

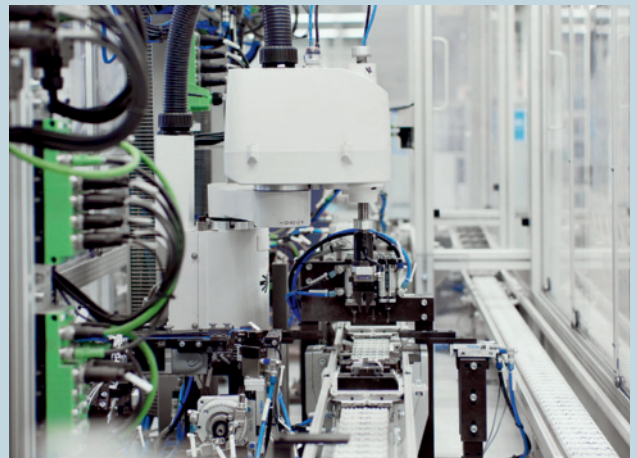
Device circuit breakers - the basics

Basic knowledge for protection in the event of overload and short circuit

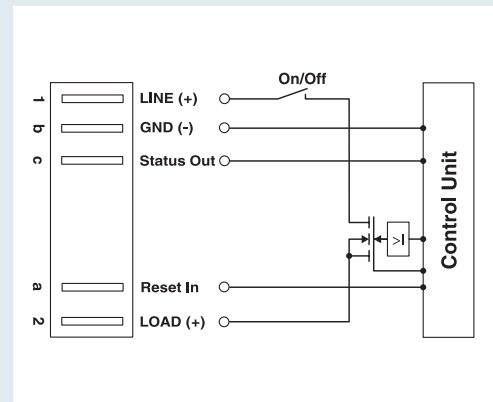
Provide devices with adequate protection

Machine downtimes and system failures during production are always associated with huge costs for companies which aim for a high supply capability and adherence to schedule. If production lines, systems, and machines break down, residual currents in the form of short circuits and overloads are frequently the cause.

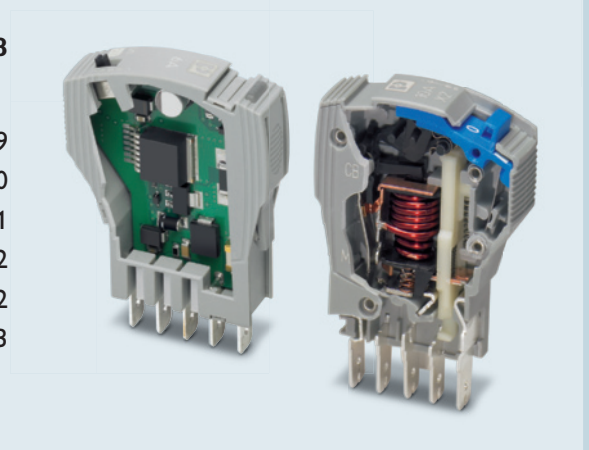
In order to prevent these costs from arising, installing device circuit breakers is a wise decision. In the event of an overload or a short circuit, the device circuit breaker switches off the affected current path. By doing so, it protects the load against being damaged or even destroyed. Other system parts continue to operate, thanks to the selective switch-off. As such, high system availability is guaranteed.



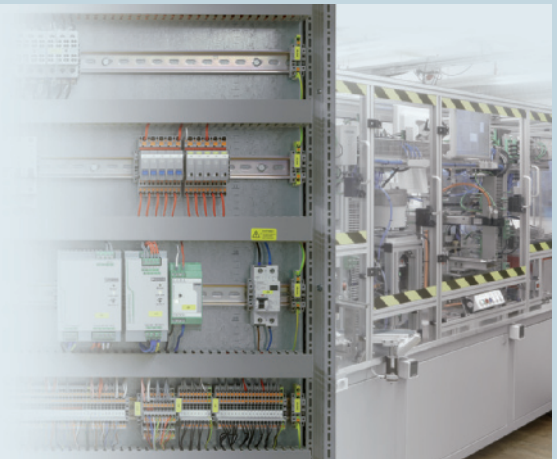
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This brochure on device circuit breakers is divided into three main sections and imparts basic information on the topic. In the first section, the causes and effects of fault currents are explained, along with standards and terms.

In the second section, the focus is on technology. The technology of the device circuit breakers is explained as well as the influence which cable lengths and power supply units have on the installation.

The final section examines application examples and uses, and is a guide to selecting the right device circuit breaker.

A new production plant is planned and built. New circuits are installed. The system is brought into operation. If there is ever a short circuit, production grinds to a halt and some system parts are seriously damaged.

This wouldn't have happened if effective device protection had been provided during the system's planning stages. Device circuit breakers, which switch off loads selectively, provide a high level of system availability.

Good reasons for using device circuit breakers

- High system availability
- Large fault tolerance
- Selective protection
- Stable supply capability
- Wide range of possible applications
- Reliable protection of the connected load

Confined space – maximum safety

Thanks to their narrow design, device circuit breakers can fit into almost every control cabinet

1.1 The right protection for a circuit

Overload currents and short-circuit currents are usually unexpected. They cause malfunctions and interruptions to the ongoing operation of a system. Production downtimes and repair costs are often the unhappy consequences. Effects of this type can be minimized with selective protection of individual devices or with appropriately coordinated device groups.

Overload currents occur if loads unexpectedly require a higher current than the rated current provided. Such situations may arise, for example, due to a blocked drive. Temporary starting currents from machines are also considered to be overload currents. The occurrence of these can essentially be calculated, but nonetheless can vary depending upon the machine load at the moment it starts. When selecting a suitable fuse for such circuits, these conditions should be taken into account. Short circuits can occur due to a faulty installation or due to damage to the insulation. Damage to the insulation can occur as a short circuit between the operating-voltage-carrying conductors or as residual current between the live conductors and ground. Typical protective devices for limiting overload and short-circuit currents are fuses or miniature circuit breakers with various tripping mechanisms. Residual current devices limit residual currents.

Selecting the right circuit breaker for protecting circuits and loads ensures safe and optimized operation of electrical systems, even in the event of a fault.

When it comes to circuit breakers, a distinction should be made between circuit breakers and device circuit breakers. Circuit breakers are used in the field of power distribution, mainly to protect the power cables which are laid in buildings or systems and supply termination devices, blocks or building complexes with power. The protection of loads or termination devices is not, however, this circuit breaker's task. It is only in the event of a short circuit in a termination device that they switch off to protect the power supply line from

overload. They have a high switching capacity of 6 kA upwards.

