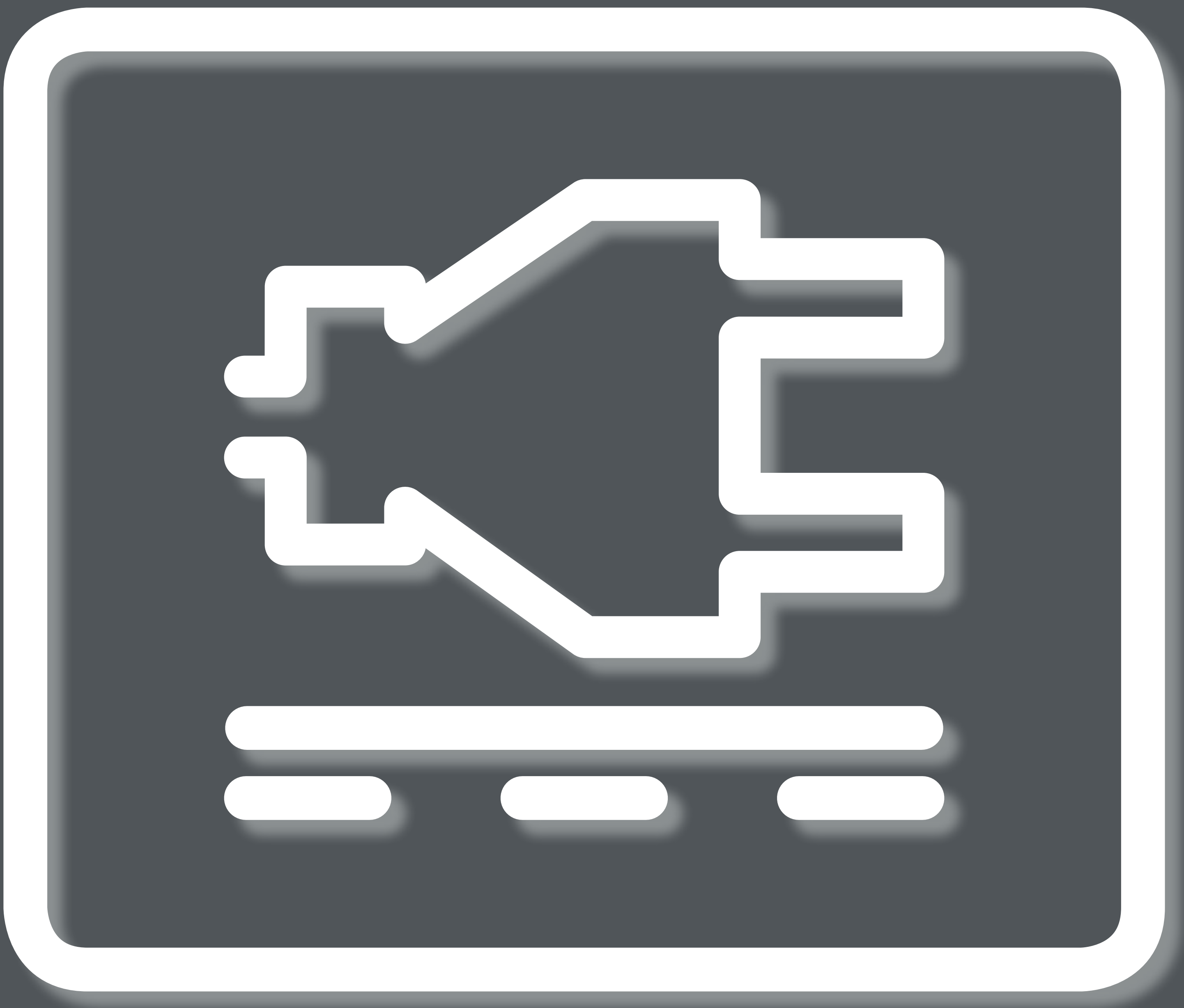
Circuit breakers for direct current applications

Complementary technical information



Schneider Electric

Circuit breakers for direct current applications

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24 V - 48 V direct current applications

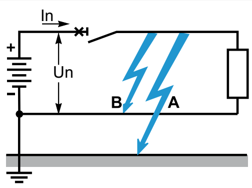
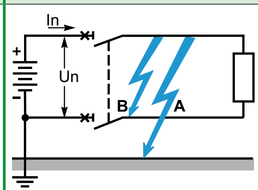
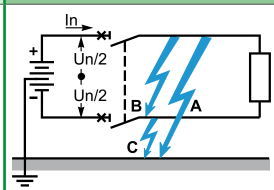
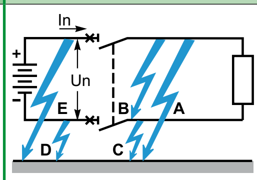
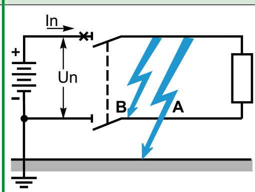
Typical applications

Direct current has been used for a long time, and in many fields. It offers major advantages, in particular immunity to electrical interference. Moreover, direct-current installations are now simpler, because they benefit from the development of power supplies with electronic converters and batteries.

- ■ Communication or measurement network:
- □ 48 V DC switched telephone network,
- □ 4-20 mA current loop.
- ■ Electrical supply for industrial PLCs:
- □ PLCs and peripheral devices (24 or 48 V DC).
- ■ Auxiliary uninterruptible direct current power supply:
- □ relays or electronic protection units for MV cubicles,
- □ switchgear opening / closing trip units,
- □ LV control and monitoring relays,
- □ indicator lights,
- □ circuit-breaker or on/off switch motor drives,
- □ power contactor coils,
- □ control/monitoring and supervision devices with communication that can be powered via a separate uninterruptible power supply.
- ■ 24 to 48 V DC wind application:
- □ isolated homes,
- □ cottages, bungalows, mountain refuges,
- □ pumps, street lighting,
- □ measuring instruments, data acquisition,
- □ telecommunication relays,
- □ industrial applications.

