world, equipment SCCR would always be considered early in the design phase so the components and overcurrent protective devices selected would not need to be substituted. The servos used in the second panel for the grinding equipment did not need to be replaced after a current-limiting solution was applied. However had no solution existed, substitution using a different servo drive might have been required, which may impact costs, and may also require reprogramming.

Example 2: retrofitting to solver inadequate SCCR in refridgeration equipment

A good example of a necessary retrofit comes from an American retailer that purchased and installed refrigeration equipment. The equipment was designed to keep snacks and soft drinks cold and was part of a 208 volt (V) three-phase system. The original equipment specifications from the retailer did not identify the fault current or a minimum equipment SCCR requirement. Once the refrigeration equipment was delivered and installed, the electrical inspector recognized that the equipment lacked an SCCR sufficient for the 35.5 kilo-ampere (kA) available fault current. The control panel on the refrigeration equipment was only marked with an SCCR of 5 kA.

Achieving an increased SCCR for the refrigeration equipment required either part substitutions and rewiring for a dozen components or adding a transformer upstream of the control panel that would lower the available fault current below 5 kA. Since the retailer was losing money every day the equipment was not working, substituting components and rewiring the panel was not an option. An upstream transformer was installed, which lowered the available fault current at the location where the equipment was installed. This solved the issue, so the retailer could start realizing ROI. However it will take longer to recuperate their investment as the total project cost increased with additional material costs for the transformer and its overcurrent protection, as well as associated labor costs.

It is clear to see that taking the extra step in the design process to identify the required equipment SCCR to meet the available fault current levels at the point of installation can save time and money. Had the refrigeration equipment's control panel been designed with a higher SCCR or a contingency to achieve a higher SCCR, the retailer and OEM could have avoided the project delays and the re-configuration of the control panels. By determining equipment SCCR requirements early in the project, end users are better able to get the ratings they need and OEMs can avoid changes and re-configuring the components inside the panel once the equipment is already installed.

Conclusion

Adhering to the equipment SCCR requirements and standards provided by the NEC and other organizations is critical to support electrical safety. Equipment control panels that meet the SCCR guidelines are designed to prevent shock, fire, and impact hazards if a short circuit should occur. By specifying the requisite SCCRs into equipment design specifications at the beginning of a project, OEMs are better able to control project costs and duration, while developing more reliable solutions that help customers enhance safety.

When it comes to the practical application of complying with the equipment SCCR requirements, the greatest difficulty can be understanding the customers' required equipment SCCR. Often, SCCRs are not included in the project specifications and simply meeting standard equipment SCCR requirements (5 kA) may not be sufficient.

Current-limiting devices can be used to help achieve the equipment SCCR customers require. They can significantly expand the permissible range of available fault currents for which equipment is properly rated, often with minimal impact to standard designs. The most successful application of these devices in terms of cost efficiency and effectiveness is in a project's design phase.

As an international company, Eaton offers customers the most comprehensive experience to achieve compliance through field-based sales and technical resources as well as an extensive range of code-compliant products and solutions to meet SCCR needs. For example, these include a complete portfolio of Bussmann¬ series fuses as well as circuit breakers, motor circuit protectors and combination controllers, and current-limiting overcurrent protective devices.

Working with an international partner is especially important to machine builders exporting worldwide. Eaton can help equipment manufacturers understand the local electrical safety guidelines and legislation to ensure their machines are fully compliant, identify their customer's equipment SCCR needs and provide expert training.

The whitepaper has explained how machine builders can realise the correct ratings, understand how to apply current-limiting devices to achieve desired SCCR, enhance safety and reliability of their machines, helping their end user customers to increase personnel safety, ensure equipment is properly protected, reduce downtime, reduce project installation time and cost, ultimately increasing ROI.

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Publication No.: WP033001EN
ip October 2016

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