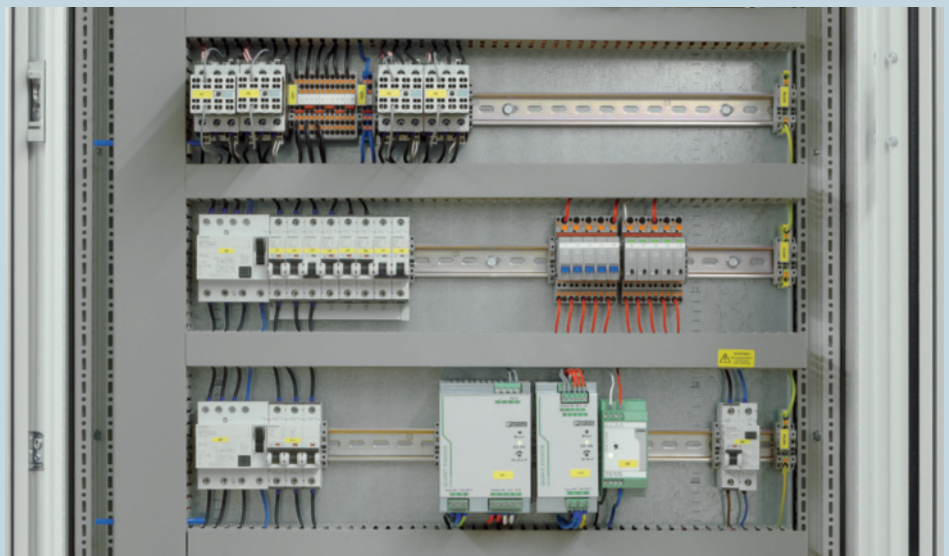
Termination devices are protected directly and selectively with the right device circuit breaker. The device circuit breaker not only protects the cable but also primarily the termination device to be protected in the event of overload and short circuit. If a new circuit is installed, appropriate fuse protection should also be installed for the intended termination device. During installation, cable lengths and conductor cross sections should be observed. The cables must be designed for the expected operating current but also must be able to deal with a potential overload current and short-circuit current. Within the scope of graded protection of system parts, the selectivity between the individual protective devices should be retained. This ensures high system availability as only the faulty circuit is switched off. All other circuits and termination devices remain unaffected. Unaffected system areas can continue to function, insofar as the overall process permits.

Moreover, the ambient conditions of the installation should be taken into account. For example, a control cabinet should not be overpopulated, in order to prevent the power supply unit from

overload. Furthermore, a sufficient air flow and cooling process should be ensured. In this way, incorrect tripping due to overheating and therefore the associated downtimes are prevented.

The installation of device circuit breakers increases the availability of technical systems and machines. Thanks to the ability to connect loads selectively, each circuit can be individually monitored, and in the event of residual currents only the defective circuit and corresponding loads are individually switched off.

Device circuit breakers should be easily accessible when installed in control cabinets, so that they can be switched on again easily and without problems after tripping.



Professional installation for problem-free operation and easy maintenance

1.2 Definition of terms

An understanding of basic terms is also vital for device protection. To enable you to understand this topic better, here is a brief list of terms which should help you.

Device circuit breakers ...

... are specially designed to protect devices and also to protect actuators and sensors in technical systems and machines from possible defects which are attributed to short circuit or overload.

Circuit breakers ...

... are used to protect cables from damage that could occur as a consequence of overload or short circuit.

Tripping characteristic

It is possible to read the tripping behavior of a device circuit breaker from the tripping characteristic. The switching time and amperage at which a circuit breaker trips is shown in a diagram.

SFB technology

SFB (Selective Fuse Breaking) technology enables current paths through which a short-circuit current flows to be switched off individually. Other system parts, which are also connected to this power supply, continue to be supplied with power.

Fuses ...

... open a circuit by switching off the power if this exceeds a specified value over a long period of time.

Ambient temperature

This is the air temperature surrounding the device circuit breaker under specified conditions.

Rated current, rated voltage

This is the current or voltage value of the device circuit breaker, as specified by the manufacturer for a particular operating condition.

These values are related to the operating and performance features.

Overcurrent

This is a current that exceeds the rated current.

Overload current

This is overcurrent that occurs in an undamaged electric circuit.

Short-circuit current ...

... arises between a faulty, low-resistance connection between two points that usually have different potentials.

Temporary dielectric strength

This is the highest temporary voltage value which can be tolerated without causing any insulation damage under specified conditions.

Main contact

This is the contact in the main circuit which conducts the current when closed.

Auxiliary contact

This is the contact in the auxiliary circuit which is operated mechanically. It functions as a remote indication contact.

N/O contact

This is a floating auxiliary contact. It is closed if the main contact is also closed.

N/C contact

This is a floating auxiliary contact. It is open if the main contact is closed.

PDT

This is a signal contact with three connections which provide N/C contact and N/O contact functions.

Creepage distance

This is the shortest distance along the surface of an insulation material between two conductive parts.

Clearance

This is the shortest distance between two conductive parts.

Cycles

The consequence of actuations from one position to another and back.

MTBF

Mean Time Between Failures – the expected value of the operating time between two consecutive failures.

Trip-free mechanism

A device circuit breaker trips without altering the switch position of the operating lever.

1.3 Standards

Device circuit breakers are governed by EN 60934. This standard applies to mechanical switching devices (device circuit breakers) which are envisaged for protecting circuits in electrical equipment. The standard states that device circuit breakers have a higher rated switching capacity than is required for overload conditions. Furthermore, together with prescribed short-circuit equipment, they have a conditional rated short-circuit current.

This standard can also be applied to switching devices used for protecting electrical equipment in the event of undervoltage and/or surge voltage. It is applicable to AC voltages up to 440 V and/or for DC voltage up to 250 V at a rated current of up to 125 A and a rated short-circuit current switching capacity of up to 3000 A.

This standard contains all of the necessary requirements to ensure adherence to the necessary operating parameters for these devices, by means of the type test.

1.4 Characteristic properties

The characteristic properties of a device circuit breaker are named using the following terms:

Number of positions

There are device circuit breakers with different numbers of positions. They specify how many electrically separated current paths can be connected to a device circuit breaker.

Mounting method

Type of device circuit breaker installation option, such as construction, installation or distributor type.

Connection method

Various ways of connecting the device circuit breakers, such as insertion, plugging in or screwing in.

Type of actuation

How or in what way is a device circuit breaker activated or restored? Automatically or manually using an operating lever, which has been designed for regular or irregular switching operations.

Rated values

Various relevant current and voltage values, such as rated voltage, rated operating voltage, rated current or rated frequency.

Operating characteristic curves

Characteristic curves which describe the behavior of a device circuit breaker under specific current and voltage values.

