Technical guide

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Regulations and general points

Regulations

In most countries, electrical installations must comply with more than one set of regulations issued by the national authorities or by recognised private bodies. It is essential to take into account these local constraints before starting the design. These regulations may be based on national standards derived from IEC 60364: Low-voltage electrical installations.

Electrical standards

This guide is based on relevant IEC standards, in particular IEC 60364, the UTE (French Electrical Commission), and French standards NFC15-100 and NFC15-500 (ed. 2003). Currently, the safety principles of IEC 60364, 61140, 60479 and 61201 are the basis of most electrical standards in the world.

Calculation parameters linked to electrical standards

For standards other than CENELEC, some parameters needed for calculations are not always defined precisely. In these cases, we take into consideration CENELEC documents (HD384) R064-001, R064-003 or the IEC 60364 standard, where the necessary information is given.

General Points

Low-voltage equipment must be selected according to three main parameters:
- The characteristics of the network.
- The installation rules.
- The environment the circuit being considered will be in.

The properties of the network

These are:
- Their source: transformer (type and power rating).
- The voltage: DC or single-phase or polyphase AC.
- The frequency: e.g. 50 Hz.
- The short-circuit current characteristics at different parts of the circuit.

Installation rules

The installation rules consist of defining the properties of the various switching or protective devices in order to ensure continuity of normal operation, while adhering to the conditions for the protection of individuals and property.

The rules take into account the characteristics of the circuit, the device being powered, how the cables are installed and the environment. They are consolidated in standard NF C 15-100.

“Protection” technical file

This allows all parts of the low-voltage installation to be calculated, applying the obligations imposed by standard NF C 15-100.
It ends with an additional section on the protection of individuals, which is achieved using products that use residual-current circuit breakers (RCCB).

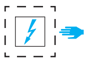
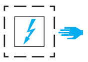
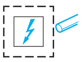
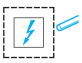
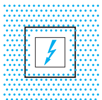
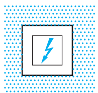
The IEC 60-529 standard describes a system for classifying the degrees of protection provided by low-voltage electrical equipment enclosures up to 1000 V AC and 1500 V DC for two conditions and given using two numbers:

1) The first number (from 0 to 6) represents protection of individuals against access to hazardous parts and protection of equipment against the ingress of solid foreign objects.

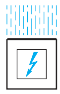
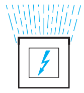
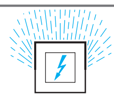
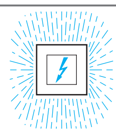
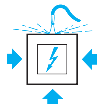
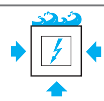
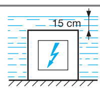
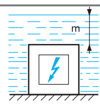
2) The second number (from 0 to 8) indicates the degree of protection provided by the enclosure with respect to harmful ingress of water.

The degree of protection against these two conditions is designated by an IP Code.

First number: Protection against solid objects

IP	Designation	
0		No protection.
1		Protected against solid objects over Ø50 mm (e.g. back of hand).
2		Protected against solid objects over Ø12 mm (e.g. fingers). Required minimum protection against direct contact.
3		Protected against solid objects over Ø2.5 mm (e.g. wires, tools, etc.).
4		Protected against solid objects over Ø1 mm (e.g. small wires, small tools, etc.).
5		Protected against dust (no harmful deposits).
6		Fully protected against dust.

Second number: Protection against liquids

IP	Designation	
0		No protection.
1		Protected against vertically falling drops of water (condensation).
2		Protected against falling drops of water up to 15° from the vertical.
3		Protected against splashes of water up to 60° from the vertical.
4		Protected against splashes of water from all directions.
5		Protected against water jets from all directions.
6		Protected against powerful water jets.
7		Protected against immersion.
8		Protected against long periods of immersion under pressure.

- **IK code: Protection against mechanical shocks**

Defined by standard EN 50-102 (new designation).
It comprises a set of numbers (from 00 to 10) that indicate protection against mechanical impacts.

IK code	Impact energy
00	Not protected
01	0.15 joules
02	0.2 joules
03	0.35 joules
04	0.5 joules
05	0.7 joules
06	1 joules
07	2 joules
08	5 joules
09	10 joules
10	20 joules

Additional letter (optional)
Protection of persons against contact with hazardous parts.

	Designation
A	Protected against access with back of hand.
B	Protected against access with finger.
C	Protected against access with a tool with – Ø2.5 mm.
D	Protected against access with a tool with – Ø1 mm.

Additional letter (optional)
Specific information about the equipment.

	Designation
H	High-voltage equipment.
M	Movement during the water test.
S	Stationary during the water test.
W	Weather conditions.

The French practical guide UTE C 15-103 contains tables showing the minimum IP and IK degrees of protection required for electrical equipment, according to the locations in which they are installed.
For certain locations, marked with an *, the UTE C 15-103 guide indicates higher IP and IK ratings for unusual uses.

Location or premises	IP	IK
Domestic locations		
Baths — see bathrooms		
Laundries	21	02
Cellars, storerooms for food*	20	02
Bedrooms	20	02
Yards*	24	02
Kitchens	20	02
Showers (bathrooms) — see bathrooms		
Attics, lofts	20	02
Gardens*	24	02
Toilet facilities	20	02
Linen rooms (ironing rooms)	20	02
Bin storage areas*	25	02
Bathrooms Zone 0	27	02
Bathrooms Zone 1	24	02
Bathrooms Zone 2	23	02
Bathrooms Zone 3	21	02
Living rooms	20	02
Drying rooms	21	02
Covered patios	21	02
Toilets (cubicles)	20	02
Verandas	20	02
Crawl spaces*	23	07
Technical locations		
Battery (storage rooms)*	23	02
Workshops*	21	07
Garages (< 100 m²)	21	07
Laboratories*	21	02
Air scrubbers	24	07
Machine (rooms)*	31	07
Control rooms	20	02
Electrical departments	20	07
Water booster pumps*	23	07
Boiler rooms and adjacent rooms (P > 70 kW)		
Coal plants*	51	07
other fuels*	21	07
Pressure-reduction stations (gas)*	20	07
Pump rooms*	21	07
Expansion tank room	21	02
Steam or hot water substation*	21	07
Coal bunker*	50	08
Fuel tank*	20	07
Liquefied gas tank*	20	07
Slag storage*	50	08
Garages and car parks over 100 m²		
Parking areas*	21	07
Workshops	21	08
Battery charging areas	23	07
Washing areas within a room	25	07
Greasing areas	23	08
Indoor safety area (fuel distribution)	21	07
Outdoor safety area (fuel distribution)	24	07
Public sanitary facilities		
Shared laundry rooms	24	07
Urinal bathrooms	21	07
Shared washrooms	23	07
Individual washrooms	21	07
Half bathrooms	21	07
Squat toilets with sink	23	07
Public buildings (other than public-access buildings)		
Libraries	20	02
Offices	20	02
Large kitchens*: (UTE C 15-201)		
- from 0 m to 1.10 m high	25	08
- from 1.10 m to 2 m high	24	07
- above 2 m high	23	02
Areas containing blueprint copying machines, computers, etc.	20	02
Barracks	20	07
Medical consultation rooms without special equipment*	20	02
Archives	20	02
Waiting rooms*	20	02
Drafting rooms	20	02
(Restaurant and canteen rooms)	21	07
Meeting rooms	20	02
Sports halls*	20	07
Sorting rooms	20	07
Showrooms*	20	02
Farm areas and sites		
Alcohol (storage)	23	07

Location or premises (cont.)	IP	IK
Threshing floors*	50	07
Sheepfolds (enclosed)	35	07
Laundries	24	07
Butchers	30	10
Distillation rooms	23	07
Storehouses (wine)	23	07
Yards	35	07
Stables	35	07
Poultry farms	35	07
Fertiliser (storage)*	50	07
Cowsheds	35	07
Haylofts*	50	07
Fodder (storage)*	50	07
Manure pits	24	07
Granaries, barns*	50	07
Straw (storage)*	50	07
Pigsties	35	07
Henhouses	35	07
Greenhouses	23	07
Silos*	50	07
Milking sheds	35	07
Miscellaneous facilities		
Fountain pools	37	02
Building sites	44	08
Fairground sites	33	08
Swimming pools Zone 0	28	02
Swimming pools Zone 1	25	02
Swimming pools Zone 2*	22	02
Marina berths	44	08
Roads, yards, gardens, exteriors*	34	07
Wastewater treatment (sites)*	24	07–08
Saunas	34	02
Camping and caravanning sites	34	07
Thermodynamic facilities, air-conditioned rooms and cold rooms		
Height above ground: from 0 m to 1.10 m	25	07
Height above ground: from 1.10 m to 2 m	24	07
Height above ground: above 2 m beneath the evaporator or water drainage tube	21	07
Height above ground: ceiling and up to 10 cm below	23	07
Temperatures < 10°C	23	07
Compressors		
- room	21	08
- monoblock placed outside or on a terrace	24	08
Commercial premises (shops and side rooms)		
Arms manufacturing (storage, workshop)	30	08
Launderette	24	07
Butchers		
- shops	24	07
- cold rooms 5–10°C	23	07
Bakeries – Patisseries (bakery outlets)*	50	07
Coffee-roasting shops – Cafes	21	02
Coal, wood, heating oil	20	08
Delicatessen (production site)	24	07
Confectionery (production site)	20	02
Shoe-repair shops	20	02
Dairy/cheese shops	24	02
Pharmacies – Paint (storage)	30	07
Furniture makers*	50	07
Exhibition halls – Art Galleries*	20	02
Florists	24	07
Fur shops	20	07
Fruit – Vegetable shops	24	07
Seed shops*	50	07
Bookshops – Stationers	20	02
Car/bike mechanics and accessories shops	20	08
Shipping shops	20	08
Furniture shops (antiques, second hand)	20	07
Mirror (manufacturers)	20	07
Wallpaper (stockroom)	20	07
Perfume (stockroom)	20	02
Pharmacy (stockroom)	20	02
Photography (laboratory)	23	02
Plumbers (stockroom)	20	08
Fishmongers	25	07
Dry-cleaners	23	02
Hardware shop	20	07
Locksmiths*	20	07
Spirit, wine and alcohol shops	20	07
Upholsterers (carding)*	50	07
Tailors – Clothing shops (stockroom)	20	02
Animal groomers, veterinary clinics	35	07

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Industrial premises (cont.)	IP	IK
Slaughterhouses*	55	08
Batteries (production)	33	07
Acids (production and storage)	33	07
Alcohols (production and storage)	33	07
Aluminium (production and storage)*	51	08
Animals (farming, fattening, sale)	45	07
Asphalt, bitumen (storage)*	53	07
Beating, carding wool*	50	08
Laundries*	24	07
Woodworking*	50	08
Butchers	24	07
Bakeries	50	07
Breweries	24	07
Brickyards*	53	08
Rubber (working and processing)*	54	07
Metal carbides (production and storage)*	51	07
Quarries*	55	08
Cardboard (production)	33	07
Cartridge factories*	53	08
Celluloid (production of objects)	30	08
Cellulose (production)	34	08
Bottling lines	35	08
Coal (storage)*	53	08
Cured meat*	24	07
Metal workshop	30	08
Lime (kilns)*	50	08
Cloth (storage)	30	07
Chlorine (production and storage)	33	07
Chrome plating	33	07
Cement works*	50	08
Coke works*	53	08
Glue (production)	33	07
Liquid fuels (storage)*	31	08
Oil (processing)*	51	07
Leather (production and storage)	31	08
Copper mineral treatment	31	08
Pickling*	54	08
Detergent (production and storage)*	53	07
Distilleries	33	07
Electrolysis	23	08
Ink (production)	31	07
Fertiliser (production and storage)*	53	07
Explosives (production and storage)*	55	08
Iron (production and storage)*	51	08
Mills*	50	07
Pelt (beating)*	50	07
Cheese dairy	25	07
Gas (plants and storage)*	31	08
Tar (treatments)	33	07
Seeds*	50	07
Metal engraving	33	07
Oil (extraction)	31	07
Hydrocarbons (production)*	33	08
Printing works	20	08
Dairies	25	07
Laundrettes, public washhouses	25	07
Liquids (production)	21	07
Halogenated liquid (use of)	21	08
Flammable liquids (storage and workshops where they are used)	21	08
Machine (rooms)	20	08
Magnesium (production, working and storage)	31	08
Plastics (production)*	51	08
Woodwork*	50	08
Metal (treating)*	31	08
Combustion engine (testing)	30	08
Munitions (storage)	33	08
Nickel (processing minerals)	33	08
Household waste (processing)*	54	07
Paper (storage)	31	07
Paper (production)	33	07
Perfume (production and storage)	31	07
Pulp (preparation)	34	07
Paint (production and storage)	33	08
Lime (grinding and storage)*	50	07
Explosives factories*	55	08
Chemical products (production)*	30	08
Oil refineries*	34	07
Meat salting	33	07
Soap (production)	31	07
Sawmills*	50	08
Locksmiths	30	08
Hair and bristle (preparation of)*	50	08
Soda (production and storage)	33	07
Sulphur (processing)*	51	07
Spirits (storage)	33	07
Sugar refineries*	55	07
Tanneries	35	07
Dyers	35	07
Woven fabrics (production)*	51	08
Varnish (production, application)	33	08
Glassworks	33	08
Zinc (working with)	31	08

	Public-access buildings	IP	IK
	The installations must meet the general conditions of the safety regulations that apply to these establishments ("EL" articles) Recital, conference and meeting rooms, performance halls and multi-purpose rooms:		
J	Access for the elderly and handicapped		
	Social and medical-social establishments	20	02
L	Theatres*	20	02
	Stages	20	08
	Scenery storage	20	08
	Wig- and shoemaking areas	20	07
M	Retail stores, commercial centres:		
	Retail spaces	20	08
	Storage and handling of packaging materials	20	08
N	Restaurants and drinking establishments	20	08
O	Hotels and boarding houses:		
	Bedrooms	20	02
P	Dance halls and games rooms	20	07
R	Teaching establishments, holiday camps:		
	Teaching rooms	20	02
	Dormitories	20	08
S	Libraries, documentation centres	20	02
T	Exhibitions		
	Halls and rooms	20	02
	Material and merchandise reception rooms	20	07
U	Medical facilities:		
	Rooms	20	02
	Cremation*	21	07
	Surgical facilities	20	07
	Centralised sterilisation*	24	02
	Pharmacies and laboratories, with over 10 litres of flammable liquids*	21	02
V	Places of worship	20	02
W	Administrative buildings, banks	20	02
X	Indoor sports establishments:		
	Halls*	20	07
	Rooms with refrigeration facilities	21	08
Y	Museums	20	02
PA	Open-air establishments*	23	08
CT	Marquees and tents	44	08
SG	Inflatable structures	44	08
PS	Covered car parks*	21	08
	Public rooms in public-access buildings:		
	Storage areas, stockrooms, packaging room	20	08
	Archives	20	02
	Film and magnetic media storage	20	02
	Linen rooms	21	02
	Laundries	24	07
	Various workshops*	21	07

Employee-access areas

Disconnection of energy sources
At the source of any installation and the source of every circuit there must be a device allowing the installation or circuit to be disconnected from its source.
This function may be provided by a protective device, control device, or emergency switching device that is able to disconnect the installation or circuit.
It must be made impossible to inadvertently reconnect the installation or circuit.

Emergency switching device
In any final circuit, an emergency switching device must be installed that is easily recognisable and can be easily and readily accessed, allowing the power to be cut to all active conductors.
This device may control multiple final circuits.

Earth electrodes and protective conductors
Protective conductor connections must be made individually to the main earth terminal such that if one protective connection becomes separated from the main earth terminal, all of the other protective connections will remain connected.

Public-access buildings (PAB)

Installation of electrical cabinets or boxes in rooms or passageways that are accessible to the public

Examples of enclosure fire resistance
Refer to the IEC 60 695-2-1
set of series of standards.

“Normal” boards
Any “normal” board must be installed in one of the following:
- In an electrical room.
- In a room or passageway that is not accessible to the public.
- In a room or passageway that is accessible to the public, with the exception of protected stairs (fire escapes), provided that one of the provisions below is adhered to (see table).

Power installed	**Implementation of fuse board**
P ≤ 100 kVA	In an electrical cabinet or box that meets one of the following conditions: - Metal enclosure - Enclosure that passes the 750°C glow-wire test (defined in standard IEC 60695-2-1), if each device meets the same condition
P > 100 kVA	In an metal electrical cabinet or box if each device passes the 750°C glow-wire test (defined in standard IEC 60695-2-1) Or in an enclosure with brick walls, fitted with a fire-resistant doorset rated for 30 minutes and, if necessary, with ventilation exclusively via baffles

Key locking:
The controls for control or protective devices, when they are located less than 2.5 metres from the ground, **must require a key or tool, where this key** or tool must allow either the device to be controlled or the **cabinet or box** in which it is located to be opened.

Protection against indirect contact may be provided:
- Either via double insulation or increased insulation of the live parts.
- Or via additional insulation added to the main insulation when the equipment is installed.

Selection of boxes – cabinets – compliance measures

- Include a locking system for each disconnection device or on the main switching device, or provide each box with a key-operated lock.
- Include a main disconnection switch (readily, easily and quickly accessible, etc.) fitted with a system to lock it in the off position.
  Solution 1: Lockable switch.
  Solution 2: Contactor + emergency shut-off button with key lock.
  Solution 3: Lockable switch + removable control (for a lockable cabinet).
- Include a earthing strip such that each conductor is connected to and individual connection point.

Fire resistance of the enclosure of electrical cabinets, boxes and accessories

Electrical cabinets and boxes	Glow-wire test result
mini gamma	850°C
gamma 13 and 18	850°C
golf	850°C
nodeis	850°C
vega surface mounting	750°C
vega flush mounting	850°C
VL	850°C
gala	750°C
volta	850°C
vega D	750°C
vega D flush mounting	850°C
vector IP55 and vector security	850°C
FW	850°C

Accessories	Glow-wire test result
Control block	960°C
Control panels	960°C
Door (gamma 13 and 18)	850°C

Selection of boxes – cabinets with key lock

Boxes	Cabinets
gamma 13 and 18 – vega – volta – vega D vector IP 55 orion plus polyester – orion plus metal	quadro

Class II boxes – cabinets by construction:

Boxes	Cabinets
vega – volta – vega D vector IP 55 orion plus polyester	FW

Class II boxes – cabinets by installation:

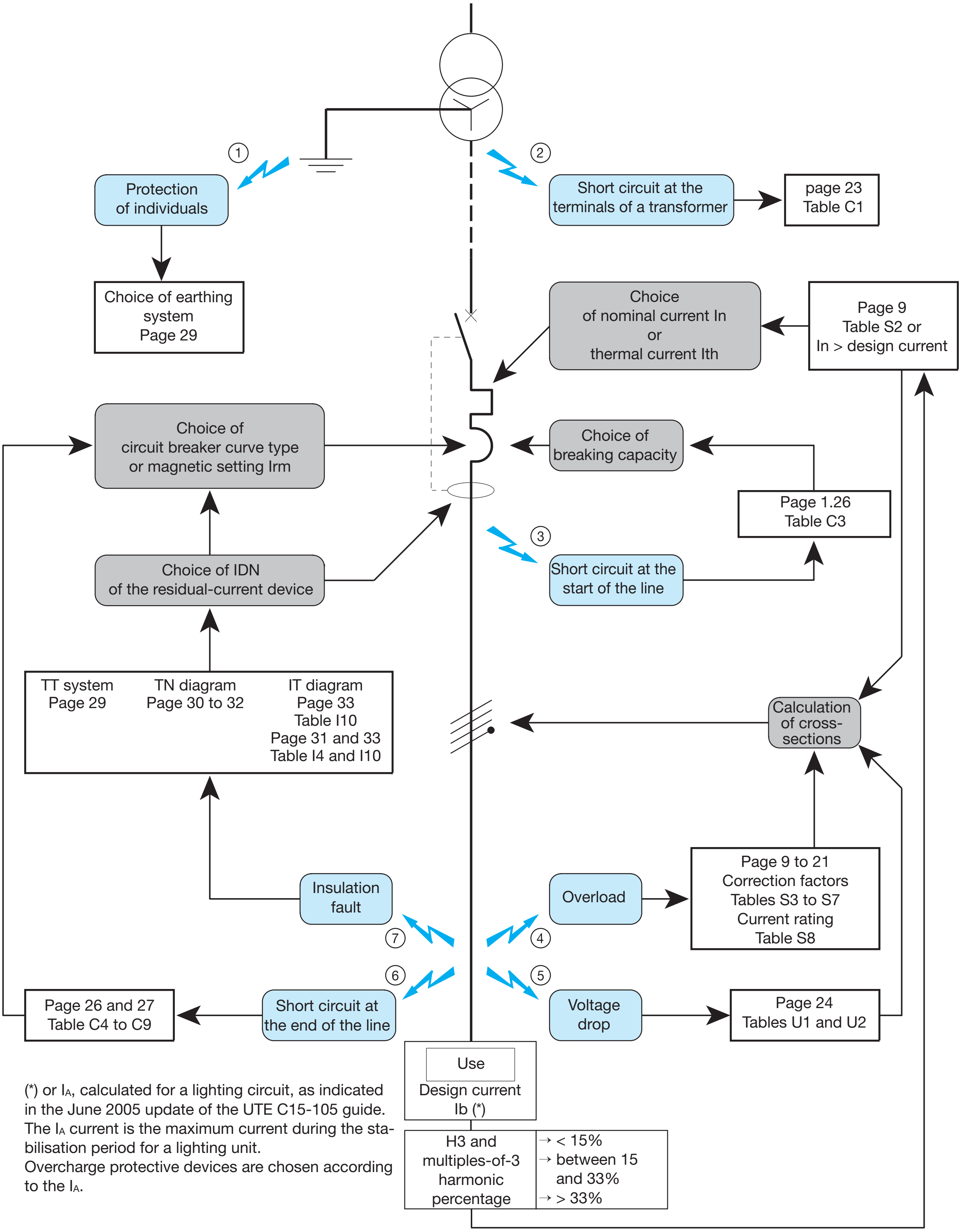
(When the main circuit breaker is not a residual-current circuit breaker)

- gamma boxes: by putting a back plate and insulating caps over the mounting screws for the box.

How to use

(According to the French practical guide UTE C 15-105 guide of June 2003).
In this type of circuit, protection of wiring and individuals is provided using the diagram below to determine the following:
- The cross-section of conductors.
- The choice of overload protective devices.
- The choice of short-circuit protective devices.
- The choice of devices for protection of individuals.

This diagram allows you, throughout the installation and by following the order of ① to ⑦, to:
- Identify risks. (light blue box)
- Analyse these risks. (white box)
- Find a solution. (grey box)



(*) or I_A, calculated for a lighting circuit, as indicated in the June 2005 update of the UTE C15-105 guide.
The I_A current is the maximum current during the stabilisation period for a lighting unit.
Overcharge protective devices are chosen according to the I_A.

Surrounding area and method of installation

Protection against overloads is ensured when the following conditions are fulfilled.

$$Iz \geq \frac{K \times I_{protection}}{f}$$

The protective current $I_{protection}$ depends on the particular installation:

Type of system	Single-phase	Three-phase without neutral	Three-phase with neutral		
Degree of harmonic distortion	any	any	H3 ≤ 33%	H3 > 33%	
Single or multi-core cable	any	any	any	Multi-core cable **Sphase < Sneutral** 1 calc. for the phase ↓↓ AND 1 calc. for the neutral ↓↓	Multi-core cable **Sphase = Sneutral**
	↓↓ ↓↓ ↓↓	↓↓ ↓↓ ↓↓	↓↓ ↓↓ ↓↓		↓↓ ↓↓ ↓↓

Condition	Device	Protective current		
Ib (*) ≤ Ith ≤ Iz	Adjustable thermal-trip circuit breaker	**$I_{protection}$ = Ith, current setting**	AND	**$I_{protection}$ = $Ib_{neutral}$ Design current for the neutral conductor**
Ib(*) ≤ In ≤ Iz	Non-adjustable circuit breaker or fuse	**$I_{protection}$ = In, protection rating**	AND	

Iz: Current-carrying capacity in the conductor to be protected page 22.
Ib: Design current for the circuit (*) or I_A maximum current during the stabilisation time for a lighting unit.
K: Factor determined by the type and rating of the protective device (see table S1 below).

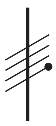
f: Correction factor.
This factor relates to the installation conditions and area surrounding the circuit to be calculated.
Each condition, if involved, adds a coefficient (f1 to f12).