Types of direct current networks

According to the types of DC networks illustrated below, we can identify the risks to the installation and define the best means of protection.

Earthed			Isolated from earth
I: Earthed (or grounded) polarity (in this case negative)		II: Earthed mid-point	III: Isolated polarities
1 pole (1P isolation)	2 poles (2P isolation)	2 poles	2 poles
DB124075 	DB124067 	DB124076 	DB124068 
	2 poles (1P isolation 1P+N)		
	DB124387 		
Worst-case faults			
Fault A and fault B (if only one polarity is protected)		**Fault B**	**Double fault A and D or C and E**

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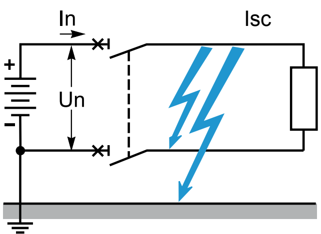


For further information on the types of networks and the faults that characterise them, refer to the direct current circuit breaker (LV) selection guide, 220E2100.indd.

For all these configurations, we propose a single protection solution that depends only on the requirement for the nominal current In and the short-circuit current Isc at the installation point concerned.

The second important point in our solution is the fact that the protection is implemented by non-polarised circuit breakers that can operate efficiently, whatever the direction of the direct current.

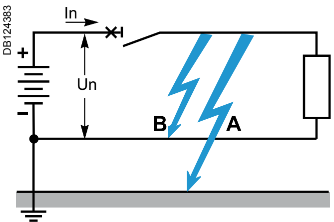
Circuit breakers for direct current applications (cont.)

24 V - 48 V direct current applications

24 - 48 V direct current protection solution

The performance levels shown in the tables below correspond to the most critical faults according to the network configuration.

- Breaking on one pole.
- Fault between polarity and earth (Fault A).



Standard solution depending on the network and the requirements of the installation (In / Isc)

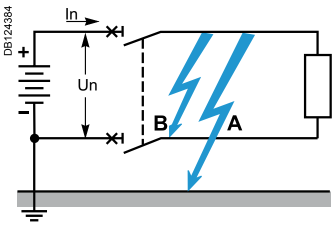
In addition to the parameters shown on the following pages, the tables below illustrate our range of circuit breakers according to the nominal current of the load and short-circuit current at the point of installation.

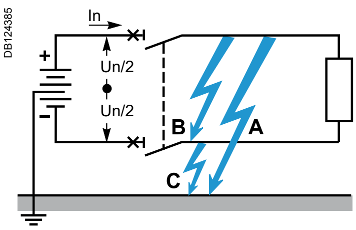
- Circuit breaker rating.
- Breaking capacity of the circuit breaker.

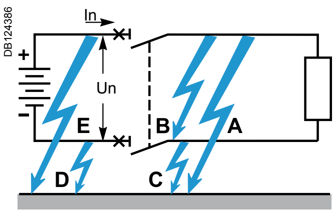
1 pole isolation solution (1P)

Circuit breakers for direct current applications (cont.)

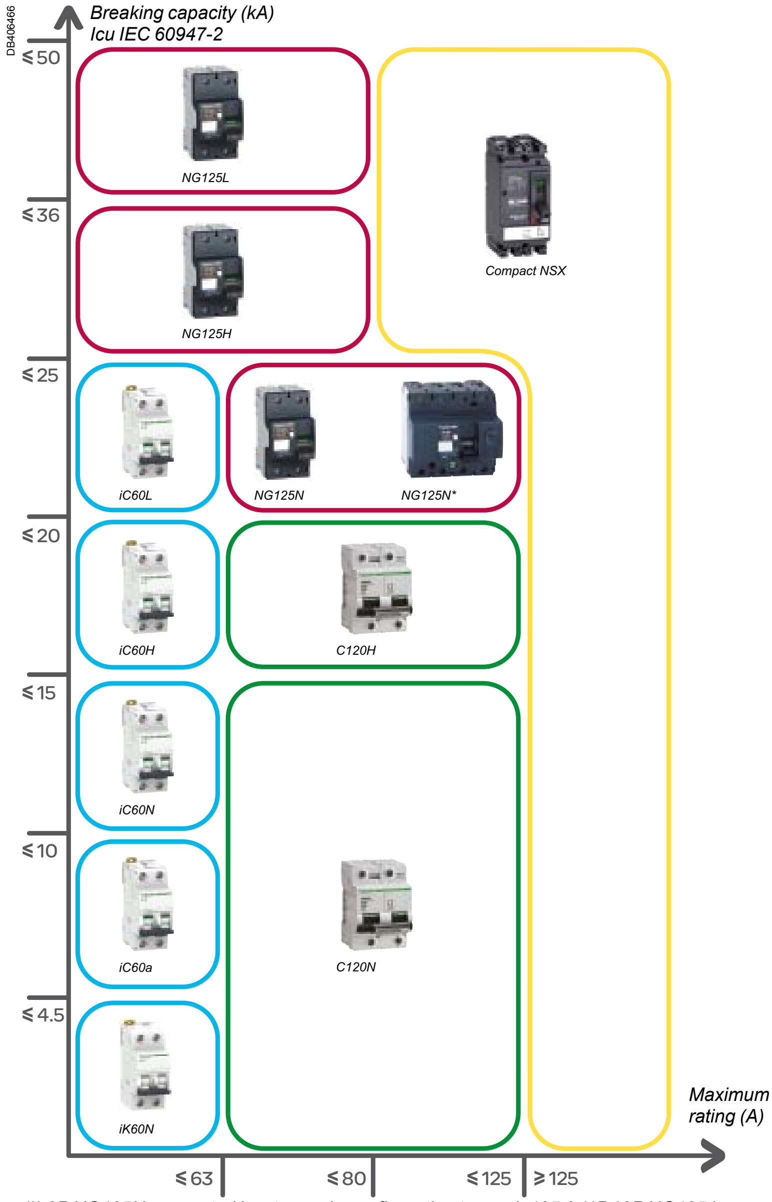
24 V - 48 V direct current applications







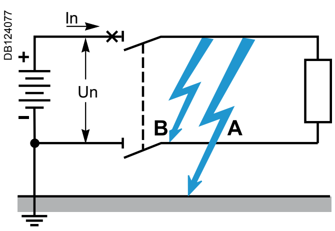
2 pôles isolation solution (2P)

