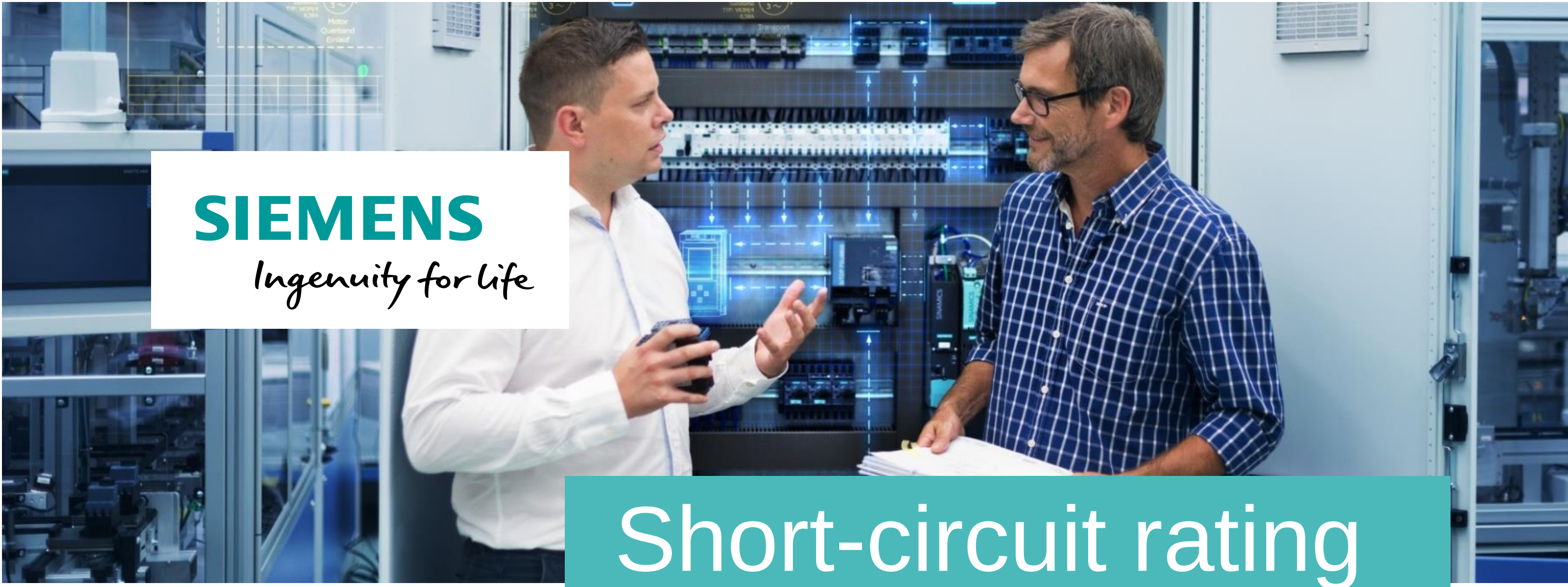

Short-circuit rating of electrical equipment

An overview of the main requirements for the short-circuit protection of electrical equipment and systems

White Paper | September 2017

Machines, their control cabinets and other types of electrical equipment must be designed and dimensioned in accordance with their electrical power supply as well as with the physical environmental and operating conditions prevailing on site. Besides fault-free operation under normal operating conditions, the objective also includes protection against damaging effects in the event of a fault. Such a fault may, for example, consist of a short circuit in the electrical equipment.

On the basis of standards, this Siemens White Paper explains the measures needed to prevent injury to persons and animals and damage to equipment, and also shows how the corresponding verification may be provided.

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Smallest and largest short-circuit current of electrical equipment

Directives and standards

According to the Machinery Directive 2006/42/EC and the Low Voltage Directive 2014/35/EU, machines and electrical equipment shall only be placed on the market if they do not endanger the safety and health of persons and, if applicable, of pets and of property. This also covers the protection of the equipment against electrical interference or faults, such as short circuits.

The standards provide guidance for risk analysis and for the fulfillment of fundamental requirements, and reflect the generally accepted rules of technology. The international standard IEC 60204-1 on “Safety of machinery – Electrical equipment of machines – Part 1: General requirements electrical equipment of machines” requires, in Paragraph 7.10 of Edition 6.0, that the short-circuit current rating be determined for the electrical equipment. As options for achieving this, the standard considers the application of engineering rules, calculation or tests. However, IEC 60204-1 does not describe any procedure of its own. Instead, it refers to other standards, including IEC 61439-1.