Table S1

In rating	Circuit breaker	gG fuse
In < 16 A	1	1.31
In ≥ 16 A	1	1.1

Coefficient f1: Type of system

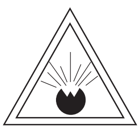
if unbalanced system **f1** ⇨ 0.84



or if third and multiples-of-three current harmonic percentages are greater than 15%

Coefficient f2: Risk of explosion

if risk of explosion **f2** ⇨ 0.85



Coefficient f3: Ambient temperature

if ambient temperature is not 30 °C **f3** ⇨ see table S3

Coefficient not used for underground installation

Table S3

Temperature in °C	Insulation around conductor		
	Elastomer (rubber) A or HO5R... A or HO7R...	Polyvinyl chloride (PVC) A or HO5V... A or HO7V...	Cross-linked polyethylene (PEX), butyl, ethylene propylene (EPR) U 1000R...
10	1.29	1.22	1.15
15	1.22	1.17	1.12
20	1.15	1.12	1.08
25	1.07	1.06	1.04
35	0.93	0.94	0.96
40	0.82	0.87	0.91
45	0.71	0.79	0.87
50	0.58	0.71	0.82
55		0.61	0.76
60		0.5	0.71
65			0.65
70			0.58
75			0.50
80			0.41

Values used for the example on page 27

Table S2

Ith current (xIn)	Types of circuit breakers																							
	x160		**x160**							**x250**					**h250LSI**			**h630LSI**			**h1000LSI**		**h1600LSI**	
	18 kA		**25/40 kA**							**40 kA**					**50 kA**			**50/70 kA**			**50/70 kA**		**50/70 kA**	
	Nominal current In																							
	125	**160**	**25**	**40**	**63**	**80**	**100**	**125**	**160**	**100**	**125**	**160**	**200**	**250**	**40**	**125**	**250**	**250**	**400**	**630**	**800**	**1000**	**1250**	**1600**
0.4															16	50	100	100	160	252	320	400	500	640
0.5															20	63	125	125	200	315	400	500	625	800
0.63	79	101	16	25	40	50	63	79	101	63	79	101	126	158	25	79	158	158	252	397	504	630	788	1008
0.8	100	128	20	32	50	64	80	100	128	80	100	128	160	200	32	100	200	200	320	504	640	800	1000	1280
0.85															34	106	213	213	340	536	680	850	1063	1360
0.9															36	113	225	225	360	567	720	900	1125	1440
0.95															38	119	238	238	380	599	760	950	1188	1520
1	125	160	25	40	63	80	100	125	160	100	125	160	200	250	40	125	250	250	400	630	800	1000	1250	1600

771.314.2, 771.465, 771.524, 771.533

- The minimum cross-sections required for conductors (see table below) are determined according to the installed power ratings and taking into account the limits of points of use powered by each final circuit.
- An installation must be able to have a sufficient number of points of use to meet the normal requirements of users, i.e. at least those indicated in the table.
- All circuits must be protected by a protective device that is either a fuse or a circuit breaker, and for which the maximum rated current is equal to the value indicated in the table.

Type of circuit	Minimum cross-section of copper conductors in mm²	Maximum rated current In (in A) circuit breaker	fuse	Equipment – Installation conditions	
16A socket	2.5	20	16	- Maximum of 8 sockets per circuit.	The minimum number of 16A sockets must be: - 3 per bedroom. - 1 per 4 m² span with a minimum of 5 in living rooms of up to 40 m². **For living rooms larger than 40 m², the number will be determined in agreement with the project manager and/or user, with a minimum of 10 sockets.** - 6 non-specialised sockets in the kitchen, of which 4 are placed above worktops. These sockets are not to be installed above sinks or hobs (except at 1.80 m from the ground, above the hobs, provided for the cooker hood). **When it is an open-plan kitchen and living room, the area of the living room is considered as being equal to the total area of the room, minus 8 m².** - At least 1 in other rooms > 4 m² and passageways, with the exception of bathrooms and detached buildings (garden sheds, garages, etc.).
	1.5	16	Not permitted	- Maximum of 5 sockets per circuit	
Socket with a switch	1.5	16	10	- 1 control switch for a maximum of two 2 sockets (located in the same room). - 1 remote switch, contactor or other similar device may control more than two sockets.	
Specialised socket or circuit	2.5	20	16	- At least 3 circuits (2 circuits for F1 accommodation) intended to power appliances such as washing machines, dishwashers, oven, freezers and tumble dryers. - 1 circuit must be planned for each additional large household appliance.	
MEV	1.5	2	Not permitted	Specialised circuit. The protection for the MEV can be increased up to 16A (special cases). The MEV circuit must include a shut-off device. The dedicated circuit breaker provides this function.	
Servo-control circuit, pilot wire, energy manager systems	1.5	2	Not permitted		

Type of circuit	Minimum cross-section of copper conductors in mm²	Maximum rated current In (in A) circuit breaker	 fuse	Equipment – Installation conditions
Hobs	6 for single-phase 2.5 for three-phase	32 20	32 16	- 1 specialised circuit must be provided (junction box or socket).
Free-standing oven	2.5	20	16	- specialised circuit (junction box or socket).
Lighting	1.5	16	10	- Maximum of 8 lighting points per circuit. - Minimum of 2 circuits in accommodation > 35 m². **The lighting point can be created either:** **- Via a ceiling rose.** **- Via one or more wall lights.** **- Via one or more controlled sockets.** a) In bedrooms, living rooms and kitchens, when the ceiling is tiled, the ceiling lighting point is mandatory. It may be supplemented with wall lights or one or more controlled sockets. b) In other rooms, it must be on the ceiling or as wall lights. This provision does not apply to detached buildings (garden sheds, garages, etc.).
Outdoor lighting	1.5	16	10	- 1 lighting point must be provided per main entrance or service entrance that connects directly to the accommodation. - 1 specialised circuit for outdoor lighting for detached buildings. - It is recommended to provide a lighting point near garage doors.
Roller shutters	1.5	16	10	- Specialised circuit.
Water heaters	2.5	20	16	- Specialised circuit.
Convector heaters, heating panels (230 V) - 2250 W - 3500 W - 4500 W - 5750 W - 7250 W	 1.5 1.5 2.5 2.5 4 4 6 6	 / 16 / 20 / 25 / 32	 10 / 16 / 20 / 25 /	- Specialised circuit. - Number of devices limited by total power rating.
Underfloor heating (230 V) - 1700 W - 3400 W - 4200 W - 5400 W - 7500 W	 1.5 2.5 4 6 10	 16 25 32 40 50	Not permitted	- Only circuit breakers may be used for protection against overloads.

Other specialised circuits are to be created, for example for each of the following applications when they are planned:
- Boiler
- Air conditioner
- Pool
- Automation functions (domestic, alarms, etc.).
- Distribution board
- Bathroom heating unit
- Heat pump
- Heating unit

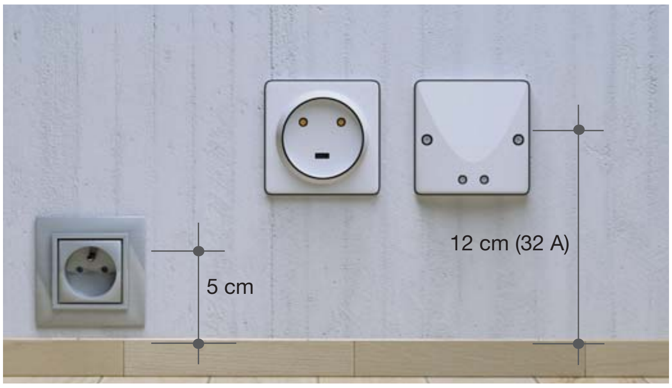
Sockets

☐ **Socket properties**

- All sockets must have shutters (child protection).
- When in use, they must not come out of their frame, exposing the conductor terminals or power cables. The mounting screws must ensure this is the case.
- When renovating, when existing enclosures do not allow this, click-in systems may still be used.

☐ **Minimum heights for sockets according to the French standard**

The heights of 5 cm and 12 cm given below apply for any method of installation and any SC external factors (presence of water).



☐ **Installation restrictions**

- Counting of number of sockets
  When sockets are fitted in a single enclosure, they are counted as follows:

For countries other than France, please see the country-specific regulations/specifications for the locations of sockets.

Number of sockets per enclosure	1	2	3	4	> 4
Number of sockets counted **in 1 circuit**	1	1	2	2	3

- Number of lighting points
  The number of lighting points powered by a single circuit is limited to 8. For spotlights or lighting strips, each 300 VA counts as one lighting point.

771.411.3.2

- Protection against indirect contact is provided by bonding (main potential equalisation connection and earthing) combined with automatic cutting of the power supply.
- In France, installations powered by a public distribution network are created as a TT system.
- In TT systems, the protective devices against indirect contact are residual-current circuit breakers.
- The impedance of the earth electrode (RA), to which metal exposed conductive parts in an installation are connected, must be at most equal to 100 V.

$$RA \leq \frac{UL}{I\Delta n}$$

UL → safety voltage limit (50 volts)

IΔn → nominal sensitivity of the residual-current circuit breaker at the start of the installation (in amperes)

for { UL: 50 V ; IΔn = 500 mA RA ≤ 100 Ω }

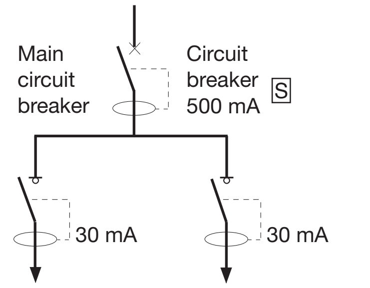
- Maximum value of the earth electrode according to the sensitivity of the RCCB at the start of the installation.

Maximum IΔn		Maximum RA (in ohms)
Average sensitivity	500 mA	100
	300 mA	167
	100 mA	500
High sensitivity	≤ 30 mA	500

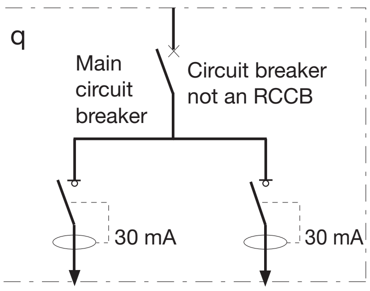
- Residual-current circuit breakers with adjustable sensitivities must not be used if the protection of individuals is not provided on all settings.
- Automatic resetting functions are not permitted for RCCBs in domestic settings (531.2.1.7).

• Residual-current circuit breakers with adjustable sensitivities must not be used if the protection of individuals is not provided on all settings.

• Automatic resetting functions are not permitted for RCCBs in domestic settings (531.2.1.7).



When the main circuit breaker at the beginning of an installation is an RCCB, its sensitivity must be 500 mA and it must be selective.



When the main circuit breaker at the start of the installation is not an RCCB, the subscriber's unit must be class II.

771.411.3.3

• All circuits must have and earth conductor.
For class II fitted electrical equipment, the earth conductor must not be connected.

Emergency circuit switching

771.463

• The main control and protective device installed at the source of the installation (main circuit breaker) may provide the emergency circuit switching functions if it is located within living quarters.

If it is located in a garage or annex, the must be direct access between this room and the living quarters.
If this is not the case, another directly operated device enabling the power to be cut must be placed within the living quarters (e.g. switch or circuit breaker).

771.558.1.6

• The control for the switching device must be at a height of between 0.90 and 1.80 m from the finished floor. This height is limited to 1.30 m in premises for the handicapped or elderly.

Disconnection

771.462

• All circuits must have, at their source, an disconnection device on all active conductors, including the neutral conductor.

• Main circuit breakers, cut-out switches and miniature circuit breakers that bear the NF label fulfil this requirement.

Additional protection against direct contact

415.1.

- The use of an RCCB with a sensitivity of at most 30 mA is recognised as an additional protective measure:
  - In the event of the failure of other protective measures against direct contact (notably for wear or deterioration of flexible cables supplying movable devices).
  - In the event of carelessness by users.

771.531.2.3.2

- All circuits in the installation must be protected by RCCBs with a maximum sensitivity of 30 mA except:
  - Those powered via an isolation transformer.
  - A surge arrestor circuit installed at the source of the installation (this circuit must be protected by a selective or time delay RCCB that passes the 5 kA test for a 8/20μs current wave).
- For a distribution circuit, the 30 mA RCCB(s) are installed:
  - At the source of the circuit.
  - Or on the distribution board.
- The protection of external circuits supplying installations not attached to the building must be separate from the protection of internal circuits.
- According to the desired continuity for each application, protection using 30 mA RCCBs can be either:
  - A single circuit breaker for a group of circuits.
  - Or an individual circuit breaker for a specialised or general circuit (washing machine, dishwasher, tumble dryer, etc.).
- For heating:
  - In electrical appliances with a pilot wire, all of the heating circuits, including the pilot wire, are placed downstream of a single 30 mA RCCB.
  - In underfloor heating (radiant heating), the protection must be provided via a 30 mA RCCB and rated for the power of the heating elements of at most:
  - 13 kW (400 V).
  - 7.5 kW (230 V).
- The number, type and rating for the RCCBs are given in the table. The table for selecting RCCBs is valid for:
  - A single-phase branch with power rating of ≤ 18 kVA, with or without electric heating.
  - A three-phase branch.
- If using RCCBs, their type and number must be at least that indicated in the table, with their rating being adapted to the circuit(s) to be protected.
- Automatic resetting functions are not permitted for highly sensitive RCCBs (531.2.1.7).

Area of living quarters	**30 mA RCCBs: minimum requirements**		
	Number	**Rating**	**Type**
Area ≤ 35 m^2	1 1	25 40 A	AAC A [(1)]
35 m^2 < area ≤ 100 m^2	2 1	40 A[(2)] 40 A	AC A[(1)]
Area > 100 m^2	3 1	40 A[(2)] 40 A	AC A[(1)]

(1) The type A 40 A RCCB must protect the following circuits:
- The specialised cooker or hob circuit.
- The specialised washing machine circuit.
- Optionally, two non-specialised circuits (lighting or sockets).

If this RCCB is used to protect one or two additional specialised circuits, the rating must be 63 A.

(2) The type AC 40 A RCCB must be replaced by a type AC 63 A RCCB when heating and electric water heater circuits, whose power rating is over 8 kVA, are placed downstream of a single RCCB.

□ Type A RCCBs

Depending on the technology used, certain equipment, when faulty, can produce a DC component.
Type A RCCBs are designed to detect these types of fault currents, which are not detected by type AC RCCBs.

□ Type HI RCCBs (high immunity)

Products with "increased immunity" reduce the risk of false triggers when protecting equipment that can cause interference (e.g. micro-computers).

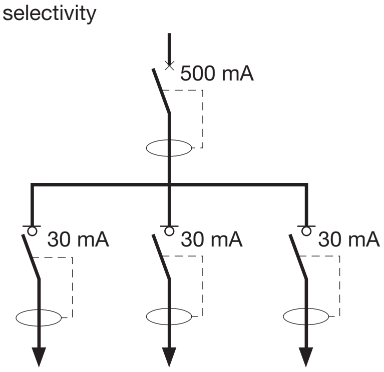
It is advisable to also protect the freezer circuit with a type HI RCCB in order to mitigate the health consequences that can arise from consecutive false triggers (or to power it directly via an isolation transformer).

Total selectivity between RCCBs

535.4.3.1

- Total selectivity allows the cutting of power to the whole installation in the event of an insulation fault on a final circuit to be avoided.
- Total selectivity is only provided between the 30 mA RCCBs and the main circuit breaker if the latter is a selective circuit breaker.

Total selectivity



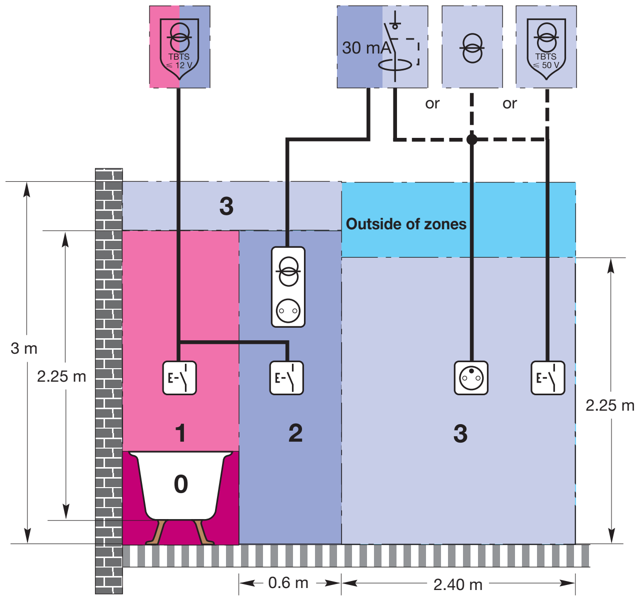
701.3

- The standard defines four zones, 0, 1, 2 and 3, which cover and surround baths and shower trays.
  It also includes measures restricting the properties of devices installed (class II, SELV, etc.) and the associated protective devices.

Devices authorised in the different zones

701.53

Devices:



Key:

SELV source < 12 V~ or 30 V ⎓ to be installed outside of zones 0, 1 and 2

SELV source < 50 V

▣ Class II equipment

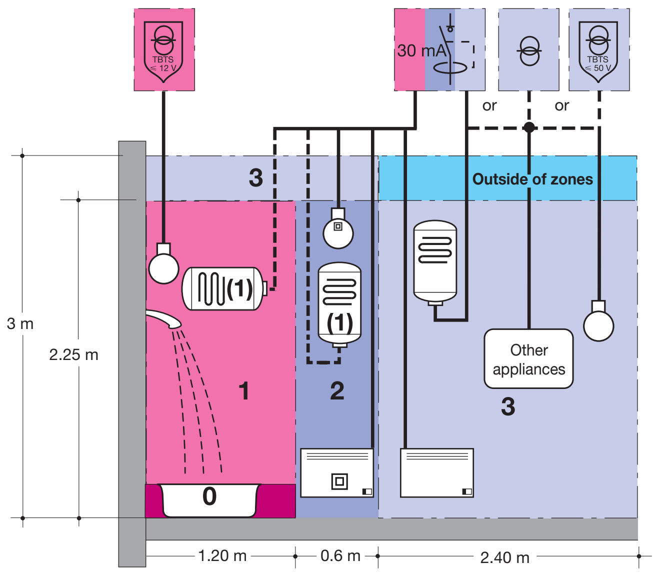
In bathrooms, sockets installed in the floor are not permitted.

Other equipment (devices) whose use is permitted

701.55

- Zones 0 and 1: Only devices intended for use in the bath, powered with SELV limited to 12 V~ or 30 V are permitted = the source being installed outside of zones 0, 1 and 2.
- Zone 2: Only light fixtures, heating units and other appliances, provided that this equipment is class II and is protected by a RCCB with a sensitivity of at most 30 mA.
- Zone 3: Appliances are permitted, provided that they are:
  - Powered individually by an isolation transformer (§413.3 NF C 15-100).
  - Powered by SELV (§414 NF C 15-100).
  - Or protected by an RCCB with a sensitivity of at most 30 mA.
- Underfloor electrical heating elements other than those powered by SELV are not permitted below zone 1 or in walls around this zone. Underfloor heating elements may be installed below zones 2 and 3 and outside of the zones, provided that the are covered with a wire mesh that is earthed or if it has a metal enclosure that is earthed, connected to a potential equalisation connection as defined in §701.415.2. NF C 15-100.

Appliances:



Key:

Source via isolation transformer

High-sensitivity RCCB ≤ 30 mA

Special case for water heaters

701.55.2

- Storage water heaters must be installed in zone 3 or outside of the zones.
  If the dimensions of the bathroom do not allow it to be placed in zone 3 or outside of the zones, these units can be installed:
  - In zone 2.
  - In zone 1, if it is a horizontal model and is placed as high up as possible.

  The storage water heater is powered via a junction box that is accessible and complies with the IP requirements for the area in which it is installed.
  The connection between the water heater and the junction box must be as short as possible.
- Instantaneous water heaters may be installed in zones 1 and 2 if they meet the following conditions:
  - Protected via a RCCB with a sensitivity of at most 30 mA.
  - It is powered directly by a cable, without the insertion of a junction box.

Space below the bath

701.320.2

- The space below the bath or shower and their sides is similar to zone 3 if it is sealed and accessible via a hatch intended for this purpose that can only be opened using a tool.
- Otherwise, the rules for zone 1 apply to this space.
- In both cases, the IPX4 degree of protection is the minimum requirement.

Degree of protection for installed equipment by zone

Table S2

Zones	0	1	2	3
Degree of protection	IPX7	IPX4(**)	IPX4(*)	IPX1 (*)
Wiring	Powered by SELV limited to 12 V~ or 30 V	II (a)	II (a)	II

II Permitted if class II or equivalent to class II.
(a) Limited to those needed to supply devices located in this zone.
(*) IPX5 if this zone will be sprayed with water for cleaning purposes (e.g. public baths).
(**) IPX5 if this zone will be sprayed with water for cleaning purposes (e.g. public baths and showers with horizontal jets).

Coefficient f4: Method of installation

f4 ⇨ see table S4

Table S4 below gives, according to the method of installation and type of cable or conductor, the following information:
- Method of installation number (1 to 74) for the correction factor in the following tables, when it is needed.
- Reference method (B to F) for the current-carrying capacity and sections of tables S13A and S13B.
- Coefficient f4 if indicated.

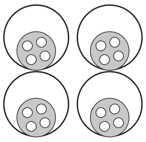
Table S4

No.	Description	Reference method	f4
	Conduits embedded in heat-insulating walls with:		
1	- Insulated conductors	**B**	**0.77**
2	- Multi-core cables	**B**	**0.70**
	Surface-mounted conduits with:		
3	- Insulated conductors	**B**	**-**
3A	- Single- or multi-core cables	**B**	**0.90**
	Surface-mounted shaped conduits with:		
4	- Insulated conductors	**B**	**-**
4A	- Single- or multi-core cables	**B**	**0.90**
	Conduits embedded in walls with:		
5	- Insulated conductors	**B**	**-**
5A	- Single- or multi-core cables	**B**	**0.90**
	Single- or multi-core cables with or without a sheath:		
11	- Wall mounted	**C**	**-**
11A	- Ceiling mounted	**C**	**0.95**
12	- On solid cable trays	**C**	**-**
13	- On horizontal or vertical perforated cable trays	Multi-core cable **E** / Single-core cable **F**	**-**
14	- On hooks or welded wire-mesh	**E** / **F**	**-**
16	- On cable ladders	**E** / **F**	**-**
17	Single- or multi-core cables hanging on a suspended cable, or self-supporting cables	**E** / **F**	**-**
18	Conductors that are bare or isolated on insulators	**C**	**1.21**
21	Single- or multi-core cables in airspaces	**B**	**0.95**
	Conduits in airspaces with:		
22	- Insulated conductors	**B**	**0.95**
22A	- Single- or multi-core cables	**B**	**0.865**
	Shaped conduits in airspaces with:		
23	- Insulated conductors	**B**	**0.95**
23A	- Single- or multi-core cables	**B**	**0.865**
	Shaped conduits embedded in the building with:		
24	- Insulated conductors	**B**	**0.95**
24A	- Single- or multi-core cables	**B**	**0.865**
25	Single- or multi-core cables: - In the space between the ceiling and the false ceiling - Installed on non-removable suspended false ceiling	**B**	**0.95**
	Horizontal wall-mounted cable duct with:		
31	- Insulated conductors	**B**	**-**
31A	- Single- or multi-core cables	**B**	**0.90**
	Vertical wall-mounted cable duct with:		
32	- Insulated conductors	**B**	**-**
32A	- Single- or multi-core cables	**B**	**0.90**
	Cable ducts embedded in floors with:		
33	- Insulated conductors	**B**	**-**
33A	- Single- or multi-core cables	**B**	**0.90**
	Suspended cable ducts with:		
34	- Insulated conductors	**B**	**-**
34A	- Single- or multi-core cables	**B**	**0.90**
41	Horizontal or vertical Insulated conductors in conduits or multi-core cables in sealed wire channels	**B**	**0.95**
42	Insulated conductors in conduits in ventilated wire channels	**B**	**-**
43	Single- or multi-core cables in open or ventilated wire channels	**B**	**-**
61	Single- or multi-core cables in buried conduits, cable ducts or shaped conduits	**D**	**0.80**
62	Buried single- or multi-core cables without additional mechanical protection	**D**	**-**
63	Buried single- or multi-core cables with additional mechanical protection	**D**	**-**
71	Insulated conductors in wooden skirting boards or moulding	**B**	**-**
73	Insulated conductors in conduits in frames (doors or chimneys)	**B**	**-**
73A	Multi-core cables in frames (doors or chimneys)	**B**	**0.90**
74	Insulated conductors in conduits in window frames	**B**	**-**
74A	Multi-core cables in window frames	**B**	**0.90**
81	Cables laid under water	**according to study**	

Values used for the example on page 21

Coefficient f5: Installation beneath conduits and joined conduits according to the number of conduits:
- In the air (tab. S5A).
- Embedded in the concrete (tab. S5B).

