

3 Design of the electrical installation protection system

To protect an electrical installation in a building, simple rules apply for the choice of

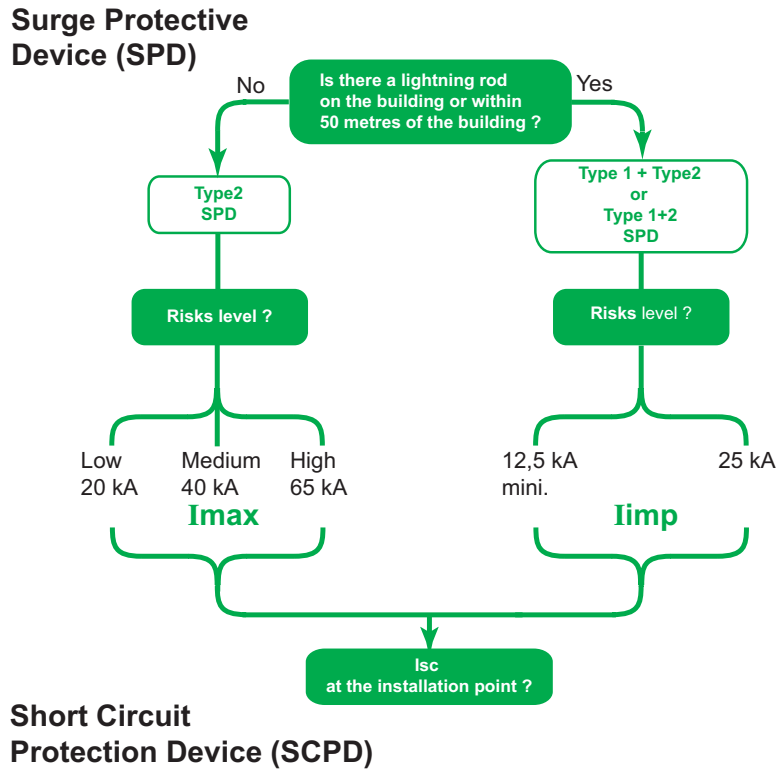
- SPD(s);
- its protection system.

3.1 Design rules

For a power distribution system, the main characteristics used to define the lightning protection system and select a SPD to protect an electrical installation in a building are:

- SPD
- quantity of SPD;
- type;
- level of exposure to define the SPD's maximum discharge current I_{max} .
- Short circuit protection device
- maximum discharge current I_{max} ;
- short-circuit current I_{sc} at the point of installation.

The logic diagram in the **Figure J20** below illustrates this design rule.



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Fig. J20 : Logic diagram for selection of a protection system

The other characteristics for selection of a SPD are predefined for an electrical installation.

- number of poles in SPD;
- voltage protection level U_p ;
- operating voltage U_c .

This sub-section J3 describes in greater detail the criteria for selection of the protection system according to the characteristics of the installation, the equipment to be protected and the environment.

A SPD must always be installed at the origin of the electrical installation.

3.2 Elements of the protection system

3.2.1 Location and type of SPD

The type of SPD to be installed at the origin of the installation depends on whether or not a lightning protection system is present. If the building is fitted with a lightning protection system (as per IEC 62305), a Type 1 SPD should be installed.

For SPD installed at the incoming end of the installation, the IEC 60364 installation standards lay down minimum values for the following 2 characteristics:

- Nominal discharge current **In = 5 kA (8/20) μ s**;
- Voltage protection level **Up (at In) < 2.5 kV**.

The number of additional SPDs to be installed is determined by:

- the size of the site and the difficulty of installing bonding conductors. On large sites, it is essential to install a SPD at the incoming end of each subdistribution enclosure.
- the distance separating sensitive loads to be protected from the incoming-end protection device. When the loads are located more than 30 m away from the incoming-end protection device, it is necessary to provide for special fine protection as close as possible to sensitive loads.
- the risk of exposure. In the case of a very exposed site, the incoming-end SPD cannot ensure both a high flow of lightning current and a sufficiently low voltage protection level. In particular, a Type 1 SPD is generally accompanied by a Type 2 SPD.