Calculation of the short-circuit current is also an essential prerequisite for selection of the electrical equipment.

Not only the largest but also the smallest short-circuit current play an important role here. As a rule, the smallest short-circuit current is produced by a single-pole short circuit, whereas the largest short-circuit current usually arises through a three-pole short circuit.

- The largest short-circuit current must be detected by the protection device and disconnected quickly in order to protect the cables and equipment against damage.
- An important factor for the smallest short-circuit current is the pick-up reliability. It must be ensured that the residual current is disconnected within at most five seconds by the upstream protection device in the case of stationary plant and machinery. The objective is to protect operating staff and service personnel against possible hazards caused by electric shock, and cables and equipment against damage.

Short-circuit current at the machine incoming supply and loads

Manufacturers and customers shall agree on the minimum and maximum short-circuit current at the incoming supply of the control cabinet. The electrical equipment shall be designed and dimensioned in accordance with these values.

The initial symmetrical short-circuit current at the transformer, as well as the line attenuation, must be taken into account. Cable lengths and cross-sections exert a substantial influence on the magnitude of the short-circuit current at the machine infeed.

The smallest short-circuit current is generally produced by a single-pole short circuit.

Initial symmetrical short-circuit current at the transformer

In the reference manual “Control Panels compliant with IEC Standards and European Directives”” and in the Siemens “SIVACON S8 Planning Manual”, you will find the approximate values for short-circuit currents on the secondary side of the transformer shown in a clear overview:

Rated power S_{rT}	Rated voltage								
	400 V AC / 50 Hz			525 V AC / 50 Hz			690 V AC / 50 Hz		
		Rated value of the short-circuit voltage u_{kr}			Rated value of the short-circuit voltage u_{kr}			Rated value of the short-circuit voltage u_{kr}	
		4%	6%		4%	6%		4%	
	Rated current I_r	Initial symmetrical short-circuit current I_k'' 1)		Rated current I_r	Initial symmetrical short-circuit current I_k'' 1)		Rated current I_r	Initial symmetrical short-circuit current I_k'' 1)	
50 kVA	72 A	1,933 A	1,306 A	55 A	1,473 A	995 A	42 A	1,116 A	754 A
100 kVA	144 A	3,871 A	2,612 A	110 A	2,950 A	1,990 A	84 A	2,235 A	1,508 A
160 kVA	230 A	6,209 A	4,192 A	176 A	4,731 A	3,194 A	133 A	3,585 A	2,420 A
200 kVA	288 A	7,749 A	5,239 A	220 A	5,904 A	3,992 A	167 A	4,474 A	3,025 A
250 kVA	360 A	9,716 A	6,552 A	275 A	7,402 A	4,992 A	209 A	5,609 A	3,783 A
315 kVA	455 A	12,247 A	8,259 A	346 A	9,331 A	6,292 A	262 A	7,071 A	4,768 A
400 kVA	578 A	15,506 A	10,492 A	440 A	11,814 A	7,994 A	335 A	8,953 A	6,058 A
500 kVA	722 A	19,438 A	13,078 A	550 A	14,810 A	9,964 A	418 A	11,223 A	7,581 A
630 kVA	910 A	24,503 A	16,193 A	693 A	18,669 A	12,338 A	525 A	14,147 A	9,349 A
800 kVA	1,154 A		20,992 A	880 A		15,994 A	670 A		12,120 A
1000 kVA	1,444 A		26,224 A	1,100 A		19,980 A	836 A		15,140 A
1,250 kVA	1,805 A		32,791 A	1,375 A		24,984 A	1,046 A		18,932 A
1,600 kVA	2,310 A		41,857 A	1,760 A		31,891 A	1,330 A		24,265 A
2,000 kVA	2,887 A		52,511 A	2,200 A	f	40,008 A	1,674 A		30,317 A
2,300 kVA	3,608 A		65,547 A	2,749 A		49,941 A	2,090 A		37,844 A
3,150 kVA	4,550 A		82,656 A	3,470 A		62,976 A	2,640 A		47,722 A

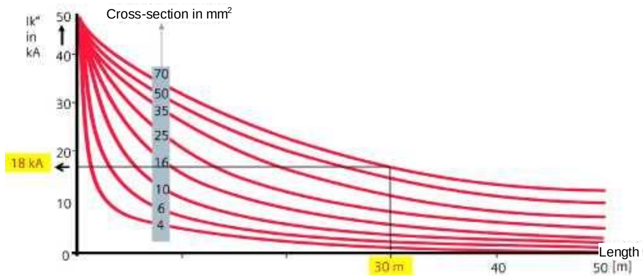
1) I_k'' is the prospective initial symmetrical short-circuit current of the transformer, taking into account the voltage factor and the correction factor of the transformer impedance according to IEC 60939-0, without consideration of the system source impedance

For a rated power of 2,000 kVA, the initial symmetrical short-circuit current is 52,511 A in this example.