If installing beneath conduits and joined conduits



f5 ⇨ see tables S5A and S5B

Table S5A

Methods of installation (tab. S4)	No. 1 – 2 – 3 – 3A – 4 – 4A – 21 – 22 – 22A – 23 – 23A – 41 – 42 – 43					
No. of conduits arranged vertically	No. of conduits arranged horizontally					
	1	2	3	4	5	6
1	1	0.94	0.91	0.88	0.87	0.86
2	0.92	0.87	0.84	0.81	0.80	0.79
3	0.85	0.81	0.78	0.76	0.75	0.74
4	0.82	0.78	0.74	0.73	0.72	0.72
5	0.80	0.76	0.72	0.71	0.70	0.70
6	0.79	0.75	0.71	0.70	0.69	0.68

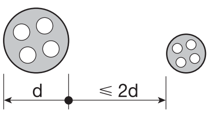
Table S5B

Methods of installation (tab. S4)	No. 5 – 5A – 24 – 24A					
No. of conduits arranged vertically	No. of conduits arranged horizontally					
	1	2	3	4	5	6
1	1	0.87	0.77	0.72	0.68	0.65
2	0.87	0.71	0.62	0.57	0.53	0.50
3	0.77	0.62	0.53	0.48	0.45	0.42
4	0.72	0.57	0.48	0.44	0.40	0.38
5	0.68	0.53	0.45	0.40	0.37	0.35
6	0.65	0.50	0.42	0.38	0.35	0.32

Coefficient f6 if NOT **installed underground:** Group of circuits or multi-core cables in a single layer

If group of circuits for a single layer

Note: 1 circuit is a group of single-core cables (1 per phase)

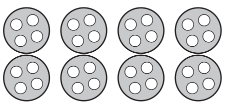


f6 ⇨ see table S6

Table S6

Method no. (tab. S4)	Number of circuits or multi-core cables											
	1	2	3	4	5	6	7	8	9	12	16	20
1 to 5A, 21 to 43, 71	1.00	0.80	0.70	0.65	0.60	0.55	0.55	0.50	0.50	0.45	0.40	0.40
11, 12	1.00	0.85	0.79	0.75	0.73	0.72	0.72	0.71	0.70	No additional correction factor for more than 9 cables		
11 A	1.00	0.85	0.76	0.72	0.69	0.67	0.66	0.65	0.64			
13	1.00	0.88	0.82	0.77	0.75	0.73	0.73	0.72	0.72			
14, 16, 17	1.00	0.88	0.82	0.80	0.80	0.79	0.79	0.78	0.78			

Coefficient f7 if NOT **installed underground:** Group of circuits of multi-core cables in multiple layers
(if group of circuits in multiple layers)



f7 ⇨ see table S7

Only applicable for method numbers 11 to 17 in table S6

Table S7

Number of layers	Correction factor
2	0.80
3	0.73
4 or 5	0.70
6 to 8	0.68
9 or more	0.66

Values used for the example on page 19

Coefficient f8 if installed UNDERGROUND according to ground temperature

If the ground temperature is not 20°C

f8 ⇨ see table S8

Table S8

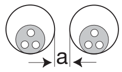
Method of instal-lation (tab. S4)	Temperature in °C	Polyvinyl chloride (PVC) A or H05V ... A or H07V ...	Cross-linked polyethylene (PEX) Butyl, ethylene propylene (EPR) U 1000R ...
61, 62, 63	10	1.10	1.07
	15	1.05	1.04
	25	0.95	0.96
	30	0.89	0.93
	35	0.84	0.89
	40	0.77	0.85
	45	0.71	0.80
	50	0.63	0.76
	55	0.55	0.71
	60	0.45	0.65
	65	-	0.60
	70	-	0.53
	75	-	0.46
	80	-	0.38

Coefficient f9 if UNDERGROUND **installation in conduits:**
Group of underground conduits arranged horizontally or vertically

f9 see table S9

A single cable per conduit or group of three single-core cables per conduit

Multi-core cables



Single-core cables

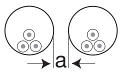


Table S9

Method of installation (tab. S4)	61			
	Distance (a) between conduits			
Number of conduits	Zero (joined conduits)	0.25 m	0.50 m	1.00 m
2	0.87	0.93	0.95	0.97
3	0.77	0.87	0.91	0.95
4	0.72	0.84	0.89	0.94
5	0.68	0.81	0.87	0.93
6	0.65	0.79	0.86	0.93

Coefficient f10 if UNDERGROUND **installation in conduits:**
Group of several circuit or cables in a single conduit

f10 see table S10

This table is valid for groups of cables with different cross-sections but which have the same maximum allowable temperature

Table S10

Method of installation (tab. S4)	61										
Number of circuits or multi-core cables											
1	2	3	4	5	6	7	8	9	12	16	20
1	0.71	0.58	0.5	0.45	0.41	0.38	0.35	0.33	0.29	0.25	0.22

Coefficient f11 if UNDERGROUND **installation directly in the ground:**
Group of underground conduits arranged horizontally or vertically

f11 see table S11

Single-core cables

Multi-core cables

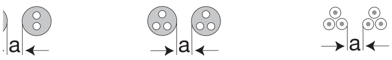


Table S11

Method of installation (tab. S4)	62, 63				
Distance (a) between multi-core cables of a group of 3 single-core cables					
Number of cables or circuits	Zero (joined cables)	The diameter of one cable	0.25 m	0.50 m	1.00 m
2	0.76	0.79	0.94	0.88	0.92
3	0.64	0.67	0.74	0.79	0.85
4	0.57	0.61	0.69	0.75	0.82
5	0.52	0.55	0.65	0.71	0.80
6	0.49	0.53	0.60	0.69	0.78

Coefficient f12 if UNDERGROUND **installation:**
Thermal resistivity of soil

f12 see table S12

Table S12

Method of installation (tab. S4)		61, 62, 63	
Thermal resistivity of soil (K.m/W)	Correction factor	Factors	
		Humidity	Type of soil
0.40	1.25	Laid under water	Swamp and sand
0.50	1.21	Very humid soil	
0.70 0.85 1.00	1.13 1.05 1	Humid soil “Normal” soil Dry soil	Clay and chalk
1.20 1.50	0.94 0.86	Very dry soil	Ash and cinders
2.00 2.50 3.00	0.76 0.70 0.65		

f The f factor (correction factor) for the installation is the product of all the relevant coefficients:

f = f1 × f2 × f3 × f4 × f5 × f6 × f7 × f8 × f9 × f10 × f11 × f12

Calculation of cross-sections and selection of protective devices:

See the flowchart below, which also analyses the impact of current harmonics.
The highlighted values are those from the example.

Note: If the device being powered is a lighting unit, the design current Ib (phase) must be replaced by the I_A current value (maximum current during the stabilisation time for a lighting unit) which is used for calculating the protection (June 2005 update of the UTE C15-105 guide).

Example:
- A balanced three-phase system with neutral.
- Yellow tariff installations (max. Ik 3 = 25 kA).
- No risk of explosion, with an ambient temperature of 40°C.
- U1000R02V cable, multi-core cable by default (the example also looks at use of single-core cables).
- Installation in perforated cable trays, in two layers of 4 cables.
- Design current of 137 A.
- Protection via main circuit breaker.

f1: Variable
f2: Not applicable
f3: 1
f4: Not applicable
f6: 1
f7: 0.80
With K = 1

Method no. 13, reference E

or

Method no. 13, reference F

Phase	Current harmonics minimal		Current harmonics distorted	
① **Assess harmonic risks** by analysing devices being powered	H3 < 15%	15% ≤ H3 ≤ 33% Lighting circuit with discharge lamps, including fluorescent tubes. Installed in offices, workshops, etc.	H3 > 33% Office circuit, computer circuit, electrical devices. Installed in office buildings, computing centres, banks, trading floors, specialist shops, etc.	
② **Indicate the type of conductor used**	-		Single-core conductors (cross-sections can vary)	Multi-core conductors
③ **Determine Ib neutral** by calculation	-		$Ib_{neutral} = 1.45 \times Ib_{phase}$	
	-		199 A	199 A
④ **Determine Ith** by choice	Ith ≥ Ib (phase)			-
	160 A	160 A	160 A	-
⑤ **Determine rating of the circuit breakers** by choice	Rating In ≥ Ith (≥ Ib)		Rating In ≥ $Ib_{neutral}$	(oversized)
	160 A	160 A	200 A	200 A
⑥ **Determine current-carrying capacities Iz_{phase} and $Iz_{neutral}$** by calculation	Iz phase = (K × Ith)/f			-
	f1 = 1 if system is balanced f1 = 0.84 if system is unbalanced	**f1 = 0.84 necessarily, as the neutral is loaded by H3**		
	-		$Iz_{neutral} = (K \times Ib_{neutral})/f$	
	Phase 286 A with f1 = 1 thus f = 0.56	Phase 340 A with f1 = 0.84 thus f = 0.47	Phase 340 A Neutral 422 A with f1 = 0.84 thus f = 0.47	Neutral 422 A with f1 = 0.84 thus f = 0.47
⑦ **Find the cross-section of the phase and neutral conductors** using tables S13A or S13B (page 1.23) for the current-carrying capacities	Find S_{phase} for $Iz_{phase} \leq Iz$ (ampacity)			-
	-		Find $S_{neutral}$ for $Iz_{neutral} \leq Iz$ (ampacity)	
	Phase 298 A (ampacity) 95 mm² The modular x160 range (25 kA) allows connection up to 95 mm², solid	Phase 346 A (ampacity) 120 mm² The x250 range (160 A) allows connection up to 185 mm², solid or flexible	Phase 382 A (ampacity) 120 mm² Neutral 441 A (ampacity) 150 mm²	Neutral 450 A (ampacity) 185 mm²
	If the load is balanced and if the cable is S_{phase} > 16 mm² copper or > 25 mm² aluminium the $S_{neutral} = S_{phase}/2$ otherwise $S_{neutral} = S_{phase}$	$S_{neutral} = S_{phase}$	At this stage, the cross-sections are determined: S_{phase} (for Ib) and $S_{neutral}$ (for 1.45 × Ib)	$S_{neutral} = S_{phase}$ by cable construction
	Neutral 95 mm² or 50 mm²	Neutral 120 mm²	-	Phase 185 mm²
⑧ **Determine the circuit breaker properties and the range**	The properties of the circuit breaker depend on the system for earthing the installation: The range absolutely must respect the number of poles switched and protected, and also allow connection using the cross-sections determined previously.			
⑨ **In TT and TNS systems** Calculation of setting ranges	4 pole-3 protected if $S_{phase} = S_{neutral}$ or 4 pole-3 protected N/2 if $S_{neutral} < S_{phase}$	4 pole-3 protected		
	$Ith_{min.} \geq Ib_{ph}$ — 137 A i.e. 0.86 × In	$Ith_{min.} \geq Ib_{ph}$ — 137 A i.e. 0.86 × In	$Ith_{min.} \geq Ib_{ph}$ — 137 A i.e. 0.69 × In	$Ith_{min.} \geq Ib_{ph}$ — 137 A i.e. 0.69 × In
	$Ith_{max.} < Iz \times f$ — 167 A i.e. 1.04 × In	$Ith_{max.} < Iz \times f$ — 163 A i.e. 1.02 × In	$Ith_{max.} < Iz_{ph} \times f$ — 180 A i.e. 0.90 × In	$Ith_{max.} < Iz \times f$ — 212 A i.e. 1.06 × In
	choice at 1 × In	choice at 1 × In	choice at 0.8 × In	choice at 0.8 × In
	x160 range in 4 pole-3 protected if S_n = 95 mm² otherwise x250 rating 160 A in 4 pole-3 protected N/2	x250 range rating 160 A in 4 pole-3/4 protected for connection in 120 mm²	x250 range rating 200 A in 4 pole-3/4 protected and connection in 150 mm²	x250 range rating 200 A in 4 pole-3/4 protected and connection in 185 mm²

Phase	Current harmonics minimal				Current harmonics distorted			
	H3 < 15%		**15% ≤ H3 ≤ 33%**		**H3 > 33%** Single-core conductors		Multi-core conductors	
⑩ **IT system** Calculation of setting ranges	**4 pole-4 protected**: with reference to phase				**4 pole-4 protected**: adjusting Ph + N if possible		**4 pole-4 protected**: with reference to neutral	
	$Ith_{min.} \geq Ib_{ph}$	137 A i.e. 0.86 × In	$Ith_{min.} \geq Ib_{ph}$	137 A i.e. 0.86 × In	Phase $Ith_{min.} \geq Ib_{ph}$	137 A i.e. 0.69 × In	$Ith_{min.} \geq Ib_{n}$	199 A i.e. 0.99 × In
	$Ith_{max.} < Iz \times f$	167 A i.e. 1.04 × In	$Ith_{max.} < Iz \times f$	163 A i.e. 1.02 × In	Phase $Ith_{max.} < Iz_{ph} \times f$	180 A i.e. 0.90 × In	$Ith_{max.} < Iz_{n} \times f$	212 A i.e. 1.06 × In
		choice at 1 × In		choice at 1 × In		choice at 0.8 × In		choice at 1 × In
	x160 range in 4 pole-4 protected if S_n = 95 mm² otherwise x250 rating 160 A in 4 pole-3 protected N/2		x250 range rating 160 A in 4 pole-3/4 protected for connection in 120 mm²		Neutral $Ith_{min.} \geq Ib_{n}$	199 A i.e. 0.99 × In	x250 range rating 200 A in 4 pole-3/4 protected for connection in 185 mm²	
					Neutral $Ith_{max.} < Iz_{n} \times f$	207 A i.e. 1.04 × In		
						choice at 1 × In		
					In practice, you will select the safety using $S_{phase} = S_{neutral}$ = 150 mm² and thermal setting at 1 × In			
					x250 range rating 200 A in 4 pole-3/4 protected and connection in 150 mm²			

Table S13A: Table of current-carrying capacities Iz (A) if not installed underground

Reference method table S4	Insulation and no. of conductors loaded PVC family: A/H07R... – A/H05R... – A/H07V... – A/H05V... PEX family: U1000R... – H07V2... 2: Single- or two-phase circuit 3: Three- or four-phase circuit							
B	PVC 3	PVC 2		PEX 3		PEX 2			
C		PVC 3		PVC 2	PEX 3		PEX 2		
E			PVC 3		PVC 2	PEX 3		PEX 2	
F				PVC 3		PVC 2	PEX 3		PEX 2
	1	2	3	4	5	6	7	8	9
Copper in mm²									
1.5	15.5	17.5	18.5	19.5	22	23	24	26	
2.5	21	24	25	27	30	31	33	36	
4	28	32	34	36	40	42	45	49	
6	36	41	43	48	51	54	58	63	
10	50	57	60	63	70	75	80	86	
16	68	76	80	85	94	100	107	115	
25	89	96	101	112	119	127	138	149	161
35	110	119	126	138	147	158	169	185	200
50	134	144	153	168	179	192	207	225	242
70	171	184	196	213	229	246	268	289	310
95	207	223	238	258	278	298	328	352	377
120	239	259	276	299	322	346	382	410	437
150		299	319	344	371	395	441	473	504
185		341	364	392	424	450	506	542	575
240		403	430	461	500	538	599	641	679
300		464	497	530	576	621	693	741	783
400					656	754	825		940
500					749	868	946		1083
630					855	1005	1088		1254
Aluminium in mm²									
2.5	16.5	18.5		21	23	24	26	28	
4	22	25	26	28	31	32	35	38	
6	28	32	33	36	39	42	45	49	
10	39	44	46	49	54	58	62	67	
16	53	59	61	66	73	77	84	91	
25	70	73	78	83	90	97	101	108	121
35	86	90	96	103	112	120	126	135	150
50	104	110	117	125	136	146	154	164	184
70	133	140	150	160	174	187	198	211	237
95	161	170	183	195	211	227	241	257	289
120	186	197	212	226	245	263	280	300	337
150		227	245	261	283	304	324	346	389
185		259	280	298	323	347	371	397	447
240		305	330	352	382	409	439	470	530
300		351	381	406	440	471	508	543	613
400					526	600	663		740
500					610	694	770		856
630					711	808	899		996

Values used for the example on page 19

Table S13B: Table of current-carrying capacities Iz (A) if installed underground

Reference method table S4: D

Diameter of conductors (mm²)	Insulation and no. of conductors loaded			
	PVC 3	PVC 2	PEX 3	PEX 2
Copper				
1.5	26	32	31	37
2.5	34	42	41	48
4	44	54	53	63
6	56	67	66	80
10	74	90	87	104
16	96	116	113	136
25	123	148	144	173
35	147	178	174	208
50	174	211	206	247
70	216	261	254	304
95	256	308	301	360
120	290	351	343	410
150	328	397	387	463
185	367	445	434	518
240	424	514	501	598
300	480	581	565	677
Aluminium				
10	57	68	67	80
16	74	88	87	104
25	94	114	111	133
35	114	137	134	160
50	134	161	180	188
70	167	200	197	233
95	197	237	234	275
120	224	270	266	314
150	254	304	300	359
185	285	343	337	398
240	328	396	388	458
300	371	447	440	520

Note:
Use of flexible cables: The current-carrying capacity values given in table S13A apply for flexible cables used in fixed installations. A tolerance of 5% is permitted in the current-carrying capacity values when selecting the cross-section of cables (Art. 523.1.2).

Calculation of cross-section of neutral conductor:

Office circuits, computer circuits, electrical devices, etc. Installed in office buildings, computing centres, banks, trading floors, specialist shops, etc.

Lighting circuits with discharge lamps, including fluorescent tubes Installed in offices, workshops, supermarkets, etc.

	$0 < H \leq 15\%$	$15\% < H \leq 33\%$	$H > 33\%$
Single-phase circuits	$S_{neutral} = S_{phase}$	$S_{neutral} = S_{phase}$	$S_{neutral} = S_{phase}$
Three-phase + N circuits multi-core cables $S_{phase} \leq 16$ mm² copper or 25 mm² aluminium	$S_{neutral} = S_{phase}$	$S_{neutral} = S_{phase}$ Factor 0.84	$S_{phase} = S_{neutral}$ $S_{neutral}$ determinant $I_{bneutral} = 1.45 \times I_{bphase}$ Factor 0.84
Three-phase + N circuits multi-core cables $S_{phase} > 16$ mm² copper or 25 mm² aluminium	$S_{neutral} = S_{phase}/2$ Protection of neutral permitted	$S_{neutral} = S_{phase}$ Factor 0.84	$S_{phase} = S_{neutral}$ $S_{neutral}$ determinant $I_{bneutral} = 1.45 \times I_{bphase}$ Factor 0.84
Three-phase + N circuits single-core cables $S_{phase} > 16$ mm² copper or 25 mm² aluminium	$S_{neutral} = S_{phase}/2$ Protection of neutral permitted	$S_{neutral} = S_{phase}$ Factor 0.84	$S_{neutral} > S_{phase}$ $I_{bneutral} = 1.45 \times I_{bphase}$ Factor 0.84

When the H3 percentage has not been determined, the following is recommended:
- Include $S_{neutral} = S_{phase}$ with f1 = 0.84.
- Protect the neutral conductor.
- Do not use a PEN conductor.

:hager

Protection against maximum short-circuit currents

Protection against maximum short-circuit currents is ensured when the following two rules are adhered to:

1 – Adjustment of breaking capacity

Bc ≥ Ik	Ik = short-circuit current

Bc: Breaking capacity of short-circuit protective device
Ik: Maximum short-circuit current in location where the device is installed

Method of calculation
Tables C1A and C1B below give the three-phase short-circuit current value at the terminals of a HVa/LV transformer according to its power rating, for a three-phase 400 V system and a high-voltage system short-circuit power of 500 MVA.

Table C1A
Oil-immersed transformer (NF C 52 112-1)

Power rating (in kVA)	50	100	160	250	400
Three-phase Ik (in kA)	1.79	3.58	5.71	8.89	14.07
Power rating (in kVA)	630	800	1000		
Three-phase Ik (in kA)	22.03	18.64	23.32		

Table C1B
Air-cooled transformer (NF C 52 115)

Power rating (in kVA)	100	160	250	400	630
Three-phase Ik (in kA)	2.39	3.82	5.95	9.48	14.77
Power rating (in kVA)	1000				
Three-phase Ik (in kA)	23.11				

Knowing the three-phase short-circuit current at the source of the circuit (Ik upstream), page 25 lets you find the three-phase short-circuit current at the end of given cross-section and length of cable and thus be able to determine the Bc of the protective device placed at this point.

Note:
When the circuit length L is not listed in table C3, use the nearest lower value.
L (table) ≤ L (circuit)
When the Ik value is not included in table C3, use the nearest higher value.

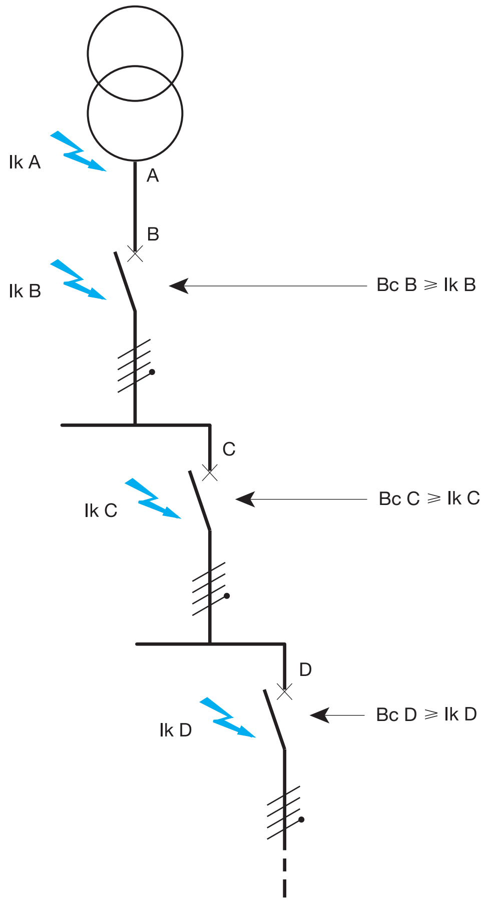
To calculate the single-phase short-circuit current, multiply the length by 2 and use the the result in the table on page 1.29.

2 – Adjustment of break time

$$\sqrt{t} \leq \frac{K \times S}{Ik}$$

The break time of the protective device must not be greater than the time it takes to increase the temperature of conductors to their maximum rated temperatures.
t = Time in seconds (t max. < 5 s)
S = Cross-section in mm²
K = Coefficient based on insulation and type of conductor, according to table C2 opposite
Ik in amperes

Note:
This rule is adhered to when a single protective device provides protection against both overloads and short circuits.



Examples

Point A

- Ik_A = 20 kA
- $Bc_A \geq$ 20 kA

} i.e. 25 kA for an x160

Point B

Table C3 page 1.26
- S_{ph} = 95 mm²
- L = 90 m
- Ik upstream = 20 kA

} use the value ≤ 90 m i.e. 80 m

Ik downstream = 8.9 kA

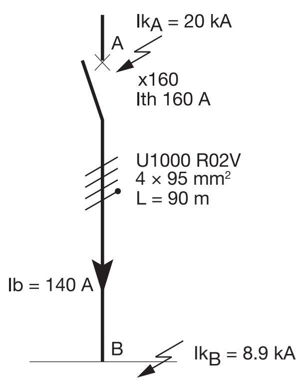


Table C2

Insulation ▶ / Material ▼	PVC 70°C A or H05V... A or H07V... ≤ 300□	> 300□	PVC 90°C H05V2... H07V2... ≤ 300□	> 300□	PEX / EPR U1000R... H07Z..., H07G...	Rubber 60°C A or H05R... A or H07R...
Copper	115	103	100	86	143	141
Aluminium	76	68	66	57	94	93

Principle

When a design current Ib flows through a conductor, the impedance of the conductor causes a drop in the voltage between the source and the end of the circuit. Table U1 opposite lists the maximum voltage drop values in %, defined by standard NF C 15-100.

Determining the voltage drop of the circuit Δ U
Table U2 lists the voltage drop value u (in volts) between the phase and the neutral for:
- Three-phase + neutral 230/400 V system
- Length of circuit L = 100 m
- Design current Ib = 1 A

For single-phase 230 V circuits, multiply the values by 2.
For different design current Ib (in A) and circuit lengths L (in metres), the voltage drop is calculated using the following formula:

$$u\ (\text{circuit}) = \frac{u\ (\text{table U2}) \times Ib \times L}{100}$$

$$\Delta u\ (\%) = \frac{u\ (\text{circuit}) \times 100}{230}$$

Note: If the device being powered is a lighting unit, the design current Ib is still the reference value for calculating the voltage drop. It is not replaced by the current value I_A (maximum current during the stabilisation time for a lighting unit). However, it is recommended that you ensure that the voltage drop for I_A allows the lighting to work during the stabilisation period (June 2005 update of the UTE C15-105 guide).

