Technical Series

Electrical installation guide

According to IEC International Standards

2008

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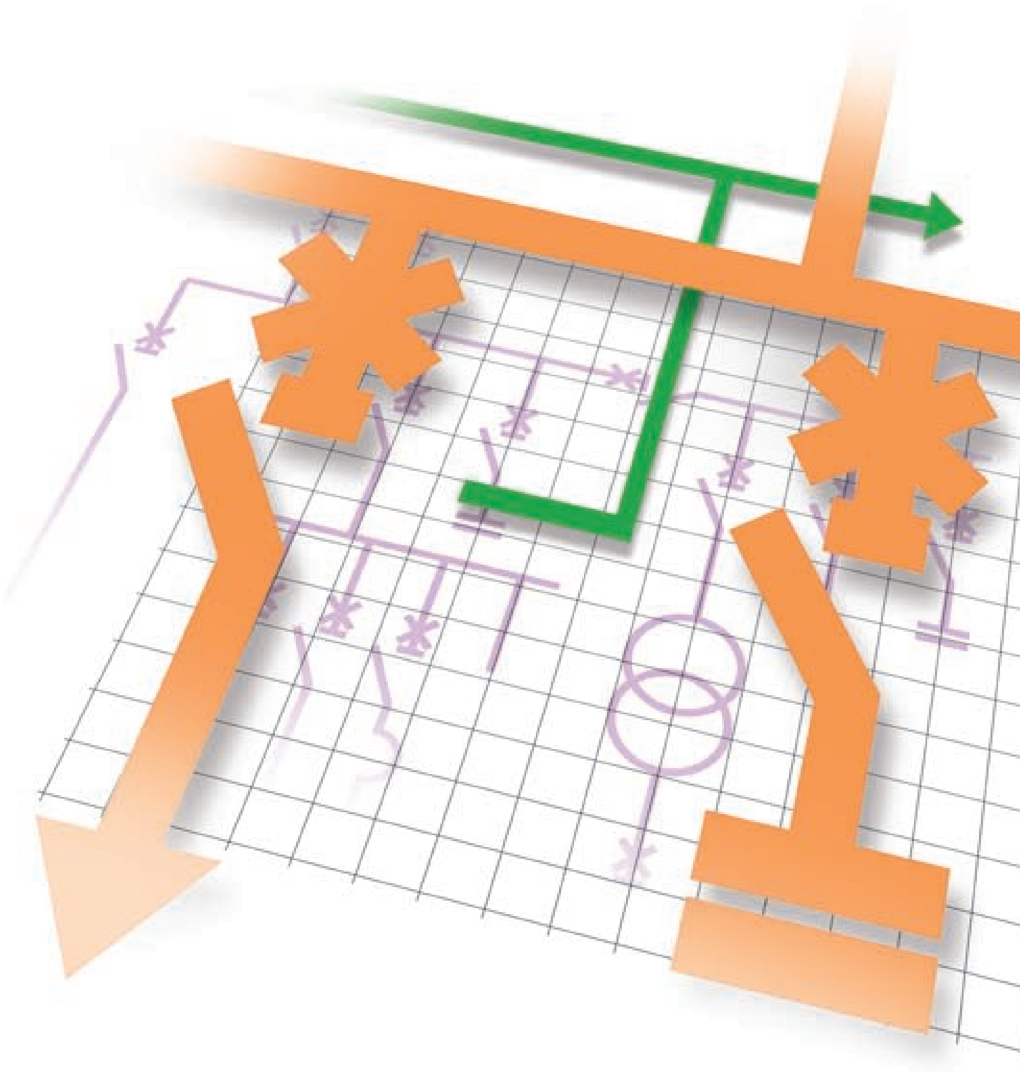


Schneider Electric

Chapter A
General rules of electrical installation design

Contents

3 Installed power loads - Characteristics

Type of lamp	Lamp power (W)	Current at 230 V (A)
Separated ballast lamp	10	0.080
	18	0.110
	26	0.150
Integrated ballast lamp	8	0.075
	11	0.095
	16	0.125
	21	0.170

Fig. A7 : Current demands and power consumption of compact fluorescent lamps (at 230 V - 50 Hz)

The power in watts indicated on the tube of a discharge lamp does not include the power dissipated in the ballast.

Discharge lamps

Figure A8 gives the current taken by a complete unit, including all associated ancillary equipment.

These lamps depend on the luminous electrical discharge through a gas or vapour of a metallic compound, which is contained in a hermetically-sealed transparent envelope at a pre-determined pressure. These lamps have a long start-up time, during which the current I_a is greater than the nominal current I_n. Power and current demands are given for different types of lamp (typical average values which may differ slightly from one manufacturer to another).

Type of lamp (W)	Power demand (W) at		Current I_n(A)				Starting		Luminous efficiency (lumens per watt)	Average timelife of lamp (h)	Utilization
			PF not corrected		PF corrected		I_a/I_n	Period (mins)			
	230 V	400 V	230 V	400 V	230 V	400 V					
High-pressure sodium vapour lamps											
50	60		0.76		0.3		1.4 to 1.6	4 to 6	80 to 120	9000	■ Lighting of large halls ■ Outdoor spaces ■ Public lighting
70	80		1		0.45						
100	115		1.2		0.65						
150	168		1.8		0.85						
250	274		3		1.4						
400	431		4.4		2.2						
1000	1055		10.45		4.9						
Low-pressure sodium vapour lamps											
26	34.5		0.45		0.17		1.1 to 1.3	7 to 15	100 to 200	8000 to 12000	■ Lighting of autoroutes ■ Security lighting, station ■ Platform, storage areas
36	46.5				0.22						
66	80.5				0.39						
91	105.5				0.49						
131	154				0.69						
Mercury vapour + metal halide (also called metal-iodide)											
70	80.5		1		0.40		1.7	3 to 5	70 to 90	6000	■ Lighting of very large areas by projectors (for example: sports stadiums, etc.)
150	172		1.80		0.88					6000	
250	276		2.10		1.35					6000	
400	425		3.40		2.15					6000	
1000	1046		8.25		5.30					6000	
2000	2092	2052	16.50	8.60	10.50	6				2000	
Mercury vapour + fluorescent substance (fluorescent bulb)											
50	57		0.6		0.30		1.7 to 2	3 to 6	40 to 60	8000 to 12000	■ Workshops with very high ceilings (halls, hangars) ■ Outdoor lighting ■ Low light output(1)
80	90		0.8		0.45						
125	141		1.15		0.70						
250	268		2.15		1.35						
400	421		3.25		2.15						
700	731		5.4		3.85						
1000	1046		8.25		5.30						
2000	2140	2080	15		11	6.1					

(1) Replaced by sodium vapour lamps.

Note: these lamps are sensitive to voltage dips. They extinguish if the voltage falls to less than 50% of their nominal voltage, and will not re-ignite before cooling for approximately 4 minutes.

Note: Sodium vapour low-pressure lamps have a light-output efficiency which is superior to that of all other sources. However, use of these lamps is restricted by the fact that the yellow-orange colour emitted makes colour recognition practically impossible.

Fig. A8 : Current demands of discharge lamps

1 Supply of power at medium voltage

In order to ensure adequate protection of equipment against abnormally-medium short term power-frequency overvoltages, and transient overvoltages caused by lightning, switching, and system fault conditions, etc. all MV equipment must be specified to have appropriate rated insulation levels.

A "rated insulation level" is a set of specified dielectric withstand values covering various operating conditions. For MV equipment, in addition to the "highest voltage for equipment", it includes lightning impulse withstand and short-duration power frequency withstand.

Switchgear

Figure B2 shown below, lists normal values of “withstand” voltage requirements from IEC 62271-1 Standard. The choice between List 1 and List 2 values of table B2 depends on the degree of exposure to lightning and switching overvoltages(1), the type of neutral earthing, and the type of overvoltage protection devices, etc. (for further guidance reference should be made to IEC 60071).

