

# INTERNATIONAL STANDARD

## NORME INTERNATIONALE



**Low-voltage surge protective devices –  
Part 12: Surge protective devices connected to low-voltage power systems –  
Selection and application principles**

**Parafoudres à basse tension –  
Partie 12: Parafoudres connectés aux réseaux à basse tension –  
Principes de choix et de mise en œuvre**



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## INTERNATIONAL ELECTROTECHNICAL COMMISSION

**LOW-VOLTAGE SURGE PROTECTIVE DEVICES –****Part 12: Surge protective devices connected to low-voltage power systems – Selection and application principles**

## FOREWORD

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International Standard IEC 61643-12 has been prepared by subcommittee 37A: Low-voltage surge protective devices, of IEC technical committee 37: Surge arresters.

This third edition cancels and replaces the second edition published in 2008. This edition constitutes a technical revision.

NOTE The following differing practice of a less permanent nature exists in the USA: In the USA, SPDs tested to Class I tests are not required. This exception applies to the entire document.

This edition includes the following significant technical changes with respect to the previous edition:

- a) Scope: Deleted reference to 1 500 V dc
- b) Added or revised some definitions
- c) Added new clause 4 on Need for protection

- d) Added new information on disconnecting devices
- e) Revised Characteristics of SPD
- f) Revised List of parameters for SPD selection
- g) Added new information on Measured Limiting Voltage
- h) Added or revised some Annexes

The text of this International Standard is based on the following documents:

| FDIS         | Report on voting |
|--------------|------------------|
| 37A/341/FDIS | 37A/347/RVD      |

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 61643 series, published under the general title *Low-voltage surge protective devices*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

**IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.**

## INTRODUCTION

### 0.1 General

Surge protective devices (SPDs) are used to protect, under specified conditions, electrical systems and equipment against various overvoltages and impulse currents, such as lightning and switching surges.

SPDs shall be selected according to their environmental conditions and the acceptable failure rate of the equipment and the SPDs.

This document provides information to the user about characteristics useful for the selection of an SPD.

This document provides information to evaluate the need for using SPDs in low-voltage systems, with reference to IEC 62305, Parts 1 to 4 and the IEC 60364 series. It also provides information on selection and coordination of SPDs, while taking into account the entire environment in which they are applied. Examples include: equipment to be protected and system characteristics, insulation levels, overvoltages, method of installation, location of SPDs, coordination of SPDs, end of life behaviour of SPDs and equipment failure consequences.

IEC 62305-2 provides a general method for evaluating the risk due to surges and lightning. IEC 60364-4-44 provides a simplified way of evaluating the risk posed to electrical installations.

Guidance on requirements for product insulation coordination is provided by IEC 60664 series. Requirements for safety (fire, overcurrent and electric shock) and installation are provided by IEC 60364 series.

The IEC 60364 series provide direct information for contractors on the installation of SPDs. IEC TR 62066 contains more information on the scientific background of surge protection.

### 0.2 Keys to understanding the structure of this document

The list below summarizes the structure of this document and provides a summary of the information covered in each clause and annex. The main clauses provide basic information on the factors used for SPD selection. Readers who wish to obtain more detail on the information provided in Clauses 4 to 7 should refer to the relevant annexes.

Clause 1 describes the scope of this document.

Clause 2 lists the normative references where additional information may be found.

Clause 3 provides definitions useful for the understanding of this document.

Clause 4 is an introduction to the risk of surges (considerations of when the use of SPDs is beneficial).

Clause 5 addresses the parameters of systems and equipment important for SPD selection. In addition to the stresses created by lightning, those created by the network itself are described, namely temporary overvoltages and switching surges.

Clause 6 lists the electrical parameters for the selection of an SPD and provides explanations regarding these parameters. These are related to those given in IEC 61643-11.

Clause 7 is the core of this document. It relates the stresses coming from the network (as discussed in Clause 5) to the characteristics of the SPD (as discussed in Clause 6). It also outlines how the protection by SPDs may be affected by its installation. The different steps for the selection of an SPD are presented, including coordination when more than one SPD is used in an installation (details about SPD coordination may be found in Annex F).

Annex A deals with information given with inquiries and explains the testing procedures used in IEC 61643-11.

Annex B provides examples of the relationship between two important parameters of SPDs,  $U_c$  and  $U_p$ , in the specific case of Metal Oxide Varistors (MOV) and also examples of the relationship between  $U_c$  and the nominal voltage of the network.

Annex C supplements the information given in Clause 5 on surge voltages in low-voltage systems.

Annex D deals with the sharing of lightning current between different earthing systems used to determine the SPD rating in case of direct lightning current.

Annex E deals with temporary overvoltages due to faults in the high-voltage system.

Annex F supplements the information given in Clause 7 on coordination rules when more than one SPD is used in a system.

Annex G provides specific examples on the use of this document.

Annex H provides specific examples of the use of the risk analysis given in Clause 4.

Annex I supplements the information given in Clause 5 about system stresses.

Annex J supplements the information given in Clause 7 on the application of SPDs in various low-voltage systems criteria for selection of SPDs.

Annex K discusses differences between immunity level and insulation withstand of electrical equipment.

Annex L provides practical examples of SPD installation as used in some countries.

Annex M discusses problems of coordination with equipment having both signaling and power terminals.

Annex N provides information on withstand of fuses in surge conditions.

Annex O provides practical methods for testing system level immunity.

Annex P provides test application to SPDs with multiple components.

## LOW-VOLTAGE SURGE PROTECTIVE DEVICES –

### Part 12: Surge protective devices connected to low-voltage power systems – Selection and application principles

#### 1 Scope

This part of IEC 61643 describes the principles for the selection, operation, location and coordination of SPDs to be connected to 50/60 Hz AC power circuits, and equipment rated up to 1 000 V RMS.

These devices contain at least one non-linear component and are intended to limit surge voltages and divert surge currents.

NOTE 1 Additional requirements for special applications are also applicable, if required.

NOTE 2 IEC 60364 and IEC 62305-4 are also applicable.

NOTE 3 This document deals only with SPDs and not with surge protection components (SPC) integrated inside equipment.

#### 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60364-4-44:2007, *Low-voltage electrical installations – Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances*

IEC 60364-5-53, *Low-voltage electrical installations – Part 5-53: Selection and erection of electrical equipment – Devices for protection for safety, isolation, switching, control and monitoring*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 60664-1:2007, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 61000-4-5, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*

IEC 61643-32, *Low-voltage surge protective devices – Part 32: Surge protective devices connected to the d.c. side of photovoltaic installations – Selection and application principles*

IEC 61643-11:2011, *Low-voltage surge protective devices – Part 11: Surge protective devices connected to low-voltage power systems – Requirements and test methods*

IEC 62305-1:2010, *Protection against lightning – Part 1: General principles*

IEC 62305-2, *Protection against lightning – Part 2: Risk management*

IEC 62305-4, *Protection against lightning – Part 4: Electrical and electronic systems within structures*

IEC 62475:2010, *High-current test techniques – Definitions and requirements for test currents and measuring systems*

### 3 Terms, definitions and abbreviated terms

#### 3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

##### 3.1.1

##### **surge protective device**

SPD

device that contains at least one nonlinear component that is intended to limit surge voltages and divert surge currents

Note 1 to entry: An SPD is a complete assembly, having appropriate connecting means.

[SOURCE: IEC 61643-11:2011, 3.1.1]

##### 3.1.2

##### **continuous operating current**

$I_c$

current flowing through each mode of protection of the SPD when energized at the maximum continuous operating voltage ( $U_c$ ) for each mode

##### 3.1.3

##### **maximum continuous operating voltage**

$U_c$

Maximum RMS voltage which may be continuously applied to the SPD's mode of protection

Note 1 to entry The  $U_c$  value covered by this document may exceed 1 000 V.

[SOURCE: IEC 61643-11:2011, 3.1.11]

##### 3.1.4

##### **voltage protection level**

$U_p$

maximum voltage to be expected at the SPD terminals due to an impulse stress with defined voltage steepness and an impulse stress with a discharge current with given amplitude and waveshape

Note 1 to entry: The voltage protection level is given by the manufacturer and is equal or exceed by:

- the measured limiting voltage, determined for front-of-wave sparkover (if applicable) and the measured limiting voltage, determined from the residual voltage measurements at amplitudes up to  $I_n$  and/or  $I_{imp}$  for test Classes II and/or I, respectively;
- the measured limiting voltage up to  $U_{OC}$  determined for the combination wave generator for test Class III.

[SOURCE: IEC 61643-11:2011, 3.1.14, modified note to entry]

**3.1.5****measured limiting voltage**

highest value of voltage that is measured across the terminals of the SPD during the application of impulses of specified waveshape and amplitude

[SOURCE: IEC 61643-11:2011, 3.1.15]

**3.1.6****residual voltage**

$U_{\text{res}}$

crest value of voltage that appears between the terminals of an SPD due to the passage of discharge current

[SOURCE: IEC 61643-11:2011, 3.1.16]

**3.1.7****temporary overvoltage test value**

$U_{\text{T}}$

test voltage applied to the SPD for a specific duration  $t_{\text{T}}$  to simulate the stress under temporary overvoltage (TOV) conditions

Note 1 to entry: It is a characteristic of the SPD declared by the manufacturer that gives information about the behaviour of the SPD when stressed with voltages  $U_{\text{T}}$  higher than  $U_{\text{c}}$  for a given specific duration  $t_{\text{T}}$ . this behaviour may either be no change in the performance after application of the temporary overvoltage or a defined failure without hazard to either personnel, equipment or facility.

[SOURCE: IEC 61643-11:2011, 3.1.17, modified (addition of Note 1 to entry)]

**3.1.8****temporary overvoltage value of the power system**

$U_{\text{TOV}}$

power frequency overvoltage occurring on the network at a given location, of relatively long duration

Note 1 to entry: TOVs may be caused by faults inside the LV system ( $U_{\text{TOV(LV)}}$ ) or inside the HV system ( $U_{\text{TOV(HV)}}$ ).

Note 2 to entry: This is a characteristic of the system. Temporary overvoltages, typically lasting up to several seconds, usually originate from switching operations or faults (for example, sudden load shedding, single-phase faults, etc.) and/or from non-linearity (ferroresonance effects, harmonics, etc.).

**3.1.9****nominal discharge current for class II test**

$I_{\text{n}}$

crest value of the current through the SPD having a current waveshape of 8/20

[SOURCE: IEC 61643-11:2011, 3.1.9]

**3.1.10****impulse discharge current for class I test**

$I_{\text{imp}}$

crest value of a discharge current through the SPD with specified charge transfer  $Q$  and specified energy  $W/R$  in the specified time

[SOURCE: definition 3.1.10 of IEC 61643-11:2011]

**3.1.11****combination wave**

wave characterized by defined voltage amplitude ( $U_{oc}$ ) and waveshape under open-circuit conditions and a defined current amplitude ( $I_{CW}$ ) and waveshape under short-circuit conditions

Note 1 to entry: The voltage amplitude, current amplitude and waveform that is delivered to the SPD are determined by the combination wave generator (CWG) fictive impedance  $Z_f$  of 2 ohms and the impedance of the DUT.

[SOURCE: IEC 61643-11:2011, 3.1.22, modified (addition of "of 2 ohms" to note to entry)]

**3.1.12****8/20 current impulse**

current impulse with a virtual front time of 8  $\mu$ s and a time to half-value of 20  $\mu$ s

Note 1 to entry: Clause 10 of IEC 62475:2010 defines the current impulse definitions of front time, time to half-value and waveshape tolerance.

[SOURCE: IEC 61643-11:2011, 3.1.21, modified (removal of "nominal" from definition)]

**3.1.13****1,2/50 voltage impulse**

voltage impulse with a virtual front time of 1,2  $\mu$ s and a time to half-value of 50  $\mu$ s

Note 1 to entry: Clause 7 of IEC 60060-1 (2010) defines the voltage impulse definitions of front time, time to half-value and waveshape tolerance.

