

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

**Parafoudres basse tension –
Partie 12: Parafoudres connectés aux réseaux de distribution basse tension –
Principes de choix et d'application**



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2008 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester.

If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de la CEI ou du Comité national de la CEI du pays du demandeur.

Si vous avez des questions sur le copyright de la CEI ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de la CEI de votre pays de résidence.

IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland
Email: inmail@iec.ch
Web: www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

- Catalogue of IEC publications: www.iec.ch/searchpub

The IEC on-line Catalogue enables you to search by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, withdrawn and replaced publications.

- IEC Just Published: www.iec.ch/online_news/justpub

Stay up to date on all new IEC publications. Just Published details twice a month all new publications released. Available on-line and also by email.

- Electropedia: www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing more than 20 000 terms and definitions in English and French, with equivalent terms in additional languages. Also known as the International Electrotechnical Vocabulary online.

- Customer Service Centre: www.iec.ch/webstore/custserv

If you wish to give us your feedback on this publication or need further assistance, please visit the Customer Service Centre FAQ or contact us:

Email: csc@iec.ch
Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00

A propos de la CEI

La Commission Electrotechnique Internationale (CEI) est la première organisation mondiale qui élabore et publie des normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications CEI

Le contenu technique des publications de la CEI est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

- Catalogue des publications de la CEI: www.iec.ch/searchpub/cur_fut-f.htm

Le Catalogue en-ligne de la CEI vous permet d'effectuer des recherches en utilisant différents critères (numéro de référence, texte, comité d'études,...). Il donne aussi des informations sur les projets et les publications retirées ou remplacées.

- Just Published CEI: www.iec.ch/online_news/justpub

Restez informé sur les nouvelles publications de la CEI. Just Published détaille deux fois par mois les nouvelles publications parues. Disponible en-ligne et aussi par email.

- Electropedia: www.electropedia.org

Le premier dictionnaire en ligne au monde de termes électroniques et électriques. Il contient plus de 20 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans les langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International en ligne.

- Service Clients: www.iec.ch/webstore/custserv/custserv_entry-f.htm

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions, visitez le FAQ du Service clients ou contactez-nous:

Email: csc@iec.ch
Tél.: +41 22 919 02 11
Fax: +41 22 919 03 00

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

**Parafoudres basse tension –
Partie 12: Parafoudres connectés aux réseaux de distribution basse tension –
Principes de choix et d'application**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

PRICE CODE
CODE PRIX

XG

ICS 29.240; 29.240.10

ISBN 978-2-88910-550-2

CONTENTS

FOREWORD.....	8
0 Introduction	11
0.1 General.....	11
0.2 Keys to understanding the structure of this standard	11
1 Scope.....	13
2 Normative references	13
3 Terms, definitions and abbreviated terms	14
3.1 Terms and definitions	14
3.2 List of abbreviations and acronyms used in this standard	25
4 Systems and equipment to be protected	26
4.1 Low-voltage power distribution systems.....	26
4.1.1 Lightning overvoltages and currents	27
4.1.2 Switching overvoltages	28
4.1.3 Temporary overvoltages U_{TOV}	28
4.2 Characteristics of the equipment to be protected	30
5 Surge protective devices	31
5.1 Basic functions of SPDs	31
5.2 Additional requirements.....	31
5.3 Classification of SPDs	31
5.3.1 SPD: classification.....	31
5.3.2 Typical design and topologies.....	32
5.4 Characteristics of SPDs.....	33
5.4.1 Service conditions described in IEC 61643-1	33
5.4.2 List of parameters for SPD selection.....	34
5.5 Additional information on characteristics of SPDs.....	35
5.5.1 Information related to power-frequency voltages.....	35
5.5.2 Information related to surge currents	36
5.5.3 Information related to voltage protection level provided by SPDs.....	37
5.5.4 Information related to SPD failure modes	39
5.5.5 Information related to short-circuit withstand	40
5.5.6 Information related to load current I_L and to voltage drop (for two-port SPDs or one-port SPDs with separate input and output terminals)	40
5.5.7 Information related to change of characteristics of SPDs	40
6 Application of SPDs in low-voltage power distribution systems	40
6.1 Installation and its effect on the protection given by SPDs.....	40
6.1.1 Possible modes of protection and installation	41
6.1.2 Influence of the oscillation phenomena on the protective distance (called separation distance in some countries)	43
6.1.3 Influence of the connecting lead length.....	44
6.1.4 Need for additional protection.....	45
6.1.5 Consideration regarding location of the SPD depending on the classes of test	46
6.1.6 Protection zone concept	46
6.2 Selection of SPD	48
6.2.1 Selection of U_C , U_T , I_n , I_{imp} , I_{max} and U_{oc} of the SPD.....	49
6.2.2 Protective distance	

6.2.3	Prospective life and failure mode	53
6.2.4	Interaction between SPDs and other devices	53
6.2.5	Choice of the voltage protection level U_p	54
6.2.6	Coordination between the chosen SPD and other SPDs	55
6.3	Characteristics of auxiliary devices	57
6.3.1	Disconnecting devices	57
6.3.2	Event counters	57
6.3.3	Status indicator	57
7	Risk analysis	57
Annex A (informative) Typical information given with inquiries and tenders and explanation of testing procedures		59
A.1	Information given with inquiries	59
A.1.1	System data	59
A.1.2	SPD application considerations	59
A.1.3	Characteristics of SPD	59
A.1.4	Additional equipment and fittings	60
A.1.5	Any special abnormal conditions	60
A.2	Information given with tender	60
A.3	Explanation of testing procedures used in IEC 61643-1	60
A.3.1	Determination of U_{res} for SPDs tested according to class I and class II tests	60
A.3.2	Impulse waveshape for assessment of U_{res}	61
A.3.3	Influence of a back filter on determination of U_{res}	61
A.3.4	Operating duty test for SPDs	61
A.3.5	TOV failure test	62
A.3.6	Differences in the testing conditions of Type 1 (test class I), 2 (test class II) and 3 (test class III) SPDs	62
A.3.7	Short-circuit withstand capability test in conjunction with overcurrent protection (if any)	63
Annex B (informative) Examples of relationship between U_c and the nominal voltage used in some systems and example of relationship between U_p and U_c for ZnO varistor		64
B.1	Relationship between U_c and the nominal voltage of the system	64
B.2	Relationship between U_p and U_c for a ZnO varistor	64
Annex C (informative) Environment – Surge voltages in LV systems		66
C.1	General	66
C.2	Lightning overvoltages	66
C.2.1	Surges transferred from MV to the LV system	67
C.2.2	Overvoltages caused by direct flashes to LV distribution systems	67
C.2.3	Induced overvoltages in LV distribution systems	68
C.2.4	Overvoltages caused by flashes to a lightning protection systems or an area of close vicinity	68
C.3	Switching overvoltages	69
C.3.1	General description	70
C.3.2	Circuit-breaker and switch operations	70
C.3.3	Fuse operations (current-limiting fuses)	71
Annex D (informative) Partial lightning current calculations		72
Annex E (informative) TOV in the low-voltage system due to faults between high-voltage systems and earth		75

E.1 General	75
E.2 Example of a TT system – Calculation of the possible temporary overvoltages	76
E.2.1 Possible stresses on equipment in low-voltage installations due to earth faults in a high-voltage system	76
E.2.2 Characteristics of the high-voltage system	77
E.2.3 TOV in low-voltage system due to faults in the high-voltage system	77
E.2.4 Conclusions	78
E.3 Values of the temporary overvoltages according to IEC 60364-4-44	78
E.4 Values of the temporary overvoltages for the US TN C-S system.....	88
Annex F (informative) Coordination rules and principles.....	90
F.1 General	90
F.2 Analytical studies: simple case of the coordination of two ZnO varistor based SPDs	90
F.2.1 General	90
F.2.2 Conclusion	92
F.3 Analytical study: case of coordination between a gap-based SPD and a ZnO varistor based SPD.....	93
F.3.1 General	93
F.3.2 Example of the calculation of the estimated values required for a decoupling inductance between a gap and a varistor.....	94
F.3.3 Conclusion	95
F.4 Analytical study: general coordination of two SPDs	95
F.5 Let-through energy (LTE) method	96
F.5.1 General	96
F.5.2 Method.....	97
Annex G (informative) Examples of application	99
G.1 Domestic application	99
G.2 Industrial application.....	101
G.3 Presence of a lightning protection system.....	105
Annex H (informative) Examples of application of the risk analysis	107
Annex I (informative) System stresses	111
I.1 Lightning overvoltages and currents [4.1.1]	111
I.1.1 Aspects of the power distribution system that affect the need for an SPD	111
I.1.2 Sharing of surge current within a structure	111
I.2 Switching overvoltages [4.1.2]	112
I.3 Temporary overvoltages U_{TOV} [4.1.3]	113
Annex J (informative) Criteria for selection of SPDs.....	114
J.1 U_T temporary overvoltage characteristic [5.5.1.2]	114
J.2 SPD failure modes [5.5.4].....	114
Annex K (informative) Application of SPDs	117
K.1 Location and protection given by SPDs [6.1].....	117
K.1.1 Possible modes of protection and installation [6.1.1]	117
K.1.2 Influence of the oscillation phenomena on the protective distance [6.1.2]	126
K.1.3 Protection zone concept [6.1.6]	127
K.2 Selection of SPDs	129
K.2.1 Selection of U_C [6.2.1]	129
K.2.2 Coordination problems [6.2.6.2].....	130

K.2.3 Practical cases [6.2.6.3]	132
Annex L (informative) Risk analysis	133
L.1 Group A – Environmental	133
L.2 Group B – Equipment and facilities	133
L.3 Group C – Economics and service interruption	134
L.4 Group D – Safety	135
L.5 Group E – Cost of protection	135
Annex M (informative) Immunity vs. insulation withstand	136
Annex N (informative) Examples of SPD installation in power distribution boards in some countries	138
Annex O (informative) Coordination when equipment has both signalling and power terminals	143
Annex P (informative) Short circuit backup protection and surge withstand	150
P.1 Introduction	150
P.2 Information single shot 8/20 and 10/350 fuses withstand	150
P.3 Fuse Influencing factors (reduction) for preconditioning and operating duty test	151
P.4 Specific examples with estimated range of factors for reduction of single shot fuse withstand	151
Bibliography	153
Figure 1 – Examples of one-port SPDs	19
Figure 2 – Examples of two-port SPDs	20
Figure 3 – Output voltage response of one-port and two-port SPDs to a combination wave impulse	22
Figure 4 – Maximum values of U_{TOV} according to IEC 60634-4-44	30
Figure 5 – Examples of components and combinations of components	33
Figure 6 – Relationship between U_p , U_o , U_c and U_{cs}	35
Figure 7 – Typical curve of U_{res} versus I for ZnO varistors	38
Figure 8 – Typical curve for a spark gap	39
Figure 9 – Flowchart for SPD application	41
Figure 10 – Connection Type 1 (CT1)	42
Figure 11 – Connection Type 2 (CT2)	42
Figure 12 – Influence of SPD connecting lead lengths	45
Figure 13 – Need for additional protection	46
Figure 14 – Flowchart for the selection of an SPD	48
Figure 15 – U_T and U_{TOV}	51
Figure 16 – Typical use of two SPDs – Electrical drawing	55
Figure D.1 – Simple calculation of the sum of partial lightning currents into the power distribution system	72
Figure E.1 – Temporary power-frequency overvoltage caused by an earth fault in the high-voltage system	76
Figure E.2 – TN systems	79
Figure E.3 – TT systems	80
Figure E.4 – IT system, example a	81
Figure E.5 – IT system, example b	82