Rated voltage U (r.m.s. value)	Rated lightning impulse withstand voltage (peak value)				Rated short-duration power-frequency withstand voltage (r.m.s. value)	
	List 1		List 2			
	To earth, between poles and across open switching device	Across the isolating distance	To earth, between poles and across open switching device	Across the isolating distance	To earth, between poles and across open switching device	Across the isolating distance
(kV)	(kV)	(kV)	(kV)	(kV)	(kV)	(kV)
3.6	20	23	40	46	10	12
7.2	40	46	60	70	20	23
12	60	70	75	85	28	32
17.5	75	85	95	110	38	45
24	95	110	125	145	50	60
36	145	165	170	195	70	80
52	-	-	250	290	95	110
72.5	-	-	325	375	140	160

Note: The withstand voltage values “across the isolating distance” are valid only for the switching devices where the clearance between open contacts is designed to meet requirements specified for disconnectors (isolators).

Fig. B2 : Switchgear rated insulation levels

It should be noted that, at the voltage levels in question, no switching overvoltage ratings are mentioned. This is because overvoltages due to switching transients are less severe at these voltage levels than those due to lightning.

Transformers

Figure B3 shown below have been extracted from IEC 60076-3.

The significance of list 1 and list 2 is the same as that for the switchgear table, i.e. the choice depends on the degree of exposure to lightning, etc.

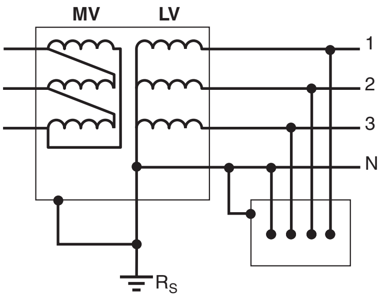
Highest voltage for equipment (r.m.s.) (kV)	Rated short duration power frequency withstand voltage (r.m.s.) (kV)	Rated lightning impulse withstand voltage (peak)	
		List 1 (kV)	List 2 (kV)
⩽ 1.1	3	-	-
3.6	10	20	40
7.2	20	40	60
12	28	60	75
17.5	38	75	95
24	50	95	125
36	70	145	170
52	95	250	
72.5	140	325	

Fig. B3 : Transformers rated insulation levels

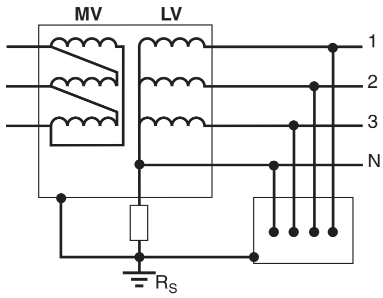
(1) This means basically that List 1 generally applies to switchgear to be used on underground-cable systems while List 2 is chosen for switchgear to be used on overhead-line systems.

Diagram | **Rs value**

A - TN-a



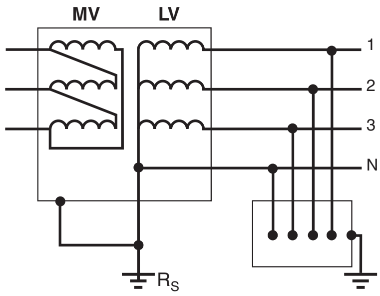
B - IT-a



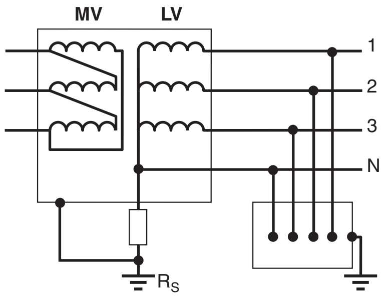
Cases A and B

No particular resistance value for Rs is imposed in these cases

C - TT-a



D - IT-b



Cases C and D

$$Rs \leqslant \frac{Uw - Uo}{Im}$$

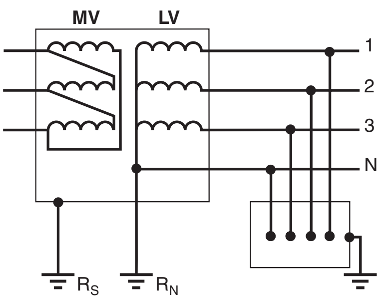
Where

Uw = the rated normal-frequency withstand voltage for low-voltage equipment at consumer installations

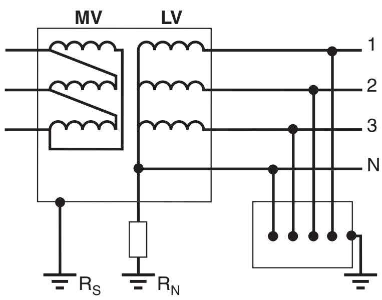
Uo = phase to neutral voltage at consumer's installations

Im = maximum value of MV earth-fault current

E - TT-b



F - IT-c



In cases E and F the LV protective conductors (bonding exposed conductive parts) in the substation are earthed via the substation earth electrode, and it is therefore the substation LV equipment (only) that could be subjected to overvoltage.

Cases E and F

$$Rs \leqslant \frac{Uws - U}{Im}$$

Where

Uws = the normal-frequency withstand voltage for low-voltage equipments in the substation (since the exposed conductive parts of these equipments are earthed via Rs)

U = phase to neutral voltage at the substation for the TT(s) system, but the phase-to-phase voltage for the IT(s) system

Im = maximum value of MV earth-fault current

Notes:

■ For TN-a and IT-a, the MV and LV exposed conductive parts at the substation and those at the consumer's installations, together with the LV neutral point of the transformer, are all earthed via the substation electrode system.

■ For TT-a and IT-b, the MV and LV exposed conductive parts at the substation, together with the LV neutral point of the transformer are earthed via the substation electrode system.

■ For TT-b and IT-c, the LV neutral point of the transformer is separately earthed outside of the area of influence of the substation earth electrode.

Uw and Uws are commonly given the (IEC 60364-4-44) value Uo + 1200 V, where Uo is the nominal phase-to-neutral voltage of the LV system concerned.

Fig. B10 : Maximum earthing resistance Rs at a MV/LV substation to ensure safety during a short-circuit to earth fault on the medium-voltage equipment for different earthing systems

The combination of restricted earth-fault currents, equipotential installations and low resistance substation earthing, results in greatly reduced levels of overvoltage and limited stressing of phase-to-earth insulation during the type of MV earth-fault situation described above.

Limitation of the MV earth-fault current and earth resistance of the substation

Another widely-used earthing system is shown in diagram C of Figure B10. It will be seen that in the TT system, the consumer's earthing installation (being isolated from that of the substation) constitutes a remote earth.

This means that, although the transferred potential will not stress the phase-to-phase insulation of the consumer's equipment, the phase-to-earth insulation of all three phases will be subjected to overvoltage.