Attenuation of the power connection cable

The longer the supply line to the machine and the smaller the cross-section of the cable, the greater is the cable attenuation or loss. The maximum possible short-circuit current at the machine is the three-pole short circuit at the end of the incoming supply conductor.

The following diagram shows a schematic view of the short-circuit loss in relation to the cable length and the cross-section.



Source: Switching, Protection and Distribution in Low-Voltage Networks

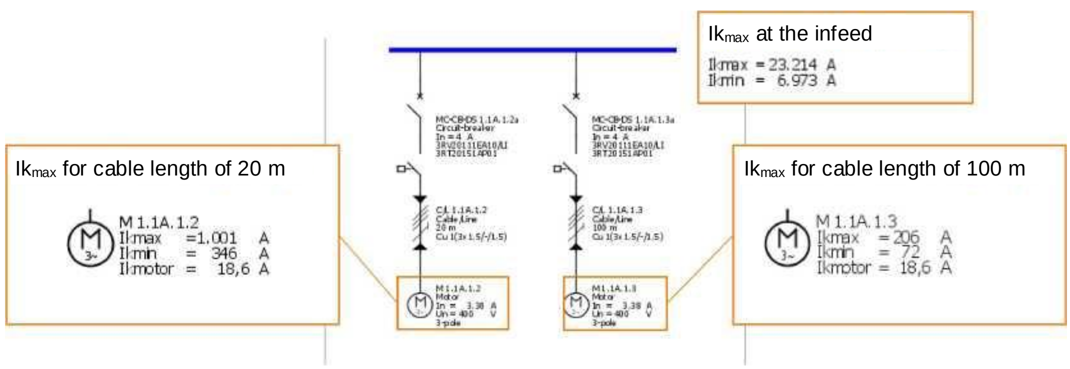
Smallest possible short-circuit current

The smallest possible short circuit that can occur is the single-phase short circuit. The longer the supply line to the short-circuit point and the smaller the cross-section, the greater is the impedance of a fault loop and the smaller the short circuit that is produced. Consequently, the smallest short-circuit current usually occurs at the connection of the load which is situated the farthest away. In all cases, it must be ensured that the short-circuit release of the upstream protection ensurance of response value. Otherwise, it is possible that the required break time of at most five seconds is not achieved.

Practical tip

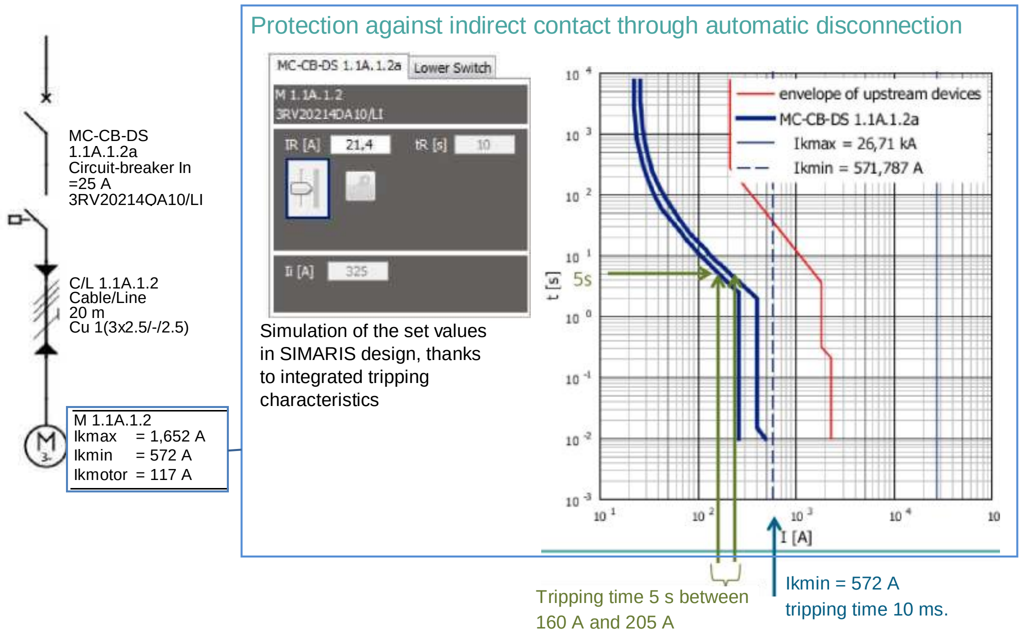
In practice, determining the smallest and largest short circuit at the installation location of the corresponding protection equipment may incur substantial engineering costs.