The table in **Figure J21** below shows the quantity and type of SPD to be set up on the basis of the two factors defined above.

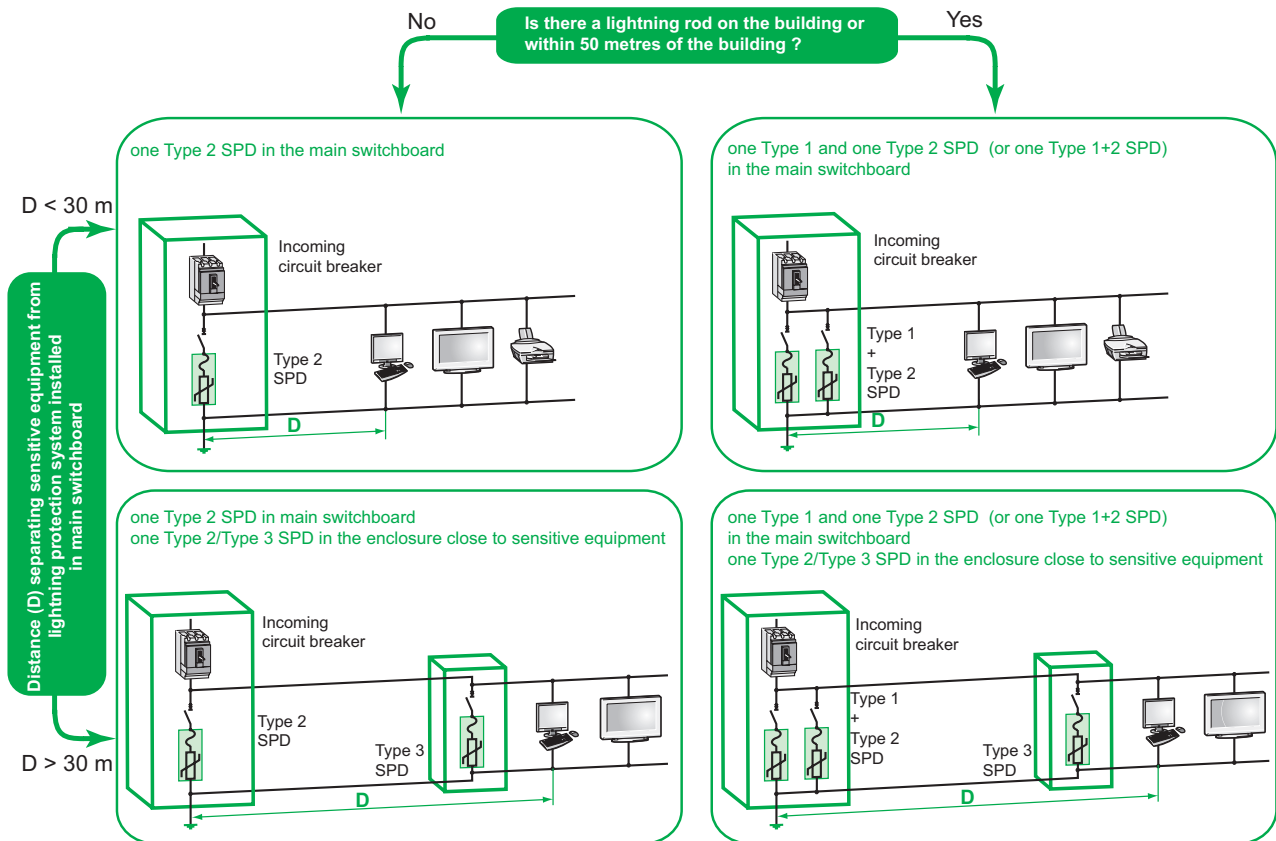


Fig. J21 : The 4 cases of SPD implementation

Note : The Type 1 SPD is installed in the electrical switchboard connected to the earth lead of the lightning protection system.