4 The consumer substation with LV metering

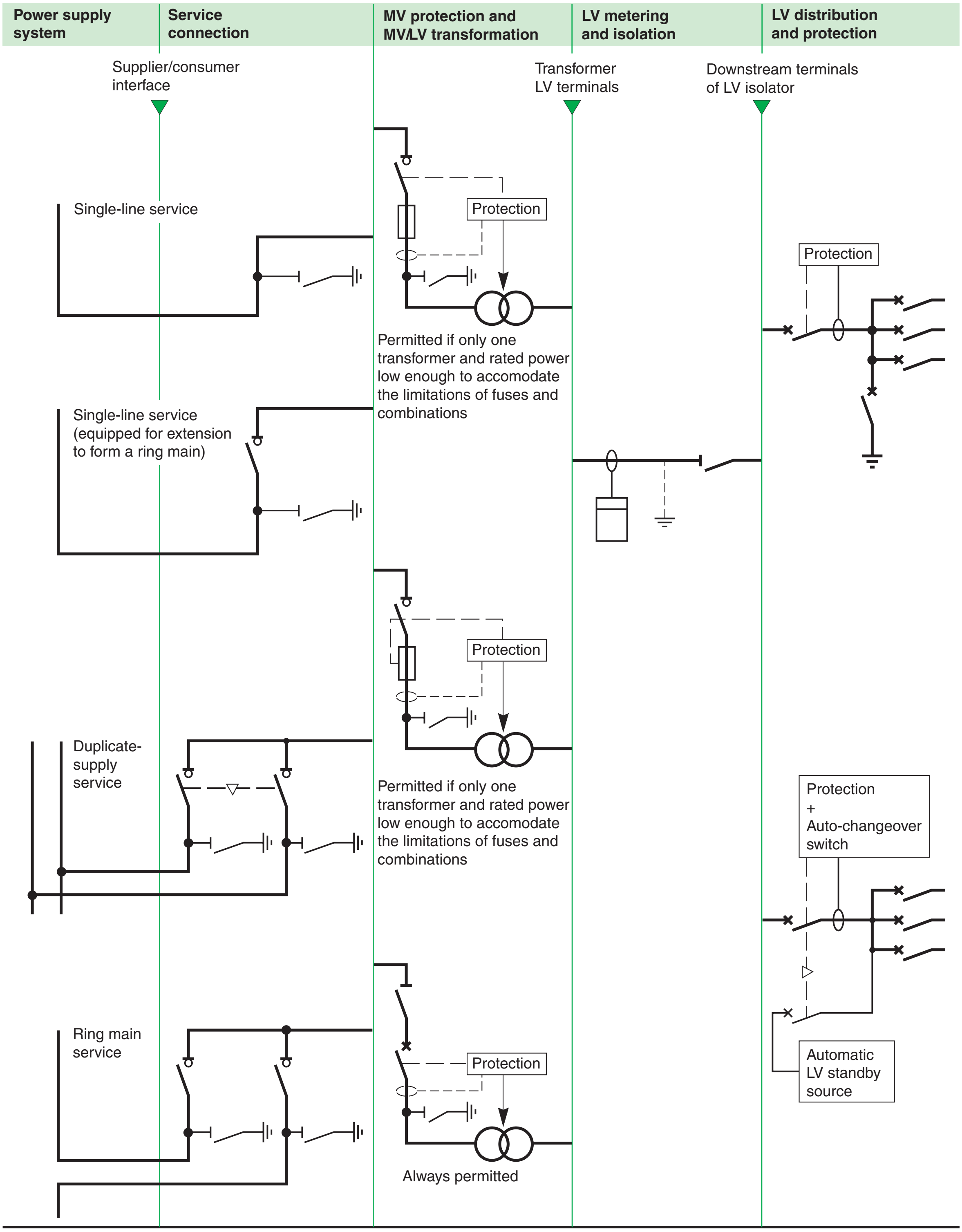


Fig. B21 : *Consumer substation with LV metering*

1 Earthing schemes

1.3 Characteristics of TT, TN and IT systems

The TT system:

■ Technique for the protection of persons: the exposed conductive parts are earthed and residual current devices (RCDs) are used

■ Operating technique: interruption for the first insulation fault

TT system (see **Fig. E12**)

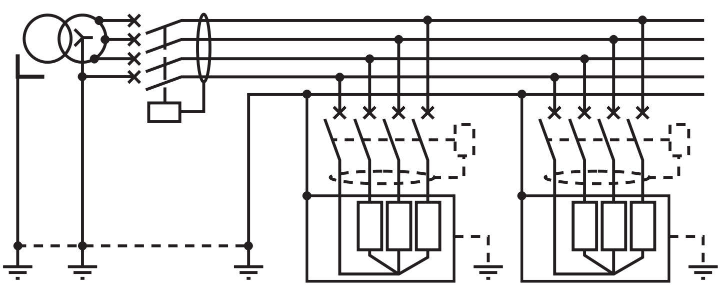


***Fig. E12** : TT system*

Note: If the exposed conductive parts are earthed at a number of points, an RCD must be installed for each set of circuits connected to a given earth electrode.

Main characteristics

■ Simplest solution to design and install. Used in installations supplied directly by the public LV distribution network.

■ Does not require continuous monitoring during operation (a periodic check on the RCDs may be necessary).

■ Protection is ensured by special devices, the residual current devices (RCD), which also prevent the risk of fire when they are set to ⩽ 500 mA.

■ Each insulation fault results in an interruption in the supply of power, however the outage is limited to the faulty circuit by installing the RCDs in series (selective RCDs) or in parallel (circuit selection).

■ Loads or parts of the installation which, during normal operation, cause high leakage currents, require special measures to avoid nuisance tripping, i.e. supply the loads with a separation transformer or use specific RCDs (see section 5.1 in chapter F).

The TN system:

■ Technique for the protection of persons:

□ Interconnection and earthing of exposed conductive parts and the neutral are mandatory

□ Interruption for the first fault using overcurrent protection (circuit-breakers or fuses)

■ Operating technique: interruption for the first insulation fault

TN system (see **Fig. E13** and **Fig. E14**)

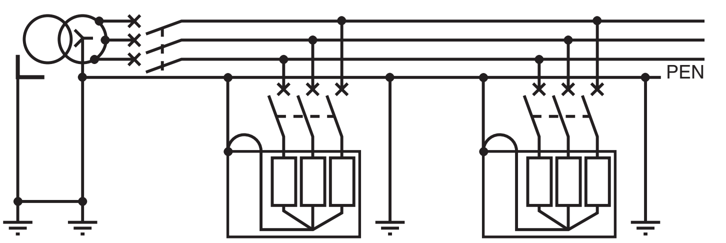


***Fig. E13** : TN-C system*

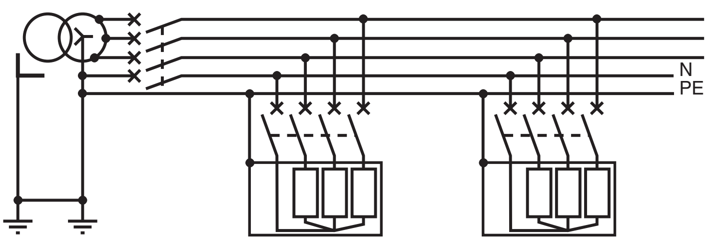


***Fig. E14** : TN-S system*

3 Protection against indirect contact

Specified maximum disconnection time

The IEC 60364-4-41 specifies the maximum operating time of protective devices used in TN system for the protection against indirect contact:

- For all final circuits with a rated current not exceeding 32 A, the maximum disconnecting time will not exceed the values indicated in **Figure F13**
- For all other circuits, the maximum disconnecting time is fixed to 5s. This limit enables discrimination between protective devices installed on distribution circuits

Note: The use of RCDs may be necessary on TN-earthed systems. Use of RCDs on TN-C-S systems means that the protective conductor and the neutral conductor must (evidently) be separated upstream of the RCD. This separation is commonly made at the service entrance.

Uo(1) (V)	T (s)
50 < Uo ⩽ 120	0.8
120 < Uo ⩽ 230	0.4
230 < Uo ⩽ 400	0.2
Uo > 400	0.1

(1) Uo is the nominal phase to earth voltage

Fig. F13 : Maximum disconnecting time for AC final circuits not exceeding 32 A

If the protection is to be provided by a circuit-breaker, it is sufficient to verify that the fault current will always exceed the current-setting level of the instantaneous or short-time delay tripping unit (Im)

Protection by means of circuit-breaker (see **Fig. F14**)

The instantaneous trip unit of a circuit-breaker will eliminate a short-circuit to earth in less than 0.1 second.