Figure E.6 – IT system, example c1	83
Figure E.7 – IT system, example c2	84
Figure E.8 – IT system, example d	85
Figure E.9 – IT system, example e1	86
Figure E.10 – IT system, example e2	87
Figure E.11 – US TN-C-S System	88
Figure F.1 – Two ZnO varistors with the same nominal discharge current	91
Figure F.2 – Two ZnO varistors with different nominal discharge currents	92
Figure F.3 – Example of coordination of a gap-based SPD and a ZnO varistor based SPD	95
Figure F.4 – LTE – Coordination method with standard pulse parameters	96
Figure G.1 – Domestic installation	100
Figure G.2 – Industrial installation	103
Figure G.3 – Circuitry of industrial installation	104
Figure G.4 – example for a lightning protection system	106
Figure I.1 – Example of diversion of lightning current into the external services (TT system)	112
Figure J.1 – Typical curve for U_T of an SPD	114
Figure J.2 – Internal disconnecter in the case of a two-port SPD	115
Figure J.3 – Use of parallel SPDs	116
Figure K.1 – Installation of surge protective devices in TN-systems	118
Figure K.2a – Connection Type 1	119
Figure K.2b – Connection Type 2	120
Figure K.2 – Installation of surge protective devices in TT-systems (SPD downstream of the RCD)	120
Figure K.3 – Installation of surge protective devices in TT-systems (SPD upstream of the RCD)	121
Figure K.4 – Installation of surge protective devices in IT-systems without distributed neutral	122
Figure K.5 – Typical installation of SPD at the entrance of the installation in case of a TN C-S system	123
Figure K.6 – General way of installing one-port SPDs	124
Figure K.7 – Examples of acceptable and unacceptable SPD installations regarding EMC aspects	125
Figure K.8 – Physical and electrical representations of a system where equipment being protected is separated from the SPD giving protection	126
Figure K.9 – Possible oscillation between a ZnO SPD and the equipment to be protected	126
Figure K.10 – Example of voltage doubling	127
Figure K.11 – Subdivision of a building into protection zones	128
Figure K.12a – Residual voltage on varistors	130
Figure K.12b – Sharing of current between two varistors	131
Figure K.12 – Coordination of two ZnO varistors:	131
Figure N.1 – A wiring diagram of an SPD connected on the load side of the main incoming isolator via a separate isolator (which could be included in the SPD enclosure)	138

Figure N.2 – SPD connected to the nearest available outgoing MCB to the incoming supply (TNS installation typically seen in the UK)	139
Figure N.3 – A single line-wiring diagram of an SPD connected in shunt on the first outgoing way of the distribution panel via a fuse (or MCB)	140
Figure N.4 – SPD connected to the nearest available circuit breaker on the incoming supply (US three phase 4W + G, TN-C-S installation)	141
Figure N.5 – SPD connected to the nearest available circuit breaker on the incoming supply (US single (split) phase 3W + G, 120/240 V system - typical for residential and small office applications)	142
Figure O.1 – Example of a PC with modem in a US power and communication system	144
Figure O.2 – Schematic of circuit of Figure O.1 used for experimental test	145
Figure O.3 – voltage recorded across reference points for the PC/modem during a surge in the example	146
Figure O.4 – typical TT system used for simulations	147
Figure O.5 – Voltage and current waveshapes when a multiservice SPD is applied to circuit of Figure O.1	149
Table 1 – Maximum TOV values as given in IEC 60634-4-44	29
Table 2 – Preferred values of I_{imp}	37
Table 3 – Possible modes of protection for various LV systems	43
Table 4 – Minimum recommended U_c of the SPD for various power systems	49
Table 5 – Typical TOV test values	50
Table B.1 – Relationship between U_c and nominal system voltage	64
Table B.2 – Relationship between U_p/U_c for ZnO varistors	65
Table F.1 –	98
Table F.2 –	98
Table F.3 –	98
Table O.1 – Simulation results	148
Table P.1 – Examples of ratio between single shot withstand and full preconditioning/operating duty test	152

INTERNATIONAL ELECTROTECHNICAL COMMISSION

LOW-VOLTAGE SURGE PROTECTIVE DEVICES –

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

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with an IEC Publication.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

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

This second edition of IEC 61643-12 cancels and replaces the first edition published in 2002. It constitutes a technical revision. Specific change with respect to the previous edition is the incorporation of Amendment 1, which was not published separately due to the number of changes and pages.

This standard shall be used in conjunction with IEC 61643-1:2005, *Low-voltage surge protective devices – Part 1: Surge protective devices connected to low-voltage power distribution systems – Requirements and tests*.

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

FDIS	Report on voting
37A/209/FDIS	37A/212/RVD

This publication has been drafted in accordance with the ISO/IEC Directives, Part 3.

IEC TC 37, SC 37A and SC 37B have adopted a new numbering scheme for all IEC publications developed within these committees.

In this standard, the IEC 61643 series of publications covers all the publications from SC 37A and SC 37B according to the table below with the common general title *Low-voltage surge protective devices*.

Publication	Title	Present document
IEC 61643	Low-voltage surge protective devices	–
IEC 61643-11	Low-voltage surge protective devices – Part 11: Surge protective devices connected to low-voltage power distribution systems – Performance requirements and testing methods	IEC 61643-1
IEC 61643-12	Low-voltage surge protective devices – Part 12: Surge protective devices connected to low-voltage power distribution systems – Selection and application principles	IEC 61643-12
IEC 61643-21	Low-voltage surge protective devices – Part 21: Surge protective devices connected to telecommunications and signalling networks – Performance requirements and testing methods	IEC 61643-21
IEC 61643-22	Low-voltage surge protective devices – Part 22: Surge protective devices connected to telecommunications and signalling networks – Selection and application principles	IEC 61643-22
IEC 61643-301	Low-voltage surge protective devices – Part 301: Components for surge protective devices – General test specifications	
IEC 61643-302	Low-voltage surge protective devices – Part 302: Components for surge protective devices – General performance specifications	
IEC 61643-303	Low-voltage surge protective devices – Part 303: Components for surge protective devices – General selection and application principles	
IEC 61643-311	Low-voltage surge protective devices – Part 311: Components for surge protective devices – Test specification for gas discharge tubes (GDTs)	IEC 61643-311
IEC 61643-312	Low-voltage surge protective devices – Part 312: Components for surge protective devices – Performance specification for gas discharge tubes (GDTs)	
IEC 61643-313	Low-voltage surge protective devices – Part 313: Components for surge protective devices – Selection and applications principles for gas discharge tubes (GDTs)	
IEC 61643-321	Low-voltage surge protective devices – Part 321: Components for surge protective devices – Test specification for avalanche breakdown diodes (ABDs)	IEC 61643-321
IEC 61643-322	Low-voltage surge protective devices – Part 322: Components for surge protective devices – Performance specification for avalanche breakdown diodes (ABDs)	
IEC 61643-323	Low-voltage surge protective devices – Part 323: Components for surge protective devices – Selection and applications principles for avalanche breakdown diodes (ABDs)	
IEC 61643-331	Low-voltage surge protective devices – Part 331: Components for surge protective devices – Test specification for metal oxide varistors (MOVs)	IEC 61643-331
IEC 61643-332	Low-voltage surge protective devices – Part 332: Components for surge protective devices – Performance specification for metal oxide varistors (MOVs)	
IEC 61643-333	Low-voltage surge protective devices – Part 333: Components for surge protective devices – Selection and application principles for metal oxide varistors (MOVs)	
IEC 61643-341	Low-voltage surge protective devices – Part 341: Components for surge protective devices – Test specification for thyristor surge suppressors (TSSs)	IEC 61643-341

IEC 61643-342	Low-voltage surge protective devices – Part 342: Components for surge protective devices – Performance specification for thyristor surge suppressors (TSSs)	
IEC 61643-343	Low-voltage surge protective devices – Part 343: Components for surge protective devices – Selection and application principles for thyristor surge suppressors (TSSs)	

The committee has decided that the contents of this publication will remain unchanged until the maintenance result 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

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

Withdrawn

0 Introduction

0.1 General

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

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

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

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

It also provides guidance for performing a risk analysis.

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

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

0.2 Keys to understanding the structure of this standard

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

Clause 1 describes the scope of this standard.

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

Clause 3 provides definitions useful for the comprehension of this standard.

Clause 4 addresses the parameters of systems and equipment relevant to SPDs. In addition to the stresses created by lightning, those created by the network itself, namely temporary overvoltages and switching surges, are described.

Clause 5 lists the electrical parameters used in the selection of an SPD and gives some explanation regarding these parameters. These are related to the data given in IEC 61643-1.

Clause 6 is the core of this standard. It relates the stresses coming from the network (as discussed in Clause 4) to the characteristics of the SPD (as discussed in Clause 5). It outlines how the protection given by SPDs may be affected by its installation. The different steps for the selection of an SPD are presented including the problems of coordination when more than one SPD is used in an installation (details about coordination may be found in Annex E).

Clause 7 is an introduction to the risk analysis (considerations of when the use of SPDs is beneficial).

Clause 8 deals with coordination between signalling and power lines (under consideration).

Annex A deals with information needed for tenders and explains testing procedures used in IEC 61643-1.

Annex B provides examples of the relationship between two important parameters of SPDs, U_c and U_p , in the specific case of ZnO varistors and also examples of the relationship between U_c and the nominal voltage of the network.

Annex C supplements the information given in Clause 4 on surge voltages in low-voltage systems.

Annex D deals with the calculation of the sharing of lightning current between different earthing systems.

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

Annex F supplements the information given in Clause 6 on coordination rules when more than one SPD is used in a system.

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

Annex H provides specific examples of the use of the risk analysis.

Annex I supplements the information given in Clause 4 about system stresses.

Annex J supplements the information given in Clause 5 on criteria for selection of SPDs.

Annex K supplements the information given in Clause 6 on the application of SPDs in various low-voltage systems.

Annex L supplements the information given in Clause 7 on the parameters used in risk analysis.

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

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

Annex O discusses problems of coordination with equipment having both signalling and power terminals

Annex P provides information on withstand of fuses in surge conditions

LOW-VOLTAGE SURGE PROTECTIVE DEVICES –

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

1 Scope

This part of IEC 61643 describes the principles for selection, operation, location and coordination of SPDs to be connected to 50 Hz to 60 Hz a.c. and to d.c. power circuits and equipment rated up to 1 000 V r.m.s. or 1 500 V d.c.

NOTE 1 Additional requirements may be necessary for special applications such as electrical traction, etc.

NOTE 2 It should be remembered that IEC 60364 series and IEC 62305-4 are also applicable.

NOTE 3 This standard deals only with SPDs and not with SPDs components integrated inside equipment.

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, *Lamp caps and holders together with gauges for the control of interchangeability and safety – Part 1: Lamp cap*

IEC 60364 (all parts), *Low-voltage electrical installations*

IEC 60364-4-41, *Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock*

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

IEC 60364-5-53: 2001, *Electrical installations of buildings – Part 5-53: Selection and erection of electrical equipment – Isolation, switching and control*

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

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

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

IEC 61008-1, *Residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs) – Part 1: General rules*

IEC 61009-1, *Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs) – Part 1: General rules*

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

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

IEC 62305-3, *Protection against lightning – Part 3: Physical damages to structures and life hazard*

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

IEC 61643-1 *Low-voltage surge protective devices – Part 1: Surge protective devices connected to low-voltage power distribution systems – Requirements and tests*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

NOTE These terms and definitions are for the most part reproduced from IEC 61643-1 (the definition number being indicated within square brackets). Where necessary a note has been added for better understanding regarding application of SPDs.

3.1.1

surge protective device

SPD

device that is intended to limit transient overvoltages and divert surge currents. It contains at least one non-linear component

[definition 3.1 of IEC 61643-1]

3.1.2

continuous operating current

I_c

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

3.1.3

maximum continuous operating voltage

U_c

maximum r.m.s. or d.c. voltage which may be continuously applied to the SPD's mode of protection. This is equal to the rated voltage

[definition 3.11 of IEC 61643-1]

3.1.4

voltage protection level

U_p

parameter that characterizes the performance of the SPD in limiting the voltage across its terminals, which is selected from a list of preferred values. This value is greater than the highest value of the measured limiting voltages

[definition 3.15 of IEC 61643-1]

3.1.5

measured limiting voltage

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

[definition 3.16 of IEC 61643-1]

3.1.6**residual voltage** U_{res}

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

[definition 3.17 of IEC 61643-1]

3.1.7**temporary overvoltage test value of the SPD** U_T

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

NOTE 1 Adapted from 3.18 of IEC 61643-1 by adding the following Note 2.

NOTE 2 It is a characteristic declared by the manufacturer that gives information about the behaviour of the SPD when stressed with voltages U_T above U_C for a given specific duration t_T (this behaviour may either be no change in the performance after application of the temporary overvoltage or a defined failure without hazard for either personnel, equipment or facility)

3.1.8**temporary overvoltage value of the power system** U_{TOV}

power frequency overvoltage occurring on the network at a given location, of relatively long duration. TOVs may be caused by faults inside the LV system ($U_{\text{TOV(LV)}}$) or inside the HV system ($U_{\text{TOV(HV)}}$)

NOTE Temporary overvoltages, typically lasting up to several seconds, usually originate from switching operations or faults (for example, sudden load shedding, single-phase faults, etc.) and/or from non-linearity (ferroresonance effects, harmonics, etc.)