2 Device circuit breakers – technology

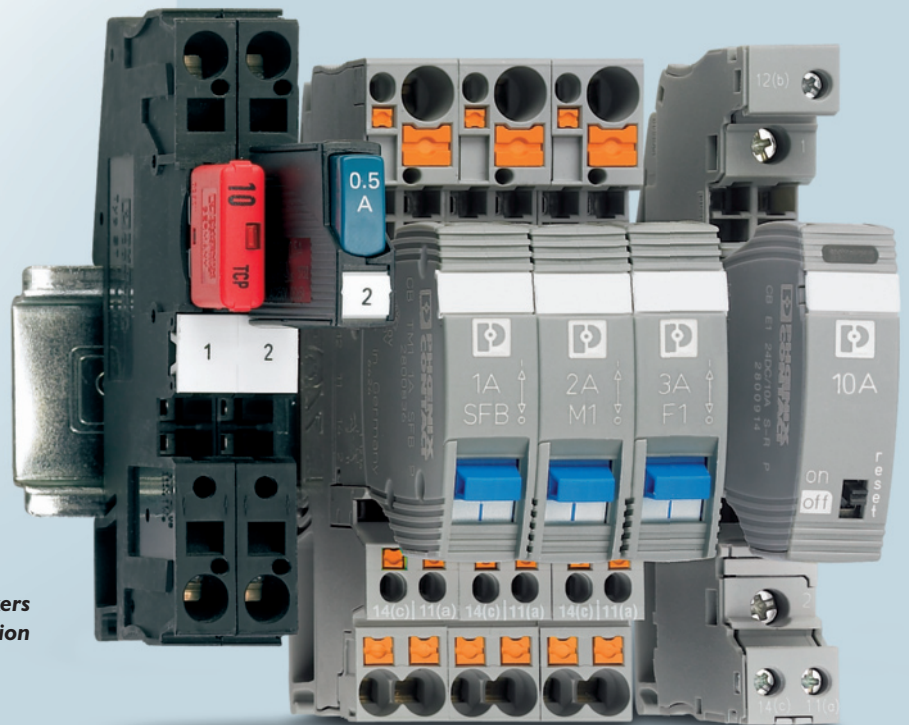
Device circuit breakers are a key factor in high system availability. In the event of overload and short circuits, they selectively shut down the faulty circuit. All other system parts remain in operation.

There are different device circuit breaker technologies. A distinction is made between electronic, thermomagnetic, and thermal device circuit breakers. The differences lie in their tripping techniques and tripping behavior. Depending on the area of application, device circuit breakers are used in a targeted manner. Characteristic curves clearly illustrate the tripping characteristics of the various device circuit breakers.

The right device circuit breaker for every residual current

Circuit breakers:	optimum protection in the event of:
<ul style="list-style-type: none">• Thermal• Thermomagnetic	<ul style="list-style-type: none">• Overload• Overload• Short circuit• Long cable paths, thanks to SFB tripping characteristic
<ul style="list-style-type: none">• Electronic	<ul style="list-style-type: none">• Overload• Short circuit• Long cable paths, thanks to active current limitation

Device circuit breakers for every application



2.1 Electronic device circuit breakers

Electronic device circuit breakers have active current limitation. As such, it is possible to almost fully allocate a DC voltage supply. Furthermore, the active current limitation enables longer cable paths between the power supply unit and the load.

These circuit breakers switch off within approx. 100 to 800 milliseconds in the event of a short circuit. This prevents the output voltage from interrupting the switched-mode power supply unit.

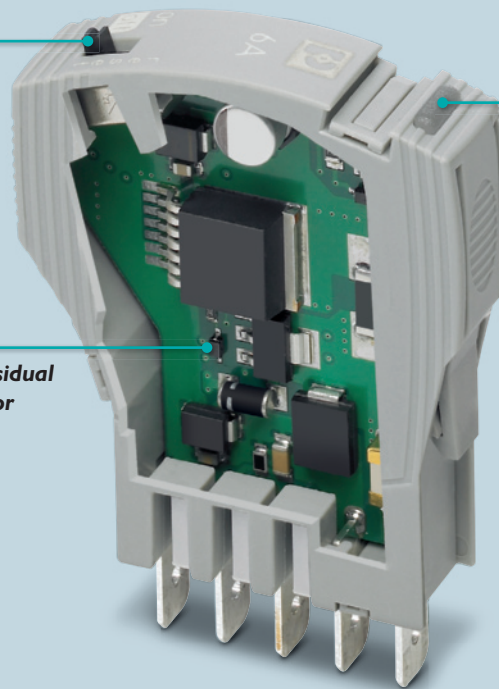
The current is continuously measured with an integrated sensor and is switched off within a matter of milliseconds in the event of an overload current or short circuit.

On/off switch
(reset)