In consequence, automatic disconnection within the maximum allowable time will always be assured, since all types of trip unit, magnetic or electronic, instantaneous or slightly retarded, are suitable: Ia = Im. The maximum tolerance authorised by the relevant standard, however, must always be taken into consideration. It is sufficient therefore that the fault current $\frac{Uo}{Zs}$ or $0.8\frac{Uo}{Zc}$ determined by calculation (or estimated on site) be greater than the instantaneous trip-setting current, or than the very short-time tripping threshold level, to be sure of tripping within the permitted time limit.

Ia can be determined from the fuse performance curve. In any case, protection cannot be achieved if the loop impedance Zs or Zc exceeds a certain value

Protection by means of fuses (see **Fig. F15**)

The value of current which assures the correct operation of a fuse can be ascertained from a current/time performance graph for the fuse concerned.

The fault current $\frac{Uo}{Zs}$ or $0.8\frac{Uo}{Zc}$ as determined above, must largely exceed that necessary to ensure positive operation of the fuse. The condition to observe therefore is that $Ia < \frac{Uo}{Zs}$ or $0.8\frac{Uo}{Zc}$ as indicated in Figure F15.

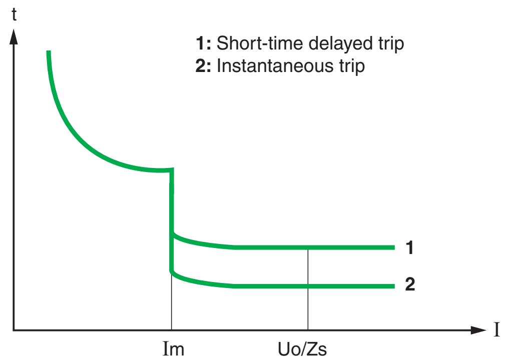


Fig. F14 : Disconnection by circuit-breaker for a TN system

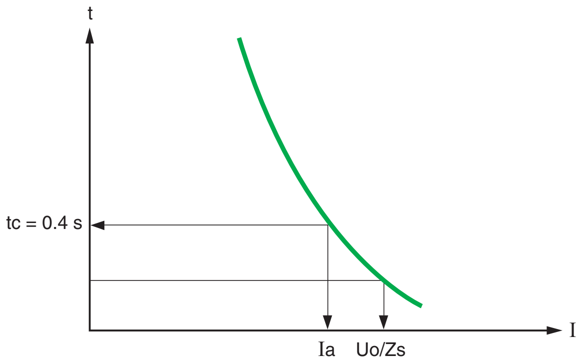


Fig. F15 : Disconnection by fuses for a TN system

Circuits protected by general purpose circuit-breakers (Fig. F41)

Nominal cross-sectional area of conductors	Instantaneous or short-time-delayed tripping current Im (amperes)																												
mm²	50	63	80	100	125	160	200	250	320	400	500	560	630	700	800	875	1000	1120	1250	1600	2000	2500	3200	4000	5000	6300	8000	10000	12500
1.5	100	79	63	50	40	31	25	20	16	13	10	9	8	7	6	6	5	4	4										
2.5	167	133	104	83	67	52	42	33	26	21	17	15	13	12	10	10	8	7	7	5	4								
4	267	212	167	133	107	83	67	53	42	33	27	24	21	19	17	15	13	12	11	8	7	5	4						
6	400	317	250	200	160	125	100	80	63	50	40	36	32	29	25	23	20	18	16	13	10	8	6	5	4				
10			417	333	267	208	167	133	104	83	67	60	53	48	42	38	33	30	27	21	17	13	10	8	7	5	4		
16					427	333	267	213	167	133	107	95	85	76	67	61	53	48	43	33	27	21	17	13	11	8	7	5	4
25							417	333	260	208	167	149	132	119	104	95	83	74	67	52	42	33	26	21	17	13	10	8	7
35								467	365	292	233	208	185	167	146	133	117	104	93	73	58	47	36	29	23	19	15	12	9
50									495	396	317	283	251	226	198	181	158	141	127	99	79	63	49	40	32	25	20	16	13
70												417	370	333	292	267	233	208	187	146	117	93	73	58	47	37	29	23	19
95														452	396	362	317	283	263	198	158	127	99	79	63	50	40	32	25
120																457	400	357	320	250	200	160	125	100	80	63	50	40	32
150																	435	388	348	272	217	174	136	109	87	69	54	43	35
185																		459	411	321	257	206	161	128	103	82	64	51	41
240																				400	320	256	200	160	128	102	80	64	51

Fig. F41 : Maximum circuit lengths (in metres) for different sizes of copper conductor and instantaneous-tripping-current settings for general-purpose circuit-breakers in 230/240 V TN system with m = 1

Circuits protected by Compact (1) or Multi 9 (1) circuit-breakers for industrial or domestic use (Fig. F42 to Fig. F44)

Sph	Rated current (A)															
mm²	1	2	3	4	6	10	16	20	25	32	40	50	63	80	100	125
1.5	1200	600	400	300	200	120	75	60	48	37	30	24	19	15	12	10
2.5		1000	666	500	333	200	125	100	80	62	50	40	32	25	20	16
4			1066	800	533	320	200	160	128	100	80	64	51	40	32	26
6				1200	800	480	300	240	192	150	120	96	76	60	48	38
10						800	500	400	320	250	200	160	127	100	80	64
16							800	640	512	400	320	256	203	160	128	102
25									800	625	500	400	317	250	200	160
35										875	700	560	444	350	280	224
50												760	603	475	380	304

Fig. F42 : Maximum circuit lengths (in meters) for different sizes of copper conductor and rated currents for type B (2) circuit-breakers in a 230/240 V single-phase or three-phase TN system with m = 1

Sph	Rated current (A)															
mm²	1	2	3	4	6	10	16	20	25	32	40	50	63	80	100	125
1.5	600	300	200	150	100	60	37	30	24	18	15	12	9	7	6	5
2.5		500	333	250	167	100	62	50	40	31	25	20	16	12	10	8
4			533	400	267	160	100	80	64	50	40	32	25	20	16	13
6				600	400	240	150	120	96	75	60	48	38	30	24	19
10					667	400	250	200	160	125	100	80	63	50	40	32
16						640	400	320	256	200	160	128	101	80	64	51
25							625	500	400	312	250	200	159	125	100	80
35							875	700	560	437	350	280	222	175	140	112
50									760	594	475	380	301	237	190	152

Fig. F43 : Maximum circuit lengths (in metres) for different sizes of copper conductor and rated currents for type C (2) circuit-breakers in a 230/240 V single-phase or three-phase TN system with m = 1

(1) Merlin Gerin products.

(2) For the definition of type B and C circuit-breakers refer to chapter H clause 4.2.

