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Protection against lightning electromagnetic impulse - Part 3: Requirements of surge protective devices (SPDs)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

PROTECTION AGAINST LIGHTNING ELECTROMAGNETIC IMPULSE –

Part 3: Requirements of surge protective devices (SPDs)

FOREWORD

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Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC 61312-3, which is a technical specification, has been prepared by IEC technical committee 81: Lightning protection, partly in cooperation with subcommittee 37A: Low-voltage surge protective devices, technical committee 64: Electrical installations and protection against electric shock, and subcommittee 77B: High-frequency phenomena.[1)]

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1) Especially for the problem of SPD coordination, joint activity has been agreed with WG 3 of SC 37A and JWG 31 of TC 64 (with members from SC 28A, SC 37A, TC 64, SC 77B and TC 81). Similar information is presented in IEC 61643-12 and IEC 62066 (both to be published).

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
81/120/CDV	81/141/RVC

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

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

IEC 61312 consists of the following parts, under the general title: Protection against lightning electromagnetic impulse:

- Part 1: General principles
- Part 2: Shielding of structures, bonding inside structures and earthing
- Part 3: Requirements of surge protective devices (SPDs)
- Part 4: Protection of equipment in existing structures

Annexes A, B and C are for information only.

The committee has decided that the contents of this publication will remain unchanged until 2005. At this date, the publication will be

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- withdrawn;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

INTRODUCTION

The Lightning Protection Zones (LPZ) concept according to IEC 61312-1 requires the installation of SPDs, whenever an electrical line crosses the boundary between two zones. These SPDs shall be well coordinated to get an acceptable sharing of stress among the SPDs according to their immunities against damage and to effectively reduce the primary lightning threat to the immunities against damage of the equipment to be protected. This technical specification provides methods and rules to ensure the energy coordination.

PROTECTION AGAINST LIGHTNING ELECTROMAGNETIC IMPULSE –

Part 3: Requirements of surge protective devices (SPDs)

1 Scope

This technical specification deals with the requirements of Surge Protective Devices (SPDs) standardized by IEC 61643-1. These SPDs are installed according to the Lightning Protection Zones concept given by IEC 61312-1.

First, starting from primary relevant threats, this technical specification gives instructions for the determination of the stress for individual SPDs.

For SPDs installed within a complex system, it is admissible to divide the system into simple basic arrangements, observing the rules described in this technical specification. When the values and directions of the partial lightning currents flowing within the system are known, the appropriate SPDs can be selected.

This technical specification also deals with basic questions of the energy coordination of SPDs among each other and between SPDs and the equipment to be protected. The specific characteristics of the individual SPDs and the threat at the respective place of installation are to be considered for effective coordination. The proof of the coordination of SPDs installed in a system, is described briefly in this specification.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 61312. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of IEC 61312 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

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: Testing and measurement techniques – Part 5: Surge immunity tests*

IEC 61024-1, *Protection of structures against lightning – Part 1: General principles*

IEC 61312-1, *Protection against lightning electromagnetic impulse – Part 1: General principles*

IEC 61312-2, *Protection against lightning electromagnetic impulse – Part 2: Shielding of structures, bonding inside structures and earthing*

IEC 61312-4, *Protection against lightning electromagnetic impulse – Part 4: Protection of equipment in existing structures*

IEC 61643-1, *Surge protective devices connected to low-voltage power distribution systems – Part 1: Performance requirements and testing methods*

ITU-T Series K, *Protection against interference*

ITU-T K.20, *Resistibility of telecommunication switching equipment to overvoltages and overcurrents*

ITU-T K.21, *Resistibility of subscriber's terminal to overvoltages and overcurrents*

3 Definitions, abbreviations and symbols

For the purposes of this technical specification, the following terms and definitions apply, in addition to those defined in IEC 61312-1, IEC 61024-1 and IEC 61643-1.