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3.2.2 Protection distributed levels

Several protection levels of SPD allows the energy to be distributed among several SPDs, as shown in **Figure J22** in which the three types of SPD are provided for:

- Type 1: when the building is fitted with a lightning protection system and located at the incoming end of the installation, it absorbs a very large quantity of energy;
- Type 2: absorbs residual overvoltages;
- Type 3: provides "fine" protection if necessary for the most sensitive equipment located very close to the loads.

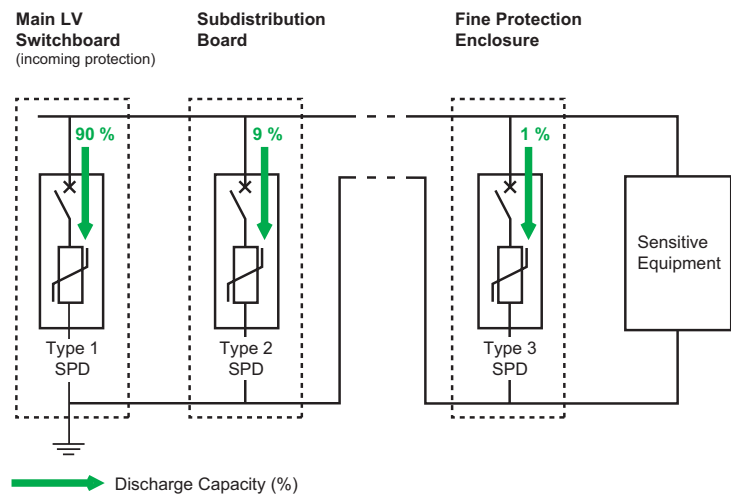
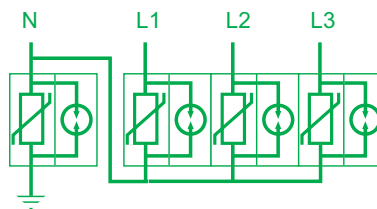


Fig. J22 : Fine protection architecture
 Note: The Type 1 and 2 SPD can be combined in a single SPD



PRD1 25 r



PRD1 25 r

Fig. J23 : The PRD1 25r SPD fulfils the two functions of Type 1 and Type 2 (Type 1+2) in the same product

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3.3 Common characteristics of SPDs according to the installation characteristics

3.3.1 Operating voltage U_c

Depending on the system earthing arrangement, the maximum continuous operating voltage U_c of SPD must be equal to or greater than the values shown in the table in **Figure J24**.

SPDs connected between	System configuration of distribution network				
	TT	TN-C	TN-S	IT with distributed neutral	IT without distributed neutral
Line conductor and neutral conductor	1.1 U_o	NA	1.1 U_o	1.1 U_o	NA
Each line conductor and PE conductor	1.1 U_o	NA	1.1 U_o	$\sqrt{3} U_o$	V_o
Neutral conductor and PE conductor	U_o	NA	U_o	U_o	NA
Each line conductor and PEN conductor	NA	1.1 U_o	NA	NA	NA

NA: not applicable

NOTE 1: U_o is the line-to-neutral voltage, V_o is the line-to-line voltage of the low voltage system.

NOTE 2: This table is based on IEC 61643-1 amendment 1.

Fig. J24 : Stipulated minimum value of U_c for SPDs depending on the system earthing arrangement (based on Table 53C of the IEC 60364-5-53 standard)

The most common values of U_c chosen according to the system earthing arrangement.

TT, TN: 260, 320, 340, 350 V

IT: 440, 460 V

3.3.2 Voltage protection level U_p (at I_n)

The 443-4 section of IEC 60364 standard, "Selection of equipment in the installation", helps with the choice of the protection level U_p for the SPD in function of the loads to be protected. The table of **Figure J25** indicates the impulse withstand capability of each kind of equipment.