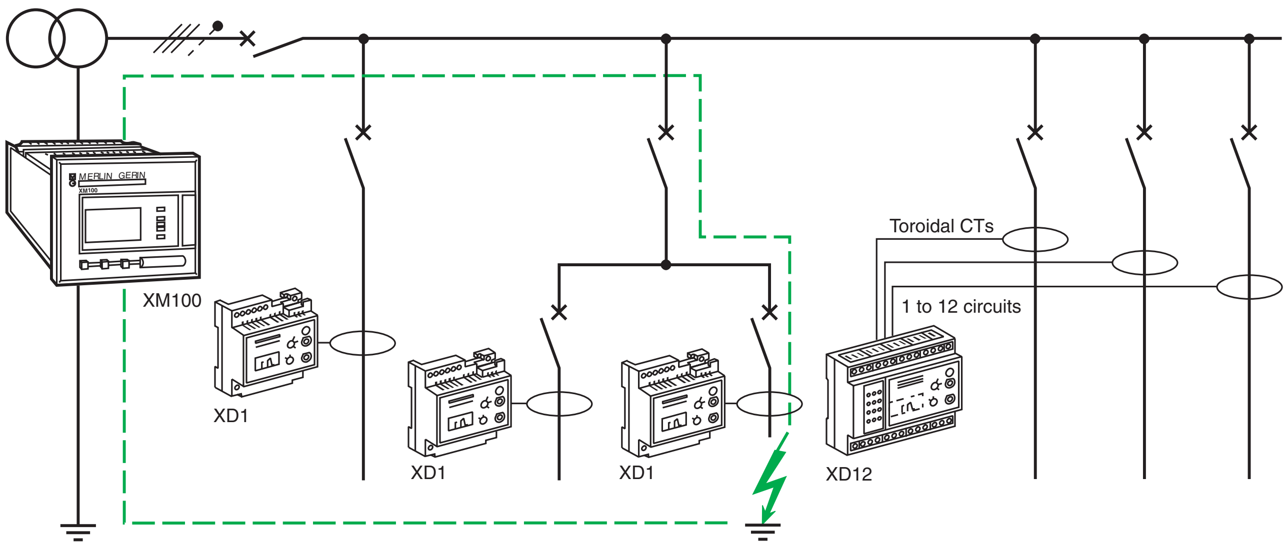


Fig. F54 : Fixed automatic fault location

- Automatic monitoring, logging, and fault location (see **Fig. F55**)

The Vigilohm System also allows access to a printer and/or a PC which provides a global review of the insulation level of an entire installation, and records the chronological evolution of the insulation level of each circuit.

The central monitor XM100, together with the localization detectors XD08 and XD16, associated with toroidal CTs from several circuits, as shown below in Figure F55, provide the means for this automatic exploitation.

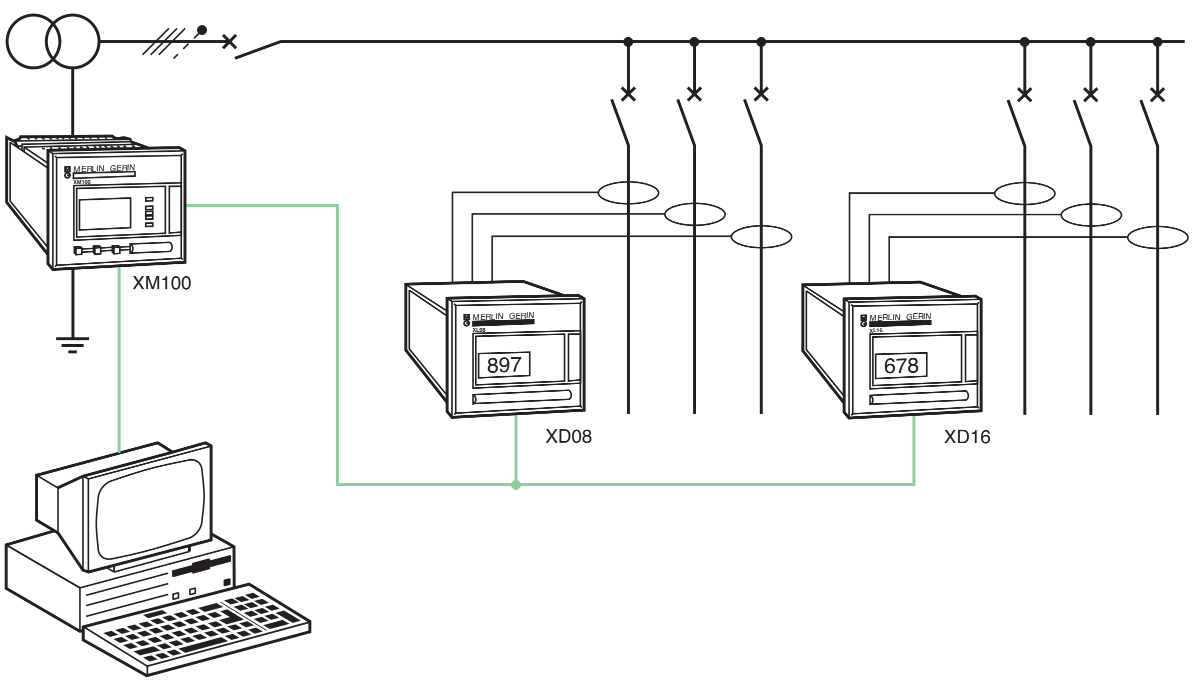


Fig. F55 : Automatic fault location and insulation-resistance data logging

7 The neutral conductor

The c.s.a. and the protection of the neutral conductor, apart from its current-carrying requirement, depend on several factors, namely:

- The type of earthing system, TT, TN, etc.
- The harmonic currents
- The method of protection against indirect contact hazards according to the methods described below

The color of the neutral conductor is statutorily blue. PEN conductor, when insulated, shall be marked by one of the following methods :

- Green-and-yellow throughout its length with, in addition, light blue markings at the terminations, or
- Light blue throughout its length with, in addition, green-and-yellow markings at the terminations

7.1 Sizing the neutral conductor

Influence of the type of earthing system

TT and TN-S schemes

- Single-phase circuits or those of c.s.a. ⩽ 16 mm² (copper) 25 mm² (aluminium): the c.s.a. of the neutral conductor must be equal to that of the phases
- Three-phase circuits of c.s.a. > 16 mm² copper or 25 mm² aluminium: the c.s.a. of the neutral may be chosen to be:
  - □ Equal to that of the phase conductors, or
  - □ Smaller, on condition that:

- The current likely to flow through the neutral in normal conditions is less than the permitted value Iz. The influence of triplen(1) harmonics must be given particular consideration or
- The neutral conductor is protected against short-circuit, in accordance with the following Sub-clause G-7.2
- The size of the neutral conductor is at least equal to 16 mm² in copper or 25 mm² in aluminium

TN-C scheme

The same conditions apply in theory as those mentioned above, but in practice, the neutral conductor must not be open-circuited under any circumstances since it constitutes a PE as well as a neutral conductor (see Figure G58 “c.s.a. of PEN conductor” column).

IT scheme

In general, it is not recommended to distribute the neutral conductor, i.e. a 3-phase 3-wire scheme is preferred. When a 3-phase 4-wire installation is necessary, however, the conditions described above for TT and TN-S schemes are applicable.

Influence of harmonic currents

Effects of triplen harmonics

Harmonics are generated by the non-linear loads of the installation (computers, fluorescent lighting, rectifiers, power electronic choppers) and can produce high currents in the Neutral. In particular triplen harmonics of the three Phases have a tendency to cumulate in the Neutral as:

- Fundamental currents are out-of-phase by 2π/3 so that their sum is zero
- On the other hand, triplen harmonics of the three Phases are always positioned in the same manner with respect to their own fundamental, and are in phase with each other (see **Fig. G63a**).

(1) Harmonics of order 3 and multiple of 3

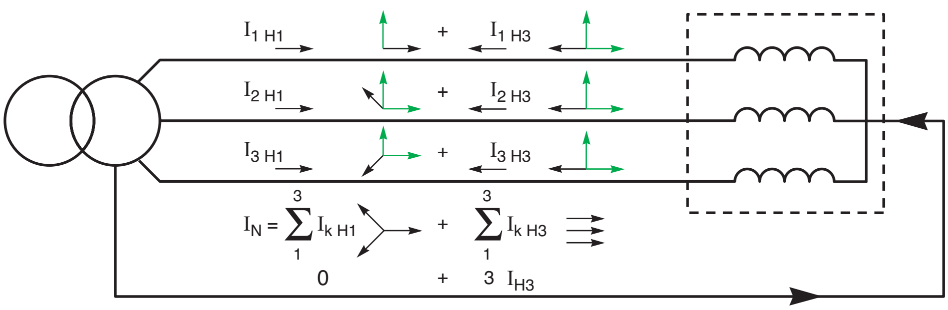


Fig. G63a : Triplen harmonics are in phase and cumulate in the Neutral

2 Overvoltage protection devices

Two major types of protection devices are used to suppress or limit voltage surges: they are referred to as primary protection devices and secondary protection devices.