Table U1

	Lighting	Other usage
Power from a public LV network	3%	5%
Power from a private HV/LV substation	6%	8%

Table U2

Cross-section in mm²	Copper			Aluminium		
	cos φ			cos φ		
	0.5	0.8	1	0.5	0.8	1
1.5	0.77	1.23	1.53	1.24	1.98	2.47
2.5	0.47	0.74	0.92	0.75	1.19	1.48
4	0.29	0.46	0.58	0.47	0.74	0.93
6	0.20	0.31	0.38	0.32	0.50	0.62
10	0.12	0.19	0.23	0.19	0.30	0.37
16	0.079	0.12	0.14	0.12	0.19	0.23
25	0.053	0.078	0.092	0.081	0.12	0.15
35	0.040	0.057	0.066	0.060	0.089	0.11
50	0.031	0.044	0.048	0.046	0.067	0.078
70	0.023	0.031	0.033	0.033	0.047	0.053
95	0.019	0.024	0.024	0.026	0.036	0.039
120	0.017	0.020	0.019	0.022	0.029	0.031
150	0.015	0.017	0.015	0.019	0.025	0.025
185	0.013	0.015	0.012	0.017	0.021	0.020
240	0.012	0.012	0.010	0.015	0.017	0.015
300	0.011	0.011	0.008	0.013	0.015	0.012

Examples

Circuit 1

Table U2
- S_{ph} = 95 mm²
- U1000R02V (copper)
- cos φ = 0.8

} u = 0.024 V

Circuit voltage drop
- L = 90 m
- Ib = 140 A

$$u\ (\text{circuit}) = \frac{0.024 \times 90 \times 140}{100}$$

u (circuit 1) = 3.02 V

$$\Delta u\ (\text{circuit}) = \frac{3.02 \times 100}{230}$$

Δu (circuit) = 1.3%

Circuit 2

Table U2
- S_{ph} = 10 mm²
- U1000R02V (copper)
- cos φ = 0.8

} u = 0.19 V

Circuit voltage drop
- L = 40 m
- Ib = 55 A

$$u\ (\text{circuit}) = \frac{0.19 \times 40 \times 55}{100}$$

u (circuit) = 4.18 V

single-phase u (circuit) =
2 × u (circuit) Ph/N i.e. 2 × 3.96

u (circuit 2) = 8.36 V

u (point B) =
u (circuit 1) + u (circuit 2) = 3.02 + 8.36

u (point B) = 11.38 V

$$\Delta u\ (\text{point B}) = \frac{11.38 \times 100}{230}$$

Δu (point B) = 4.95%

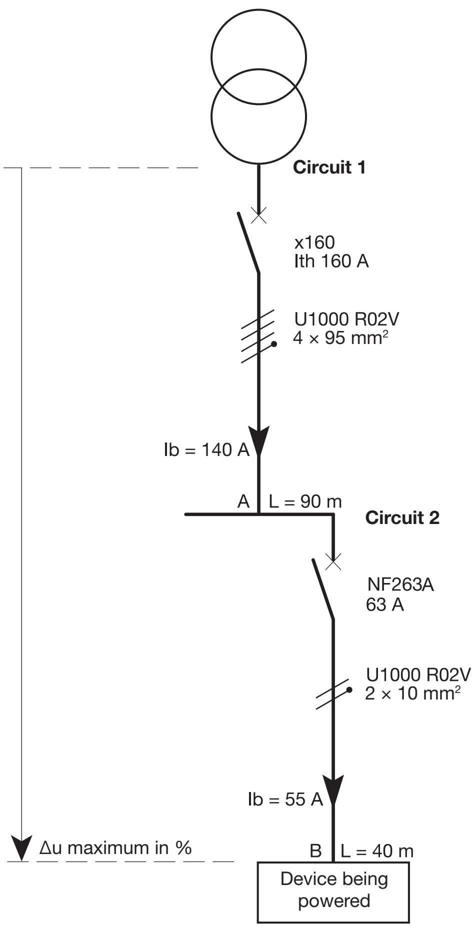


Table C3 – Short-circuit currents at the end of a given cable according to the C3 tables, C 15-105 guide of June 2003

CA	**Cross-section of phase conductors (mm²)**	Length of cable (in metres)																					
	Copper																						
230 V 400 V	1.5														1.3	1.8	2.6	3.6	5.1	7.3	10.3	15	21
	2.5												1.1	1.5	2.1	3.0	4.3	6.1	8.6	12	17	24	34
	4												1.7	1.9	2.6	3.7	5.3	7.4	10.5	15	21	30	42
	6											1.4	2.0	2.8	4.0	5.6	7.9	11.2	16	22	32	45	63
	10										2.1	3.0	4.3	6.1	8.6	12.1	17	24	34	48	68	97	137
	16								1.7	2.4	3.4	4.8	6.8	9.7	14	19	27	39	55	77	110	155	219
	25						1.3	1.9	2.7	3.8	5.4	7.6	10.7	15	21	30	43	61	86	121	171	242	342
	35						1.9	2.6	3.7	5.3	7.5	10.5	15	21	30	42	60	85	120	170	240	339	479
	50					1.8	2.5	3.6	5.1	7.2	10.2	14	20	29	41	58	81	115	163	230	325	460	
	70					2.6	3.7	5.3	7.5	10.6	15	21	30	42	60	85	120	170	240	339			
	95 →				2.5	3.6	5.1	7.2	10.2	14	20	29	41	58	81	115	163	230	325	460			
	120		1.6	2.3	3.2	4.5	6.4	9.1	13	18	26	36	51	73	103	145	205	291	411				
	150	1.2	1.7	2.5	3.5	4.9	7.0	9.9	14	20	28	39	56	79	112	158	223	316	447				
	185	1.5	2.1	2.9	4.1	5.8	8.2	11.7	16	23	33	47	66	93	132	137	254	373	528				
	240	1.8	2.6	3.6	5.1	7.3	10.3	15	21	29	41	58	82	116	164	232	329	465	658				
	300	2.2	3.1	4.4	6.2	8.7	12.3	17	25	35	49	70	99	140	198	279	395	559					
	2 × 120	2.3	3.2	4.5	6.4	9.1	12.8	18	26	36	51	73	103	145	205	291	411	581					
	2 × 150	2.5	3.5	4.9	7.0	9.9	14.0	20	28	39	56	79	112	158	223	316	447	632					
	2 × 185	2.9	4.1	5.8	8.2	11.7	16.5	23	33	47	66	93	132	187	264	373	528	747					
	S → L ↓ Ik before → Ik after	Short-circuit current at point being considered (Ik downstream in kA)													↓								
	50	47.7	47.7	46.8	45.6	43.9	41.8	39.2	36.0	32.2	28.1	23.8	19.5	15.6	12.1	9.2	6.9	5.1	3.7	2.7	1.9	1.4	1.0
	40	38.5	38.5	37.9	37.1	36.0	34.6	32.8	30.5	27.7	24.6	21.2	17.8	14.5	11.4	8.8	6.7	5.0	3.6	2.6	1.9	1.4	1.0
	35	33.8	33.8	33.4	32.8	31.9	30.8	29.3	27.5	25.2	22.6	19.7	16.7	13.7	11.0	8.5	6.5	4.9	3.6	2.6	1.9	1.4	1.0
	30	29.1	29.1	28.8	28.3	27.7	26.9	25.7	24.8	22.5	20.4	18.0	15.5	12.9	10.4	8.2	6.3	4.8	3.5	2.6	1.9	1.4	1.0
	25	24.4	24.4	24.2	23.8	23.4	22.8	22.0	20.9	19.6	18.0	16.1	14.0	11.9	9.8	7.8	6.1	4.6	3.4	2.5	1.9	1.3	1.0
	20 →	19.6	19.6	19.5	19.2	19.0	18.6	18	17.3	16.4	15.2	13.9	12.3	10.6	8.9	7.2	5.7	4.4	3.3	2.5	1.8	1.3	1.0
	15	14.8	14.8	14.7	14.6	14.4	14.2	13.9	13.4	12.9	12.2	11.3	10.2	9.0	7.7	6.4	5.2	4.1	3.2	2.4	1.8	1.3	0.9
	10	9.9	9.9	9.9	9.8	9.7	9.6	9.5	9.3	9.0	8.6	8.2	7.6	6.9	6.2	5.3	4.4	3.6	2.9	2.2	1.7	1.2	0.9
	7	7.0	7.0	6.9	6.9	6.9	6.8	6.7	6.6	6.5	6.3	6.1	5.7	5.3	4.9	4.3	3.7	3.1	2.5	2.0	1.6	1.2	0.9
	5	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.8	4.7	4.6	4.5	4.3	4.1	3.8	3.5	3.1	2.7	2.2	1.8	1.4	1.1	0.8
	4	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.8	3.8	3.7	3.6	3.4	3.2	3.0	2.7	2.3	2.0	1.7	1.3	1.0	0.8
	3	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.9	2.9	2.9	2.8	2.7	2.6	2.5	2.4	2.2	2.0	1.7	1.0	0.8
	2	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.9	1.9	1.9	1.8	1.8	1.7	1.6	1.5	1.3	1.2	1.0	0.8	0.7
	1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.8	0.8	0.7	0.7	0.6	0.5
CB	Cross-section of phase conductors (mm²)	Length of cable (in metres)																					
	Aluminium																						
230 V 400 V	2.5														1.3	1.9	2.7	3.8	5.4	7.6	10.8	15	22
	4												1.1	1.5	2.2	3.0	4.3	6.1	8.6	12	17	24	34
	6												1.6	1.7	2.5	3.5	4.9	7.0	9.9	14	20	28	40
	10											1.5	2.1	2.9	4.1	5.8	8.2	11.6	16	23	33	47	66
	16										2.2	3.0	4.3	6.1	8.6	12	17	24	34	49	69	98	138
	25								1.7	2.4	3.4	4.8	6.7	9.5	13	19	27	38	54	76	108	152	216
	35							1.7	2.4	3.3	4.7	6.7	9.4	13	19	27	38	53	75	107	151	213	302
	50						1.6	2.3	3.2	4.5	6.4	9.0	13	18	26	36	51	72	102	145	205	290	410
	70						2.4	3.3	4.7	6.7	9.4	13	19	27	38	53	75	107	151	213	302	427	
	95					2.3	3.2	4.5	6.4	9.0	13	18	26	36	51	72	102	145	205	290	410		
	120					2.9	4.0	5.7	8.1	11.4	16	23	32	46	65	91	129	183	259	366			
	150					3.1	4.4	6.2	8.8	12	18	25	35	50	70	99	141	199	281	398			
	185				2.6	3.7	5.2	7.3	10.4	15	21	29	42	59	83	117	166	235	332	470			
	240		1.6	2.3	3.2	4.5	6.5	9.1	13	18	26	37	52	73	103	146	207	293	414				
	300	1.4	1.9	2.7	3.9	5.5	7.8	11.0	16	22	31	44	62	88	124	176	249	352	497				
	2 × 120	1.4	2.0	2.9	4.0	5.7	8.1	11.4	16	23	32	46	65	91	129	183	259	366	517				
	2 × 150	1.6	2.2	3.1	4.4	6.2	8.8	12	18	25	35	50	70	99	141	199	281	398					
	2 × 185	1.8	2.6	3.7	5.2	7.3	10.4	15	21	29	42	59	83	117	166	235	332	470					
	2 × 240	2.3	3.2	4.6	6.5	9.1	12.9	18	26	37	52	73	103	146	207	293	414	585					

Protection against minimum short-circuit currents

A short circuit can occur at the end of a line. In this case, the worst-case current, i.e. the minimum short-circuit current, must be taken into account, as indicated in the diagram opposite. The installation conditions consist of verifying that the protective device placed at the source of the line cuts the Ik min. within a determined time, before the conductors and installation deteriorate, according to the following conditions:

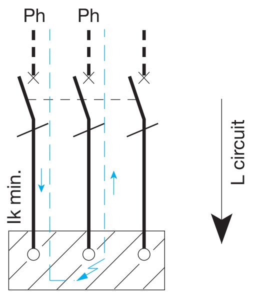
Irm < Ik min. for the circuit breakers
Ia < Ik min. for the fuses

Irm: Magnetic trip current
Ia: 5-second fusing current for fuse

In practice, checking the following is L circuit < L max.

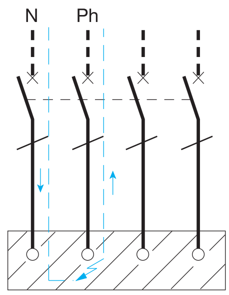
The tables below list the maximum lengths (in metres) protected against short circuits, for the following conditions:
- Copper conductors.
- Three-phase + neutral 230/400 V system and cross-section of neutral = cross-section of phase.
- Type and rating of protective device.

Three-phase system



Ik two-phase

Three-phase + neutral system



Ik single-phase

For different characteristics, multiply the table values by the following C coefficients:
- C = 1.33: If Sneutral = 0.5 Sphase, starting with cross-section of the neutral in the table.
- C = 1.73: If the neutral is not distributed.
- C = 0.42: If the conductors are made of aluminium and are protected by fuses.
- C = 0.63: If the conductors are made of aluminium and protected by circuit breakers.

For tables C8 and C9, on fuses, when 2 values are listed (e.g. 59/61): The first is for cables insulated with PVC: A/H05V..., A/H07V..., the second is for cables insulated with rubber, PEX or EPR: A/H07R..., H07Z..., H07G..., U1000R....

Table C4 – Protection using type B circuit breakers

Cross-section (mm²)	Rating of the type B circuit breakers (A)										
	6	10	16	20	25	32	40	50	63	80	100
1.5	200	120	75	60	48	37	30	24	19	15	12
2.5	333	200	125	100	80	62	50	40	32	25	20
4	533	320	200	160	128	100	80	64	51	40	32
6	800	480	300	240	192	150	120	96	76	65	48
10		800	500	400	320	250	200	160	127	100	80
16			800	640	512	400	320	256	203	160	128
25					800	625	500	400	317	250	200
35	L max. in metres					875	700	560	444	350	280
50								760	603	475	380

Table C5 – Protection using type C circuit breakers

Cross-section (mm²)	Rating of the type C circuit breakers (A)										
	6	10	16	20	25	32	40	50	63	80	100
1.5	100	60	37	30	24	18	15	12	9	7	6
2.5	167	100	62	50	40	31	25	20	16	12	10
4	267	160	100	80	64	50	40	32	25	20	16
6	400	240	150	120	96	75	60	48	38	30	24
10	667	400	250	200	160	125	100	80	63	50	40
16		640	400	320	256	200	160	128	101	80	64
25			625	500	400	312	250	200	159	125	100
35	L max. in metres		875	700	560	437	350	280	220	175	140
50					760	594	475	380	301	237	190

Table C6 – Protection using type D circuit breakers

Cross-section (mm²)	Rating of the type D circuit breakers										
	6	10	16	20	25	32	40	50	63	80	100
1.5	50	30	18	15	12	9	7	6	5	4	3
2.5	83	50	31	25	20	16	12	10	8	6	5
4	133	80	50	40	32	25	20	16	13	10	8
6	200	120	75	60	48	37	30	24	19	15	12
10	333	200	125	100	80	62	50	40	32	25	20
16	533	320	200	160	128	100	80	64	51	40	32
25	833	500	312	250	200	156	125	100	79	62	50
35		700	437	350	280	219	175	140	111	87	70
50			594	474	380	297	237	190	151	119	95

Table C7 – Protection using general-use circuit breakers

Sph copper mm²	ref.	x160		x160							x250									
	Bc	18 kA		25/40 kA							40 kA									
	In (A)	125	160	25	40	63	80	100	125	**160**	100		125		160		200		250	
	Setting (xIn)	Fixed		Fixed							6 – 8 – 10 – 13								5 – 7 – 8 – 11	
	Irm (A)	1500	1600	600	600	1000	1000	1500	1500	**1600**	600	1300	750	1625	960	2080	1200	2600	1250	2750
6		13	13	32	32	20	20	13	13	13	32	13	25	13	20	10	16	8	16	6
10		21	21	53	53	33	33	21	21	21	53	21	42	21	33	17	27	13	27	10
16		33	33	85	85	53	53	33	33	33	85	33	67	33	53	27	43	21	43	17
25		52	52	132	132	83	83	52	52	52	132	52	104	52	83	42	67	33	67	26
35		73	73	185	185	117	117	73	73	73	185	73	146	73	117	58	93	47	93	36
50		99	99	251	251	158	158	99	99	99	251	99	198	99	158	79	127	63	127	49
70		146	146	370	370	233	233	146	146	146	370	146	292	146	233	117	187	93	187	73
95		198	198			317	317	198	198	**198**		198	396	198	317	158	253	127	253	99
120		250	250			400	400	250	250	250		250		250	400	200	320	160	320	125
150		272	272			435	435	272	272	272		272		272	435	217	348	174	348	136
185		321	321					321	321	321		321		321		257	411	206	411	161
240		400	400					400	400	400		400		400		320		256		200

Table C8 – Protection using general-use circuit breakers

Sph copper mm²	ref.	h250 LSI						h630 LSI						h1000 LSI				h1600 LSI		
	Bc	50 kA						50/70 kA						50/70 kA				50/70 kA		
	In (A)	40		125		250		250		400		630		800		1000		1250		1600
	Setting (xIn)	2.5 – 5 – 10						2.5 – 5 – 10				2.5 – 5 – 8		2.5 – 5 – 10		2.5 – 5 – 8		2.5 – 5 – 10		
	Irm (A)	100	400	313	1250	625	2500	625	2500	1000	4000	1575	5040	2000	8000	2500	8000	3125	12500	4000
6		200	50	63	16	32	8	32	8	20	5	13	4	10		8		6		5
10		333	83	104	27	53	13	53	13	33	8	21	7	17	4	13	4	10		8
16			133	167	43	85	21	85	21	53	13	33	11	27	7	21	7	17	4	13
25			208	260	67	132	33	132	33	83	21	52	17	42	10	33	10	26	7	21
35			292	365	93	185	47	185	47	117	29	73	23	58	15	47	15	36	9	29
50			396	495	127	251	63	251	63	158	40	99	32	79	20	63	20	49	13	40
70					187	370	93	370	93	233	58	146	47	117	29	93	29	73	19	58
95					253		127		127	317	79	198	63	158	40	127	40	99	25	79
120					320		160		160	400	100	250	80	200	50	160	50	125	32	100
150					348		174		174	435	109	272	87	217	54	174	54	136	35	109
185					411		206		206		128	321	103	257	64	206	64	161	41	128
240							256		256		160	400	128	320	80	256	80	200	51	160

Table C9 – Protection using aM fuses

Cross-section (mm²)	Rating of aM fuses (A)								
	16	20	25	32	40	50	63	80	100
1.5	28/33	19/23	13/15	8/10	6/7				
2.5	67	47/54	32/38	20/24	14/16	9/11	6/7		
4	108	86	69	47/54	32/38	22/25	14/17	9/11	6/7
6	161	129	104	81	65/66	45/52	29/34	19/23	13/15
10				135	108	88	68	47/54	32/38
16						140	109	86	69
25	L max. in metres							135	108
35									151

Table C10 – Protection using gG fuses

Cross-section (mm²)	Rating of gG fuses (A)								
	16	20	25	32	40	50	63	80	100
1.5	82	59/61	38/47	18/22	13/16	6/7			
2.5		102	82	49/56	35/43	16/20	12/15	5/7	
4			131	89	76	42/52	31/39	14/17	8/10
6				134	113	78	67/74	31/39	18/23
10					189	129	112	74	51/57
16							179	119	91
25	L max. in metres							186	143
35									200

Example:
Calculation of max. length protected by a x160 /160 A circuit breaker
Calculation of C coefficient:
- Distributed neutral
- U 1000 R02V Δ ⟶ copper cable
- Sphase = Sneutral = 95 mm²

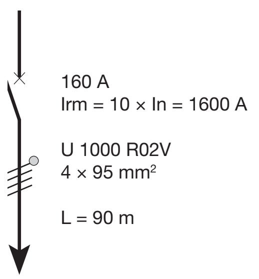
} ⟶ C = 1

- Sphase = 95 mm²
- 160 A (Irm at 1600 A)

} table C7 ⟶ L max. = 198 m

L max. = 198 × 1 = 198 m

› L max. (198 m) > L circuit (90 m)
› Protection against minimum short-circuit currents is provided



General points

Electrical risks

Electrical risks are primarily **physical**:
The human body, accidentally subjected to a source of voltage, conducts the electrical current, which can have two types of consequences:
- internal and external burns.
- muscular contractions (tetanus).

There are also **thermal** risks:
In order to provide protection against the risk of fire, the earth fault current must be limited to 0.3 A (NFC 15-100 art. 531.2.3.3).

The sources of electrical risks

In order for contact to be made through the body, there has to be two points of contact with simultaneously accessible parts carrying different potentials. Two types of contact can lead to the risk of electrical shock:
- direct contact.
- indirect contact.

Direct contact

Direct contact is when a person accidentally comes into contact with either:
- 2 active conductors.
- or 1 active conductor and an exposed conductive part connected to the earth.

Direct contact is generally the result of negligence, clumsiness or a failure to abide by safety rules.

Indirect contact

Indirect contact is when a person comes into contact with a metal object that has accidentally had current applied to it by an poorly insulated active conductor, and an exposed conductive part connected to the earth.
It is generally an accident connected to the state of the electrical equipment.

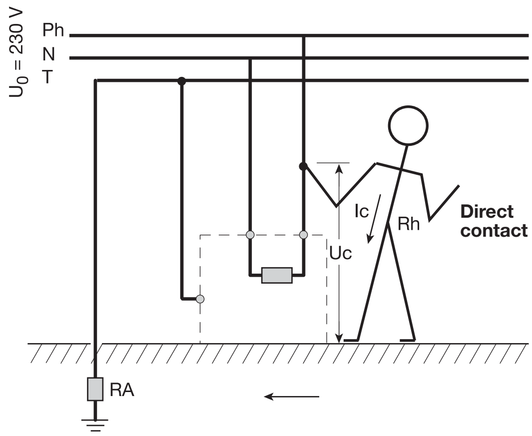
RA = Impedance of the earth electrode for the exposed conductive parts
Uc = Contact voltage
Ic = Current through body
Rh = Impedance of human body ∼ 2000 Ω

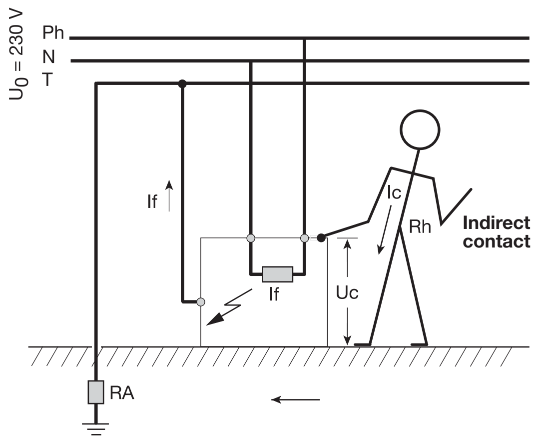
If = Fault current

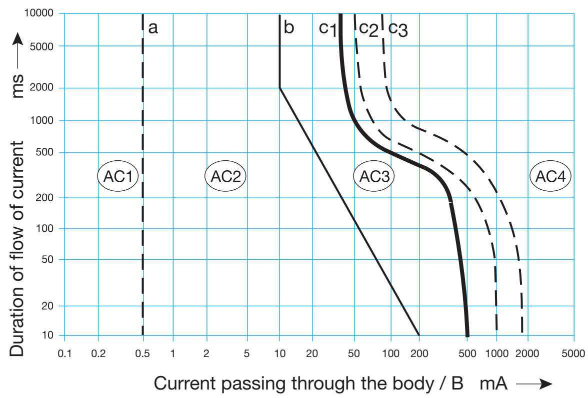
The parameters of electrical risks

They are as follows:
- The intensity of the electric current passing through the human body: Ic (the intensity is directly linked to the impedance of the human body: Rh).
- The contact voltage at the source of the accident: Uc.
- The duration the voltage is accidentally applied for: t.
- The consequences of the electrical risk according to the intensity (Ic) and duration (t); they are estimated in the diagram opposite (IEC 479-1).
- The limits of the electrical risk according to the contact voltage Uc and duration t.

Since the publication of practical guide UTE C. 15-105 in June 1999, following studies by a group of experts from the IEC, it is accepted that the skin can be penetrated by an contact voltage of around 100 V.
For this value of 100 V, as the skin was damaged, the humidity had no influence on the impedance of the human body. As such, for practical reasons, the conventional voltage limit of 50 V applies generally in all situations (UL = 50 V).







Duration/current areas for effects of alternating current on individuals

Areas	Physiological effects
Area AC1	Usually no reaction
Area AC2	Usually no dangerous physiological effect
Area AC3	Usually no organ damage; likelihood of muscular contractions and respiratory problems
Area AC4	In addition to area AC3, likelihood of ventricular fibrillation increases up to around 5% (curve c_2) or up to around 50% (curve c_3); increasing intensity and duration raise the risk of pathophysiological effects such as cardiac arrest, respiratory arrest and severe burns occurring

Protection of individuals against electrical risks

A – Direct contact
Irrespective of the neutral point connection used, the fault must be eliminated when it arises (high-sensitivity RCCBs: IDn ≤ 30 mA).

B – Indirect contact
Protection of individuals according to the neutral point connection system used
There are three neutral point connection system, which differ by:
1) The state of the the neutral with respect to the earth.
2) The state of exposed conductive parts with respect to the earth or neutral, with each of these being represented by a letter.
3) The neutral point connection system, represented by the combination of two letters.

Special cases for all of the neutral point connection systems: High-sensitivity RCCB ≤ 30 mA
This type of protection is required for the following installations and circuits (NF C 15-100 532.2.6):

- Power socket circuits
  In ≤ 32 A irrespective of the location and neutral point connection system.

- Power socket circuits irrespective of the rating for:
  - Wet rooms (at least class AD4).
  - Temporary installations, such as those for building sites.