3.1.9**nominal discharge current** I_n

crest value of the current through the SPD having a current waveshape of 8/20. This is used for the classification of the SPD for class II test and also for preconditioning of the SPD for class I and II tests

[definition 3.8 of IEC 61643-1]

3.1.10**impulse current** I_{imp}

it is defined by three parameters, a current peak value I_{peak} , a charge Q and a specific energy W/R . Tested according to the test sequence of the operating duty test. This is used for the classification of the SPD for class I test

[definition 3.9 of IEC 61643-1]

3.1.11**combination wave**

delivered by a generator that applies a 1,2/50 voltage impulse across an open circuit and an 8/20 current impulse into a short circuit. The voltage, current amplitude and waveforms that are delivered to the SPD are determined by the generator and the impedance of the SPD to which the surge is applied. The ratio of peak open-circuit voltage to peak short-circuit current is 2Ω , this is defined as the fictive impedance Z_f . The short-circuit current is symbolized by I_{sc} . The open-circuit voltage is symbolized by U_{oc}

[definition 3.24 of IEC 61643-1]

3.1.12

8/20 current impulse

current impulse with a virtual front time of 8 μ s and a time to half-value of 20 μ s where

- the front time is defined according to IEC 60060-1 to be $1,25 \times (t_{90} - t_{10})$, where t_{90} and t_{10} are the 90 % and 10 % points on the leading edge of the waveform;
- the time to half-value is defined as the time between the virtual origin and the 50 % point on the tail. The virtual origin is the point where a straight line, drawn through the 10 % and 90 % points on the leading edge of the waveform, intersects the $I = 0$ line.

[definition 3.23 of IEC 61643-1]

3.1.13

1,2/50 voltage impulse

voltage impulse with a virtual front time of 1,2 μ s and a time to half-value of 50 μ s where

- the front time is defined according to IEC 60060-1 to be $1,67 \times (t_{90} - t_{30})$, where t_{90} and t_{30} are the 90 % and 30 % points on the leading edge of the waveform;
- the time to half-value is defined as the time between the virtual origin and the 50 % point on the tail. The virtual origin is the point where a straight line, drawn through the 30 % and 90 % points on the leading edge of the waveform, intersects the $U = 0$ line.

[definition 3.22 of IEC 61643-1]

3.1.14

thermal runaway

operational condition when the sustained power dissipation of an SPD exceeds the thermal dissipation capability of the housing and connections, leading to a cumulative increase in the temperature of the internal elements culminating in failure

[definition 3.25 of IEC 61643-1]

3.1.15

thermal stability

an SPD is thermally stable if after the operating duty test causing temperature rise, the temperature of the SPD decreases with time when the SPD is energized at specified maximum continuous operating voltage and at specified ambient temperature conditions

[definition 3.26 of IEC 61643-1]

3.1.16

SPD disconnecter

device (internal and/or external) required for disconnecting an SPD from the power system

NOTE This disconnecting device is not required to have isolating capability. It is to prevent a persistent fault on the system and is used to give indication of the SPD failure.

There may be more than one disconnecter function for example, an over-current protection function and a thermal protection function. These functions may be integrated into one unit or performed in separate units.

[definition 3.29 of IEC 61643-1]

3.1.17

type tests

tests which are made upon the completion of the development of a new SPD design. They are used to establish representative performance and to demonstrate compliance with the relevant standard. Once made, these tests need not be repeated unless the design is changed so as to modify its performance. In such a case, only the relevant tests need be repeated

[definition 3.31 of IEC 61643-1]

3.1.18**routine tests**

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

[definition 3.32 of IEC 61643-1]

3.1.19**acceptance tests**

tests which are made when it has been agreed between the manufacturer and the purchaser that the SPD or representative samples of an order are to be tested

[definition 3.33 of IEC 61643-1]

3.1.20**degrees of protection provided by enclosure (IP code)**

extent of protection provided by an enclosure against access to hazardous parts, against ingress of solid foreign objects and/or against ingress of water (see IEC 60529)

[definition 3.30 of IEC 61643-1]

3.1.21**voltage drop (in per cent)**

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

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

[definition 3.20 of IEC 61643-1]

3.1.22**insertion loss**

at a given frequency, the insertion loss of an SPD connected into a given power system is defined as the ratio of voltages appearing across the mains immediately beyond the point of insertion before and after the insertion of the SPD under test. This result is expressed in decibels (dB)

NOTE Requirements and tests are under consideration.

[definition 3.21 of IEC 61643-1]

3.1.23**load-side surge withstand capability for a two-port SPD**

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

[definition 3.19 of IEC 61643-1]

3.1.24**short-circuit withstand**

maximum prospective short-circuit current that the SPD is able to withstand

NOTE 1 Adapted from 3.28 of IEC 61643-1 by adding the following Note 2.

NOTE 2 This definition refers both to d.c. and a.c. 50/60 Hz. Two short-circuit withstand values may be defined for two-port SPDs or one-port SPDs having separated input and output terminals: one corresponding to an internal short circuit (by-passing the internal active part) and another one corresponding to an external short circuit (load-side short-circuit) directly at the output terminals (case of a failure at the load).

3.1.25

one-port SPD

SPD connected in shunt with the circuit to be protected. A one-port device may have separate input and output terminals without a specified series impedance between these terminals

NOTE 1 Adapted from 3.2 of IEC 61643-1 by adding the following Note 2.

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

3.1.26

two-port SPD

SPD with two sets of terminals, input and output. A specific series impedance is inserted between these terminals

NOTE 1 Adapted from 3.3 of IEC 61643-1 by adding the following Note 2.

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

3.1.27

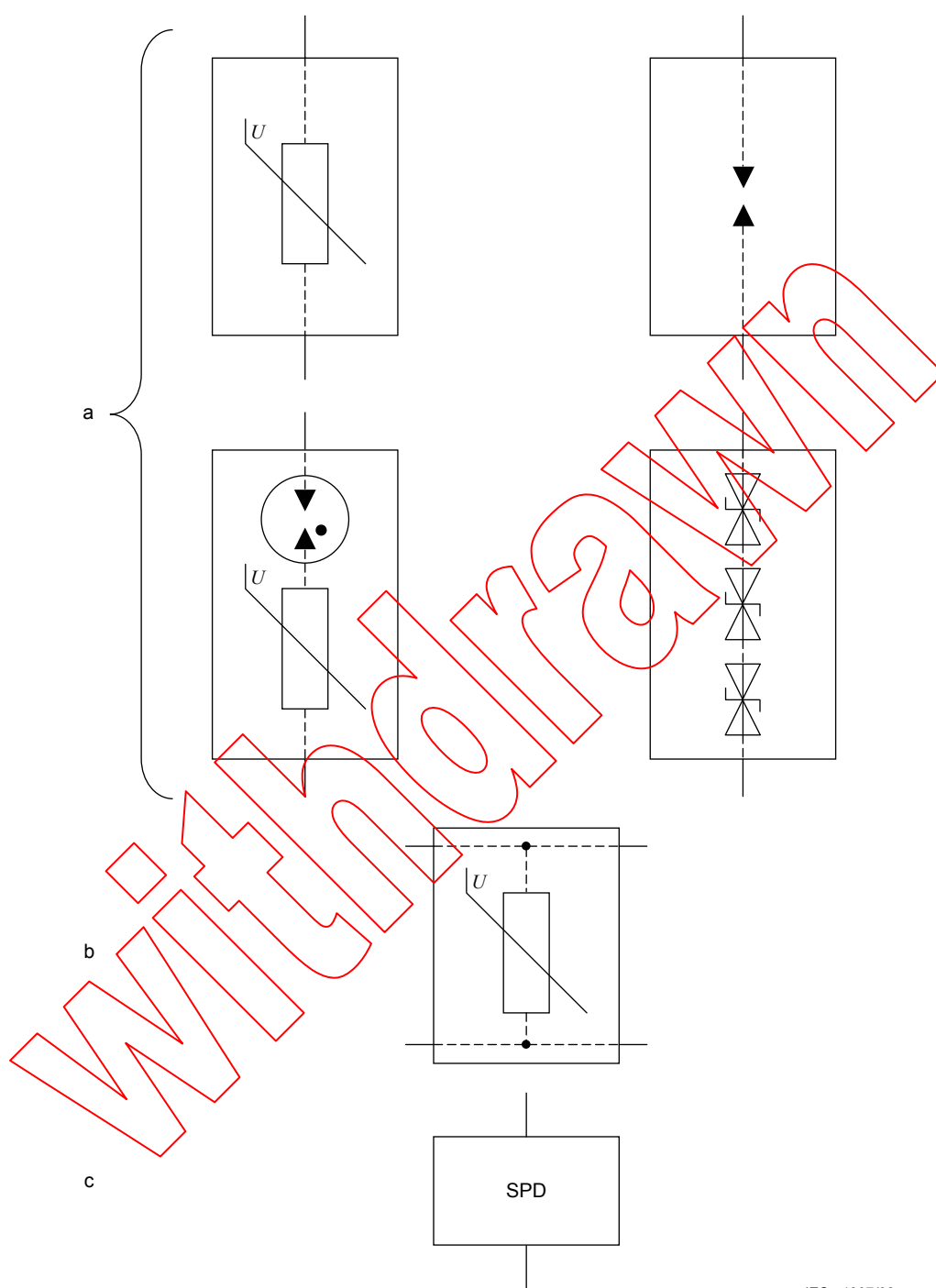
voltage switching type SPD

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 1 Common examples of components used as voltage-switching devices are spark-gaps, gas discharge tubes (GDT), thyristors (silicon controlled rectifiers) and triacs. These SPDs are sometimes called "crowbar type"

NOTE 2 Adapted from 3.4 of IEC 61643-1 by adding the following Note 3.

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

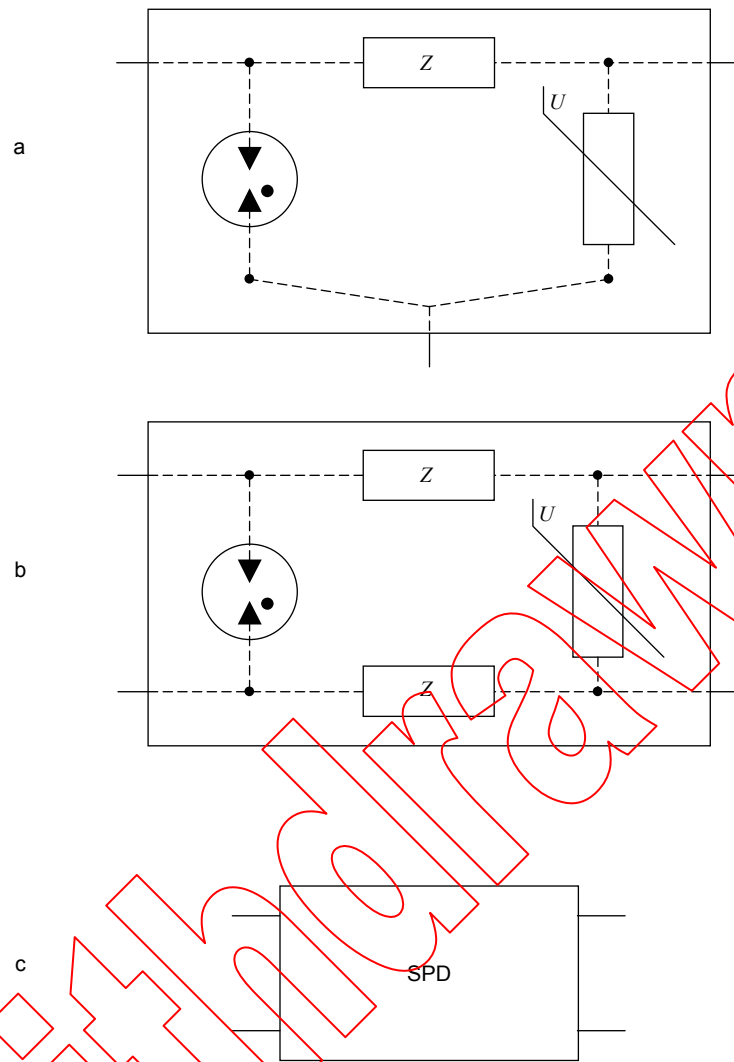


IEC 1907/08

Key

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

Figure 1 – Examples of one-port SPDs



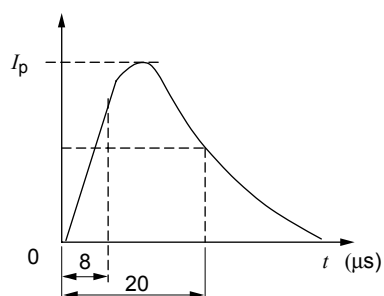
IEC 1908/08

Key

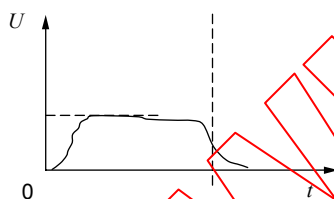
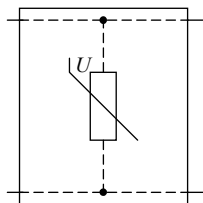
- a Three-terminal two-port SPD
- b Four-terminal two-port SPD
- c Generic symbol for a two-port SPD
- Z Series impedance between input and output terminals