Nominal voltage of the installation ⁽¹⁾ V		Required impulse withstand voltage for kV			
Three-phase systems ⁽²⁾	Single-phase systems with middle point	Equipment at the origin of the installation (impulse withstand category IV)	Equipment of distribution and final circuits (impulse withstand category III)	Appliances (impulse withstand category II)	Specially protected equipment (impulse withstand category I)
	120-240	4	2.5	1.5	0.8
230/400 ⁽²⁾	-	6	4	2.5	1.5
277/480 ⁽²⁾	-	6	4	2.5	1.5
400/690	-	8	6	4	2.5
1,000	-	Values subject to system engineers			

(1) As per IEC 60038.

(2) In Canada and the United States, for voltages exceeding 300 V relative to earth, the impulse withstand voltage corresponding to the immediately higher voltage in the column is applicable.

(3) This impulse withstand voltage is applicable between live conductors and the PE conductor

Fig. J25 : Equipment impulse withstand category for an installation in conformity with IEC 60364 (Table 44B).

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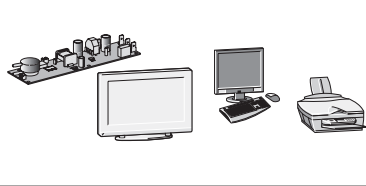

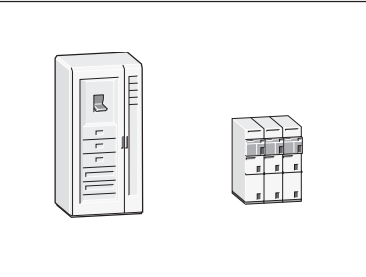
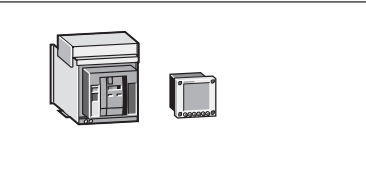
	<p>■ Equipment of overvoltage category I is only suitable for use in the fixed installation of buildings where protective means are applied outside the equipment – to limit transient overvoltages to the specified level. Examples of such equipment are those containing electronic circuits like computers, appliances with electronic programmes, etc.</p>
	<p>■ Equipment of overvoltage category II is suitable for connection to the fixed electrical installation, providing a normal degree of availability normally required for current-using equipment. Examples of such equipment are household appliances and similar loads.</p>
	<p>■ Equipment of overvoltage category III is for use in the fixed installation downstream of, and including the main distribution board, providing a high degree of availability. Examples of such equipment are distribution boards, circuit-breakers, wiring systems including cables, bus-bars, junction boxes, switches, socket-outlets) in the fixed installation, and equipment for industrial use and some other equipment, e.g. stationary motors with permanent connection to the fixed installation.</p>
	<p>■ Equipment of overvoltage category IV is suitable for use at, or in the proximity of, the origin of the installation, for example upstream of the main distribution board. Examples of such equipment are electricity meters, primary overcurrent protection devices and ripple control units.</p>

Fig. J26 : Overvoltage category of equipment

The "installed" Up performance should be compared with the impulse withstand capability of the loads.

SPD has a voltage protection level Up that is intrinsic, i.e. defined and tested independently of its installation. In practice, for the choice of Up performance of a SPD, a safety margin must be taken to allow for the overvoltages inherent in the installation of the SPD (see Fig. J27).

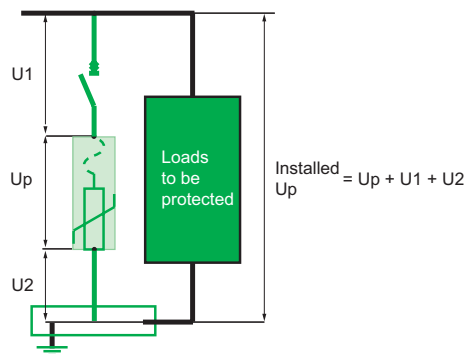


Fig. J27 : "Installed" Up

The "installed" voltage protection level Up generally adopted to protect sensitive equipment in 230/400 V electrical installations is 2.5 kV (overvoltage category II, see Fig. J28).

Note:

If the stipulated voltage protection level cannot be achieved by the incoming-end SPD or if sensitive equipment items are remote (see section 3.2.1), additional coordinated SPD must be installed to achieve the required protection level.