2.1 Primary protection devices (protection of installations against lightning)

The purpose of primary protection devices is to protect installations against direct strokes of lightning. They catch and run the lightning current into the ground. The principle is based on a protection area determined by a structure which is higher than the rest.

The same applies to any peak effect produced by a pole, building or very high metallic structure.

There are three types of primary protection:

- Lightning conductors, which are the oldest and best known lightning protection device
- Overhead earth wires
- The meshed cage or Faraday cage

The lightning conductor

The lightning conductor is a tapered rod placed on top of the building. It is earthed by one or more conductors (often copper strips) (see **Fig. J8**).

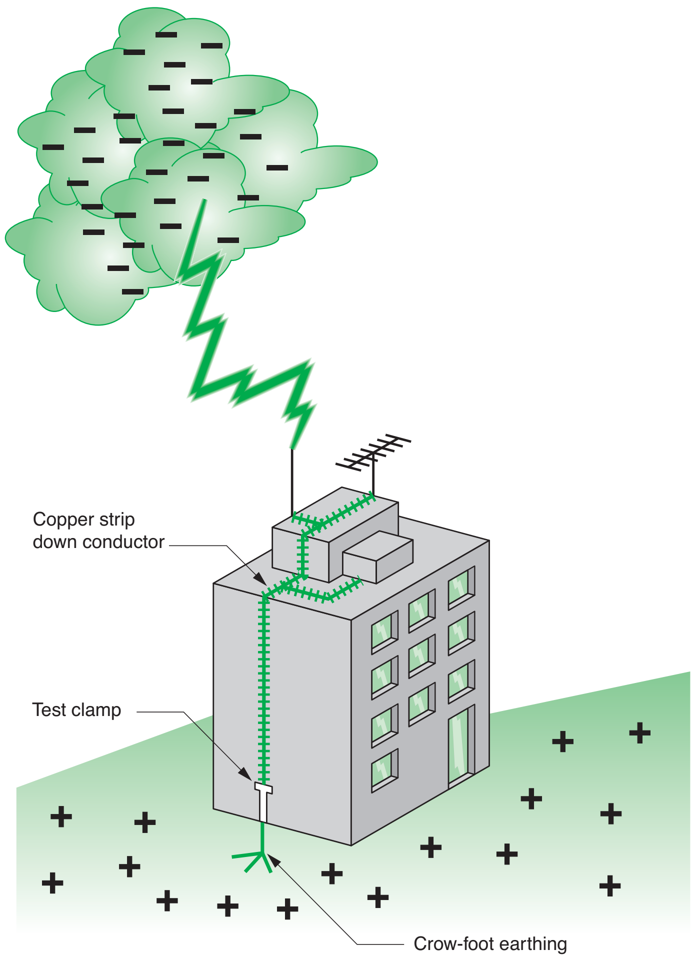


Fig. J8 : Example of protection using a lightning conductor

4 From electrical measurement to electrical information

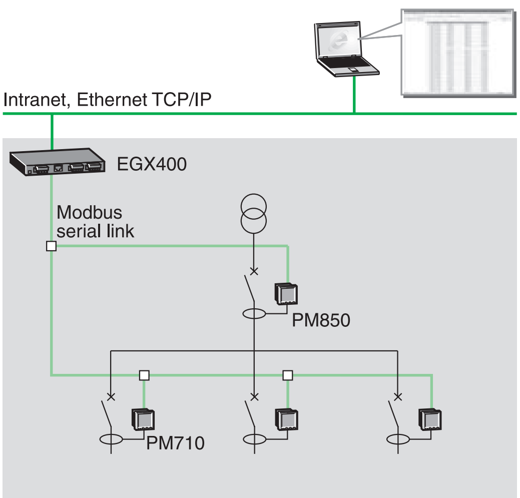


Fig. K11 : Example of electrical network protected and monitored via the Intranet site

Example of solutions for a medium-sized site:

Analysesample Ltd. is a company specialized in analyzing industrial samples from regional factories: metals, plastics, etc., to certify their chemical characteristics. The company wants to carry out better control of its electrical consumption for the existing electrical furnaces, its air conditioning system and to ensure quality of electrical supply for high-precision electronic devices used to analyze the samples.

Electrical network protected and monitored via the Intranet site

The solution implemented involves recovering power data via metering units that also allows measurement of basic electrical parameters as well as verification of energy power quality. Connected to a web server, an Internet browser allows to use them very simply and export data in a Microsoft Excel™ type spreadsheet. Power curves can be plotted in real time by the spreadsheet (**Fig. K11**).

Therefore no IT investment, either in software or hardware, is necessary to use the data.

For example to reduce the electricity bill and limit consumption during nighttime and weekends, we have to study trend curves supplied by the measurement units (**Fig. K12**).

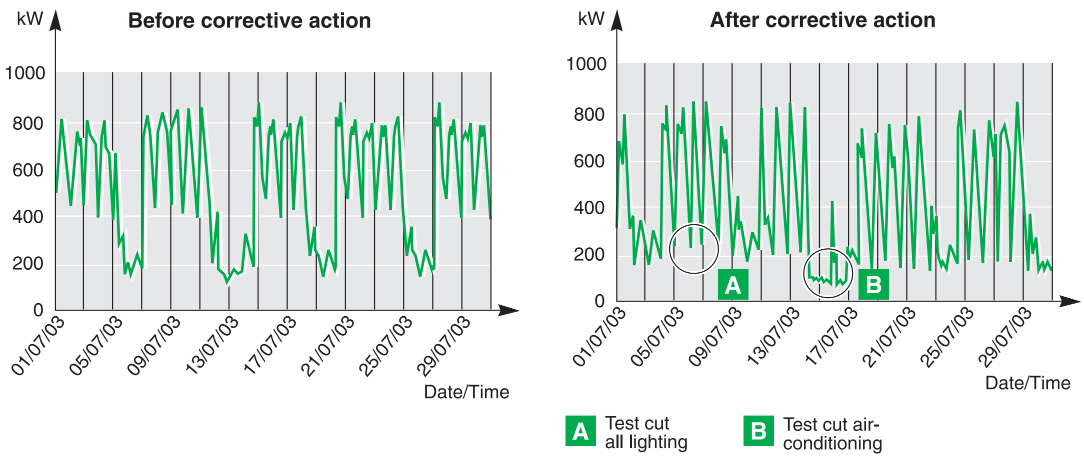


Fig. K12 : A Test to stop all lighting B Test to stop air conditioning
Here consumption during non-working hours seems excessive, consequently two decisions were taken:
- *reducing night time lighting*
- *stopping air conditioning during weekends*

The new curve obtained shows a significant drop in consumption.