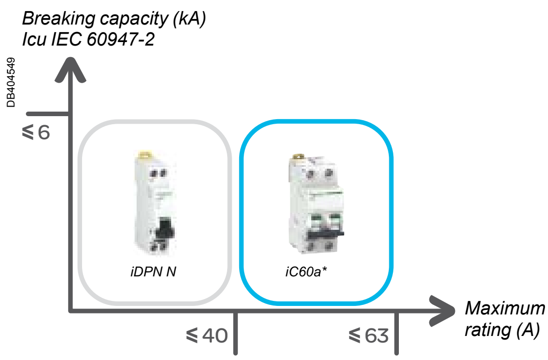


(*) 3P NG125N connected in a two-pole configuration to reach 125 A (1P / 2P NG125 has a maximum rating of 80 A).

1 pole isolation solution (1P+N)

Specific use of the iDPN range in a network with one polarity earthed and both poles isolated: compact solution (1P+N in 18 mm).





(*) iC60a breaking capacity Icu = 10 kA.

Circuit breakers for direct current applications (cont.)

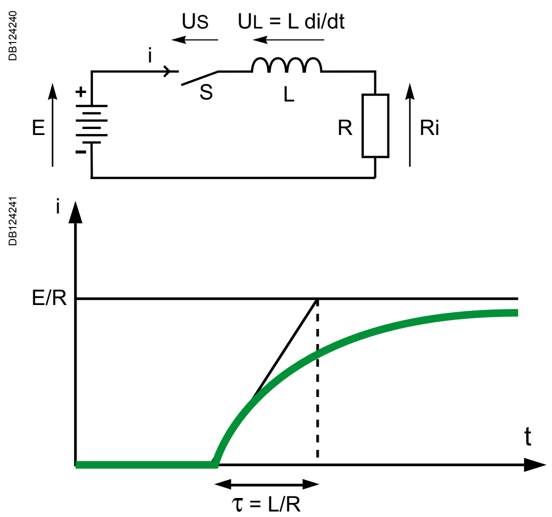
24 V - 48 V direct current applications

Constraints related to "direct current" applications

In direct current, inductors and capacitors do not disturb the operation of the installation in steady state. Capacitors are charged and inductors no longer oppose changes in the current.
However, they create transient phenomena when the circuit opens or closes, during which time the current varies. Actual loads have both characteristics and generate oscillatory phenomena.

Type of load

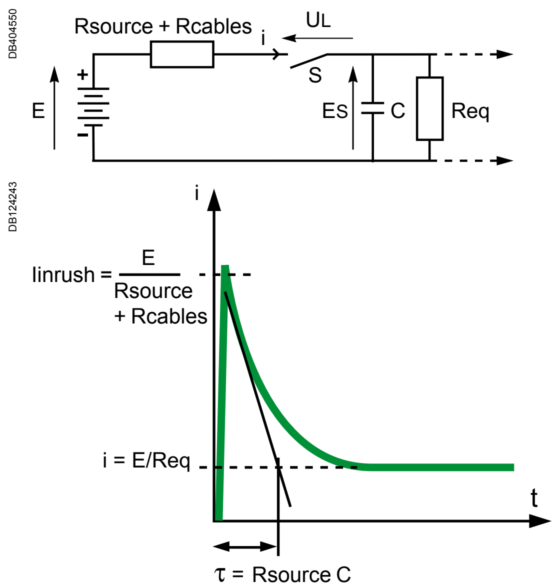
Inductive load



Inductive load

An inductive load will tend to lengthen the current interrupt or establishment time, because the inductance **L** then opposes the change in the current (**Ldi/dt**).
The transient phenomenon will mainly be characterised by a time constant imposed by the load and whose value corresponds approximately to the interrupt or closing time that the switchgear has to withstand. In addition, during the interrupt time, the switchgear must be able to withstand the additional energy stored in the inductor in steady state.
An inductive load therefore requires particular attention with respect to its time constant.
A low value (typically < 5 ms) facilitates interruption.

Capacitive load



Capacitive load

During a closing operation, a capacitive load will cause an inrush current due to the load on the capacitor, virtually under short-circuit condition at the beginning of the phenomenon.
On opening, it will tend to discharge. The time constant is generally very low (< 1 ms) and its effect is secondary with respect to the inrush current. A capacitive load will require particular attention to the inrush or discharge current surges.

Circuit breakers for direct current applications (cont.)

24 V - 48 V direct current applications

Time constant L/R

When a short-circuit occurs across the terminals of a direct current circuit, the current increases from the operating current (< In) to the short-circuit current Isc during a time depending on the resistance **R** and the inductance **L** of the short-circuited loop.

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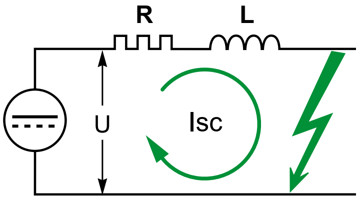

The equation that governs the current in this loop is: **$U = Ri + L di/dt$**.

A short-circuit current is established (neglecting In with respect to Isc) by the equation:
$i = Isc (1 - \exp(-t/\tau))$,
where **$\tau = L/R$** is the time constant used to establish the short-circuit.

