

# INTERNATIONAL STANDARD

## NORME INTERNATIONALE



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

**Parafoudres basse tension –  
Partie 11: Parafoudres connectés aux systèmes basse tension – Exigences et  
méthodes d'essai**



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## INTERNATIONAL ELECTROTECHNICAL COMMISSION

**LOW-VOLTAGE SURGE PROTECTIVE DEVICES –****Part 11: Surge protective devices connected  
to low-voltage power systems –  
Requirements and test methods**

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International Standard IEC 61643-11 has been prepared by subcommittee 37A: Low-voltage surge protective devices, of IEC technical committee 37: Surge arresters.

This first edition of IEC 61643-11 cancels and replaces the second edition of IEC 61643-1 published in 2005. This edition constitutes a technical revision.

The main changes with respect of the second edition of IEC 61643-1 are the complete restructuring and improvement of the test procedures and test sequences.

The text of this standard is based on the following documents:

|              |                  |
|--------------|------------------|
| FDIS         | Report on voting |
| 37A/229/FDIS | 37A/232/RVD      |

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

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

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

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

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## INTRODUCTION

This part of IEC 61643 addresses safety and performance tests for surge protective devices (SPDs).

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 generally recommended for locations at points of high exposure, e.g., line entrances to buildings protected by lightning protection systems.

SPDs tested to Class II or III test methods are subjected to impulses of shorter duration.

SPDs are tested on a “black box” basis as far as possible.

IEC 61643-12 addresses the selection and application principles of SPDs in practical situations.

## LOW-VOLTAGE SURGE PROTECTIVE DEVICES –

### Part 11: Surge protective devices connected to low-voltage power systems – Requirements and test methods

#### 1 Scope

This part of IEC 61643 is applicable to devices for surge protection against indirect and direct effects of lightning or other transient overvoltages. These devices are packaged to be connected to 50/60 Hz a.c. power circuits, and equipment rated up to 1 000 V r.m.s. Performance characteristics, standard methods for testing and ratings are established. These devices contain at least one nonlinear component and are intended to limit surge voltages and divert surge currents.

#### 2 Normative references

The following referenced documents are indispensable for the application 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 60060-1:1989, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60112, *Method for the determination of the proof and the comparative tracking indices of solid insulating materials*

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 60695-2-11:2000, *Fire hazard testing – Part 2-11: Glowing/hot-wire based test methods – Glow-wire flammability test method for end-products*

IEC 61000 (all parts), *Electromagnetic compatibility (EMC)*

IEC 61180-1, *High-voltage test techniques for low voltage equipment – Part 1: Definitions, test and procedure requirements*

#### 3 Terms, definitions and abbreviations

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

### 3.1 Terms and definitions

#### 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 An SPD is a complete assembly, having appropriate connecting means.

#### 3.1.2

##### **one-port SPD**

SPD having no intended series impedance

NOTE A one port SPD may have separate input and output connections.

#### 3.1.3

##### **two-port SPD**

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

#### 3.1.4

##### **voltage switching type 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 Common examples of components used in voltage switching type SPDs are spark gaps, gas tubes and thyristors. These are sometimes called "crowbar type" components.

#### 3.1.5

##### **voltage limiting type SPD**

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

NOTE Common examples of components used in voltage limiting type SPDs are varistors and avalanche breakdown diodes. These are sometimes called "clamping type" components.

#### 3.1.6

##### **combination type SPD**

SPD that incorporates both, voltage switching components and voltage limiting components. The SPD may exhibit voltage switching, limiting or both

#### 3.1.7

##### **short-circuiting type 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  $I_n$

#### 3.1.8

##### **mode of protection of an SPD**

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

#### 3.1.9

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

$I_n$

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

**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

**3.1.11****maximum continuous operating voltage** $U_C$ 

maximum r.m.s. voltage, which may be continuously applied to the SPD's mode of protection

NOTE The  $U_C$  value covered by this standard may exceed 1 000 V.

**3.1.12****follow current** $I_f$ 

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

**3.1.13****rated load current** $I_L$ 

maximum continuous rated r.m.s. current that can be supplied to a resistive load connected to the protected output of an SPD

**3.1.14****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 The voltage protection level is given by the manufacturer and may not be exceeded 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 corresponding to  $I_n$  and/or  $I_{\text{imp}}$  respectively for test classes II and/or I;
- the measured limiting voltage at  $U_{OC}$ , determined for the combination wave for test class III.

**3.1.15****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

**3.1.16****residual voltage** $U_{\text{res}}$ 

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

**3.1.17****temporary overvoltage test value** $U_T$ 

test voltage applied to the SPD for a specific duration  $t_T$ , to simulate the stress under TOV conditions

**3.1.18****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

**3.1.19****voltage rate-of-rise of a two-port SPD**

rate of change of voltage with time measured at the output terminals of a two port SPD under specified test conditions

**3.1.20****1,2/50 voltage impulse**

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

NOTE The Clause 6 of IEC 60060-1 (1989) defines the voltage impulse definitions of front time, time to half-value and waveshape tolerance.

**3.1.21****8/20 current impulse**

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

NOTE The Clause 8 of IEC 60060-1 (1989) defines the current impulse definitions of front time, time to half-value and waveshape tolerance.

**3.1.22****combination wave**

a 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 The voltage amplitude, current amplitude and waveform that is delivered to the SPD are determined by the combination wave generator (CWG) impedance  $Z_f$  and the impedance of the DUT.

**3.1.23****open circuit voltage**

$U_{OC}$

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

**3.1.24****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 When the SPD is connected to the combination wave generator, the current that flows through the device is generally less than  $I_{CW}$ .

**3.1.25****thermal stability**

SPD is thermally stable 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

**3.1.26****degradation (of performance)**

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

**3.1.27****short-circuit current rating**

$I_{SCCR}$

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

### 3.1.28

#### **SPD disconnecter (disconnecter)**

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

NOTE 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.

### 3.1.29

#### **degree of protection 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

### 3.1.30

#### **type test**

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

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

### 3.1.31

#### **routine test**

test made on each SPD or on parts and materials as required to ensure that the product meets the design specifications

[IEC 60050-151:2001, 151-16-17, modified]

### 3.1.32

#### **acceptance tests**

contractual test to prove to the customer that the item meets certain conditions of its specification

[IEC 60050-151:2001, 151-16-23]

### 3.1.33

#### **decoupling network**

an electrical circuit intended to prevent surge energy from being propagated to the power network during energized testing of SPDs

NOTE This electrical circuit is sometimes called a "back filter".

### 3.1.34

#### **Impulse test classification**

##### **3.1.34.1**

##### **class I tests**

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

##### **3.1.34.2**

##### **class II tests**

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

##### **3.1.34.3**

##### **class III tests**

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

**3.1.35****residual current device****RCD**

switching device or associated devices intended to cause the opening of the power circuit when the residual or unbalance current attains a given value under specified conditions

**3.1.36****sparkover voltage of a voltage switching SPD****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

**3.1.37****specific energy for class I test** **$W/R$** 

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

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

**3.1.38****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 This prospective symmetrical current is expressed by its rms value.

**3.1.39****follow current interrupt rating** **$I_{fi}$** 

prospective short-circuit current that an SPD is able to interrupt without operation of a disconnector

**3.1.40****residual current** **$I_{PE}$** 

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

**3.1.41****status indicator**

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

NOTE Such indicators may be local with visual and/or audible alarms and/or may have remote signalling and/or output contact capability.

**3.1.42****output contact**

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

**3.1.43****multipole SPD**

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

### 3.1.44

#### total discharge current

$I_{\text{Total}}$

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

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

NOTE 2  $I_{\text{Total}}$  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.

### 3.1.45

#### reference test voltage

$U_{\text{REF}}$

r.m.s. 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

NOTE The reference test voltage is selected from Annex A based on the information given by the manufacturer according to 7.1.1 b8).

### 3.1.46

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

$I_{\text{trans}}$

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

### 3.1.47

#### Voltage for clearance determination

$U_{\text{max}}$

highest measured voltage during surge applications according 8.3.3 for clearance determination

### 3.1.48

#### maximum discharge current

$I_{\text{max}}$

crest value of a current through the SPD having an 8/20 waveshape and magnitude according to the manufacturers specification.  $I_{\text{max}}$  is equal to or greater than  $I_n$

## 3.2 Abbreviations

The Table 1 below provides the list of abbreviations used in this standard.

**Table 1 – List of Abbreviations**

| Abbreviation                            | Description                                                   | Definition/clause |
|-----------------------------------------|---------------------------------------------------------------|-------------------|
| <b>General abbreviations</b>            |                                                               |                   |
| ABD                                     | avalanche breakdown device                                    | 7.2.5.2           |
| CWG                                     | combination wave generator                                    | 3.1.22            |
| RCD                                     | residual current device                                       | 3.1.35            |
| DUT                                     | device under test                                             | General           |
| IP                                      | degree of protection of enclosure                             | 3.1.29            |
| TOV                                     | temporary overvoltage                                         | General           |
| SPD                                     | surge protective device                                       | 3.1.1             |
| $k$                                     | trip current factor for overload behaviour                    | Table 20          |
| $Z_f$                                   | fictive impedance (of combination wave generator)             | 8.1.4 c)          |
| $W/R$                                   | specific energy for class I test                              | 3.1.37            |
| $T1$ , $T2$ , and/or $T3$               | product marking for test classes I, II and/or III             | 7.1.1             |
| $t_T$                                   | TOV application time for testing                              | 3.1.17            |
| <b>Abbreviations related to voltage</b> |                                                               |                   |
| $U_C$                                   | maximum continuous operating voltage                          | 3.1.11            |
| $U_{REF}$                               | Reference test voltage                                        | 3.1.45            |
| $U_{OC}$                                | open circuit voltage of the combination wave generator        | 3.1.22, 3.1.23    |
| $U_p$                                   | voltage protection level                                      | 3.1.14            |
| $U_{res}$                               | residual voltage                                              | 3.1.16            |
| $U_{max}$                               | voltage for clearance determination                           | 3.1.47            |
| $U_T$                                   | temporary overvoltage test value                              | 3.1.17            |
| <b>Abbreviations related to current</b> |                                                               |                   |
| $I_{imp}$                               | impulse discharge current for class I test                    | 3.1.10            |
| $I_{max}$                               | maximum discharge current                                     | 3.1.48            |
| $I_n$                                   | nominal discharge current for class II test                   | 3.1.9             |
| $I_f$                                   | follow current                                                | 3.1.12            |
| $I_{fi}$                                | follow current interrupt rating                               | 3.1.39            |
| $I_L$                                   | rated load current                                            | 3.1.13            |
| $I_{CW}$                                | short-circuit current of the combination wave generator       | 3.1.24            |
| $I_{SCCR}$                              | short-circuit current rating                                  | 3.1.27            |
| $I_P$                                   | prospective short-circuit current of the power supply         | 3.1.38            |
| $I_{PE}$                                | residual current at $U_{REF}$                                 | 3.1.40            |
| $I_{Total}$                             | total discharge current for multipole SPD                     | 3.1.44            |
| $I_{trans}$                             | transition surge current rating for short-circuiting type SPD | 3.1.46            |

## 4 Service conditions

### 4.1 Frequency

Frequency range is from 47 Hz to 63 Hz a.c.

### 4.2 Voltage

The voltage applied continuously between the terminals of the surge protective device (SPD) must not exceed its maximum continuous operating voltage  $U_C$ .

### 4.3 Air pressure and altitude

Air pressure is 80 kPa to 106 kPa. These values represent an altitude of +2 000 m to -500 m, respectively.

### 4.4 Temperatures

- normal range: –5 °C to +40 °C

NOTE This range addresses SPDs for indoor use in weather-protected locations having neither temperature nor humidity control and corresponds to the characteristics of external influences code AB4 in IEC 60364-5-51.