Figure 2 – Examples of two-port SPDs

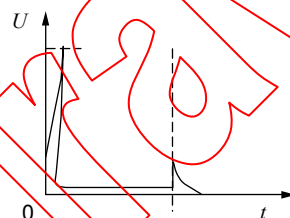
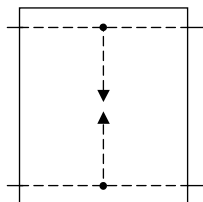
a



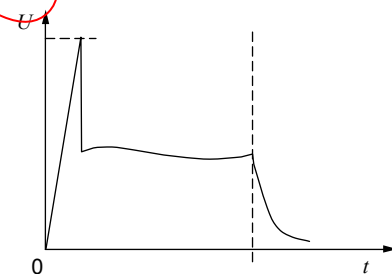
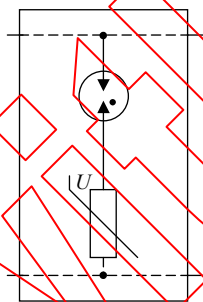
b



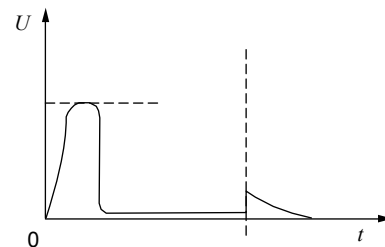
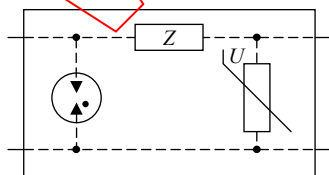
c



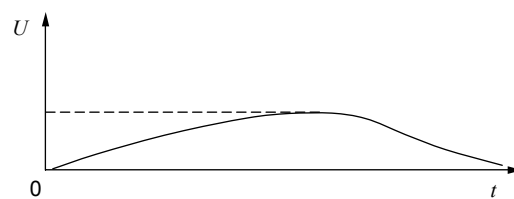
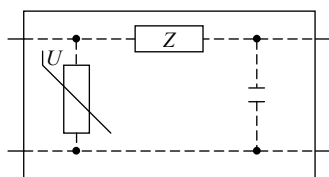
d



e



f



IEC 1909/08

Key

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

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

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

3.1.28

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 1 Common examples of components used as non-linear devices are: varistors and suppressor diodes. These SPDs are sometimes called "clamping type".

NOTE 2 Adapted from 3.5 of IEC 61643-1 by adding the following Note 3.

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

3.1.29

combination type SPD

SPD that incorporates both voltage switching type components and voltage limiting type components may exhibit voltage-switching, voltage-limiting, or both voltage-switching and voltage-limiting behaviour depending upon the characteristics of the applied voltage

NOTE 1 Adapted from 3.6 of IEC 61643-1 by adding the following Note 2.

NOTE 2 Figure 3d and Figure 3e show the response of various typical combination type SPDs to a combination wave impulse.

3.1.30

modes of protection

SPD protective components may be connected line to line or line to earth or line to neutral or neutral to earth and combination thereof. These paths are referred to as modes of protection

[definition 3.7 of IEC 61643-1]

3.1.31

follow current

(I_f)

current supplied by the electrical power system and flowing through the SPD after a discharge current impulse. The follow current is significantly different from the continuous operating current (I_c)

[definition 3.13 of IEC 61643-1]

3.1.32

maximum discharge current for class II test

(I_{max})

crest value of a current through the SPD having an 8/20 waveshape and magnitude according to the test sequence of the class II operating duty test. I_{max} is greater than I_n

[definition 3.10 of IEC 61643-1]

3.1.33

degradation

change of original performance parameters as a result of exposure of the SPD to surge, service or unfavourable environment

NOTE 1 Adapted from 3.27 of IEC 61643-1 by adding the following Note 2.

NOTE 2 Degradation is a measure of the ability of an SPD to withstand the conditions for which it is designed throughout its service life. Two type tests are applied to provide confidence with respect to degradation. The first one is the operating duty test and the second is the ageing test. However, these two tests may be combined.

The operating duty test is conducted by applying a specified number of defined current waveshapes to the SPD. Permitted changes in the SPD characteristics are given in IEC 61643-1.

The ageing test is carried out at a specified temperature with a voltage of specified magnitude and duration applied to the SPD. Permitted changes in the SPD characteristics are given in this standard (this test is under consideration).

This can be used to determine the SPD prospective installed life, which should also consider the following:

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

3.1.34

residual current device

RCD

mechanical switching device or association of devices intended to cause the opening of the contacts when the residual or unbalanced current attains a given value under specified conditions

[definition 3.37 of IEC 61643-1]

3.1.35

nominal voltage of the system

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

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

NOTE 2 The nominal voltage of the system phase to earth is called U_n (see IEC 60038).

NOTE 3 The line-to-neutral voltage of the system is called U_0 .

NOTE 4 The line-to-line voltage of the system is called U .

3.1.36

Impulse test classification

3.1.36.1

class I test

test carried out with the nominal discharge current (I_n) defined in 3.1.9, the 1,2/50 voltage impulse defined in 3.1.13, and the maximum impulse current (I_{imp}) for class I test defined in 3.1.10

3.1.36.2

class II test

test carried out with the nominal discharge current (I_n) defined in 3.1.9, the 1,2/50 voltage impulse defined in 3.1.13, and the maximum discharge current (I_{max}) for class II test defined in 3.1.32

3.1.36.3

class III test

tests carried out with the combination wave (1,2/50, 8/20) defined in 3.1.11

NOTE Adapted from 3.35 of IEC 61643-1.

3.1.37

rated load current

(I_L)

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

NOTE 1 Adapted from 3.14 of IEC 61643-1 by adding the following Note 2.

NOTE 2 This is only relevant to SPD(s) having separate input and output terminals.

3.1.38

overcurrent protection

overcurrent device (e.g. circuit breaker or fuse), which could be part of the electrical installation located externally up-stream of the SPD

[definition 3.36 of IEC 61643-1]

3.1.39

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

(U_{cs})

maximum r.m.s. or d.c. voltage to which the SPD may be permanently subjected at the point of application of the SPD

NOTE 1 This takes into account only voltage regulation and/or voltage drop or increase. It is also called actual maximum system voltage (see Figure 6) and is directly linked to U_0 .

NOTE 2 This voltage does not take into account harmonics, faults, TOVs or transient conditions.

3.1.40

sparkover voltage of a voltage-switching SPD

maximum voltage value before disruptive discharge between the electrodes of the gap of a SPD

NOTE 1 Adapted from 3.38 of IEC 61643-1 by adding the following Note 2.

NOTE 2 A voltage-switching SPD may be based on components other than gaps (for example, silicon-based components).

3.1.41

lightning protection system

LPS

complete system used to protect a structure and its contents against the effects of lightning

3.1.42

multiservice SPD

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

3.1.43**residual current****(I_{PE})**

current flowing through the PE terminal, when the SPD is energized at the maximum continuous operating voltage (U_c) when connected according to the manufacturer instructions

[definition 3.42 of IEC 61643-1]

3.1.44**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

[definition 3.40 of IEC 61643-1]

3.1.45**follow current interrupting rating****(I_{fi})**

prospective short-circuit current that an SPD is able to interrupt by itself

[definition 3.41 of IEC 61643-1]

3.1.46**Specific energy for class I test****(W/R)**

energy dissipated by a unit resistance of 1 Ω with the impulse discharge current I_{imp}

3.1.47**Rated impulse withstand voltage****(U_w)**

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

NOTE For the purpose of this standard only withstand voltages between live conductors and earth is considered.

3.2 List of abbreviations and acronyms used in this standard

List of abbreviations	
E_{MAX}	Maximum energy withstand
I_c	Continuous operating current
I_f	Follow current
I_{fi}	Follow current interrupting rating
I_{imp}	Impulse current for class I test
I_L	Rated load current
I_{max}	Maximum discharge current for class II test
I_n	Nominal discharge current
I_p	Prospective short-circuit current of a power supply
I_{peak}	Current peak value of impulse current
I_{PE}	Residual current
I_{sc}	Short-circuit current of the CWG
N_g	Ground flash density
N_k	Keraunic level
U_c	Maximum continuous operating voltage
U_{cs}	Maximum continuous operating voltage of the power system
U_m	Measured limiting voltage
U_n	Nominal voltage of the system phase to earth

U_0	Line-to-neutral voltage of the system
U_{oc}	Open-circuit voltage for class III test
U_p	Voltage protection level
U_{ref}	Reference voltage of a varistor
U_{res}	Residual voltage
U_T	Temporary overvoltage
U_{TOV}	Temporary overvoltage of the power system
$U_{TOV(HV)}$	Temporary overvoltage of the network inside the high-voltage system
$U_{TOV(LV)}$	Temporary overvoltage of the network inside the low-voltage system
U_W	Voltage withstand
ΔU	Voltage drop (in %)
Z_i	Fictive impedance

List of acronyms	
ABD	Avalanche breakdown diode
dB	Decibel
CWG	Combination wave generator
EMC	Electromagnetic compatibility
GDT	Gas discharge tube
HV	High voltage
IP	Degrees of protection provided by the enclosure
L	Inductance
LPS	Lightning protection system
LPZ	Lightning protection zone
LTE	let-through energy
LV	Low voltage
MEB	Main equipotential bonding
MOV	Metal oxide varistor
HVA	High voltage A (medium voltage, <50 kV)
MV	Medium voltage
PE	Protective earth
Q	Charge (of impulse current)
RCD	Residual current device
TOV	Temporary overvoltage
SPD	Surge protective device
W/R	Specific energy
ZnO	Zinc oxide

4 Systems and equipment to be protected

When evaluating an installation with regard to the use of an SPD, two factors need to be considered:

- the characteristics of the low-voltage power distribution system on which it will be used, including expected types and levels of overvoltage and current;
- the characteristics of the equipment requiring protection.

4.1 Low-voltage power distribution systems

Low-voltage power distribution systems are basically characterized by the type of system earthing (TNC, TNS, TNC-S, TT, IT) and the nominal voltage (see 3.35). Various types of

overvoltages and currents can occur. In this standard, the overvoltages are classified into three groups:

- lightning;
- switching;
- temporary overvoltages.

4.1.1 Lightning overvoltages and currents

In most cases lightning stress is the main factor for the selection of an SPD's class of test and associated current or voltage values (I_{imp} , I_{max} or U_{oc} , according to IEC 61643-1).

Evaluation of the waveshape and current (or voltage) amplitude of the lightning surges is necessary for the proper selection of an SPD. It is important to determine if the voltage protection level of the SPD will be adequate to protect the equipment in such circumstances.

For buildings with lightning protection systems, additional information on current amplitude and waveshape can be found in IEC 62305-1

NOTE For example, areas prone to frequent lightning strikes may require an SPD suitable to withstand class I or class II tests.

Generally (for example, in the case of direct strike to the lines or induced surges on the lines), higher stresses occur on the electrical installation external to the structure. Within the structure, the stresses are decreased when moving from the installation's entrance to internal circuits. The decrease is due to the change of circuit configuration and impedances.

The need for protection against lightning surges depends on

- the local ground flash density N_g (average annual ground flash density, in lightning flashes per km² per year, concerning the region where the structure is located). Modern lightning location systems can provide information on N_g with reasonable accuracy;
- the exposure of the electrical installation, including incoming services. Underground systems are generally considered to be less exposed than overhead systems.

Even if the supply is provided by an underground cable, the use of an SPD may be recommended to provide protection. To determine if surge protection is needed, the following are some items that should be considered:

- the installation has a lightning protection system in its vicinity;
- the length of the cable is not sufficient to provide adequate separation (attenuation) of the installation from the overhead part of the network;
- high surges of atmospheric origin can be expected on the overhead line supplying the MV (medium voltage) side of the transformer connected to the installation;
- the underground cable may be affected by direct lightning in the presence of high soil resistivity;
- the size or height of the building powered by the cable is large enough to significantly increase the risk for direct strikes to the building. The risk for direct strikes to other incoming (outgoing) services (telephone lines, antenna systems, etc.) that could affect the power system and equipment;
- other overhead services are present.

