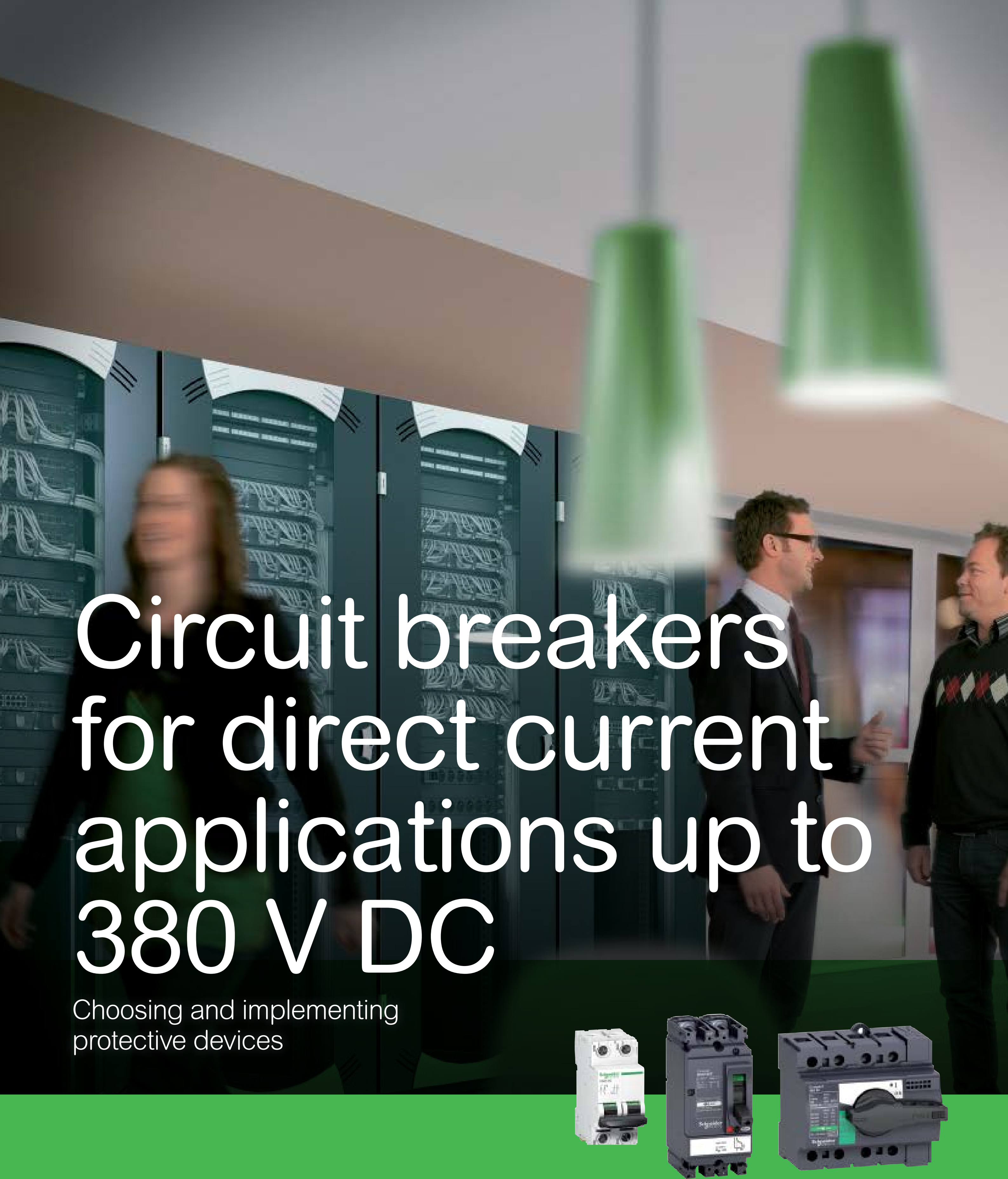


Circuit breakers for direct current applications up to 380 V DC

Choosing and implementing protective devices

schneider-electric.com

Life Is On

Schneider Electric

Green Premium™

Endorsing eco-friendly products in the industry

Green Premium™ Product

Green Premium is the only label that allows you to effectively develop and promote an environmental policy whilst preserving your business efficiency. This ecolabel guarantees compliance with up-to-date environmental regulations, but it does more than this.

Over 75% of Schneider Electric manufactured products have been awarded the Green Premium ecolabel

Schneider Electric's Green Premium ecolabel is committed to offering transparency, by disclosing extensive and reliable information related to the environmental impact of its products:

RoHS

Schneider Electric products are subject to RoHS requirements at a worldwide level, even for the many products that are not required to comply with the terms of the regulation. Compliance certificates are available for products that fulfil the criteria of this European initiative, which aims to eliminate hazardous substances.

REACh

Schneider Electric applies the strict REACh regulation on its products at a worldwide level, and discloses extensive information concerning the presence of SVHC (Substances of Very High Concern) in all of these products.

PEP: Product Environmental Profile

Schneider Electric publishes complete set of environmental data, including carbon footprint and energy consumption data for each of the lifecycle phases on all of its products, in compliance with the ISO 14025 PEP ecopassport program. PEP is especially useful for monitoring, controlling, saving energy, and/or reducing carbon emissions.

EoLI: End of Life Instructions

Available at the click of a button, these instructions provide:
- Recyclability rates for Schneider Electric products.
- Guidance to mitigate personnel hazards during the dismantling of products and before recycling operations.
- Parts identification for recycling or for selective treatment, to mitigate environmental hazards/ incompatibility with standard recycling processes.

Discover what we mean by green ....

Check your products!

General content

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

- Telecommunication infrastructure:
- 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 coils and motors,
  - LV control and monitoring relays,
  - indicator lights,
  - circuit-breaker or on/off switch motor drives,
  - power contactor coils,
  - communicating control/monitoring and supervision devices.

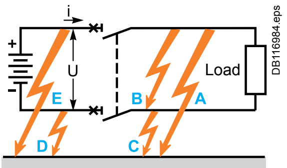
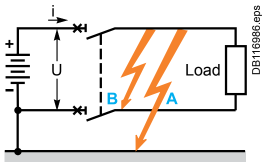
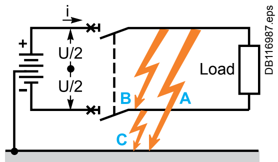
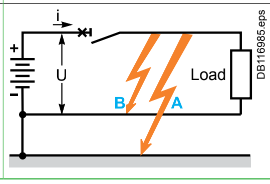
PM103715-150.eps

DB409890.eps

Scope

This application paper seeks to offer guidance in selecting the best protection and control components for a given DC system. It covers DC systems supplied by rectifier (AC/DC or DC/DC converter) and/or battery, isolated or connected to earth. The main voltages are 24 V DC, 48 V DC, 110 V DC, 220 V DC and 380 V DC.

Selection of devices in DC can be challenging due to the diversity of voltage levels and earthing system.
In this document we will consider the following systems:

IT	TN		
Isolated from earth + and - conductors protected and disconnected	**- (or +) earthed** + and - conductors protected and disconnected	**Midpoint earthed (not distributed)** + and - conductors protected and disconnected	**- (or +) earthed** + (or -) conductor only protected and disconnected
			

Disconnection of one or two polarities in TN ?

IEC 60364 Electrical Installation Rules (Chapter 42) can be applied to protect and break only the polarity that is not earthed in TN, but both + & - conductors are "active" conductors, so we recommend disconnecting both polarities.

Positive or negative polarity earthed in TN ?

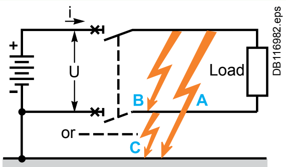
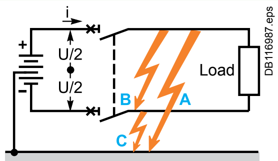
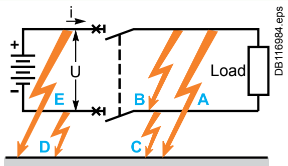
According to IEC 60479-1 upward current is twice as dangerous as downward current so for protection against electric shock it is recommended to earth the negative pole. (In some DC applications the positive polarity can be earthed for galvanic corrosion reason).

Circuit breaker selection

Selection of a circuit breaker depends essentially on the distribution-system parameters presented below which are used to determine the corresponding characteristics: (Page A4 of NSX DC catalog).

- Type of system - determines the type of product and the number of poles connected in series for each polarity.
- Rated voltage - determines the number of series poles taking part in current interruption.
- Nominal current - determines the rated current of the circuit breaker.
- Maximum short-circuit current at the point of installation - determines the breaking capacity.

Types of systems

	Earthed systems		**Isolated systems**
	The source has one earthed polarity (1)	The source has an earthed mid-point	
Diagrams and various faults			
			
Fault analysis (neglecting resistance of earth electrodes)			
Fault **A**	■ Maximum Isc at U ■ Only protected polarity concerned ■ All poles of protected polarity must have breaking capacity ⩾ Isc max. at U	■ Maximum Isc at U/2 ■ Only positive polarity concerned ■ All poles of positive polarity must have breaking capacity ⩾ Isc max. at U/2	■ No consequences ■ The fault must be indicated by an IMD (insulation-monitoring device) and cleared (standard IEC/EN 60364)
Fault **B**	■ Maximum Isc at U ■ If only one polarity (the positive here) is protected, all poles of protected polarity must have breaking capacity ⩾ Isc max. at U ■ If both polarities are protected, to enable disconnection, all poles of the two polarities must have breaking capacity ⩾ Isc max. at U	■ Maximum Isc at U ■ Both polarities are concerned ■ All poles of the two polarities must have breaking capacity ⩾ Isc max. at U	■ Maximum Isc at U ■ Both polarities are concerned ■ All poles of the two polarities must have breaking capacity ⩾ Isc max. at U
Fault **C**	■ No consequences	■ Same as fault **A** ■ All poles of the ■ Negative polarity must have breaking capacity ⩾ Isc max. at U/2	■ Same as fault **A** with the same obligations
Double fault **A** and **D** or **C** and **E**	■ Double fault not possible, system trips on first fault	■ Double fault not possible, system trips on first fault	■ Maximum Isc at U ■ Only positive polarity (cases **A** and **D**) or negative polarity (**C** and **E**) concerned ■ All poles of each polarity must have breaking capacity ⩾ Isc max. at U
Most unfavorable cases			
	Fault **A** and fault **B** (if only one polarity is protected)	Fault **B**	Double fault **A** and **D** or **C** and **E**

Switch-disconnector selection

For a TN system switch-disconnectors have to break load current only, so the above rules are simplified:
If the negative and positive polarities are disconnected, the switch-disconnector must be able to break the load current with the two poles (or 2 x 2 poles in series) at system voltage, If the negative OR positive polarity only is disconnected, the switch-disconnector must be able to break the load current with one pole (or 1 x 2 poles in series) at system voltage.

For an IT system, switch-disconnectors have to break load current, but the risk of opening in a double fault situation cannot be ruled out, so we recommend to selecting a switch-disconnector for IT as circuit breaker if there is no action at the first fault detection.
If switch-disconnectors are used for the isolation function, the load current breaking constraint could be eliminated, but special marking and interlock would have to be implemented to prevent operation under load.

24/48 V DC application

Protection against electric shocks

In 24 or 48 V DC applications, the "extra-low-voltage" (SELV or PELV) is usually the protective measure for protection of persons against electrical shocks in case of fault. The table on the left shows the voltage limits according to the IEC 60479-2 standard. In that case, the circuit breakers are required only for circuit protection against over-currents (overload, short-circuit and earth fault).