[SOURCE: IEC 61643-11:2011, 3.1.20, modified (removal of "nominal" from definition)]

**3.1.14****thermal stability**

state of an SPD if, after heating up during the operating duty test, its temperature decreases with time while energized at specified maximum continuous operating voltage and at specified ambient temperature conditions

[SOURCE: IEC 61643-11:2011, 3.1.25, modified (addition of "state of an" and removal of "is thermally stable" from definition)]

**3.1.15****SPD disconnecter (disconnecter)**

device for disconnecting an SPD, or part of an SPD, from the power system

Note 1 to entry: This disconnecting device is not required to have isolating capability for safety purposes. It is to prevent a persistent fault on the system and is used to give an indication of an SPD's failure. Disconnectors can be internal (built in) or external (required by the manufacturer). There may be more than one disconnector function, for example, an over-current protection function and a thermal protection function. These functions may be in separate units.

[SOURCE IEC 61643-11:2011, 3.1.28]

**3.1.16****type tests**

conformity test made on one or more items representative of the production

[SOURCE: IEC 60050-151:2001, 151-16-16]

### 3.1.17

#### degree of protection provided of enclosure

IP

classification preceded by the symbol IP indicating the extent of protection provided by an enclosure against access to hazardous parts, against ingress of solid foreign objects and possibly harmful ingress of water

[SOURCE: IEC 61643-11:2011, 3.1.29]]

### 3.1.18

#### voltage drop (in percent)

$$\Delta U = [(U_{in} - U_{out}) / U_{in}] \times 100 \%$$

where  $U_{in}$  is the input voltage and  $U_{out}$  is the output voltage measured simultaneously with a full rated resistive load connected. This parameter is used only for two-port SPDs

### 3.1.19

#### load-side surge withstand capability for a two-port SPD

ability of a two-port SPD to withstand surges on the output terminals originating in circuitry downstream of the SPD

[SOURCE: definition 3.1.18 of IEC 61643-11:2011]

### 3.1.20

#### short-circuit current rating

$I_{SCCR}$

maximum prospective short-circuit current from the power system for which the SPD, in conjunction with the disconnect specified, is rated

Note 1 to entry: Two short-circuit current rating may be defined for two-port SPDs or one-port SPDs having separate input and output terminals: one corresponding to an internal short circuit (shorting out the internal active part) and another one corresponding to an external short circuit (load-side short-circuit) directly at the output terminals (in case of a failure at the load).

SOURCE: IEC 61643-11:2011, 3.1.27, modified (addition of note to entry)]

### 3.1.21

#### one-port SPD

SPD having no intended series impedance

Note 1 to entry: A one port SPD may have separate input and output terminals.

Note 2 to entry: Figure 1 shows some typical one-port SPDs and the generic drawing for a one-port SPD (Figure 1c). A one-port SPD may be connected in shunt, Figure 1, or in line with the power supply, Figure 1b. In the first case, the load current is not flowing through the input and output terminals of the SPD. In the second case, the load current is flowing through the input and output terminals of the SPD and the temperature rise under load current and the associated maximum admissible load current may be determined as for a two-port SPD. Figure 3b to Figure 3d show the response of various types of one-port SPD to an 8/20 impulse applied via a combination wave generator.

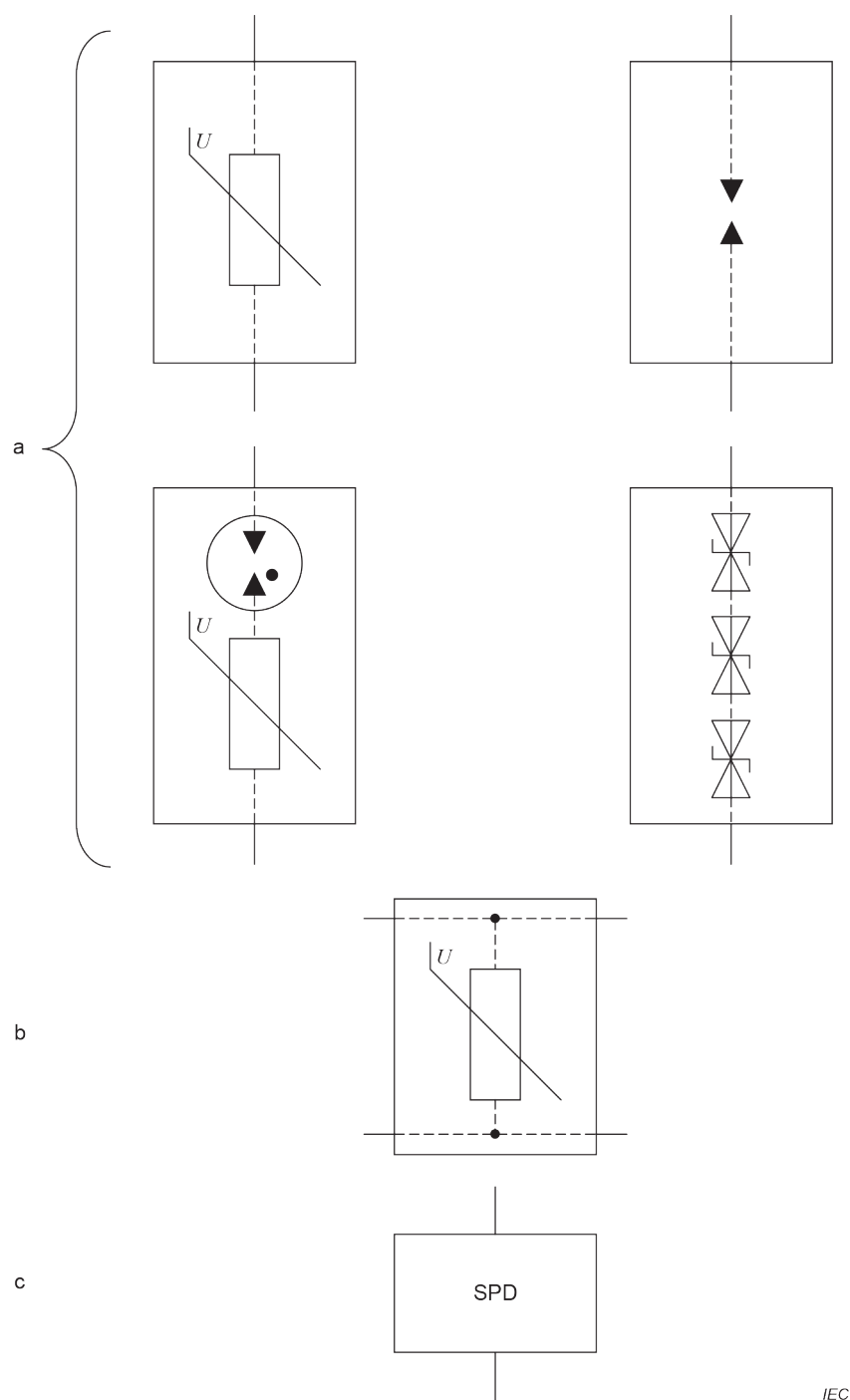
### 3.1.22

#### two-port SPD

SPD having a specific series impedance connected between separate input and output terminals

Note 1 to entry: The measured limiting voltage may be higher at the input terminals than at the output terminals. Therefore, equipment to be protected is to be connected to the output terminals. Figure 2 shows typical two-port SPDs. Figure 3e and Figure 3f show the response of a two-port SPD to an 8/20 impulse applied via a combination wave generator.

[SOURCE: IEC 61643-11:2011, 3.1.3, modified (addition of note to entry)]

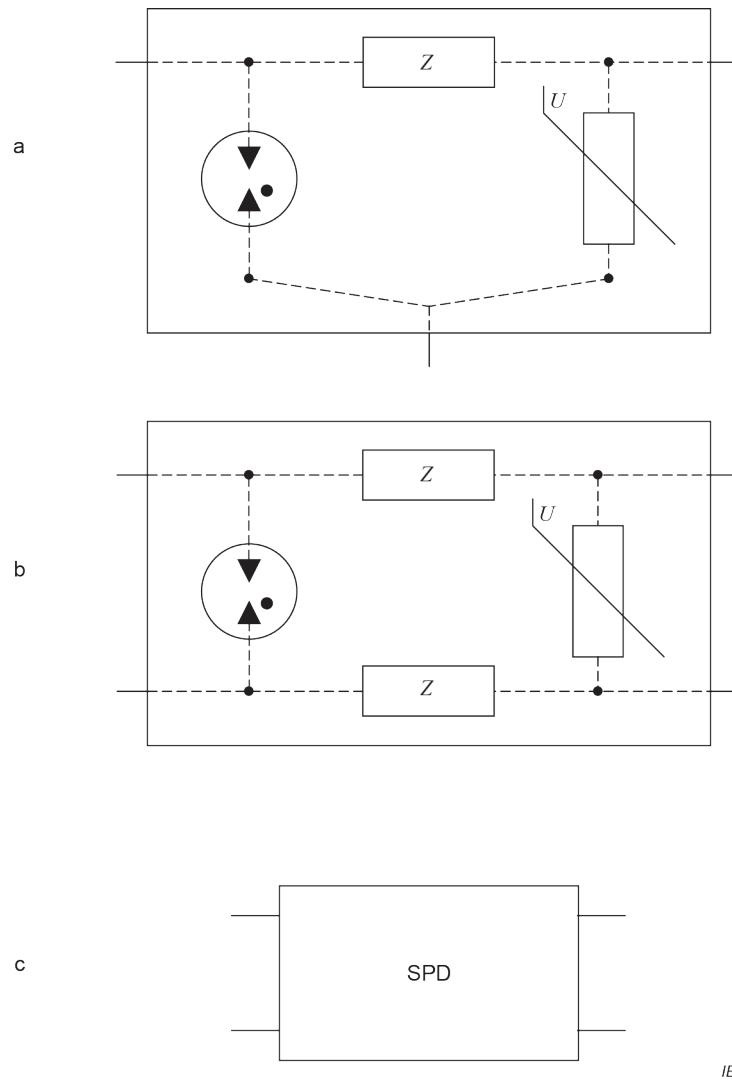


IEC

**Key**

- a One-port SPDs
- b One-port SPD with separate input and output terminals
- c Generic symbol for a one-port SPD

