Industrial Control Panels for North America

Determining the short-circuit current rating (SCCR)

White Paper I February 2018

This White Paper provides guidance for correct configuration of Industrial control panels as prescribed by US codes and standards for the required short-circuit. Moreover, it includes practical information and references additional information sources in the appendix.

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Contents

Introduction

National Electrical Code (NEC)

The National Electrical Code (NEC) applies as the primary directive for electrical installations in the USA. It is legally recognized as state-of-the-art and shall therefore be strictly observed. It serves as a basis for acceptance by the AHJ (Authorities Having Jurisdiction), the electrical inspector in the USA. It is not permitted for electrical equipment to be operated in the USA without the approval of the AHJ.

A revised version of the NEC is published by the National Fire Protection Association (NFPA) as NFPA 70 every three years. The current version is the NEC 2017.

Article 409 of the NEC specifically covers industrial control cabinets, referred to as "industrial control panels".

Short-circuit at the incoming supply terminal is the responsibility of the user

Article 409.22 (A) stipulates that an industrial control panel shall not be connected to an incoming supply for which the maximum possible short-circuit exceeds the short-circuit current rating of the industrial control panel.

In accordance with Article 409.22 (B), the short-circuit at the incoming supply terminal of the industrial control panel shall be calculated and this calculation shall be documented with the respective date of calculation. This documentation shall then be submitted to the inspector upon acceptance of the equipment.

Unless otherwise agreed, this remains solely the responsibility of the user. The user shall stipulate the maximum possible short-circuit at the incoming supply to the manufacturer.

Short-circuit-based configuration of the industrial control panel shall be performed by the manufacturer

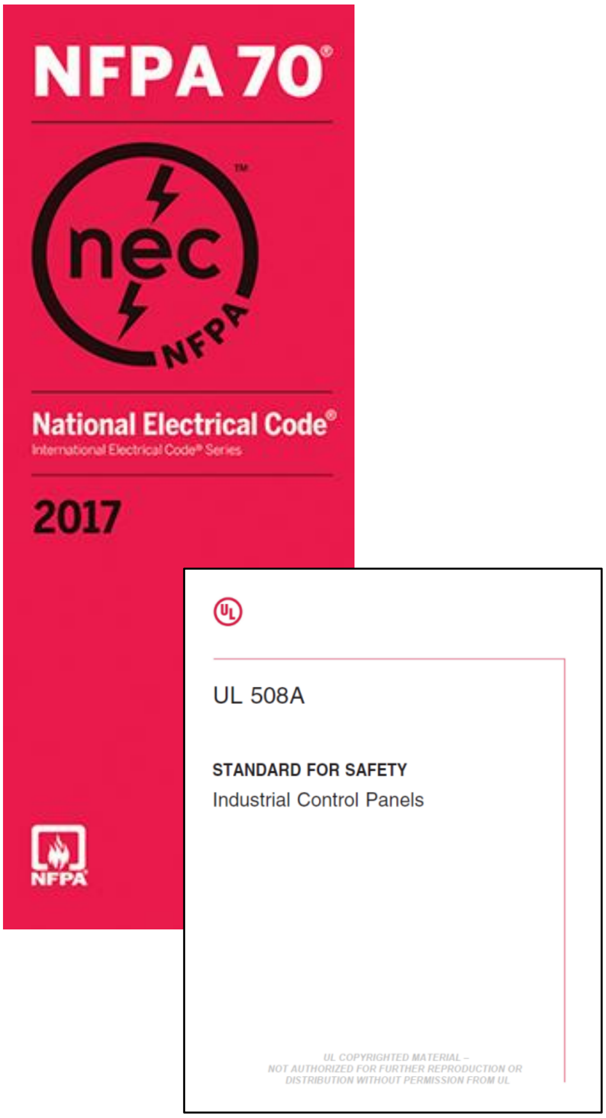
It is then the responsibility of the manufacturer to ensure that the industrial control panel is configured with the maximum short-circuit stipulated by the user for the incoming supply.

In accordance with Article 409.110 (4), the short-circuit strength, referred to as the short-circuit current rating (SCCR), is specified on the nameplate of the industrial control panel.