Environment		Voltage specifications	
		AC	DC
Dry environment Zman = 2000 Ohms	Uf = Z x If	50 V	120 V
Wet environment Zman = 1000 Ohms	Uf = Z x If	25 V	60 V

The voltage level is not enough to ensure compliance with SELV or PELV requirements: the source and circuits must also comply with IEC 60364-4-41-414 (isolation/separation from higher voltage system).
If "automatic disconnection of the supply" is the protective measure selected, then the circuit breaker tripping time for a minimum earth fault current shall be checked according to table 41.1 of IEC 60364 -4-41.
In IT an insulation monitoring system is mandatory. See "Chapter E page 24".

Selection of circuit breaker (Table A.1 page 8)

Range, rating and number of poles

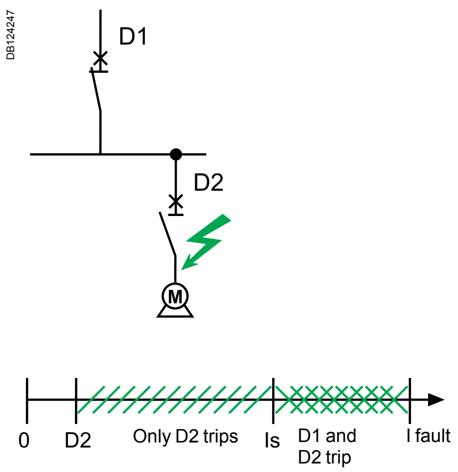
"Table A.1" shows our recommended solution according to the earthing system and current rating for short-circuit currents up to 10 kA (alternative solutions are also proposed for higher short-circuit currents up to 36 kA).

Tripping curves

The tripping curves for C60HDC/iC60/C120/NG125 ranges shall be selected according to the load (inrush current), see "Appendix A page 27". In some applications polarized circuit breakers (C60H-DC) cannot be used, see "Appendix B page 27".

Discrimination

The 230/400 V AC discrimination table cannot be used in DC. See example below. The tables for DC are available in complementary technical information 2017.



Selection of switch-disconnector (Table A.2 page 10)

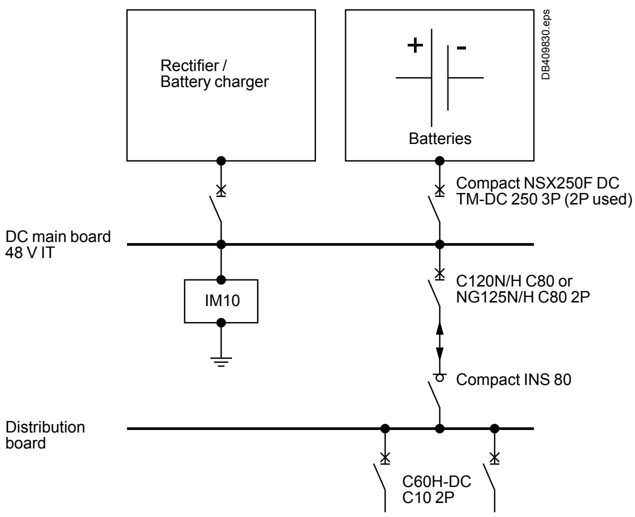
Range, rating and number of poles

"Table A.2" shows our recommended solution according to the earthing system and current rating.

Coordination with circuit breaker

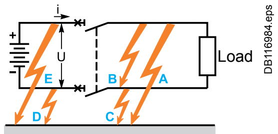
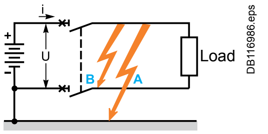
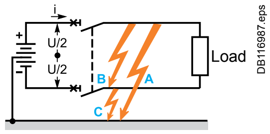
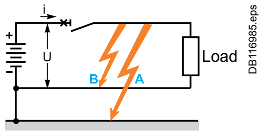
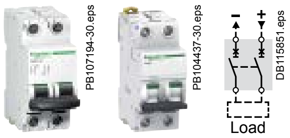
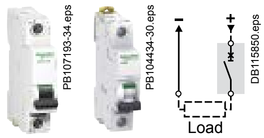
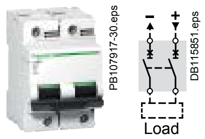
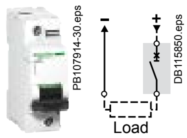
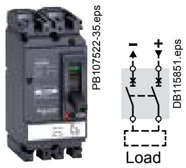
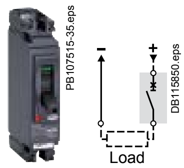
All switches must be protected by an over-current protection device located upstream.
The switch-disconnector proposed in "Table A.2 page 10" are fully coordinated with the circuit breakers of "Table A.1 page 8" up to 10 kA.

Example of 48 V DC system with 3 levels of circuit breaker and total discrimination



24/48 V DC application

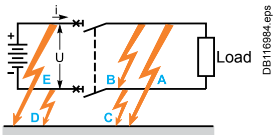
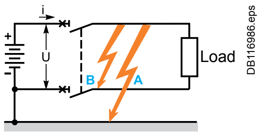
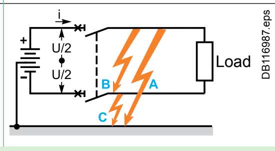
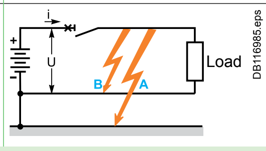
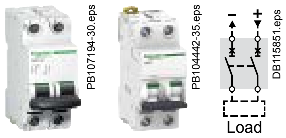
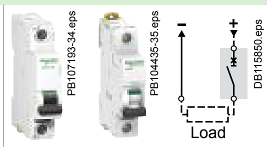
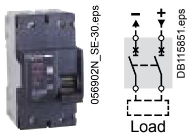
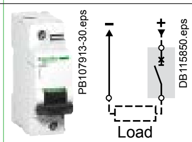
Table A.1: circuit breaker selection for 24/48 V DC according to earthing system

24/48 V DC Presumed short-circuit current Isc ≤ 10 kA				
Earthing system	**IT**	**TN**		
	Isolated from earth + and - conductors protected and disconnected	**- (or +) earthed** + and - conductors protected and disconnected	**Midpoint earthed (not distributed)** + and - conductors protected and disconnected	**- (or +) earthed** + (or -) conductor only protected and disconnected
				
CB rating				
In ≤ 63 A				
	C60H-DC 2P or iC60N 2P			C60H-DC or iC60N 1P
80 - 125 A				
	C120N 2P			C120N 1P
125 - 160 A				
	NSX160F 2P			NSX160F 1P
I >160 A				
	Compact NSX DC F (see Table B.2 page 14) 110 V DC application			
IMD				
	IM10[1]	Not applicable		

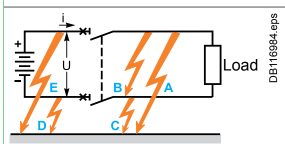
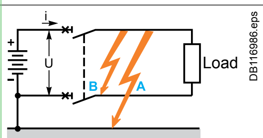
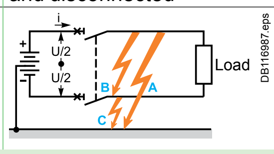
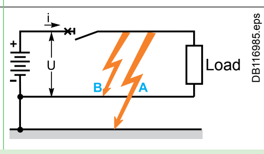
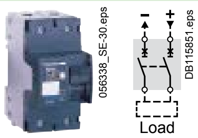
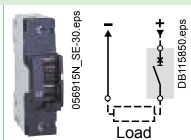
(1) IM10 or IM20 or IM400 see selection criteria "Insulation monitoring system for DC application", page 24

24/48 V DC application

Complement for short-circuit currents higher than 10 kA

24/48 V DC Presumed short-circuit current Isc ≤ 20 kA				
Earthing system	**IT**	**TN**		
	Isolated from earth + and - conductors protected and disconnected	**- (or +) earthed** + and - conductors protected and disconnected	**Midpoint earthed (not distributed)** + and - conductors protected and disconnected	**- (or +) earthed** + (or -) conductor only protected and disconnected
				
CB rating				
In ≤ 63 A				
	C60H-DC 2P or iC60L			C60H-DC 1P or iC60H
80 - 125 A				
	NG125N(1) 2P			C120H 1P
I > 125 A				
	Compact NSX DC F (see Table B.1 page 12) 110 V DC application			

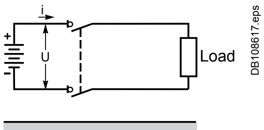
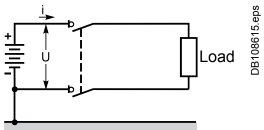
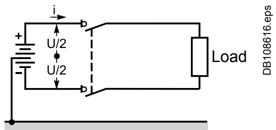
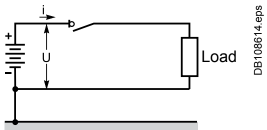
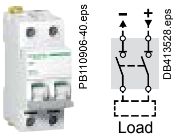
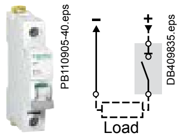
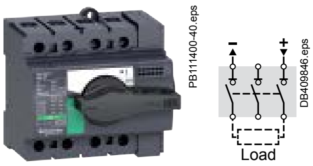
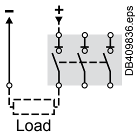
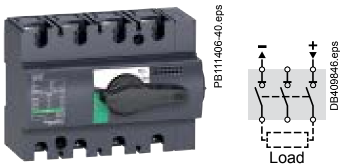
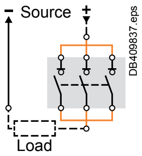
(1) NG125H (80 A Max) up to 25 kA
IMD see Table A.1

24/48 V DC Presumed short-circuit current Isc ≤ 36 kA				
Earthing system	**IT**	**TN**		
	Isolated from earth + and - conductors protected and disconnected	**- (or +) earthed** + and - conductors protected and disconnected	**Midpoint earthed (not distributed)** + and - conductors protected and disconnected	**- (or +) earthed** + (or -) conductor only protected and disconnected
				
CB rating				
≤ 80 A				
	NG125L 2P			NG125H 1P
I > 80 A				
	Compact NSX DC F (see Table B.1 page 12) 110 V DC application			

IMD see Table A.1

24/48 V DC application

Table A.2: switch-disconnector selection for 24/48 V DC according to earthing system

<table>
<tr><th colspan="5">24/48 V DC Presumed short-circuit current Isc 10 kA(2)</th></tr>
<tr><td>Earthing system</td><td>IT</td><td colspan="3">TN</td></tr>
<tr><td></td><td>Isolated from earth
+ and - conductors protected and disconnected</td><td>- (or +) earthed
+ and - conductors protected and disconnected</td><td>Midpoint earthed (not distributed)
+ and - conductors protected and disconnected</td><td>- (or +) earthed
+ (or -) conductor only protected and disconnected</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="5">SW rating</td></tr>
<tr><td>Ie ≤ 63 A</td><td colspan="3">
iSW 2P</td><td>
iSW 1P</td></tr>
<tr><td>Ie ≤ 80 A</td><td colspan="3">
INS40/80 3P (2P used)</td><td>
INS40/80 3P (1P used)</td></tr>
<tr><td>Ie =
100 - 125 -160 A</td><td colspan="3">
INS160 3P (2P used)</td><td>
INS80 3P(1)
(2P or 3P in parallel)</td></tr>
</table>

(1) Current carrying capacity of Compact INS Switch-disconnector with parallel connection of poles:
- 2 poles used: Ith = 1.6 x In,
- 3 poles used: Ith = 2.25 x In.