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

For SPD installations in a structure, which is equipped with an external lightning protection system, it is (in case of direct lightning to the structure) generally sufficient to make

calculations using earthing d.c. resistance readings (for example, earthing of the building and power distribution system, pipes, etc), to determine the current distribution through the SPDs.

The evaluation of the waveform and current amplitude, as function of the lightning protection level and due to different sources of damage (i.e. direct to or close to the structure, direct to or near the power line) are reported in Annex E of IEC 62305-1.

Annex C and Annex I give more information about lightning stress.

4.1.2 Switching overvoltages

These stresses, in terms of peak current and voltage, are usually lower than lightning stresses but could have longer duration. However, in some cases, particularly deep inside a structure or close to switching overvoltage sources, the switching stress can be higher than the stresses caused by lightning. The energy related to these switching surges needs to be known to permit the choice of appropriate SPDs. The time duration of the switching surges, including transients due to faults and fuse operations, can be much longer than the lightning surge duration.

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

Annex C and Annex I give more information about switching stress.

4.1.3 Temporary overvoltages U_{TOV}

4.1.3.1 General

Any SPD can be exposed to a temporary overvoltage U_{TOV} during its lifetime that exceeds the maximum continuous operating voltage of the power system.

A temporary overvoltage has two dimensions, magnitude and time. The time duration of the overvoltage primarily depends upon the earthing of the supply system (this includes both the high-voltage supply system as well as the low-voltage system to which the SPD is connected). In determining the temporary overvoltages, consideration should be given to the maximum continuous operating voltage of the power system (U_{CS}).

Annex E and Annex I provide more information about temporary overvoltage.

4.1.3.2 Standardized values

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

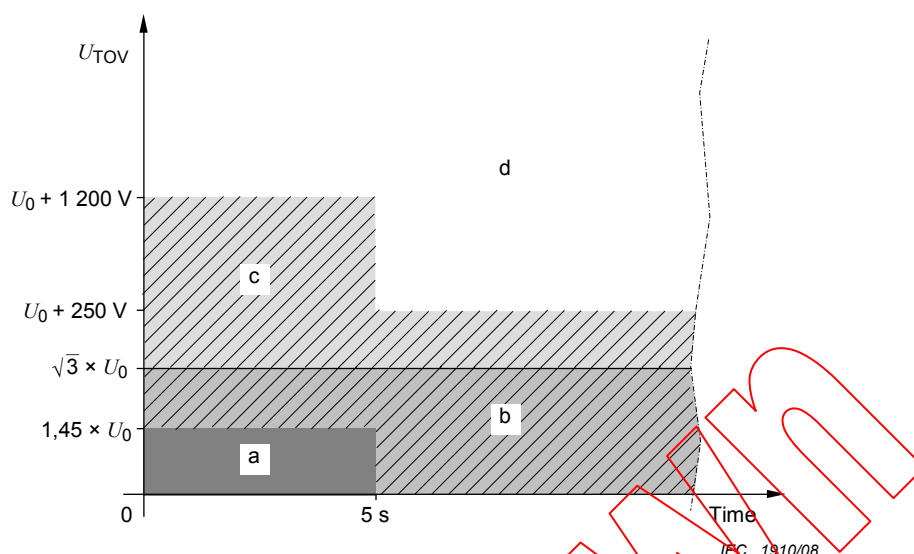
Lower values are possible depending on many factors such as the location of the SPD, the type of power system, etc.

The maximum values (see also Figure 4) given in Table 1 are at the consumer installation for transformer location (see Table 1, Note 2).

Table 1 – Maximum TOV values as given in IEC 60634-4-44

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

For further information, see Annex E.



Key

- a Area of $U_{TOV(LV)}$ between phase and neutral for TT, TN and IT systems for a fault in the LV installation (short circuit)
- b Area of $U_{TOV(LV)}$ between phase and earth for IT (TT, see Table 1, Note 1) system for a fault in the LV installation (accidental earthing of a phase conductor) and area of $U_{TOV(LV)}$ between phase and neutral for TT and TN systems for a fault in the LV installation (loss of neutral)
- c Maximum value for $U_{TOV(HV)}$ at the consumer installation between phase and earth for TT and IT systems in the case of a fault occurring in the HV system
- d Undefined area

Figure 4 – Maximum values of U_{TOV} according to IEC 60634-4-44

4.2 Characteristics of the equipment to be protected

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

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

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

NOTE The selected SPDs should provide a protective level U_p lower than the impulse withstand capability of the equipment or, in some cases where the continuous operation of the equipment is critical, lower than the impulse immunity of the equipment. U_p should be selected in accordance with 6.2.2 and 6.2.5. In addition, due to possible interaction between the equipment under test and the generator, the immunity of the equipment is a function not only of U_p but of the waveshape of the applied surge.

5 Surge protective devices

5.1 Basic functions of SPDs

The SPDs considered in this standard are those installed external to the equipment to be protected.

Their function can be described as follows.

- In power systems in the absence of surges: the SPD shall not have a significant influence on the operational characteristics of the system to which it is applied.
- In power systems during the occurrence of surges: the SPD responds to surges by lowering its impedance and thus diverting surge current through it to limit the voltage to its protective level. The surges could initiate a power follow current through the SPD.
- In power systems after the occurrence of surges: the SPD recovers to a high-impedance state after the surges and extinguishes any possible power follow current.

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

5.2 Additional requirements

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

- protection of SPDs against direct contact (it shall be in accordance with IEC 60364-4-41);
- safety in the event of SPD failures.

An SPD may fail when subjected to a surge greater than its designed maximum energy and discharge current capability. For the purpose of this standard, failure modes of SPDs are divided into open-circuit and short-circuit mode.

In the open-circuit mode the system to be protected is no longer protected. In this case, failure of an SPD is usually difficult to detect since it has almost no influence on the system. To ensure that the failed SPD is replaced before the next surge, an indication function may be required.

In the short-circuit mode, the system is severely influenced by the failed SPD. The short-circuit current flows through the failed SPD from the power source. Energy dissipated during the conduction of short-circuit current may be excessive and cause a fire hazard. The short-circuit withstand capability test of IEC 61643-1 covers this problem. In cases where the system to be protected has no suitable device to disconnect the failed SPD from its circuit, a suitable disconnecting device may be required to be used in conjunction with a SPD which has a short-circuit failure mode.

5.3 Classification of SPDs

5.3.1 SPD: classification

Surge protective devices are classified according to IEC 61643-1 as follows.

Number of ports:	one or two
Design topology:	voltage switching, voltage limiting or combination
SPD Class I, II and/or III tests	
Location:	indoor or outdoor
Accessibility:	accessible, inaccessible (out-of-reach)

Mounting method: fixed or portable

Disconnecter: location (external, internal, both external and internal, none) and protection functions (thermal, leakage current, overcurrent)

Overcurrent protection: specified or not

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

Temperature range: normal or extended

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

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

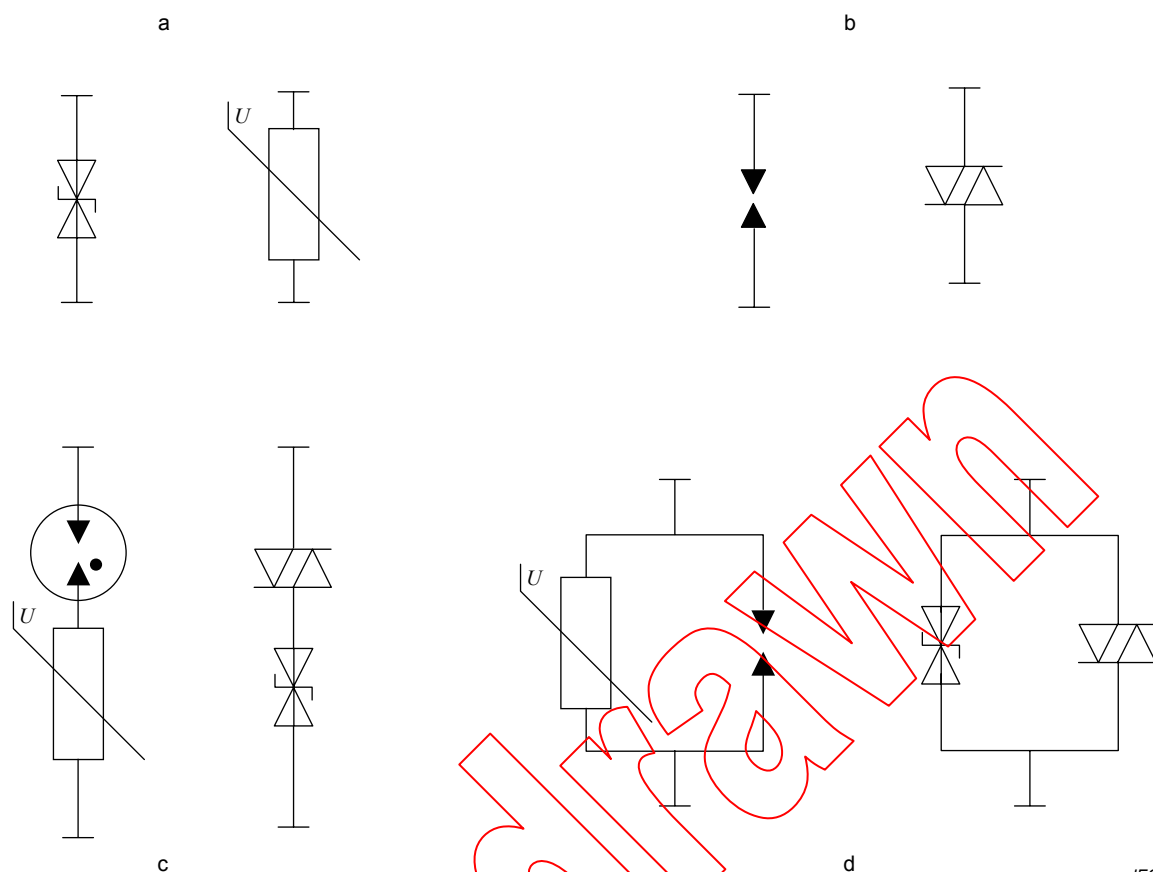
5.3.2 Typical design and topologies

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

- voltage-limiting components: varistors, avalanche or suppressor diodes, etc.;
- voltage-switching components: air gaps, gas discharge tubes, thyristors (silicon-controlled rectifiers), triacs, etc.

Based on these components, typical SPD designs are given below (see Figure 5):

- single voltage-limiting component (Figure 5a): limiting type SPD;
- single voltage-switching component (Figure 5b): switching type SPD;
- combination of voltage-limiting and switching components (Figures 5c and d): combination type SPD.



IEC 1911/08

Key

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

Figure 5 – Examples of components and combinations of components

Not all SPDs are defined by a simple arrangement of basic components. They may additionally incorporate indicators, disconnectors, fuses, inductors, capacitors and other components.

Additionally an SPD can be configured as: one-port SPD (see 3.25) or two-port SPD (see 3.26).

5.4 Characteristics of SPDs**5.4.1 Service conditions described in IEC 61643-1**

Normal service conditions:

- The frequency of the supply mains is between 48 Hz and 62 Hz a.c. or d.c.
- The altitude shall not exceed 2 000 m.
- Operating temperature: normal range $-5\text{ }^{\circ}\text{C}$ to $+40\text{ }^{\circ}\text{C}$, extended range $-40\text{ }^{\circ}\text{C}$ to $+70\text{ }^{\circ}\text{C}$.
- The relative humidity in indoor temperature conditions shall be between 30 % and 90 %.

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

NOTE 2 IEC 61643-1 also gives indications regarding maximum continuous operating voltage of the SPDs. See 6.2.1 of this standard.

NOTE 3 In general, the temperature ranges for storage of a product is greater than for operation

Abnormal service conditions:

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

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

NOTE 3 In general, the degree of protection of the SPD enclosure should be greater than IP2X. In some instances, other values could be used (for example, for outdoor SPDs).

5.4.2 List of parameters for SPD selection

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

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

- a) U_c : Maximum continuous operating voltage
- b) Temporary overvoltage characteristic
- c) I_n : Nominal discharge current (only for class I and for class II tests)
- d) I_{max} for class II tests, I_{imp} for class I tests, U_{oc} for class III tests
- e) U_p : Voltage protection level
- f) Failure modes
- g) Short-circuit withstand
- h) I_{fi} : Follow current interrupting rating (except in the case of voltage limiting type SPDs)
- i) Rated load current I_L (for two-port SPDs or one-port SPDs with separate input and output terminals)
- j) Voltage drop (for two-port SPDs or one-port SPDs with separate input and output terminals)
- k) I_{PE} : Residual current (optional)

Figure 6 shows the relationship between U_p , U_0 , U_c and U_{cs} .