The SCCR can either be verified by a control panel already "listed" or "labeled", or by an alternative approved method.

The NEC proposes the method stipulated in UL 508A, Supplement SB, as an example for an approved method. The method stipulated in UL 508A, Supplement SB, is also referenced in Article 670, Industrial Machinery.

As a rule, the control panels are designed individually for specific applications, usually produced as individual units or as limited editions, and consequently a "listed" or "labeled" control panel is not practical in most cases due to time restrictions or for economic reasons. The method stipulated in UL 508A, Supplement SB, therefore provides an equivalent, approved and economic alternative.



UL 508A, Industrial Control Panels

The UL 508A, Industrial Control Panels, is published by UL and covers industrial control panels up to a maximum 1000 volts in standard ambient conditions up to a maximum 40 °C ambient temperature.

"Short-Circuit Current Ratings for Industrial Control Panels" are described in Supplement SB. Supplement SB4 describes in particular the method for determining the SCCR of an industrial control panel.

Components which shall be included for SCCR consideration

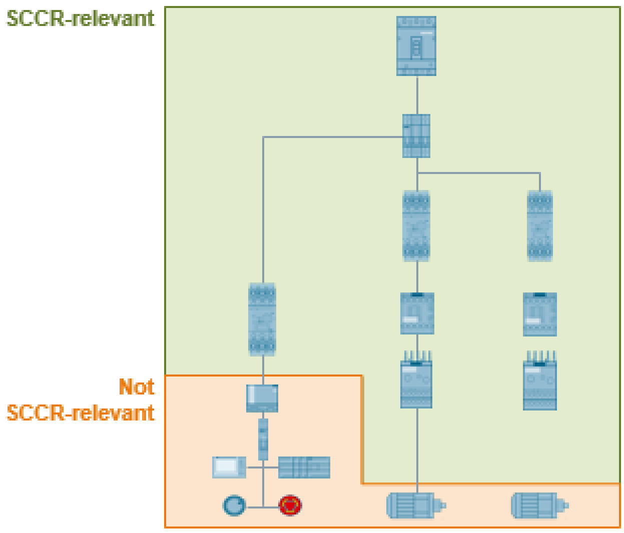
SCCR calculation according to UL 508A, Supplement SB4.

In accordance with Supplement SB4.2, excluding certain exceptions, all components in the power circuit shall be included for SCCR consideration and shall indicate a SCCR in amperes or kiloamperes with specification of the voltage.

This includes:

- Disconnect switches
- Supplementary protectors
- Branch circuit protective devices
- Bus bars
- Fuse holders
- Current meters
- Load controllers
- Current shunts
- Motor overload relays
- Switching devices
- Receptacles
- Terminal blocks or power distribution blocks

The primary protective device of the power supply for the control circuit is still within the power circuit and therefore also applies for SCCR consideration. For control circuits which are tapped directly from the power circuit without transformer or power supply unit, the first protective device following tapping also remains a part of the power circuit, which is no longer the case for downstream components.



Components which are not relevant for SCCR consideration

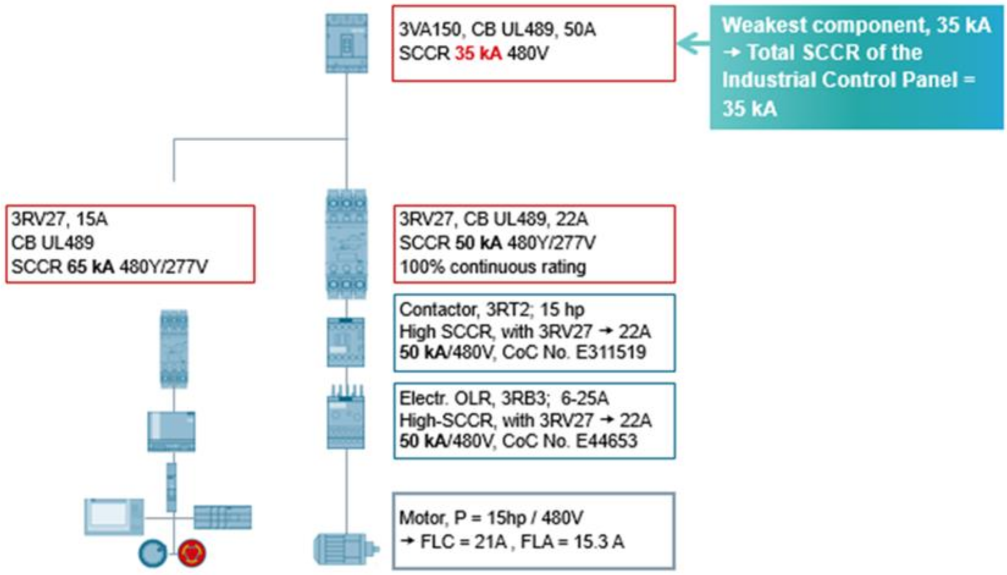
The following components in the power circuit are excluded from SCCR consideration:

- Power transformers
- Reactors
- Current transformers
- Dry-type capacitors
- Resistors
- Varistors
- Voltmeters
- The “S” contactor of a wye delta combination
- Enclosure air conditioners that are cord-and-attachment-plug connected
- Ferrules
- Conductors, wires and cables (naturally, conductor protection shall nevertheless be guaranteed)
- Loads in the field (e.g. motors, heaters, etc.)

Moreover, components operated entirely within the control circuit are also not SCCR-relevant.

The weakest component in the power circuit is decisive

Of all SCCR-relevant components, the component with the lowest SCCR value generally determines the overall SCCR value for the industrial control panel. In other words: All SCCR-relevant components shall be approved for at least the short-circuit at the incoming supply.



Example of overall SCCR for an industrial control panel

If the SCCR of one or more SCCR-relevant components does not comply with the short-circuit at the incoming supply, measures shall be introduced to ensure that these components may nevertheless be used.

The following measures are possible:

1. Increase of SCCR of the component by applying tested combinations, referred to as "High Capacity Short Circuit Ratings".

2. Limiting of the short-circuit current by using current-limiting devices in the feeder circuit.

Three steps are required, or available as an option, to determine the SCCR for the entire industrial control panel:

1. Determination of the SCCRs for all components in the power circuit which shall be included for SCCR consideration. **Required!**

2. Reduction of the maximum possible short-circuit for parts of the power circuit using current-limiting components in the feeder circuit. **Optional, where necessary!**

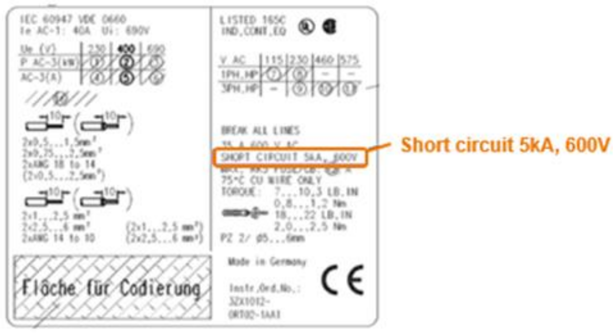
3. Determining the overall SCCR for the industrial control panel. **Required!**

Step 1: Determination of the SCCRs for the components in the power circuit (required!)

The short-circuit current rating of individual power circuit components shall be determined by applying one of the following three methods:

- Based on device markings or component data sheets
- Based on the assumed short-circuit current rating
- Based on tested device combinations

The majority of control devices and protective devices for the power circuit are marked on the front or on the nameplate with a standard SCCR.



Example: name plate Siemens contactor

For components which are not marked with a SCCR, the SCCR is to be defined on the basis of UL 508A, Table SB4.1.