The Siemens "SIMARIS design" planning tool is a valuable aid for professional electrical planning. For example, the application provides support for the correct sizing of the conductor cross-sections, for the selection of tested motor starter combinations, and for the dimensioning of the protection devices.



SIMARIS design calculates, amongst other things, the Ik_{min} and Ik_{max} at various points in the circuit: here at the machine infeed and at the load for two identical motor outgoing feeders with a capacity of 1.1 kW, identical conductor cross-sections, and differing cable lengths.

The tripping characteristics of the protection devices support the project engineer with both the safe dimensioning of the load feeders as well as the verification of safety-related disconnection in the event of a fault.

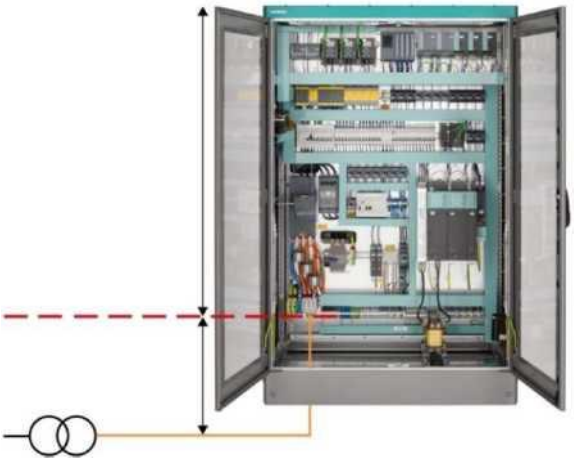


Simulation of the set values in SIMARIS design, thanks to integrated tripping characteristics of the protection equipment:
here for a load feeder with a capacity of 11 kW and In = 21.4 A.

Selection of equipment in the main circuit

Subdivision into incoming supply and load feeders

Unless agreed otherwise by the operator and the manufacturer of the machine, the area of responsibility of the manufacturer begins at the point of supply of the machine. This is at the feeder terminal of the disconnector unit or, where applicable, at upstream connecting terminals.



From the infeed, the functions to be fulfilled include:

- Disconnecting unit for safe isolation/switching off of the plant
- Short-circuit protection
- Overload protection (cables)

Supply disconnecting device

According to IEC 60204-1, devices as per IEC 60947-2 and IEC 60947-3 are permitted. As the disconnecting device for safe isolation/switching off of the plant, the following solutions by Siemens may be applied:

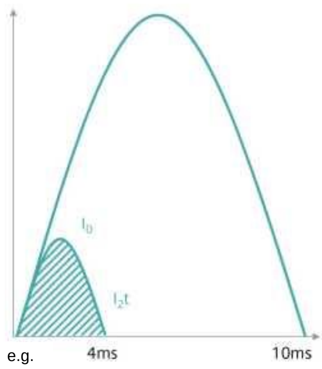
- Fused design with load-break function

- Switch disconnector without fuse

- Fuseless design with circuit breaker

If disconnecting device without integrated protection equipment are used, the cables at the outgoing terminal of the disconnecting unit are not protected. In this case, the manufacturer must specify a suitable back-up fuse in the technical documentation.

Current-limiting short-circuit protection devices, such as circuit breakers or fuse (e.g. Siemens 3VA MCCB, Siemens LV HRC fuse links) interrupt the short-circuit current before it reaches its peak value (the peak short-circuit current). The disconnection takes place within only a few milliseconds and corresponds to the hatched envelope curve.



Schematic break oscillogram, 50 Hz system

Load feeders

The various load feeders are tapped off downstream of the disconnecting unit.