- extended range: –40 °C to +70 °C

NOTE This range addresses SPDs for outdoor use in non weather protected locations.

### 4.5 Humidity

- normal range: 5 % to 95 %

NOTE This range addresses SPDs for indoor use in weather-protected locations having neither temperature nor humidity control and corresponds to the characteristics of external influences code AB4 in IEC 60364-5-51.

- extended range: 5 % to 100 %

NOTE This range addresses SPDs for outdoor use in non weather protected locations.

## 5 Classification

The manufacture shall classify the SPDs in accordance with the following parameters.

### 5.1 Number of ports

#### 5.1.1 One

#### 5.1.2 Two

### 5.2 SPD design

#### 5.2.1 Voltage switching

#### 5.2.2 Voltage limiting

#### 5.2.3 Combination

### 5.3 Class I, II and III tests

Information required for class I, class II and class III tests is given in Table 2.

**Table 2 – Class I, II and III tests**

| Tests     | Required information | Test procedures<br>(see subclauses) |
|-----------|----------------------|-------------------------------------|
| Class I   | $I_{\text{imp}}$     | 8.1.1; 8.1.2; 8.1.3                 |
| Class II  | $I_n$                | 8.1.2; 8.1.3                        |
| Class III | $U_{\text{oc}}$      | 8.1.4; 8.1.4.1                      |

**5.4 Location****5.4.1 Indoor**

SPDs intended for use in enclosures and/or inside buildings or shelters.

SPDs installed in outdoor enclosures or shelters are considered for indoor use.

**5.4.2 Outdoor**

SPDs intended for use without enclosures and outside of buildings or shelters (e.g. on low voltage overhead lines).

**5.5 Accessibility****5.5.1 Accessible**

An SPD which can be fully or partly touched by an unskilled person, without the use of a tool to open any covers or enclosures, once installed.

**5.5.2 Inaccessible**

An SPD which cannot be touched by an unskilled person either due to being mounted out of reach (e.g. mounted on overhead lines) or due to being located within enclosures which can only be opened by using a tool, once installed.

**5.6 Mounting method****5.6.1 Fixed****5.6.2 Portable****5.7 Disconnectors (including overcurrent protection)****5.7.1 Location****5.7.1.1 Internal****5.7.1.2 External****5.7.1.3 Both (internal and external)****5.7.2 Protection functions****5.7.2.1 Thermal****5.7.2.2 Leakage current****5.7.2.3 Overcurrent****5.8 Degree of protection provided by enclosures**

According to IP code of IEC 60529.

## 5.9 Temperature and humidity range

### 5.9.1 Normal

### 5.9.2 Extended

## 5.10 Power system

### 5.10.1 AC between 47 Hz and 63 Hz

### 5.10.2 AC other than the range of 47 Hz to 63 Hz

This may require additional and/or modified test procedures.

## 5.11 Multipole SPD

## 5.12 SPD failure behaviour

### 5.12.1 open circuit (standard type SPD)

### 5.12.2 short-circuit (short-circuiting type SPD)

## 6 Preferred values for SPD

NOTE Preferred values means values which are often used in practice. Depending on real conditions lower and in some cases higher values may be needed.

### 6.1 Preferred values of impulse discharge current $I_{\text{imp}}$ for class I tests

|                  |       |      |       |     |       |     |              |
|------------------|-------|------|-------|-----|-------|-----|--------------|
| $I_{\text{imp}}$ | 1;    | 2;   | 5;    | 10; | 12,5; | 20  | and 25 kA    |
| Q                | 0,5;  | 1;   | 2,5;  | 5;  | 6,25; | 10  | and 12,5 As  |
| W/R              | 0,25; | 1,0; | 6,25; | 25; | 39;   | 100 | and 156 kJ/Ω |

### 6.2 Preferred values of nominal discharge current for class II tests $I_n$

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

### 6.3 Preferred values of open-circuit voltage for class III tests $U_{\text{oc}}$

0,1; 0,2; 0,5; 1; 2; 3; 4; 5; 6; 10 and 20 kV

### 6.4 Preferred values of voltage protection level $U_p$

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

### 6.5 Preferred values of r.m.s. maximum continuous operating voltage $U_c$

45; 52; 63; 75; 85; 95; 110; 130; 150; 175; 220; 230; 240;  
255; 260; 275; 280; 320; 335; 350; 385; 400; 420; 440; 460; 510  
530; 600; 635; 660; 690; 800; 900; 1 000; 1 500; 1 800 and 2 000 V

## 7 Requirements

### 7.1 General requirements

#### 7.1.1 Identification

The following information shall be provided by the manufacturer.

**Markings which are mandatory on the body, or permanently attached to the body, of the SPD:**

- a1) Manufacturer's name or trademark and model number
- a2) Maximum continuous operating voltage  $U_c$  (one value for each mode of protection)
- a3) Type of current: a.c. or “~” and/or frequency
- a4) Test classification and discharge parameters shall be printed next to each other for each mode of protection declared by the manufacturer:

For test class I:

either “test class I” and “ $I_{imp}$ ” and the value in kA,  
and/or “T1” (T1 in a square) and “ $I_{imp}$ ” and the value in kA

For test class II:

either “test class II” and “ $I_n$ ” and the value in kA,  
and/or “T2” (T2 in a square) and “ $I_n$ ” and the value in kA

For test class III:

either “test class III” and “ $U_{oc}$ ” and the value in kV,  
and/or “T3” (T3 in a square) and “ $U_{oc}$ ” and the value in kV.

- a5) Voltage protection level  $U_p$  (one value for each mode of protection)
- a6) Degree of protection provided by the enclosure (IP code) if >IP20
- a7) Identification of terminals or leads (if not otherwise identified on the devices)
- a8) Rated load current  $I_L$  for two port SPDs and for one port SPDs with separate input and output terminals.

Where space does not allow all the above markings to be placed, the manufacturer's name or trademark and model number is sufficient on the SPD; other remaining required markings shall appear on the installation instruction.

An SPD may be classified according to more than one test class (e.g. test class I (T1) and test class II (T2)). In this case, the tests required for all declared test classes shall be performed. If in such case the manufacturer declares only one protection level, the highest protection level shall appear in the marking.

**Information which shall be provided with the products to be delivered:**

- b1) Location (See 5.4)
- b2) Number of ports
- b3) Method of mounting
- b4) Short-circuit current rating  $I_{SCCR}$  (exemptions see 7.2.5.3)
- b5) Ratings and characteristics for external disconnectors, if required.
- b6) Indication of disconnector operation (if any)
- b7) Orientation for normal installation, if significant
- b8) Installation instructions
  - type of LV systems (TN-system, TT-system, IT-system)

- intended connection (line to neutral, line to ground, neutral to ground, line to line)
- nominal a.c. system voltages and maximum allowed voltage regulation for which the SPD is designed, mechanical dimensions, lead lengths, etc.
- b9) Temperature and humidity range (see 4.4 and 4.5)
- b10) Follow current interrupt rating  $I_{fi}$  (except in the case of voltage-limiting SPDs)
- b11) Residual current  $I_{PE}$
- b12) Transition surge current rating for short-circuiting type SPD  $I_{trans}$
- b13) The minimum distance from any earthed conductive surface at which the SPD can be installed
- b14)  $I_{MAX}$ , (optional).

**Information which shall be available in a product datasheet:**

- c1) Temporary overvoltage rating  $U_T$  and/or the type(s) of power system(s) the SPD is designed for according to Annex B and corresponding connection details
- c2) Total discharge current  $I_{Total}$  for multipole SPDs (if declared by the manufacturer) and the corresponding test class
- c3) Voltage drop for two port SPDs
- c4) Load-side surge withstand capability for two-port SPDs (if declared by the manufacturer)
- c5) Information about replaceable parts (indicators, fuses, etc. if applicable)
- c6) Voltage rate of rise  $du/dt$  (if declared by the manufacturer)
- c7) Current factor  $k$ , if different from Table 20
- c8) Modes of protection (for SPDs with more than one mode of protection)

**Information which shall be provided by the manufacturer for type testing:**

- d1) Presence of switching component(s) (see Annex C)
- d2) Follow current to be expected during preconditioning test ( $\leq 500$  A or  $> 500$  A - see Annex C)
- d3) If the status indication circuitry does not use certified components operated within their ratings, the manufacturer shall provide the appropriate testing standards for the specific component to allow it to be tested.
- d4) Isolation and dielectric withstand of separate isolated circuits
- d5) prospective short-circuit current for conditioning according 8.3.5.3.2

Compliance is checked by visual inspection.

### 7.1.2 Marking

Markings on the device shall be indelible and legible and shall not be placed on screws or removable parts.

NOTE A plug-in SPD module is not considered a removable part.

Compliance is checked by the test in accordance with 8.2.

## 7.2 Electrical requirements

### 7.2.1 Protection against direct contact

These requirements are valid for accessible SPDs where the maximum continuous operating voltage  $U_c$  is above 50 V r.m.s.

For protection against direct contact (inaccessibility of live parts), SPDs shall be designed in such a way that live parts cannot be touched when the SPD is installed for the intended use.

SPDs, except SPDs classified for mounting out-of-reach-only, shall be so designed that, when they are wired and mounted as for normal use, live parts are not accessible, even after removal of parts which can be removed without the use of a tool.

The connection between the earthing terminals and all accessible parts connected thereto shall be of low resistance.

Compliance is checked by the tests according IEC 60529 and according 8.3.1.

### **7.2.2 Residual current $I_{PE}$**

For all SPDs with a terminal for the protective conductor, the residual current  $I_{PE}$  shall be measured when all SPD terminals are connected to a power supply at the reference test voltage ( $U_{REF}$ ) according to the manufacturer's instructions.

Compliance is checked by the test according 8.3.2

### **7.2.3 Voltage protection level $U_p$**

The measured limiting voltage of the SPDs shall not exceed the voltage protection level that is specified by the manufacturer.

Compliance is checked by the test in accordance with 8.3.3.

### **7.2.4 Operating duty**

The SPD shall be capable of withstanding specified discharge currents during application of the maximum continuous operating voltage  $U_c$  without unacceptable changes in its characteristics.

Compliance is checked by the test in accordance with 8.3.4.

### **7.2.5 Disconnectors and status indicators**

#### **7.2.5.1 Disconnectors**

The SPD shall have disconnectors (which can be either internal, external or both), except SPDs for connection N-PE in TN and/or TT systems only. Their operation shall be indicated by a corresponding status indicator.

The required behaviour of the disconnectors during and after various type tests is given in Table 3.

Table 3 provides information on the inclusion of disconnectors during the various type tests. The required behaviour of disconnectors during and after various type tests is given by pass criteria **F**, **G**, **H** and **J** of Table 4, and is checked by the tests in accordance with 8.3.5.

#### **7.2.5.2 Thermal protection**

SPDs shall be protected against overheating due to degradation or overstress.

This test is not performed on SPDs containing only voltage switching components and/or ABD devices.

Compliance is checked by the test in accordance with 8.3.5.2.

### 7.2.5.3 Short-circuit current behaviour

An SPD shall fail without causing a hazardous condition or withstand the prospective short-circuit currents of the power system that may occur during an SPD failure.

Compliance is checked by the test in accordance with 8.3.5.3, 8.3.5.3.1 and 8.3.5.3.2.

The test according 8.3.5.3.1 is only performed if the declared follow current interrupt rating  $I_{fi}$  is smaller than the test current.

These tests are not performed on SPDs classified for outdoor use and for mounting out of reach and for SPDs for connection N-PE in TN and/or TT systems only.