Table SB4.1
Assumed maximum short circuit current rating for unmarked components

Component	Short circuit current rating, kA
Bus bars	10
Circuit breaker (including GFCI type)	5
Current meters	a
Connectors for Use in Data, Signal, Control and Power Applications	10
Current shunt	10
Fuseholder	10
Industrial control equipment:	
a. Auxiliary devices (overload relay)	5
b. Switches (other than mercury tube type)	5
c. Mercury tube switches	
Rated over 60 amperes or over 250 volts	5
Rated 250 volts or less, 60 amperes or less, and over 2 kVA	3.5
Rated 250 volts or less and 2 kVA or less	1
Motor controller, (including combination motor controllers, float and pressure operated motor controllers, power conversion equipment and solid state motor controllers), rated in horsepower (kW)[d]	
a. 0 – 50 (0 – 37.3)	5[c]
b. 51 – 200 (38 – 149)	10[c]
c. 201 – 400 (150 – 298)	18[c]
d. 401 – 600 (299 – 447)	30[c]
e. 601 – 900 (448 – 671)	42[c]
f. 901 – 1600 (672 – 1193)	85[c]

Excerpt from UL 508A, Table SB4.1, "Assumed maximum short-circuit current rating for unmarked components"

If components are now identified in the power circuit which exhibit a lower SCCR than the maximum occurring short-circuit current at the incoming supply, the most practical method is generally to check whether the respective component has been checked with an upstream protective device for a high-capacity short-circuit rating.

Protective devices from Siemens, such as circuit breakers according to UL 489, manual self-protected combination motor controller according to UL 508, type E, or fuses according to UL 248 are generally capable of interrupting even high short-circuits. This does not apply for other devices such as contactors, soft starters, semi-conductor contactors, overload relays or frequency converters. For these components, a check would have to be carried out as to whether a high capacity short-circuit rating has been tested.

For many devices such as contactors, soft starters, semi-conductor contactors and overload relays, these specifications can be obtained in the "Certificate of Compliance (CoC)". The CoC is created by UL for the manufacturer of the respective components and shall be made available to the user by the equipment manufacturer. CoCs for Siemens can be obtained from the Siemens Industry Online Support.

High Capacity Short Circuit Ratings:

Type No.	Fuse Class J	Comb. Mot. Ctlr. 3RV201 or 3RV202 1)	Circuit Breaker Bkr TM 3RV1742	Circuit Breaker Bkr TM 3RV1721, 3RV1821	Circuit Breaker Bkr TM 3RV27, 3RV28	Circuit Breaker Bkr I	Short Circuit	Voltage
3RT2023	60 A	-				-	100 kA	600 V
				22 A	22 A	-	50 kA	480 V
	-	12.5 A			15 A	-	65 kA	480 V
				8 A	12.5 A	-	10 kA	600 V
			20 A			-	20 kA	600 V
	-	12.5 A				-	30 kA	600 V
3RT2024	60 A	-				-	100 kA	600 V
				22 A	22 A	-	50 kA	480 V
		12.5 A			15 A	-	65 kA	480 V
				8 A	12.5 A	-	10 kA	600 V
			20 A			-	20 kA	600 V
		12.5 A				-	30 kA	600 V

Excerpt from the Certificate of Compliance for Siemens contactors 3RT202

Frequency converters are to be protected in accordance with manufacturer's specifications as prescribed in UL 508A, section 31.3.2. Siemens offer corresponding manuals in the Siemens Industry Online Support for their SINAMICS converters featuring details of the SCCR and tested protective device.

2.2 UL/CSA Type E Combination Motor Controllers

Note

3RV20 motor starter protectors are approved in accordance with UL 508/UL60947-4-1 in combination with the terminal blocks listed below:

- 3RV2011 and 3RV2021 with 3RV2928-1H
- 3RV2031 with 3RV2938-1K
- 3RV2032 with 3RV2938-1K

3RV104 motor starter protectors are approved in accordance with UL 508/UL60947-4-1 in combination with the 3RT1946-4GA07 terminal blocks.