For each individual load feeder, the following functions must also be fulfilled:

- Short-circuit protection
- Overload protection of the cables and motors
- Control of the individual loads

Load feeders can be fused or fuseless, depending on requirements. Siemens offers solutions for both types.

Fuseless load feeder, optionally for customer assembly or as a preassembled 3RA2 combination

Fused load feeder with Siemens fuse links, e.g. 5SE, 3NA, 3RT2 contactor and thermal overload relay

Verification

Short-circuit rating according to IEC 60204-1

As a result of the requirement of IEC 60204-1 that determination of the short-circuit current rating is needed for the electrical equipment by application of engineering rules, calculation or tests, in conjunction with reference to the standards IEC 61439-1, IEC 60909-0,
IEC/TR 60909-1 or IEC/TR 61912-1, the topic of “short-circuit rating” is defined and regulated clearly. We will examine the requirements arising from IEC 61439-1 in more detail below.

Requirements from IEC 61439-1

This standard defines how the short-circuit rating of the electrical equipment is determined and how verification must be provided. Verification can be provided by tests or by comparison with a reference design.

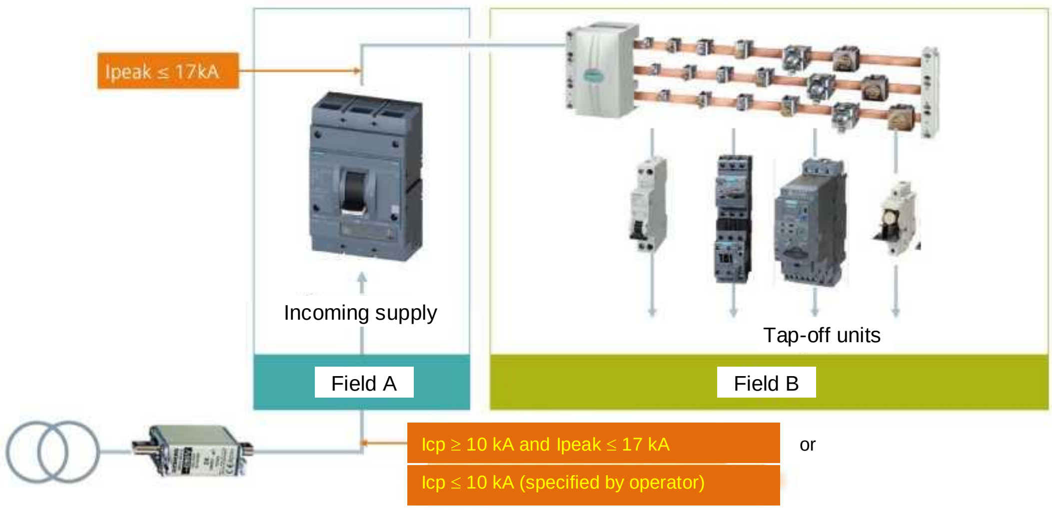
Verification of the short-circuit rating may be waived for:

- Controlgear assemblies with a rated short-time withstand current I_{cw} or a rated conditional short-circuit current I_{cc} of at most 10 kA rms.
- Controlgear assemblies protected by means of current-limiting devices whose let-through current does not exceed a maximum of 17 kA (I_{peak}).
- Auxiliary circuits of controlgear assemblies for connection to transformers:
  - ≤ 10 kVA rated power with a secondary rated voltage of ≥ 110 V, or
  - ≤ 1.6 kVA with a secondary rated voltage of < 110 V and short circuit impedance of ≥ 4%.

Because of the effort required, verification by testing is not always carried out in practice for the electrical equipment of machinery. Verification is usually provided through comparison with a reference design. This means that the manufacturer of the electrical equipment refers to the short-circuit specifications in the data sheets of the components used; these short-circuit values will have been determined through testing by the device manufacturers.

Operational short-circuit current breaking capacity (Ics) for AC	
• at 240 V rated value	100 kA
• at 400 V rated value	50 kA
• at 500 V rated value	8 kA
• at 690 V rated value	4 kA
Maximum short-circuit current breaking capacity (Icu)	
• for AC at 240 V rated value	100 kA
• for AC at 400 V rated value	100 kA
• for AC at 500 V rated value	15 kA
• for AC at 690 V rated value	6 kA

Excerpt from the product data sheet of the 3RV2032-4EA10 circuit breaker



If none of the three exceptions applies, verification must be provided through comparison with a reference design or by testing.