Example: an INS80 with 2 poles in parallel can be used up to 80 x 1.6 = 128 A,
INS80 with 3 poles in parallel can be used up to 180 A.

(2) Prospective short-circuit current of switch-disconnector with related circuit breaker:

	iSW	INS 40/63/80	INS 100/125/160
	Ie ≤ 63 A	Ie ≤ 80 A	Ie ≤ 160 A
iC60N/H/L	10 kA	10/15/20 kA	10/15/20 kA
C60H-DC (In ≤ 63 A)	10 kA	20 kA	20 kA
C120N/H (In ≤ 125 A)	-	10/15 kA	10/15 kA
NG125N/H/L	-	20/25/36 kA	20/25/36 kA
NSX160 (In ≤ 160 A)	-	-	36 kA

The circuit breaker’s rating or "Ir" setting shall be less than or equal to the rated current of the switch-disconnector.

Protection against electric shocks

In 110 V DC applications, "extra-low-voltage" (SELV or PELV) is usually the protective measure for protection of persons against electrical shocks in case of fault. The table below shows the voltage limits according to the IEC 60479-2 standard. In that case, the circuit breakers are required only for circuit protection against over-current (overload, short-circuit and earth fault).

The voltage level is not enough to ensure compliance with SELV or PELV requirements: the source and circuits must also comply with IEC 60364-4-41-414 (isolation/separation from higher voltage system).
If "automatic disconnection of the supply" is the protective measure selected, then the circuit-breaker tripping time for a minimum earth fault current shall be checked according to table 41.1 of IEC 60364 -4-41.
In IT, an insulation monitoring system is mandatory. See "Chapter E page 24".

Environment		Voltage specifications	
		AC	DC
Dry environment Zman = 2000 Ohms	Uf = Z x If	50 V	120 V
Wet environment Zman = 1000 Ohms	Uf = Z x If	25 V	60 V

Selection of circuit breaker (Table B.1 page 12)

Range, rating and number of poles
"Table B.1" shows our recommended solution according to the earthing system and current rating for short-circuit currents up to 10 kA. (alternative solutions are also proposed for higher short-circuit currents up to 36 kA).

Tripping curves
The tripping curves for C60H-DC/iC60/C120/NG125 ranges shall be selected according to the load (inrush current), see "Appendix A page 27" and requirements for protection against electric shock, where applicable (see above).
In some applications polarized circuit breakers (C60H-DC) cannot be used, see "Appendix B page 27".

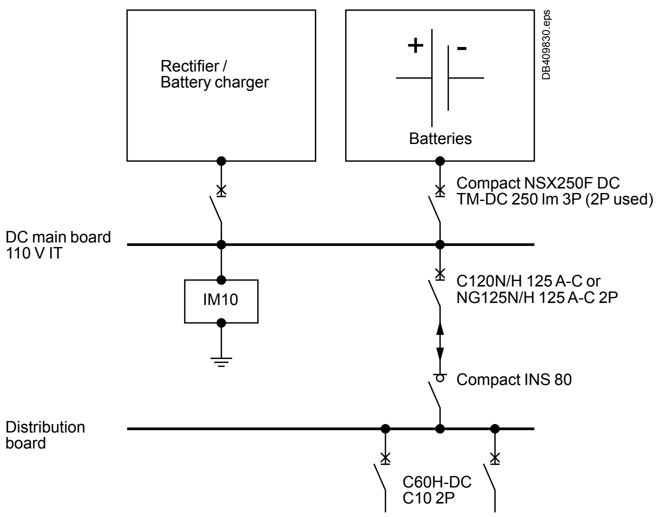
Discrimination
The 230/400 V AC discrimination table cannot be used in DC. The tables for DC are available inside complementary technical information 2017. See example below.

Selection of switch-disconnector (Table B.2 page 14)

Range, rating and number of poles
Table B.2 shows our recommended solution according to the earthing system and current rating.

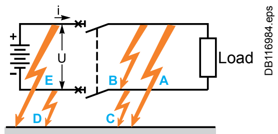
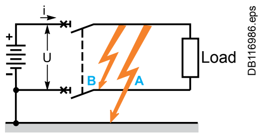
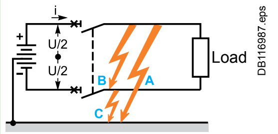
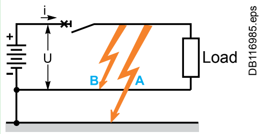
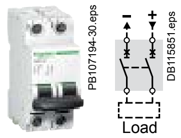
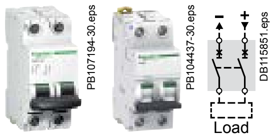
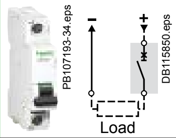
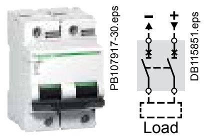
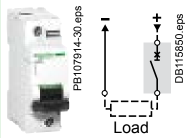
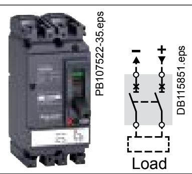
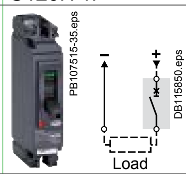
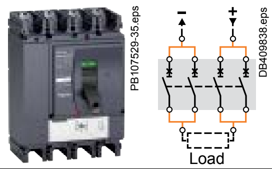
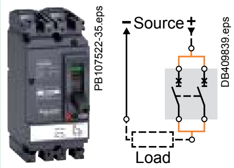
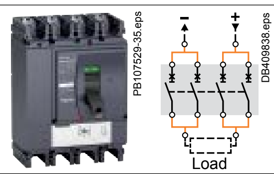
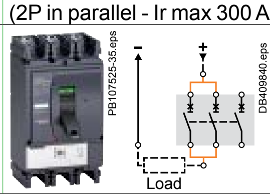
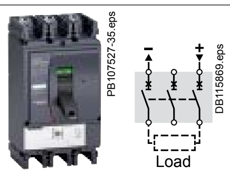
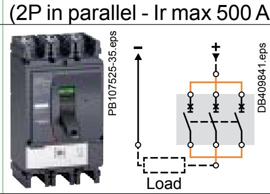
Coordination with circuit breaker
All switches must be protected by an over-current protection device located upstream.
The switch-disconnectors proposed in "Table B.2 page 14" are fully coordinated with circuit breakers of "Table B.1 page 12" up to 10 kA.

Example of 110 V DC system with 3 levels of circuit breaker and total discrimination



110 V DC application

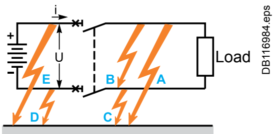
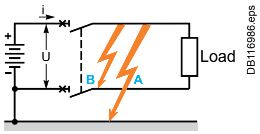
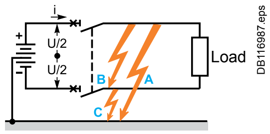
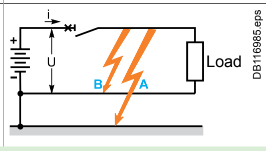
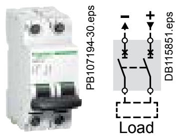
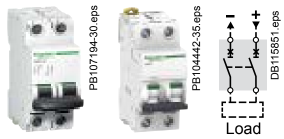
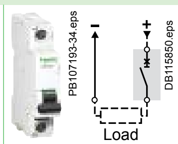
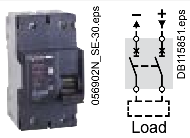
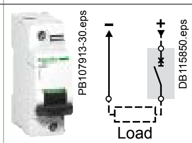
Table B.1: circuit breaker selection for 110 V DC according to earthing system

110 V DC Presumed short-circuit current Isc ≤ 10 kA				
Earthing system	**IT**	**TN**		
	Isolated from earth + and - conductors protected and disconnected	**- (or +) earthed** + and - conductors protected and disconnected	**Midpoint earthed (not distributed)** + and - conductors protected and disconnected	**- (or +) earthed** + (or -) conductor only protected and disconnected
				
CB rating				
In ≤ 63 A				
	C60H-DC 2P		C60H-DC 2P or iC60N	C60H-DC 1P
80 - 125 A				
	C120N 2P			C120N 1P
125 - 160 A				
	NSX160F DC 2P			NSX160F DC 1P
200 - 300 A				
	NSX160F DC 4P(1) (2x2P in parallel - Ir max 288 A) or NSX250F 3P (2P used up to 250 A)			NSX160F DC 2P(1) (2P in parallel - Ir max 300 A)
300 - 500 A				
	NSX250F DC 4P(1) (2x2P in parallel - Ir max 460 A)			NSX250F DC 3P(1) (2P in parallel - Ir max 500 A)
400 - 630 A				
	NSX400-630F DC 3P (2P used)			NSX250F DC 3P(1) (3P in parallel - Ir max 720 A)
IMD				
	IM10(2)	Not applicable		

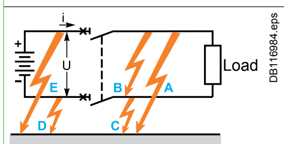
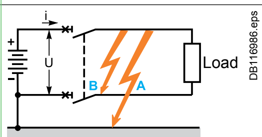
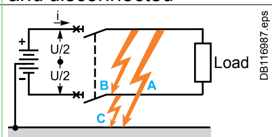
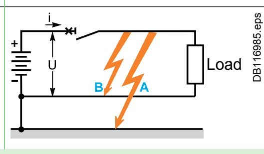
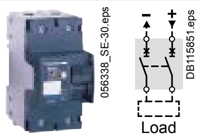
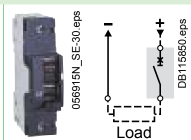
(1) See Compact NSX, Compact INS/INV, Masterpact NW DC- DCPV, catalog page B-7 for detail tripping characteristics with parallel connections
(2) IM10 or IM20 or IM400 see selection criteria "Insulation monitoring system for DC application", page 24

110 V DC application

Complement for short-circuit currents higher than 10 kA

Ue = 110 V DC Presumed short-circuit current Isc ⩽ 20 kA				
Earthing system	**IT**	**TN**		
	Isolated from earth + and - conductors protected and disconnected	**- (or +) earthed** + and - conductors protected and disconnected	**Midpoint earthed (not distributed)** + and - conductors protected and disconnected	**- (or +) earthed** + (or -) conductor only protected and disconnected
				
CB rating				
In ⩽ 63 A	 C60H-DC 2P		 C60H-DC 2P or iC60L	 C60H-DC 1P
80 - 125 A	 NG125N[1] 2P			 C120H 1P
I > 125 A	 Compact NSX DC F (see Table B.1 page 12)			