3 General

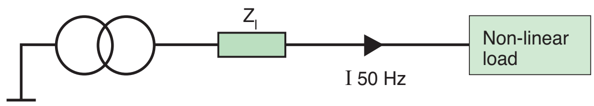


Fig. M3 : Installation supplying a non-linear load, where only the phenomena concerning the 50 Hz frequency (fundamental frequency) are shown

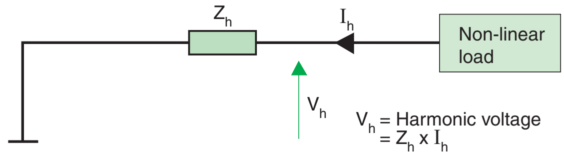
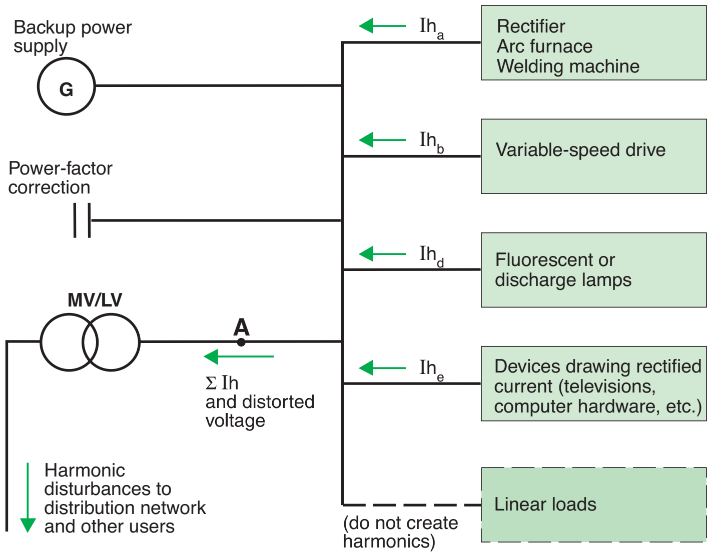


Fig. M4 : Same installation, where only the phenomena concerning the frequency of harmonic order h are shown

Supply of the non-linear load creates the flow of a current I_{50Hz} (shown in figure M3), to which is added each of the harmonic currents Ih (shown in figure M4), corresponding to each harmonic order h.

Still considering that the loads reinject harmonic current upstream into the distribution network, it is possible to create a diagram showing the harmonic currents in the network (see **Fig. M5**).



Note in the diagram that though certain loads create harmonic currents in the distribution network, other loads can absorb the harmonic currents.

Fig. M5 : Flow of harmonic currents in a distribution network

Harmonics have major economic effects in installations:
- Increases in energy costs
- Premature ageing of equipment
- Production losses

2 Uninterruptible Power Supply units (UPS)

Selection tables

Figure N29 indicates the voltage drop in percent for a circuit made up of 100 meters of cable. To calculate the voltage drop in a circuit with a length L, multiply the value in the table by L/100.

- Sph: Cross section of conductors
- I_n: Rated current of protection devices on circuit

Three-phase circuit

If the voltage drop exceeds 3% (50-60 Hz), increase the cross section of conductors.

DC circuit

If the voltage drop exceeds 1%, increase the cross section of conductors.

a - Three-phase circuits (copper conductors)
50-60 Hz - 380 V / 400 V / 415 V three-phase, cos φ = 0.8, balanced system three-phase + N

In	Sph (mN²)											
(A)	10	16	25	35	50	70	95	120	150	185	240	300
10	0.9											
15	1.2											
20	1.6	1.1										
25	2.0	1.3	0.9									
32	2.6	1.7	1.1									
40	3.3	2.1	1.4	1.0								
50	4.1	2.6	1.7	1.3	1.0							
63	5.1	3.3	2.2	1.6	1.2	0.9						
70	5.7	3.7	2.4	1.7	1.3	1.0	0.8					
80	6.5	4.2	2.7	2.1	1.5	1.2	0.9	0.7				
100	8.2	5.3	3.4	2.6	2.0	2.0	1.1	0.9	0.8			
125		6.6	4.3	3.2	2.4	2.4	1.4	1.1	1.0	0.8		
160			5.5	4.3	3.2	3.2	1.8	1.5	1.2	1.1	0.9	
200				5.3	3.9	3.9	2.2	1.8	1.6	1.3	1.2	0.9
250					4.9	4.9	2.8	2.3	1.9	1.7	1.4	1.2
320							3.5	2.9	2.5	2.1	1.9	1.5
400							4.4	3.6	3.1	2.7	2.3	1.9
500								4.5	3.9	3.4	2.9	2.4
600									4.9	4.2	3.6	3.0
800										5.3	4.4	3.8
1,000											6.5	4.7

For a three-phase 230 V circuit, multiply the result by e
For a single-phase 208/230 V circuit, multiply the result by 2

b - DC circuits (copper conductors)

In	Sph (mN2)											
(A)	-	-	25	35	50	70	95	120	150	185	240	300
100			5.1	3.6	2.6	1.9	1.3	1.0	0.8	0.7	0.5	0.4
125				4.5	3.2	2.3	1.6	1.3	1.0	0.8	0.6	0.5
160					4.0	2.9	2.2	1.6	1.2	1.1	0.6	0.7
200						3.6	2.7	2.2	1.6	1.3	1.0	0.8
250							3.3	2.7	2.2	1.7	1.3	1.0
320								3.4	2.7	2.1	1.6	1.3
400									3.4	2.8	2.1	1.6
500										3.4	2.6	2.1
600										4.3	3.3	2.7
800											4.2	3.4
1,000											5.3	4.2
1,250												5.3

*Fig. N29 : Voltage drop in percent for **[a]** three-phase circuits and **[b]** DC circuits*

Special case for neutral conductors

In three-phase systems, the third-order harmonics (and their multiples) of single-phase loads add up in the neutral conductor (sum of the currents on the three phases).

For this reason, the following rule may be applied:

neutral cross section = 1.5 x phase cross section

4 Lighting circuits

Standard EN 1838 ("Lighting applications. Emergency lighting") gives some fundamental concepts concerning what is meant by emergency lighting for escape routes:
"The intention behind lighting escape routes is to allow safe exit by the occupants, providing them with suffi cient visibility and directions on the escape route …"
The concept referred to above is very simple:
The safety signs and escape route lighting must be two separate things.

Functions and operation of the luminaires

The manufacturing specifi cations are covered by standard EN 60598-2-22, "Particular Requirements - Luminaires for Emergency Lighting", which must be read with EN 60598-1, "Luminaires – Part 1: General Requirements and Tests".

Duration

A basic requirement is to determine the duration required for the emergency lighting. Generally it is 1 hour but some countries may have different duration requirements according to statutory technical standards.

Operation

We should clarify the different types of emergency luminaires:

■ Non-maintained luminaires
□ The lamp will only switch on if there is a fault in the standard lighting
□ The lamp will be powered by the battery during failure
□ The battery will be automatically recharged when the mains power supply is restored

■ Maintained luminaires
□ The lamp can be switched on in continuous mode
□ A power supply unit is required with the mains, especially for powering the lamp, which can be disconnected when the area is not busy
□ The lamp will be powered by the battery during failure.

Design

The integration of emergency lighting with standard lighting must comply strictly with electrical system standards in the design of a building or particular place.
All regulations and laws must be complied with in order to design a system which is up to standard (see **Fig. N61**).

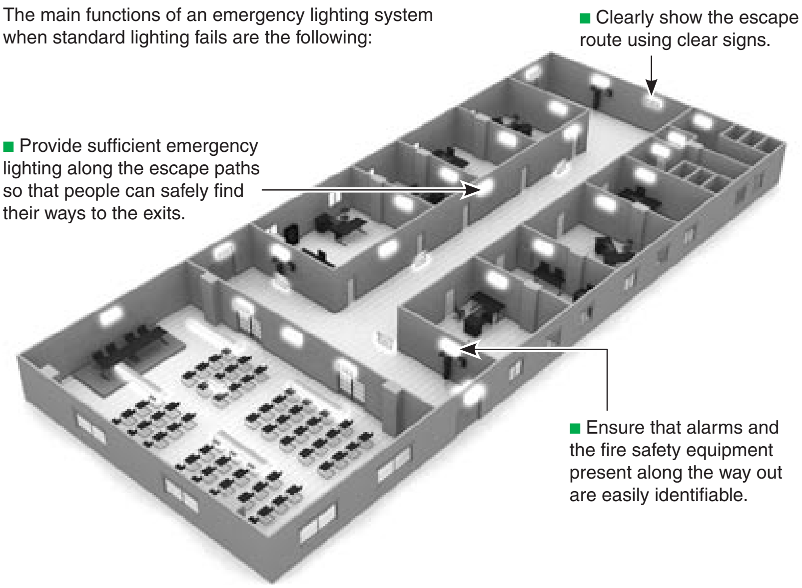


Fig. N61 : *The main functions of an emergency lighting system*

European standards

The design of emergency lighting systems is regulated by a number of legislative provisions that are updated and implemented from time to time by new documentation published on request by the authorities that deal with European and international technical standards and regulations.
Each country has its own laws and regulations, in addition to technical standards