In practice, after a time **$t = 3\tau$** the short-circuit is considered to be established, because the value of exp(-3) = 0.05 is negligible compared to 1.
The lower the corresponding time constant (e.g. battery circuit), the faster a short-circuit is established.

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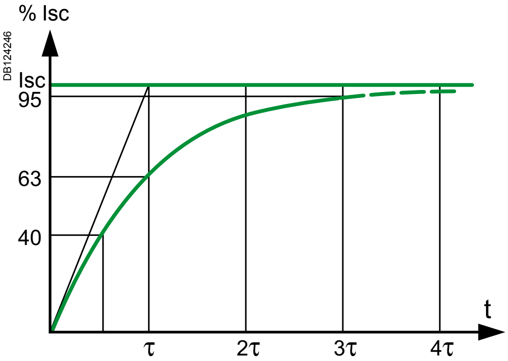


L/R	Description	DC applications
2 ms	Very fast short-circuit	■ Photovoltaic applications
5 ms	Fast short-circuit established	■ Resistive or slightly inductive circuits: □ indicator light □ trip units (MN, MX) □ motor armatures □ battery charger/uninterruptible power supply (UPS) ■ Capacitive circuits: electronic controller
15 ms	Standardised value used in standard IEC 60947-2	■ Inductive circuits: □ electromagnetic coil □ contactor coil □ motor inductor
30 ms	Slower short-circuit established	■ Highly inductive circuits: □ electromagnetic coil □ contactor coil □ motor inductor

In general, the system time constant is calculated under worst case conditions, across the terminals of the generator.

Circuit breakers for direct current applications (cont.)

24 V - 48 V direct current applications

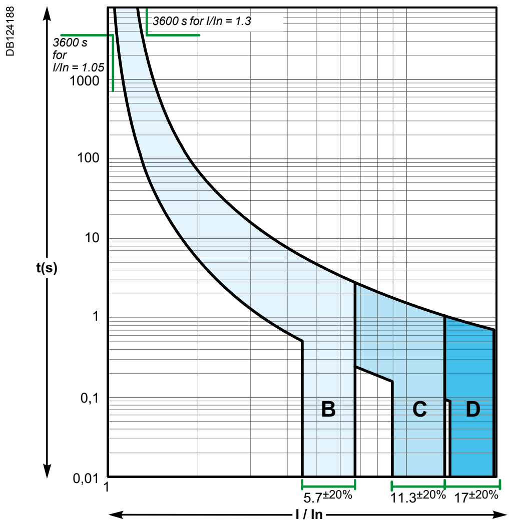
Tripping curves

We can choose our solution according to the inrush currents generated by our loads, in the same way as for alternating current. In direct current, the same thermal tripping curves are obtained as in alternating current. The only difference is that the magnetic thresholds are offset by a coefficient $\sqrt{2}$ compared to the curves obtained in alternating current.

Characteristics of the various curves and their applications:

Curves	Magnetic thresholds		DC applications
	AC	DC	
Z	2.4 to 3.6 In	3.4 to 5 In	■ Resistive loads ■ Loads with electronic circuits
B	3.2 to 4.8 In	4.5 to 6.8 In	■ Motor inductor: starting current 2 to 4 In ■ Battery charger/Uninterruptible power supply (UPS)
C	6.4 to 9.6 In	9.05 to 13.6 In	■ Electronic controller
D et K	9.6 to 14.4 In	13.6 to 20.4 In	■ Electromagnetic coil: inrush overvoltage 10 to 20 Un ■ LV relay ■ Trip units (MN, MX) ■ Indicator light ■ PLCs (industrial programmable logic controllers)

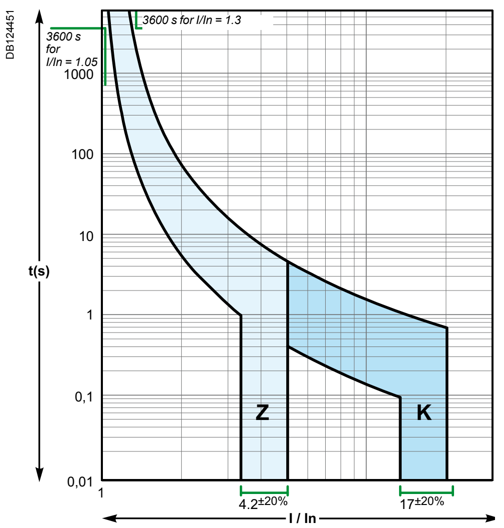
The figures opposite are iC60 tripping curves showing DC magnetic thresholds and normative limits



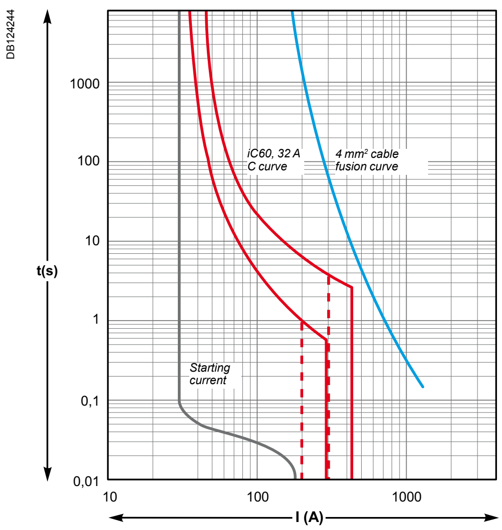
Curves B, C, D, ratings 6 A to 63 A

Example

Protection of the 4 mm² cable supplying a load at In = 30 A with a 32 A rating and a tripping curve that allows the starting current for this load to be absorbed.