- Circuits in bathrooms and swimming pools

- Fairground installations

- Supplying caravans and recreational boats

- Installations for agricultural and horticultural establishments

State of the neutral		State of exposed conductive parts		Neutral point connection system	
Neutral connected directly to the earth	T	Exposed conductive parts connected to an earth electrode	T	System	TT
Neutral connected directly to the earth	T	Exposed conductive parts connected to the neutral	N	System	TN
Neutral isolated from the earth (or only via a high impedance)	I	Exposed conductive parts connected to an earth electrode	T	System	IT

Additional protection using a high-sensitivity RCCB (NF C15-100 Art. 411.3.3):

The use of high-sensitivity RCCBs is especially justified to provide protection for flexible cables supplying movable or portable devices. Wear or ageing of these cables can lead to deterioration of the insulation or the breaking of the protective conductor, with it being possible for these faults to go unnoticed.

TT system: Separate earthing of exposed conductive parts

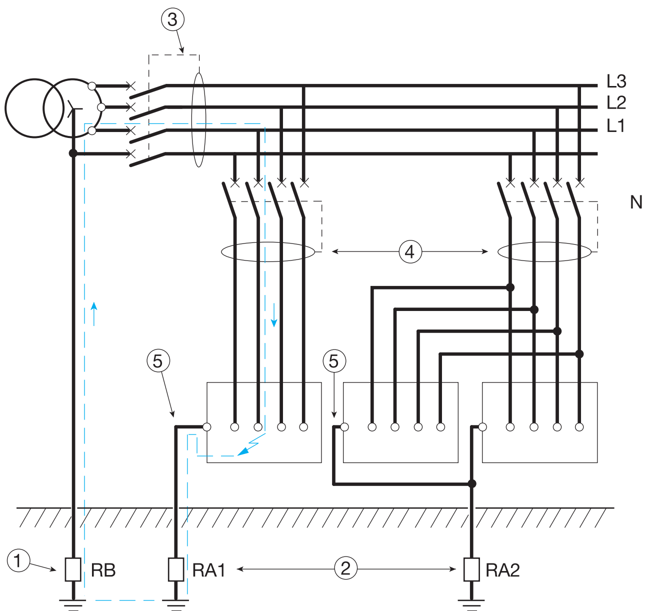
Principle:
The occurrence of an insulation fault leads to a dangerous increase in the potential of exposed conductive parts.
This means that the installation is to include a device that cuts the power when the first fault occurs.
In practice, this is achieved using an RCCB, the sensitivity of which is determined according to the impedance of the earth electrode (RA).

Using the formula: $I\Delta n \leq \frac{UL}{RA}$ with UL = 50 V

The table below gives the maximum RA values (Ω) according to Δn.

Table I1

Nominal residual current (IΔn)		Maximum value of impedance of earth electrode for the exposed conductive parts in Ω (RA)
Low sensitivity	20 A 10 A 5 A 3 A	2.5 5 10 17
Average sensitivity	1 A 500 mA 300 mA 100 mA	50 100 167 500
High sensitivity	≤ 30 mA	≥ 500



1. Earth electrode for the neutral RB
2. Separate earth electrode for exposed conductive parts: RA1 – RA2
3. General differential protection
4. Differential protection by earth leakage
5. Earthing of exposed conductive parts

TN system

This diagram shows two variants:

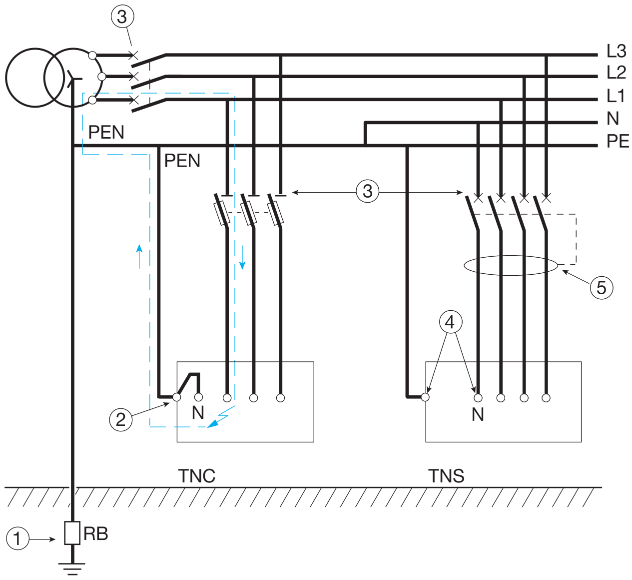
A) **TNC**: Neutral conductor and with shared **PEN** protection. The occurrence of an insulation fault results in a phase-neutral short circuit. This means that the continuity of the PEN conductor should be checked continually in order to prevent the risk of power being cut.

The use of this system is limited to lines with a cross-section $\geq 10^2$ for copper and $\geq 16^2$ for aluminium.

in order to limit interference of the current harmonics in the installation, the TNC system must be avoided (risk for sensitive equipment) (NF C15-100 art. 330.1.1.d).

When the third and multiples-of-three current harmonic percentage is unknown, it is recommended that a PEN is not used and that a separate PE is used instead (TNS system).

B) **TNS**: Separate neutral **N** and protective **PE** conductors. This system is to be used in all cases where the TNC system is not suitable:
- Circuits with cable cross-sections of $< 10^2$ for copper or $< 16^2$ for aluminium.
- In areas with a risk of explosion or fire.
- When the impedance of the fault loop (Zs) is unknown (movable devices).

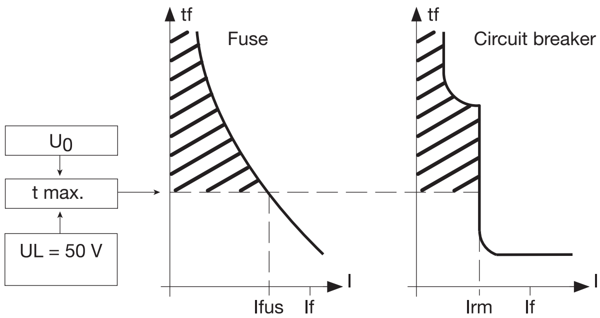


1. Earth electrode for the neutral RB
2. Exposed conductive parts connected to the PEN (TNC)
3. Power cut when first fault occurs via fuses or circuit breakers
   Cutting the PEN is not permitted in the TNC system
4. Separate PE and neutral (TNS)
5. Differential protection possible and cutting of neutral mandatory

Protection against indirect contact

This is provided by overload protective devices and respecting the conditions that connect the fault current value and the operating current of the protective device.

Ifus < If	or	Irm < If	See diagram opposite



Ifus = Fusing current of fuses ($t \leq t0$, see table I2)

Irm = Magnetic trip current (for circuit breakers)

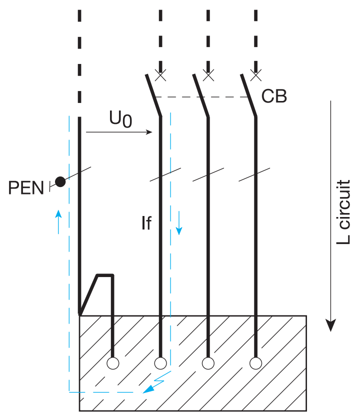
If = Fault current If being $= \frac{U_0}{Zs}$

U_0 = Phase/neutral voltage

Zs = Impedance of fault loop

Practical method

As the fault current If is directly connected to the impedance Zs, which is itself connected to the length of the circuit considered, the practical method consists of determining the maximum length for a given line cross-section, which has a protective device CB at its source, as indicated in the diagram opposite.



Calculation of maximum length protected against indirect contact

The formula is as follows:

$$L\ max. = \frac{0.8\ U_0\ Sph}{\rho\ (1 + m)\ I a}$$

U_0 = Voltage between the phase and neutral, in volts
Sph = Cross-section of the phase conductor, in mm^2

$m = \frac{Sph}{Spe}$ or $\frac{Sph}{Spen}$

I a = Operating current for the protective device, equal to:
Either the magnetic trip value
For circuit breakers
- Type B: 5 In
- Type C: 10 In
- Type D: 20 In
- General purpose: 1.2 times the magnetic setting or the fusing current **for fuses**, according to the maximum duration as shown in table I2

Spe = Cross-section of the protective conductor
Spen = Cross-section of the combined protective and neutral conductor
ρ = Impedance of the conductor at temperature of 20° × 1.25, equal to 0.023 ohms.mm^2/m for copper and 0.037 ohms.mm^2/m for aluminium

Determining the maximum length
In practice, simply determine this length using tables I4 to I8, according to:
① - The m ratio: 1/2/3 } see table I3
- The material of the conductor, copper/aluminium } see table I3

The “C” coefficients given in table I3 are multiplied by the values listed in the tables of lengths (tables I4 to I8).
② - Cross-section of the conductor
- Rating of the protective devices
⟶ tables I4 to I8

Protection against indirect contact is provided is the max. protected L > L in circuit being considered

Table I2

Nominal voltage of the installation U_o (in volts)	Maximum break time in seconds for final circuits (U_L = 50 V (t_o))
120	0.8
230	0.4
400	0.2

Table I3

m	C coefficient	
1	Copper	1
	Aluminium	0.63
2	Copper	0.67
	Aluminium	0.42
3	Copper	0.5
	Aluminium	0.32

Table I4
Maximum length of conductors protected using a gG fuse

Cross-section (mm^2)	Nominal rated current of fuse (A)								
	16	20	25	32	40	50	63	80	100
1.5	53	40	32	22	18	13	11	7	6
2.5	88	66	53	36	31	21	18	12	9
4	141	106	85	58	49	33	29	19	15
6	212	159	127	87	73	50	43	29	22
10	353	265	212	145	122	84	72	48	37
16	566	424	339	231	196	134	116	77	59
25	884	663	530	361	306	209	181	120	92
35		928	742	506	428	293	253	169	129
50				687	581	398	343	229	176
70					856	586	506	337	259
95	L max. in metres					795	687	458	351
120							868	578	444

Table I5
Maximum length of conductors protected using type B circuit breakers

Cross-section (mm^2)	Nominal rated current of circuit breaker (A)										
	6	10	16	20	25	32	40	50	63	80	100
1.5	200	120	75	60	48	37	30	24	19	15	12
2.5	333	200	125	100	50	40	50	40	32	25	20
4	533	320	200	160	128	100	80	64	51	40	32
8	800	480	300	240	192	150	120	96	76	60	48
10		800	500	400	320	250	200	160	127	100	80
16			800	640	512	400	320	256	203	160	128
25					800	625	500	400	317	250	200
35						875	700	560	444	350	280
50								760	603	475	380

Table I6
Maximum length of conductors protected using type C circuit breakers

Cross-section (mm^2)	Nominal rated current of circuit breaker (A)										
	6	10	16	20	25	32	40	50	63	80	100
1.5	100	60	37	30	24	18	15	12	9	7	6
2.5	167	100	62	50	40	31	25	20	16	12	10
4	267	160	100	80	64	50	40	32	25	20	16
6	400	240	150	120	96	75	60	48	38	30	24
10	667	400	250	200	160	125	100	80	63	50	40
16		640	400	320	256	200	160	128	101	80	64
25			625	500	400	312	250	200	159	125	100
35			875	700	560	437	350	280	222	175	140
50					760	594	475	380	301	237	190

Table I7
Maximum length of conductors protected using type D circuit breakers

Cross-section (mm^2)	Nominal rated current of circuit breaker (A)										
	6	10	16	20	25	32	40	50	63	80	100
1.5	50	30	18	15	12	9	7	6	5	4	3
2.5	83	50	31	25	20	16	12	10	8	6	5
4	133	80	50	40	32	25	20	16	13	10	8
6	200	120	75	60	48	37	30	24	19	15	12
10	333	200	125	100	80	62	50	40	32	25	20
16	533	320	200	160	128	100	80	64	51	40	32
25	833	500	312	250	200	156	125	100	79	62	50
35		700	437	350	280	219	175	140	111	87	70
50			594	475	380	297	237	190	151	119	95

Table I8
Maximum length of conductors protected using general-purpose circuit breakers

Sph copper mm^2	ref.	x160		x160							x250									
	Bc	18 kA		25/40 kA							40 kA									
	In (A)	125	160	25	40	63	80	100	125	**160**	100		125		160		200		250	
	Setting (xIn)	Fixed		Fixed							6 – 8 – 10 – 13								5 – 7 – 8 – 11	
	Irm (A)	1500	1600	600	600	1000	1000	1500	1500	**1600**	600	1300	750	1625	960	2080	1200	2600	1250	2750
6		13	13	32	32	20	20	13	13	13	32	13	25	13	20	10	16	8	16	6
10		21	21	53	53	33	33	21	21	21	53	21	42	21	33	17	27	13	27	10
16		33	33	85	85	53	53	33	33	33	85	33	67	33	53	27	43	21	43	17
25		52	52	132	132	83	83	52	52	52	132	52	104	52	83	42	67	33	67	26
35		73	73	185	185	117	117	73	73	73	185	73	146	73	117	58	93	47	93	36
50		99	99	251	251	158	158	99	99	99	251	99	198	99	158	79	127	63	127	49
70		146	146	370	370	233	233	146	146	146	370	146	292	146	233	117	187	93	187	73
95		198	198			317	317	198	198	**198**		198	396	198	317	158	253	127	253	99
120		250	250			400	400	250	250	250		250		250	400	200	320	160	320	125
150		272	272			435	435	272	272	272		272		272	435	217	348	174	348	136
185		321	321					321	321	321		321		321		257	411	206	411	161
240		400	400					400	400	400		400		400		320		256		200

Sph. copper mm^2	ref.	h250 LSI						h630 LSI						h1000 LSI				h1600 LSI		
	Bc	50 kA						50/70 kA						50/70 kA				50/70 kA		
	In (A)	40		125		250		250		400		630		800		1000		1250		1600
	Setting (xIn)	2.5 – 5 – 10						2.5 – 5 – 10				2.5 – 5 – 8		2.5 – 5 – 10		2.5 – 5 – 8		2.5 – 5 – 10		
	Irm (A)	100	400	313	1250	625	2500	625	2500	1000	4000	1575	5040	2000	8000	2500	8000	3125	12500	4000
6		200	50	63	16	32	8	32	8	20	5	13	4	10		8		6		5
10		333	83	104	27	53	13	53	13	33	8	21	7	17	4	13	4	10		8
16			133	167	43	85	21	85	21	53	13	33	11	27	7	21	7	17	4	13
25			208	260	67	132	33	132	33	83	21	52	17	42	10	33	10	26	7	21
35			292	365	93	185	47	185	47	117	29	73	23	58	15	47	15	36	9	29
50			396	495	127	251	63	251	63	158	40	99	32	79	20	63	20	49	13	40
70					187	370	93	370	93	233	58	146	47	117	29	93	29	73	19	58
95					253		127		127	317	79	198	63	158	40	127	40	99	25	79
120					320		160		160	400	100	250	80	200	50	160	50	125	32	100
150					348		174		174	435	109	272	87	217	54	174	54	136	35	109
185					411		206		206		128	321	103	257	64	206	64	161	41	128
240							256		256		160	400	128	320	80	256	80	200	51	160

Example:
Calculation of maximum protected L using a x160 A circuit breaker

- U 1000 R02V ⟶ copper
- Circuit breaker
- $S_{pen} = S_{ph}$ ⟶ m: 1

} table I3 ⟶ C = 1

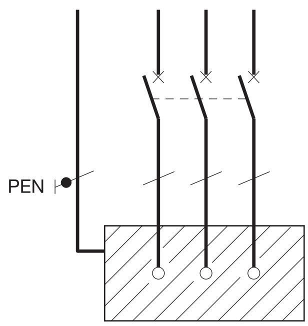
- S_{ph} = 95 mm^2
- 160 A
- Irm at 1600 A

} table I8 ⟶ L = 198 m

L max. = 198 m

⟶ L max. (198 m) > L circuit (90 m)
⟶ Protection against indirect contact is provided

TNC system



x160 range
HHA160H three-pole, thermal adjusted to 160 A

magnetic adjusted to 1600 A
U 1000 R02V

Sph = 95 mm^2
Spen = 95 mm^2

L = 90 m

IT system
The occurrence of an insulation fault does not result in an dangerous increase in the potential of the exposed conductive parts, but it must be alerted, found and resolved.
This involves the installation of an insulation monitoring device (IMD).
The occurrence of a second insulation fault results in situations identical to:
- In the **TT** system: When the exposed conductive parts are not interconnected
- In the **TN** system: When the exposed conductive parts are interconnected

Calculation of maximum length protected against indirect contact
The method is identical to that in the TN system, with only some parts of the formula differing, according to the distribution of the neutral.

$$L\ max. = \frac{0.4\ U\ S}{\rho\ (1 + m)\ I\ a}$$

- Neutral not distributed
U = Voltage between phases
S = Sph = cross-section of phase conductor

$$m = \frac{Sph}{Spe}$$

- Distributed neutral
$U = U_0$ = Voltage between the phase and neutral
S = Sn = Cross-section of neutral conductor

$$m = \frac{Sph}{Spe}$$

- Maximum break time for the protective device (see table I9)
- C coefficient (table I10) multiplied by the length values in tables I4 to I8

Example:
IT system, distributed neutral

x160 range
HHA161H, four poles, thermal set to 160 A
magnetic set to 1600 A

160 A
U 1000 R02V

4 × 95 mm^2
Spe = 95 mm^2

L = 90 m

Calculation of max. length protected by a x160 circuit breaker

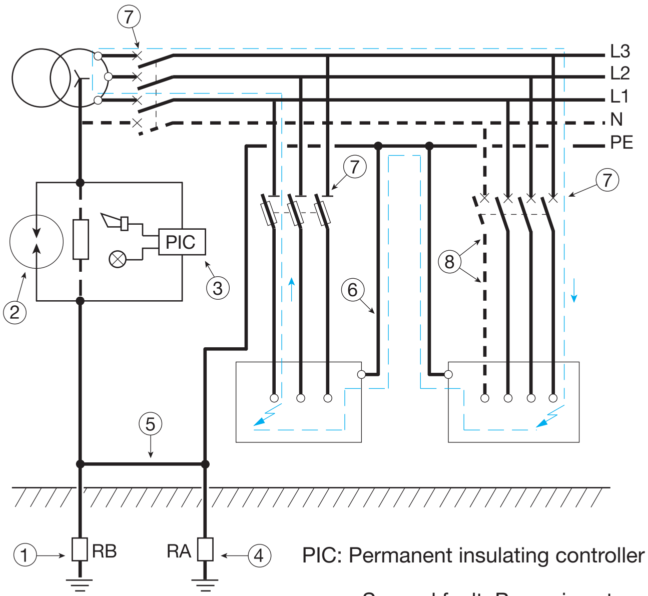
- U 1000 R02V → copper
- Circuit breaker
- Distributed neutral
- Sn = ph
- Spe = Sph } → m: 1
} table I10 → c = 0.5

- Sph = 95 mm^2
- x160
- Irm set to 1600 A
} table I8 → L = 198 m page 391

L max. = 0.5 × 198 = 99 m

L max. (99 m) > L circuit (90 m) → protection against indirect contact is provided

IT system: Interconnection of earth electrodes



PIC: Permanent insulating controller

First fault: Find
Resolve

Second fault: Power is cut

① Earth electrode for the neutral RB (isolated or high impedance)
② Overload protective device
③ Insulation monitoring device
④ Earth electrode for exposed conductive parts RA
⑤ Interconnection of earth electrodes
⑥ Earthing of exposed conductive parts
⑦ Power is cut upon second fault by fuses or circuit breakers
⑧ If the neutral is distributed: Protection against overloads

Table I9

Nominal voltage of the installation U_0 (in volts)	Maximum break time in seconds for final circuits (U_L = 50 V (t_0))
	Distributed and non-distributed neutral
120	0.8
230	0.4
400	0.2

Table I10

C coefficient			With neutral		Without neutral	
			Fuse	Circuit breaker	Fuse	Circuit breaker
m	1	Copper	0.6	0.5	0.86	0.86
		Aluminium	0.37	0.31	0.53	0.53
	2	Copper	0.4	0.33	0.57	0.57
		Aluminium	0.25	0.21	0.35	0.35
	3	Copper	0.3	0.25	0.43	0.43
		Aluminium	0.18	0.15	0.26	0.26

General points

For high power requirements (industries, tertiary buildings with high power demands, etc.) a high-voltage (HV) power supply of between 1 and 33 kV (generally 20 kV) is provided by the energy providers from a public distribution network.

The high-voltage (HV) supply arrives at a delivery substation, which act as a boundary between the public distribution network and the internal installation (private).
There are two possible options:

- Option 1: Delivery substation with a HVa/LV transformer, with low-voltage electrical distribution, where the energy consumption is metered in low voltage (LV).
- Option 2: Delivery substation with metering in HV. The internal distribution from the substation is carried out in HV to several transformers (located as close as possible to consumption areas).

There are different types of supply systems: Single-line, ring-main and parallel-feeder. These different systems are used according to the type of need (supply cut in the event of a fault, continuity needed in the event of a fault, etc.).

Substations are to be metered in low voltage (LV) when they consist of a single HVa/LV transformer, the secondary current of which is rated at at most 2000 A (power rating 1250 kVA).
In other cases (power rating > 1250 kVA or combination of multiple HVa/LV transformers), the substations are metered in HV.

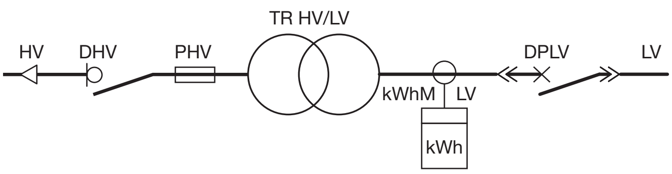
Generally, the client is the owner of their HVa/LV transformer substation which is considered to be the electrical point of supply.
The client is also responsible for its maintenance.
The type of substation and its location are chosen jointly by the distributor and the client.
The HV connection has several advantages:
- Free choice of neutral point connection for their installation (earthing system, "ES").
- Adaptable pricing and the possibility of changing the subscribed demand.

Different options allow the client to adapt the pricing to their usage. These are specified in the subscription contract.

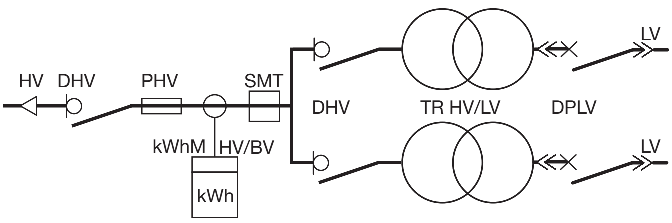
Note: The client only has access to the LV part and the HV switch-disconnector. HVa/LV interlocks are to be included in order to allow interventions to be performed in safety.

Single-line diagrams

- **Delivery substation with low-voltage metering**
  (only supplying an single HVa/LV transformer)



- **Delivery substation with high-voltage metering**
  (supplying two HVa/LV transformers)



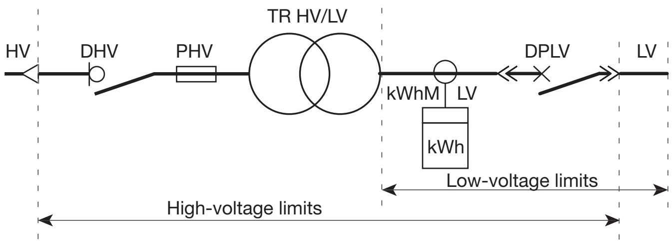
Restrictions from standards and legislation

There are three main supply systems:
- Single-line.
- Ring-main (passing through the substation).
- Parallel-feeder, with manual or automatic switching.

The Hager energy distribution service can create the low-voltage distribution part, up to the powers covered by a single 1000 kVA HVa/LV transformer or two 800 kVA transformers in parallel.

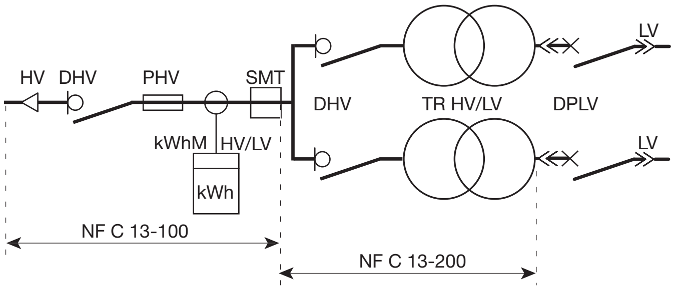
Single-line diagrams

- **Single-line supply with low-voltage metering**
  (1 × 1250 kVA HVa/LV transformer)



HV:	*Connection point between the substation and the high-voltage distribution network*
DHV:	*High-voltage disconnector*
PHV:	*High-voltage fuse protection*
TR HV/LV:	*High-/low-voltage transformer*
SMT:	*Earthing switch*
kWhM LV or HV/LV:	*High/low-voltage kilowatt-hour metering*
DPLV:	*Low-voltage disconnector and protection*
LV:	*Low-voltage distribution*

- **Single-line supply with high-voltage metering**
  (2× 800 kVA HVa/LV transformers)



HV:	*Connection point between the substation and the high-voltage distribution network*
DHV:	*High-voltage disconnector*
PHV:	*High-voltage fuse protection*
TR HV/LV:	*High-/low-voltage transformer*
SMT:	*Earthing switch*
kWhM LV or HV/LV:	*High/low-voltage kilowatt-hour metering*
DPLV:	*Low-voltage disconnector and protection*
LV:	*Low-voltage distribution*

General characteristics (high voltage)

These substations are powered at high-voltage with the voltage > 1000 V and via different means – single-line, parallel-feeder or ring-main – from the high-voltage distribution network. As such, the internal installation has a private transformer substation, known as the "Client Substation" and the metering of energy consumption is done according to the amount of subscribed demand, in either high or low voltage. Apart from the three means mentioned above, other simplified substations powered via the overhead network are also possible:
- Pole-mounted substations for power ratings of at most 160 kVA.
- Prefabricated substations within an enclosure for power ratings of at most 250 kVA.