2.2.1 Active Line Modules

Line Module Type	Line Module Article no.	Line Module Rated power [kW]	Combination Motor Controller Rated power (@ 460 V 3-ph) [hp]	Combination Motor Controller Article no.	Combination Motor Controller Max. rated current [A]	Combination Motor Controller SCCR @ 480 Y / 277 V AC [kA]
ALM	6SL313x-7TE21-6A..	16	30	3RV1031-4F...	40	65
			30	3RV2031-4U...	40	65
			30	3RV2032-4U...	40	100
			30	3RV1041-4F...	40	65
			30	3RV1042-4F...	40	65
			30	3RV2041-4F...	40	65
			30	3RV2042-4F...	40	65
ALM	6SL313x-7TE23-6A..	36	75	3RV1041-4L...	90	65
			75	3RV1042-4L...	90	65
			60	3RV2041-4R...	84	65
			60	3RV2042-4R...	84	65

x = 0: Internal air cooling; x = 1: External air cooling; x = 6: Cold-Plate

Excerpt from the handbook "Protective Devices for SINAMICS S120 Line Modules Booksize"

The Siemens product portfolio has been extensively tested for high SCCRs to ensure that Step 2, i.e. the use of current-limiting components in the feeder circuit, is generally not required with the utilization of Siemens devices.

Step 2: Reduction of maximum possible short-circuit for parts of the power circuit by using current-limiting components in the feeder circuit (optional, where necessary!)

In accordance with UL 508A Supplement SB4.3, the maximum possible short-circuit current for parts of the power circuit can be reduced by using current-limiting components in the feeder circuit. **It is imperative here, however, that the current-limiting components are situated entirely within the feeder circuit.**

The power circuit is subdivided into branch circuit and feeder circuit. The exact threshold between branch circuit and feeder circuit forms the first short-circuit protective device, upstream as viewed from the load, or more precisely, the feeder terminal of the protective device. The feeder terminal is still a part of the feeder circuit; anything below this is part of the branch circuit.

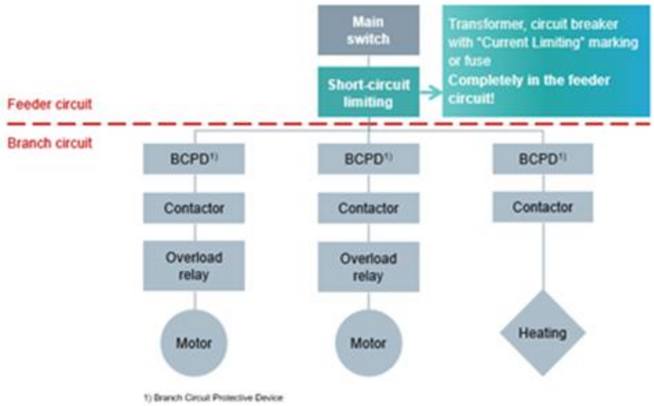


Figure "Short-circuit current-limiting components in the feeder circuit"

Possible current-limiting components in the feeder circuit include:

- Transformers
- Listed circuit breakers according to UL 489 marked with "current limiting"
- Fuses, Class CC, G, J, L, RK1, RK5 or T

Current limitation by transformers

Transformers limit the short-circuit for all components on the load side of the transformer.

In this regard, a distinction is to be made between:

1. Transformers with **known** relative short-circuit voltage
   (= Impedance Z according to UL 508A)

   and

2. Transformers with **unknown** relative short-circuit voltage
   (= Impedance Z according to UL 508A)

Transformers with known relative short-circuit voltage (= impedance Z according to UL 508A)

The short-circuit current which can occur on the secondary side of the transformer is calculated as follows:

$$\text{Secondary rated current } (I_{FL}) \text{ [A]} = \frac{\text{Transformer performance (P) [VA]}}{\text{Secondary voltage (Usec) [V]} \times \sqrt{3}}$$

Factor √3 is not applicable for single-phase transformers.

$$\text{Secondary short-circuit current } (I_{SC}) \text{ [A]} = \frac{\text{Secondary rated current } (I_{FL}) \text{ [A]}}{\text{Impedance (Z) [\%]}}$$

Transformers with unknown relative short-circuit voltage (= impedance Z according to UL 508A)

The maximum secondary short-circuit current can either be calculated in accordance with the aforementioned formulas with the assumed impedance Z = 2.1%, or determined using the tables SB4.3 "Secondary short-circuit current single-phase transformers" or SB4.4 "Secondary short-circuit current three-phase transformers" as follows:

1. The transformer capacity shall be ≤ that of column 1

   and

2. The secondary voltage may not be less than the values in column 2. If the secondary voltage is between values, the column with the next lowest voltage shall be selected.