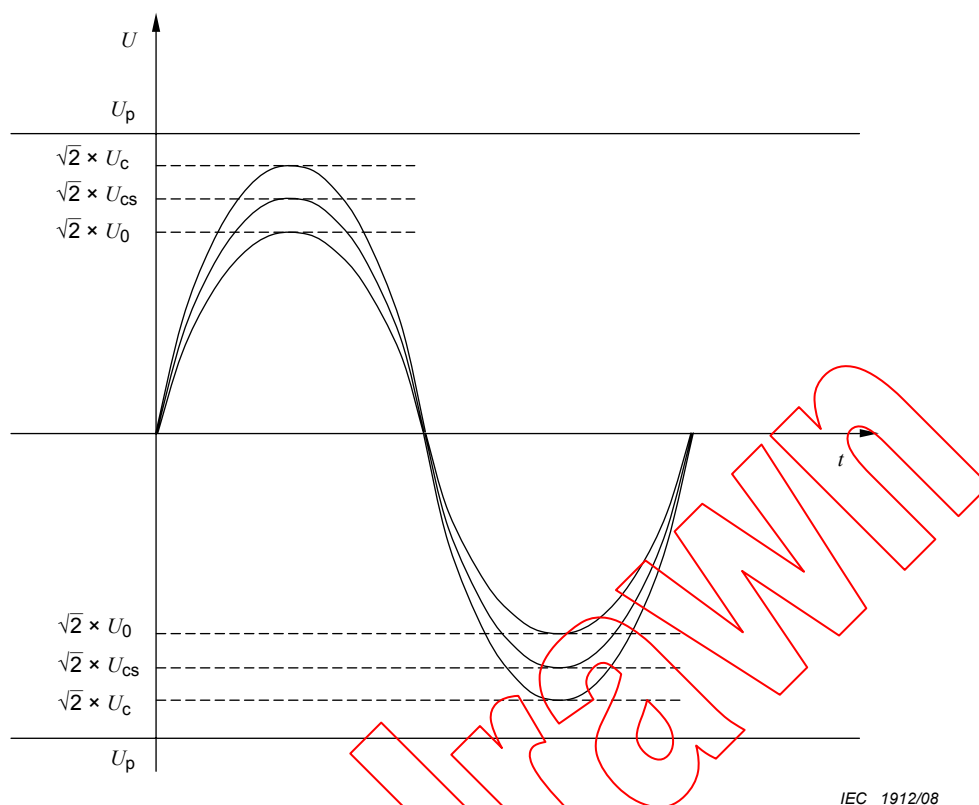


Figure 6 – Relationship between U_p , U_0 , U_c and U_{cs}

5.5 Additional information on characteristics of SPDs

5.5.1 Information related to power-frequency voltages

5.5.1.1 U_C : Maximum continuous operating voltage and I_C continuous operating current

~~U_C shall be selected in order to minimize any changes in SPD characteristics (ageing, thermal runaway, etc.) under normal conditions.~~

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

See Annex J for further information on how the effect of the operation of an overcurrent or other protective device depends on the configuration of the system.

5.5.1.2 Temporary overvoltage characteristics

A few sets of values of power frequency (or d.c.) overvoltage versus time (up to several seconds) are sufficient to characterise the temporary overvoltage characteristic of an SPD.

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

SPDs installed according to IEC 60364-5-53 shall withstand the TOV due to fault in the low voltage power system (See TOV values for 5 s duration in Table 5). The SPD installed between neutral and PE according to CT2 connection scheme (see Figure 11) shall also

withstand the TOV due to fault in the high voltage power system (See TOV values for 200 ms duration in Table 5)

Durations for TOVs considered by IEC 61643-1 are limited to two durations 200 ms and 5 s and related test voltage values are called U_T .

The temporary characteristic shall be given by the manufacturer according to IEC 61643-1.

NOTE Selecting an SPD with both a high temporary overvoltage withstand and a low voltage protection level may be difficult while still maintaining coordination with the equipment to be protected.

The user can select the most suitable SPD by comparing the temporary overvoltage characteristic of the SPD and the temporary overvoltages (U_{TOV}) occurring on the power system. Standardized values used for SPD testing are given in Table 5.

5.5.2 Information related to surge currents

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

Guidance to the selection of the appropriate test class(es) for an SPD is given in the introduction to IEC 61643-1, which states the following.

- 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, for example, 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. These SPDs are generally recommended for locations with lesser exposure to direct impulses.

When selecting an SPD it is necessary to consider both the test class and the magnitude of the impulse for which it is rated.

NOTE 1 The class II test applies an impressed current to the SPD. The class III test applies a voltage to the SPD, and the resultant current depends on the characteristics of the SPD.

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

5.5.2.1 I_n : Nominal discharge current (8/20) (for SPDs according to class I and II tests)

This is the current that is used as one test parameter for determining the measured limiting voltage for SPDs tested according to the class I and class II tests. This current is also used during preconditioning (applied 15 times) for the operating duty test for class I and class II.

I_n is lower than I_{max} and corresponds to a current that is expected to occur quite frequently in the field.

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

5.5.2.2 I_{imp} and I_{max} (for SPDs according to class I and II tests)

I_{imp} and I_{max} are test parameters used in the operating duty test for class I and class II tests respectively. They are related to the maximum values of discharge currents, which are expected to occur only very rarely at the location of the SPD in the system. I_{max} is associated with class II tests and I_{imp} is associated with class I tests.

The preferred values for I_{imp} (I_{peak} , Q , W/R), according to IEC 61643-1, are given in Table 2.

Table 2 – Preferred values of I_{imp}

I_{peak} kA	Q C	W/R kJ/ Ω
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 1 In general I_{imp} is associated with longer waveshapes than I_n

NOTE 2 The 10/350 waveshape is one example of a waveshape which meets the requirements of Table 2

5.5.3 Information related to voltage protection level provided by SPDs

5.5.3.1 Measured limiting voltage

a) Class I and class II tests

The determination of the measured limiting voltage is made by performing two tests:

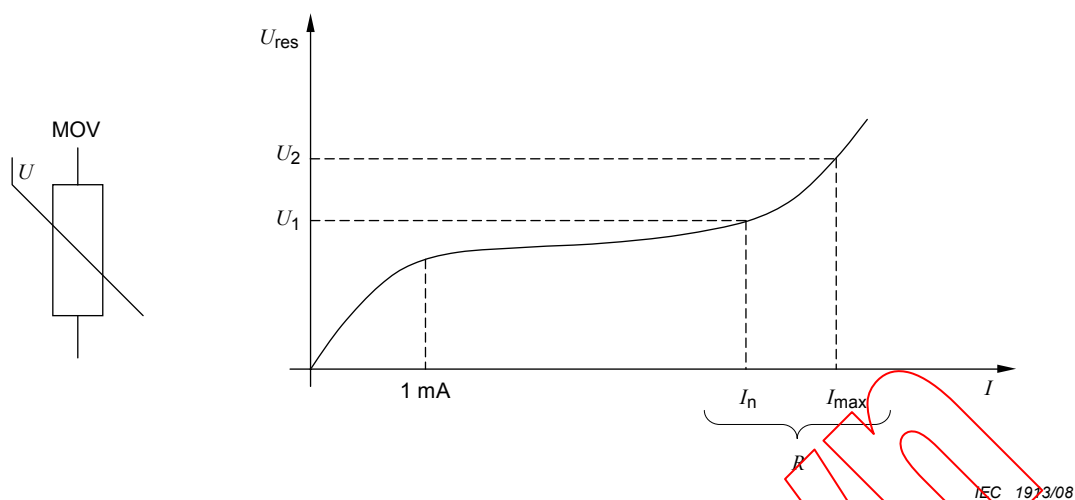
- measurement of the residual voltage at various values of current using 8/20 wave;
- measurement of the sparkover voltage using a 1,2/50 wave.

The measured limiting voltage is the highest voltage value of

- either the residual voltage, for the range of current from $0,1 \times I_n$ up to I_{peak} or I_n whichever is the greater for class I test; from $0,1 \times I_n$ up to $1,0 \times I_n$ for class II test;
- or the front of wave sparkover voltage using a 1,2/50 wave.

• SPDs with voltage-limiting components

Figure 7 shows a typical curve U_{res} versus I for a ZnO varistor. This shows that the residual voltage of the SPD at I_{max} shall also be considered. If this voltage is higher than the voltage protection level and especially if it is higher than the impulse withstand voltage of the equipment to be protected, then there is a risk that the SPD will survive such a stress but the equipment will not be protected. Voltage protection level and surge current withstand of the SPD shall, therefore, be selected accordingly.



Key

U_1 Residual voltage at I_n

U_2 Residual voltage at I_{max}

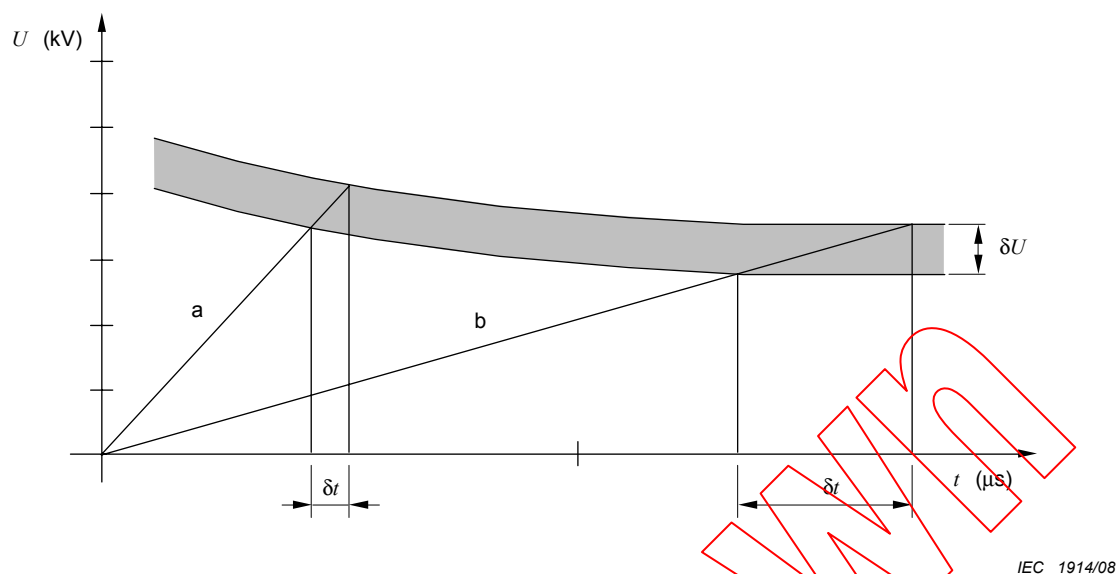
R Range of several kA

Figure 7 – Typical curve of U_{res} versus I for ZnO varistors

- SPDs with voltage-switching components

The impulse sparkover voltage of a spark gap device (gas discharge tube etc.) is dependent upon the rate of rise (dU/dt) of the applied transient overvoltage.

Generally, an increase in the voltage rate of rise (dU/dt) of the transient leads to an increase of the impulse sparkover voltage. As impulse sparkover voltage is a statistical value at a defined dU/dt , there will be a spread in the measured values (see Figure 8).



Key

- a Higher rate of rise – 10 kV/μs
- b Lower rate of rise – 1 kV/μs
- δt Spread in time of sparkover
- δU Spread in voltage of sparkover

Figure 8 – Typical curve for a spark gap

b) Class III tests

For SPDs tested according to class III, a combination wave generator is used. The maximum value measured during the test is then used as the measured limiting voltage.

5.5.3.2 Voltage protection level U_p

U_p is declared by the manufacturer. By definition it is equal to or greater than, the highest value of the measured limiting voltage. Selection of this value by the manufacturer should allow for manufacturing tolerances.

The preferred voltage protection levels are: (0,08; 0,09; 0,10; 0,12; 0,15; 0,22; 0,33; 0,4; 0,5; 0,6; 0,7; 0,8; 0,9; 1,0; 1,2; 1,5; 1,8; 2,0; 2,5; 3,0; 4,0; 5,0; 6,0; 8,0; and 10) kV.

Annex B gives a typical relationship between the nominal voltage of the system and the voltage protection level of the SPD for a ZnO varistor.

5.5.4 Information related to SPD failure modes

These modes are used to define the compatibility of the SPD with other equipment, with its application and with the devices used in conjunction with the SPD.

Failure mode of the SPD is dependent on the magnitude, number and waveshape of the surge current and voltage, short-circuit capacity of the power system and value of the voltage applied to the SPD at the time of the failure. This standard considers that there are two failure modes of an SPD:

- short-circuit or low impedance

- open-circuit or high impedance.