2 Bathrooms and showers

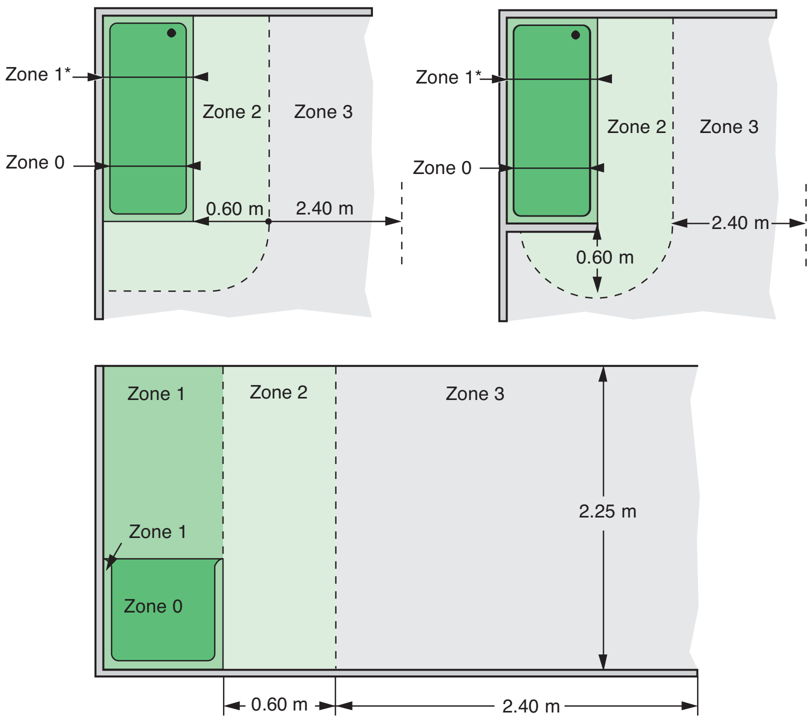
Bathrooms and showers rooms are areas of high risk, because of the very low resistance of the human body when wet or immersed in water.
Precaution to be taken are therefore correspondingly rigorous, and the regulations are more severe than those for most other locations.
The relevant standard is IEC 60364-7-701.

Precautions to observe are based on three aspects:

- The definition of zones, numbered 0,1, 2, 3 in which the placement (or exclusion) of any electrical device is strictly limited or forbidden and, where permitted, the electrical and mechanical protection is prescribed
- The establishment of an equipotential bond between all exposed and extraneous metal parts in the zones concerned
- The strict adherence to the requirements prescribed for each particular zones, as tabled in clause 3

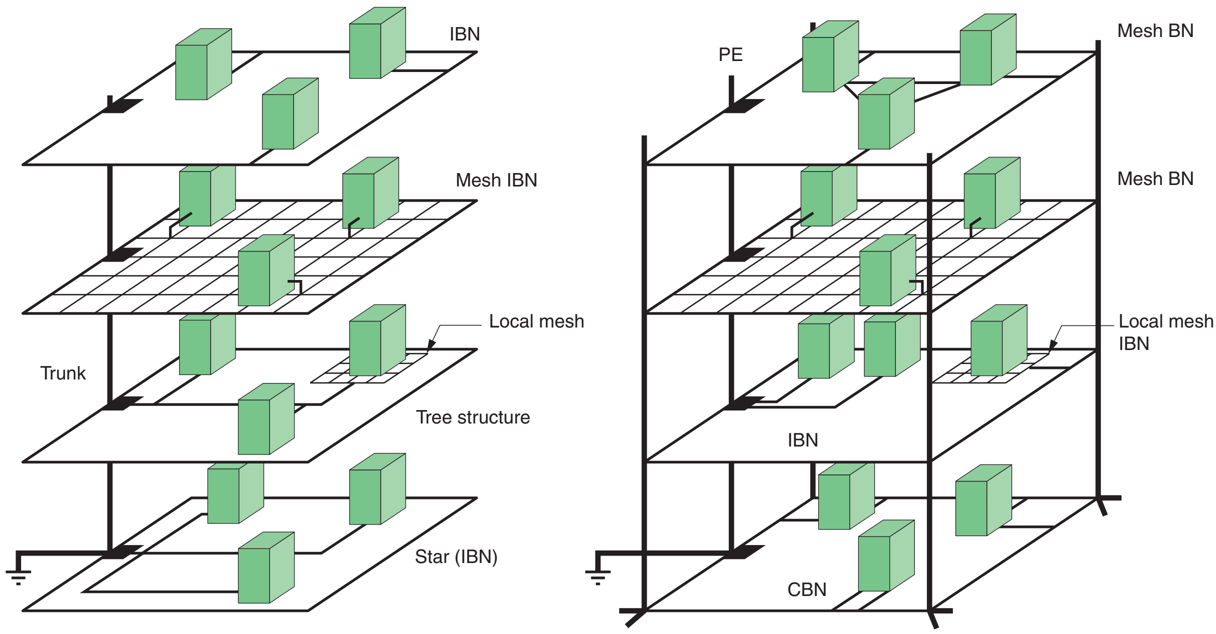
2.1 Classification of zones

Sub-clause 701.32 of IEC 60364-7-701 defines the zones 0, 1, 2, 3 as shown in the following diagrams (see **Fig. P12** below to **Fig P18** opposite and next pages):



(*) Zone 1 is above the bath as shown in the vertical cross-section

Fig. P12 : Zones 0, 1, 2 and 3 in proximity to a bath-tub



BN: Bonding network
CBN: Common bonding network
IBN: Isolated bonding network

Fig. Q7 : Examples of bonding networks

The length of connections between a structural element and the bonding network does not exceed 50 centimetres and an additional connection should be installed in parallel at a certain distance from the first. The inductance of the connection between the earthing bar of the electrical enclosure for a set of equipment and the bonding network (see below) should be less than one µHenry (0.5 µH, if possible). For example, it is possible to use a single 50 cm conductor or two parallel conductors one meter long, installed at a minimum distance from one another (at least 50 cm) to reduce the mutual inductance between the two conductors.

Where possible, connection to the bonding network should be at an intersection to divide the HF currents by four without lengthening the connection. The profile of the bonding conductors is not important, but a flat profile is preferable. The conductor should also be as short as possible.

Parallel earthing conductor (PEC)

The purpose of a parallel earthing conductor is to reduce the common-mode current flowing in the conductors that also carry the differential-mode signal (the common-mode impedance and the surface area of the loop are reduced).

The parallel earthing conductor must be designed to handle high currents when it is used for protection against lightning or for the return of high fault currents. When cable shielding is used as a parallel earthing conductor, it cannot handle such high currents and the solution is to run the cable along metal structural elements or cableways which then act as other parallel earthing conductors for the entire cable. Another possibility is to run the shielded cable next to a large parallel earthing conductor with both the shielded cable and the parallel earthing conductor connected at each end to the local earthing terminal of the equipment or the device.

For very long distances, additional connections to the network are advised for the parallel earthing conductor, at irregular distances between the devices. These additional connections form a shorter return path for the disturbing currents flowing through the parallel earthing conductor. For U-shaped trays, shielding and tubes, the additional connections should be external to maintain the separation with the interior ("screening" effect).

Bonding conductors

Bonding conductors may be metal strips, flat braids or round conductors. For high-frequency systems, metal strips and flat braids are preferable (skin effect) because a round conductor has a higher impedance than a flat conductor with the same cross section. Where possible, the length to width ratio should not exceed 5.