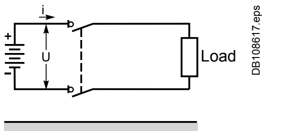
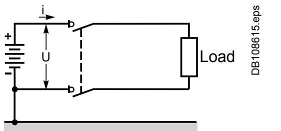
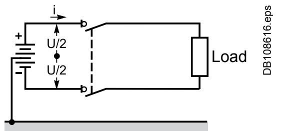
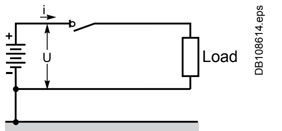
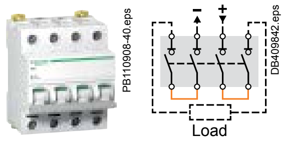
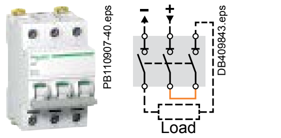
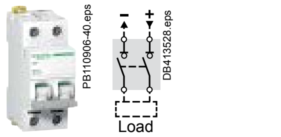
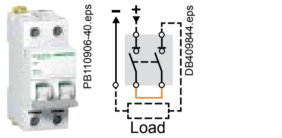
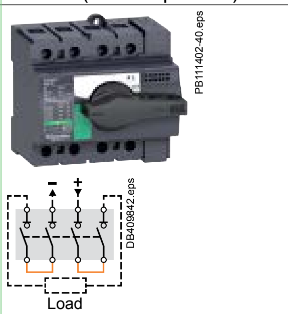
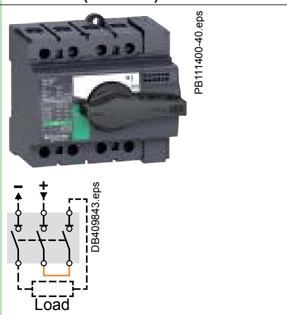
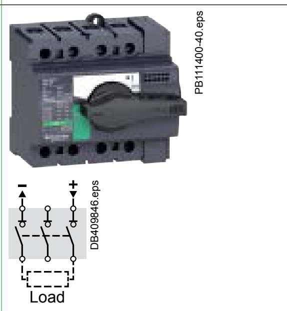
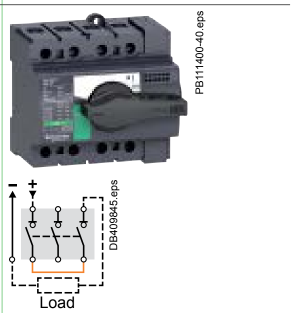
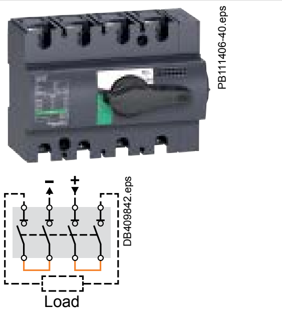
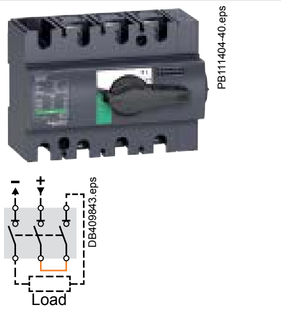
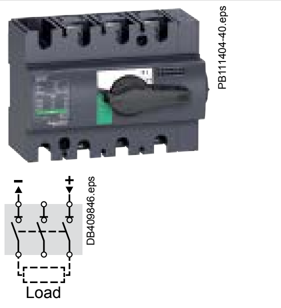
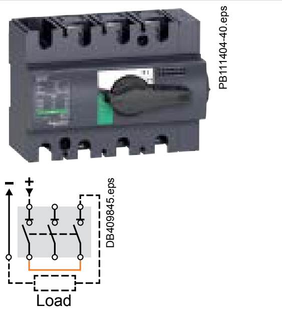
(1) NG125H up to 25 kA
IMD see Table B.1

110 V DC Presumed short-circuit current Isc ⩽ 36 kA				
Earthing system	**IT**	**TN**		
	Isolated from earth + and - conductors protected and disconnected	**- (or +) earthed** + and - conductors protected and disconnected	**Midpoint earthed (not distributed)** + and - conductors protected and disconnected	**- (or +) earthed** + (or -) conductor only protected and disconnected
				
CB rating				
⩽ 80 A	 NG125L 2P			 NG125H 1P
I > 80 A	 Compact NSX DC F (see Table B.1 page 12) (starting with 80/100/125 A ratings)			

IMD see Table B.1

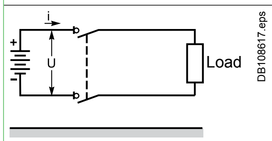
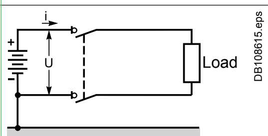
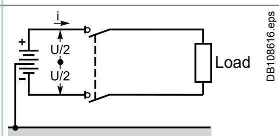
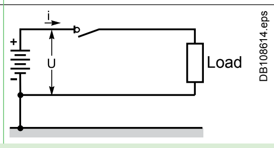
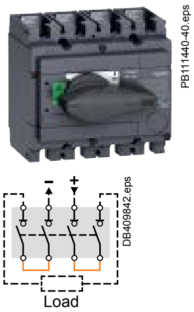
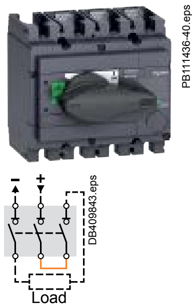
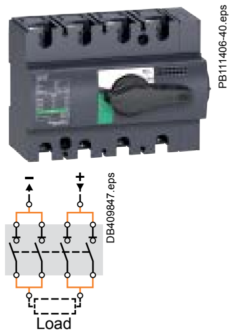
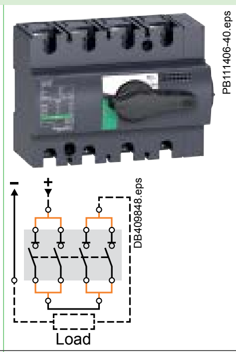
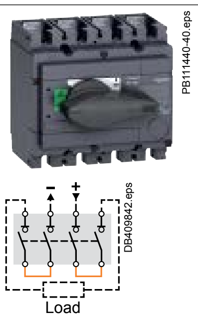
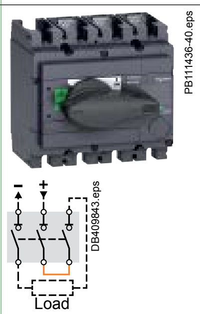
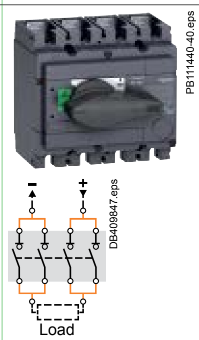
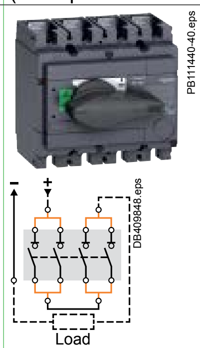
110 V DC application

Table B.2: switch-disconnector selection for 110 V DC according to earthing system

110 V DC Presumed short-circuit current Isc ⩽ 10 kA				
Earthing system	**IT**	**TN**		
	Isolated from earth + and - conductors protected and disconnected	**- (or +) earthed** + and - conductors protected and disconnected	**Midpoint earthed (not distributed)** + and - conductors protected and disconnected	**- (or +) earthed** + (or -) conductor only protected and disconnected
				
SW rating				
Ie ⩽ 63 A	 iSW 4P (2x2P in parallel)	 iSW 3P (1P+2P)	 iSW 2P	 iSW 2P
Ie ⩽ 80 A	 INS40/80 4P (2x2P in parallel)	 INS40/80 3P (1P+2P in serie)	 INS40/80 3P (2P used)	 INS40/80 3P (2P used)
Ie = 100 - 125 - 160 A	 INS160 4P (2x2P in serie)	 INS160 3P (1P+2P in serie)	 INS160 3P (2P used)	 INS160 3P (2P used in serie)

110 V DC application

Table B.2 (cont.): switch-disconnector selection for 110 V DC according to earthing system

110 V DC Presumed short-circuit current Isc ⩽ 10 kA (2)				
Earthing system	**IT**	**TN**		
	Isolated from earth + and - conductors protected and disconnected	**- (or +) earthed** + and - conductors protected and disconnected	**Midpoint earthed (not distributed)** + and - conductors protected and disconnected	**- (or +) earthed** + (or -) conductor only protected and disconnected
				
SW rating				
Ie = 160 A - 250 A				
	INS250 4P (2x2P in serie)	INS250 3P (1P+2P in serie)	INS160 4P(1) (2x2P parallel)	INS160 4P(1) (2x2P parallel in serie)
250 - 400 A				
	INS320/400 4P (2x2P in serie)	INS320/400 3P (1P+2P in serie)	INS250 4P(1) (2x2P parallel)	INS250 4P(1) (2x2P parallel in serie)

(1) Current carrying capacity of Compact INS Switch-disconnector with parallel connection of poles:
- 2 poles used: Ith = 1.6 x In,
- 3 poles used: Ith = 2.25 x In.

Example: an INS80 with 2 poles in parallel can be used up to 80 x 1.6 = 128 A,
INS80 with 3 poles in parallel can be used up to 180 A.

(2) Prospective short-circuit current of switch-disconnector with related circuit breaker:

	iSW	INS 40/63/80	INS 100/125/160
	Ie ⩽ 63 A	Ie ⩽ 80 A	Ie ⩽ 160 A
iC60N/H/L	10 kA	10/15/20 kA	10/15/20 kA
C60H-DC (In ⩽ 63 A)	10 kA	20 kA	20 kA
C120N/H (In ⩽ 125 A)	-	10/15 kA	10/15 kA
NG125N/H/L	-	20/25/36 kA	20/25/36 kA
NSX160 (In ⩽ 160 A)	-	-	36 kA

The circuit breaker's rating or "Ir" setting shall be less than or equal to the rated current of the switch-disconnector.

Protection against electric shocks

Except for TN with Midpoint Earthed where SELV/PELV is still an option, the protective measure is usually “automatic disconnection of the supply” for this voltage level. The circuit-breaker tripping time for a minimum earth fault current shall be checked according to Table 41.1 of IEC 60364 -4-41.
In IT, an insulation monitoring system is mandatory. See "Chapter E page 24".

Selection of circuit breaker (Table C.1 page 17)

Range, rating and number of poles

"Table C.1" shows our recommended solution according to the earthing system and current rating for short-circuit currents up to 10 kA. (alternative solutions are also proposed for higher short-circuit currents up to 36 kA).

Tripping curves

The tripping curves for C60H-DC/iC60/C120/NG125 ranges shall be selected according to the load (inrush current), see "Appendix A page 27" and requirements for protection against electric shock, where applicable (see above). In some applications, polarized circuit breakers (C60H-DC) cannot be used, see "Appendix B page 27".

Discrimination

The 230/400 V AC discrimination table cannot be used in DC. The tables for DC are available in complementary technical information 2017. See example below.

Selection of switch-disconnector (Table C.2 page 19)

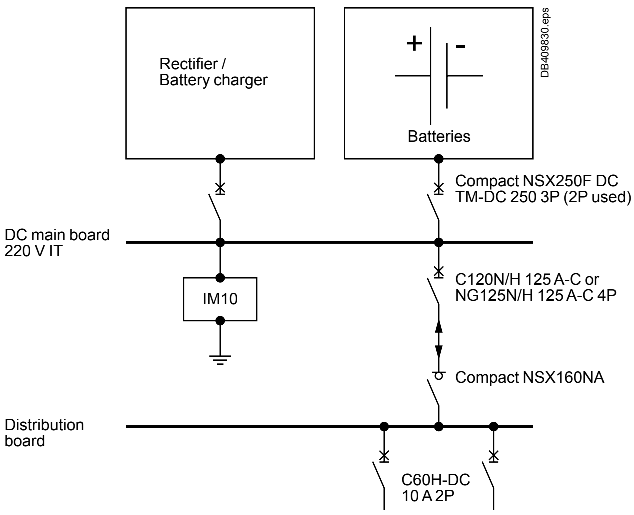
Range, rating and number of poles

"Table C.2" shows our recommended solution according to the earthing system and current rating.