### 7.2.5.4 Status indicators

The manufacturer shall provide information about the function of the indicator and the actions to be taken after change of status indication.

A status indicator may be composed of two parts (one of which is not replaced on replacement of the SPD), linked by a coupling mechanism which can be mechanical, optical, audio, electromagnetic, etc. The part of the status indicator which is not replaced shall be capable of operating at least 50 times.

NOTE The action of the coupling mechanism which operates the non-replaced part of the status indicator may be simulated by means other than operation of the section within the replaced part of the SPD, e.g. a separate electromagnet or a spring.

Where there is an appropriate standard for the type of indication used, this shall be met by the non-replaced part of the status indicator, with the exception that the indicator need only be tested for 50 operations.

### 7.2.6 Insulation resistance

The insulation resistance of the SPD shall be sufficient with respect to leakage currents and protection against direct contact.

Compliance is checked by the test in accordance with 8.3.6.

### 7.2.7 Dielectric withstand

The dielectric withstand of the SPD shall be sufficient with respect to insulation breakdown and protection against direct contact.

Compliance is checked by the test in accordance with 8.3.7.

### 7.2.8 Behaviour under temporary overvoltages

An SPD shall pass the TOV-tests according 8.3.8.1 and 8.3.8.2 and shall fulfil the pass criteria according to the relevant tables in Annex B and according 8.3.8.1 and 8.3.8.2.

NOTE 1 The tests given in 8.3.8.1 and 8.3.8.2 do not take into account the possibility of a surge occurring simultaneously with a TOV event.

SPD shall withstand the overvoltages caused by faults or disturbances in the high voltage system or fail in manner not creating a hazard.

SPDs, for which the manufacturer declares in his installation instructions that they may be installed in TT-systems between neutral and PE upstream the main RCD, shall pass the TOV withstand mode criteria given 8.3.8.2.

NOTE 2 This covers the application described in 534.2.3.3 of IEC 60364-5-53.

#### **7.2.8.1 TOVs caused by faults or disturbances in the low voltage system**

For SPDs with a  $U_C$  greater than or equal to  $U_T$  there is no need to perform this test.

This test shall be performed in accordance with 8.3.8.1.

#### **7.2.8.2 TOVs caused by faults in the high (medium) voltage system**

For SPDs with a  $U_C$  greater than or equal to  $U_T$  there is no need to perform this test.

Compliance is checked by the test in accordance with 8.3.8.2.

### **7.3 Mechanical requirements**

#### **7.3.1 Mounting**

SPDs shall be provided with appropriate means for mounting that will ensure mechanical stability.

Mechanical coding/interlock shall be provided to prevent incorrect combinations of plug-in SPD modules and sockets.

Compliance is checked by visual inspection.

#### **7.3.2 Screws, current carrying parts and connections**

Compliance is accordance with 8.4.1 and checked by inspection and trial mounting.

#### **7.3.3 External connections**

Electrical connections shall be possible using one of the following means:

- screw terminals and bolted connections;
- screwless terminals;
- insulation piercing connections;
- flat quick connect terminations;
- flying leads;
- other equally effective means;

or

- standardised plugs and/or sockets.

The following requirements do not apply to standardised plugs and/or sockets:

Terminals shall be designed for the connection of cables having a minimum and a maximum cross-sectional area according to 8.4.2.

Terminals shall be fastened to the SPD in such a way that they will not work loose if the clamping screws or the lock nuts are tightened or loosened. A tool shall be required to loosen the clamping screws or the lock nuts.

- a) Terminals for external conductors shall be such that the conductors may be connected so as to ensure that the necessary contact pressure is maintained permanently. The terminals shall be readily accessible under the intended conditions of use.

- b) The means for clamping the conductors in the terminals shall not serve to fix any other component, although they may hold the terminals in place or prevent them from turning.
- c) Terminals shall have adequate mechanical strength.
- d) Terminals shall be so designed that they clamp the conductor without undue damage to the conductor.
- e) Terminals shall be so designed that they clamp the conductor reliably and between metal surfaces.
- f) Terminals shall be so designed or positioned that neither a rigid solid conductor nor a wire of a stranded conductor can slip out while the clamping screws or nuts are tightened.

#### **7.3.3.1 Screw terminals**

- a) Screws and nuts for clamping the conductors shall have a metric ISO thread or a thread comparable in pitch and mechanical strength.

NOTE SI, BA and UN threads may be used as they are virtually equivalent in pitch and mechanical strength to metric ISO threads.

- b) Terminals shall be so fixed or located that, when the clamping screws or nuts are tightened or loosened, the terminals shall not work loose from their fixings to the SPDs.

These requirements do not imply that the terminals shall be so designed that their rotation or displacement is prevented, but any movement shall be sufficiently limited so as to prevent non-compliance with the requirements of this standard.

The use of sealing compound or resin is considered to be sufficient for preventing a terminal from working loose, provided that:

- the sealing compound or resin is not subject to stress during normal use, and
- the effectiveness of the sealing compound or resin is not impaired by temperatures attained by the terminal under the least favourable conditions specified in this standard.
- c) Clamping screws or nuts of terminals intended for the connection of protective conductors shall be adequately secured against accidental loosening.
- d) Screws shall not be made of metal that is soft or liable to creep, such as zinc or aluminium

Compliance is checked by inspection and by the tests in accordance with 8.4.2.1.

#### **7.3.3.2 Screwless terminals**

Terminals shall be so designed and constructed that:

- a) each conductor is clamped individually. During the connection or disconnection the conductors can be connected or disconnected either at the same time or separately,
- b) it is possible to clamp securely any number of conductors up to the maximum provided.

Compliance is checked by inspection and by the tests in accordance with 8.4.2.2.

#### **7.3.3.3 Insulation piercing connections**

Compliance is checked by inspection and by the tests in accordance with 8.4.2.3.

#### **7.3.3.4 Flat quick connect terminations**

Compliance is checked by inspection and by the tests in accordance with 8.4.2.4 (under consideration).

#### **7.3.3.5 Pigtail connections (flying leads)**

Compliance is checked by inspection and by the tests in accordance with 8.4.2.5.

#### **7.3.3.6 Standardised plugs and/or socket outlets**

Plugs and socket outlets shall correspond to the relevant international or national requirements (e.g. IEC 60884-1, IEC 60320-series).

#### **7.3.4 Air clearances and creepage distances**

The SPD shall have sufficient air clearances and creepage distances.

Compliance is checked by the test in accordance with 8.4.3.

#### **7.3.5 Mechanical strength**

All parts of the SPD relating to the protection against direct contact shall have sufficient mechanical strength.

Compliance is checked by the test in accordance with 8.4.4.

### **7.4 Environmental and material requirements**

SPDs shall operate satisfactorily under the service conditions specified in accordance with Clause 4.

#### **7.4.1 Protection provided by enclosure (IP code)**

SPDs shall be provided with an enclosure for protection against ingress of solid objects and water in accordance with the IP code declared by the manufacturer.

Compliance is checked by inspection and by the tests in accordance with 8.5.1.

#### **7.4.2 Heat resistance**

SPDs shall be sufficiently resistant to heat.

Compliance is checked by the tests in accordance with 8.3.5.1, 8.5.2 and 8.5.3.

#### **7.4.3 Fire resistance**

Insulating parts of the housing shall be either non-flammable or self-extinguishing.

Compliance is checked by the test in accordance with 8.5.4.

#### **7.4.4 Tracking resistance**

The tracking index of insulating materials, which may create a conductive path between electrical connections, are checked by the test in accordance with 8.5.5.

Testing is not necessary if the creepage distances are greater or equal to double the values indicated in 8.4.3 or in case of insulating materials made out of ceramic, mica or similar materials.

## **7.4.5 Electromagnetic compatibility**

### **7.4.5.1 Electromagnetic immunity**

SPDs either incorporating no electronic circuits or incorporating electronic circuits in which all components are passive (for example diodes, resistors, capacitors, inductors, varistors and other surge protective components) are not sensitive to electromagnetic disturbances expected under normal service conditions and therefore no immunity tests are required. For SPDs containing sensitive electronic circuits, refer to IEC 61000 series.

### **7.4.5.2 Electromagnetic emission**

For SPDs not incorporating electronic circuits, or incorporating electronic circuits that do not generate fundamental frequencies greater than 9 kHz in normal operation, electromagnetic disturbances can only be generated during protective operations. The duration of these disturbances is in the order of microseconds to milliseconds.

The frequency, level and the consequences of these emissions are considered as part of the normal electromagnetic environment of low-voltage installations. Therefore, the requirements for electromagnetic emissions are deemed to be satisfied and no verification is necessary.

For SPDs containing electronic circuits that perform a switching function operating at a frequency of 9 kHz or greater, refer to IEC 61000 series.

## **7.5 Additional requirements for specific SPD designs**

### **7.5.1 Two port SPDs and one port SPDs with separate input/output terminals**

#### **7.5.1.1 Rated load current $I_L$**

The manufacturer shall declare the rated load current.

Compliance is checked by the test in accordance with 8.6.1.1.

#### **7.5.1.2 Overload behaviour**

The SPD shall not be damaged or altered by overloads, which may occur in normal use.

Compliance with this requirement is checked according to 8.6.1.2.

#### **7.5.1.3 Load-side short-circuit rating**

The SPD shall be able to carry the currents caused by a power short-circuit on the load side until it is interrupted either by the SPD itself or by an internal or external disconnector.

Compliance is checked by the test in accordance with 8.6.1.3.

### **7.5.2 Environmental tests for outdoor SPDs**

Outdoor SPDs shall be sufficiently resistant to UV radiation and corrosion.

For proposed test procedures refer to 8.6.2 and Annex F.

### **7.5.3 SPDs with separate isolated circuits**

Where a SPD includes a circuit that is electrically isolated from the main circuit, the manufacturer shall provide information about the isolation and dielectric withstand voltages between the circuits as well as the relevant standards that the manufacturer is claiming conformity with.

Where there are more than two circuits, declarations shall be made with regard to each combination of circuits.

The isolation and dielectric withstand between the main circuits and separate isolated circuits shall be tested according to 8.3.6 and 8.3.7.

#### **7.5.4 Short-circuiting type SPDs**

These SPDs shall be capable of withstanding a short-circuit current test at their declared short-circuit current rating after having been overstressed by a surge current according to their transition surge rating  $I_{trans}$ .

Compliance is checked in accordance with 8.6.4

### **7.6 Additional requirements as may be declared by the manufacturer**

#### **7.6.1 One-port and two-port SPDs**

##### **7.6.1.1 Total Discharge Current $I_{Total}$ (for multipole SPDs)**

This test is only conducted if the manufacturer claims a total discharge current. Compliance is checked in accordance with 8.7.1.

#### **7.6.2 Two port SPDs only**

##### **7.6.2.1 Voltage drop**

The voltage drop shall be checked in accordance with 8.7.2.

##### **7.6.2.2 Load-side surge withstand capability**

If the manufacturer declares a load-side surge withstand capability then compliance is checked in accordance with 8.7.3.

##### **7.6.2.3 Voltage rate of rise $du/dt$**

If the manufacturer declares a  $du/dt$  value for a two port SPD containing a filtering device, this value shall be tested in accordance with 8.7.4.

## **8 Type tests**

Type tests are carried out as indicated in Table 3 on three samples per test sequence. Within any test sequence, the tests shall be carried out in the order given in Table 3. The order in which test sequence are carried out may be varied. Test on terminals shall be performed on three terminal samples for each construction/terminal type. (An SPD with at least three identical terminals fulfils this sample requirement).

A sample has passed a test sequence of Table 3 if all the requirements of the relevant test clauses and the relevant pass criteria are fulfilled.