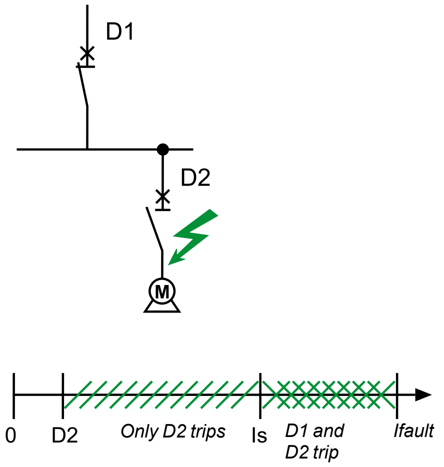
Curves Z, K, ratings 6 A to 63 A

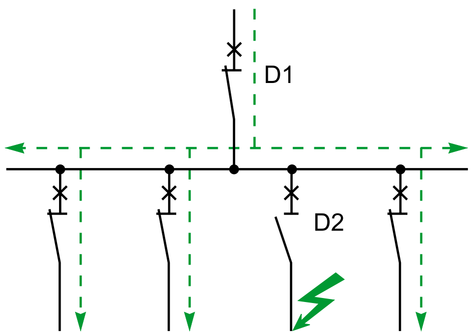


Curve C, rating 32 A (AC magnetic thresholds in dotted lines)

Circuit breakers for direct current applications (cont.)

24 V - 48 V direct current applications





Continuity of service of the solutions

Discrimination of the direct current protection devices

Discrimination is a key element that must be taken into account right from the design stage of a low-voltage installation to allow continuity of service of the electrical power.

Discrimination involves coordination between two circuit breakers connected in series, so that in the event of a fault, only the circuit breaker positioned immediately upstream of the fault trips. A discrimination current Is is defined as:

- I fault < Is: only D2 removes the fault, discrimination ensured,
- I fault > Is: both circuit breakers may trip, discrimination not ensured.

Discrimination may be partial or total, up to the breaking capacity of the downstream circuit breaker. To ensure total discrimination, the characteristics of the upstream device must be higher than those of the downstream one.

The same principles apply to designing both direct current and alternating current installations. Only the limit currents change when direct current is used.

Once again, we find the same concepts of discrimination:

- **total**: up to the breaking capacity of the downstream device. Our tests have been performed at up to 25 kA or 50 kA depending on the breaking capacity of the devices in question.
- **partial**: indication of the discrimination limit current **Is**. Discrimination is ensured below this value; above this value, the upstream device participates in the breaking process,
- **none**: no discrimination ensured, the upstream and downstream circuit breakers will trip.

For further information about the discrimination concept for protection devices in general, refer to technical supplement 557E4300, "Discrimination of modular circuit breakers".

Total discrimination solutions

In the following tables, we offer you solutions that favour continuity of service (total discrimination between circuit breakers), for different short-circuit currents.

Total discrimination: 10 kA

		Upstream Curve C Time constant (L/R) = 15 ms								
		iC60a					C120N			NSX
	In (A)	10 - 16	20 - 25	32	40	50 - 63	80	100	125	≥ 100
Downstream										
iC60a	≤ 3	T	T	T	T	T	T	T	T	T
Curves B,C	4		T	T	T	T	T	T	T	T
	6			T	T	T	T	T	T	T
	10					T	T	T	T	T
	13					T	T	T	T	T
	16 to 25						T	T	T	T
	32						T	T	T	T
	40							T	T	T
	50 - 63								T	T

T — *Total discrimination.*

(blank) — *No discrimination.*

Circuit breakers for direct current applications (cont.)

24 V - 48 V direct current applications

Total discrimination: 15 kA

		Upstream	Curve C		Time constant (L/R) = 15 ms					
		iC60N					C120N			NSX
	In (A)	10 - 16	20 - 25	32	40	50 - 63	80	100	125	≥ 100
Downstream										
iC60N	≤ 3	T	T	T	T	T	T	T	T	T
Curves B,C	4		T	T	T	T	T	T	T	T
	6				T	T	T	T	T	T
	10					T	T	T	T	T
	13						T	T	T	T
	16 to 25						T	T	T	T
	32							T	T	T
	40							T	T	T
	50 - 63								T	T

Total discrimination: 20 kA

		Upstream	Curve C		Time constant (L/R) = 15 ms					
		iC60H					C120H			NSX
	In (A)	10 - 16	20 - 25	32	40	50 - 63	80	100	125	≥ 100
Downstream										
iC60H	≤ 3	T	T	T	T	T	T	T	T	T
Curves B,C	4		T	T	T	T	T	T	T	T
	6				T	T	T	T	T	T
	10						T	T	T	T
	13						T	T	T	T
	16 to 25						T	T	T	T
	32							T	T	T
	40								T	T
	50 - 63								T	T

Total discrimination: 25 kA

		Upstream	Curve C		Time constant (L/R) = 15 ms					
		iC60L					NG125N			NSX
	In (A)	10 - 16	20 - 25	32	40	50 - 63	80	100	125	≥ 100
Downstream										
iC60L	≤ 3	T	T	T	T	T	T	T	T	T
Curves B,C	4		T	T	T	T	T	T	T	T
	6				T	T	T	T	T	T
	10						T	T	T	T
	13						T	T	T	T
	16 to 25						T	T	T	T
	32								T	T
	40								T	T
	50 - 63									T

Total discrimination: 36 kA

		Upstream Curve C	Time constant (L/R) = 15 ms
		NG125H	NSX
	In (A)	80	≥ 100
Downstream			
NG125H	10	T	T
Curves B,C	16 to 63		T

Total discrimination: 50 kA

		Upstream Curve C	Time constant (L/R) = 15 ms
		NG125L	NSX
	In (A)	80	≥ 100
Downstream			
NG125L	10	T	T
Curves B,C	16 to 63		T