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

See Annex J for further information on how the effect of the operation of an overcurrent or other protective device depends on the configuration of the system.

Changes in the characteristics of the SPD are not considered as a failure mode, but are addressed in 5.5.7.

5.5.5 Information related to short-circuit withstand

The SPD alone or in conjunction with its disconnect and/or overcurrent protection is required to withstand the short-circuit withstand current declared by the manufacturer. The SPD should pass the test without burning, charring or expulsion of molten material or by creating an opening in the enclosure. It is necessary to ensure that the SPD will not be used at a place where the prospective short-circuit current of the power supply I_p is greater than its short-circuit withstand. It is also necessary to ensure that an adequate disconnect and/or overcurrent protection as recommended by the manufacturer is present and working.

For an SPD which is not of the voltage limiting type, it is also necessary to check that its follow current interrupting rating I_{fi} is higher than the prospective short-circuit current at the point of the installation I_p .

5.5.6 Information related to load current I_L and to voltage drop (for two-port SPDs or one-port SPDs with separate input and output terminals)

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

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

It is also necessary to check that the installation of a two-port SPD, or one-port SPD with separate input and output terminals, does not result in an unacceptable voltage drop at the equipment located downstream. This is characterized by the voltage drop ΔU .

5.5.7 Information related to change of characteristics of SPDs

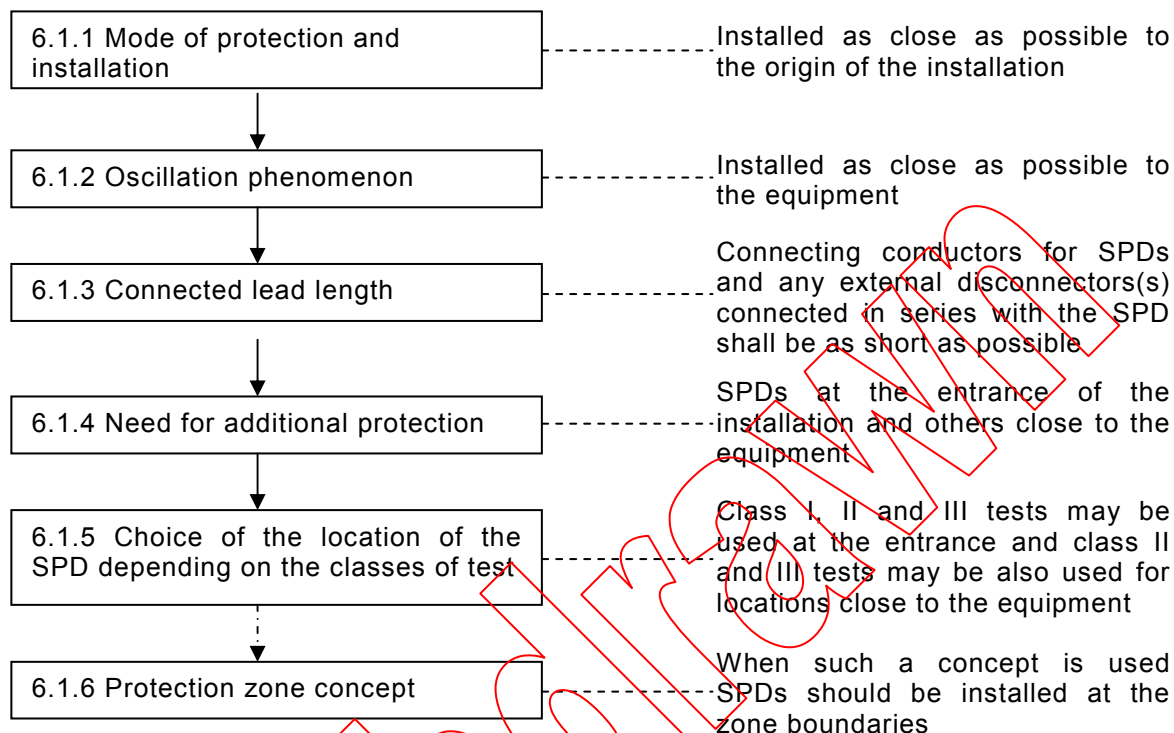
Certain SPDs may enter an intermediate state when subjected to higher stress than that defined in the standard tests. In this case some of their characteristics may change from the designed values, for example: U_p , I_n , I_c , etc. In particular, this may occur for SPDs having active parts in parallel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

6 Application of SPDs in low-voltage power distribution systems

6.1 Installation and its effect on the protection given by SPDs

When a risk analysis is performed (see Clause 7), the stresses in the system (Clause 4) and the characteristics of the SPD (Clause 5) being identified can be specified.

In applying an SPD in a power-distribution system the flow chart shown in Figure 9 may be used.



IEC 343/02

Figure 9 – Flowchart for SPD application

Examples of practical installation of SPDs are given in Annex N

At the point of entry depending on the incoming stress, SPDs tested according to class I, class II or class III may be used. Consideration of the electrical stress involved in the surge is a key to choosing the right SPDs. In particular when a lightning protection system is present additional information can be found in the 62305 series. SPDs tested according to class II and class III tests are also suited for location close to the protected equipment.

6.1.1 Possible modes of protection and installation

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

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

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

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

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

between each line conductor and either the main earthing terminal or the main protective conductor, and between the neutral conductor and either the main earthing terminal or the protective conductor, whichever route is shorter - Connection type 1 (CT 1), see Figure 10

or

between each line conductor and the neutral conductor and between the neutral conductor and either the main earthing terminal or the protective conductor, whichever route is shorter - Connection type 2 (CT 2), see Figure 11.

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

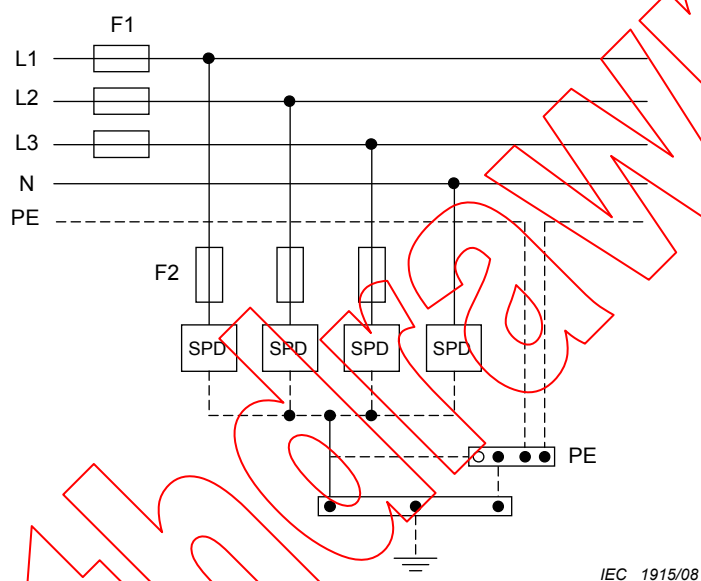


Figure 10 – Connection Type 1 (CT1)

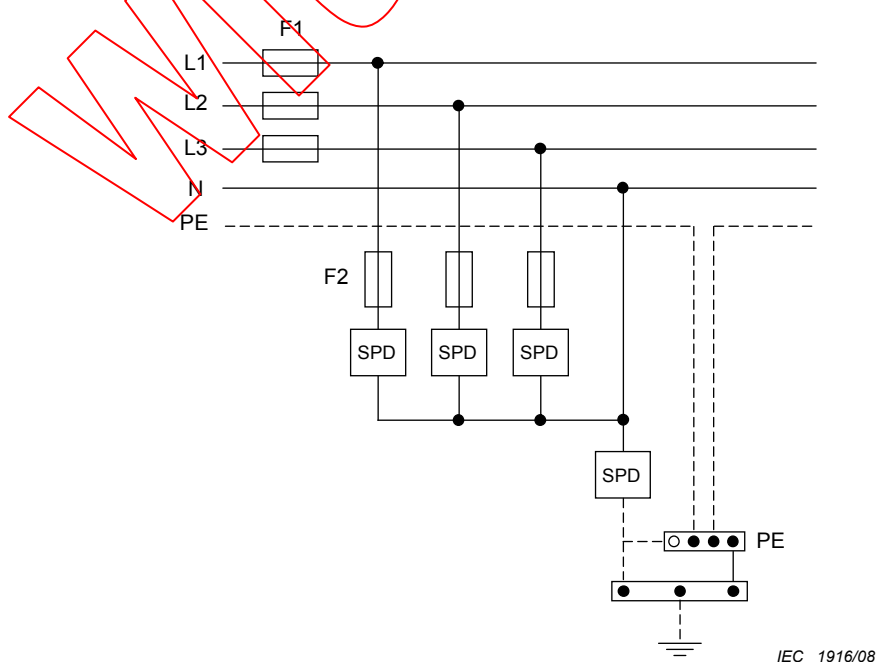


Figure 11 – Connection Type 2 (CT2)

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

NOTE 3 If more than one SPD is connected on the same conductor, it is necessary to ensure coordination between them.

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

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

Table 3 – Possible modes of protection for various LV systems

SPDs connected between:	System configuration at the installation point of SPD							
	TT		TN-C	TN-S		IT with distributed neutral		IT without distributed neutral
	Installation according to			Installation according to		Installation according to		
	CT 1	CT 2		CT 1	CT 2	CT 1	CT 2	
Each line conductor and neutral conductor	+	•	NA	+	•	+	•	NA
Each line conductor and PE conductor	•	NA	NA	•	NA	•	NA	•
Neutral conductor and PE conductor	•	•	NA	• See Note 1	• See Note 1	•	•	NA
Each line conductor and PEN conductor	NA	NA	•	NA	NA	NA	NA	NA
Line conductors	+	+	+		+	+	+	+
• : required NA : not applicable + : optional, in addition to required SPDs CT : connection type								
NOTE 1 When distance between SPD location and PE – N bonding point is short (typically less than 10 m) this SPD may not be required NOTE 2 When CT2 is used the withstand voltage of equipment U_w should be compared to the protective level obtained as the result of two SPDs in series (L-N and N-PE). This may give a different result than the simple addition of the U_p of both SPDs.								

It is recommended that the power and signalling networks enter the structure to be protected close to each other and are bonded together at a common bonding bar. This is especially important for structures made of non-shielding material (wood, bricks, concrete, etc.).

For further information, see Annex K.

6.1.2 Influence of the oscillation phenomena on the protective distance (called separation distance in some countries)

When an SPD is used to protect specific equipment or when the SPD located at the main distribution board cannot provide enough protection for some equipment, SPDs should be installed as close as possible to the equipment to be protected. If the distance between the SPD and the equipment to be protected is too large, oscillations could lead to a voltage at the equipment terminals which is generally up to two times higher than U_p but, under some circumstances, can even exceed this level. This can cause a failure of the equipment to be

protected, in spite of the presence of the SPD (see Figures K.8 to K.10). Acceptable distance (called protective distance) depends on SPD type, type of system, steepness and waveform of the incoming surge and connected loads. In particular, this doubling is only possible if the equipment corresponds to a high impedance load or if the equipment is internally disconnected. Figure K.10 shows an example of a doubling of voltage in such conditions to illustrate the phenomenon.

In general, oscillations may be disregarded for distances less than 10 m.. Sometimes the equipment has internal protective components (for example, varistors), that will significantly reduce oscillations even at longer distances. Care is necessary in this last case to avoid coordination problems between the SPD and the protective component inside the equipment.

NOTE Protective distance may be reduced due to the voltage directly induced by the lightning current in the circuit loop existing between the SPD and equipment to be protected.

For further information, see Annex K.