Table SB4.3
Single phase transformer secondary available short circuit currents (Amps)[a]

Column 1	Column 2							
Transformer	Minimum Transformer Secondary Voltage (V)							
Max kVA	120	120/240[b]	208	240	277	347	480	600
1	400 A	300 A	230 A	200 A	180 A	140 A	100 A	80 A
3	1,200 A	900 A	690 A	600 A	520 A	420 A	300 A	240 A
5	1,990 A	1,490 A	1,150 A	1,000 A	860 A	690 A	500 A	400 A
10	3,970 A	2,980 A	2,290 A	1,990 A	1,720 A	1,380 A	1,000 A	800 A
15	5,960 A	4,470 A	3,440 A	2,980 A	2,580 A	2,060 A	1,490 A	1,200 A
25	9,930 A	7,450 A	5,730 A	4,970 A	4,300 A	3,440 A	2,490 A	1,990 A
37.5	14,890 A	11,170 A	8,590 A	7,450 A	6,450 A	5,150 A	3,730 A	2,980 A
50	19,850 A	14,890 A	11,450 A	9,930 A	8,600 A	6,870 A	4,970 A	3,970 A
75	29,770 A	22,330 A	17,180 A	14,890 A	12,900 A	10,300 A	7,450 A	5,960 A

[a] Z assumed to be 2.1%. All values are rounded up.
[b] Short-circuit current shown is line-to-neutral. (1.5 times line-to-line)

Source: UL 508A, Table SB4.3

Table SB4.4
Three phase transformer secondary available short circuit currents (Amps)[a]

Column 1	Column 2						
Transformer	Minimum Transformer Secondary Voltage (V)						
Max kVA	208Y/120[b]	208	240	480Y/277[b]	480	600Y/347[b]	600
5	830 A	670 A	580 A	360 A	290 A	290 A	230 A
10	1,660 A	1,330 A	1,150 A	720 A	580 A	580 A	460 A
15	2,480 A	1,990 A	1,720 A	1,080 A	860 A	860 A	690 A
20	3,310 A	2,650 A	2,300 A	1,440 A	1,150 A	1,150 A	920 A
25	4,140 A	3,310 A	2,870 A	1,800 A	1,440 A	1,440 A	1,150 A
30	4,960 A	3,970 A	3,440 A	2,150 A	1,720 A	1,720 A	1,380 A
45	7,440 A	5,950 A	5,160 A	3,230 A	2,580 A	2,580 A	2,070 A
75	12,400 A	9,920 A	8,600 A	5,370 A	4,300 A	4,300 A	3,440 A
100	16,530 A	13,220 A	11,460 A	7,160 A	5,730 A	5,730 A	4,590 A

[a] Z assumed to be 2.1%. All values are rounded up.
[b] Short-circuit current shown is line-to-neutral. (1.25 times line-to-line)

Source: UL 508A, Table SB4.4

The values from the tables or the calculation with an assumed impedance Z of 2.1% are also suitable for transformers with impedance Z ≥ 2.1%.

All components on the load side of the transformer shall be configured ≥ the determined short-circuit current (I_{sc}).

The disadvantage of this method, however, is the additional spatial requirement and the additional costs for the transformer.

Current limitation by using listed circuit breakers according to UL 489 with "Current Limiting" marking

The current-limiting effect may only be incorporated for components in the branch circuit when using listed circuit breakers according to UL 489 with the "Current Limiting" marking.

The SCCR of branch circuits which are additionally protected by a listed circuit breaker according to UL 489 in the feeder circuit corresponds with:

1. The **breaking capacity** of the **feeder circuit breaker**, referred to as the "interrupting rating", if:

    a. SCCR of each individual component in the branch circuit is ≥ the peak let-through current
    of the feeder circuit breaker

    and

    b. Interrupting ratings of all branch circuit protective devices (BCPDs) or SCCRs of the combination motor controller ≥ the interrupting rating of the feeder circuit breaker

    For BCPDs which are not marked with an interrupting rating or combination motor controllers which are not marked with a SCCR, the values from UL 508A, Table SB4.1 apply.

    or

2. The **lowest interrupting rating of a BCPD or lowest SCCR of a combination motor controller** on the load side of the feeder circuit breaker if this is less than the interrupting rating of the feeder circuit breaker.

    or

3. The lowest SCCR of a branch circuit on the load side of the feeder circuit breaker if neither condition 1 nor condition 2 applies.