T — *Total discrimination.*

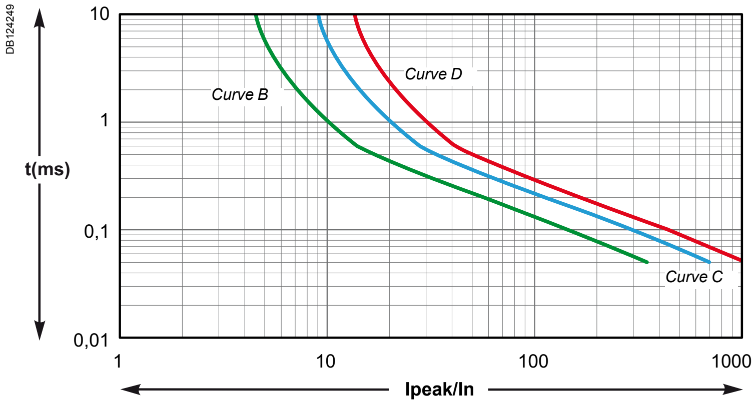
(blank) — *No discrimination.*

Circuit breakers for direct current applications (cont.)
24 V - 48 V direct current applications

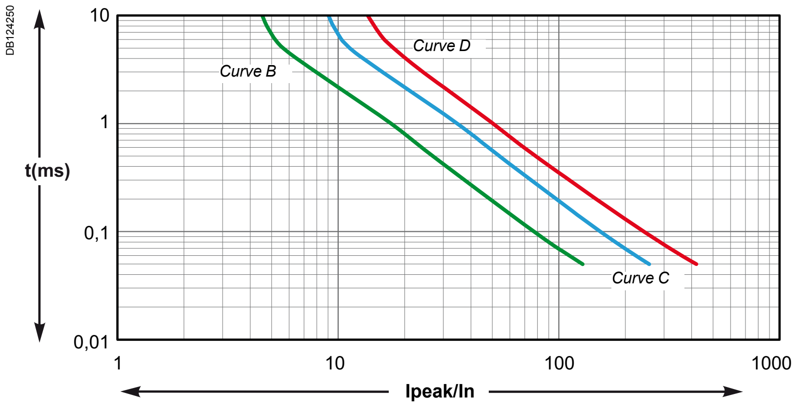
Coordination with loads
As seen above, the circuit-breaker characteristics chosen depend on the type of load downstream of the installation.
The rating depends on the size of the cables to be protected and the curves depend on the load inrush current.

Product selection according to the load inrush current
When certain "capacitive" loads are switched on, very high inrush currents appear during the first milliseconds of operation. The following graphs show the average DC non-tripping curves of our products for this time range (50 µs to 10 ms).

iC60

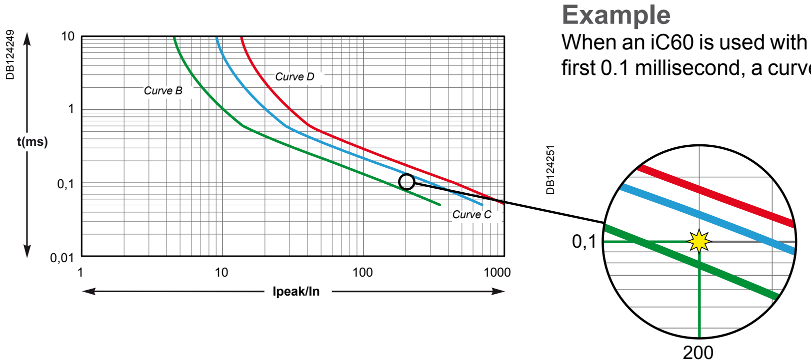


NG125 / C120



This information allows us to select the most appropriate product, according to the load specifications: curve and rating.

Example
When an iC60 is used with a load with current peaks in the order of 200 In during the first 0.1 millisecond, a curve C or D product must be installed.



Circuit breakers for direct current applications (cont.)

24 V - 48 V direct current applications

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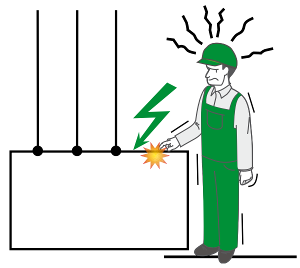

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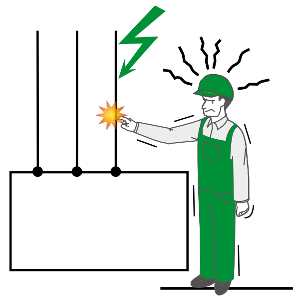

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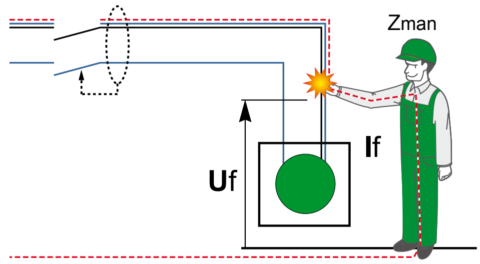


Standards: IEC 60479-2, NF C 15100, IEC 60755.

Personal protection

Personal protection (earth-leakage protection) is not mandatory for this voltage range (24-48 V DC).
In fact, according to the standards currently in force, the minimum ventricular fibrillation current **If** for human beings is in the order of 25 mA for alternating current (50 Hz), whereas for direct current, it is more than 50 mA.
The table below shows the data according to the standards and conditions:

Environment		Voltage specifications	
		AC	**DC**
Dry environment Zman = 2000 Ohm	Uf = Z x If	50 V	100 V
Wet environment Zman = 1000 Ohm	Uf = Z x If	25 V	50 V

*With **Z** corresponding to the impedance of the human body in the different types of environment, **If** being the current passing through the body and **Uf** the minimum contact voltage required to reach the danger current.*

Under normal operating conditions, this voltage range (< 50 V) is therefore not dangerous to human beings.