If all required samples pass a test sequence, the design of the SPD is acceptable for that test sequence. If two or more test samples fail a test sequence, the SPD does not comply with this standard.

In the event that a single sample does not pass a test, this test, and those preceding in the same test sequence that may have influenced the result of this test, shall be repeated with three new samples, but this time no failure of any sample is allowed.

A set of three samples may be used for more than one test sequence, if agreed by the manufacturer.

NOTE For short-circuit current behaviour according 8.3.5.3 special prepared samples are required.

If the SPD is an integral part of a product covered by another standard, the requirements of the other standard shall apply to those parts of the product, which do not belong to the SPD section of the product. The SPD section shall comply with the general (7.1), the electrical (7.2), the environmental and material (7.4) requirements of this document. The mechanical requirements of other standards shall also be applied to the SPD.

## 8.1 General testing procedures

If not otherwise specified, the reference standard for high voltage test procedures is IEC 61180-1.

Unless otherwise specified, a.c. values given in this standard are r.m.s. values.

The SPD shall be mounted and electrically connected in accordance with the manufacturer's installation procedures. Neither external cooling nor heating shall be employed.

When not otherwise specified, the test shall be performed in free air and the ambient temperature shall be  $20^{\circ}\text{C} \pm 15^{\circ}\text{C}$ .

If not otherwise specified, for all tests where a power supply at  $U_{\text{REF}}$  or  $U_{\text{C}}$  is required, the voltage tolerance for testing shall be  $\begin{matrix} 0 \\ -5 \end{matrix} \%$ .

When testing SPDs for which the manufacturer supplies integral cables, the full length of those cables shall form part of the SPD under test.

If not otherwise specified, during the test, no maintenance or dismantling of the SPD is allowed. External disconnectors shall be selected according to the manufacturer's instructions and connected for testing if required according to Table 3.

All tests shall be performed on each mode of protection declared by the manufacturer, however, if some modes of protection have identical circuitry, one single test can be performed on the mode of protection which presents the most vulnerable configuration, using new samples each time.

For multimode devices (e.g. 3 phase SPD) in which the protective component circuitry is identical, the testing of each of the modes (e.g. three phases) can fulfil the three sample requirement.

For SPDs with a designated N terminal which may be applied in systems without distributed neutral according to the manufacturers instructions, separate testing is required for the L-PE mode of protection with the neutral being unconnected.

If the use of tissue paper is required according to Table 3:

- For fixed SPDs: tissue paper shall be fixed at a distance of  $100 \text{ mm} \pm 20 \text{ mm}$  in all directions of the sample, except the mounting surface.
- For portable SPDs: tissue paper shall be wrapped loosely around on all sides of the SPD including the bottom side.

If required according to Table 3, a metallic screen shall be located adjacent to all sides of the SPD at the minimum distance specified in 7.1.1 b13). Details, including distances of the

metallic screen from the SPD, shall be stated in the test report. The characteristics of the metallic screen shall be as follows:

- Structure:
  - Woven wire mesh
  - Perforated metal or expanded metal
- Ratio hole area/total area: 0,45-0,65
- Size of hole not exceeding 30 mm<sup>2</sup>
- Finish: bare or conductive plating
- Resistance: The resistance between the furthest point of the metallic screen and the connection point of the metallic screen shall be sufficiently low not to limit the short-circuit current of the screen circuit

The metallic screen shall be connected via a 6A gL/gG fuse to one of the SPD terminals under test (Figure 1). The connection of the screen shall be changed to the other SPD-terminal after each short-circuit application.

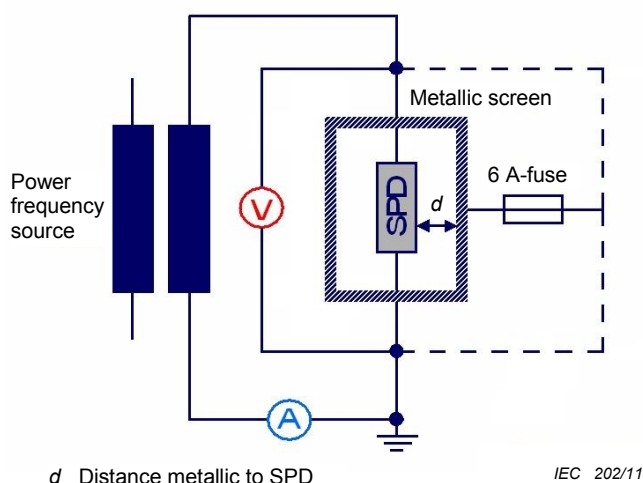


**Figure 1 – Metallic screen test set-up**

If the manufacturer sets different requirements for the external disconnector(s) depending upon the prospective short-circuit current of the supply system, all relevant test sequences shall be performed for every combination of required disconnector(s) and corresponding prospective short-circuit currents.

Throughout the entire type testing procedure, the status shown by the indicator(s) shall give a clear sign of the status of the part to which it is linked. Where there is more than one method of status indication, for example local and remote indication, each type of indication shall be checked.

It should be noted that good testing techniques are required for impulse testing and measurements. This is needed to ensure that correct test values are measured and recorded.

SPDs shall not create any hazard when operated under the test conditions in accordance with this standard.

**Table 3 – Type test requirements for SPDs**

| Test sequence         | Test description                                                | Subclause requirement/test   | External disconnectors connected <sup>a</sup> | Tissue paper used | Metallic screen used | Test class I | Test class II | Test class III |
|-----------------------|-----------------------------------------------------------------|------------------------------|-----------------------------------------------|-------------------|----------------------|--------------|---------------|----------------|
| <b>1</b>              | Identification and marking                                      | 7.1.1/7.1.2/8.2              | -                                             | -                 | -                    | A            | A             | A              |
|                       | Mounting                                                        | 7.3.1                        | -                                             | -                 | -                    | A            | A             | A              |
|                       | Terminals and connections                                       | 7.3.2/7.3.3/8.4.2            | -                                             | -                 | -                    | A            | A             | A              |
|                       | Testing for protection against direct contact                   | 7.2.1/8.3.1                  | -                                             | -                 | -                    | A            | A             | A              |
|                       | Environment, IP code                                            | 7.4.1 / 8.5.1                | -                                             | -                 | -                    | A            | A             | A              |
|                       | Residual current                                                | 7.2.2 / 8.3.2                | -                                             | -                 | -                    | A            | A             | A              |
|                       | Operating duty test                                             | 7.2.4/8.3.4 <sup>b</sup>     |                                               |                   |                      |              |               |                |
|                       | Operating duty test for test classes I, II or III               | 8.3.4.2 / 8.3.4.3/ 8.3.4.5   | A                                             | -                 | -                    | A            | A             | A              |
|                       | Additional duty test for test class I                           | 8.3.4.4                      | A                                             | -                 | -                    | A            | –             | –              |
|                       | Thermal stability                                               | 7.2.5.2 / 8.3.5.2            | A                                             | -                 | -                    | A            | A             | A              |
|                       | Air clearances and creepage distances                           | 7.3.4 / 8.4.3                | -                                             | -                 | -                    | A            | A             | A              |
|                       | Ball pressure test                                              | 7.4.2 / 8.5.3                | -                                             | -                 | -                    | A            | A             | A              |
|                       | Resistance to abnormal heat and fire                            | 7.4.3 / 8.5.4                | -                                             | -                 | -                    | A            | A             | A              |
|                       | Tracking resistance                                             | 7.4.4 / 8.5.5                | -                                             | -                 | -                    | A            | A             | A              |
| <b>2</b>              | Voltage protection level                                        | 7.2.3/8.3.3                  |                                               |                   |                      |              |               |                |
|                       | Residual voltage                                                | 8.3.3.1                      | -                                             | -                 | -                    | A            | A             | –              |
|                       | Front of wave sparkover voltage                                 | 8.3.3.2                      | -                                             | -                 | -                    | A            | A             | –              |
|                       | Limiting voltage with combination wave                          | 8.3.3.3                      | -                                             | -                 | -                    | –            | –             | A              |
| <b>2a</b>             | See below - only if applicable                                  |                              |                                               |                   |                      |              |               |                |
| <b>2b</b>             | See below - only if applicable                                  |                              |                                               |                   |                      |              |               |                |
| <b>3</b>              | Insulation resistance                                           | 7.2.6 / 8.3.6                | -                                             | -                 | -                    | A            | A             | A              |
|                       | Dielectric withstand                                            | 7.2.7 / 8.3.7                | -                                             | -                 | -                    | A            | A             | A              |
| <b>3a</b>             | See below - only if applicable                                  |                              |                                               |                   |                      |              |               |                |
|                       | Mechanical strength                                             | 7.3.5 / 8.4.4                | -                                             | -                 | -                    | A            | A             | A              |
|                       | Temperature withstand                                           | 7.2.5 / 8.3.5.1 <sup>b</sup> | -                                             | -                 | -                    | A            | A             | A              |
| <b>3b<sup>c</sup></b> | See below - only if applicable                                  |                              |                                               |                   |                      |              |               |                |
| <b>3c</b>             | See below - only if applicable                                  |                              |                                               |                   |                      |              |               |                |
| <b>4<sup>c</sup></b>  | Heat resistance                                                 | 7.4.2 / 8.5.2                | -                                             | -                 | -                    | A            | A             | A              |
|                       | TOV tests                                                       | 7.2.8 / 8.3.8                |                                               |                   |                      |              |               |                |
|                       | TOVs caused by faults or disturbances in the low voltage system | 7.2.8.1/8.3.8.1 <sup>b</sup> | A                                             | A                 | -                    | A            | A             | A              |
|                       | TOVs caused by faults in the high (medium) voltage system       | 7.2.8.2/8.3.8.2 <sup>b</sup> | A                                             | A                 | -                    | A            | A             | A              |
| <b>5<sup>c</sup></b>  | Short-circuit current behaviour                                 | 7.2.5.3 / 8.3.5.3            | A                                             | -                 | A                    | A            | A             | A              |