PCB with residual
current sensor

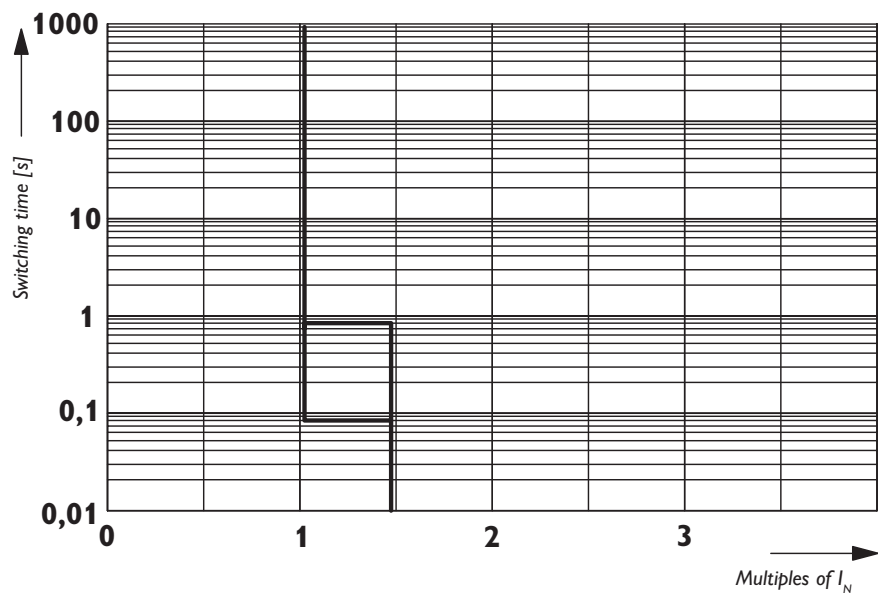
Status indicator

- Connected through
- Current limitation
- Switched off



Tripping characteristics

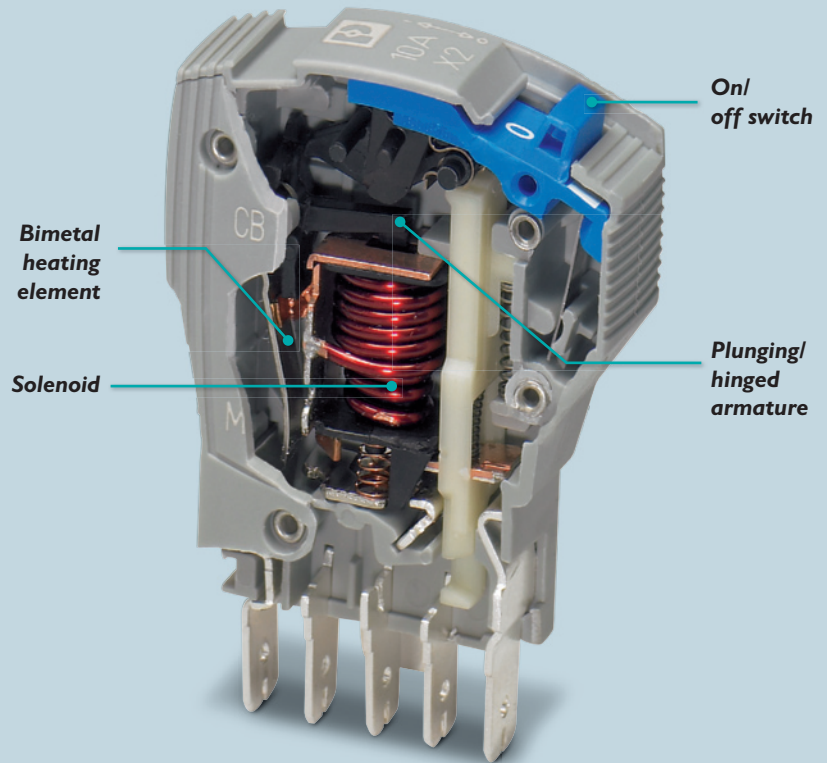
In the event of a short circuit, electronic device circuit breakers trip within a few milliseconds. Here the current is limited to 1.25 times the nominal current. Even with a high cable resistance, the circuit breakers disconnect the circuit within the shortest possible time.



CB E ...

2.2 Thermomagnetic device circuit breakers

The thermomagnetic circuit breaker is equipped with two tripping mechanisms. The thermal part of the mechanism in the form of a bimetal reacts to pending overloads with a time delay. The magnetic tripping, which occurs by means of a solenoid in a plunging or hinged armature and thereby switches off the pending current, reacts to high overload currents and short-circuit currents within milliseconds.

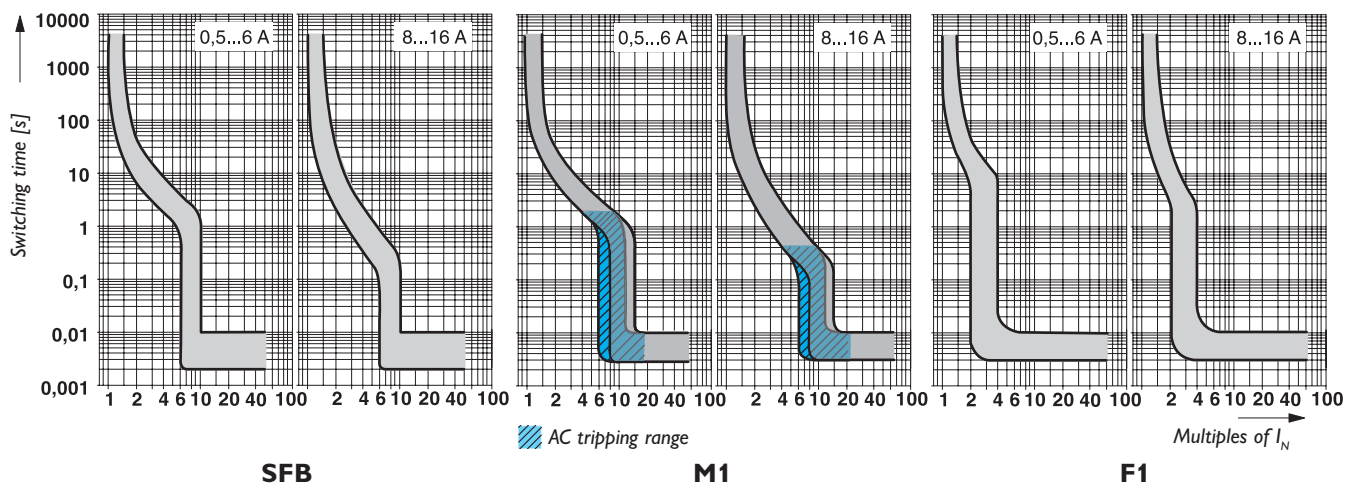


Tripping characteristics

With thermomagnetic device circuit breakers, the tripping time depends on the type of overload. In the event of an overload, the load is disconnected from the mains

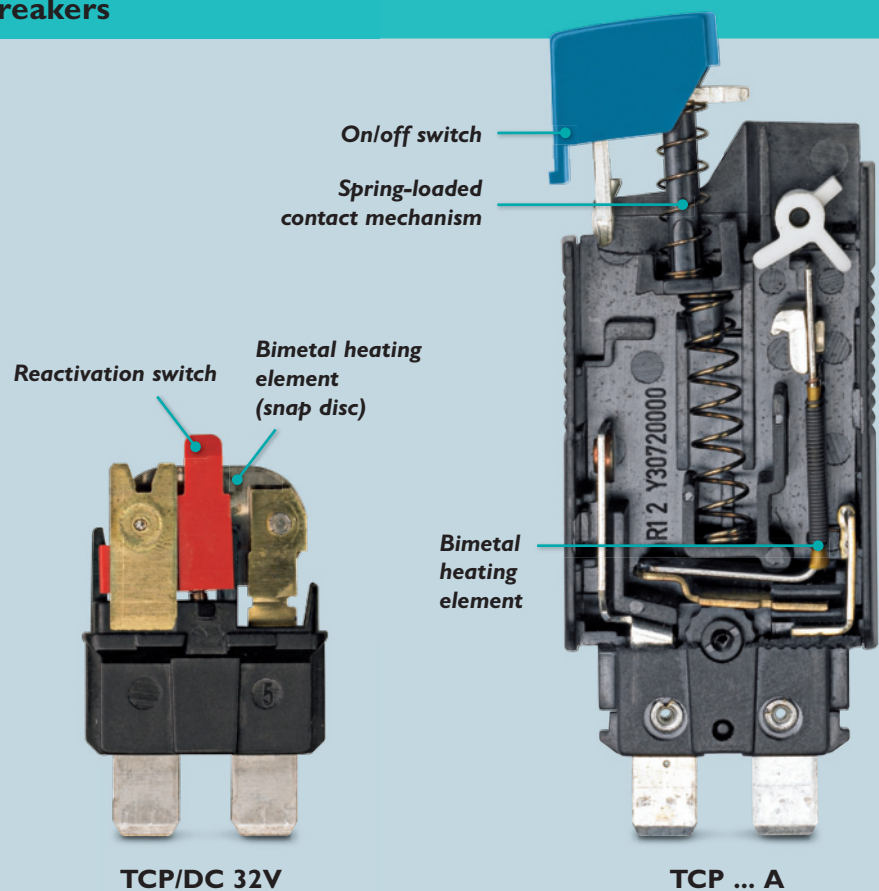
by means of time-delayed thermal tripping. If there is a high overload current or even a short circuit, the magnetic tripping interrupts the circuit in a matter of milliseconds. Protective

devices should be selected with the most suitable characteristic curve in relation to the area of application, the load, and the protection requirements.