Coordination with circuit breaker

All switches must be protected by over-current protection device located upstream. The switch-disconnectors proposed in "Table C.2 page 19" are fully coordinated with the circuit breakers of "Table C.1 page 17".

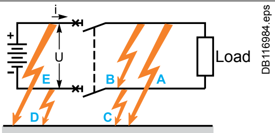
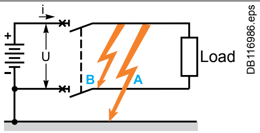
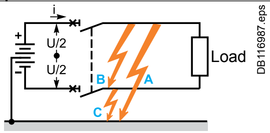
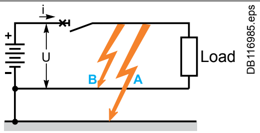
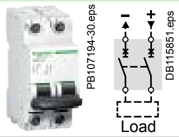
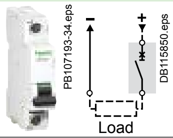
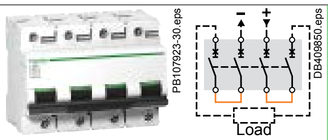
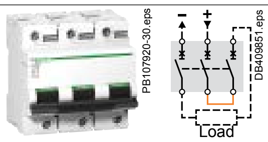
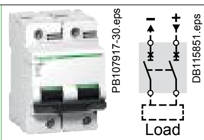
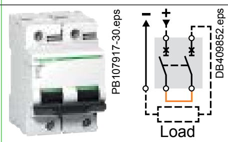
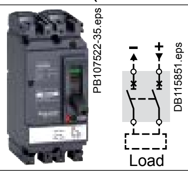
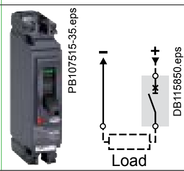
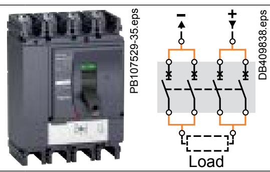
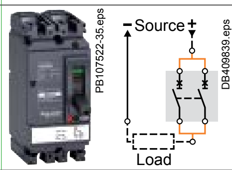
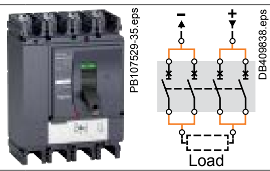
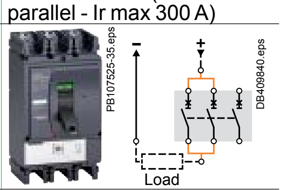
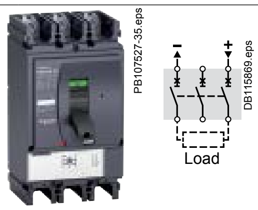
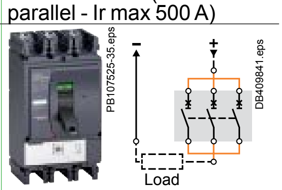
Example of 220 V DC system with 3 levels of circuit breaker and total discrimination



C

220 V DC application

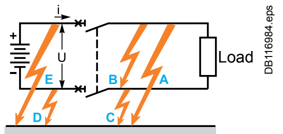
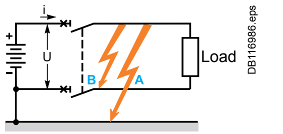
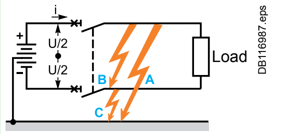
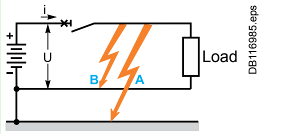
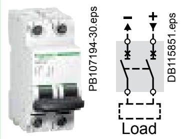
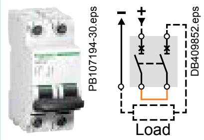
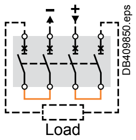
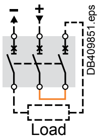
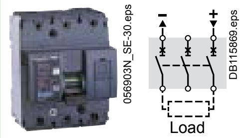
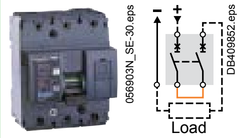
Table C.1: circuit breaker selection for 220 V DC according to earthing system

220 V DC Presumed short-circuit current Isc ≤ 10 kA				
Earthing system	**IT**	**TN**		
	Isolated from earth + and - conductors protected and disconnected	**- (or +) earthed** + and - conductors protected and disconnected	**Midpoint earthed (not distributed)** + and - conductors protected and disconnected	**- (or +) earthed** + (or -) conductor only protected and disconnected
				
CB rating				
In ≤ 63 A	 C60H-DC 2P			 C60H-DC 1P
80 - 125 A	 C120N 4P (2x2P in serie)	 C120N 3P (1P+2P in serie)	 C120N 2P	 C120N 2P
125 - 160 A	 NSX160F 2P			 NSX160F 1P
200 - 300 A	 NSX160F 4P(1) (2x2P in parallel - Ir max 288 A) or NSX250F 3P (2P used up to 250 A)			 NSX160F 2P(1) (2P in parallel - Ir max 300 A)
300 - 500 A	 NSX250F 4P(1) (2x2P in parallel - Ir max 460 A)			 NSX250F 3P(1) (2P used in parallel - Ir max 500 A)
400 - 630 A	 NSX400-630F 3P (2P used)			 NSX250F 3P(1) (3P parallel connection for + or - (Ir max 720 A)
IMD	 IM10(1)	Not applicable		

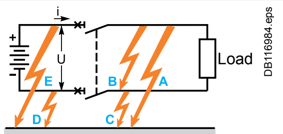
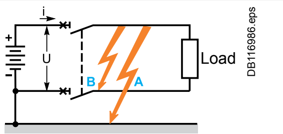
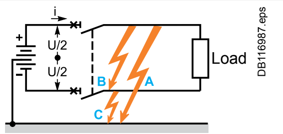
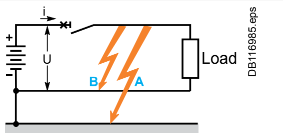
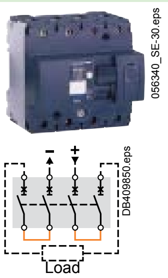
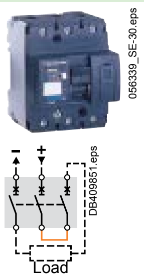
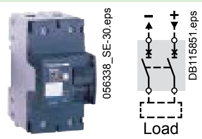
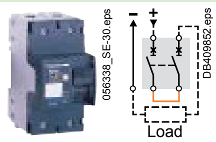
(1) See Compact NSX, Compact INS/INV, Masterpact NW DC- DCPV, catalog page B-7 for detail tripping characteristics with parallel connections.
(2) IM10 or IM20 or IM400 see selection criteria "Insulation monitoring system for DC application", page 24

220 V DC application

Complement for short-circuit currents higher than 10 kA

220 V DC Presumed short-circuit current Isc ≤ 20 kA				
Earthing system	**IT**	**TN**		
				
CB rating				
In ≤ 63 A			 C60H-DC 2P	 C60H-DC 2P
80 - 125 A				
	NG125N(1) (4P 2x2P)	NG125N(1) (3P 1+2P)	NG125N(1) 3P (2P used)	NG125N(1) 3P (2P serie)
I ≥ 160 A	 Compact NSX DC F as for 10 kA (see Table C.1 page 17)			

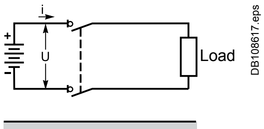
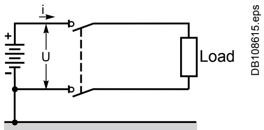
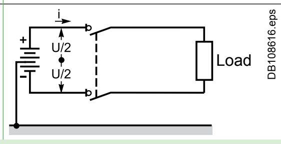
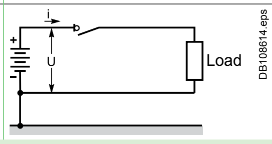
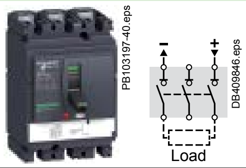
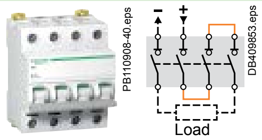
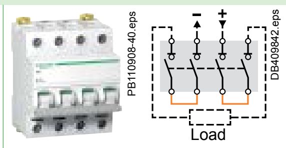
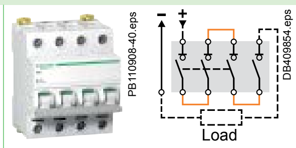
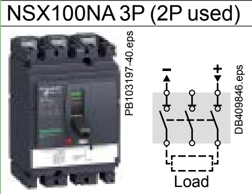
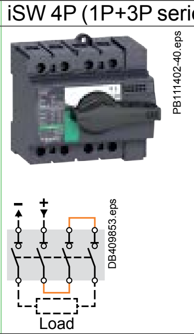
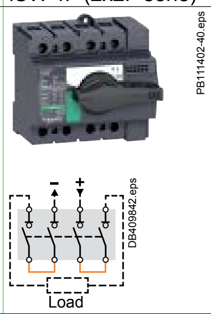
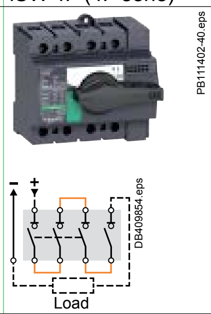
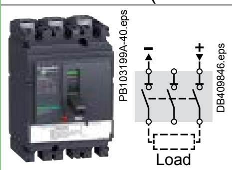
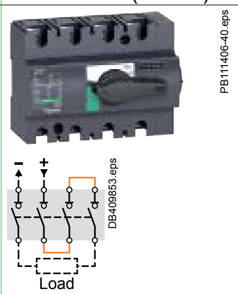
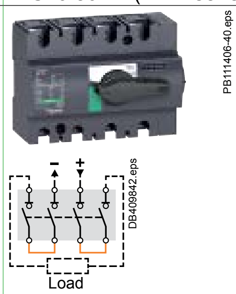
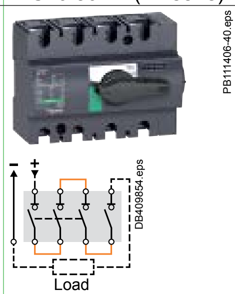
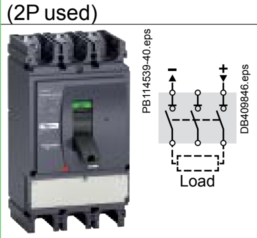
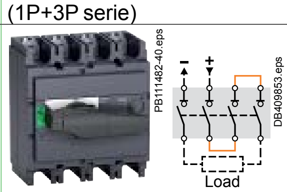
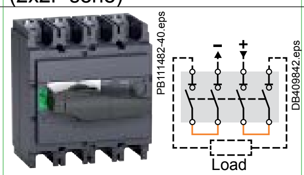
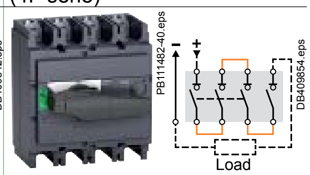
(1) NG125H up to 25 kA
IMD see Table C.1