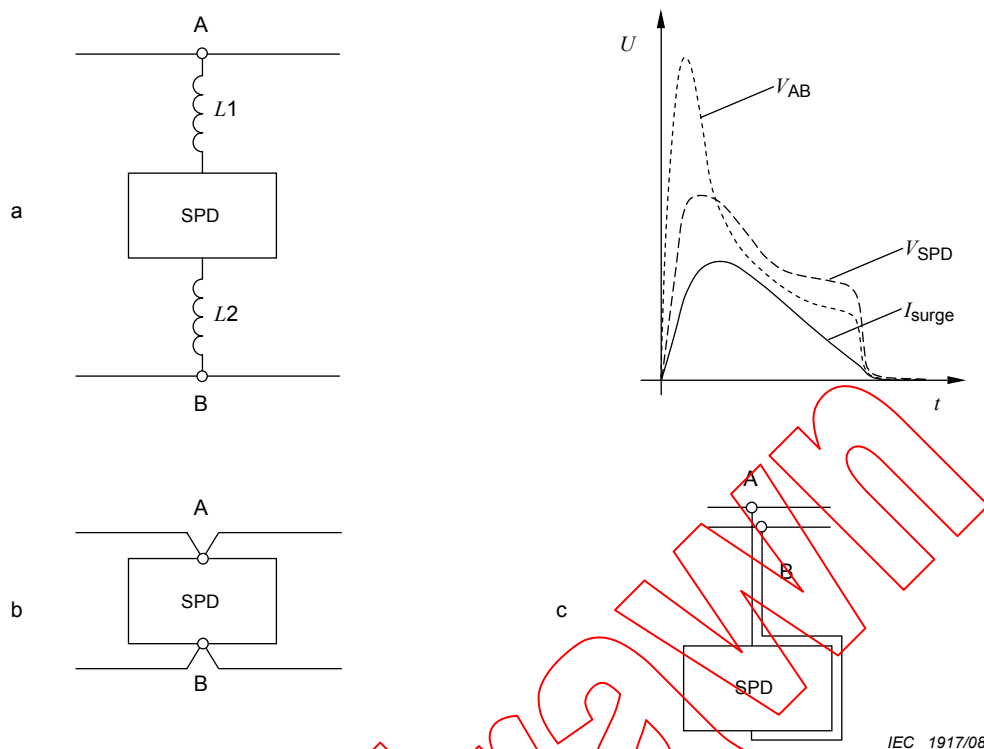
6.1.3 Influence of the connecting lead length

In order to achieve optimum overvoltage protection, connecting conductors of SPDs shall be as short as possible. Long lead lengths will degrade the protection offered by the SPD. Therefore, it may be necessary to select an SPD with a lower voltage protection level, in order to provide efficient protection. The residual voltage transferred to equipment will be the sum of the residual of the SPD and the inductive voltage drop along the connecting leads. The two voltages may not peak exactly at the same instant, but for most practical purposes, may simply be added. Figure 10 shows the effect of the inductance of connecting leads on the voltage measured between connection points of the SPD during the impulse discharge current.

As a general rule, the lead inductance is assumed to be 1 $\mu\text{H}/\text{m}$. This inductive voltage drop, when caused by an impulse with a rate of rise of 1 $\text{kA}/\mu\text{s}$ will be approximately 1 kV/m of lead length. Furthermore, if the steepness of dI/dt is greater, this value will be increased.

As far as possible, it is better to use scheme b) shown in Figure 12 where the effect of this inductance is considerably reduced. Scheme c) using twisted wires can be used when it is not possible to use scheme b). As far as possible scheme a) should be avoided. Because increasing the length of the connecting conductors of SPDs reduces the effectiveness of overvoltage protection, optimum overvoltage protection is achieved in scheme a) when all connecting conductors of SPDs are as short as possible (preferably not exceeding 0,5 m for the total lead length) and without any loops.

NOTE If the return current path is magnetically coupled to the incoming current conductors by placing the conductors in close proximity the inductance will be reduced (see Figure 12 c).

**Key**

- a) $L1, L2$ inductances corresponding to lead lengths $l1, l2$
 I_{surge} Waveshape of surge current versus time
 V_{SPD} Voltage at the SPD terminals during the surge
 V_{AB} Voltage between points A and B during the surge = V_{SPD} + voltage drop due to inductance $L1 + L2$
 THIS SCHEME IS TO BE AVOIDED WHEN POSSIBLE, ESPECIALLY WHEN EITHER $L1$ OR $L2$ IS LARGE
 b) THIS SCHEME IS TO BE PREFERRED
 c) THIS SCHEME IS ACCEPTABLE WHERE SCHEME b IS NOT POSSIBLE

Figure 12 – Influence of SPD connecting lead lengths

For further information, see Annex K.

6.1.4 Need for additional protection

In some conditions one SPD is sufficient, for example, if the stresses at the entrance to the structure are low. It is then better to install the SPD close to the mains entrance (see 6.1.1).

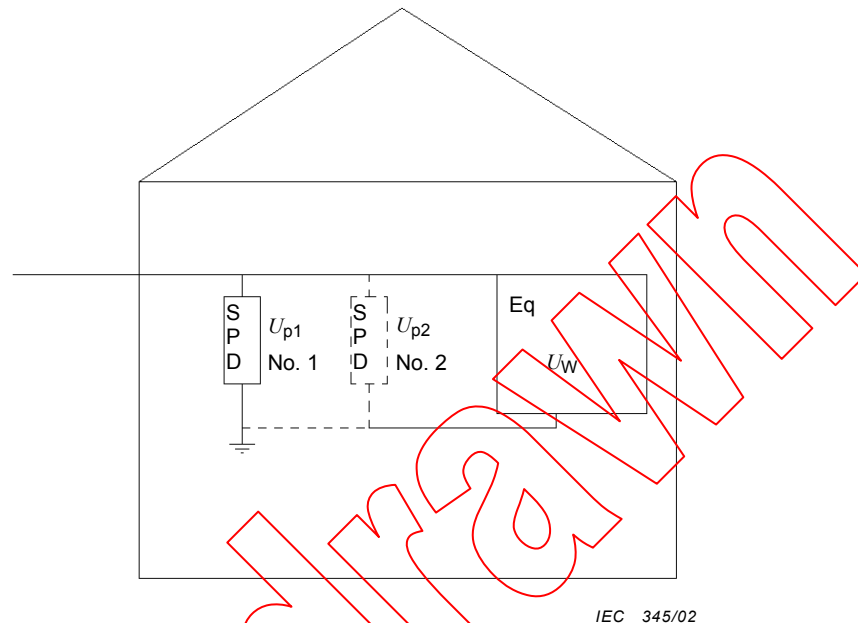
Additional protection close to the equipment to be protected may be necessary, for example where

- very sensitive equipment (electronic, computer) is present;
- the distance between the SPD located at the entrance and the equipment to be protected is too long (see 6.1.2);
- there are electromagnetic fields inside the structure created by lightning discharges and internal interference sources.

It is necessary to consider the voltage withstand (U_W , see IEC 60664-1) of the most sensitive equipment to be protected in the system or, in some cases where the continuous operation of the equipment is critical, the impulse immunity level of the equipment. In the example below where the equipment is not critical and U_W is only considered, the SPD located closest to this equipment shall be selected with a voltage protective level of $Up2$ at least 20 % below the

voltage withstand of this equipment. If the protective level (U_{p1}) of the entrance SPD combined with the effect described in 6.1.2, due to the distance between this SPD and the equipment leads to a voltage below $0,8 \times U_W$ at the terminals of the equipment, then no additional SPD is necessary close to the equipment (see Figure 13).

See K.1.2 and Figure K.9 for further information.



Key

If $U_{p1} \times k < 0,8 \times U_W$, only SPD No. 1 (installed at the entrance to the installation) is needed.

If $U_{p1} \times k > 0,8 \times U_W$, SPD No. 2 (with $U_{p2} < 0,8 U_W$) should be installed in addition to SPD No. 1.

Eq is the equipment to be protected having a withstand voltage U_W as defined by IEC 60664-1.

k is a coefficient ($1 < k < 2$, see 6.1.2) taking account of possible oscillations.

Figure 13 – Need for additional protection

NOTE The immunity of the equipment obtained from IEC 61000-4-5 may be different from the withstand voltage defined in IEC 60664-1 (U_W). The reason for this is that the test of IEC 61000-4-5 uses a combination wave generator, and a part of the surge current may flow through the equipment (especially if it has a low impedance). In this case, proper coordination is required (see 6.2.6). Additional information on comparison between immunity and insulation withstand is given in Annex M. It should be noted that in spite of IEC 60664-1 describing how to obtain U_W , it may difficult in practice to obtain U_W value for every type of equipment

Potentially damaging switching surges can be generated inside buildings. In this case, additional SPDs may be needed.

When two SPDs are used on the same circuit, they shall be co-ordinated.

6.1.5 Consideration regarding location of the SPD depending on the classes of test

At the point of entry depending on the incoming stress, SPDs tested according to class I, class II or class III may be used. Consideration of the electrical stress involved in the surge is a key to choosing the right SPDs. SPDs tested according to class II and class III tests are also suited for location close to the protected equipment.

6.1.6 Protection zone concept

For the purpose of designing and applying appropriate surge protection, it may be useful to consider a hierarchy of zones of protection as described in IEC 62305-4.

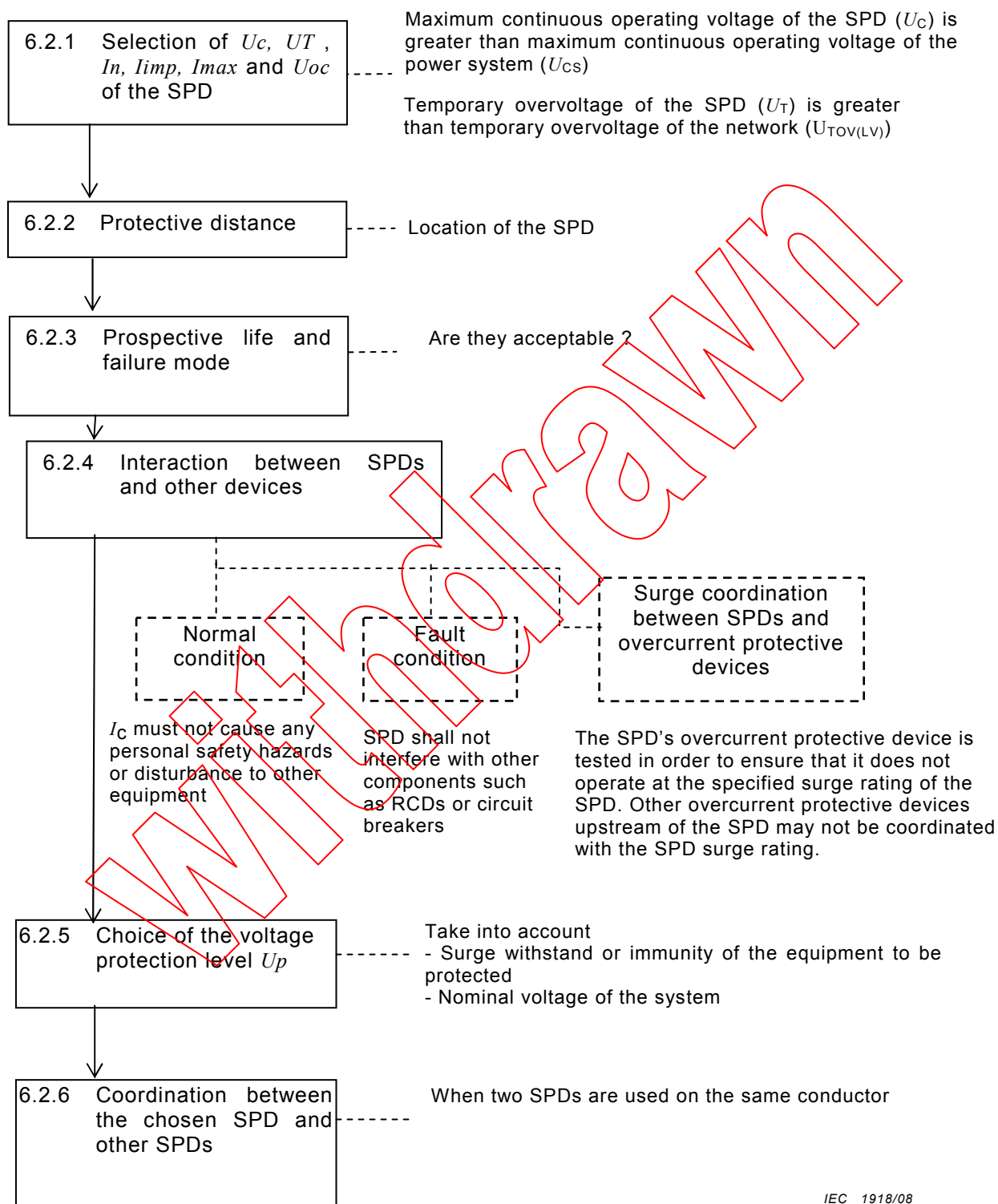
This planning concept assumes that the conducted threatening parameters caused by switching in the power distribution systems and direct/indirect lightning strokes, are reduced in steps (the distance between the steps should be in accordance with 6.1.2) from the unprotected environment to the protected sensitive equipment.

An example of the subdivision of the building power distribution system into protection zones and the allocation of SPDs is shown in Figure K.11.

Withdrawn

6.2 Selection of SPD

SPDs are selected according to the following scheme in six steps given in 6.2.1 through 6.2.6.



IEC 1918/08

Figure 14 – Flowchart for the selection of an SPD