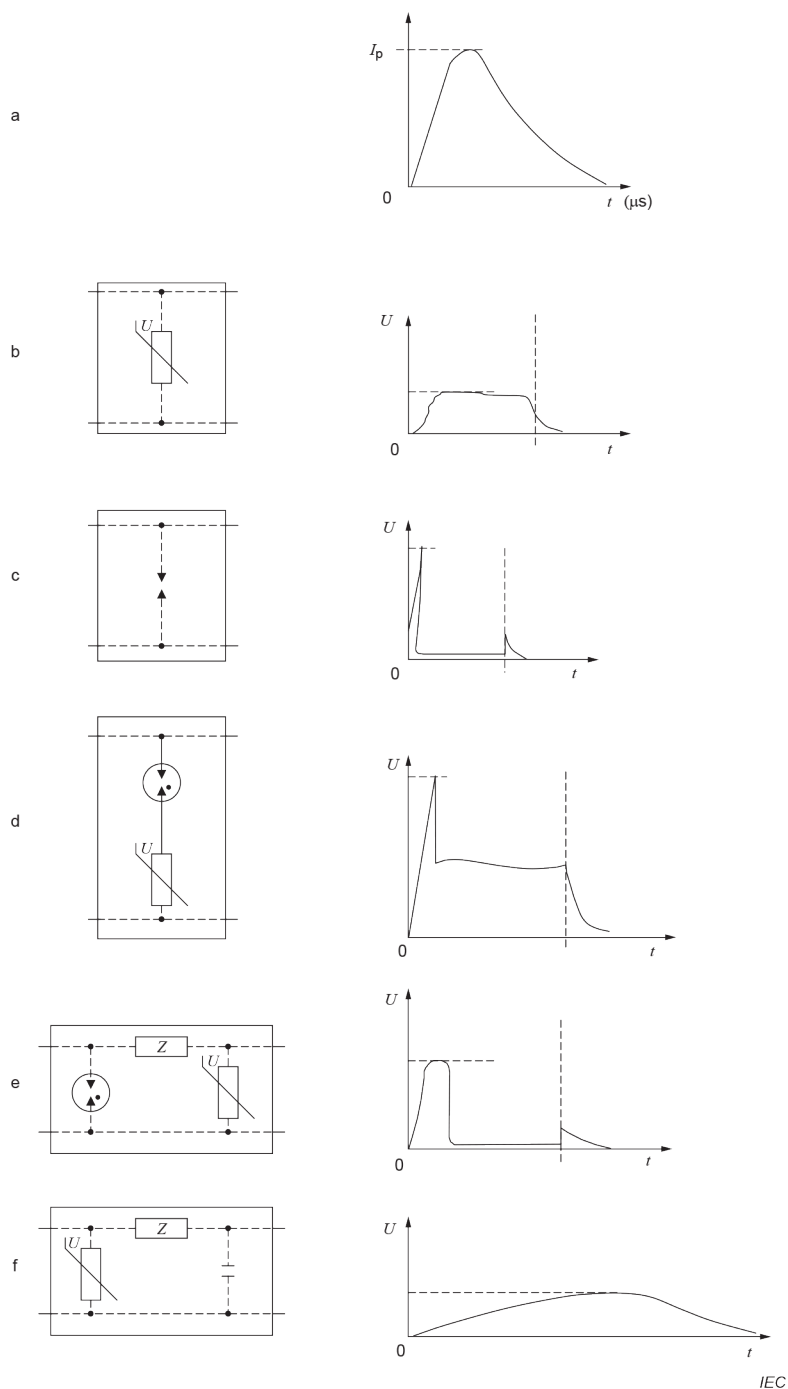
**Figure 1 – Examples of one-port SPDs**



# Key

- a Three-terminal two-port SPD
- b Four-terminal two-port SPD
- c Generic symbol for a two-port SPD
- Z Series impedance between input and output terminals

**Figure 2 – Examples of two-port SPDs**

**Key**

- a Applied current waveform
- b Output voltage waveform of voltage-limiting SPD
- c Output voltage waveform of voltage-switching SPD
- d Output voltage waveform of one-port combination SPD
- e Output voltage waveform of two-port combination SPD
- f Output voltage waveform of two-port voltage-limiting SPD with filtering

NOTE The voltage levels are only representative and not an indication of actual values.  $U$  in the right part of the figure means the output voltage of the SPDs where  $U$  in the left part is the symbol for varistor.

**Figure 3 – Output voltage response of one-port and two-port SPDs to a combination wave generator impulse**

[SOURCE: IEC 61643-11:2011, 3.1.2, modified (addition of Note 2 to entry and Figures 1 to 3)]

### 3.1.23

#### **Voltage-switching SPD**

SPD that has a high impedance when no surge is present, but can have a sudden change in impedance to a low value in response to a voltage surge

Note 1 to entry: Common examples of components used in voltage switching SPDs are spark gaps, gas discharge tubes and silicon-based components (for example thyristors). These are sometimes called "crowbar-type" components.

Note 2 to entry: A voltage-switching device has a discontinuous  $U$  versus  $I$  characteristic. Figure 3c shows the response of a typical voltage-switching SPD to an impulse applied via a combination wave generator.

[SOURCE: IEC 61643-11:2011, 3.1.4, modified (addition of Note 2 to entry)]

### 3.1.24

#### **Voltage-limiting SPD**

SPD that has a high impedance when no surge is present, but will reduce it continuously with increased surge current and voltage

Note 1 to entry: Common examples of components used in voltage-limiting SPDs are metal oxide varistors and avalanche breakdown diodes. These are sometimes called "clamping type" components.

Note 2 to entry: A voltage limiting device has a continuous  $U$  versus  $I$  characteristic. Figure 3b shows the response of a typical voltage limiting SPD to an impulse applied via a combination wave generator.

[SOURCE: IEC 61643-11:2011, 3.1.5, modified (addition of Note 2 to entry)]

### 3.1.25

#### **combination SPD**

SPD that incorporates both voltage-switching components and voltage-limiting components

Note 1 to entry: The SPD may exhibit voltage-switching, limiting or both.

Note 2 to entry: Figure 3d and Figure 3e show the response of various typical combination SPDs to an impulse applied via a combination wave generator.

[SOURCE: IEC 61643-11:2011, 3.1.6, modified (addition of note to entry)]

### 3.1.26

#### **mode of protection**

intended current path between terminals that contains protective components, e.g. line-to-line, line-to-earth, line-to-neutral, neutral-to-earth

[SOURCE: IEC 61643-11:2011, 3.1.8]

### 3.1.27

#### **follow current**

$I_f$

peak current supplied by the electrical power system and flowing through the SPD after a discharge current impulse

[SOURCE: IEC 61643-11:2011, 3.1.12]

### 3.1.28

#### **maximum discharge current**

$I_{max}$

crest value of a current through the SPD having an 8/20 waveshape and magnitude according to the manufacturer's specification

Note 1 to entry:  $I_{\max}$  is equal to or greater than  $I_n$ .

[SOURCE: IEC 61643-11:2011, 3.1.48]

### 3.1.29

#### **degradation (of performance)**

undesired permanent departure in the operational performance of equipment or a system from its intended performance

Note 1 to entry: Durability is a measure of the ability of an SPD to withstand the conditions for which it is designed throughout its service life. Two type tests are applied to provide confidence with respect to degradation. The first one is the operating duty test and the second is the ageing test. However, these two tests may be combined. The operating duty test is conducted by applying a specified number of defined current waveshapes to the SPD. Permitted changes in the SPD characteristics are given in IEC 61643-11. The ageing test is carried out at a specified temperature with a voltage of specified magnitude and duration applied to the SPD. Permitted changes in the SPD characteristics are given in IEC 61643-11 (this test is under consideration). These tests can be used to determine the SPD prospective installed life, which should also consider the following:

- replacement policy;
- location and accessibility;
- acceptable failure rate;
- operating practices.

[SOURCE: IEC 61643-11:2011, 3.1.26, modified (addition of note to entry)]

### 3.1.30

#### **residual current device**

##### **RCD**

mechanical switching device designed to make, carry and break currents under normal service conditions and to cause the opening of the contacts when the residual current attains a given value under specified conditions

Note 1 to entry: A residual current device can be a combination of various separate elements designed to detect and evaluate the residual current and to make and break current.

[SOURCE: IEC 60050-442:1998, 442-05-02]

### 3.1.31

#### **nominal voltage of the system**

voltage by which a system or equipment is designated and to which certain operating characteristics are referred (for example, 230/400 V)

Note 1 to entry: Under normal system conditions, the voltage at the supply terminals may differ from the nominal voltage as determined by the tolerances of the supply systems. In this document, a tolerance of  $\pm 10\%$  is used.

Note 2 to entry: The nominal voltage of the system phase to earth is called  $U_n$  (see IEC 60038).

Note 3 to entry: The line-to-neutral voltage of the system is called  $U_0$ .

Note 4 to entry: The line-to-line voltage of the system is called  $U$ .

### 3.1.32

#### **impulse test classification**

##### **3.1.32.1**

##### **Class I tests**

tests carried out with the impulse discharge current  $I_{\text{imp}}$ , with an 8/20 current impulse having a crest value equal to the crest value of  $I_{\text{imp}}$ , and, if relevant, with a 1,2/50 voltage impulse

[SOURCE: IEC 61643-11:2011, 3.1.34.1, modified (addition of "if relevant")]

### 3.1.32.2

#### class II tests

tests carried out with the nominal discharge current  $I_n$ , and if relevant, with a 1,2/50 voltage impulse

[SOURCE: IEC 61643-11:2011, 3.1.34.2, modified (addition of "if relevant")]

### 3.1.32.3

#### class III tests

tests carried out with a 1,2/50 voltage – 8/20 current combination wave generator

[SOURCE: IEC 61643-11:2011, 3.1.34.3]

### 3.1.33

#### rated load current

$I_L$

maximum continuous rated RMS current that can be supplied to a resistive load connected to the protected output of an SPD

Note 1 to entry: This is only relevant to SPD(s) having separate input and output terminals.

[SOURCE: IEC 61643-11:2011, 3.1.13, modified (addition of note to entry)]

### 3.1.34

#### maximum continuous operating voltage of the power system at the SPD location

$U_{cs}$

maximum RMS voltage to which the SPD may be permanently subjected at the point of application of the SPD

Note 1 to entry: This takes into account only voltage regulation and/or voltage drop or increase. It is also called actual maximum system voltage and is directly linked to  $U_0$ .

Note 2 to entry: This voltage does not take into account harmonics, faults, TOVs or transient conditions.

### 3.1.35

#### trigger voltage of a voltage switching SPD

maximum voltage value at which the sudden change from high to low impedance starts for a voltage switching SPD

Note 1 to entry: A voltage switching SPD may be based on components other than gaps (for example, silicon-based components).

[SOURCE: IEC 61643-11:2011, 3.1.36, modified (addition of note to entry)]

### 3.1.36

#### lightning protection system

LPS

complete system used to reduce physical damage due to lightning flashes to a structure

Note 1 to entry: This consists of both external and internal lightning protection systems

[SOURCE: IEC 62305-3:2010, 3.1]

### 3.1.37

#### multiservice SPD

surge protective device providing protection for two or more services such as power, telecommunication and signalling in a single enclosure in which a reference bond is provided between services

**3.1.38  
residual current**

$I_{PE}$   
current flowing through the PE terminal of the SPD while energized at the reference test voltage ( $U_{REF}$ ) when connected according to the manufacturer's instructions

Note 1 to entry: Protective conductor (PE) is conductor provided for purposes of safety, for example protection against electric shock (according to IEC 195-02-09).

[SOURCE: IEC 61643-11:2011, 3.1.40, modified (addition of note to entry)]

**3.1.39  
prospective short-circuit current of a power supply**

$I_p$   
current which would flow at a given location in a circuit if it were short-circuited at that location by a link of negligible impedance

Note 1 to entry: This prospective symmetrical current is expressed by its RMS value.

[SOURCE: IEC 61643-11:2011, 3.1.38]

**3.1.40  
follow current interrupt rating**

$I_{fi}$   
prospective short-circuit current that an SPD is able to interrupt without operation of a disconnector

[SOURCE: IEC 61643-11:2011, 3.1.39]

**3.1.41  
specific energy for class I test**

$W/R$   
energy dissipated by a unit resistance of 1  $\Omega$  with the impulse discharge current  $I_{imp}$

Note 1 to entry: This is equal to the time integral of the square of the current ( $W/R = \int i^2 dt$ ).

[SOURCE: IEC 61643-11:2011, 3.1.37]

**3.1.42  
rated impulse voltage**

$U_W$   
impulse withstand voltage value assigned by the manufacturer to the equipment or to a part of it, characterizing the specified withstand capability of its insulation against transient overvoltages

Note 1 to entry: For the purposes of this document only withstand voltages between live conductors and earth are considered.

[SOURCE: IEC 60664-1:2007:3.9.2, modified (addition of note to entry)]

**3.1.43  
impulse withstand voltage**

highest peak value of impulse voltage of prescribed form and polarity which does not cause breakdown of insulation under specified conditions

[SOURCE: IEC 60664-1:2007, 3.8.1]

### 3.1.44

#### **overvoltage category**

numeral defining a transient overvoltage condition

[SOURCE: IEC 60664-1:2007:3.10, modified]

### 3.1.45

#### **overcurrent protective device**

OCPD

device provided to interrupt an electric circuit in case the conductor current in the electric circuit exceeds a predetermined value for a specified duration

[SOURCE: IEC 60050-826:2004, 826-14-14]

### 3.1.46

#### **effective voltage protection level**

$U_{p/f}$

voltage at the connection point of the SPD assembly resulting from the voltage protection level of the SPD and the voltage drop across a disconnector and connecting leads, if present

### 3.1.47

#### **short-circuiting SPD**

SPD tested according to Class II tests which changes its characteristic to an intentional internal short-circuit due to a surge current exceeding its nominal discharge current  $I_n$

[SOURCE: IEC 61643-11:2011, 3.1.7]

### 3.1.48

#### **status indicator**

device that indicates the operational status of an SPD, or a part of an SPD

Note 1 to entry: Such indicators may be local with visual and/or audible alarms and/or may have remote signaling and/or output contact capability.