The let-through currents of the circuit breakers are to be obtained from the peak let-through curve provided by the manufacturer.

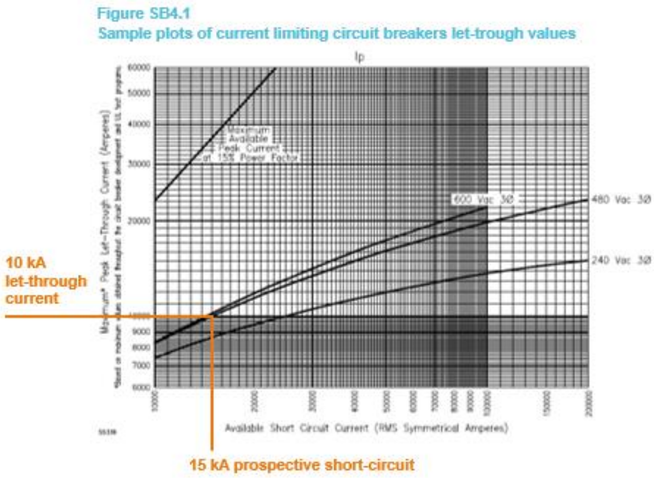
The utilization of circuit breakers according to UL 489 with the "Current Limiting" marking does not generally offer any significant advantages for the following reasons:

1. Short-circuit current limitation for components in the feeder circuit is not possible (busbar systems, including adapters, from which one or more load circuits are tapped, are still situated in the feeder circuit, for example).

2. As the SCCR of **each individual component** in the branch circuit shall be ≥ the let-through value of the circuit breaker, this requires relatively low let-through values of the circuit breaker.

    Individually, many components feature only low SCCRs. Thus, for example, a contactor of up to 50 hp or an overload relay only has a SCCR of 5 kA, a terminal block has 10 kA, etc. These low let-through values are only found in smaller circuit breakers within the low rated current range.

    The following diagram from UL 508A shows an example of let-through current curves of a current limiting circuit breaker for rated voltages of 240, 480 and 600 V. This shows that a voltage of 480 V, for example, and a prospective short-circuit of 15 kA will only be limited to 10 kA. This would be too much for a contactor up to 50 hp or an overload relay. A let-through current of 5 kA is not depicted at all in this example.



Source: UL 508A, Figure SB4.1

Current limitation by using fuses, Class CC, G, J, L, RK1, RK5 or T

Only Class CC, G, J, L, RK1, RK5 or T fuses may be used as a current-limiting component.

The same conditions as those for circuit breakers apply, with the exception that the let-through currents shall be obtained from UL 508A, Table SB4.2. Manufacturer's specifications may not be applied as a let-through current. "Worst-case values" are depicted in Table SB4.2. UL-approved fuses generally provide considerably superior let-through values. Application of the values from UL 508A, Table SB4.2, however, ensures that the current-limiting effect is still guaranteed, even if the fuse is replaced with that of a different manufacturer.

Even when using fuses, let-through currents of 5 kA are exceeded relatively quickly, and thus will also only prove practical under certain conditions. A Class CC fuse with a rated current of 30 A features a let-through current of 6 kA with a prospective short-circuit of 50 kA, thus already demonstrating an excessive let-through current for most components.