Short-circuit verification in practice

Siemens makes short-circuit verification easy. For example, through a clear overview in table form showing which protection devices limit the short circuit to < 17 kA.

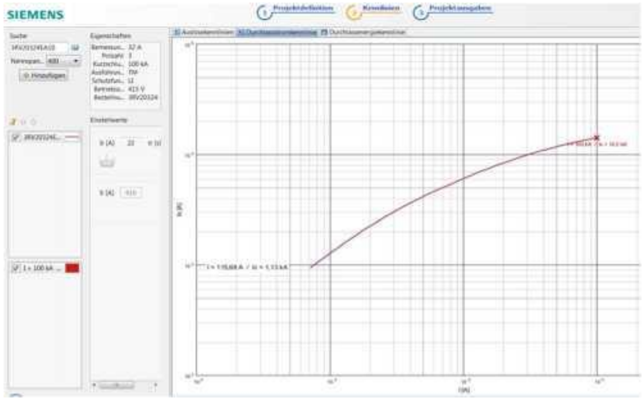
Integration		Making/breaking capacity class						
IEC 61439 – short-circuit test								
Values for 415 V		B	N	S	M	H	C	L
3VA1	I_{cu}	16 kA	25 kA	36 kA	55 kA	70 kA	-	-
3VA10 (3/4p)								
	16-80 A	OK	OK	OK	-	-	-	-
	100 A	OK	OK	33.0 kA	-	-	-	-
3VA11 (1/2p)								
	16-160 A	-	OK	OK	-	-	-	-
3VA11 (3/4p)								
	16-32 A	-	OK	OK	OK	OK	-	-
	40-80 A	-	OK	OK	OK	68.0 kA	-	-
	100-160 A	-	OK	33.0 kA	33.0 kA	33.0 kA	-	-
3VA12 (3/4p)								
	160-250 A	-	-	14.5 kA	14.5 kA	14.5 kA	-	-
3VA2	I_{cu}	-	-	-	55 kA	85 kA	110 kA	150 kA
3VA20								
	25-100 A	-	-	-	38.1 kA	38.1 kA	38.1 kA	38.1 kA
3VA21								
	25-160 A	-	-	-	19.4 kA	19.4 kA	19.4 kA	19.4 kA
3VA22								
	160-250 A	-	-	-	16.7 kA	16.7 kA	16.7 kA	16.7 kA
3VA23								
	250-400 A	-	-	-	17kA	> 17 kA	> 17 kA	> 17 kA
3VA24								
	400-630 A	-	-	-	> 17 kA	> 17 kA	> 17 kA	> 17 kA

3VA molded case circuit breaker
Integration IEC 61439 – IC < 17 kA


Size	Width	I_n	I_d 1)	I_k 2)	U_n
	mm	A			AC V/ DC V
2	47,2	35	< 17 kA	120 kA	500/ 440
		50	< 17 kA	120 kA	
		63	< 17 kA	120 kA	
		80	< 17 kA	120 kA	
		100	< 17 kA	120 kA	
		125	< 17 kA	120 kA	
		160	17 kA bei 94,7 kA		
		200	17 kA bei 59,6 kA		
		224	17 kA bei 31,6 kA		
		250	17 kA bei 20,1 kA		
	57,8	300	> 17 kA		
		315	> 17 kA		
		355	> 17 kA		
		400	> 17 kA		
3	57,8	200	17 kA bei 59,3 kA		500/440
		224	17 kA bei 31,9 kA		
		250	17 kA bei 20,9 kA		
		300	> 17 kA		
		315	> 17 kA		
		355	> 17 kA		
		400	> 17 kA		
	71,2	425	> 17 kA		
		500	> 17 kA		
		630	> 17 kA		

LV HRC fuse systems Integration
IEC 61439 – IC < 17 kA

SIMARIS curves is a useful digital tool. This free software visualizes the tripping characteristics, let-through current and let-through energy curves of the various protection devices made by Siemens.



Let-through current curve of the 3RV2032-4EA10 circuit breaker for motor protection. For a short-circuit I_k of 100 kA, the circuit breaker has a let-through current of 14.2 kA.

Further information

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: usa.siemens.com/controlpanels

Still have questions or need additional support?
Siemens supports panel builders with free consulting and training on standards. Get in contact with one of our experts by sending us an email to:
controlpanelquestions.us@siemens.com

Siemens Industry, Inc.
Digital Factory Control Products

5300 Triangle Parkway NW

Nocross, GA 30092