220 V DC Presumed short-circuit current Isc ≤ 36 kA				
Earthing system	**IT**	**TN**		
				
CB rating				
In ≤ 63 A	 NG125L 4P (2x2P serie)	 NG125L 3P (1P+2P serie)	 NG125L 2P	 NG125L 2P
I ≥ 80 A	 Compact NSX DC F as for 10 kA (see Table C.1 page 17) (starting with 80/100/125 A ratings)			

IMD see Table C.1

220 V DC application

Table C.2: switch-disconnector selection for 220 V DC according to earthing system

220 V DC Presumed short-circuit current Isc ⩽ 10 kA[1]				
Earthing system	**IT**	**TN**		
	Isolated from earth + and - conductors protected and disconnected	**- (or +) earthed** + and - conductors protected and disconnected	**Midpoint earthed (not distributed)** + and - conductors protected and disconnected	**- (or +) earthed** + (or -) conductor only protected and disconnected
				
SW rating				
Ie ⩽ 63 A				
	NSX100NA 3P (2P used)	iSW 4P (1P+3P serie)	iSW 4P (2x2P serie)	iSW 4P (4P serie)
Ie ⩽ 80 A				
	NSX100NA 3P (2P used)	INS40/80 4P (1P+3P)	INS40/80 4P (2x2P serie)	INS40/80 4P (4P serie)
Ie = 100 - 250 A				
	NSX100 - 250NA 3P (2P used)	INS100 - 160 - 250 4P (1P+3P serie)	INS100 - 160 - 250 4P (2x2P serie)	INS100 - 160 - 250 4P (4P serie)
Ie = 400 A - 630 A				
	NSX630NA DC 3P (2P used)	INS400 - 630 4P (1P+3P serie)	INS400 - 630 4P (2x2P serie)	INS400 - 630 4P (4P serie)

(1) Prospective short-circuit current of switch-disconnector with related circuit breaker:

	iSW	INS				NSX		
	(63A)	40/63/80	100/125/160	250	320/630	100 - 160NA	250NA	400 - 630NA
iC60N/H/L	10 kA	10/15/20 kA	10/15/20 kA	10/15/20 kA	10/15/20 kA	10/15/20 kA	10/15/20 kA	10/15/20 kA
C60H-DC (In ⩽ 63 A)	10 kA	20 kA	20 kA	20 kA	20 kA	20 kA	20 kA	20 kA
C120N/H (In ⩽ 125 A)	-	10/15 kA	10/15 kA	10/15 kA	10/15 kA	10/15 kA	10/15 kA	10/15 kA
NG125N/H/L	-	20/25/36 kA	20/25/36 kA	20/25/36 kA	20/25/36 kA	20/25/36 kA	20/25/36 kA	20/25/36 kA
NSX100/160 (In ⩽ 160 A)	-	-	36 kA	36 kA	36 kA	36 kA	36 kA	36 kA
NSX250	-	-	-	36 kA	36 kA	-	36 kA	36 kA
NSX400-630	-	-	-	-	36 kA	-	-	36 kA

The circuit breaker's rating or "Ir" setting shall be less than or equal to the rated current of the switch-disconnector.

C

Protection against electric shocks

The protective measure is usually “automatic disconnection of the supply” for this voltage. The circuit-breaker tripping time for a minimum earth fault current shall be checked according to Table 41.1 of IEC 60364 -4-41.
In IT, an insulation monitoring system is mandatory. See "Chapter E page 24".

Selection of circuit breaker (Table D.1 page 21)

Circuit breakers in addition to automatic disconnection of the supply ensure conductor protection against overloads and short-circuits. Their tripping characteristics shall be selected according to the conductors protected.

Range, rating and number of poles

"Table D.1" shows our recommended solution according to the earthing system and current rating for short-circuit currents up to 10 kA (alternative solutions are also proposed for higher short-circuit currents up to 36 kA).
In some applications, polarized circuit breakers (C60H-DC) cannot be used, see "Appendix B page 27".

Tripping curves

The tripping curves for C60H-DC/iC60/C120/NG125 ranges shall be selected according to the load (inrush current), see "Appendix A page 27" and requirements for protection against electric shock, where applicable (see above).

Discrimination

The 230/400 V AC discrimination table cannot be used in DC. The tables for DC are available in complementary technical information 2017. See example below.

Selection of switch-disconnector (Table D.2 page 23)

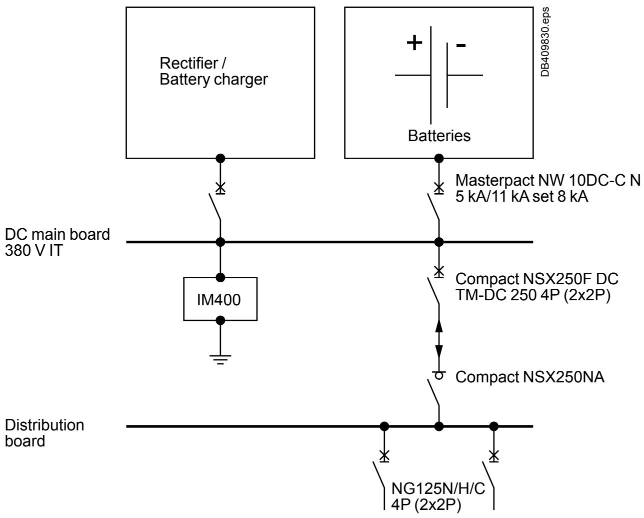
Range, rating and number of poles

"Table D.2" shows our recommended solution according to the earthing system and current rating.

Coordination with circuit breaker

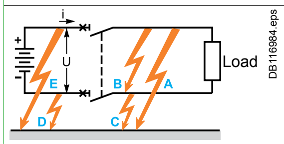
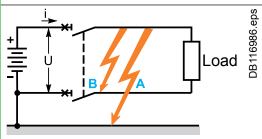
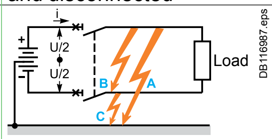
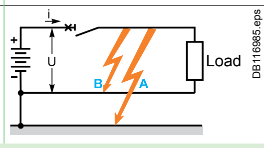
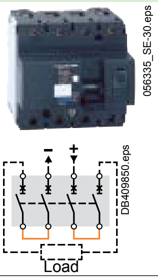
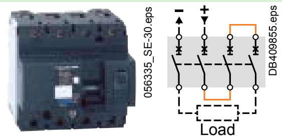
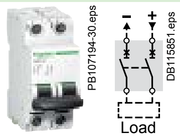
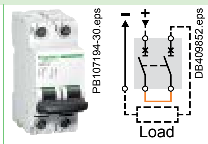
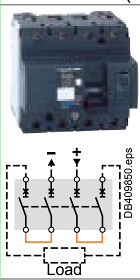
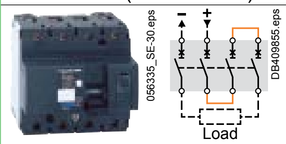
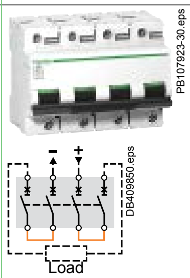
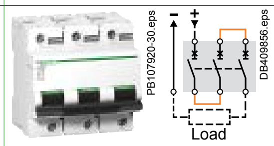
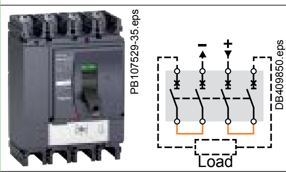
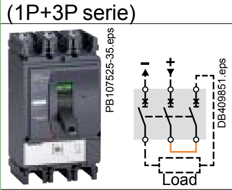
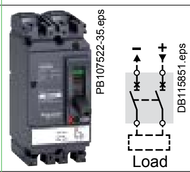
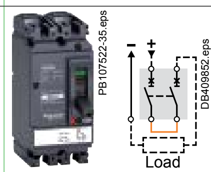
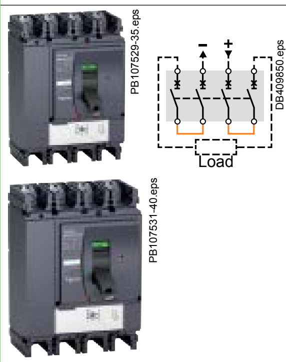
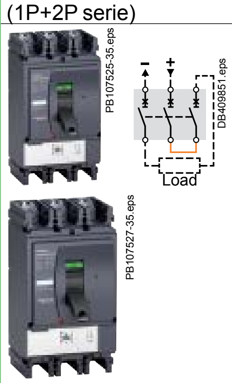
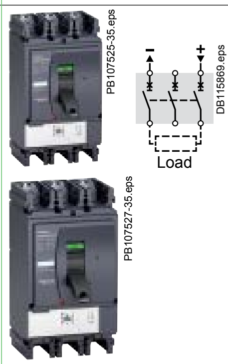
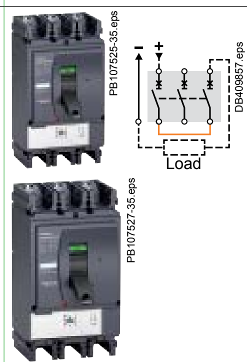
All switches must be protected by an over-current protection device located upstream.
The switch-disconnectors proposed in "Table D.2 page 23" are fully coordinated with the circuit breakers of "Table D.1 page 21".

Example of 380 V DC system with 3 levels of circuit breaker and total discrimination



D

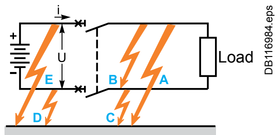
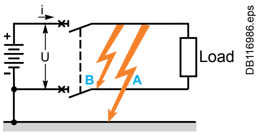
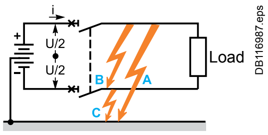
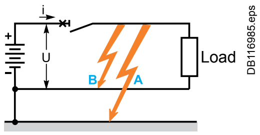
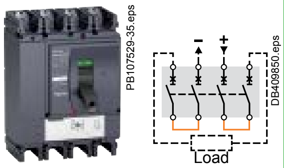
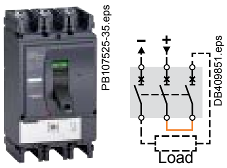
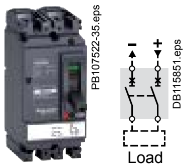
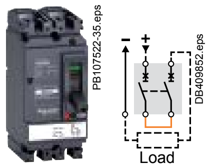
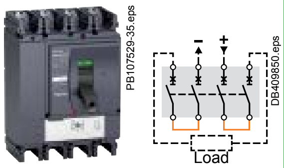
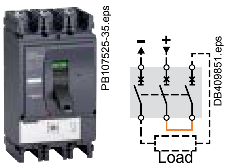
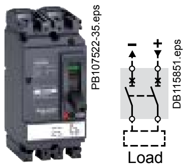
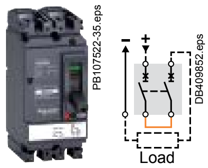
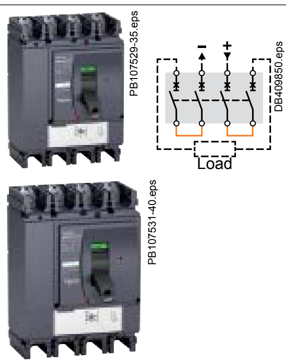
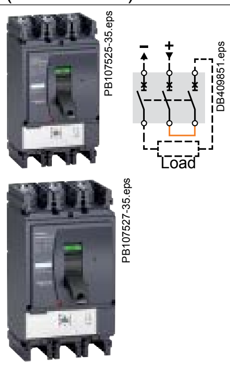
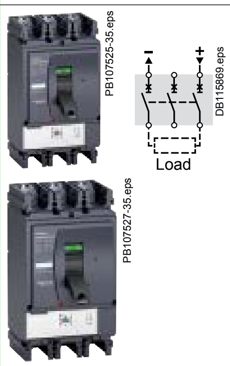
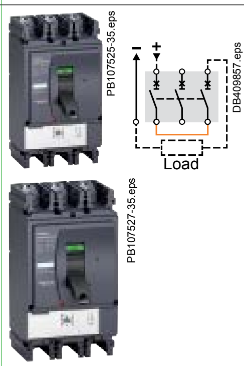
Table D.1: circuit breaker selection for 380 V DC according to earthing system