3.3.3 Number of poles

■ Depending on the system earthing arrangement, it is necessary to provide for a SPD architecture ensuring protection in common mode (CM) and differential mode (DM).

	TT	TN-C	TN-S	IT
Phase-to-neutral (DM)	Recommended ¹	-	Recommended	Not useful
Phase-to-earth (PE or PEN) (CM)	Yes	Yes	Yes	Yes
Neutral-to-earth (PE) (CM)	Yes	-	Yes	Yes ²

¹ The protection between phase and neutral can either be incorporated in the SPD placed at the origin of the installation, or be removed close to the equipment to be protected
² If neutral distributed

Fig. J28 : Protection need according to the system earthing arrangement

Note:

■ **Common-mode overvoltage**

A basic form of protection is to install a SPD in common mode between phases and the PE (or PEN) conductor, whatever the type of system earthing arrangement used.

■ **Differential-mode overvoltage**

In the TT and TN-S systems, earthing of the neutral results in an asymmetry due to earth impedances which leads to the appearance of differential-mode voltages, even though the overvoltage induced by a lightning stroke is common-mode.

2P, 3P and 4P SPDs (see Fig. J29)

- These are adapted to the TT and TN-S systems.
- They provide protection merely against common-mode overvoltages.

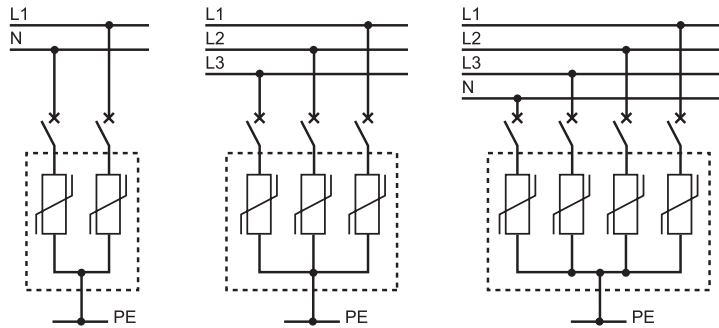


Fig. J29 : 2P, 3P, 4P SPDs

1P + N, 3P + N SPDs (see Fig. J30)

- These are adapted to the TT and TN-S systems.
- They provide protection against common-mode and differential-mode overvoltages.

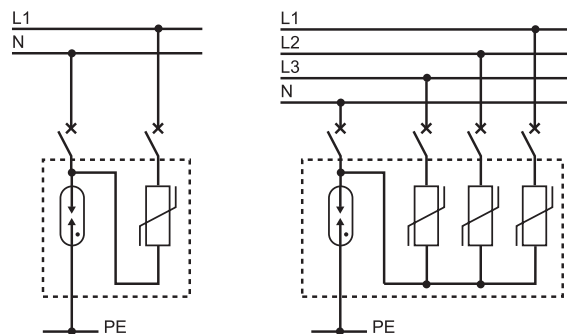


Fig. J30 : 1P + N, 3P + N SPDs

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3.4 Selection of a Type 1 SPD

3.4.1 Impulse current I_{imp}

■ Where there are no national regulations or specific regulations for the type of building to be protected:
the impulse current I_{imp} shall be at least 12.5 kA (10/350 μ s wave) per branch in accordance with IEC 60364-5-534.

■ Where regulations exist:
standard 62305-2 defines 4 levels: I, II, III and IV
The table in **Figure J31** shows the different levels of I_{imp} in the regulatory case.

Protection level as per EN 62305-2	External lightning protection system designed to handle direct flash of:	Minimum required I_{imp} for Type 1 SPD for line-neutral network
I	200 kA	25 kA/pole
II	150 kA	18.75 kA/pole
III / IV	100 kA	12.5 kA/pole

Fig. J31 : Table of I_{imp} values according to the building's voltage protection level (based on IEC/EN 62305-2)

3.4.2 Autoextinguish follow current I_{fi}

This characteristic is applicable only for SPDs with spark gap technology. The autoextinguish follow current I_{fi} must always be greater than the prospective short-circuit current I_{sc} at the point of installation.