**Table 3 – Type test requirements for SPDs (continued)**

| <b>Additional tests for specific SPD designs</b>                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                   |                                |                                               |                   |                      |              |               |                |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|--------------------------------|-----------------------------------------------|-------------------|----------------------|--------------|---------------|----------------|
| Test sequence                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Test description                                                                  | Subclause requirement/test     | External disconnectors connected <sup>a</sup> | Tissue paper used | Metallic screen used | Test class I | Test class II | Test class III |
| <b>Additional tests for two-port SPDs and one port-SPDs with separate input / output terminals</b>                                                                                                                                                                                                                                                                                                                                                                            |                                                                                   |                                |                                               |                   |                      |              |               |                |
| <b>3c</b> <sup>c</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Rated load current                                                                | 7.5.1.1 / 8.6.1.1              | A                                             | -                 | -                    | A            | A             | A              |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Overload behaviour                                                                | 7.5.1.2 / 8.6.1.2 <sup>b</sup> | -                                             | -                 | -                    | A            | A             | A              |
| <b>2b</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Load side short-circuit current behaviour                                         | 7.5.1.3 / 8.6.1.3 <sup>b</sup> | A                                             | -                 | A                    | A            | A             | A              |
| <b>Additional tests if declared by the manufacturer</b>                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                   |                                |                                               |                   |                      |              |               |                |
| <b>3b</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Voltage drop                                                                      | 7.6.2.1 / 8.7.2                | -                                             | -                 | -                    | A            | A             | A              |
| <b>2a</b> <sup>c</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Load side surge withstand                                                         | 7.6.2.2 / 8.7.3 <sup>b</sup>   | A                                             | -                 | -                    | A            | A             | A              |
| <b>6</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Total discharge current test for multipole SPDs                                   | 7.6.1.1 / 8.7.1 <sup>b</sup>   | -                                             | -                 | -                    | A            | A             | -              |
| <b>Additional tests for outdoor use SPDs</b>                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                   |                                |                                               |                   |                      |              |               |                |
| <b>7</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | For SPDs classified "outdoor"                                                     | 7.5.2 / 8.6.2                  | -                                             | O                 | -                    | A            | A             | -              |
| <b>Additional tests for SPDs with separate isolated circuits</b>                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                   |                                |                                               |                   |                      |              |               |                |
| <b>3a</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Isolation between separate circuits                                               | 7.5.3/ 8.3.6 / 8.3.7           | -                                             | -                 | -                    | A            | A             | A              |
| <b>Additional tests for short-circuiting type SPDs</b>                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                   |                                |                                               |                   |                      |              |               |                |
| <b>8</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Change of characteristic procedure (preconditioning to short-circuited condition) | 7.5.4 / 8.6.4                  | -                                             | -                 | -                    | -            | A             | -              |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Surge withstand test (in short-circuited condition)                               | 7.5.4 / 8.6.4                  | -                                             | -                 | -                    | -            | A             | -              |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Short-circuit current behaviour (in short-circuited condition)                    | 7.5.4 / 8.6.4                  | A                                             | -                 | A                    | -            | A             | -              |
| A = applicable<br>- = not applicable<br>O = optional                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                   |                                |                                               |                   |                      |              |               |                |
| <sup>a</sup> external disconnectors connected means that all disconnectors as specified by the manufacturer shall be tested with the SPD during the type tests, except for RCDs, which are not tested during the operating duty test according to 8.3.4.<br><sup>b</sup> For these tests initial measurements of leakage currents according to Table 4, pass criterion E may be necessary.<br><sup>c</sup> For this test sequence more than one set of samples may be needed. |                                                                                   |                                |                                               |                   |                      |              |               |                |

**Table 4 – Common pass criteria for type tests**

|          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>A</b> | Thermal stability shall be achieved. The SPD is considered to be thermally stable if the crest of the resistive component of the current flowing into the SPD or the power dissipation shows either a decreasing tendency or does not increase during 15 min of $U_C$ voltage application immediately after the application of $U_C$ . If the test itself is performed with the SPD energized at $U_C$ , then $U_C$ either remains applied for these 15 min without interruption or is reapplied within less than 30 s.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>B</b> | Voltage and current records and visual inspection shall show no indication of puncture or flashover.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>C</b> | No visible damage shall occur during the test. After the test, small indents and cracks not impairing the protection against direct contact are disregarded during this check, unless the degree of protection (IP-code) given for the SPD is no longer provided. There shall be no visual evidence of burning of the sample after the test.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>D</b> | Values for measured limiting voltage after the test shall be below or equal to $U_P$ . The measured limiting voltage shall be determined, using the tests described in 8.3.3, but the test of 8.3.3.1 is performed only with a 8/20-surge current with a crest value of $I_{imp}$ for Test Class I or with $I_n$ for Test Class II or with the test of 8.3.3.3 but only at $U_{OC}$ for Test class III.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>E</b> | <p>No excessive leakage currents shall occur after the test.</p> <p>The SPD shall be connected as for normal use according to the manufacturer's instructions to a power supply at the reference test voltage (<math>U_{REF}</math>). The current that flows through each terminal is measured. Its resistive component (measured at the crest of the sine wave) shall not exceed a value of 1 mA, or the current shall not have changed by more than 20 % compared to the initial value determined at the beginning of the relevant test sequence.</p> <p>Any resettable or rearmable disconnecter shall be switched off manually, if applicable, and the dielectric withstand shall be checked by application of two times <math>U_C</math> or 1 000 V a.c., whichever is greater. During the test, no flashover, breakdown of insulation either internally (puncture) or externally (tracking) or any other manifestation of disruptive discharge shall occur.</p> <p>In addition for SPD modes connected N-PE only the current through the PE-terminal shall be measured, whereas the terminals are connected to a power supply at the maximum continuous operating voltage (<math>U_C</math>). Its resistive component (measured at the crest of the sine wave) shall not exceed a value of 1 mA, or the current shall not have changed by more than 20 % compared to the initial value determined at the beginning of the relevant test sequence.</p> <p>If there is more than one possible connection arrangement for normal use, this check shall be performed for all arrangements.</p> |
| <b>F</b> | <p>External disconnectors as specified by the manufacturer shall not operate during the test and shall be in working order after the test.</p> <p>For the purpose of this clause, working order means that there is no damage to the disconnector and that it is still operational. Operation can be checked either manually (where possible) or by a simple electrical test agreed between the manufacturer and the laboratory.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>G</b> | <p>Internal disconnectors as specified by the manufacturer shall not operate during the test and shall be in working order after the test.</p> <p>For the purpose of this clause, working order means that there is no damage of the disconnector and that it is still operational. Operation can be checked either manually (where possible) or by a simple electrical test agreed between the manufacturer and the laboratory.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>H</b> | Disconnection shall be provided by one or more internal and/or external disconnector(s). Their correct indication shall be checked.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>I</b> | SPDs with an IP degree equal to, or greater than, IP20 shall not have live parts accessible with the standardized test finger applied with a force of 5 N (see IEC 60529), except the live parts which were already accessible before the test when the SPD is fitted as in normal use.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>J</b> | <p>If disconnection (internal or external) occurs during the test, there shall be clear evidence of effective disconnection of the corresponding protective component(s).</p> <p>If internal disconnection occurs, the test sample is connected as for normal use at the maximum continuous operating voltage <math>U_C</math> and at rated frequency for 1 min. The test source shall have a short-circuit current capability equal or greater than 200 mA. The current that flows through the relevant protective components shall not exceed a value of 1 mA.</p> <p>Currents through components connected in parallel to the relevant protective component(s), or otherwise connected (e.g. indicator circuits), are disregarded for this measurement, as long as they cannot cause a current through the relevant protective component(s).</p> <p>In addition the current through the PE-terminal, including parallel circuits and other circuits (e.g. indicator circuits), if any, shall not exceed 1 mA.</p> <p>If there is more than one possible connection arrangement for normal use, this check shall be performed for all arrangements.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>K</b> | The short-circuit current from the power source, if any, shall be interrupted within 5 s by one or more internal and/or external disconnector(s).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>L</b> | The tissue paper shall not catch fire.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>M</b> | There shall be no explosion or other hazard to either personnel or the facility.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>N</b> | There shall be no flashover to the metallic screen and the 6 A gL/gG fuse connecting the screen shall not operate during the test.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>O</b> | <p>After completion of this test the samples shall be allowed to return to room temperature and be connected to a power source at <math>U_C</math> for 2 h.</p> <p>The residual current shall be monitored and not exceed the value measured at the beginning of the test by more than 10 %.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |

**Table 5 – Cross reference for pass criteria versus type tests**

| <b>Pass<br/>criteria<br/>clause</b>        | <b>A</b> | <b>B</b> | <b>C</b> | <b>D</b> | <b>E</b> | <b>F</b> | <b>G</b> | <b>H</b> | <b>I</b> | <b>J</b> | <b>K</b> | <b>L</b> | <b>M</b> | <b>N</b> | <b>O</b> |
|--------------------------------------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| <b>8.3.3.4</b>                             |          | A        | A        |          |          |          |          |          | A        |          |          |          | A        |          |          |
| <b>8.3.4.6</b>                             | A        | A        | A        | A        | A        | A        | A        |          |          |          |          |          | A        |          |          |
| <b>8.3.5.1</b>                             |          |          | A        |          |          |          | A        |          |          |          |          |          |          |          |          |
| <b>8.3.5.2</b>                             |          |          | A        |          |          |          |          | A        | A        | A        |          |          | A        |          | A        |
| <b>8.3.5.3 a)</b>                          |          |          | A        |          |          |          |          | A        | A        | A        | A        |          | A        | A        |          |
| <b>8.3.5.3 b)</b>                          |          |          | A        |          |          |          |          | C        | A        | C        | C        |          | A        | A        |          |
| <b>8.3.5.3.1</b>                           |          |          | A        |          |          |          |          | A        | A        | A        | A        |          | A        | A        |          |
| <b>8.3.5.3.2</b>                           |          |          | A        |          |          |          |          | C        | A        | C        |          |          | A        | A        |          |
| <b>8.3.8.1 a)</b>                          |          |          | A        |          |          |          |          | A        | A        | A        | A        | A        | A        |          |          |
| <b>8.3.8.1 b)</b>                          | A        | A        | A        | A        | A        | A        | A        |          | A        |          |          | A        | A        |          |          |
| <b>8.3.8.2 a)</b>                          |          |          | A        |          |          |          |          | A        | A        | A        | A        | A        | A        |          |          |
| <b>8.3.8.2 b)</b>                          | A        | A        | A        | A        | A        |          | A        |          | A        |          | A        | A        | A        |          |          |
| <b>8.5.2</b>                               |          |          | A        |          |          |          |          |          | A        |          |          |          |          |          |          |
| <b>8.6.1.1</b>                             |          |          | A        |          |          | A        | A        |          |          |          |          |          |          |          |          |
| <b>8.6.1.2 a)</b>                          |          |          | A        |          |          |          |          | A        | A        | A        |          |          | A        |          |          |
| <b>8.6.1.2 b)</b>                          |          |          | A        | A        | A        |          |          |          | A        |          |          |          |          |          |          |
| <b>8.6.1.3 a)</b>                          |          |          | A        |          | A        |          |          | A        | A        | A        | A        |          | A        | A        |          |
| <b>8.6.1.3 b)</b>                          |          |          | A        | A        | A        |          |          | A        | A        | A        | A        |          | A        | A        |          |
| <b>8.6.4.2</b>                             |          |          | A        |          |          |          |          |          | A        |          |          |          | A        |          |          |
| <b>8.6.4.3</b>                             |          |          | A        |          |          |          |          | A        | A        | A        | A        |          | A        | A        |          |
| <b>8.7.1</b>                               |          | A        | A        | A        | A        |          | A        |          | A        |          |          |          | A        |          |          |
| <b>8.7.3</b>                               | A        | A        | A        | A        | A        | A        | A        |          |          |          |          |          |          |          |          |
| A applicable<br>C conditionally applicable |          |          |          |          |          |          |          |          |          |          |          |          |          |          |          |

### 8.1.1 Impulse discharge current used for class I additional duty test

The impulse discharge current passing through the device under test (SPD) is defined by the crest value  $I_{\text{imp}}$ , the charge  $Q$  and the specific energy  $W/R$ . The impulse current shall show no polarity reversal and shall reach  $I_{\text{imp}}$  within 50  $\mu\text{s}$ . The transfer of the charge  $Q$  shall occur within 5 ms and the specific energy  $W/R$  shall be dissipated within 5 ms.

The impulse duration shall not exceed 5 ms.

Table 6 gives values of  $Q$  (As) and  $W/R$  (kJ/ $\Omega$ ) for example values of  $I_{\text{imp}}$  (kA).

The relationship between  $I_{\text{imp}}$ ,  $Q$  and  $W/R$  is as follows:

$$Q = I_{\text{imp}} \times a \quad \text{where } a = 5 \times 10^{-4} \text{ s}$$

$$W/R = I_{\text{imp}}^2 \times b \quad \text{where } b = 2,5 \times 10^{-4} \text{ s}$$

**Table 6 – Preferred parameters for class I test**

| $I_{\text{imp}}$<br>within 50 $\mu\text{s}$<br>kA                                                                       | $Q$<br>within 5 ms<br>As | $W/R$<br>within 5 ms<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 One of the possible test impulses which meet the above parameters is the 10/350 waveshape proposed in IEC 62305-1. |                          |                                      |

The following tolerances shall apply:

- $I_{\text{imp}}$        $-10 \text{ } \%/+10 \text{ } \%$ ;
- $Q$            $-10 \text{ } \%/+20 \text{ } \%$ ;
- $W/R$         $-10 \text{ } \%/+45 \text{ } \%$ .