[SOURCE: IEC 61643-11:2011, 3.1.41]

### 3.1.49

#### **open circuit voltage**

$U_{oc}$

open circuit voltage of the combination wave generator at the point of connection of the device under test

[SOURCE: IEC 61643-11:2011, 3.1.23]

### 3.1.50

#### **combination wave generator short-circuit current**

$I_{cw}$

prospective short-circuit current of the combination wave generator, at the point of connection of the device under test

Note 1 to entry: When the SPD is connected to the combination wave generator, the current that flows through the device is in most cases less than  $I_{cw}$ .

[SOURCE: IEC 61643-11:2011, 3.1.24]

### 3.1.51

#### **output contact**

contact included in a circuit separate from the main circuit of an SPD, and linked to a disconnector or status indicator

[SOURCE: IEC 61643-11:2011, 3.1.42]

### 3.1.52

#### **multimode SPD**

type of SPD with more than one mode of protection, or a combination of electrically interconnected SPDs offered as a unit

[SOURCE: IEC 61643-11:2011, 3.1.43, modified]

### 3.1.53

#### **total discharge current**

$I_{\text{Total}}$

current which flows through the PE or PEN conductor of a multimode SPD during the total discharge current test

Note 1 to entry: The aim is to take into account cumulative effects that occur when multiple modes of protection of a multimode SPD conduct at the same time.

Note 2 to entry:  $I_{\text{Total}}$  is particularly relevant for SPDs tested according to test class I, and is used for the purpose of lightning protection equipotential bonding according to IEC 62305 series.

Note 3 to entry: PEN conductor is conductor combining the functions of both a protective earthing conductor and a neutral conductor (according to IEC 195-02-12).

[SOURCE: IEC 61643-11:2011, 3.1.44, modified (addition of Note 3 to entry)]

### 3.1.54

#### **reference test voltage**

$U_{\text{REF}}$

RMS value of voltage used for testing which depends on the mode of protection of the SPD, the nominal system voltage, the system configuration and the voltage regulation within the system

[SOURCE: IEC 61643-11:2011, 3.1.45]

### 3.1.55

#### **transition surge current rating for short-circuiting SPD**

$I_{\text{trans}}$

8/20 impulse current value exceeding the nominal discharge current  $I_n$ , that will cause a short-circuiting SPD to short-circuit

[SOURCE: IEC 61643-11:2011, 3.1.46]

### 3.1.56

#### **voltage for clearance determination**

$U_{\text{max}}$

highest measured voltage during surge applications for clearance determination

[SOURCE: IEC 61643-11:2011, 3.1.47, modified]

### 3.1.57

#### **Varistor voltage**

$V_V$

Voltage across the MOV measured at a specified current (typically 1 mA) for a specific duration

[SOURCE: IEC 61643-331, 3.2.3]

### 3.2 List of abbreviated terms and acronyms used in this document

| List of abbreviated terms |                                                                                                   |
|---------------------------|---------------------------------------------------------------------------------------------------|
| $E_{\max}$                | Maximum energy withstand                                                                          |
| $I_c$                     | Continuous operating current                                                                      |
| $I_{CW}$                  | short-circuit current of the combination wave generator                                           |
| $I_f$                     | Follow current                                                                                    |
| $I_{fi}$                  | Follow current interrupting rating                                                                |
| $I_{\text{imp}}$          | impulse discharge current for class I test                                                        |
| $I_L$                     | Rated load current                                                                                |
| $I_{\max}$                | maximum discharge current                                                                         |
| $I_n$                     | nominal discharge current for class II test                                                       |
| $I_p$                     | Prospective short-circuit current of a power supply                                               |
| $I_{PE}$                  | residual current at $U_{\text{REF}}$                                                              |
| $I_{sc}$                  | Short-circuit current of the CWG                                                                  |
| $I_{\text{SCCR}}$         | short-circuit current rating                                                                      |
| $I_{\text{Total}}$        | total discharge current for multimode SPD                                                         |
| $I_{\text{trans}}$        | transition surge current rating for Short-circuiting SPD                                          |
| $L$                       | Inductance                                                                                        |
| $N_G$                     | Ground flash density                                                                              |
| $N_k$                     | Keraunic level                                                                                    |
| $P_{\text{SPD}}$          | Probability that an apparatus will be damaged, in spite of protection by a coordinated SPD system |
| $Q$                       | Charge (of impulse current)                                                                       |
| $t_T$                     | TOV application time for testing                                                                  |
| $U_{cs}$                  | Maximum continuous operating voltage of the power system                                          |
| $U_{\max}$                | voltage for clearance determination                                                               |
| $U_n$                     | Nominal voltage of the system phase to earth                                                      |
| $U_0$                     | Line-to-neutral voltage of the system                                                             |
| $U_{oc}$                  | open circuit voltage of the combination wave generator                                            |
| $U_p$                     | Voltage protection level                                                                          |
| $U_{\text{REF}}$          | Reference test voltage                                                                            |
| $U_{\text{res}}$          | Residual voltage                                                                                  |
| $U_T$                     | temporary overvoltage test value                                                                  |
| $U_{\text{TOV}}$          | Temporary overvoltage of the power system                                                         |
| $U_{\text{TOV(HV)}}$      | Temporary overvoltage of the network inside the high-voltage system                               |
| $U_{\text{TOV(LV)}}$      | Temporary overvoltage of the network inside the low-voltage system                                |
| $U_W$                     | Rated impulse voltage                                                                             |
| $V_V$                     | Varistor voltage                                                                                  |
| $W/R$                     | Specific energy                                                                                   |
| $Z_f$                     | fictive impedance (of combination wave generator)                                                 |
| $\Delta U$                | Voltage drop (in %)                                                                               |

| List of acronyms |                                                 |
|------------------|-------------------------------------------------|
| ABD              | Avalanche breakdown device                      |
| dB               | Decibel                                         |
| CWG              | Combination wave generator                      |
| DFIG             | Double-Feed induction generator                 |
| DUT              | Device under test                               |
| EB               | Equipotential Bonding bar                       |
| EMC              | Electromagnetic compatibility                   |
| GDT              | Gas discharge tube                              |
| HV               | High voltage                                    |
| IGBT             | Insulated gate bipolar transistor               |
| IP               | Degrees of protection provided by the enclosure |
| LEMP             | Lightning electromagnetic pulse                 |
| LPS              | Lightning protection system                     |
| LPZ              | Lightning protection zone                       |
| LTE              | let-through energy                              |
| LV               | Low voltage                                     |
| MEB              | Main equipotential bonding                      |
| MOV              | Metal oxide varistor                            |
| HVA              | High voltage A (medium voltage, <50 kV)         |
| MV               | Medium voltage                                  |
| OCPD             | Overcurrent protective device                   |
| PDS              | Power distribution system                       |
| PE               | Protective earth                                |
| PV               | Photovoltaic                                    |
| PWM              | Pulse width modulation                          |
| RCD              | Residual current device                         |
| TOV              | Temporary overvoltage                           |
| SPC              | Surge protective component                      |
| SPD              | Surge protective device                         |

## 4 Need for protection

The decision as to whether or not to use SPDs is dependent upon a wide range of parameters which are weighted by the user. The parameters that should be considered are listed in Clause H.2.

Further information on performing risk analysis can be found in the following two documents:

- IEC 62305-2 (for a complete analysis).
- IEC 60364-4-44 (structures needing protection only against flashes to, or near to, a line). Examples on how to use this method are described in Clause H.1.

Probability that a SPD reaches its end of life with given surge conditions ( $P_{SPD}$  as defined in IEC 62305-2) is when there is a LPS is given in IEC 62305-2. When the SPD's surge withstand increases,  $P_{SPD}$  decreases.

NOTE If an authority having jurisdiction specifies the need for surge protection for specific applications without requiring a risk assessment, the decision of the need and protection level will be specified by this authority. In some cases, a risk assessment can be performed additionally to define the test class of SPD, but not the need of SPD.

## 5 Low-voltage power systems and equipment to be protected

### 5.1 General

When evaluating an installation for the need of an SPD, two factors need to be considered:

- the characteristics of the low-voltage power distribution system on which the SPD will be installed, including expected types and levels of overvoltage and current;
- the characteristics of the equipment to be protected.

### 5.2 Low-voltage power systems

#### 5.2.1 General

Low-voltage power systems are basically characterized by the type of system earthing (TN-C, TN-S, TN-C-S, TT, IT) and its nominal voltage, its types of overvoltages and surge currents. In this document, the overvoltages and surge currents are classified into three groups:

- lightning;
- switching;
- temporary overvoltages.

#### 5.2.2 Lightning overvoltages and surge currents

In most cases lightning stress is the major factor to consider in the selection of an SPD's class of test and associated current or voltage values ( $I_{imp}$ ,  $I_n$  or  $U_{oc}$ ) defined in IEC 61643-11.

Evaluation of the lightning stress (based on waveshape and magnitude of current or voltage) is necessary for the proper selection of an SPD. It is also important to determine that the voltage protection level  $U_p$  of the SPD is adequate to protect the equipment under such conditions.

When a Lightning Protection System (LPS) is present, an SPD at the entrance of the installation is mandatory and an SPD tested according to test Class I shall be selected. For buildings with Lightning Protection Systems (LPS), additional information on lightning stress can be found in IEC 62305-1. For selection of  $I_{imp}$ , more information can also be found in Annex J.3.

In many cases, higher stresses occur on the electrical installation external to the structure (for example, direct strike to or induced surges on the external power lines connected to the structure). Within the structure, the stresses decrease from the installation's entrance to internal circuits, due to the change of circuit configuration, SPD interaction and impedances.

The risk analysis is performed either by applying the simplified method described in IEC 60364-4-44 (see Clause H.2) or the detailed risk analysis described in IEC 62305-2. For performing a risk analysis, the user will need to know at least the following:

- The local ground flash density  $N_G$  (average annual ground flash density, in lightning flashes per km<sup>2</sup> per year, related to the region where the structure is located). Modern Lightning Location Systems (LLS) can provide information on  $N_G$ ;
- The exposure of the electrical installation.

To determine if surge protection is needed when the supply is provided by an underground cable, the following should be considered:

- the installation has a LPS in its vicinity;
- is the length of the underground cable sufficient to provide adequate surge attenuation? (according to IEC 62305 series a minimum length of 1 000 m is needed to consider surges as being reduced to an acceptable level)
- the underground cable may be affected by direct lightning in the presence of high soil resistivity (except if the cable is shielded or in metal conduit);
- high surges of atmospheric origin can be expected on the overhead line supplying the HV (high voltage) side of the transformer connected to the installation;
- the size or height of the building powered by the underground cable is high enough to significantly increase the risk of direct strikes.;
- other overhead services present (telephone lines, antenna systems, etc.) that could affect the power system and equipment.

When many buildings are supplied from a single supply system, those buildings which do not have SPDs can experience high stresses on their electrical systems.

The evaluation of the waveshape and current magnitude due to proximity to a strike/event (i.e. directly on or close to the structure, directly on or near the power lines) are reported in Annex E of IEC 62305-1:2010. The risk evaluation for each of these sources of damage can be performed using the method described in IEC 62305-2.

Annex C and Annex I provide more information about lightning stresses.

Equipment within the electrical installation, upstream of the SPD, may influence the surge withstand of the installation; their surge withstand should be determined.