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3.5 Selection of a Type 2 SPD

3.5.1 Maximum discharge current I_{max}

The maximum discharge current I_{max} is defined according to the estimated exposure level relative to the building's location.

The value of the maximum discharge current (I_{max}) is determined by a risk analysis (see table in **Figure J32**).

	Exposure level		
	Low	Medium	High
Building environment	Building located in an urban or suburban area of grouped housing	Building located in a plain	Building where there is a specific risk: pylon, tree, mountainous region, wet area or pond, etc.
Recommended I_{max} value (kA)	20	40	65

Fig. J32 : Recommended maximum discharge current I_{max} according to the exposure level

The protection devices (thermal and short circuit) must be coordinated with the SPD to ensure reliable operation, i.e.

- ensure continuity of service:
 - withstand lightning current waves;
 - not generate excessive residual voltage.
- ensure effective protection against all types of overcurrent:
 - overload following thermal runaway of the varistor;
 - short circuit of low intensity (impedant);
 - short circuit of high intensity.

3.6 Selection of external Short Circuit Protection Device (SCPD)

3.6.1 Risks to be avoided at end of life of the SPDs

■ Due to ageing

In the case of natural end of life due to ageing, protection is of the thermal type. SPD with varistors must have an internal disconnecter which disables the SPD.

Note: End of life through thermal runaway does not concern SPD with gas discharge tube or encapsulated spark gap.

■ Due to a fault

The causes of end of life due to a short-circuit fault are:

- Maximum discharge capacity exceeded.
This fault results in a strong short circuit.
- A fault due to the distribution system (neutral/phase switchover, neutral disconnection).
- Gradual deterioration of the varistor.

The latter two faults result in an impedant short circuit.

The installation must be protected from damage resulting from these types of fault: the internal (thermal) disconnecter defined above does not have time to warm up, hence to operate.

A special device called "external Short Circuit Protection Device (external SCPD)", capable of eliminating the short circuit, should be installed. It can be implemented by a circuit breaker or fuse device.

3.6.2 Characteristics of the external SCPD

The external SCPD should be coordinated with the SPD. It is designed to meet the following two constraints:

Lightning current withstand

The lightning current withstand is an essential characteristic of the SPD's external Short Circuit Protection Device.

The external SCPD must not trip upon 15 successive impulse currents at I_n .

Short-circuit current withstand

■ **The breaking capacity** is determined by the installation rules (IEC 60364 standard):

The external SCPD should have a breaking capacity equal to or greater than the prospective short-circuit current I_{sc} at the installation point (in accordance with the IEC 60364 standard).

■ Protection of the installation against short circuits

In particular, the impedant short circuit dissipates a lot of energy and should be eliminated very quickly to prevent damage to the installation and to the SPD.

The right association between a SPD and its external SCPD must be given by the manufacturer.

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3.6.3 Installation mode for the external SCPD

■ Device "in series"

The SCPD is described as "in series" (see Fig. J33) when the protection is performed by the general protection device of the network to be protected (for example, connection circuit breaker upstream of an installation).

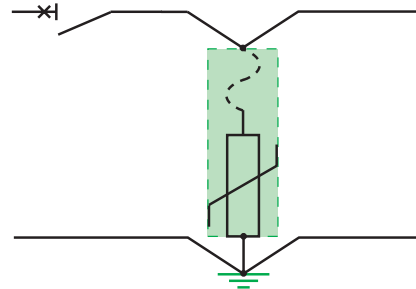


Fig. J33 : SCPD "in series"

■ Device "in parallel"

The SCPD is described as "in parallel" (see Fig. J34) when the protection is performed specifically by a protection device associated with the SPD.

- The external SCPD is called a "disconnecting circuit breaker" if the function is performed by a circuit breaker.
- The disconnecting circuit breaker may or may not be integrated into the SPD.