When designing the HV installation, the following aspects must be taken into account:
- Equipment designed for voltage of 24 kV.
- Maximum power demand.
- Continuity of service.
- Earthing systems.
- External influences.
- HV short-circuit current.
- Supply systems.

The energy distributor supplies all of the technical information (nominal voltage of the HV network, short-circuit current for the HV network, etc.) that is of use for developing the project. A request for approval must be made to the energy distributor before any work is started.

Voltage range

Classification of voltages

Range	ELV	LVa	LVb
Alternating	U ≤ 50 V	50 < U ≤ 500 V	500 < U ≤ 1000 V
Direct	U ≤ 120 V	120 < U ≤ 750 V	750 < U ≤ 1500 V

Range	HVa	HVb
Alternating	1000 < U ≤ 50000 V	U > 50000 V
Direct	1500 < U ≤ 75000 V	U > 75000 V

Point of supply

This is the boundary between so-called "internal" private installations belonging to the client and those for which the energy distributor is responsible. This point of supply is located:
- In an overhead connection, upstream of where the HVa line is anchored to the "client" substation building.
- In an underground connection; immediately downstream of the end of the substation supply cable(s).

Earthing

Exposed conductive parts in the substation, the neutral of the low-voltage installation and exposed conductive parts in the LV installation connected to the earth. According to the circumstances, these earth electrodes can be separated or interconnected.
- Systems for earthing the substation: TNR, TTN, TTS, and ITR, ITN, ITS (see NF C 13-100 Art. 312).
- Systems for earthing the LV part – three systems; TT, TN or IT (see NF C 15-100 and pages 1.30 to 1.34 of the Hager technical guide).

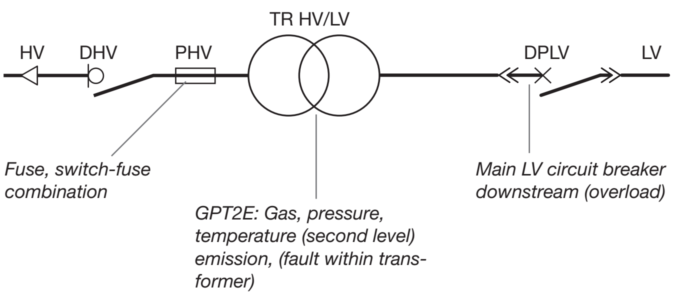
High- and low-voltage protection

The protection of HV circuits against short circuits is provided using a HV fuse (see table for standard power ratings NF C 64-210). In certain cases there can be combinations of switches and fuses. Several types of protection are to be included in a delivery substation (protection against short circuits between phases, against earth faults, against atmospheric overvoltage). The transformers must also be protected against overloads (the various adjustments are carried out by the energy distributor).

The protection of transformers against overloads is achieved using:
- Either a thermal detector that detects the maximum coil temperature of the transformer or liquid dielectric material.
- Or a current-based relay or release on the low-voltage part.

These devices must control either the removal of load from the transformer through the use of a switching device on the LV part, or the removal of load from the transformer through the use of a switching device on the HV part.

Single-line diagrams



Protection for a air-cooled transformer

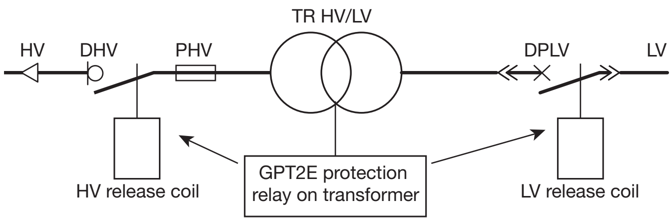
The coils are fitted with a sensor to monitor the internal temperatures and to allow the cutting of the LV load and HV supply in the event of a noticeable technical issue.

Protection for an oil-immersed transformer (transformer in an oil tank)

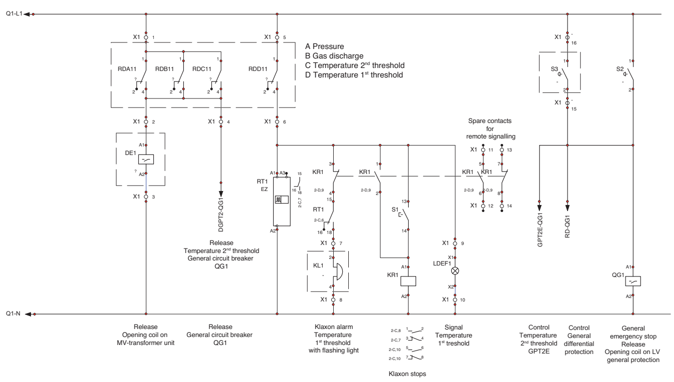
A “GPT2E” monitoring and protection relay (internal transformer fault) will be implemented when using a transformer with a mineral-oil tank. Several checks are carried out: Detection of gas, pressure and temperature at 1 or 2 thresholds.
Detection of temperature at the second temperature threshold, detection of gas or pressure must result in the cutting of the LV load, then of the HV supply in the event of a internal transformer fault.

Single-line diagrams

- **Protection using “GPT2E” monitoring relay**



- **GPT2E control system created with the Elcom program**

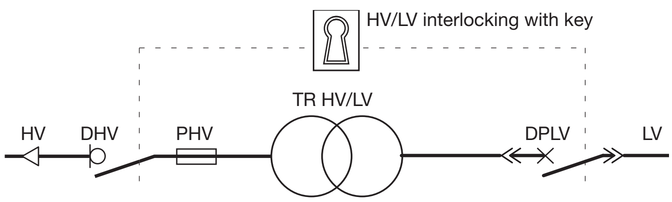


HV/LV interlocking

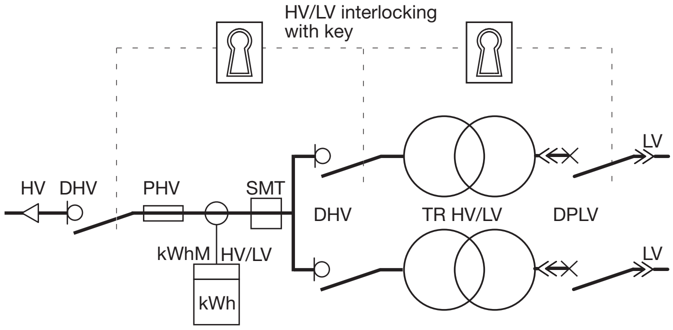
A safety interlocking system uses multiple locks to ensure the safety of individuals using the electrical installations. It also provides protection for the electrical installations, avoiding mishandling in any operating and maintenance of installations.
HV/LV interlocking (see NF C 13-100 Art. 462 and 463) enables the following:
- Preventing access to HV units before they are made dead.
- Preventing the opening or closing of a loaded disconnector.

Single-line diagrams

- **Interlocking with one HVa/LV transformer**



- **Interlocking with two HVa/LV transformers**



Equipment in the substation

The transformer substation room has the following equipment:
- Three-phase HVa/LV double-wound transformers (power rating of between 25 and 1250 kVA).
  The main properties of a transformer (power rating, voltage and transformation ratio, short-circuit current and coupling) are displayed on its data plate.
- HV switchgear: Surge arrestor, fuse, etc.
- Meter panel according to type (simplified, type 1 or 2) with current transformers. The metering is in LV up to 2000 A, or HV above this.
- LB circuit breaker: The circuit breaker must provide protection for the transformer against overloads and LV short circuits.
  Thermal releases must be adjustable according to the subscribed demand in the even the metering is simplified (at least 250 kVA).
  Magnetic releases must be able to be adjusted separately from thermal ones.
  It must be possible to seal off the thermal and magnetic controls.
  According to the type of earthing system (e.g. TT), a differential protective device could be included with it.
- Displays: Posters, notices, safety signs, etc.

Location

The type of substation and its location are chosen jointly by the distributor and the client. The client only has access to the LV part and the HV switch. The client ensures that private indoor electrical installations that they use remain operational. There are several possible installations:
- Substation within a building.
- Prefabricated substation that is partially below ground within an enclosure (max. 1000 kVA).
- Prefabricated simplified substations within an enclosure for power ratings of at most 250 kVA.
- Pole-mounted substation (limited to 160 kVA).

Transformer power ratings, standardised values

Standardised power rating values (kVA)	25	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250
Usual values (kVA)	25		50			100		160		250		400		630		1000	

Example of a "substation within a building" (characteristics)

Example: Installation of a substation in a metal enclosure, ring-main system (LV metering).

The HVa network power supply is brought close to the transformer substation. The HVa cable is connected to a ring-main unit in the substation. As the delivery substation is within the site, the distributor shall be guaranteed access to it at any time.
From the transformer substation onwards, the electrical distribution is done in low voltage, either within the same room or in different rooms (according to the design and usage). The low-voltage main distribution board (LVMDB) is installed either:
- In the transformer substation room.
- Or in an electrical room located nearby or in another location in the building, according to how it used or designed.

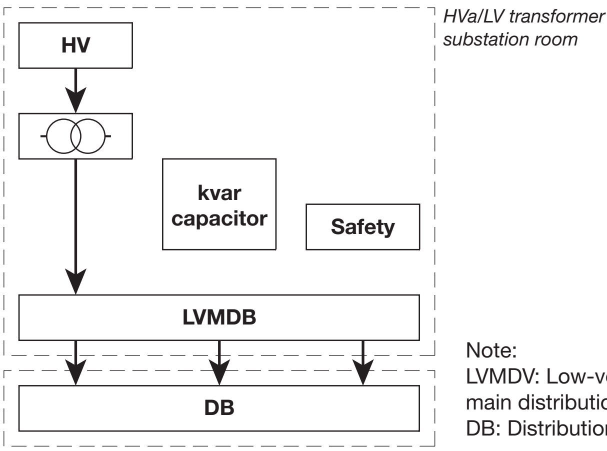
HVa/LV interlocks are to be included in order to allow interventions to be performed in safety.

Equipment in the transformer substation room and the electrical room

Example 1: Low-voltage main distribution board installed In the transformer substation room

- HV board.
- HVa/LV transformer (air-cooled or oil-immersed).
- Temperature protection for transformer (air-cooled, GPT2E for oil-immersed).
- Lighting, substation room power sockets.
- Key-lockable interlocking.
- Various signs.
• Standard NF C 13-100, NF C 13-200, etc.

Low-voltage connection and distribution in the same room:
- Green tariff metering, type 1 and 2.
- Low-voltage main distribution board (protection panel and transformer low-voltage switching device along with distribution (LVMDB)), including:
- Safety connections.
- LV protection and general switching.
- Distribution to secondary and final protective devices.
• Standard NF C 13-100.
• Standard NF C 15-100, UTE C 15-105 guide.
• Public- and employee access decrees and orders.



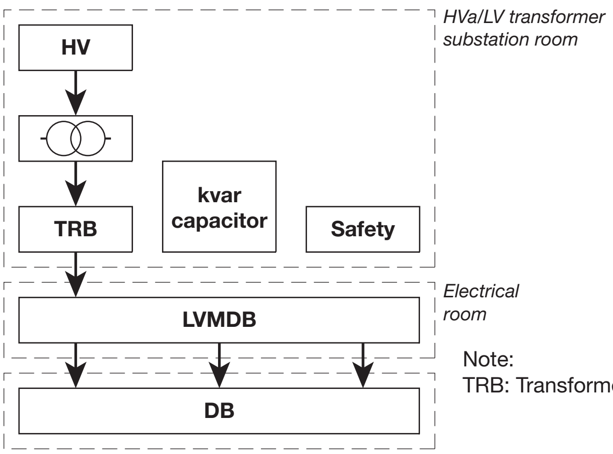
Note:
LVMDV: Low-voltage main distribution board
DB: Distribution board

Example 2: Low-voltage main distribution board installed in the electrical room located close to or far from the transformer room

- HV board.
- HVa/LV transformer (air-cooled or oil-immersed).
- Temperature protection for transformer (air-cooled, GPT2E for oil-immersed).
- Lighting, transformer substation room power sockets.
- Key-lockable interlocking.
- Various signs.
• Standards NF C 13-100, NF C 13-200, etc.

Low-voltage connection, protection and switching for the transformer in the same room:
- Green tariff metering, type 1 and 2.
- LV protection and switching transformer board (TRB) including safety other connections.

Low-voltage main distribution board (LVMDB) installed in an dedicated electrical room, including:
- General switching, emergency disconnection, etc.
- Various secondary and final protective devices.
• Standard NF C 15-100, UTE C 15-105 guide.
• Public- and employee access decrees and orders.



Note:
TRB: Transformer board

Additional HV/LV equipment

The delivery or transformer substation also had the following equipment:
- HV units (ring-main unit, meter, disconnector and various HV protective devices).
- Various remote indication and information equipment.
- Various controls and interlocking in order to ensure the HV safety of staff.
- General disconnector for the LV installation. (See NF C 13-100 Art.571)
- The circuits intended to supply the following as connected upstream of the general disconnector:
  - Substation lighting (In 10 A), normal and fixed safety lighting (see NF C 13-100 Art.762).
  - Protection relays.
  - Fault-current detectors for the incoming HV units.
  - Insulation monitoring device (in the IT earthing system).
  - Power supply (In 6 A) for remote control devices, information devices and general auxiliary contacts.
  - A power socket circuit (In 16 A – see NF C 13-200 Art.712.5).
- General LV overload protection at terminals downstream of the transformer.
- Instrument transformers (current and voltage) and the energy meter.
- Reactive power compensating capacitors. (Could be use to improve the power factor according to standards NF C 54-100 and NF C 13-100 Art.572).
- Substation room ventilation (see NF C 13-200 Art.712.3).
- Operating and maintenance equipment (see NF C 13-100 Art.621 and 622).

Note: The LV disconnection and general protection can be provided using:
- A switch-disconnector with visible break (immediately visible separation of contacts) that meets the regulations in standard NF EN 60947-3, combined with a moulded-case circuit breaker.
- Or a removable circuit breaker (moulded-case or air circuit breaker) that meets the regulations in standard NF EN 60439-1.

LV installations

For the designing of LV installations powered via a HVa/LV transformer substation, see the applicable requirements regarding installations powered by a private transformer substation. In these installations, the earthing system (neutral point connection) must be chosen by the head of the establishment according to the operating, installation and maintenance criteria.
The source of the LV installation are the transformer output terminals.

The technical pages of the “tertiary catalogue” offer methods and guides for selecting “products and equipment” to provide protection of property and individuals against electric shocks (overloads, short circuits, indirect contact, etc.).
Calculations justifying the choice of wiring and protective devices can be created in accordance with the standart, using our “ElcomNet” network calculation program.

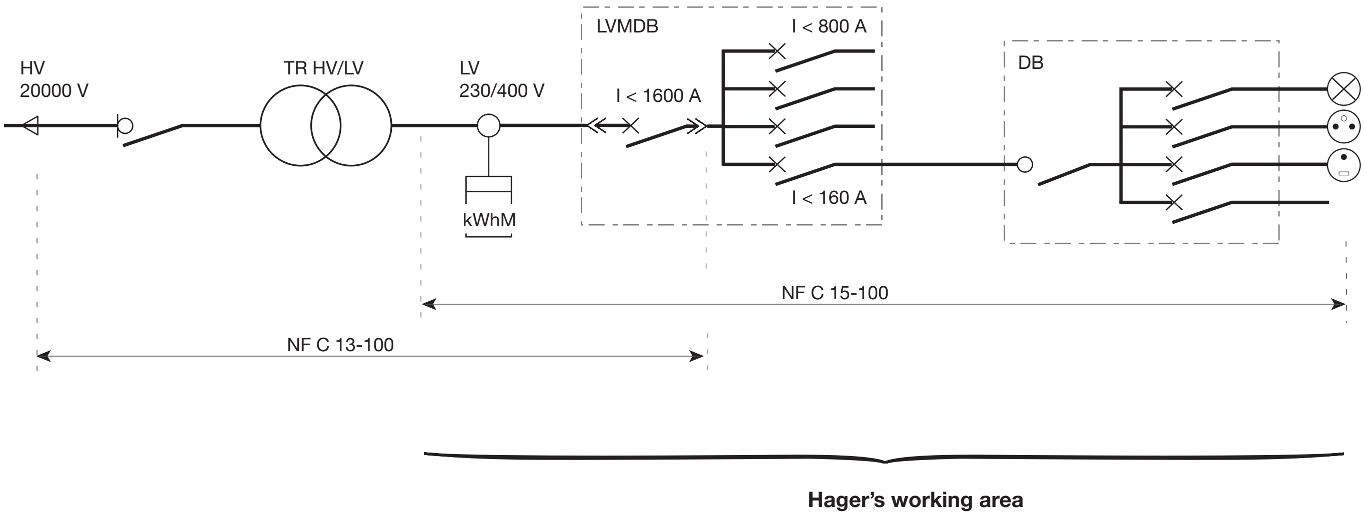
Aspects to be considered when drafting an installation plan:
- **Electrical characteristics**: Installed loads, neutral point treatment and grounding system (TT, TN, IT, etc.), supply (HV, LV, etc.), safety (source, power rating), short-circuit power, main, distribution and final boards and circuits.
- **External influences** (by building, room and location): Temperature, humidity, dust, impacts (IP, IK), corrosion, vibrations, fire, explosion.
- **Compatibility characteristics**: Overvoltage, starting, harmonics, leakage currents.
- **Special requirements regarding** operation, continuity of service, additional sources (replacement sources).
- **Protection of individuals** against electric shocks.

Note: The entire project is to be based on appliances and their control equipment, working backwards to the source, also considering the distribution boards and cabinets and the main distribution board.

The following standards and regulations are to be adhered to:
- NF C 15-100 and its UTE guides.
- The Decree of 14 November 1988 on the protection of workers.
- The regulation of 25 June 1980 on fire safety and its decrees and orders on public-access buildings.

Creation of low-voltage main distribution boards up to 1600 A

Example electrical diagram for a distribution system for electrical installations powered via a private transformer substation.



Technical characteristics of an implementation

Electrical distribution to buildings in the tertiary sector are limited to a power rating of:
- P = 1250 kVA (Ik3 max. = 28.5 kA – In = 1805 A) for 1 transformer.
- P = 2× 800 kVA (Ik3 max. = 36 kA – In = 2500 A) for 2 transformers.

Example implementations: Supermarket, school campus (senior school and sixth form college), retirement home, hotel, residential building, short-stay business premises, performance hall (theatre, socio-cultural, cinema, etc.), sports halls, hotel/restaurant, medical centre, campsite, office and service building, etc.

Standards and regulations

The standards and regulations that apply to this type of implementation are:
- **NF C 13-100, *postes de livraison établis à l'intérieur d'un bâtiment et alimentés par un réseau de distribution publique HTA (jusqu'à 33 kV)* (delivery substations located within a building and powered by a HVa public distribution network (up to 33 kV).**
- **NF C 14-100, *branchement réseau public BT* (connection to a public LV network).**
- **NF C 15-100 *installations électriques* (electrical installations) with its guides UTE C 15-105, 15-103, etc.**
- **Employee-access building Decree of 14/11/88 on employee protection and its orders.**
- **Safety regulations for public-access buildings of 25 June 1980 with its decrees and orders.**

Layouts (provisions for internal separations)

The layouts use separations by screens or partitions within the low-voltage main distribution board unit.
- They are described in chapter 7.7 of standard NF EN 60 439-1.

They are subject to agreement between the manufacturer and the user. There are 4 distinct layouts: Layouts 1, 2 (a and b), 3 (a and b) and 4 (a and b) to protection against direct contacts in order to provide the required level of safety and availability.
- **Layout 1**: No separation.
- **Layout 2**: Separation of functional unit busbars, the terminals for external conductors are not (layout 2a) or are (layout 2b) separated from the busbars.
- **Layout 3**: Separation of functional unit busbars and separation of each functional unit from each other, the terminals for external conductors are not (layout 3a) separated from the busbars and the terminals for external conductors are separated from the functional units but not from each other (layout 3b).
- **Layout 4**: Identical separation as in layout 3a with the addition of the terminals for external conductors being part of the functional unit (layout 4a) or are separated from the functional units (layout 4b).

Note: Boards created using quadro+ units can be laid out as layout 2b as a maximum.

Low-voltage service ratings (IS – indices de service)

Before	After
MPC 634 *www* *Removable* *Layout 4a* *IP25C*	***IS = 223***

The aim of the IS is to qualify the level of service provided by each type of low-voltage board regarding interventions for:
- Operating, for any operation leading to the installation or functional units (FU*) being made safe.
- Maintenance, for any intervention leading to the installation or functional units (FU*) being made safe.
- Modification, for any intervention leading to the modification or addition of a functional units (FU*) of the installation.

*FU (functional unit): Set of devices connected to a piece of low-voltage equipment, such as protective, switching, and control devices, etc.

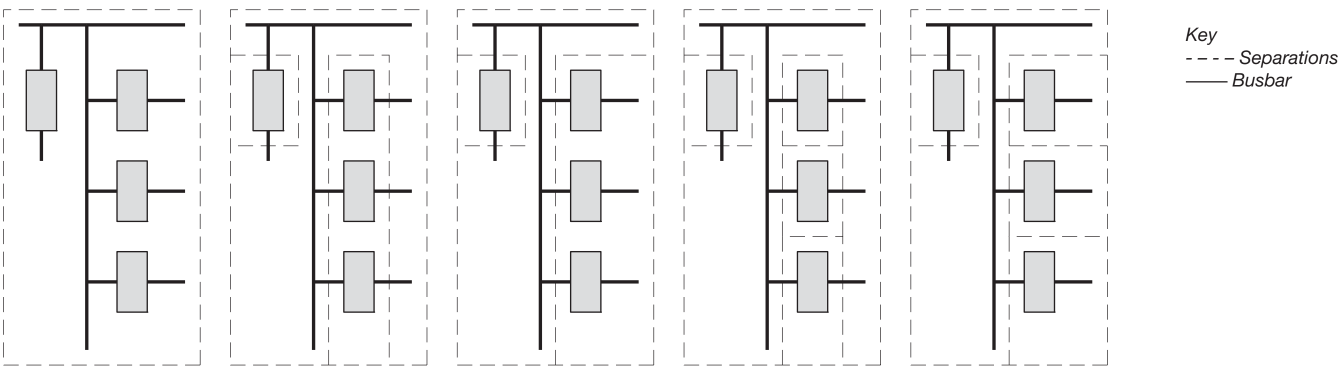
The IS comprises 3 numbers, the first for operating, the second for maintenance and the third for modifying the board.
Each IS rating is associated with a board design adapted to:
- Technical and economic needs.
- The level of authorisation of the operating staff.
- The level of qualification of the maintenance staff.
- The maximum intervention time in the event of a fault or for modifying the installation.

The IS helps to increase the reliability of the installation.

Note: Our equipment, created using quadro+ units, combined with a quadro 1600 equipment system have a maximum service rating for IS211.

With a rating of IS211, the consequences for the LV board the following areas are:
- **Operating – any locking or breaking operation = 2xx: Operation limited to the single FU involved.**
- **Maintenance – any maintenance operation = x1x: Requires power to the entire board to be cut.**
- **Modification – any modification operation = xx1: Requires power to the entire board to be cut.**

- **See UTE C 60-429 guide. This guide is references in NF C 15-100 in chapter 558 *Ensembles d'appareillage* (sets of devices) concerning agreements between the user and the manufacturer.**



Layout 1 *Layout 2a* *Layout 2b* *Layouts 3a and 3b* *Layouts 4a and 4b*

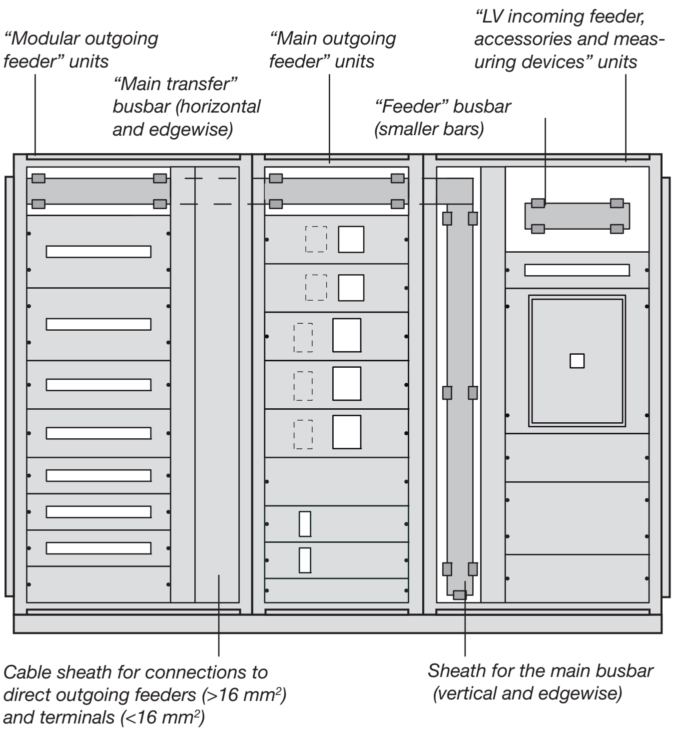
Technical characteristics for the creation of a "LVMDB" unit

Example of a low-voltage main distribution board (LVMDB) created using floor-standing combinable quadro+ units.