### 5.2.3 Switching overvoltages

These stresses, in terms of peak current and voltage, are usually lower than lightning stresses but could have much longer duration (e.g. transients due to faults and fuses operations) or less energetic but much more frequent (e.g. operation of contactors, capacitor banks for power factor correction, IGBTs, etc.). However, in some cases, particularly deep inside a structure or close to switching overvoltage sources, the switching stress can be higher than the stresses caused by lightning. The energy related to these switching surges needs to be determined to permit the choice of appropriate SPDs.

In general, the selection of the surge rating of an SPD is based on the stresses due to lightning.

For additional information on surges generated within the power distribution system inside a facility, see Subclause 4.3 of IEEE Std C62.41.1-2002 and Subclause 5.2.2 of C62.72-2016. These types of surges, although not always immediately damaging to the power distribution system or connected equipment, often cause interruption and disruption of the operation of the system. These surges have significantly different waveshapes and amplitudes than those expected from sources external to the power distribution system and may require SPDs designed to specifically mitigate the effects of these internally generated surges. Additional recommended waveshapes and test amplitudes that represent these surges are defined in IEEE Standard C62.41.2-2002. Additional information on such surges can be found in IEC TR 62066:2002, *Surge overvoltages and surge protection in low-voltage AC power systems – General basic information*.

Annex C and Annex I provide more information about switching stress. Additional information on switching surges can be found in IEC TR 62066.

## 5.2.4 Temporary overvoltages $U_{TOV}$

### 5.2.4.1 General

During its lifetime, any SPD may be exposed to a temporary overvoltage  $U_{TOV}$  that exceeds the normal voltage of the power system.

A temporary overvoltage has two dimensions: magnitude and time. The time duration of the overvoltage depends primarily upon the earthing of the supply system (including both the high-voltage supply system as well as the low-voltage system to which the SPD is connected). In determining the temporary overvoltages of a system, consideration should be given to the line to neutral and line to line voltages of the system (see Table E.3).

TOVs may occur on the low-voltage system between L-N or L-PEN in the case of a failure in the low voltage system:

- for an undefined time until an OCPD operates in the case of short circuit condition,
- for an unlimited time in the case of loss of neutral.

TOVs may occur on the low voltage system for a limited time between N-PE or L-PE in case of a ground fault in the high voltage system, depending on the earthing configuration of the high voltage system and the low voltage system or possible interaction between both systems.

SPDs are not intended for protection against system TOVs. SPDs may withstand or fail in a safe manner as described in IEC 61643-11.

TOVs due to loss of Neutral are responsible of line-neutral overvoltages for very long times (up to hours) and which may reach voltage values up to the line-line voltages of the power system. Protection against such TOVs cannot be obtained with SPDs. POP (Power frequency Overvoltage Protection devices) may be used in such cases.

NOTE POP is defined in IEC 63052<sup>1</sup>.

Annex E, and Annex I provide more information about temporary overvoltages.

### 5.2.4.2 Standardized values

IEC 60364-4-44 provides the maximum values of  $U_{TOV}$  to be expected in low-voltage power systems. (For a more detailed calculation of these values, refer to Annex E).

Lower values are possible depending on many factors, including the location of the SPD, the type of power system, and the like.

The maximum temporary overvoltage values at the consumer installation are given in Table 1.

Values used for testing SPDs are indicated in Annex E.

<sup>1</sup> Under preparation. Stage at the time of publication: IEC/PRVC 63052:2019.

**Table 1 – Maximum TOV values based on IEC 60364-4-44:2007**

| Occurrence of $U_{TOV}$                                                                                                                                                               | System                                  | Maximum values for $U_{TOV(HV)}$           |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------|--------------------------------------------|
| Between phase and earth                                                                                                                                                               | TT, IT                                  | $U_0 + 250$ V for duration >5 s            |
|                                                                                                                                                                                       |                                         | $U_0 + 1\,200$ V for duration up to 5 s    |
| Between neutral and earth                                                                                                                                                             | TT, IT                                  | 250 V for duration >5 s                    |
|                                                                                                                                                                                       |                                         | 1 200 V for duration up to 5 s             |
| The above values are extreme values related to faults in the high-voltage power systems and can be calculated depending on the type of power systems according to Annex E.            |                                         |                                            |
| Occurrence of $U_{TOV}$                                                                                                                                                               | System                                  | Maximum values for $U_{TOV(LV)}$           |
| Between phase and neutral                                                                                                                                                             | TT and TN                               | $\sqrt{3} \times U_0$                      |
| The above value is related to a loss of the neutral conductor in the low-voltage system.                                                                                              |                                         |                                            |
| Between phase and earth                                                                                                                                                               | IT system<br>(TT system:<br>see note 1) | $\sqrt{3} \times U_0$                      |
| The above value is related to accidental earthing of the phase conductor in the low-voltage system.                                                                                   |                                         |                                            |
| Between phase and neutral                                                                                                                                                             | TT, IT and TN                           | $1,45 \times U_0$ for a duration up to 5 s |
| The above value is related to short circuit between a line conductor and the neutral conductor.                                                                                       |                                         |                                            |
| NOTE 1 It has been demonstrated that high TOVs can also occur in TT systems for durations up to 5 s. See Annex E for more details. This condition is not addressed in IEC 60364-4-44. |                                         |                                            |
| NOTE 2 Maximum TOV values at the transformer location may be different from the tables above (higher or lower). See Annex E for more details.                                         |                                         |                                            |
| $U_0$ is the line-to-neutral voltage of the low-voltage system.                                                                                                                       |                                         |                                            |

### 5.3 Characteristics of the equipment to be protected

Characteristics of the equipment to be protected under transient conditions are determined by two test methods, as follows:

- The impulse withstand of the equipment test, according to IEC 60664-1. This is only an insulation coordination test. During the test, the equipment is de-energized.
- The impulse immunity of the equipment test, according to IEC 61000-4-5. This test evaluates the equipment's operational immunity capabilities. The test is mainly performed with a combination wave generator (1,2/50, 8/20) at different levels. It determines where a malfunction, error or failure can occur during energized operation.

A comparison of the impulse withstand and impulse immunity levels, with respect to the transient environment in which the equipment is to be used, determines the potential need for SPDs. For more information, see Annex O.

NOTE The selected SPD can provide an effective protection level  $U_{p/f}$  lower than the impulse withstand capability  $U_W$  of the equipment to be protected. In some cases where the continuous operation of the equipment is critical,  $U_{p/f}$  is lower than the impulse immunity of the equipment, see 7.4.5.  $U_p$  can be selected in accordance with 7.5.2 and 7.5.6.

## 6 Surge protective devices

### 6.1 Basic functions of SPDs

The SPDs considered in this document are those installed external or internal to the equipment to be protected.

NOTE Electric and electronic equipment are often protected with overvoltage components (e.g. MOVs compliant with IEC 61643-331) which are not taken into consideration here. Only overvoltage protection provided with devices (SPDs) compliant with IEC 61643-11 is considered in this document.

Their functioning in power systems can be described as follows.

- In the absence of surges: the SPD shall not have a significant influence on the operational characteristics of the system to which it is applied.
- During the occurrence of surges: the SPD responds to surges by lowering its impedance and thus diverting surge current through it to limit the voltage (in most cases much lower than its protective level  $U_p$ ). The surges could initiate a power follow current through the SPD depending on the SPD design (SPD with power follow current).
- After the occurrence of surges: the SPD recovers to a high-impedance state after the surges and extinguishes any possible power follow current.

The characteristics of SPDs are intended to achieve the above functions under normal service conditions. Normal service conditions are specified by the frequency of the power-system voltage, load current, altitude (i.e. air pressure), humidity and ambient air temperature.

## 6.2 Additional requirements

Depending on the application of the SPD, additional requirements may be needed such as:

- Protection of SPDs against direct contact (which shall be in accordance with IEC 60364-4-41);
- Safe behaviour in the event of SPD end of life.

An SPD may end its life when subjected to a surge greater than its designed discharge current capability or when exposed to a sustained overvoltage that exceeds its maximum continuous operating voltage. For the purpose of this document, the SPD end of life mode is divided into open-circuit or short-circuit (see also 6.5.4).

**NOTE** In the context of this clause, this does not address the concept of SPD classification of IEC 61643-11 (SPD failure behaviour) which is linked to particular technologies of SPDs. However, SPDs classified as short-circuiting type SPDs will, by definition, end up in short circuit when reaching their end of life.

End of life of an SPD is usually difficult to detect since it has almost no influence on the system. However, the system is no longer protected. To ensure that such failed SPD is replaced before the next surge, a fault indicator is required (see 7.6.3).

A short-circuit current may flow through the failed SPD when it reaches its end of life. The short circuit withstand capability test of IEC 61643-11 is performed to ensure that energy dissipated during the conduction of short-circuit current will not result in a fire hazard. Independent of the declared SPD failure behaviour (open circuit or short circuit behaviour) according to IEC 61643-11, a suitable disconnecting device may be required to protect the SPD in case of overload (see 7.5.2.4).

## 6.3 Classification of SPDs

### 6.3.1 SPD: classification

Surge protective devices are classified according to IEC 61643-11 as follows.

|                         |                                                                                                                                     |
|-------------------------|-------------------------------------------------------------------------------------------------------------------------------------|
| Number of ports:        | one or two                                                                                                                          |
| Design topology:        | voltage-switching, voltage-limiting or combination                                                                                  |
| SPD Class of test:      | I, II, III                                                                                                                          |
| Location:               | indoor or outdoor                                                                                                                   |
| Accessibility:          | accessible, inaccessible (out-of-reach)                                                                                             |
| Mounting method:        | fixed or portable                                                                                                                   |
| Disconnecter:           | location (external, internal, both external and internal, none)<br>and protection functions (thermal, leakage current, overcurrent) |
| Overcurrent protection: | specified or not                                                                                                                    |

Degree of protection: provided by the SPD enclosure (IP)

Temperature range: normal or extended

NOTE By definition, outdoor means outside closed shelters. Hence, such SPDs are subjected to all external conditions. Indoor means inside closed shelters. Hence, such SPDs are subjected to indoor atmospheric conditions. Out-of-reach means no access to live parts without the use of tools or other equipment.

Some of the above choices are linked to the technology used and are defined by the manufacturer.

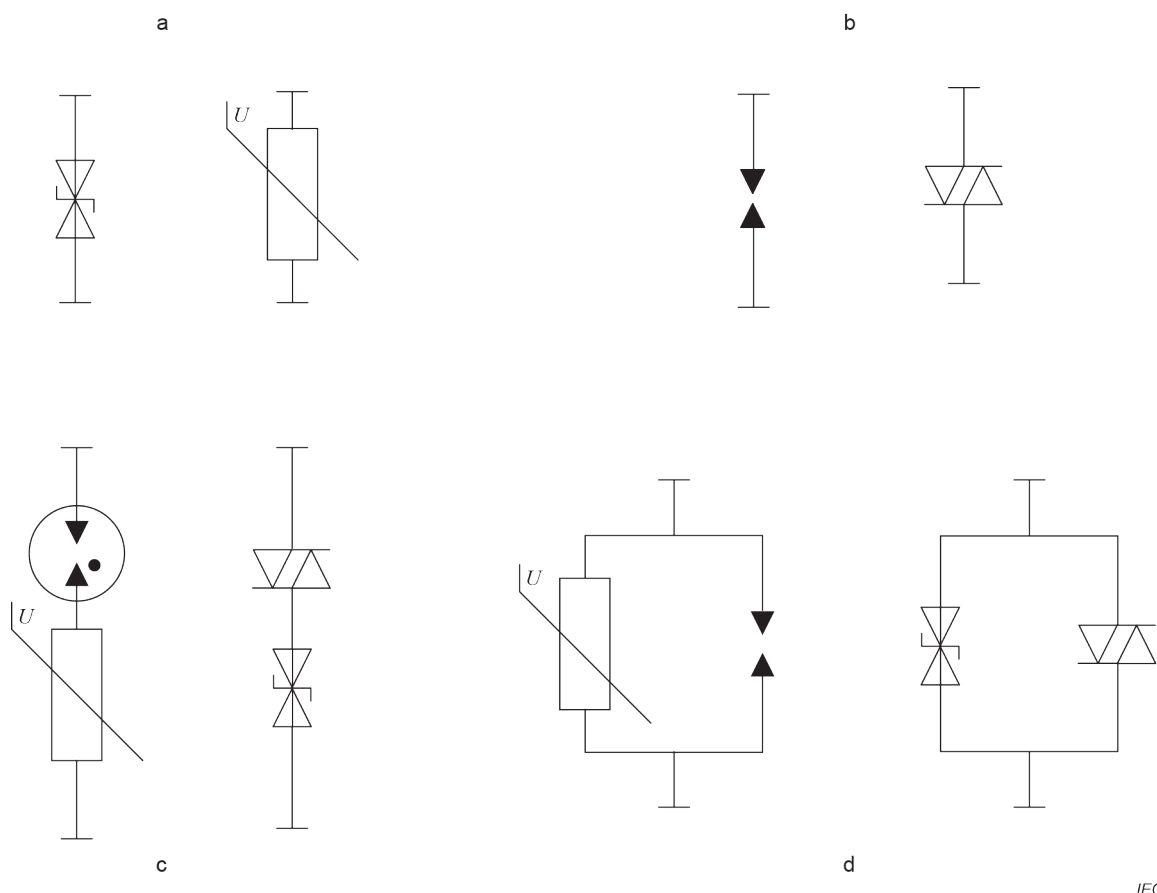
### 6.3.2 Typical design and topologies

The main protective components used in SPDs belong to two categories:

- voltage-limiting components: metal oxide varistors (MOV, see IEC 61643-331), avalanche breakdown diodes (ABD, see IEC 61643-321) or suppressor diodes (see IEC 61643-321), etc.;
- voltage-switching components: air gaps, gas discharge tubes (GDT, see IEC 61643-311), thyristors; surge suppressors (TSS, see IEC 61643-341), triacs (see IEC 61643-341) etc.

Based on these components, typical SPD designs are given in Figure 4:

- single voltage-limiting component (Figure 4a): voltage-limiting SPD;
- single voltage-switching component (Figure 4b): voltage-switching SPD;
- combination of voltage-limiting and voltage-switching components (Figure 4c and Figure 4d): combination SPD.



IEC

#### Key

- a Voltage-limiting components
- b Voltage-switching components
- c Voltage-limiting components in series with voltage-switching components
- d Voltage-limiting components in parallel with voltage-switching components

**Figure 4 – Examples of components and combinations of components**

SPDs may consist of a simple arrangement of surge protective components, but they may also incorporate indicators, disconnectors, fuses, inductors, capacitors, thermal cutoff and positive temperature coefficient thermistor and other components. SPDs are generally divided into one-port SPDs (see 3.1.21) and two-port SPDs (see 3.1.22)

See Annex P for further information on test application to SPDs with multiple components.

## 6.4 Characteristics of SPDs

### 6.4.1 Service conditions as described in IEC 61643-11

#### 6.4.1.1 Normal service conditions

- The frequency of the supply mains is between 47 Hz and 63 Hz AC.
- The altitude shall not exceed 2 000 m.
- Operating temperature: normal range – 5 °C to +40 °C, extended range – 40 °C to +70 °C.
- Relative humidity for indoor temperature conditions shall be between 5 % and 95 % for normal range and between 5 % and 100 % for the extended range.

The normal range addresses SPDs for indoor use in weather-protected locations having neither temperature nor humidity control. The extended range addresses SPDs for outdoor use in non-weather-protected locations.

NOTE 1 The user determines the location where the SPD is to be applied (outdoor, indoor, etc.) and decides whether the environmental temperature conditions are within the normal or the extended range.

NOTE 2 In general, the temperature range for storage is greater than for operation.

#### 6.4.1.2 Abnormal service conditions

Exposure of the SPD to abnormal service conditions may require special consideration in the design or application of the SPD and should be called to the attention of the manufacturer.

Solar radiation: most SPDs are not exposed to solar radiation. In general, solar radiation is not considered during type testing. Where SPDs are exposed to solar radiation, this should be taken into account and tested accordingly.

NOTE In general, the degree of protection of the SPD enclosure is greater than IP2X. In some instances, other values could be used (for example, for outdoor SPDs).

#### 6.4.2 List of parameters for SPD selection

The following is a non-exclusive list of parameters needed by the user(s) to properly select the SPD(s).

NOTE Some of these parameters are defined for each mode of protection.

- a)  $U_c$  Maximum continuous operating voltage
- b)  $U_T$  Temporary overvoltage test value and/or the type(s) of power system(s) the SPD is designed for
- c)  $I_{imp}$  for class I tests
- d)  $I_n$  Nominal discharge current for class II tests
- e)  $U_{oc}$  for class III tests
- f)  $U_p$  Voltage protection level
- g) Failure behaviour (if declared by the manufacturer)
- h)  $I_{SCCR}$  Short-circuit current rating
- i)  $I_{fi}$  Follow current interrupting rating (except in the case of voltage-limiting SPDs)
- j)  $I_L$  Rated load current (for two-port SPDs or one-port SPDs with separate input and output terminals)
- k) Voltage drop (for two-port SPDs)
- l)  $I_{PE}$  Residual current (for SPDs with a terminal for the protective conductor)
- m)  $I_{trans}$  transition surge current (for Short-circuiting SPD)
- n) Ratings and characteristics for external disconnectors, if required.
- o)  $I_{max}$  maximum discharge current (optional)
- p)  $I_{Total}$  Total discharge current for multimode SPDs (if declared by the manufacturer)
- q) Load-side surge withstand capability for two-port SPDs (if declared by the manufacturer)
- r) Modes of protection (for SPDs with more than one mode of protection)
- s)  $du/dt$  Voltage rate of rise (if declared by the manufacturer)

## 6.5 Additional information on characteristics of SPDs

### 6.5.1 Information related to power-frequency voltages

#### 6.5.1.1 $U_c$ maximum continuous operating voltage, $I_c$ continuous operating current and residual current $I_{PE}$

$U_c$  shall be high enough to minimize any changes in SPD characteristics (ageing, thermal runaway, etc.) under normal conditions.

$I_c$  is the value of current through the SPD when  $U_c$  is applied. The current flowing through the earth (PE) terminal, if any, is called the residual current  $I_{PE}$ . This current  $I_{PE}$  is used in selecting an SPD to avoid unnecessary operation of overcurrent devices or other protective devices (for example RCDs) (see 531.2.1.2 of IEC 60364-5-53:2001).

NOTE  $I_c$  is not measured in IEC 61643-11 and is an optional parameter.

#### 6.5.1.2 Temporary overvoltage characteristics

The temporary overvoltage characteristic of an SPD is generally represented by a few dots (voltage/time) on a curve of voltage (at power frequency) versus time (up to several seconds).

Durations for TOVs considered by IEC 61643-11 are limited to three durations:

- 200 ms for TOV caused by faults on the HV side,
- 5 s caused by faults in the LV system and
- 120 min caused by loss of neutral.

and related test voltage values are called  $U_T$  (temporary overvoltage test value).

The SPD may either withstand the TOV tests without unacceptable changes in its characteristics or fail in a safe manner

SPDs installed according to IEC 60364-5-53 shall withstand the TOV due to fault in the low voltage power system (See TOV values for 5 s duration in Table E.3).

SPDs, for which the manufacturer declares in the installation instructions that they may be installed in TT-systems between neutral and PE upstream of the main RCD, shall also withstand the TOV due to fault in the high voltage power system (See TOV values for 200 ms duration in Table E.3).

The temporary overvoltage test value shall be declared by the manufacturer according to IEC 61643-11.

NOTE Selecting an SPD with both a high temporary overvoltage withstand and a low voltage protection level can be difficult.

The user can select the most suitable SPD by comparing the temporary overvoltage test value of the SPD and the temporary overvoltages ( $U_{TOV}$ ) occurring on the power system. Standardized values used for SPD testing are given in Table E.3.

The manufacturer's data sheet shall provide either  $U_T$  (Temporary overvoltage test value) or the type(s) of power system(s) the SPD is designed for. When the type of system suitable for the SPD is provided, all the necessary tests have been performed at the required  $U_T$  values and thus there is no need to compare  $U_T$  and  $U_{TOV}$  for systems compliant with TOV defined in IEC 60364-4-44. It is now common that the type(s) of power system(s) the SPD is designed for is provided in the data sheet to simplify the task of the user.

## 6.5.2 Information related to surge currents

### 6.5.2.1 General

The factors discussed below relate to the voltage, current and time characteristics of the surge waveform. Different surge waveforms and levels are used for testing depending upon the stresses to which the SPD is expected to be exposed.

Guidance for the selection of the appropriate test class(es) for an SPD is given in the introduction to IEC 61643-11, which states the following:

There are three classes of tests

- The Class I test is intended to simulate partial conducted lightning current impulses. SPDs subjected to Class I test methods are in most cases recommended for locations at points of high exposure, e.g. line entrances to buildings protected by LPS.
- SPDs tested to Class II or III test methods are subjected to impulses of shorter duration.

When selecting an SPD, it is necessary to consider both the test class and the magnitude of the impulse for which it is rated. SPDs tested to Class II or III test methods are in most cases recommended for locations with lesser exposure to direct impulses. Class II tested SPDs may be used at the entrance and sub-distribution boards while class III tested SPDs should be used for locations close to the equipment

NOTE 1 The class II test applies an impressed current to the SPD. The class III test applies a voltage to the SPD, and the resultant current depends on the characteristics of the SPD. The marking on the SPD relates to the generator used and not the actual current that flowed through the SPD during the test.

NOTE 2 The class of test which the SPD has undergone is provided on the nameplate using the format represented by a T in a square: "T1" for class I test, "T2" for class II test and "T3" for class III test, or by writing "test class" in words.

#### 6.5.2.2 $I_n$ : nominal discharge current (8/20)

For SPDs meeting the class II test, this is the current that is used as one test parameter for determining the measured limiting voltage. (The other test is the front-of-wave sparkover voltage test for voltage-switching and combination SPDs.) This current is also used for the operating duty test (applied 15 times).

$I_n$  corresponds to a current that is expected to occur frequently in the field.

The preferred values for  $I_n$  are: 0,05; 0,1; 0,25; 0,5; 1,0; 1,5; 2,0; 2,5; 3,0; 5,0; 10; 15 and 20 kA.

IEC 60364-5-53 requires a minimum of 5 kA at the entrance of the installation.

#### 6.5.2.3 $I_{imp}$ : current impulse discharge (e.g.10/350)

For SPDs meeting Class I tests,  $I_{imp}$  is the test parameter used in the additional operating duty test for Class I tests. They are related to the maximum values of discharge currents, which may occur at the location of the SPD in the system.

NOTE An impulse with a waveshape 8/20 and a magnitude  $I_{imp}$  is used for determining the measured limiting voltage. (The other test being the front-of-wave sparkover voltage test for voltage-switching and combination SPDs) and is used for the operating duty test (applied 15 times).

The preferred values for  $I_{imp}$  ( $Q$ ,  $W/R$ ), according to IEC 61643-11, are given in Table 2.

**Table 2 – Preferred values of  $I_{\text{imp}}$** 

| $I_{\text{imp}}$<br>kA                                                                                 | $Q$<br>C | $W/R$<br>kJ/ $\Omega$ |
|--------------------------------------------------------------------------------------------------------|----------|-----------------------|
| 25                                                                                                     | 12,5     | 156                   |
| 20                                                                                                     | 10       | 100                   |
| 12,5                                                                                                   | 6,25     | 39                    |
| 10                                                                                                     | 5        | 25                    |
| 5                                                                                                      | 2,5      | 6,25                  |
| 2                                                                                                      | 1        | 1                     |
| 1                                                                                                      | 0,5      | 0,25                  |
| NOTE The 10/350 waveshape is a typical example of a waveshape which meets the requirements of Table 2. |          |                       |

**6.5.2.4  $I_{\text{max}}$ : maximum discharge current**

$I_{\text{max}}$  is an optional test parameter. There is no impulse at  $I_{\text{max}}$  in the operating duty test. It is related to the maximum values of discharge currents, which are expected to occur rarely at the location of the SPD in the system

When  $I_{\text{max}}$  is declared by the manufacturer, an additional 8/20 current impulse with a crest value  $I_{\text{max}}$  is applied and the residual voltage shall be measured and recorded. For an SPD based on limiting components the voltage  $U_{\text{max}}$  is equal to or greater than the residual voltage at  $I_{\text{n}}$ .