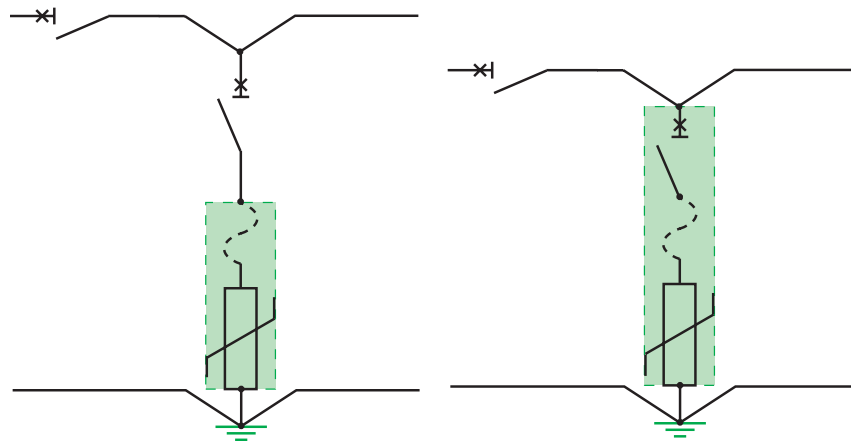


Fig. J34 : SCPD "in parallel"

Note:

In the case of a SPD with gas discharge tube or encapsulated spark gap, the SCPD allows the current to be cut immediately after use.

3.6.4 Guarantee of protection

The external SCPD should be coordinated with the SPD, and tested and guaranteed by the SPD manufacturer in accordance with the recommendations of the IEC 61643-11 standard (NF EN 61643-1) Chap. 7.7.3. It should also be installed in accordance with the manufacturer's recommendations. When this device is integrated, conformity with product standard IEC 61643-11 naturally ensures protection.



Fig. J35 : SPDs with external SCPD, non-integrated (C60N + PRD 40r) and integrated (Quick PRD 40r)

3.6.5 Summary of external SCPDs characteristics

A detailed analysis of the characteristics is given in section 6.4.

The table in Figure J36 shows, on an example, a summary of the characteristics according to the various types of external SCPD.