### 8.1.2 Current impulse used for class I and class II residual voltage and operating duty tests

The waveshape is 8/20. The tolerances on the current waveshape passing through the device under test are as follows:

- crest value       $\pm 10 \text{ } \%$
- front time        $\pm 10 \text{ } \%$
- time to half value  $\pm 10 \text{ } \%$

A small overshoot or oscillation is tolerated provided that the amplitude of any oscillation is not more than 5 % of the crest value. Any polarity reversal after the current has fallen to zero shall not be more than 30 % of the crest value.

In the case of two port devices, the magnitude of the reversal shall be less than 5 %, so that it does not affect the measured limiting voltage.

### 8.1.3 Voltage impulse used for class I and II sparkover tests

The standard voltage waveshape is 1,2/50. The tolerances of the voltage waveshape of the open circuit voltage at the points where the device under test (DUT) will be connected are the following:

- crest value  $\pm 5 \%$
- front time  $\pm 30 \%$
- time to half value  $\pm 20 \%$

Oscillations or overshoot may occur at the crest of the impulse. If the frequency of such oscillations is more than 500 kHz or the duration of the overshoot is less than 1  $\mu\text{s}$ , a mean curve shall be drawn and, for the purpose of the measurement, the maximum amplitude of this mean curve defines the measured crest value of the test voltage.

Oscillations exceeding 3 % of the crest value are not allowed on the rising portion of the voltage impulse between 0 % and 80 % of the crest value.

The measuring devices shall have an overall bandwidth of at least 25 MHz and the overshoot shall be less than 3 %.

The short-circuit current of the test generator shall be less than 20 % of the nominal discharge current  $I_n$  of the SPD.

### 8.1.4 Combination wave used for class III tests

The standard impulse of a combination waveform generator is characterized by the output voltage under open-circuit conditions and the output current under short-circuit conditions. The open-circuit voltage shall have a front time of 1,2  $\mu\text{s}$  and a time to half value of 50  $\mu\text{s}$ . The short-circuit current shall have a front time of 8  $\mu\text{s}$  and a time to half value of 20  $\mu\text{s}$ .

NOTE 1 For further guidance on this subject see IEEE C62.45:2009

a) The tolerances of the open circuit voltage  $U_{oc}$  at the points where the device under test (DUT) will be connected are as follows:

- crest value  $\pm 5 \%$
- front time  $\pm 30 \%$
- time to half value  $\pm 20 \%$ .

These tolerances are for the generator alone, without any SPD or power supply circuit being connected.

Oscillations or overshoot may occur at the crest of the impulse. If the frequency of such oscillations is more than 500 kHz or the duration of the overshoot is less than 1  $\mu\text{s}$ , a mean curve shall be drawn and, for the purpose of the measurement, the maximum amplitude of this mean curve defines the measured crest value of the test voltage.

Oscillations exceeding 3 % of the crest value are not allowed on the rising portion of the voltage impulse between 0 % and 80 % of the crest value.

The measuring devices shall have an overall bandwidth of at least 25 MHz and an overshoot of less than 3 %.

b) The tolerances of the short-circuit current  $I_{sc}$  at the points where the device under test (DUT) will be connected are as follows:

- crest value  $\pm 10\%$
- front time  $\pm 10\%$
- time to half value  $\pm 10\%$ .

These generator tolerances shall be met with or without any power supply circuit being connected, depending if the test has to be performed energised or un-energized.

A small overshoot or oscillation is tolerated provided that the amplitude of any oscillation is not more than 5 % of the crest value. Any polarity reversal after the current has fallen to zero shall not be more than 30 % of the crest value.

c) Test setup:

The fictive impedance  $Z_f$  of the generator shall be nominally  $2\ \Omega$ . By definition, the fictive impedance is the ratio of the crest value of the open-circuit voltage  $U_{oc}$  divided by the crest value of the short-circuit current  $I_{sc}$ .

The above waveform and tolerance requirements only apply to the test performed at the value of  $U_{oc}$  declared by the manufacturer, which may require some generator adjustment to achieve. For tests performed below  $U_{oc}$  under clause 8.3.3.3 b), no further generator adjustment is required, and the same settings shall be used.

The generator coupling element shall preferably be realised by a varistor element with a rating as close as possible to the continuous operating voltage  $U_C$  of the device under test, to ensure comparable results among different test laboratories.

NOTE 2 This avoids excessive efforts for test set-ups because of the non-linearity in the generator coupling element which influences the total generator impedance at different settings for  $U_{oc}$ .

The maximum values for crest open-circuit voltage  $U_{oc}$  and crest short-circuit current  $I_{sc}$  are 20 kV and 10 kA respectively. Above these values (20 kV /10 kA), class II tests shall be performed.

The possibility of using decoupling networks for energised testing depends on the internal design of the SPD:

- when the SPD does not contain reactive components, the decoupling network is not required.
- when the SPD contains reactive components, but does not contain any voltage switching components, preferably no decoupling network shall be used or the measured limiting voltage test according 8.3.3 may be performed by using the alternate test procedure according 8.1.4.1.
- when the SPD contains reactive components and voltage switching components, no decoupling network shall be used.

Coupling elements and decoupling networks are only necessary for energised testing.

Examples for decoupling networks are given in Figure 2 and Figure 3.

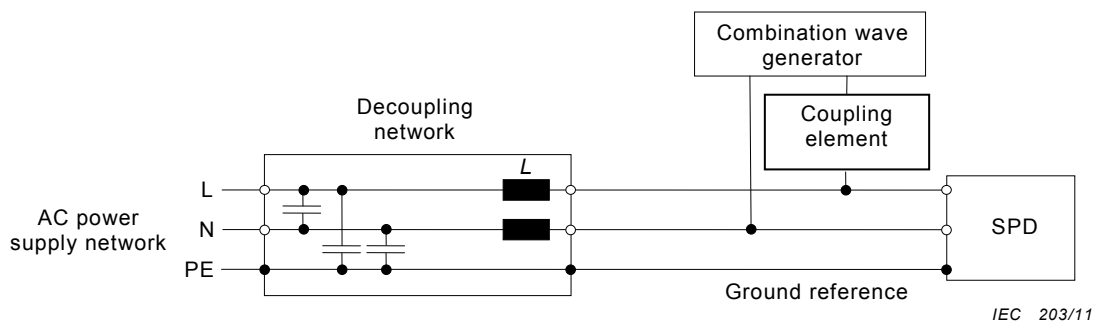


**Figure 2 – Example of a decoupling network for single-phase power**

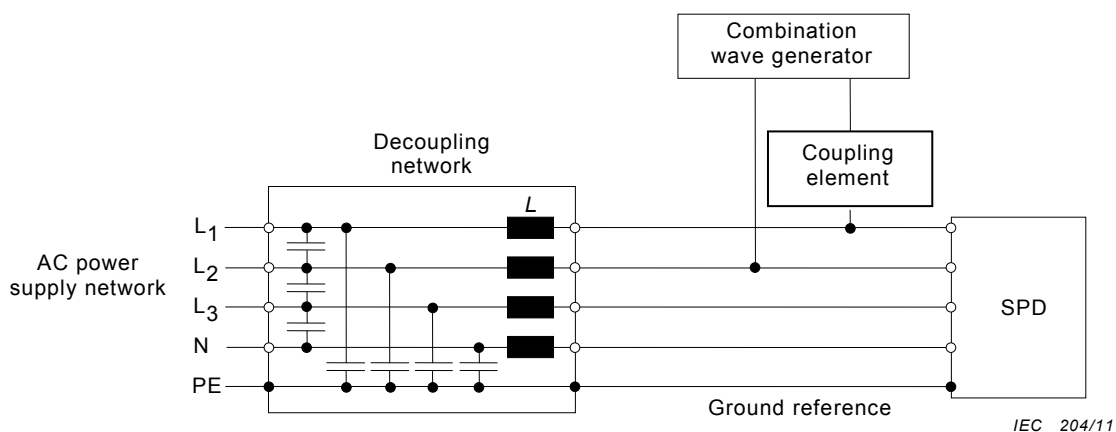


**Figure 3 – Example of a decoupling network for three-phase power**

#### 8.1.4.1 Alternate test circuit to determine the measured limiting voltage (8.3.3) without a decoupling network

Two-port SPDs with reactive components create interaction with the reactive components of a back filter. This can produce artificially low values of measured limiting voltage. Tests in such cases shall use the alternative test circuit according to Figure 4.

- For a.c. rated SPDs a d.c. voltage of  $U_c \cdot \sqrt{2}$ , shall be applied to the SPD via a diode. The impulse shall preferably be applied via a varistor.
- The application of the impulse shall occur at  $100 \text{ ms}^{+10}_{-0} \%$  after closure of S1. The d.c. voltage shall be disconnected within 10 ms after impulse application.
- Reverse polarity tests can be conducted by reversing the SPD connection to the test circuit.

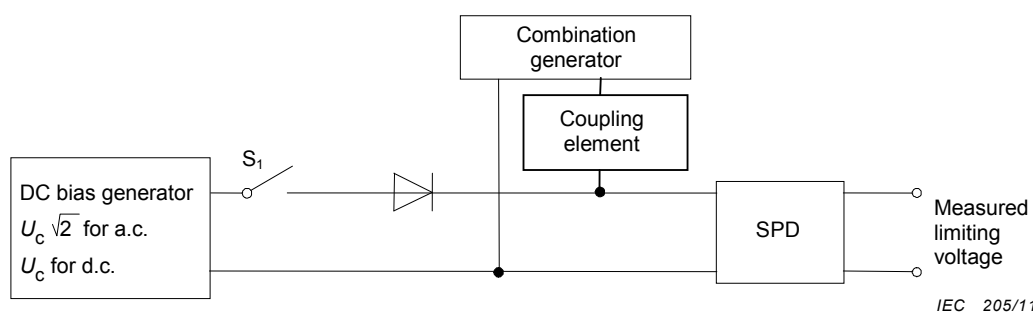


**Figure 4 – Alternate test for the measured limiting voltage**

## 8.2 Indelibility of markings

This test shall be applied on markings of all types except those made by impressing, molding and engraving.

The test is made by rubbing the marking by hand for 15 s with a piece of cotton soaked with water and again for 15 s with a piece of cotton soaked with aliphatic solvent hexane with a content of aromatics of maximum 0,1 % volume, a kauributanol value of 29, initial boiling-point approximately 65 °C and specific gravity of 0,68 g/cm<sup>3</sup>).

After this test, the marking shall be easily legible.

## 8.3 Electrical tests

### 8.3.1 Protection against direct contact

#### 8.3.1.1 Insulated parts

The sample is mounted as for normal use and the test is conducted using conductors of the smallest cross-sectional area and then again using conductors of the largest cross-sectional area specified in 8.4.2.

The standard test finger (in accordance with IEC 60529) is applied in every possible position.

For plug-in SPDs (which can be changed without a tool), the test finger is applied in every possible position, when the plug is partially inserted or completely inserted in a socket outlet.

An electrical continuity indicator operating from a voltage of not less than 40 V and not more than 50 V, one side of which is connected between the all live terminals of the sample linked together and the other side is connected to the test finger to check for the possibility of contact with any live part of the sample.

#### 8.3.1.2 Metal parts

Metal parts which are accessible when the SPD is wired and mounted as for normal use shall be connected to earth through a low resistance connection, except of small screws and the like, isolated from live parts, for fixing bases and covers or cover plates of socket-outlets.