2.3 Thermal device circuit breakers

Thermal device circuit breakers trip when current-carrying heating elements warm up. These heating elements consist of a thermal bimetal made from steel and zinc which expands and deforms in the presence of heat. This metal is either used in the form of a strip with a latch and a separate, spring-loaded contact mechanism or it is used in the form of a washer with a snap-on effect, to which a contact is fastened directly. Thanks to their construction with a snap-on washer, device circuit breakers have a somewhat more flexible characteristic curve than those made with bimetal strips. The thermal device circuit breakers can be switched on and off or on again after tripping by means of a button. They are a simple and cost-effective alternative for applications which do not necessarily require fast tripping.

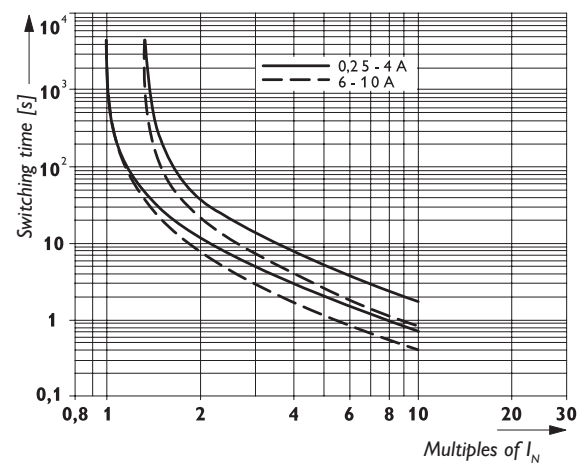
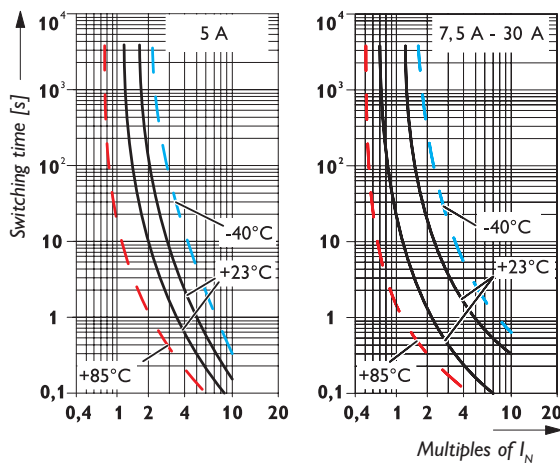


Tripping characteristics

The tripping time of the thermal device circuit breakers varies with the pending overload current. As can be seen in the characteristic curves, the circuit breaker trips more quickly as

the overload increases. The protective function provided by a bimetal reacts at a defined tripping temperature. With a relatively low overload current it therefore takes longer for the connected

load to be disconnected from the mains.



2.4 Influence of cable lengths on shutdown behavior

The maximum cable lengths that can be used between a power supply unit and a termination device are defined by various criteria:

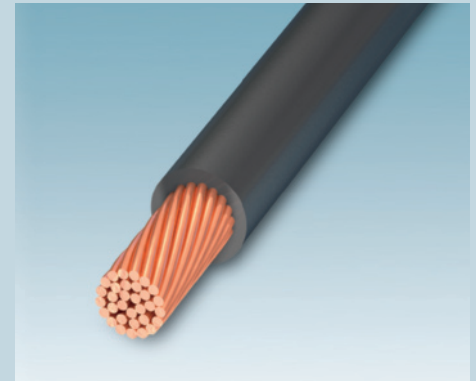
- The power supply's maximum current
- Internal resistance of the circuit breaker
- Resistance of the cable

The longer a cable is and the smaller its cross section, the higher the cable resistance. For this reason, the shortest cable path should be selected during installation.

Cable resistance counteracts a short-circuit current. In the case of low voltage sources, a short-circuit current can be limited by the cable resistance in such a way that safety equipment at the end of the cable no longer recognizes this current as a short-circuit current. In the case of circuit breakers with C characteristics, the upper tripping limit is significantly higher than the nominal



The tripping resistance of a device circuit breaker is influenced by the length and cross section of a cable.



current. For this reason, a delayed switch-off is highly likely in the event of a short circuit when using this safety equipment.

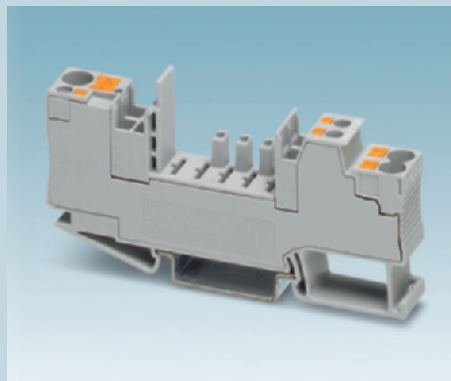
The tripping characteristics of the circuit breaker with SFB characteristics as well as the electronic circuit breaker with active current limitation are optimized. These protective devices detect that

the nominal current has been exceeded significantly faster than a short-circuit current. This prevents a dangerous overload of the affected equipment and at the same time functions as preventive fire protection.

2.5 Connection technologies

Connecting conductors to the base element of the device circuit breaker with push-in technology is easy and user friendly. Simply insert a conductor (either solid or fitted with a ferrule) into the conductor shaft, push it in gently, and the contact spring opens automatically. The spring-cage ensures that the necessary pressure is exerted against the current bar. Conductors from 0.12 mm² to 6 mm² can easily be connected using push-in technology. Alternatively, a base element can be used for device circuit breakers with screw connection technology.

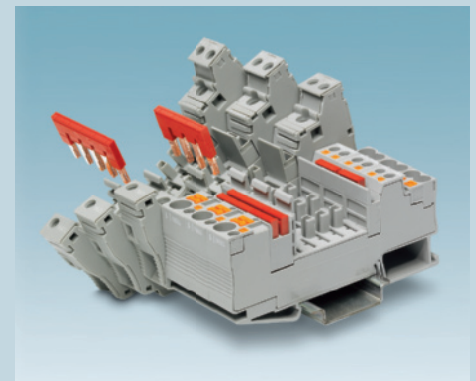
With the help of plug-in bridges, fast and individual potential distribution can be implemented in a series installation of device circuit breakers. By means of double bridging, the supply can be subjected to 41 A.



Base element

Optionally with push-in connection or screw connection technology

Even telecommunications connections can be easily connected to one another in this way.



Plug-in bridges

For potential distribution in the case of series installation

2.6 Power supply unit

By the planning stage, the requirements for a power supply unit in terms of capacity for future extensions have normally already been defined. This is because the demands placed on a power supply unit are constantly on the rise. The size of 24 V DC power supply units in industrial applications is important, so as to enable space-saving installation. Simultaneously, they must offer increasingly high levels of performance as well as matching the power requirement of the termination devices to be connected. Furthermore, no more than 80% of the nominal current should be planned for.

This ensures that, in the event of an error, a short-circuit current can be supplied which trips the circuit breaker. If the selected power supply unit is too small or the connection value is too high, then the necessary current cannot be supplied. This results in an undervoltage, causing entire system components to fail and the manufacturing process to be interrupted.