380 V DC Presumed short-circuit current Isc ≤ 10 kA				
Earthing system	**IT**	**TN**		
	Isolated from earth + and - conductors protected and disconnected	**- (or +) earthed** + and - conductors protected and disconnected	**Midpoint earthed (not distributed)** + and - conductors protected and disconnected	**- (or +) earthed** + (or -) conductor only protected and disconnected
				
CB rating				
In ≤ 63 A	 NG125N 4P (2x2P serie)	 NG125N 4P (1P+3P serie)	 C60H-DC 2P	 C60H-DC 2P
80 - 125 A	 NG125N 4P (2x2P serie)	 NG125N or C120N 4P (1P+3P serie)	 C120N 4P (2x2P serie)	 C120N 3P (serie)
125 - 160 A	 NSX160F DC 4P (2x2P serie)	 NSX160F DC 3P (1P+2P serie)	 NSX160F DC 2P	 NSX160F DC 2P (serie)
200 - 630 A	 NSX250/400/630F DC 4P (2X2P serie)	 NSX250/400/630F DC 3P (2P used)	 NSX250/400/630F DC 3P (2P used)	 NSX250/400/630F DC 3P (2P serie used)
IMD	 IM400(1)	Not applicable		

(1) IM10 or IM20 or IM400 see selection criteria "Insulation monitoring system for DC application", page 24

380 V DC application

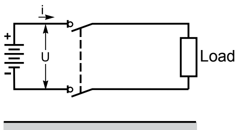
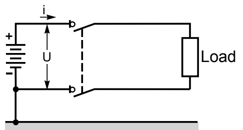
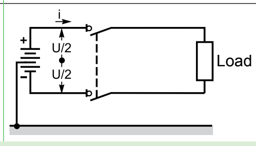
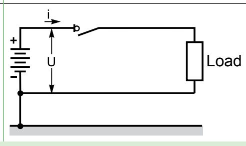
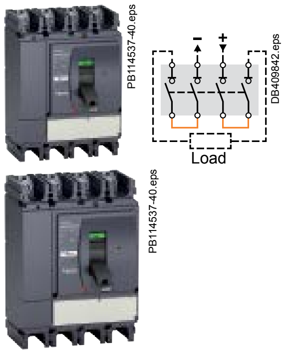
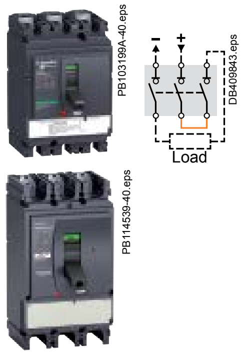
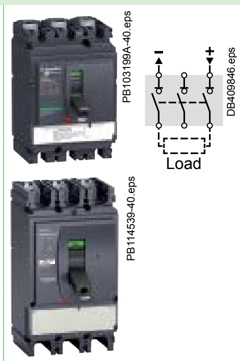
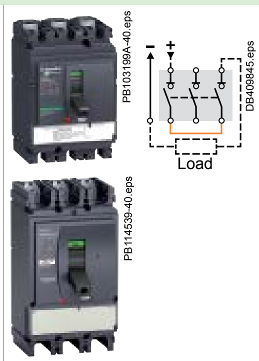
Complement for short-circuit currents higher than 10 kA

380 V DC Presumed short-circuit current 10 kA ≤ Isc ≤ 36 kA				
Earthing system	**IT**	**TN**		
	Isolated from earth + and - conductors protected and disconnected	**- (or +) earthed** + and - conductors protected and disconnected	**Midpoint earthed (not distributed)** + and - conductors protected and disconnected	**- (or +) earthed** + (or -) conductor only protected and disconnected
				
SW rating				
I ≤ 100 A				
	NSX100F DC 4P (2x2P serie)	NSX100F DC 3P (1P+2P serie)	NSX100F DC 2P	NSX100F DC 2P (serie)
125 - 160 A Icu: 36 kA				
	NSX160F DC 4P (2x2P serie)	NSX160FDC 3P (1P+2P serie)	NSX160F DC 2P	NSX160F DC 2P (serie)
I ≥ 250 A Icu: 36 kA				
	NSX250/400/630 DC F 4P (2x2P serie)	NSX250/400/630 DC F 3P (1P+2P serie)	NSX250/400/630 DC F 3P (2P used)	NSX250/400/630 DC F 3P (2P serie used)

IMD see Table D.1

380 V DC application

Table D.2: switch-disconnector selection for 380 V DC according to earthing system

380 V DC Presumed short-circuit current Isc ≤ 36 kA(1)				
Earthing system	**IT**	**TN**		
	Isolated from earth + and - conductors protected and disconnected	**- (or +) earthed** + and - conductors protected and disconnected	**Midpoint earthed (not distributed)** + and - conductors protected and disconnected	**- (or +) earthed** + (or -) conductor only protected and disconnected
				
SW rating				
Ie ≤ 630 A				
	NSX100 160/250 NA 4P (2 x2P serie)	NSX100 160/250 NA 3P (1P+2xP serie)	NSX100 160/250 NA 3P (2P used)	NSX100 160/250 NA 3P (2P serie used)

(1) Prospective short-circuit current of switch-disconnector with related circuit breaker:

	NSX		
	100 - 160NA	250NA	400 - 630NA
NSX100/160	36 kA	36 kA	36 kA
NSX250	-	36 kA	36 kA
NSX400-630	-	-	36 kA

The circuit breaker’s "Ir" setting shall be less than or equal to the rated current of the switch-disconnector.

Insulation monitoring system for DC application

Insulation monitoring is required whenever the DC installation is ungrounded.

Ungrounded DC applications

Ungrounded earthing is selected when continuity of service is critical on the application. Indeed, with ungrounded networks, the occurrence of an insulation fault does not require the trip of protections.

DC ungrounded applications include high availability applications such as :

- Nuclear power generating stations
- Other power generating stations
- Oil and Gas power distribution stations
- Other DC control systems
- Telecom
- Control command systems.

Note: Photovoltaic fields are other examples of ungrounded DC application, but are out of the scope of this document.

Selection of the Insulation Monitor for DC applications

In order to be compatible with the monitoring of ungrounded DC installations, the Insulation Monitor must not operate by the injection of a DC component on the network. Instead, the IMD should inject an alternative signal on the network. Considering the Vigilohm range; the IM9 is not suited for DC network monitoring. Instead the IM10, IM20 and IM400 will be selected.

	 PB106372-35.eps IM10	 PB106374-35.eps IM20	 PB111226-40.eps IM400 and IM400C
Maximum voltage direct connection	345 V DC	345 V DC	480 V DC
Leakage capacitance	40 µF	150 µF	2000 µF
Fault location device	No	No	XD301/312
Communication	No	Yes	Yes

The selection of IMD depends on criterias such as:

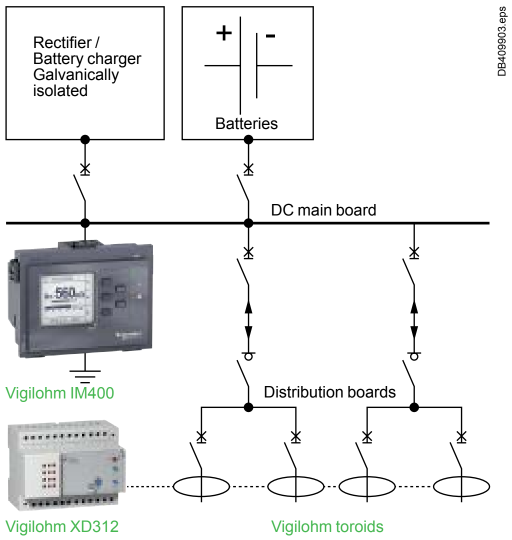
- Size of the network and value of leakage capacitance
- Disturbing loads on the network
- Need for automatic fault locators
- Need for Modbus communication
- The environment: IM400C (coated version of IM400) can be selected when environmental conditions are harsh (humidity, important variation of temperature, salty atmosphere…).

As an option, **Insulation Fault Locators** can be installed in addition to the Insulation Monitor. The locators facilitate OPEX reduction by designating automatically the faulty feeder, keeping the continuity of service on the installation.
If Insulation Fault Locators are needed, the recommendation is to use as the IMD the IM400 together with XD3xx locators.

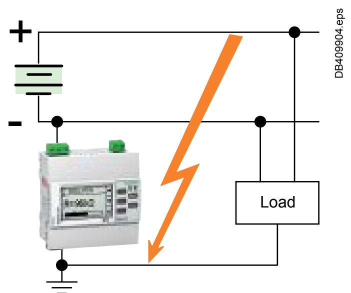
Insulation monitoring system for DC application

Examples of architecture

Example of 380 V DC ungrounded network with Insulation Monitor and Fault Locators.



The Insulation Fault Locator detects the injected current from the IM400 through its toroid. The IM400 injects a low frequency component on the network (2.5 Hz) which allows measuring the network insulation, and locating the insulation fault.
XD312 type of locator is suited for the automatic location of low impedance faults (typically less than 1 kOhm).

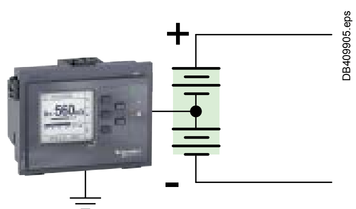


Installation of the IMD- Points of Attention

Connection of the injection

IMD injection is only connected on one of the polarity on the network. Whenever the network is including loads or battery, the injection signal of IMD will be able to flow in both polarities. As a consequence an insulation fault between any of the polarity and the ground will be properly detected.

Note: If there are no load and no battery on the installation, the injection signal of IMD only flows through the polarity it is connected to. An insulation fault between the other polarity and ground may not be detected. If this configuration was to happen, a system has to be implemented to connect for a few minutes the injection of IMD on one polarity, then next few minutes on the other polarity etc.