A current (derived from an a.c. source having a no-load voltage not exceeding 12 V) equal to 1,5 times the rated load current or 25 A, whichever is the greater, is passed between the earthing terminal and each of the accessible metal parts in turn.

The voltage drop between the earthing terminal and the accessible metal part is measured and the resistance is calculated from the current and this voltage drop. The resistance shall not exceed 0,05 Ω.

NOTE Care should be taken that the contact resistance between the tip of the measuring probe and the metal part under test does not influence the test results.

### 8.3.2 Residual current $I_{PE}$

The SPD shall be connected as for normal use according to the manufacturer's instructions. The voltage shall be adjusted to the reference test voltage of ( $U_{REF}$ ).

The residual current flowing through the PE terminal is measured.

NOTE 1 If the manufacturer allows more than one configuration for the SPD installation, this test should be performed for every configuration.

NOTE 2 The true r.m.s. current value should be measured.

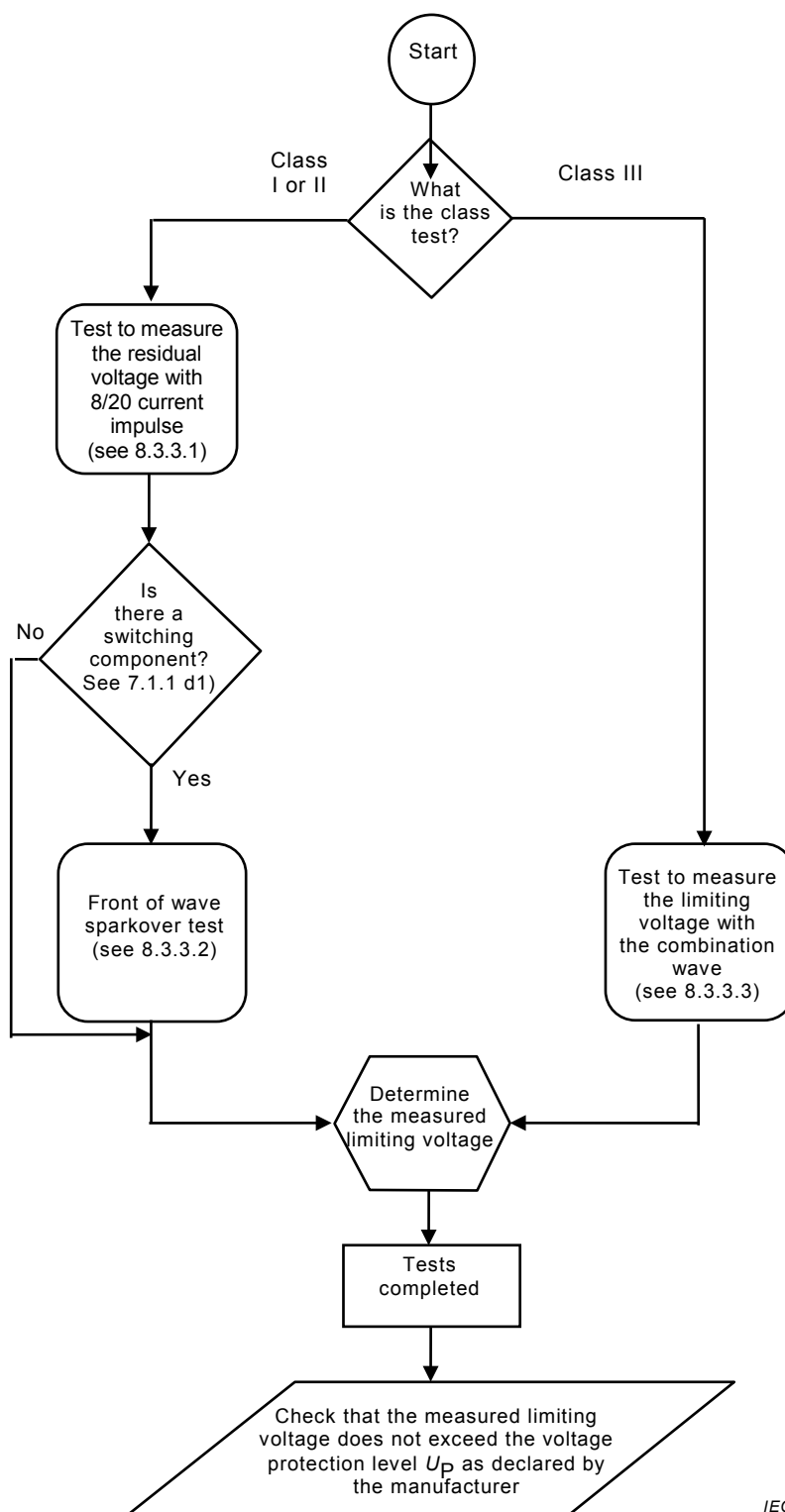
NOTE 3 If the SPD contains a terminal which is dedicated to be connected to a PEN conductor only, then this terminal is not considered to be a PE terminal.

**Pass criteria**

The measured residual current value shall not exceed the value declared by the manufacturer according 7.1.1 b11).

**8.3.3 Measured limiting voltage**

The tests on the different SPD types to determine their measured limiting voltages shall be performed according to the flow chart in Figure 5 and the following Table 7.



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Figure 5 – Flow chart of testing to check the voltage protection level  $U_P$

**Table 7 – Tests to be performed to determine the measured limiting voltage**

|                                                                                   | Class I        | Class II       | Class III |
|-----------------------------------------------------------------------------------|----------------|----------------|-----------|
| Test 8.3.3.1                                                                      | X              | X              |           |
| Test 8.3.3.2                                                                      | X <sup>a</sup> | X <sup>a</sup> |           |
| Test 8.3.3.3                                                                      |                |                | X         |
| <sup>a</sup> To be performed only on voltage switching and combination type SPDs. |                |                |           |

The following specific test conditions apply.

- All one-port SPDs shall be tested unenergized.
- All two-port SPDs shall be tested energized for the tests according 8.3.3.1 and 8.3.3.3 by means of a voltage source having a nominal current of at least 5 A at  $U_C$ . Positive impulses are applied at the  $(90 \pm 5)^\circ$  point and negative impulses at  $(270 \pm 5)^\circ$  point on the sinusoidal voltage waveform.
- For a one-port SPD having terminals, the test is performed without external disconnectors and the voltage is measured at the terminals. For a one-port SPD having connecting leads the voltage is measured with external lead lengths of 150 mm. For a two-port SPD, and a one-port SPD having separate load terminals, the voltage for determining the measured limiting voltage is measured at the output/load port or load terminals of the SPD and the voltage for determining  $U_{\max}$  is measured at the input/line port or terminals of the SPD.
- The measured limiting voltage and  $U_{\max}$  are determined by the tests performed according to Figure 5 and Table 7, relevant to the SPD test class.

#### 8.3.3.1 Residual voltage with 8/20 current impulses

- When testing SPDs to class I, 8/20 current impulses with a sequence of crest values of approximately 0,1; 0,2; 0,5; 1,0 times the crest value of  $I_{\text{imp}}$  shall be applied. When testing SPDs to class II, 8/20 current impulses with a sequence of crest values of approximately 0,1; 0,2; 0,5; 1,0 times  $I_n$  shall be applied. If the SPD contains only voltage-limiting components, this test needs only to be performed at crest values of  $I_{\text{imp}}$  for test class I or  $I_n$  for test class II. When  $I_{\max}$  is declared by the manufacturer an additional 8/20 current impulse with a crest value of  $I_{\max}$  shall be applied and the residual voltage shall be measured and recorded.
- One sequence of positive polarity and one sequence of negative polarity are applied to the SPD.
- The interval between individual impulses shall be long enough for the sample to cool down to ambient temperature.
- A current and a voltage oscillogram shall be recorded for each impulse. If relevant, the (absolute) crest values shall be plotted into a discharge current versus residual voltage diagram to  $I_n$  or  $I_{\text{imp}}$ . A curve which best fits the data points shall be drawn. There shall be sufficient points on the curve to ensure that there are no significant deviations on the curve up to  $I_n$  or  $I_{\text{imp}}$ .
- The residual voltage used for determining the measured limiting voltage is the highest voltage value corresponding to the range of currents for:
  - class I: up to  $I_{\text{imp}}$
  - class II: up to  $I_n$

NOTE The residual voltage is the highest crest value measured during surge current flow. Any high frequency disturbances and spikes before and during current flow caused by specific generator design, like crowbar generators, are disregarded.

- The value for determining  $U_{\max}$  is the highest residual voltage measured at  $I_n$ ,  $I_{\max}$  or  $I_{\text{imp}}$ , as applicable depending on the SPD test class.

### 8.3.3.2 Front-of-wave sparkover voltage

The 1,2/50 voltage impulse is used. The generator voltage is set to an open circuit output voltage of 6 kV.

- a) 10 impulses are applied to the SPD, five of positive and five of negative polarity.
- b) The interval between individual impulses shall be long enough for the sample to cool down to ambient temperature.
- c) If sparkover is not observed during each of the 10 impulses on the front of the wave, then a) and b) above are repeated with the generator output voltage increased up to a maximum 10 kV. This shall be recorded in the test report.
- d) The voltage at the SPD shall be recorded with an oscilloscope.
- e) The value for determining the measured limiting voltage and  $U_{\max}$  is the maximum sparkover voltage recorded during this test.

### 8.3.3.3 Limiting voltage with the combination wave

To perform this test a combination wave generator is used.

- a) The interval between the individual impulses shall be long enough for the sample to cool down to ambient temperature.
- b) The voltage of the combination wave generator is set to provide an open-circuit voltage of 0,1; 0,2; 0,5; 1,0 times the  $U_{OC}$  as declared by the manufacturer for the SPD. If the SPD only contains voltage-limiting components this test needs to be carried out at  $U_{OC}$  only.
- c) With these generator settings four surges will be applied to the SPD at each amplitude: two with positive and two with negative polarity.
- d) An oscillographic record shall be made of the current delivered by the generator into the SPD and the voltage at the output port of the SPD for each impulse.
- e) The value for determining the measured limiting voltage and  $U_{\max}$  is the maximum voltage recorded during this test.