**6.5.2.5  $I_{\text{trans}}$ : transition surge current (for Short-circuiting SPD)**

$I_{\text{trans}}$  is a 8/20 impulse greater than  $I_{\text{n}}$  and corresponds to a current that causes a short-circuiting SPD to short-circuit.

This current is also used during pre-conditioning for the short-circuit current behaviour test.

The values of  $I_{\text{trans}}$  are selected from among preferred values of  $I_{\text{n}}$ .

**6.5.3 Information related to voltage protection level provided by SPDs****6.5.3.1 Measured limiting voltage****a) Class I and class II tests**

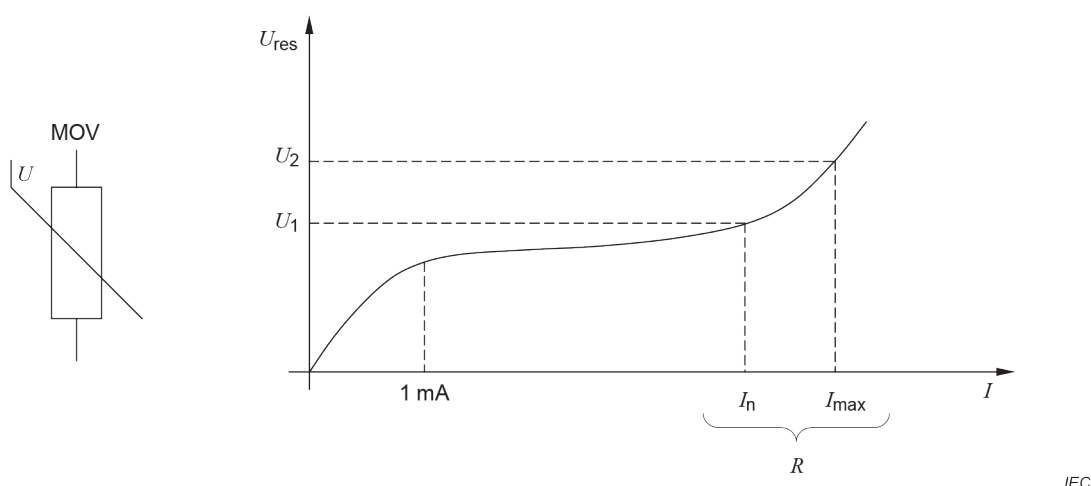
The measured limiting voltage is determined by performing two tests:

- measurement of the residual voltage at various values of current using 8/20 wave;
- measurement of the front-of-wave sparkover voltage using a 1,2/50 wave (for voltage-switching and combination SPDs only).

The measured limiting voltage is the highest voltage value of either

- the residual voltage, for a range of current impulse with a 8/20 front-of-wave and a crest value from 0,1 up to one time the magnitude of  $I_{\text{imp}}$  for class I test; and from 0,1 up to one time  $I_{\text{n}}$  for class II test;
- or the front-of-wave sparkover voltage using a 1,2/50 wave.

For SPDs with voltage-limiting components, for example, Figure 5 shows a typical residual voltage curve ( $U_{\text{res}}$  versus  $I$ ) for a metal oxide varistor (MOV). The curve shows that the residual voltage of the SPD for current at  $I_{\text{max}}$  is greater than the residual voltage at  $I_n$  and when  $I_{\text{max}}$  is declared. If this voltage at  $I_{\text{max}}$  is higher than the voltage protection level and especially if it is higher than the impulse withstand voltage of the equipment to be protected, then there is a risk that the SPD will survive such a stress but the equipment will not be protected. Therefore, the voltage protection level and surge current withstand of the SPD shall be selected accordingly.

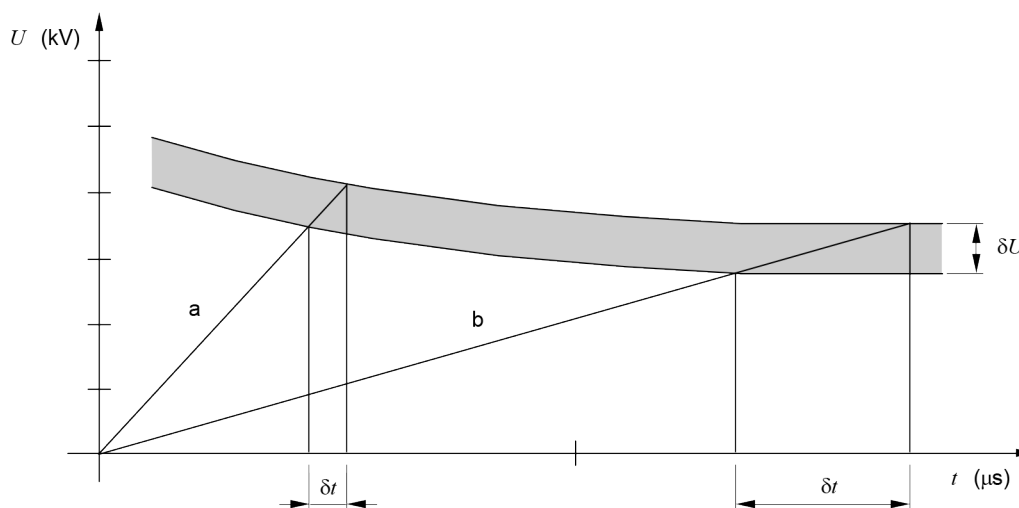


#### Key

- $U_1$  Residual voltage at  $I_n$
- $U_2$  Residual voltage at  $I_{\text{max}}$
- $R$  Range of several kA

**Figure 5 – Typical curve of  $U_{\text{res}}$  versus  $I$  for Metal oxide varistors (MOV)**

For SPDs with voltage-switching components, (for example, a spark gap device, gas discharge tube, etc.) the impulse sparkover voltage is dependent upon the rate of rise ( $du/dt$ ) of the applied transient overvoltage. In most cases, the higher the voltage rate of rise ( $du/dt$ ) of the transient is, the higher the impulse sparkover voltage will be. As the impulse sparkover voltage is a statistical value at a defined  $du/dt$ , there will be a spread in the measured values (see Figure 6).



#### Key

- a Higher rate of rise – 10 kV/μs
- b Lower rate of rise – 1 kV/μs
- $\delta t$  Spread in time of sparkover
- $\delta U$  Spread in voltage of sparkover

**Figure 6 – Typical curve for a spark gap**

#### b) Class III tests

For SPDs tested according to class III, a combination wave generator is used. The maximum value measured during the test with combination wave generator impulses from  $0,1 \times U_{OC}$  up to  $U_{OC}$  is the measured limiting voltage.

#### 6.5.3.2 Voltage protection level $U_p$

$U_p$  is declared by the manufacturer. By definition, it is equal to or greater than, the highest value of the measured limiting voltage. Selection of this value by the manufacturer should allow for manufacturing tolerances. In practice, it is not rare that the protection provided by an SPD is better than the  $U_p$  declared. In a few cases, the manufacturer publishes in its data sheet either a curve  $U$  or  $U_{res}$  vs.  $I$  or a table of  $U$  or  $U_{res}$  for a few values of  $I$ . If the current flowing through the SPD in the installation location is lower than the current used for determining  $U_p$ , it is possible to use this voltage value ( $U$  or  $U_{res}$ ) to achieve a better protection.

The preferred voltage protection levels are: (0,08; 0,09; 0,10; 0,12; 0,15; 0,22; 0,33; 0,4; 0,5; 0,6; 0,7; 0,8; 0,9; 1,0; 1,2; 1,5; 1,8; 2,0; 2,5; 3,0; 4,0; 5,0; 6,0; 8,0; and 10) kV depending on the overvoltage category and the nominal voltage of the protected equipment..

Annex B provides an example of the relationship between  $U_c$  and  $U_p$  for voltage-limiting SPD based on a metal oxide varistors (MOV).

#### 6.5.4 Information related to the SPD's status at its end of life

The end of life behaviour of the SPD is dependent on the magnitude, number of the surge current and voltage and their waveshape, short-circuit capacity of the power system and value of the voltage applied to the SPD at the end of life. This document considers that there are two basic end of life behaviours of an SPD:

- short-circuit (or low impedance)
- open-circuit (or high impedance).

NOTE 1 In the context of this clause, this does not address the concept of SPD classification of IEC 61643-11:2011, Subclause 5.12 (SPD failure behaviour) which is linked to particular technologies of SPDs. However, SPDs classified as per 5.12.2 (short circuiting type SPDs) will (by definition) end up in short circuit when reaching their end of life.

Occasionally, SPDs may enter an indeterminate state for some periods of time. This state involves energy absorption and eventually leads to an open-circuit (itself or in conjunction with a disconnecter or an upstream overcurrent protection device) or a short-circuit condition. For the purpose of this document, it is assumed that this state is temporary and, as such, is not addressed.

NOTE 2 Intermediate state – the parameters have lower (worse) levels than those specified by the manufacturer, but the SPD is not at the end of life.

Changes in the characteristics of the SPD are not necessarily considered an end of life. This topic is addressed in 6.5.7.

#### **6.5.5 $I_{SCCR}$ : Short-circuit current rating and $I_{fi}$ : Follow current interrupt rating**

The SPD, alone or in conjunction with its disconnecter and/or overcurrent protection, is required to withstand the short-circuit current rating  $I_{SCCR}$  declared by the manufacturer. This value is defined and tested in IEC 61643-11 in conjunction with the disconnecter and/or overcurrent protection declared by the manufacturer. The SPD should pass the test without burning, charring or expelling molten material or by creating an opening in the enclosure. It is necessary to ensure that the SPD will not be used at a location where the prospective short-circuit current of the power supply  $I_p$  is greater than its short-circuit withstand. It is also necessary to ensure that an adequate disconnecter and/or overcurrent protection device, as recommended by the manufacturer, is present and in working order. The  $I_{SCCR}$  value is a rated value of the SPD when used in conjunction with its specified disconnecter and/or its overcurrent protection device. This value, as well as the rating and characteristics of the external disconnecter, if required, is provided in the manufacturer documentation, with the product to be delivered.

For an SPD which is not a voltage-limiting type, the follow current is the peak current supplied by the electrical power system and flows through the SPD after a discharge current impulse is applied. The follow current interrupting rating  $I_{fi}$  is the prospective short-circuit current that an SPD is able to interrupt without the operation of a disconnecter. The follow current interrupting rating ( $I_{fi}$ ) should be considered in the selection of an SPD which is not of the voltage-limiting type. This information is given in the manufacturer documentation, with the product to be delivered. According to installation rules, external disconnectors or overcurrent protective devices used for the protection of SPDs shall comply with a relevant IEC standard for overcurrent protective devices, or a local national standard as applicable.

#### **6.5.6 $I_L$ : Rated load current and $\Delta U$ : Voltage drop (for two-port SPDs or one-port SPDs with separate input and output terminals)**

For a two-port SPD or a one-port SPD connected in line with the supply, it is necessary to ensure that the equipment load current does not exceed its rated load current  $I_L$ .

NOTE It is also necessary to consider the type of load. For example, some loads may have in-rush currents which can be as high as three times the RMS value. These peak currents can produce additional heating within series elements of two-port SPDs.

It is also necessary to check that the installation of a two-port SPD does not result in an unacceptable voltage drop for the equipment located downstream. This is characterized by the optional parameter voltage drop  $\Delta U$ .