Table SB4.2
Fuse Peak let through currents, I_p, and clearing, I^2t, based on available short circuit current levels

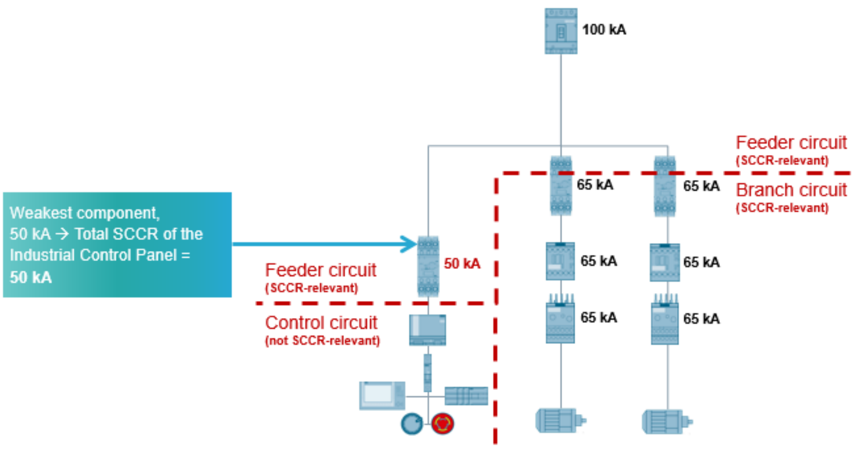
Fuse types	Fuse rating amperes	Between threshold and 50 kA		100 kA		200 kA	
		$I^2t \times 10^3$	$I_p \times 10^3$	$I^2t \times 10^3$	$I_p \times 10^3$	$I^2t \times 10^3$	$I_p \times 10^3$
Class CC	15	2	3	2	3	3	4
	20	2	3	3	4	3	5
	30	7	6	7	7.5	7	12

Excerpt from UL 508A, Table SB4.2

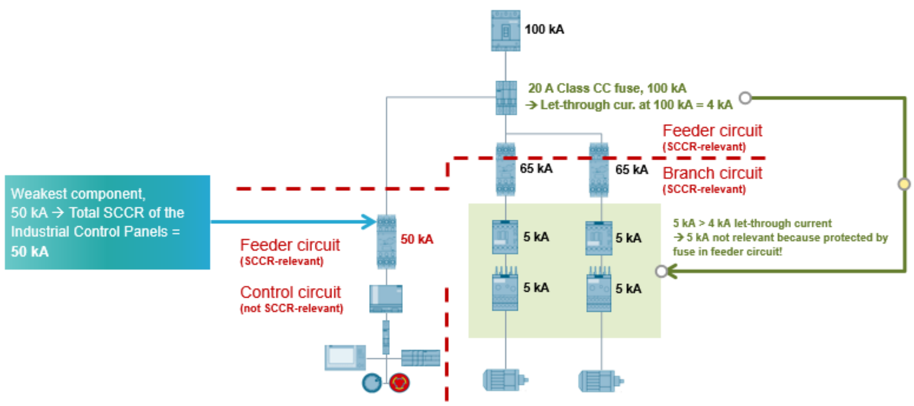
Step 3: Determining the overall SCCR for the industrial control panel (required!)

Following conclusion of Step 1, and where necessary Step 2, it is possible to determine the SCCR for the entire industrial control panel.

The SCCR of the industrial control panel is determined by the component in the power circuit with the lowest SCCR which is not additionally protected by a current-limiting component in the feeder circuit, in accordance with Step 2.



Example 1: SCCR of the industrial control panel **without** current-limiting component in the feeder circuit



Example 2: SCCR of the industrial control panel **with** current-limiting component in the feeder circuit

Summary

The weakest component in the power circuit determines the overall SCCR for the industrial control panel.

The simplest practical solution is to use components which have already been tested inherently for the required value. Protective devices are self-protecting and are tested for a specific breaking capacity. Components which do not trip automatically in the event of a short-circuit shall be tested together with an upstream protective device for a SCCR.

We recommend the utilization of components which fulfill the desired short-circuit automatically, or with an upstream protective device. In this case, the utilization of current-limiting components is not necessary.

A common misconception in this regard is that circuit breakers according to UL 489 shall feature the additional "Current Limiting" approval. As the explanations provided in this White Paper attest, this is only one of several possibilities, and is in no way mandatory. On the contrary: in practice, this option is only applicable with restrictions.

Further information from Siemens

Siemens keeps you up-to-date.
Whether you are looking for reference works, web-based training courses, helpful engineering tools or useful information on panel building, you will find comprehensive information on "expert know-how", "tools and data for digitalization in engineering" and "aligned product and system portfolio" on our market portal for panel building:
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