Circuit breakers for direct current applications (cont.)

24 V - 48 V direct current applications

Examples of applications

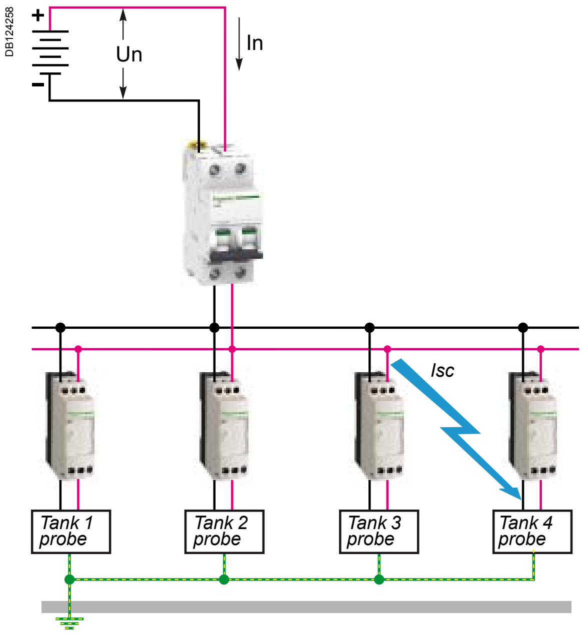
Industrial applications

Monitoring of agro-food tanks with 24 V DC converters for probes and other sensors

- Isolated network:
  - Isc = 25 kA,
  - In = 40 A.

Solution

iC60L 2P 40 A + 24 V converters

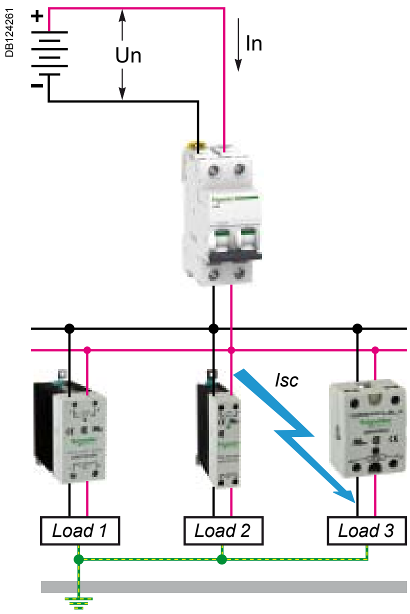


Control of industrial process measurement by 12/24/48 V DC control

- Isolated network:
  - Isc = 20 kA,
  - In = 40 A.

Solution

iC60H 2P 40 A + DC solid-state relays



Circuit breakers for direct current applications (cont.)
24 V - 48 V direct current applications

24 V DC generator power supply protection
■ Earthed network:
□ Isc = 10 kA / In = 63 A,
□ Isc = 10 kA / In = 20 A.

Solution

iC60N 2P 63 A + iC60N 2P 20 A + DC loads

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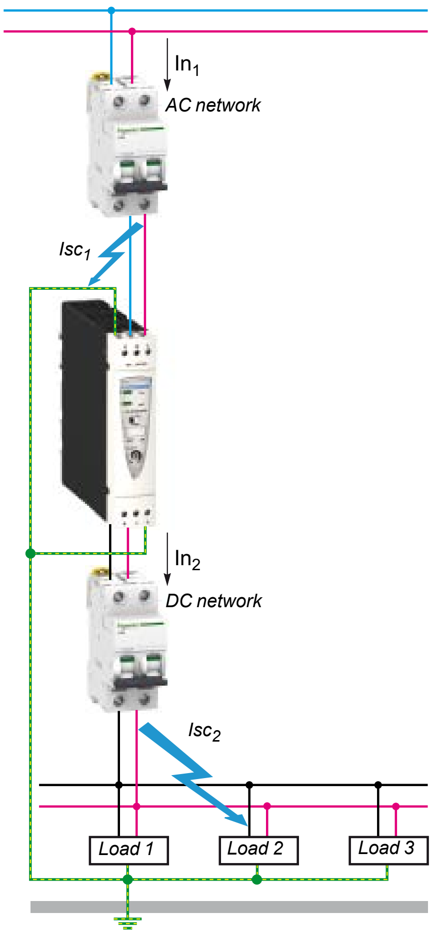

Circuit breakers for direct current applications (cont.)
24 V - 48 V direct current applications

Tertiary applications

Control and monitoring of the 48 V DC emergency lighting distribution for a shopping centre

■ Mid-point of the network:
□ Isc = 20 kA,
□ In = 125 A.

Solution

NG125H 3P 125 A + power contactors

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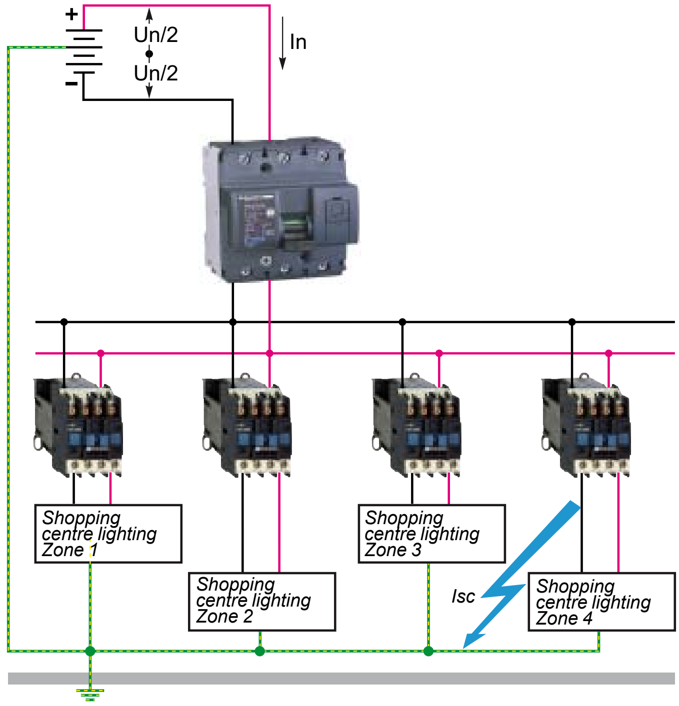