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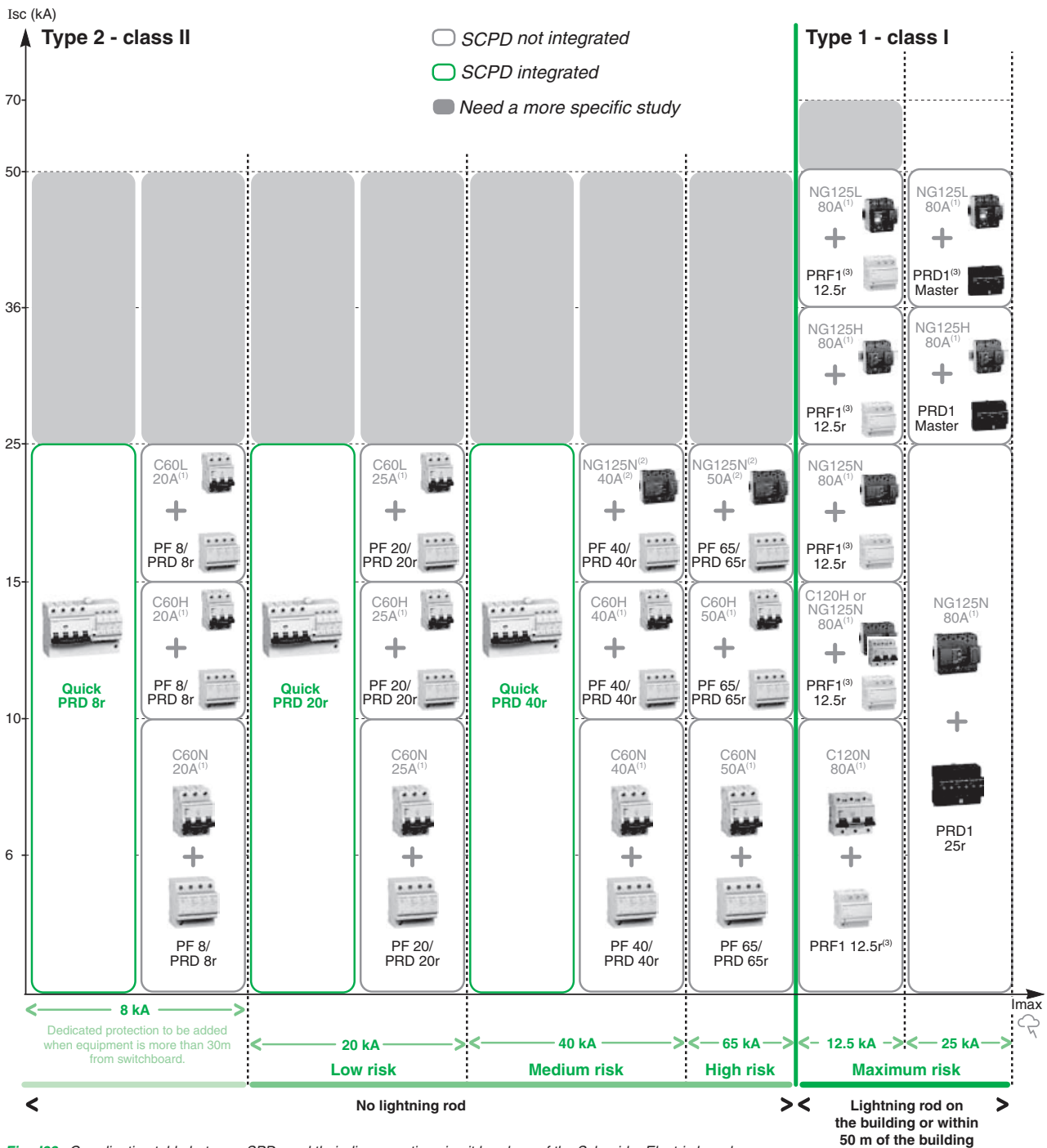
Installation mode for the external SCPD	In series	In parallel		
		Fuse protection associated	Circuit breaker protection associated	Circuit breaker protection integrated
Surge protection of equipment	=	=	=	=
	SPDs protect the equipment satisfactorily whatever the kind of associated external SCPD			
Protection of installation at end of life	-	=	+	++
	No guarantee of protection possible	Manufacturer's guarantee	Protection from short circuits perfectly ensured	Full guarantee
Continuity of service at end of life	--	+	+	+
	The complete installation is shut down	Only the SPD circuit is shut down		
Maintenance at end of life	--	=	+	+
	Shutdown of the installation required	Change of fuses	Immediate resetting	

Fig. J36 : Characteristics of end-of-life protection of a Type 2 SPD according to the external SCPDs

3.7 SPD and protection device coordination table

The table in Figure J37 below shows the coordination of disconnecting circuit breakers (external SCPD) for Type 1 and 2 SPDs of the Schneider Electric brand for all levels of short-circuit currents. Coordination between SPD and its disconnecting circuit breakers, indicated and guaranteed by Schneider Electric, ensures reliable protection (lightning wave withstand, reinforced protection of impedant short-circuit currents, etc.)

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Fig. J22 : Coordination table between SPDs and their disconnecting circuit breakers of the Schneider Electric brand
 (1): All circuit breakers are C curve - (2): NG 125 L for 1P & 2P - (3): Also Type 2 (class II) tested

3.7.1 Coordination with upstream protection devices

Coordination with overcurrent protection devices

In an electrical installation, the external SCPD is an apparatus identical to the protection apparatus: this makes it possible to apply **discrimination and cascading** techniques for technical and economic optimization of the protection plan.

Coordination with residual current devices

If the SPD is installed downstream of an earth leakage protection device, the latter should be of the "si" or selective type with an immunity to pulse currents of at least 3 kA (8/20 μs current wave).

Note: S type residual current devices in conformity with the IEC 61008 or IEC 61009-1 standards comply with this requirement.