3.1
surge protective device (SPD)
device that is intended to limit transient overvoltages and divert surge currents. It contains at least one non-linear component

[IEC 61643-1, definition 3.1]

3.1.1
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. Common examples of components used as voltage switching devices are: spark gaps, gas tubes, thyristors (silicon-controlled rectifiers) and triacs. These SPDs are sometimes called "crowbar type"

[IEC 61643-1, definition 3.4]

3.1.2
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. Common examples of components used as non-linear devices are varistors and suppressor diodes. These SPDs are sometimes called "clamping type"

[IEC 61643-1, definition 3.5]

3.1.3
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 "their combined parameters" and the characteristics of the applied voltage

[IEC 61643-1, definition 3.6]

3.2
class I test
test procedure for lightning current arrester, which is installed at the interface of LPZ $0_A/1$, as defined in IEC 61643-1. Other SPDs are installed sequentially.

SPDs tested according to this class are submitted to the operating duty test with the impulse current I_{imp}

3.3
class II test
Test procedure for overvoltage arrester as defined in IEC 61643-1.

SPDs tested according to this class are submitted to the operating duty test with the impulse current I_{max}

3.4
class III test
Test procedure for overvoltage arrester as defined in IEC 61643-1.

SPDs tested according to this class are submitted to the operating duty test with a combination wave

3.5
maximum continuous operating voltage U_c
maximum r.m.s. or d.c. voltage which may be continuously applied to SPDs mode of protection. This is equal to the rated voltage

[IEC 61643-1, definition 3.11]

3.6
residual voltage U_{res}
peak value of voltage that appears between the terminals of an SPD due to the passage of discharge current

[IEC 61643-1, definition 3.17]

3.7
impulse current I_{imp}
current defined by a current peak value I_{peak} and the charge Q_S and tested according to the test sequence of the operating duty test. This is used for the classification of the SPD for class I test

[IEC 61643-1, definition 3.9]

3.8
maximum discharge current 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

[IEC 61643-1, definition 3.10]

3.9
immunity against damage
withstand capability against conducted and radiated lightning effects

[IEC 61312-2, definition 1.3.3]

3.10 Abbreviations

EUT	Equipment under test
LPZ	Lightning protection zone
MOV	Metal oxide varistor
EB	Lightning protection equipotential bonding

3.11 Symbols

$C_{(T1\text{-}3)}$	Winding capacitance of the LV transformer
$\mathrm{d}i/\mathrm{d}t$	Current rate of rise
I_{ES}	Part of the lightning current through the earthing system of the building struck
I_{ET}	Part of the lightning current through the earthing system of the LV transformer
$L_{lightning}$	Total lightning current (simplified calculation method)
I_{LV}	Part of the lightning current through the LV system
I_{mains}	Part of the lightning current through the power distribution system of the building struck
$I_{neutral}$	Part of the lightning current through the neutral conductor line
I_{peak}	Peak current (of the first stroke)
I_{SC}	Short-circuit current of an SPD (LTE coordination method)
$I_{phase1\text{-}3}$	Part of the lightning current through the phase conductor lines
l_{CC}	Length of the connecting cable
$L_{(1\text{-}3)}$	Line inductance between two SPDs
L_{CC}	Inductance of the shielded telecommunication cable
L_{CT}	Inductance of the power supply cable
L_{DE}	Inductance of the decoupling element
L_{EC}	Inductance of the earthing system of the substation for telecommunication
L_{ES}	Inductance of the earthing system of the building struck
L_{ET}	Inductance of the earthing system of the LV transformer
L_{mains}	Inductance of the complete (LV) mains network
$L_{(T1\text{-}3)}$	Winding inductance of the LV transformer
L_{WP}	Inductance of the waterpipe
Q_S	Charge (of the short-duration stroke)
R_{CC}	Resistance of the shielded telecommunication cable
R_{CT}	Resistance of the power supply cable
R_{DE}	Resistance of the decoupling element
$R_{earth/G}$	Resistance of the earthing system of the building struck (simplified calculation method)
$R_{earth/1\text{-}n}$	Resistance of the earthing system of the parallel buildings (simplified calculation method)
R_{EC}	Resistance of the earthing system of the substation for telecommunication