### 6.5.7 Information related to change of characteristics of SPDs

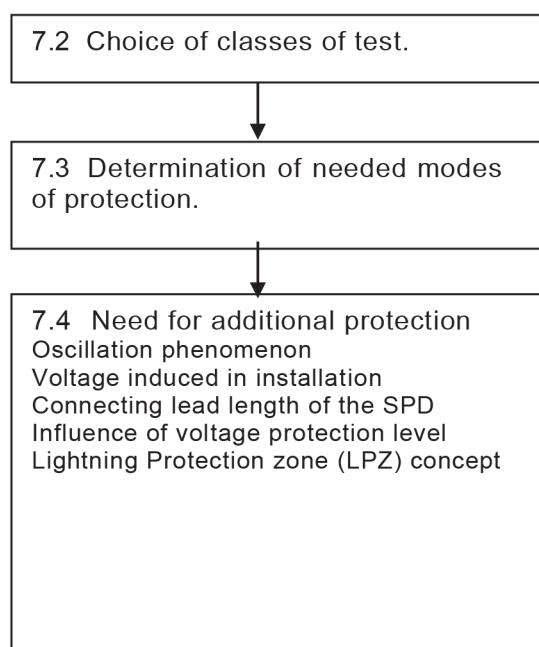
Certain SPDs may enter an intermediate state when subjected to a higher stress than defined in the standard tests. In that event, some of their characteristics may change from the designed values, for example:  $U_p$ ,  $I_n$ ,  $I_c$ , etc. In particular, this may occur for SPDs having active parts in parallel where one of these active parts may be disconnected after a surge. In these instances, the user may not be aware of these changes in characteristics. Any such intermediate state should be avoided in the design of an SPD, unless there is a clear indication of the state when it occurs.

## 7 Application of SPDs in low-voltage power systems

### 7.1 General

When a risk analysis is performed (see Clause 4) to define the need for an SPD and when the possible stresses in the system are known (identified in Clause 5), the characteristics of the SPD (listed in Clause 6) to protect equipment can be specified using the procedures shown in Figure 7.

SPDs in a power-distribution system may be selected using the principles listed in Subclause 7.1 and their characteristics selected in accordance with the procedures described in Subclause 7.2.

**SPD selection**

Class I, II and III tested SPDs may be used at the entrance and class II and III tested SPDs may be used for locations close to the equipment

For protection against effects of lightning and against switching overvoltages, class II tested SPDs shall be used.

Where the structure is equipped with a LPS class I tested SPDs shall be used.

Where the structure is not equipped with a LPS and where the occurrence of direct lightning strike to the overhead lines between the last pole and the entrance of the installation is to be taken into consideration, class I tested SPDs at or near the origin of the electrical installation may be also selected

SPDs shall be installed as close as possible to the origin of the installation and possibly others, if required, close to equipment to be protected.

All these SPDs should be coordinated (see 7.5.7) Oscillation need to be considered as SPD have generally limited protective distance.

Generally, voltage induced in installation can be ignored (see 7.4.3).

Connecting conductors for SPDs shall be as short as possible.

When the Lightning Protection Zone (LPZ) concept is used, SPDs should be installed at the zone boundaries.

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**Figure 7 – Flowchart for SPD application**

Examples of application of SPDs are provided in Annex G.

Examples of practical installation of SPDs are provided in Annex L.

## 7.2 Consideration regarding location of the SPD depending on the classes of test

At the point of entry, depending on the incoming stress, SPDs tested according to class I or class II may be used depending on the result of the risk analysis (see Clause 4). The installation of SPDs as close as possible to the origin of the installation reduces surge currents flowing through downstream installation device (e.g. meters, terminals, protective devices, switches, etc.). Consideration of the electrical stress involved in the surge is a key factor in choosing the right SPD. In case of switching overvoltages produced within the installation or overvoltages on other incoming services such as telephone lines, internet connections or overvoltages on other services feeding other structures, SPDs should be located as close as possible to the origin of such threats. When an LPS is present, additional information can be found in the IEC 62305 series of documents. SPDs tested to class II and class III tests are also suited for locations close to the protected equipment.

## 7.3 SPD modes of protection and installation

When the equipment to be protected has a sufficient overvoltage withstand or is located close to the main distribution board, one SPD may be sufficient and should be installed as close as possible to the entrance of the installation. The SPDs should have sufficient surge withstand capability for this location. Figure L.1 to Figure L.5 show typical connections of SPDs located at the entrance of the installation for different types of systems. Figure L.5 presents the particular case of a TN C-S system.

SPDs at or near the entrance of the installation shall be connected at least between the following points:

- a) if there is a direct connection between the neutral conductor and PE at or near the origin of the installation or, if there is no neutral conductor, between each line conductor and either the main earthing terminal or the main protective conductor, whichever route is shorter; or

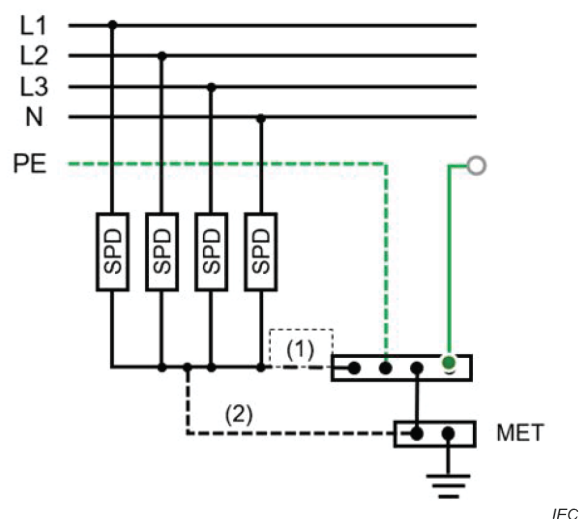
NOTE 1 The impedance connecting the neutral to PE in IT systems is not considered as a connection.

- b) if there is no direct connection between the neutral conductor and PE at or near the entrance of the installation either:

between each line conductor and either the main earthing terminal or the main protective conductor, and between the neutral conductor and either the main earthing terminal or the protective conductor, whichever route is shorter – Connection Type 1 (CT 1), see Figure 8  
or

between each line conductor and the neutral conductor and between the neutral conductor and either the main earthing terminal or the protective conductor, whichever route is shorter – Connection Type 2 (CT 2), see Figure 9.

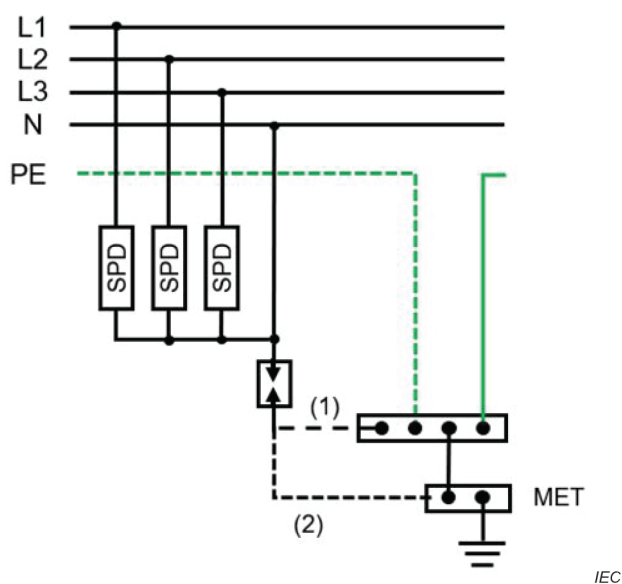
NOTE 2 If a line conductor is earthed, it is considered to be equivalent to a neutral conductor for the application of this subclause.

**Key**

MET: main equipotential terminal

NOTE Earthing connection of surge protective devices, either (1) and/or (2) should be the shortest route; National regulations may make the use of 1, 2 or both mandatory

**Figure 8 – Example of connection Type 1 (CT1)**

**Key**

MET: main equipotential terminal

NOTE Earthing connection of surge protective devices, either (1) and/or (2) should be the shortest route; National regulations may make the use of 1, 2 or both mandatory.

**Figure 9 – Example of connection Type 2 (CT2)**

Table 3 indicates the modes of protection that may be required for various LV systems.

NOTE 3 If more than one SPD is connected on the same conductor, coordination between them can be considered (see 7.5.7).

NOTE 4 The number of modes of protection depends on the type of equipment to be protected (for example, if the equipment is not connected to earth, line- or neutral-to-earth protection may not be necessary), the withstand of the equipment according to each mode of protection, the electrical system structure and earthing and the characteristics of the incoming surge. For example, protection between phase/neutral and PE conductor or between phase and neutral are in most cases sufficient, and protection between phase and phase is not in most cases used.

NOTE 5 Installation of SPDs in front of the electricity supplier's meter is carried out with the agreement of the electricity supplier.

**Table 3 – modes of protection for various LV systems**

| SPDs connected between:                                                                                                                                                                                                                                                                     | System configuration at the installation point of SPD |        |      |                           |        |                             |      |                                |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|--------|------|---------------------------|--------|-----------------------------|------|--------------------------------|
|                                                                                                                                                                                                                                                                                             | TT                                                    |        | TN-C | TN-S                      |        | IT with distributed neutral |      | IT without distributed neutral |
|                                                                                                                                                                                                                                                                                             | Installation according to                             |        |      | Installation according to |        | Installation according to   |      |                                |
|                                                                                                                                                                                                                                                                                             | CT 1 <sup>c</sup>                                     | CT 2   |      | CT 1                      | CT 2   | CT 1                        | CT 2 |                                |
| Each line conductor and neutral conductor                                                                                                                                                                                                                                                   | +                                                     | •      | NA   | +                         | •      | +                           | •    | NA                             |
| Each line conductor and PE conductor                                                                                                                                                                                                                                                        | •                                                     | NA     | NA   | •                         | NA     | •                           | NA   | •                              |
| Neutral conductor and PE conductor                                                                                                                                                                                                                                                          | •                                                     | • b, d | NA   | • a                       | • a, b | •                           | • b  | NA                             |
| Each line conductor and PEN conductor                                                                                                                                                                                                                                                       | NA                                                    | NA     | •    | NA                        | NA     | NA                          | NA   | NA                             |
| Line conductors                                                                                                                                                                                                                                                                             | +                                                     | +      | +    | +                         | +      | +                           | +    | +                              |
| <ul style="list-style-type: none"> <li>• required</li> </ul> NA : not applicable<br>+ : optional, in addition to required SPDs<br>CT: connection type                                                                                                                                       |                                                       |        |      |                           |        |                             |      |                                |
| <sup>a</sup> In TN-S or TN-C-S systems, the SPD between neutral and PE may be omitted if the distance between the separation point of PE to N and the location of the installed SPDs is less than 0,5 m or if the separation point and the SPDs are located in the same distribution board. |                                                       |        |      |                           |        |                             |      |                                |
| <sup>b</sup> When CT2 is used the withstand voltage of equipment $U_w$ should be compared to the protective level obtained as the result of two SPDs in series (L-N and N-PE). This may give a different result than the simple addition of the $U_p$ of both SPDs.                         |                                                       |        |      |                           |        |                             |      |                                |
| <sup>c</sup> Only downstream of an RCD.                                                                                                                                                                                                                                                     |                                                       |        |      |                           |        |                             |      |                                |
| <sup>d</sup> To be used upstream the main RCD, SPD shall withstand the TOV, see 6.5.1.2.                                                                                                                                                                                                    |                                                       |        |      |                           |        |                             |      |                                |

For further information, see Annex J.

## 7.4 Need for additional protection

### 7.4.1 General

When SPDs are needed, a first SPD should be installed near the entrance of the installation. The purpose of this SPD is to mitigate the effects and reduce the impact of surges that originate from outside the facility. In some conditions one SPD is sufficient, for example, if the stresses at the entrance to the structure are low or if the equipment has a high surge withstand and/or the SPD has a low  $U_p$ .

Additional protection in distribution boards or close to the equipment (for example, in the socket outlet) to be protected may be necessary, for example where:

- The distance between SPD and the equipment to be protected is too long;