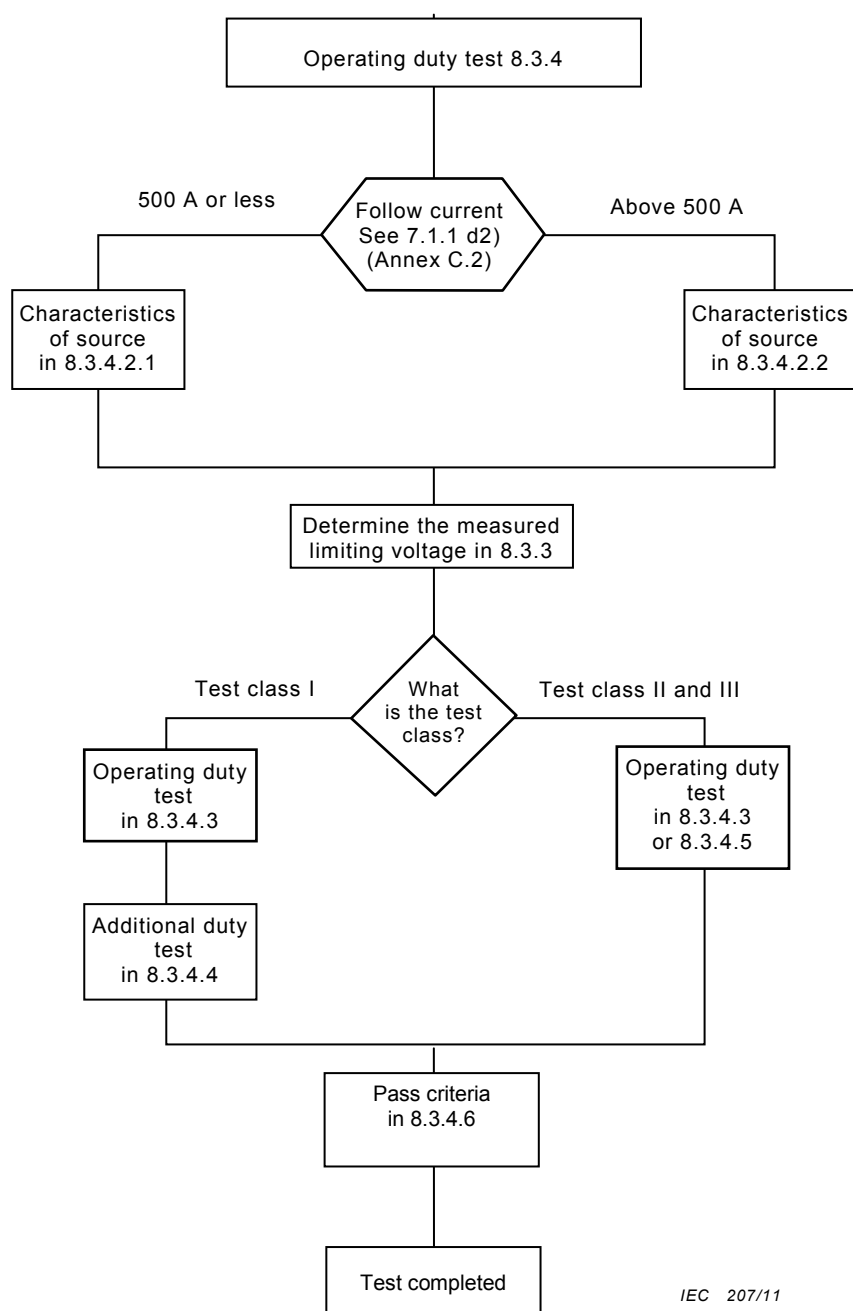
NOTE This may either be the sparkover voltage or the residual voltage depending on the SPD design.

### 8.3.3.4 Pass criteria for all measured limiting voltage tests

The pass criteria **B**, **C**, **I** and **M** according to Table 4 shall apply.

### 8.3.4 Operating duty test

An overview is given in the flow chart for the operating duty test in Figure 6.



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**Figure 6 – Flow chart of the operating duty test****8.3.4.1 General**

This is a test in which service conditions are simulated by the application of a stipulated number of specified impulses to the SPD while it is energized at the maximum continuous operating voltage  $U_c$  via an a.c. source according to 8.3.4.2.

The test setup shall comply in with the circuit diagram given in Figure 7.

The measured limiting voltage shall be determined using the tests described in 8.3.3.

To avoid overstress of the samples, the test is performed:

- according to 8.3.3.1, but only at a crest value corresponding to  $I_{imp}$  for test class I
- according to 8.3.3.1, but only at  $I_n$  for test class II

- according to 8.3.3.3, but only at  $U_{oc}$  for test class III

with one positive and one negative surge applied.

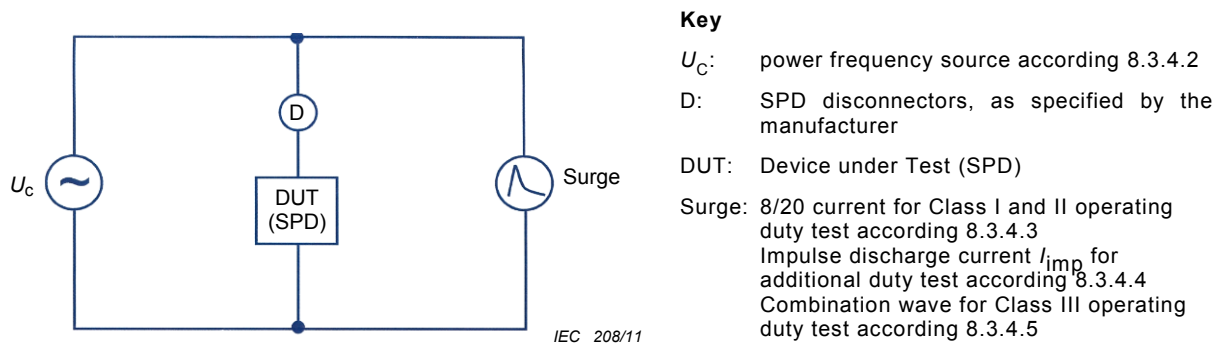


**Figure 7 – Test set-up for operating duty test**

### 8.3.4.2 Power frequency source characteristics for the operating duty test

#### 8.3.4.2.1 SPDs with follow current 500 A or less

The test sample shall be connected to a power frequency voltage source. The impedance of the power source shall be such that during the flow of follow current the crest value of the power frequency voltage, measured at the SPD terminals, does not fall below the crest value of its  $U_c$  by more than 10 %.

#### 8.3.4.2.2 SPDs with follow current above 500 A

The test sample shall be connected to a power frequency voltage at  $U_c$  with a prospective short-circuit current being:

- either equal to the follow current interrupt rating  $I_{fi}$  declared by the manufacturer in accordance with Table 8
- or 500 A

whichever is greater, except for SPDs which are only connected between neutral and protective earth in TT- and/or TN-Systems, for which the prospective short-circuit current shall be at least 100 A.

NOTE For information on SPD follow current interrupt rating coordination with the available prospective short-circuit current of the particular power distribution system at the point of installation, refer to IEC 61643-12 and IEC 60364-5-53, Subclause 534.2.3.5.

### 8.3.4.3 Class I and II operating duty tests

Three groups of five impulses of 8/20 current impulses with positive polarity shall be applied. The test samples are connected to a power source according to 8.3.4.2. Each impulse shall be synchronized to the power frequency. Starting from 0° the synchronization angle shall be increased in steps of 30° with a tolerance of  $\pm 5^\circ$  for each synchronization angle. The tests are described in Figure 8.

The SPD shall be energized at  $U_c$ . The prospective short-circuit current of the power source shall comply with 8.3.4.2 during the application of groups of impulses. After the application of each group of impulses and after the interruption of the last follow current (if any) the SPD shall remain energized without interruption for at least 1 min to check for reignition. After the last group of impulses and the 1 min period the SPD either remains applied or is reapplied within less than 30 s to  $U_c$  for another 15 min to check for stability. For that purpose, the short-circuit capability of the power source (at  $U_c$ ) may be reduced to 5 A.

When testing SPDs to class I, 8/20 current impulses with a crest corresponding to  $I_{imp}$  shall be applied.

When testing SPDs to class II, 8/20 current impulses with  $I_n$  shall be applied.

NOTE If an SPD is classified for test class I and test class II, this test may be performed only once, but with the most severe set of parameters of both test classes, subject to agreement by the manufacturer.

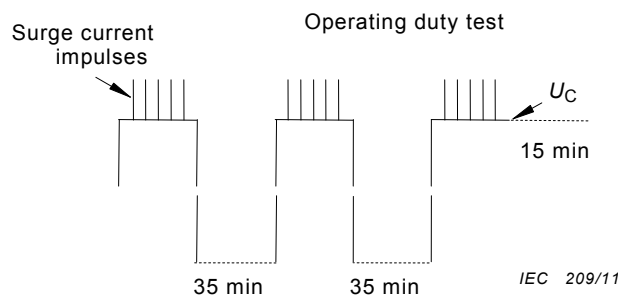


**Figure 8 – Operating duty test timing diagram for test classes I and II**

The interval between the impulses is 50 s – 60 s, the interval between the groups is 30 min – 35 min.

It is not required that the test sample is energized between the groups.

All current impulses shall be recorded and the current records shall show no sign of puncture or flashover of the samples.

#### 8.3.4.4 Additional duty test for test class I

This test is carried out with current impulses in steps up to  $I_{imp}$  passing through the SPD.

The SPD shall be energized at  $U_C$ . The prospective short-circuit current of the power source shall be 5 A during the application of impulses. After the application of each impulse and after interruption of each follow current (if any) the SPD shall remain energized without interruption for at least 1 min to check for re-ignition. After that period the SPD either remains applied or is reapplied within less than 30 s to  $U_C$  for another 15 min to check for stability. For that purpose the short-circuit capability of the power source shall also be 5 A.

Current impulses of positive polarity shall be initiated in the corresponding positive crest value of the power frequency voltage source to the energized test sample as follows.

- One current impulse at 0,1  $I_{imp}$ ; check thermal stability; cool down to ambient temperature.
- One current impulse at 0,25  $I_{imp}$ ; check thermal stability; cool down to ambient temperature.
- One current impulse at 0,5  $I_{imp}$ ; check thermal stability; cool down to ambient temperature.
- One current impulse at 0,75  $I_{imp}$ ; check thermal stability; cool down to ambient temperature.
- One current impulse at 1,0  $I_{imp}$ ; check thermal stability; cool down to ambient temperature.

The timing diagram is described in Figure 9

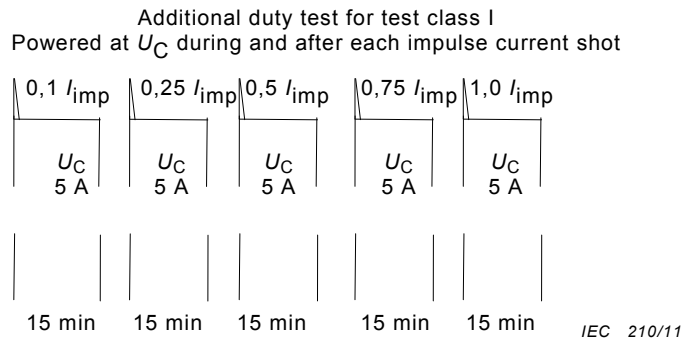


**Figure 9 – Additional duty test timing diagram for test class I**

#### 8.3.4.5 Class III operating duty tests

The SPD is tested with three groups of impulses corresponding to  $U_{oc}$  with:

- five positive impulses initiated at crest value of positive half cycle ( $\pm 5^\circ$ )
- five negative impulses initiated at crest value of negative half cycle ( $\pm 5^\circ$ )
- five positive impulses initiated at crest value of positive half cycle ( $\pm 5^\circ$ )

The timing diagram is described in Figure 10.

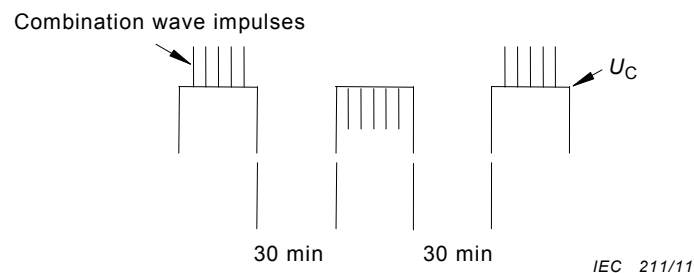


**Figure 10 – Operating duty test timing diagram for test class III**

#### 8.3.4.6 Pass criteria for all operating duty tests and for the additional duty test for test class I

The pass criteria **A**, **B**, **C**, **D**, **E**, **F**, **G** and **M** according to Table 4 shall apply.

### 8.3.5 Disconnectors and safety performance of overstressed SPDs

#### 8.3.5.1 Temperature withstand test

The SPD is kept in a heated cabinet at an ambient temperature of  $80^\circ\text{C} \pm 5\text{ K}$  for 24 h.

The pass criteria **C** and **G** according to Table 4 shall apply.

#### 8.3.5.2 Thermal stability

##### Test settings

This test procedure addresses two different designs:

- for SPDs containing only voltage limiting components the following procedure a) applies.