Main characteristics:

- Board located within the HVa/LV transformer substation (without a door, IP30, IK08, IS 211, layout 2a).
- HVa/LV transformer, rated at 630 kVA.
- Earthing system: TNC/TNS.
- Entry via the top of the unit (via cable tray) to the "feeder" busbar, connection using 4 conductors (aluminium) per phase (L1/L2/L3) and for the PEN, connection using lugs.
- Connects to the air circuit breaker (according to NF C 13-100 – disconnector with visible break and LV protection).
- "General" busbar in the vertical sheath and transfer via the top of the horizontally mounted units.
- Horizontal mounting of protective devices (H3 moulded-case circuit breakers) for the main outgoing feeders and direct connection via "cable sheath" (with crosspieces for attaching cables outside of the sheath.
- Distribution outgoing feeders are connected to a terminal (max. 16 mm^2) installed in the cable sheath.
- Various control accessories (emergency shut-off, signalling, GPT2E protection, measuring, etc.).
- All external conductors for outgoing feeders enter via a channel.

Design of a low-voltage main distribution board (In 1000 A)

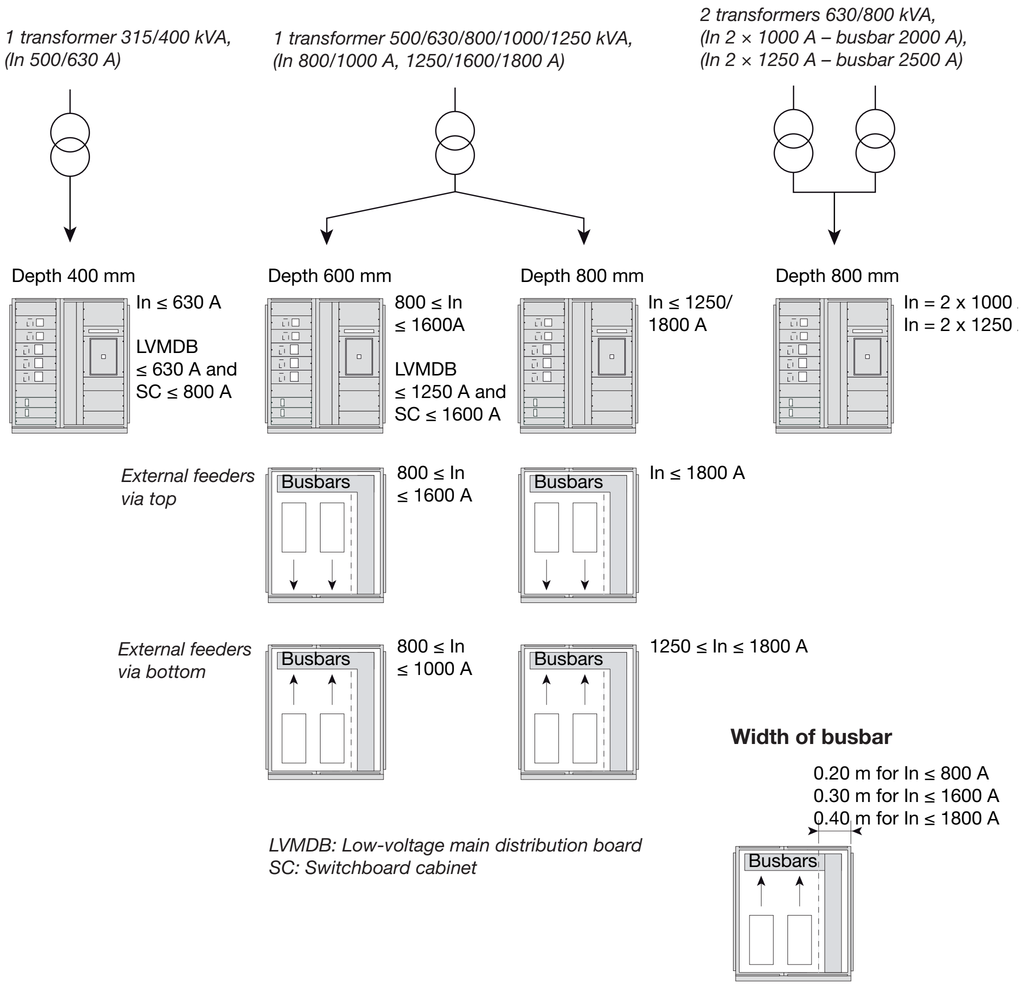


Type of source (number and power rating) and selection of equipment

The size of the enclosures (depth, width) are selected according to the power rating and number of source transformers, the nominal current of the general energy distribution, the number of outgoing feeders, the types of connection to external conductors (terminals, direct, top, bottom, etc.), type of room the LVMDB is in, etc.

Degree of protection for units according to external influences, according to type of room and configuration:
- IP 40, open, frame only.
- IP 54, frame with panels.
- IP 55, sealed.

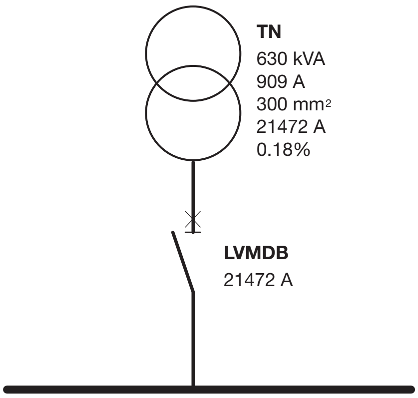
Note:
LVMDB: Low-voltage main distribution board
SC: Switchboard cabinet



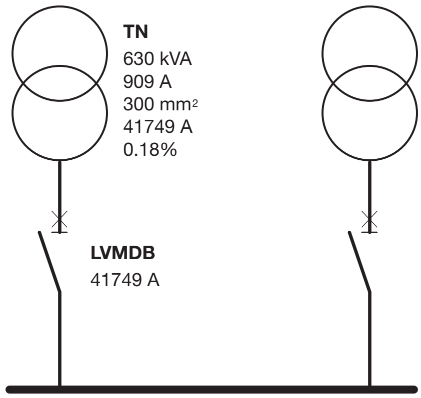
Technical characteristics of sources

In Hager's working area, there are two possible source configurations:

- **Source with 1 HV/LV transformer**



- **Source with 2 HV/LV transformers**



According to the type of implementation (e.g. public-access building), a replacement source ("emergency" source) in the form of a generating set (e.g. retirement home, etc.) can be added to either of these two configurations.

Standard characteristics commonly encountered in this type of installation

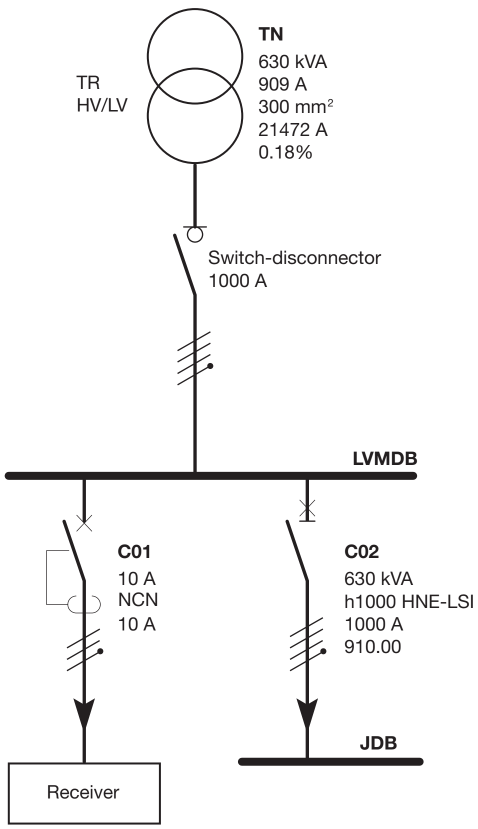
Power rating (kVA)	**315**	**400**	**500**	**630**	**2 × 630**	**800**	**2 × 800**	**1000**	**1250**
Number of sources	1	1	1	1	2	1	2	1	1
TR Ucc (%)	4	4	4	4	4	6	6	6	6
Copper/Ph cable	1*150	1*240	1*300	2× 1*185	2× 1*185 (for 1 transformer)	2× 1*300	2× 1*300 (for 1 transformer)	4× 1*185	4× 1*240
Aluminium/Ph cable	1*240	2× 1*150	2× 1*240	2× 1*300	2× 1*300 (for 1 transformer)	4× 1*185	4× 1*185 (for 1 transformer)	4× 1*300	4× 1*400
Copper cable PE/PEN	1*150	1*240	1*300	2× 1*185	2× 1*185 (for 1 transformer)	2× 1*300	2× 1*300 (for 1 transformer)	4× 1*185	4× 1*240
Aluminium cable PE/PEN	1*240	2× 1*150	2× 1*240	2× 1*300	2× 1*300 (for 1 transformer)	4× 1*185	4× 1*185 (for 1 transformer)	4× 1*300	4× 1*400
Ib (A)	455	578	722	910	2× 910 1820	1155	2 × 1155 2310	1444	1805
Irth (A)	500	630	800	1000	2 × 1000	1250	2 × 1250	1600	2000
IN busbar	500	630	800	1000	2000	1250	2500	1600	2000
Du (%)	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Ik3 max. (kA)	10.9	13.9	17.3	21.5	43	18.6	37.1	23	28.5
Ik1 max. (kA)	10.6	13.6	16.9	21	41.9	18.3	36.6	22.7	27

Note: These calculations were computer using the ElcomNet electrical system program and are indicative only. They must be checked for each implementation, the criteria (calculation variables) may change for each project.

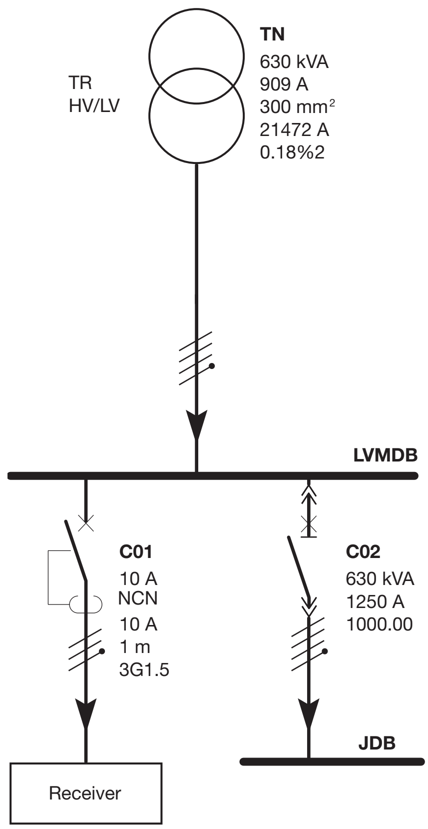
Incoming feeder devices

The general disconnection of the LV installation (NF C 13-100 Art.571) is provided using a visible-break device (immediately visible separation of contacts). This can be a switch-disconnector that meets the requirements of standard NF EN 60947-3 or a removable circuit breaker that meets the requirements of standard NF EN 60439-1.
The general LV protection against overloads downstream of the transformer is provided by a moulded-case circuit breaker combined with a disconnector with visible break or included in the removable circuit breaker (air circuit breaker).
Various additional controls and key-controlled interlocking provide safety for staff.

Version 1: Disconnector with visible break combined with a moulded-case circuit breaker (CO02)



Version 2: Removable circuit breaker C02 (air circuit breaker)



Energy distribution (busbars) using quadro+ units

The "general energy distribution" busbars are mounted edgewise vertically in a sheath installed for this purpose (width 200, 300 or 400 mm), or mounted horizontally at the top of the unit.
The busbar supports (ref. UC823 and UC824) are recommended. They can hold 1 or 2 busbars with a width of 5 or 10 mm and a maximum height of 100 mm.

These supports can also be used to create "incoming feeder" busbars placed at the top or bottom of the unit, or "secondary" intermediate busbars which can be placed at any height in the unit (mounted on quatro+ perforated crossbars).
Above a certain rating (I_N) for this type of assembly, it is more convenient to connect busbars with a thickness of 10 mm to external conductors.

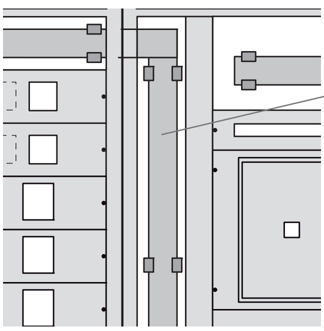
There are two types of assembly:
a) Main distribution busbar.
b) Incoming feeder connection busbar.

Example of the creation of a "main" busbar
1. Mounting in 400 mm deep quatro+ units
For busbars with In max. = 800 A, with:
- Copper busbars 50/63/80 × 5 × 1
- Busbar supports 3P-UC823/4P-UC824
- Fasteners for copper busbar 3P-UC825/4P-UC826

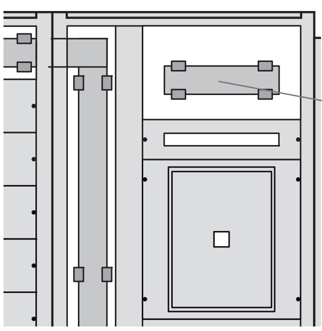
2. Mounting in 600 or 800 mm deep quatro+ units
For busbars with In max. = 1600 A, with:
- Copper busbars 50/63/80/100 × 5 × 1 – Copper 80/100 × 5 × 2
- Busbar supports 3P-UC823 or 4P-UC824
- Fasteners for copper busbar 3P-UC822 or 4P-UC825

In rating of busbars: Copper 63 × 5 × 1 (630 A) – Copper 80 × 5 × 1 (800 A) – Copper 100 × 5 × 1 (1000 A) – Copper 80 × 5 × 2 (1250 A) – Copper 100 × 5 × 2 (1600 A)

The number of supports is determined according to the length of the copper busbars and the maximum distance calculated according to the IK.
(For other configurations, please contact us)



Main distribution busbar



Incoming feeder connection busbar

Technical characteristics for selecting the busbars in the quatro+ units

The supports, ref. UC823/UC824, can hold 1 to 2 busbars per pole with a thickness of 5 or 10 mm, and can be mounted in units with a depth of 400, 600 and 800 m on perforated crossbars.
In units with a depth of 400 mm, it is preferable to mount only a single busbar per pole.
In units with a depth of 600 or 800 mm, 1 or 2 busbars can be mounted per pole, with the recommendations below:
For "transformer" distributions, P 800 kVA (1200 A) and 1000 kVA (1600 A), a unit with a depth of 800 mm will be selection if any of the following criteria apply:

- Unit installed against the wall (no rear access).
- A large number of cables for different outgoing feeders enter via the top behind the horizontal busbars positioned at the top of the unit.
- Number of incoming feeder cables (> 3 cables/phase) requires the creation of an "incoming feeder" busbar.
- The use of a four-phase 1600 A moulded-case circuit breaker or 2000 A air circuit breaker.

The main distribution busbars: Horizontal and vertical mounting in quadro+ units

Transformer power rating (kVA)	Busbar In (A)	Copper busbar (perforated)	Busbar supports	Unit depth (mm)	Notes
315 (455 A)	540	50 × 5 × 1	UC823 UC824 and UC822 UC825	400	
400 (577 A)	650	63 × 5 × 1		400	
500 (722 A)	800	80 × 5 × 1		400	
630 (909 A)	950	100 × 5 × 1		600	
800 (1155 A)	1400	80 × 5 × 2		600	With rear access to units
800 (1155 A)	1400	80 × 5 × 2		800	Units installed directly against the wall
1000 (1443 A)	1700	100 × 5 × 2		600	With rear access to units
1000 (1443 A)	1700	100 × 5 × 2		800	Units installed directly against the wall

The values in the table above are calculated for the use of perforated copper busbars:
- With ambient temperature of 35°C.
- With internal temperature of 45°C.
- With maximum busbar temperature of 80°C.
- In a IP54 enclosure.

The busbars for connecting the "incoming feeder": Horizontal mounting in quadro+ units

Transformer power rating (kVA)	Copper busbar (solid)	Busbar In (A)	Copper busbar (perforated)	Busbar In (A)	Busbar support	Cover height	Unit depth (mm)	Notes
315 (455 A)	50 × 5 × 1	600	50 × 5 × 1	540	UC823 UC824 and UC822 UC825	300	400	Direct connection to moulded-case terminal pads
400 (577 A)	63 × 5 × 1 40 × 10 × 1	700	63 × 5 × 1	650		300	400	
500 (722 A)	80 × 5 × 1 50 × 10 × 1	850	80 × 5 × 1	800		300	400	
630 (909 A)	100 × 5 × 1 63 × 10 × 1	1050	100 × 5 × 1	950		400	600	On busbar
800 (1155 A)	80 × 10 × 1	1300				400	600	With rear access to units
800 (1155 A)	80 × 10 × 1	1300				600	800	Units installed directly against the wall
1000 (1443 A)	100 × 10 × 1	1550				600	600	With rear access to units
1000 (1443 A)	100 × 10 × 1	1550				600	800	Units installed directly against the wall

The values in the tables above are calculated for the use of perforated or solid copper busbars:
- With ambient temperature of 35°C.
- With internal temperature of 45°C.
- With maximum busbar temperature of 80°C.
- In a IP54 enclosure.

General electrical distribution
For selecting products: Enclosures, moulded-case protective devices and modular circuit breakers, busbars, control and information devices, etc. see the various catalogue selection guides.

Terminology

Some general terms used in specifications

HV network: HVa high voltage 1 kV < U < 50 kV, HVb high voltage U > 50 kV.
Delivery substation (private): HV/HV or HV/LV delivery substation located within a private building that complies with standards NF C 13-100 and NF C 13-200.
Source, power of the source: Source and power rating of the power supply to the electrical installation (HVa/LV transformer or turbo generator).
Role of electrical boards: They are vital core in the installation, involved in the distribution of electrical energy and the protection circuits, individuals and property, as well as monitoring and controlling the installation.
LV system layout: Tree diagram of the various boards, geographically distributed according to the architectural configuration of the buildings and the source of the electrical installation.
Metering method: LV metering for a delivery substation with 1 transformer, HV metering if multiple HVa/LV transformers.
LV, LV distribution, LV system: LVa low voltage 50 V < U < 500 V, LVb low voltage 500 V < U < 1000 V.
LV boards: Distribution cabinets and boxes in the electrical installation. LV boards control the electrical energy for the entire installation.
LVMDB: Low-voltage main distribution board.
TRB: Transformer board (protection and LV switching) in the event the LVMDB is not located in the transformer substation room.
Enclosure: A sealed unit and the general terms for cabinets and boxes.
Electrical cabinet: Enclosure or sealed unit designed to be placed on the group. It contains and protects the electrical equipment.
Electrical box: Enclosure or sealed unit attached to a wall.
Earthing system: (Older term: neutral point treatment), TT, IT, TN (TNC/TNS).
Front- and rear-access cabinet: A cabinet in which the electrical equipment can also be accessed from the rear. This is important for devices that connect to rear terminals. Installation and maintenance of the cabinet are made easier with front and rear access.
Rear access space: Space reserved behind the entire length of the cabinet. This space must allow all technical interventions behind the cabinet to be carried out. Front and rear access to electrical boards and the type of connection are determined by the design of the rooms and the space reserved for the electrical equipment.
Against wall: For distribution boards with connections via the front; for LVMDBs (In > 800 A in incoming feeder), “against wall” installations are not advised due to issues relating to access (maintenance) and installation of equipment.
Cable channel: A space in the floor reserved for the wiring for electrical boards. The LVMDB is generally installed above the channel.
Board layout: Electrical boards are subdivided into areas. The areas can be partitioned or not partitioned. The areas increase safety and ensuring that the equipment works properly. The areas are as follows: power connection area, feeder equipment area, measurement area, busbar area, outgoing circuit breaker area, modular device and final circuit areas, ELV area, low current area and terminals area.
Main LV circuit breaker: Main circuit breaker downstream of the HVa/LV transformer.
Mounted device: Device that can be removed from the system using a tool.
Front-mounted device: Front terminal connection.
Rear-mounted device: Rear terminal connection.
Removable device: The device can be moved manually from the rear to the front to a set position corresponding to the disconnection distance between its upstream and downstream connection terminals. According to the weight and size of the device, it can be removed from either a socket or the frame.
Disconnectable device: The upstream terminals of the device can be removed. The downstream terminal connections are fixed.
Draw-out circuit breaker: Circuit breaker combined with a special cradle that allows the device to be racked in and racked out. This combination meets the requirements of Article 571 of NF C 13-100 (disconnector with visible break). It is fitted with a key locking device that complies with Article 462 of NF C 13-100.
These provisions are intended to ensure to safety of individuals working on the HV part. The aim is to avoid voltage returning to the LV system.
Disconnector with visible break: Switch-disconnector with visible break combined with a front- or rear-mounted moulded-case circuit breaker providing the visible break and overload protector (LV transformer) required in Article 571 of NF C 13-100. A key locking device is fitted to the disconnector with visible break.
Manual and automatic changeover switches: Allows switching between two sources. E.g.: Switching of emergency circuits from the “normal system” position to the “emergency generator” position, and vice versa.
Coupling switch: Allows switching or coupling of two LV circuits as well as their disconnection for safety (e.g. coupling 2 transformers operating in parallel or independently).
Feeder busbars: Smaller busbars mounted on the incoming feeder pads of the main device (circuit breaker or switch). The feeder busbars enable and increase the number of connection points for feeder equipment supply terminals (e.g. connection of 3 or 5 single-core cables per phase).
Main busbar: Busbar powered directly via the main circuit breaker. At its source, it has the current measurement transformers. The arrangement of the main busbar is often vertical or horizontal.
Connector: The horizontal busbar is interrupted where the units meet. They are transported individually or in pairs. The connectors (pieces of copper) allow the busbars to be connected when assembling the units at the site.
Insulated flexible bars or insulated copper strips: Insulated flat, flexible copper conductor used for certain electrical connections in cabinets. These flexible bars are more easily installed than bare rigid copper bars, which require prior work done on them.

Selection of ducts by material

	PVC	Aluminium	Steel	PC-ABS	Polyester	PPO
Distribution ducts	FB, lifea		LFS	LFH	LFG	
Installation ducts with direct device clip-in, 45 × 45	queraz PVC	queraz aluminium				
Installation ducts with device installation	lifea, BR	BRA	BRS			
Moulding with device installation	ateha					
Skirting boards with device installation	SL					
Fire-resistant ducts			FWK			
Columns and mini-columns		topaz				
Cable ducts	BA7A, DNG					HNG

PVC
Impact resistance: Equivalent to **IK7**
Flame retardant **M1**
(doe not easily catch fire)
UL94 rating **V0**
Service temperature range –5°C to +65°C.

PPO
Contains no halogens
UL94 rating **V1**
Service temperature range –25°C to +90°C.

Aluminium
Naturally anodised

PC-ABS
Good impact resistance (14 kj/mm²)
Contains no halogens
UL94 rating **V0**
Service temperature range –30°C to +90°C.

Polyester
Good impact resistance (70 kj/mm²)
Contains no halogens
UL94 rating **V0**
Service temperature range –80°C to +130°C.