R_{ES}	Resistance of the earthing system of the building struck
R_{ET}	Resistance of the earthing system of the LV-transformer
R_{mains}	Resistance of the complete LV mains network
R_{NL}	Resistance of the neutral line of the LV transformer
R_{TL}	Resistance of the earthing of the telephone line
$R_{(T1\text{-}3)}$	Winding resistance of the LV transformer
R_{WP}	Resistance of the earthing of the waterpipe
$R_{(1\text{-}3)}$	Line resistance between two SPDs
S_n	Apparent power of the LV transformer
T_1	Front time (of the first stroke)
T_2	Time to half-value (of the first stroke)
U_{ARC}	Arc voltage of the spark gap
U_{DE}	Voltage drop across the decoupling element
U_{OC}	Open-circuit voltage of an SPD (LTE coordination method)
U_{LOAD}	Voltage drop across the load
U_N	Nominal voltage of the system
U_{max}	Maximum voltage stressing
$U_{ref(1mA)}$	MOV voltage at a current of 1 mA
U_{SG}	Voltage drop across the spark gap
$W_{max(t=2ms)}$	Maximum energy absorption MOV (within 2 ms)
W/R	Specific energy (of the first stroke)
Z_i	"Fictive" impedance of a combination wave generator
Z_{mains}	Impedance of the complete (LV) mains network

4 Relevant threats – Lightning current parameters

The primary lightning threat is given by three current components:

– first stroke
– subsequent stroke
– long-duration stroke

(see IEC 61312-1, figure 2).

The lightning current parameters for the different protection levels are listed in tables 1 to 3 of IEC 61312-1 (see note 1).

All three components are effective as impressed currents. Concerning the coordination of subsequently installed SPDs, the first stroke is the decisive factor, because the subsequent stroke has a relatively low W/R, Q_S, I_{peak} and shorter current front time (see note 2). The long-duration stroke is only an additional stressing factor for the lightning current arrester SPD (class I test) and should, therefore, be left out of consideration concerning coordination problems.

For coordination purposes, the necessary characteristic values (for example, waveshape, energy) are to be derived from these parameters.

- Starting from the primary relevant threat parameters of the first stroke, the 10/350 µs waveshape is the defined surge current to simulate a direct lightning strike. This is the appropriate impulse current proofing the energy coordination of SPDs.
- Considering the interaction between direct lightning current and the low-voltage installation, the waveshape of the partial lightning currents within the system may be different. In such cases, a test current with a minimum current steepness of 0,1 kA/µs is also to be taken into account.

NOTE 1 The parameters describe the lightning current threat. Each SPD will only be stressed with a portion of the total lightning current.

NOTE 2 The analytical function of the lightning current and the parameters for the equations are given in IEC 61312-1 (annex B) for the purposes of analysis.

NOTE 3 If the SPDs are specified for the first stroke threat, the subsequent stroke causes no additional problems for the SPDs. If inductances are used as decoupling elements, the shorter current rise time makes co-ordination easier.

NOTE 4 In case resistive components are used as decoupling elements (for example, usually in SPDs for information systems), the permissible peak current must be considered.

5 Arrangement of SPDs within the Lightning Protection Zones concept

5.1 Lightning protection zones

The volume to be protected shall be divided into lightning protection zones to define volumes of different LEMP severities. Metal services penetrating zone boundaries shall be bonded at each penetration point. In this technical specification, it is assumed that the bonding network represents a negligibly low impedance and the cable routing is carried out in accordance with 3.5 of IEC 61312-2. If this precondition is not fulfilled then refer for further information to IEC 61312-3.

5.2 Zone definitions

Lightning protection zones are defined according to IEC 61312-1 (see 3.1 and figures 3 to 5). The general principle for the division of a volume to be protected into different lightning protection zones is shown in figures 1a, 1b and 2.

5.3 Arrangement of SPDs at the zone interfaces

Figure 2 shows an example for the application of SPDs for power distribution systems within the Lightning Protection Zones concept. SPDs are installed in sequence (see note 1). They are chosen according to the requirements of the penetration point.

It is recommended that the power and information networks enter the volume to be protected close to each other and be bonded together at a common bar. This is especially important for a building (or the protected volume) made of non-shielding material (wood, bricks, etc.).