Some power supply units feature Selective Fuse Breaking Technology, or SFB. These power supply units are able to supply 6 times the nominal current for a few milliseconds, thereby ensuring safe tripping of the device circuit breakers. Together with thermomagnetic device circuit breakers, they form a reliable unit which guarantees maximum system availability.



A power supply unit with SFB technology guarantees fast and safe tripping of device circuit breakers in the event of an error

3

Using device circuit breakers

Device circuit breakers are used in production systems and assembly machines in order to selectively protect the most varied of loads from overload and short circuit.

In order to fully protect a system from overcurrents, it must be clear which parts of a system should be protected with which circuit breaker. Not every circuit breaker is suited to all applications. In order to select the right device circuit breaker for an application, the nominal current and, where applicable, the starting current of the load must be taken into account.

Examples of use

Thermomagnetic circuit breakers

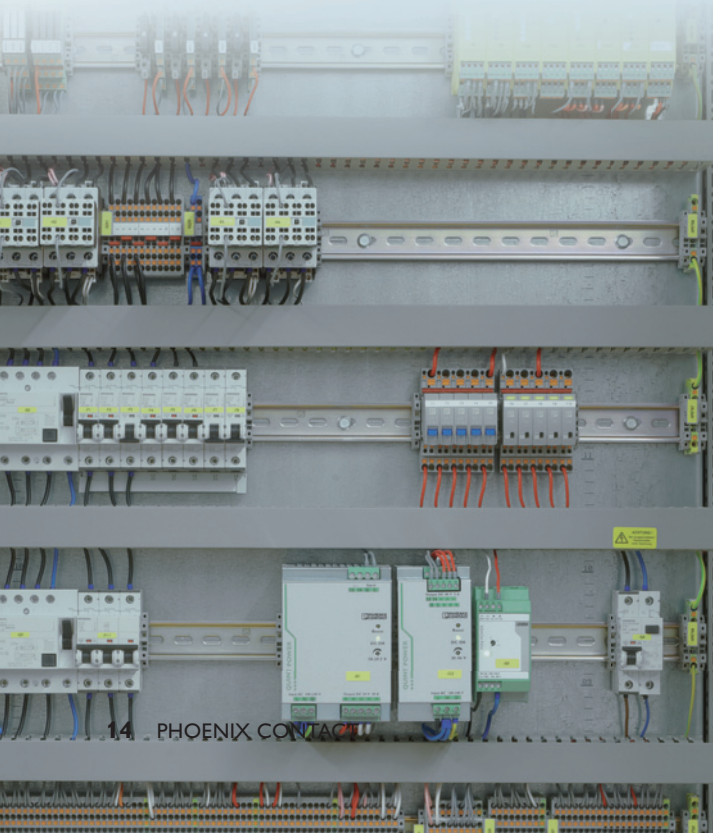
- Programmable controllers
- Valves
- Motors
- Frequency inverters

Electronic circuit breakers

- Relays
- Programmable controllers
- Motors

Thermal circuit breakers

- Motors
- Heating elements
- Fans
- Devices with high starting current



3.1 Main target sectors

Thermomagnetic device circuit breakers are used in information and communication technology as well as in process technology.

Thanks to the various tripping characteristics, the circuit breakers can be used in a wide range of applications. The reclosing and the immediate remote signaling of the operating state ensure high availability.

Electronic device circuit breakers are not only used in communication technology, but are also frequently used in automation technology. Thanks to the active current limitation, the output voltage on the switched-mode power supply unit remains in place and all other circuits continue to operate.

Thermal device circuit breakers provide optimum protection for inductive loads against overload in power distribution systems, in control cabinet engineering, and systems manufacturing.

In addition, they are also resistant to high starting currents, such as those which occur when starting a motor or transformer.

The main areas of application for device circuit breakers:



Gas and oil industry



Automotive industry



Process technology



Machine building



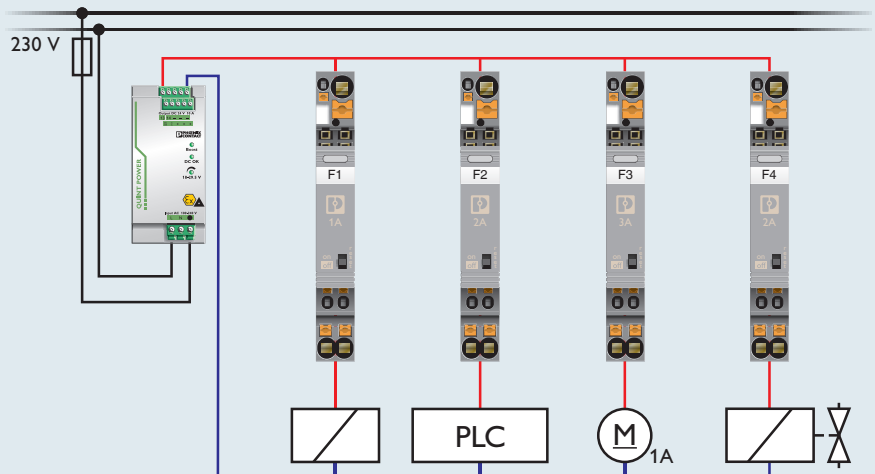
Railway technology



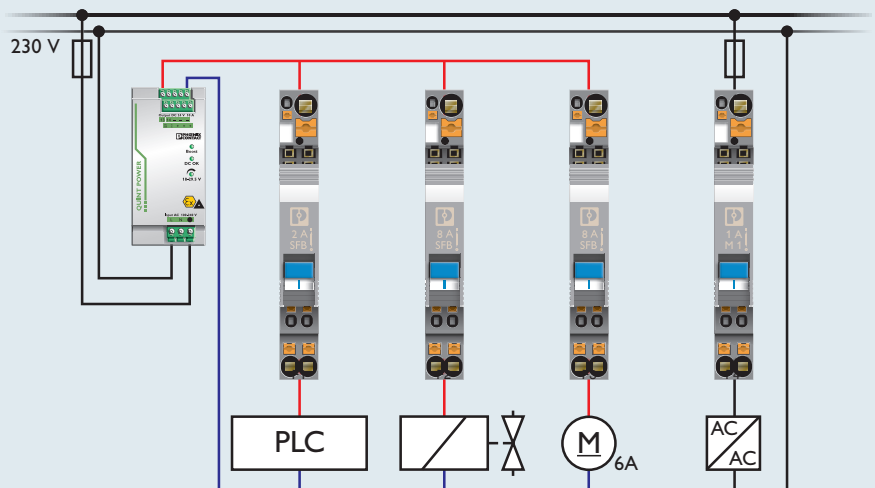
Telecommunications technology

3.2 Applications

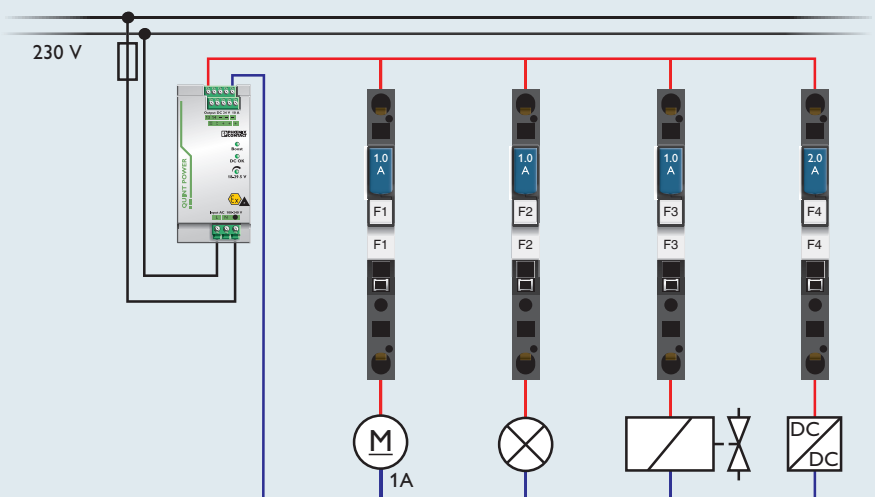
Electronic device circuit breakers are ideal for protecting relays, programmable controllers, motors, sensors/actuators, and valves, for example.



Thermomagnetic device circuit breakers are ideal for protecting programmable controllers, valves, motors, and frequency inverters, for example.



Thermal device circuit breakers are ideal for protecting motors, lighting, solenoid valves, transformers, and onboard networks, for example.



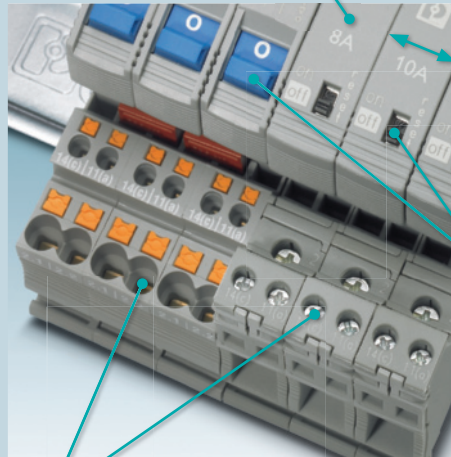
3.3 Key features

All device circuit breakers have a compact design with precise nominal current levels. Thermo-magnetic and electronic device circuit breakers have a sophisticated remote signaling concept, which enables remote function monitoring.

Long cable paths can be created, thanks to the SFB technology of the thermomagnetic and the active current limitation of the electronic device circuit breakers.

Furthermore, they are easy to reclose after tripping. As such, the circuit can be immediately brought back into operation. Due to their modularity and plug-in capability, device circuit breakers can be installed flexibly. Even in the event of an error, they can be replaced quickly.

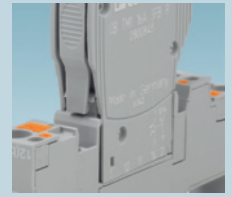
Nominal current levels
from 0.5 – 16 A



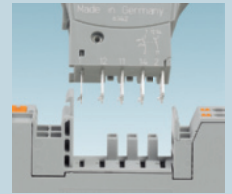
Compact
design

On/off switch

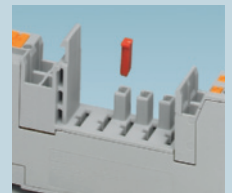
Variable connection technology,
push-in and screw



Plug locking



Two-piece/plug-in



Coding between
plug and base element

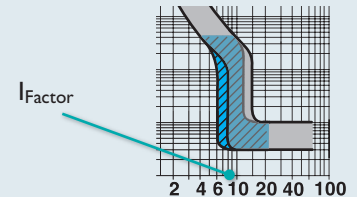
3.4 Cable calculations

Some information is needed in order to calculate cable lengths. This basic data includes the output voltage of the power supply unit (U), the rated current of the GS switch (I_{CB}) and the conductor cross section of the cable to be used. The characteristic curves of the respective GS switch types serve as a basis for calculation.

Cable calculation

1. Calculation of the maximum resistance:

$$R_{\max} = \frac{U}{I_{CB} \times I_{\text{Factor}}} = \frac{24 \text{ V}}{1 \text{ A} \times 15} = 1.6 \, \Omega$$



2. Calculation of the maximum cable resistance:

$$\begin{aligned} R_{\text{Cable max}} &= R_{\max} - R_{CB1A} \\ &= 1.6 \, \Omega - 1.1 \, \Omega \\ &= 0.5 \, \Omega \end{aligned}$$

CB	Internal resistance
CB 1A	1.1 Ω
CB 2A	0.32 Ω
CB 3A	0.14 Ω

3. Now all the necessary information is available in order to calculate the maximum cable lengths using the following formula:

$$L = \frac{R \times A}{\rho} \quad L = \frac{0.5 \times 1.5}{0.01786} \quad L = 42 \text{ m (forward and return line)}$$

ρ = specific resistance (copper 0.01786)

A = cross section/conductor

3.5 Device circuit breaker board

The multi-channel device circuit breaker boards are used in standard production machines or in control and process technology, for example.

The central potential distribution reduces installation time to a minimum. Thanks to the individual assembly with thermomagnetic circuit breakers, the boards are extremely versatile.

They offer connection options for up to five loads per protective path. As such, the boards combine the advantages of the CB TM1... device circuit breaker series with easy and space-saving potential distribution.

Group remote signaling is evaluated, for example, using a programmable controller.