Vigilohm IM400

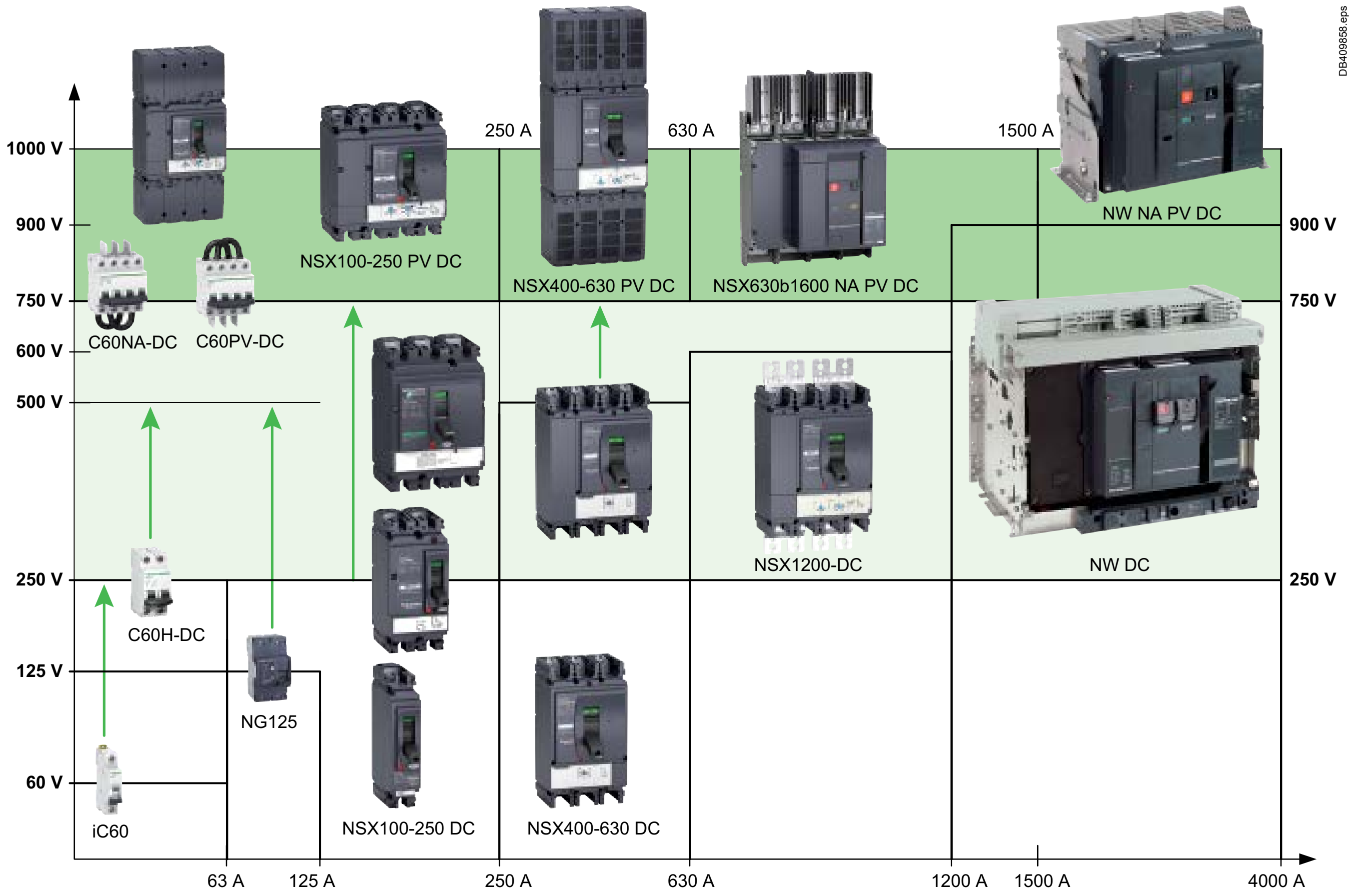
When available, it is suggested to connect the injection of IMD in the central point of the battery.
If this is not possible, then injection is connected to one of the polarities; and this creates an unbalance between the two phase voltages.

Blocking diodes

IMDs measuring current has the ability to go through blocking diodes, back and forward, as long as these diodes are polarized by the load current (high current).
Every part of the DC auxiliary power system that is flown by load current is therefore monitored by the IMD.

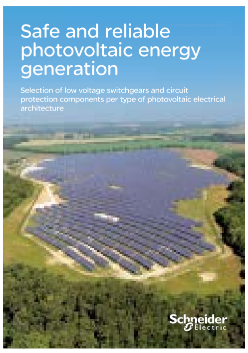
To know more about Schneider Electric's DC offer

In addition to distribution for critical services as described in this guide, DC is also used in two other main applications: battery protection in UPS and storage systems and photovoltaic applications.
Schneider Electric offers a comprehensive DC range for these three applications.



E

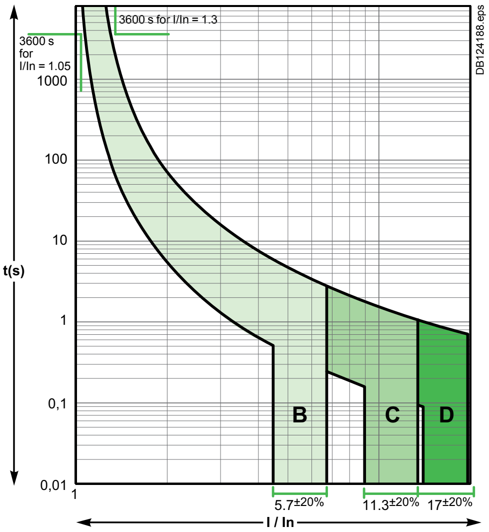
Compact NSX, Compact INS/INV, Masterpact NW, DC-DCPV catalog



Safe and reliable photovoltaic generation
EDCED112005EN

Miniature circuit breakers for 24/48 V direct current applications
CA908032E

Vigilohm catalog
PLSED310020EN



Example: iC60, B, C, D curves, ratings from 6 A to 63 A.

Appendix A: tripping curve for MCB

Choosing the curve

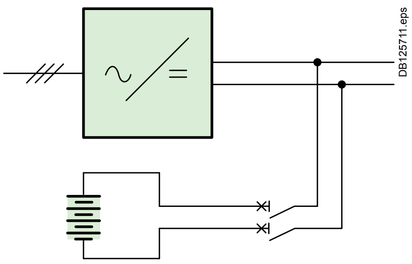
The magnetic tripping threshold must be:

- Higher than the inrush currents due to loads (motors, capacitors, etc.)
- Lower than the short-circuit current at the installation point, which depends on:
  - the short-circuit power of the source (indicated by the manufacturer),
  - the impedance of the supply line.

In direct current:

- The short-circuit power of the sources is generally low: batteries, photovoltaic panels, generators, electronic converters, etc
- The loads generate lower inrush currents than in alternating current (e.g. motor start-up: 2 to 4 times the rated current)
- The magnetic threshold of Acti 9 circuit breakers (relative to the rated current) is higher than in alternating current.

Circuit breaker	iC60 / C120 / NG125				C60H-DC
Curve	Z	B	C	D	C
Magnetic tripping threshold	3.4 …5 In	4.5 …7 In	9…14 In	14…20 In	7….10 In



Batteries with rectifier/charger.

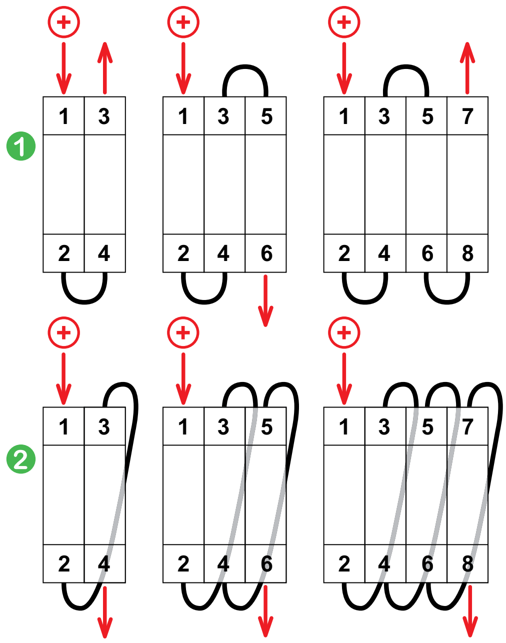
Appendix B: polarized circuit breaker

For a battery application, the current can have 2 flows (battery to load or rectifier to battery).

The polarized circuit breaker or polarized switch-disconnector cannot be used.

Polarized circuit breaker	Non-polarized circuit breaker
C60H-DC	iC60N/H/L
	C120N/H
	NG125N/H/L
	NSX100-160DC F/N/M 1P - 2P
	NSX250DC F/S
	NSX400-630DC F/S

All Schneider Electric switch-disconnectors described in this technical guide are non-polarized.



DB405952.eps

Appendix C: pole connection

Series connection

Series connection of the poles, by dividing the voltage per pole, optimizes the circuit breaking performance for high-voltage networks.
Series connection of the poles of a circuit breaker used in direct current therefore makes it possible to:

- Divide the network voltage by the number of poles
- Have the rated current for each pole
- Have the circuit breaker's breaking capacity for all the poles.

Direction of cabling and cable length

In the case of series connection, the direction of cabling has a major impact on the product's performance.

Usually the first product cabling method 1.
will be used. For special applications where there is only a single possible current direction, the second cabling method 2 is preferable, especially for electrical endurance properties.
Subsequently the cable cross section and length combination should be optimized, depending on the loads. Generally, a greater length and cross section improves performance.

Rating (In)	Cross section (mm²)	Min. shunt length (mm)
⩽ 63 A	⩽ 16	500
	25	200
	35	100
⩽ 125 A	35	300
	50	200

Note: this table gives the minimum cable (shunt) lengths optimizing the equipment's performance according to the cable cross sections.

Clarification concerning voltage drops

Importance of allowing for voltage drops

Voltage drops are an issue that must be taken into account especially in direct current distribution due to:

- The common use of very low voltage (24, 48 or sometimes 12 V):
  - for a given resistance and current in a circuit, increasing relative voltage drops increase as the voltage is lowered,
  - natural voltage drop of batteries in power reserve mode, as they are discharged,
  - criticality of associated applications, often requiring a high level of security and continuity of service.

Cause of voltage drops

Voltage drops are caused by the sum of the resistances in series in the circuit:

- Internal resistance (r) of the source
- Resistance of connecting cables
- Internal resistance of control and protection switchgear, often significant for circuit breakers of low rating (a few amperes) powered at very low voltage
- Generally expressed in mΩ
- Which, if there is no direct data from the manufacturer, can be calculated by dividing the power consumption by the square of the current: $r = P/I^2$
- Spurious resistance of connections.

Voltage drops in the circuit must be less than the rated operating tolerances of the various loads in steady-state conditions and especially at start-up (inrush current).

E

Table G.52.1 – Voltage drop

Type of installation	Lighting %	Other uses %
A – Low voltage installations supplied directly from a public low voltage distribution system	3	5
B – Low voltage installation supplied from private LV supply[a]	6	8

[a] As far as possible, it is recommended that voltage drop within the final circuits do not exceed those indicated in installation type A.

When the main wiring systems of the installations are longer than 100 m, these voltage drops may be increased by 0,005 % per metre of wiring system beyond 100 m, without this supplement being greater than 0,5 %.

Voltage drop is determined from the demand by the current-using equipment, applying diversity factors where applicable, or from the values of the design current of the circuits.

DB406089.eps

IEC 60364-5-52 standard.

Multipolar low rating use (< 4 A) is not suitable for very-low-voltage networks (< 24 V DC).

Life Is On | Schneider Electric

Schneider Electric Industries SAS

35, rue Joseph Monier
CS 30323
92506 Rueil Malmaison Cedex
France

RCS Nanterre 954 503 439
Capital social 896 313 776 €
www.schneider-electric.com

01-2018
CA908061E

Evolutions

This page must be removed before publishing

Indice	Date	Modification	Name
1.1	12/01/2018	Changed title texts	Sonovision
1.0	02/02/2017	Creation	Sonovision