Galvanised steel
Zinc coating on both sides
Can be coated in any RAL colour

Selection of ducts by type of device

Hager	systo kallysta essensya		Moulding	Skirting boards SKE	Ducts with device installation SKE	SKE	Ducts and columns with direct device clip-in S	S	S
			ateha	SL	LFF	BR/BRA/BRS	queraz PVC	queraz aluminium	topaz
Tehalit	zenith	Socket unit			■		■	■	■
		RJ cable socket		■	■	■	■	■	■
Legrand		Surface-mounted devices	■						
		Céliane		■	■	■			
		Neptune		■	■	■			
	Mosaïc	Standard mechanism		■	■	■	■	■	■
		DLP			■		■	■	■
		RJ-45 socket		■	■	■	■	■	■
		ACO socket			■ except depth of 40	■ except depth of 50	■	■	■
Arnould		Profil²	■						
	Espace Liberté	45 × 45 mechanism		■	■	■	■	■	■
		Special duct socket			■		■	■	■
		Espace		■	■	■			
		Initia		■	■	■			
Alombard		Alréa	■						
		Alvaïs		■	■	■			
		Alcyon		■	■	■			
		Altira		■	■	■	■	■	■

Diameter and cross-section of high- and low-voltage cables and wires

	Approx. external Ø in mm	Cross-section in mm²
Wire: H 07 V		
1.5	2.8	6.2
2.5	3.4	9.1
4	3.9	11.9
6	4.7	17.3
Telephone cable – STY1		
1 pair	3.8	11.3
2 pairs	4.9	18.9
3 pairs	5.2	21.2
4 pairs	5.7	25.5
5 pairs	6.1	29.2
Data cable – Cat 5		
FTP 100 V 4 pairs	6.0	28.3
L120 120 V 4 pairs	8 × 5	40.0
L120 120 V 8 pairs	10.5 × 8	84.0
Television cable		
Coax 75 V	7.0	38.5

	Approx. external Ø in mm	Cross-section in mm²
Cable U1000R02V – H07RNF		
2 × 1.5	8.4	55.4
2 × 2.5	9.6	72.4
2 × 4	10.5	86.6
2 × 6	11.8	109.4
3 × 1.5	8.8	60.8
3 × 2.5	10.0	78.5
3 × 4	11.0	95.0
3 × 6	12.9	130.7
4 × 1.5	9.6	72.4
4 × 2.5	11.0	95.0
4 × 4	12.2	116.9
4 × 6	14.2	158.4
5 × 1.5	10.0	78.5
5 × 2.5	11.6	105.7
5 × 4	13.5	143.1
5 × 6	15.5	188.7

Installation advice

Mounting conduits

Drilling into plastics
Metal bits, lip and spur bits and cylindrical and conical bits that are widely available in shops can be used for drilling. Do not use a centre punch for the hole.
Any burr that appears when sawing and drilling can be removed with a knife, razor scraper or a file.

- Mounting
Use 4 × 40 mm screws, combined with suitable washers and plugs that are widely available in shops.

- Intervals between screws
Standard length conduits are mounted attached at at least four points with a pair of screws. On PVC conduits, the intervals between screws must be no longer than 0.66 mm.

- Gluing hard PVC
The surfaces must be clean, degreased and dry.
The PVC should be cleaned using solvents recommended by the glue manufacturer, e.g. dichloromethane or common solvents available in shops.
Clean metal surfaces using trichloroethylene or white spirit. Sand using coarse emery paper to increase the surface area and increase the adhesive strength of the glue. We especially recommend roughening up metal and wood surfaces that are to be glued.

Cutting to length

- Plastic conduits
To cut plastic conduits to length, it is recommended tat you use a fine-toothed saw (hacksaw or jigsaw). If the cutting must be done using a machine, use a circular saw fitted with a blade for cutting plastics with a diameter of between 250 and 350mm (number of teeth: between 80 and 108, alternate top bevel, rotation speed 2800 rpm, approx 37–51 m/s).

- Polyester conduits reinforced with fibreglass
Use a diamond blade for a circular saw or jigsaw.
Sawing by hand: Bow saw with blade for cutting metals.

- Aluminium conduits
Cut using a circular saw with a blade with 96 to 108 carbide-tipped teeth with a diameter of between 250 and 350 mm.
Rotation speed: 2800 rpm.
Cutting speed: 37–51 m/s.

- Sheet steel conduits
Machine sawing:
Bandsaw: Blade 0.9 mm thick, carbide, 24 TPI.
Cutting speed: 60 m/min.
Reciprocating saw, Ackermann u. Schmitt brand, model ZS 110, 500 W, 1.7 kg, 10,000 strokes/min.
Jigsaw with blade for cutting metals.
Sawing by hand: Hacksaw.

PVC (BA7A/DNG)

Mechanical properties
Tensile strength: 30 N/mm^2
Impact resistance: 4 kj/mm^2
Termite resistant (Entomology laboratory Rap BFA 132/68)

Electrical properties
Specific resistivity: > 10^{17} Ω/cm
Surface resistivity: > 10^{11} Ω
Dielectric strength: > 35 kV/mm
Dielectric constant: ∼ 2.7

Thermal properties
Service temperature range: –5°C to +65°C
Coefficient of thermal expansion: 71 × 10^{-6}/°C (equal to expansion of 2.1 mm per metre from a difference of 30°C)

Behaviour when exposed to fire
Reaction to fire classification: M1 (Laboratory LCPP PV N° 1382/99)
UL94 rating: V0 (Laboratory LCIE PV N° 284598C)

Fibreglass reinforced polyester (FRP)

Mechanical properties
Impact resistance: 70 kj/mm^2
Tensile strength: (ISO R 727) 22 N /mm^2
Modulus of elasticity: (ISO R 727) 8400 N/mm^2

Electrical properties
Surface resistivity: 2 × 10^{14} Ω
Dielectric strength: 6.5 kV/mm

Thermal properties
Service temperature range: –80°C to +130°C
Coefficient of thermal expansion: 40 × 10^{-6}/°C (equal to expansion of 1.2 mm per metre from a difference of 30°C)

Behaviour when exposed to fire
Contains no halogens
Does not propagate fire according to BS 476 part 7: Class 2
UL94 rating: V0

PC ABS (HA7)

Mechanical properties
Impact resistance: 14 kj/mm^2
Tensile strength at break: 64 Mpa (ISO 527)

Electrical properties
Surface resistivity: > 10^{15} Ω
Dielectric strength: > 21 kV/mm
Dielectric constant: ∼ 2.7

Thermal properties
Service temperature range: –30°C to +90°C
Coefficient of thermal expansion: 1 × 10^{-4}/°C (equal to expansion of 3 mm per metre from a difference of 30°C)

Behaviour when exposed to fire
Contains no halogens
Reaction to fire classification: M1
UL94 rating: V0

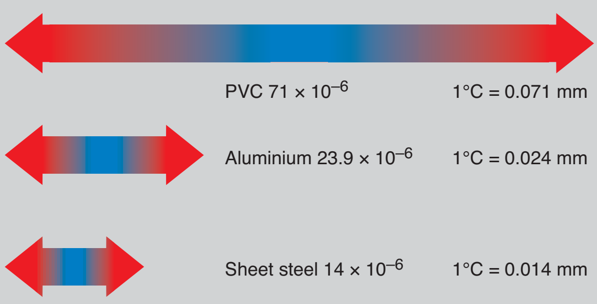
PPO

Electrical properties
Specific resistivity: > 10^{17} Ω/cm
Surface resistivity: > 10^{11} Ω
Dielectric strength: > 35 kV/mm
Dielectric constant: ∼ 2.7

Thermal properties
Service temperature range: –25°C to +90°C
Coefficient of thermal expansion: 59 × 10^{-6}/°C (equal to expansion of 1.77 mm per metre from a difference of 30°C)

Behaviour when exposed to fire
Contains no halogens
UL94 rating: V1

Thermal expansion



Linear thermal expansion = change in length from 1°C

Regulatory approvals and certifications
Cable ducts

BA7A, DNG
CSA no. 184n 90; Reg. no. 22009 (DNG, VK flex)
UL no. E48414
EN 50085, UL no. 48414, CSA no. 22009, UL 94V0

HA7
EN 50085, UL no. 48414, UL 94V0

Ateha, moulding
France:
NFC 68-104 (except ATA 20752, ATA 6300: NFC 68-102)
Equivalent to IK7 IP40
Others:
EZU, MEEI, EVPU, SEP-BBJ

SL, skirting boards
France:
NFC 68-104
Equivalent to IK7
Others:
VDE 00604/3, ÖVE, KEMA, EZU, MEEI, EVPU, SEP-BBJ

LF, Lifea, distribution ducts
France:
NFC 68-102
Equivalent to IK7
Others:
VDE 00604/1, ÖVE, SEV, SEMKO, KEMA, NEMKO, EZU, MEEI, EVPU, SEP-BBJ

FB, distribution ducts
France:
NFC 68-102
Equivalent to IK7
Others:
VDE 00604/2, ÖVE, SEV, SEMKO, KEMA, NEMKO, EZU, MEEI, EVPU, SEP-BBJ

GBD, ducts with direct device clip-in
France:
NFC 68-102

BR, distribution ducts
France:
NFC 68-102
Equivalent to IK7
Others:
VDE 00604/2, ÖVE, SEMKO, KEMA, EZU, MEEI, EVPU, SEP-BBJ

BA7A, DNG, cable ducts
CSA no. 184n 90; Reg. no. 22009 (DNG, VK flex)
UL no. E48414
EN 50085, UL no. 48414, CSA no. 22009, UL 94V0

HA7
EN 50085, UL no. 48414, UL 94V0

FWK
Fire-resistant electrical distribution duct system

FWK 30
Fire resistance: **I 90**
Certified according to DIN 4102/11

The **FWK 30** ducts comply with this standard, with fire resistance within the ducts for a minimum of 90 minutes.

Any other regulatory approvals on request

FWK 90
Fire resistance: **I 120 and E**
Certified according to DIN 4102/11 and DIN 4102/12.

The **FWK 90** ducts comply with standard DIN 4102/11 (class **I**), guaranteeing fire resistance within the ducts for a minimum of 120 minutes.

The **FWK 90** ducts comply with standard DIN 4102/12 (class **E**), guaranteeing fire resistance outside of the ducts, remaining operational, for a minimum of 60 or 80 minutes (according to the duct) if the duct is mounted directly on a wall or ceiling, or 30 minutes if mounted on tables (in cable trays).

DIN 4102/11
The class **I** test for DIN 4102/11 determines the duration for which the duct prevents the escape of flames and hot or inflammable gases when a fire occurs within the duct. For this duration, the outer surface shall not exceed 140°C on average or 180°C at any given point.

DIN 4102/12
The class **E** test for DIN 4102/12 determines the minimum duration for which the duct will allow the electrical conductors within to continue to operate when a fire occurs outside of the duct.

hager

The products listed below have obtained NF or EN approval.
When this symbol has been placed on a product, it certifies that it has successfully undergone mechanical and electrical tests, guaranteeing optimal performance and reliability.

Miniature circuit breakers	Miniature circuit breakers	Miniature circuit breakers	Miniature circuit breakers	Miniature circuit breakers
MHN – 4500 A EN 60 898-1	MW225	MU210A	MC103A	NGN201
MHN706	MW232	MU216A	MC104A	NGN202
MHN710	MW240	MU220A	MC106A	NGN203
MHN716		MU225A	MC110A	NGN204
MHN720	MW306	MU232A	MC116A	NGN206
MHN725	MW310	MU240A	MC120A	NGN210
MHN732	MW316	MU250A	MC125A	NGN216
MHN740	MW320	MU263A	MC132A	NGN220
	MW325		MC140A	NGN225
MJN – 4500 A EN 60 898-1	MW332	MU306A	MC150A	NGN232
MJN702	MW340	MU310A	MC163A	NGN240
MJN706		MU316A		NGN250
MJN710	MW406	MU320A	MC200A	NGN263
MJN716	MW410	MU325A	MC201A	
MJN720	MW416	MU332A	MC202A	NGN300
MJN725	MW420	MU340A	MC203A	NGN301
MJN732	MW425	MU350A	MC204A	NGN302
MJN740	MW432	MU363A	MC206A	NGN303
	MW440		MC210A	NGN304
MLN – 6000 A EN 60 898-1		MU406A	MC216A	NGN306
MLN702	**MT – 6000 A** EN 60 898-1	MU410A	MC220A	NGN310
MLN706	MT106A	MU416A	MC225A	NGN316
MLN710	MT110A	MU420A	MC232A	NGN320
MLN716	MT116A	MU425A	MC240A	NGN325
MLN720	MT120A	MU432A	MC250A	NGN332
MLN725	MT125A	MU440A	MC263A	NGN340
MLN732	MT132A	MU450A		NGN350
	MT140A	MU463A	MC300A	NGN363
MV – 3000 A EN 60 898-1	MT150A		MC301A	
MV106	MT163A	**MB – 6000 A** EN 60 898-1	MC302A	NGN400
MV110		MB106A	MC303A	NGN401
MV116	MT206A	MB110A	MC304A	NGN402
MV120	MT210A	MB116A	MC306A	NGN403
MV125	MT216A	MB120A	MC310A	NGN404
MV132	MT220A	MB125A	MC316A	NGN406
MV140	MT225A	MB132A	MC320A	NGN410
	MT232A	MB140A	MC325A	NGN416
MV206	MT240A	MB150A	MC332A	NGN420
MV210	MT250A	MB163A	MC340A	NGN425
MV216	MT263A		MC350A	NGN432
MV220		MB206A	MC363A	NGN440
MV225	MT306A	MB210A		NGN450
MV232	MT310A	MB216A	MC400A	NGN463
MV240	MT316A	MB220A	MC401A	
	MT320A	MB225A	MC402A	**NBN – 10000 A** EN 60 898-1
MV306	MT325A	MB232A	MC403A	NBN106A
MV310	MT332A	MB240A	MC404A	NBN110A
MV316	MT340A	MB250A	MC406A	NBN116A
MV320	MT350A	MB263A	MC410A	NBN120A
MV325	MT363A		MC416A	NBN125A
MV332		MB306A	MC420A	NBN132A
MV340	MT406A	MB310A	MC425A	NBN140A
	MT410A	MB316A	MC432A	NBN150A
MV406	MT416A	MB320A	MC440A	NBN163A
MV410	MT420A	MB325A	MC450A	
MV416	MT425A	MB332A	MC463A	NBN206A
MV420	MT432A	MB340A		NBN210A
MV425	MT440A	MB350A	**NGN – 10000 A** EN 60 898-1	NBN216A
MV432	MT450A	MB363A	NGN100	NBN220A
MV440	MT463A		NGN101	NBN225A
		MB406A	NGN102	NBN232A
MW – 3000 A EN 60 898-1	**MU – 6000 A** EN 60 898-1	MB410A	NGN103	NBN240A
MW106		MB416A	NGN104	NBN250A
MW110	MU106A	MB420A	NGN106	NBN263A
MW116	MU110A	MB425A	NGN110	
MW120	MU116A	MB432A	NGN116	NBN306A
MW125	MU120A	MB440A	NGN120	NBN310A
MW132	MU125A	MB450A	NGN125	NBN316A
MW140	MU132A	MB463A	NGN132	NBN320A
	MU140A		NGN140	NBN325A
MW206	MU150A	**MC – 6000 A** EN 60 898-1	NGN150	NBN332A
MW210	MU163A	MC100A	NGN163	NBN340A
MW216		MC101A		NBN350A
MW220	MU206A	MC102A	NGN200	NBN363A

Miniature circuit breakers

NBN406A
NBN410A
NBN416A
NBN420A
NBN425A
NBN432A
NBN440A
NBN450A
NBN463A

NCN – 10000 A EN 60 898-1
NCN100A
NCN101A
NCN102A
NCN103A
NCN104A
NCN106A
NCN110A
NCN116A
NCN120A
NCN125A
NCN132A
NCN140A
NCN150A
NCN163A

NCN200A
NCN201A
NCN202A
NCN203A
NCN204A
NCN206A
NCN210A
NCN216A
NCN220A
NCN225A
NCN232A
NCN240A
NCN250A
NCN263A

NCN300A
NCN301A
NCN302A
NCN303A
NCN304A
NCN306A
NCN310A
NCN316A
NCN320A
NCN325A
NCN332A
NCN340A
NCN350A
NCN363A

NCN400A
NCN401A
NCN402A
NCN403A
NCN404A
NCN406A
NCN410A
NCN416A
NCN420A
NCN425A
NCN432A
NCN440A
NCN450A
NCN463A

NDN – 10000 A EN 60 898-1
NDN100A
NDN101A
NDN102A
NDN103A
NDN104A
NDN106A

Miniature circuit breakers

NDN110A
NDN116A
NDN120A
NDN125A
NDN132A
NDN140A
NDN150A
NDN163A

NDN200A
NDN201A
NDN202A
NDN203A
NDN204A
NDN206A
NDN210A
NDN216A
NDN220A
NDN225A
NDN232A
NDN240A
NDN250A
NDN263A

NDN300A
NDN301A
NDN302A
NDN303A
NDN304A
NDN306A
NDN310A
NDN316A
NDN320A
NDN325A
NDN332A
NDN340A
NDN350A
NDN363A

NDN400A
NDN401A
NDN402A
NDN403A
NDN404A
NDN406A
NDN410A
NDN416A
NDN420A
NDN425A
NDN432A
NDN440A
NDN450A
NDN463A

HLE – 10000 A EN 60 898-1
HLE180S
HLE190S
HLE199S

HLE280S
HLE290S
HLE299S

HLE380S
HLE390S
HLE399S

HLE480S
HLE490S
HLE499S

HLF – 10000 A EN 60 898-1
HLF180S
HLF190S
HLF199S

HLF280S
HLF290S

Miniature circuit breakers

HLF299S

HLF380S
HLF390S
HLF399S

HLF480S
HLF490S
HLF499S

HMB – 15000 A EN 60 898-1
HMB180
HMB190
HMB199

HMB280
HMB290
HMB299

HMB380
HMB390
HMB399

HMB480
HMB490
HMB499

HMC – 15000 A EN 60 898-1
HMC180
HMC190
HMC199

HMC280
HMC290
HMC299

HMC380
HMC390
HMC399

HMC480
HMC490
HMC499

HMD – 15000 A EN 60 898-1
HMD180
HMD190
HMD199

HMD280
HMD290
HMD299

HMD380
HMD390
HMD399

HMD480
HMD490
HMD499

HMJ – 30000 A EN 60 898-1
HMJ180
HMJ190
HMJ199

HMJ280
HMJ290
HMJ299

HMJ380
HMJ390
HMJ399

HMJ480
HMJ490
HMJ499

Miniature circuit breakers

HMK – 30000 A EN 60 898-1
HMJ180
HMK180
HMK190
HMK199

HMK280
HMK290
HMK299

HMK380
HMK390
HMK399

HMK480
HMK490
HMK499

HMX – 50000 A EN 60 898-1
HMX110
HMX116
HMX120
HMX125
HMX132
HMX140
HMX150
HMX163

HMX210
HMX216
HMX220
HMX225
HMX232
HMX240
HMX250
HMX263

HMX310
HMX316
HMX320
HMX325
HMX332
HMX340
HMX350
HMX363

HMX410
HMX416
HMX420
HMX425
HMX432
HMX440
HMX450
HMX463

Ph/N RCCBs

AD – 6000 A EN 61 009-1
AD104
AD105
AD107
AD108
AD109
AD110
AD111
AD113

AD119
AD120
AD121
AD122
AD123
AD124
AD125
AD126
AD128

Ph/N RCCBs

AE – 6000 A EN 61 009-1
AE106Z
AE110Z
AE116Z
AE120Z
AE125Z
AE132Z
AE140Z
AE150Z
AE163Z

AF – 6000 A EN 61 009-1
AF106Z
AF110Z
AF116Z
AF120Z
AF125Z
AF132Z
AF140Z
AF145Z

ADB – 10000 A EN 61 009-1
ADB106
ADB110
ADB116
ADB120
ADB125
ADB132
ADB140
ADB150

ADC – 10000 A EN 61 009-1
ADC106
ADC110
ADC116
ADC120
ADC125
ADC132
ADC140
ADC150

AEC – 10000 A EN 61 009-1
AEC106
AEC110
AEC116
AEC120
AEC125
AEC132
AEC140

ADA – 10000 A EN 61 009-1
ADA156U
ADA160U
ADA166U
ADA170U
ADA175U
ADA182U

AD – 4500 A EN 61 009-1
AD806J
AD810J
AD816J
AD820J
AD825J
AD832J
AD840J

AD856J
AD860J
AD866J
AD870J
AD875J
AD882J
AD890J

AD – 6000 A EN 60 009-1
AD906B
AD910B

Ph/N RCCBs

AD916B
AD920B
AD925B
AD932B
AD940B

AD956B
AD960B
AD966B
AD970B
AD975B
AD982B
AD990B

AE – 6000 A EN 61 009-1
AE956B
AE960B
AE966B
AE970B
AE975B
AE982B
AE990B

AF – 6000 A EN 61 009-1
AF956B
AF960B
AF966B
AF970B
AF975B
AF982B
AF990B

AF – 6000 A EN 61 009-1
AD906J
AD910J
AD916J
AD920J
AD925J
AD932J
AD940J

AD956J
AD960J
AD966J
AD970J
AD975J
AD982J
AD990J

AF – 6000 A EN 61 009-1
AF956J
AF960J
AF966J
AF970J
AF975J
AF982J
AF990J

Add-on block

BDC940F
BDH225F
BDH240F
BDH325F
BDH340F
BDH425F
BDH440F
BDH925F
BDH940F
BFC225F
BFC240F
BFC325F
BFC340F
BFC425F
BFC440F
BFC925F
BFC940F

Add-on block

BFH225F
BFH240F
BFH325F
BFH340F
BFH425F
BFH440F
BFH925F
BFH940F

BDC280E
BDC380E
BDC480E
BDC825
BDC840
BDC863
BDH280E
BDH380E
BDH480E
BDH825
BDH840
BDH863
BFC480E
BFC825
BFC840
BFC863
BFH480E
BFH825
BFH840
BFH863
BPC863
BSC863
BTC280E
BTC380E
BTC480E
BTH280E
BTH380E
BTH480E

RCCBs EN 61 009-1

CC217J
CD225J
CD226J
CD240J
CD241J
CD263J
CD264J
CD281Z
CD285Z
CD425J
CD426J
CD440J
CD441J
CD463J
CD464J
CD481Z
CD485Z
CDB440F
CDB463F
CE19010
CE226J
CE241J
CE264J
CE281Z
CE285Z
CE29010
CE39010
CE426J
CE441J
CE464J
CE481Z
CE485Z
CF225J
CF226J
CF240J
CF241J
CF263J
CF264J

RCCBs EN 61 009-1

CF281Z
CF285Z
CF425J
CF426J
CF440J
CF441J
CF463J
CF464J
CF481Z
CF485Z
CH225J
CH240J
CH263J
CH425J
CH440J
CH463J

Switches/changeover switches EN 60 669-1 and IEC 60 947-3

SBB116
SBB125
SBB132
SBB216
SBB225
SBB232
SBN116
SBN125
SBN132
SBN140
SBN163
SBN180
SBN190
SBN199
SBN216
SBN225
SBN232
SBN240
SBN263
SBN280
SBN290
SBN299
SBN325
SBN325
SBN332
SBN332
SBN340
SBN340
SBN363
SBN363
SBN380
SBN380
SBN390
SBN390
SBN399
SBN399
SFH125
SFH125
SFH132
SFH225
SFH232
SFM125
SFM132
SFT125
SFT132
SFT140
SFT225
SFT232
SFT240

16 A sockets NF C 61-314

SN216
SN316

20 A sockets NF C 61-316

SN120
SN220
SN320

Transformers EN 61 558-1 and EN 61 558-2

ST301
ST303
ST305
ST312
ST313
ST314
ST315

Overvoltage release EN 50 550

MZ212

Remote switches EN 60 669-1 and EN 60 669-2

EPN501
EPN503
EPN510
EPN511
EPN513
EPN515
EPN518
EPN519
EPN520
EPN521
EPN524
EPN525
EPN526
EPN528
EPN540
EPN541
EPN546
EPS410B
EPS450B
EPS510B

Standard modular contactors without override control

ESC125
ESC126
ESC225
ESC240
ESC263
ESC226
ESC241
ESC264
ESC227
ESC325
ESC340
ESC363
ESC425
ESC440
ESC463
ESC426
ESC441
ESC464
ESC427
ESC442
ESC465
ESC428
ESC443
ESC466
ESM225
ESM227
ESM440
ESM463
ESD125

Standard modular contactors without override control

ESD225
ESD240
ESD263
ESD226
ESD241
ESD264
ESD227
ESD425
ESD440
ESD463
ESD426
ESD464
ESD427
ESD428
ESL125
ESL225
ESL240
ESL263
ESL226
ESL241
ESL264
ESL227
ESL425
ESL440
ESL463
ESL426
ESL427
ESL428

Low noise modular contactors without override control

ESC125S
ESC225S
ESC240S
ESC263S
ESC325S
ESC340S
ESC363S
ESC326S
ESC425S
ESC440S
ESC463S
ESC426S
ESC427S
ESC428S
ESD125S
ESD225S
ESD240S
ESD263S
ESD325S
ESD340S
ESD363S
ESD326S
ESD425S
ESD440S
ESD463S
ESD426S
ESD427S
ESD428S
ESL240S
ESL263S
ESL440S
ESL463S

Standard modular contactors with override control

ERC125
ERC216
ERC225
ERC240
ERC263
ERC217

Standard modular contactors with override control				
ERC226 ERC316 ERC325 ERC416 ERC425 ERC426 ERC418 ERC427 ERC428 ERD216 ERD225 ERD240 ERD263 ERD217 ERD218 ERD418 ERD425 ERL216 ERL225 ERL240 ERL263 ERL217 ERL218 ERL418 ERL425				
Low noise modular contactors with override control				
ERC125S ERC225S ERC240S ERC425S ERD225S ERD240S ERD263S ERD418S ERL240S ERL263S				
DC control voltage contactors use with and without override control				
ESL225SDC ESL240S ESL263S ESL326S ESL425SDC ESL440S ESL463S ESL426SDC ESC427SDC ESC428SDC ESC240S ESC263S ESC425SDC ESC440S ESC263S ERL625SDC ERL240S ERL263S ERL425SDC ERL418SDC ERD225SDC ERD240S ERD263S				

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