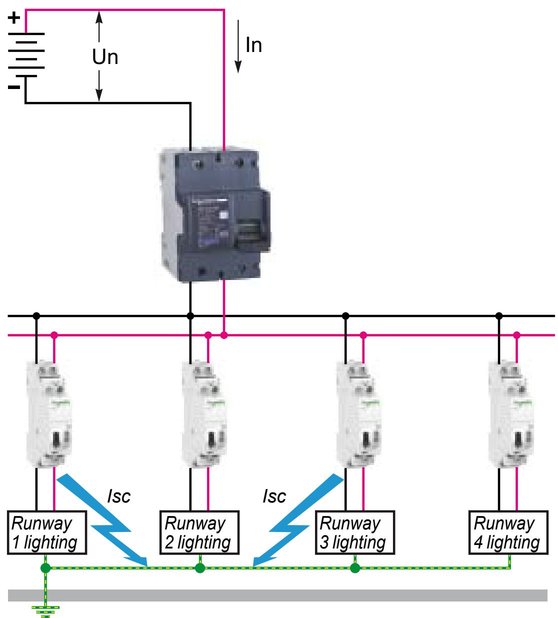
Major airport in France, 48 V DC emergency lighting for runways

■ Isolated network:
□ Isc = 50 kA,
□ In = 80 A.

Solution

NG125L 2P 80 A + impulse relays

DB124260



Circuit breakers for direct current applications (cont.)

24 V - 48 V direct current applications

Power supply protection by 24 V DC direct current generator

■ Earthed network:

□ Isc_1 = 10 kA / In = 40 A,

□ Isc_2 = 10 kA / In = 2/4/6 A.

Solution
iC60N 2P 40 A + iC60N 2P 2/4/6 A + PLC inputs + DC loads

The Phaseo network failure solution provides the installation (or part thereof) with a 24 V DC power supply in the event of a mains voltage failure:

■ throughout the mains failure, to ensure the continuity of service of the installation.

■ during a limited time to allow:

□ data to be backed up,

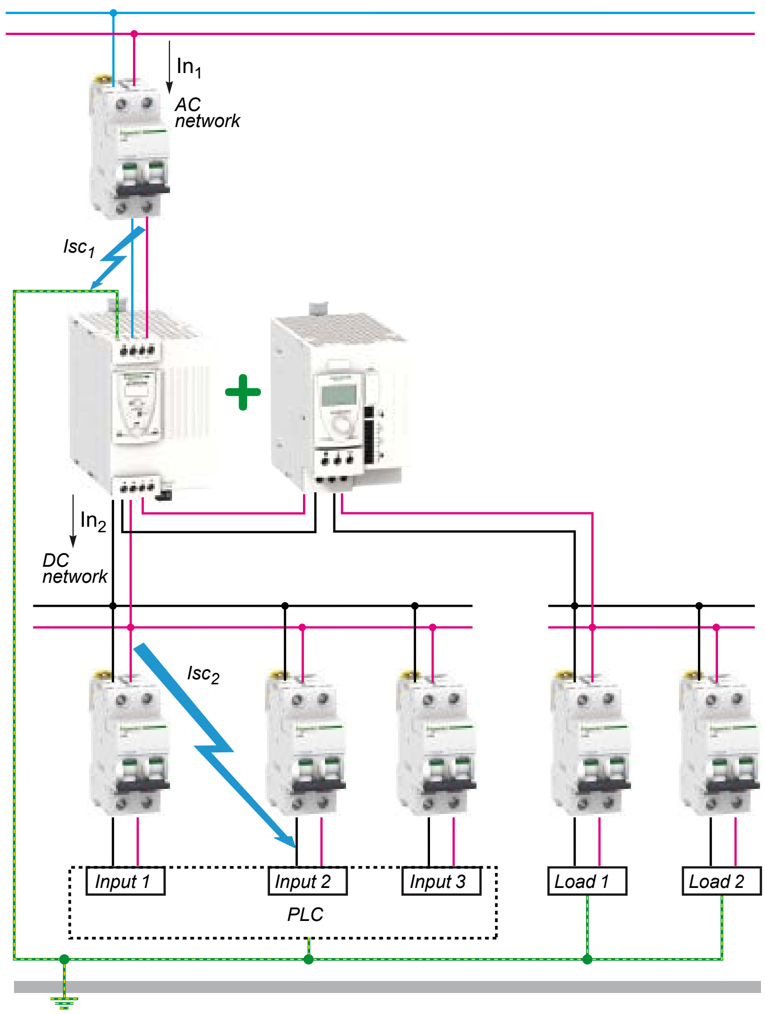
□ actuators to be put in the fallback position,

□ a generating set to be started up,

□ the operating systems to be shut down,

□ remote supervision data to be transmitted.

DB124282



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Circuit breakers for direct current applications (cont.)

24 V - 48 V direct current applications

Evolutions

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Indice	Date	Modification	Name
1.5	4/10/2013	Changed NS by NSX and photos	Sedoc
1.4	5/04/2013	Replace I by In and U by Un	Sedoc
1.3	29/05/2012	Changed solution diagrams page 4 and 5	Sedoc
1.2	21/09/2011	Changed solution diagrams page 4 and 5. Add 2 ms line in table page 7	Sedoc
1.1	24/08/2011	Changed content page 2 - texts page 3, 4, 9 - Z, K curves page 8	Sedoc
1.0	21/04/2011	Creation	Sedoc