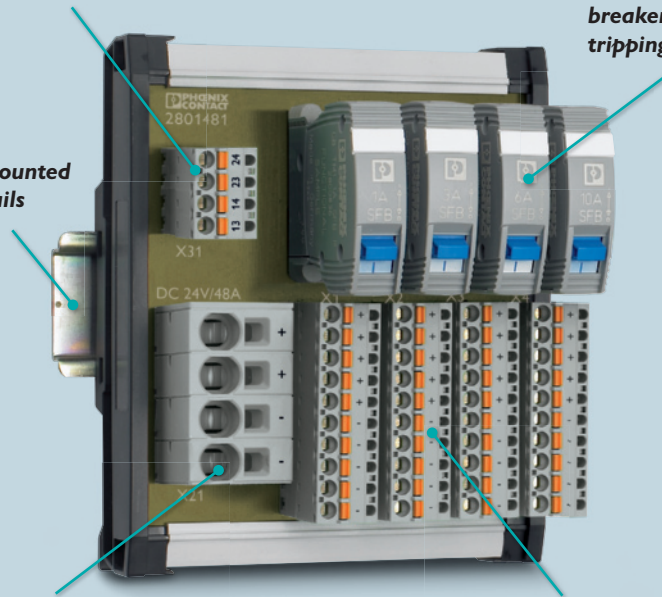
Contacts for group remote signaling

Slots for device circuit breakers with different tripping characteristics

Can be mounted on DIN rails

Current supply

Connection terminal blocks for up to five loads

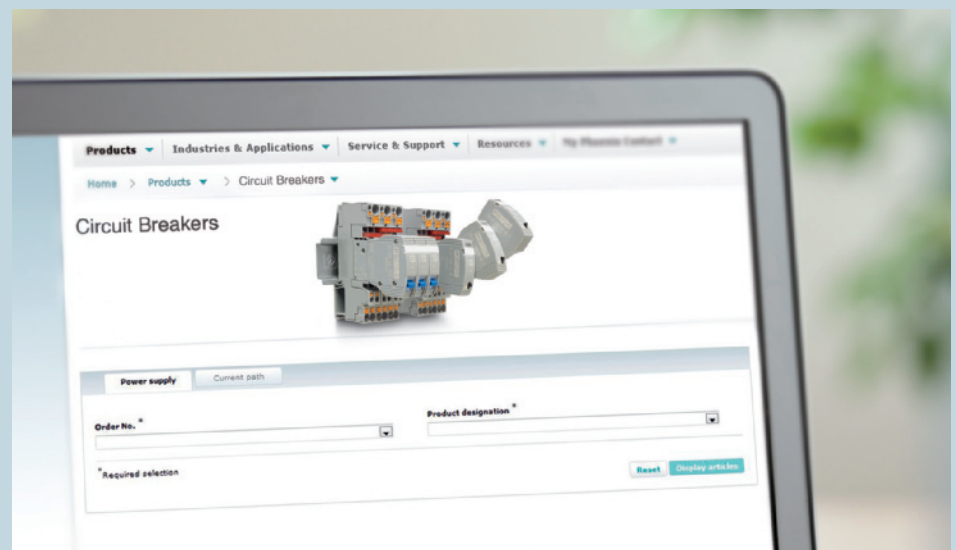


3.6 Configurator

Selecting the right product for the desired application can be difficult when there are many products to choose from.

However, this is easy to master with the help of a configurator.

Simply select the power supply unit which is to be used in the application and specify the number of current paths. Then quickly input a few items of relevant data such as the nominal current and cable lengths, and the matching device circuit breakers will be displayed.



Easy to find

The configurator helps to select a suitable device circuit breaker

The configurator can be found at:
www.phoenixcontact.com > Products > Configurators > Device circuit breakers

3.7 Configuration matrix for CB device circuit breakers

The configuration matrix can help with the secondary-side planning of your power supply unit. It describes the maximum cable lengths depending on:

- The device circuit breaker
- The conductor cross section
- The performance class of the power supply unit

Cable lengths

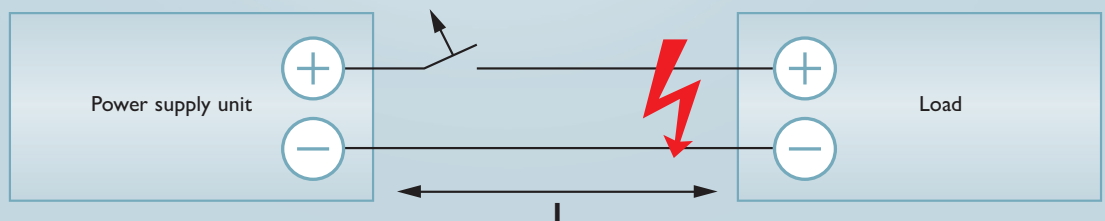
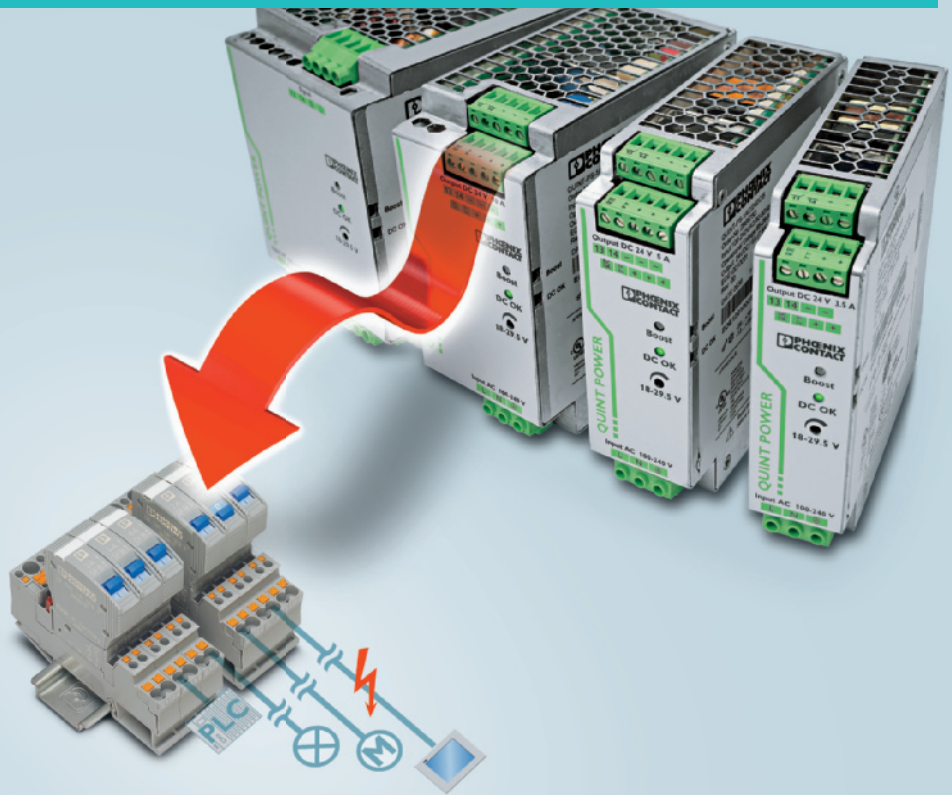
The values specified relate to the distance (l) from the power supply unit to the load.

Boundary parameters for the calculation:

- CB TM1 x A SFB P device circuit breaker
- Electromagnetic tripping at the latest at:
 - 10 times the rated current
 - Ambient temperature: +20°C

The internal resistance of the device circuit breakers is taken into account.

In addition to the short-circuit current, the respective power supply unit also supplies half the nominal current for paths connected in parallel.



[Conductor cross section] mm²	0.75	1	1.5	2.5	4
	Distance in m				
24 V/5 A					
CB TM1 1A SFB P	27	36	54	91	
CB TM1 2A SFB P	10	13	20	34	
24 V/10 A					
CB TM1 1A SFB P	27	36	54	91	
CB TM1 2A SFB P	18	25	37	63	
CB TM1 3A SFB P	11	15	22	38	
CB TM1 4A SFB P	6	8	13	22	
CB TM1 5A SFB P	4	5	8	14	

Extract from the configuration matrix. The complete matrix can be found at:
www.phoenixcontact.com > Products > Protective devices > Device circuit breakers



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