

INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Protection against lightning –
Part 1: General principles**

**Protection contre la foudre –
Partie 1: Principes généraux**



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2024 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 l'IEC ou du Comité national de l'IEC du pays du demandeur. Si vous avez des questions sur le copyright de l'IEC ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de l'IEC de votre pays de résidence.

IEC Secretariat
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
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 corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform

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 It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch

Discover our powerful search engine and read freely all the publications previews, graphical symbols and the glossary. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org

The world's leading online dictionary on electrotechnology, containing more than 22 500 terminological entries in English and French, with equivalent terms in 25 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

A propos de l'IEC

La Commission Electrotechnique Internationale (IEC) 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 IEC

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

Recherche de publications IEC -

webstore.iec.ch/advsearchform

La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études, ...). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished

Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et une fois par mois par email.

Service Clients - webstore.iec.ch/csc

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch

Découvrez notre puissant moteur de recherche et consultez gratuitement tous les aperçus des publications, symboles graphiques et le glossaire. Avec un abonnement, vous aurez toujours accès à un contenu à jour adapté à vos besoins.

Electropedia - www.electropedia.org

Le premier dictionnaire d'électrotechnologie en ligne au monde, avec plus de 22 500 articles terminologiques en anglais et en français, ainsi que les termes équivalents dans 25 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Protection against lightning –
Part 1: General principles**

**Protection contre la foudre –
Partie 1: Principes généraux**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 29.020, 91.120.40

ISBN 978-2-8322-8002-7

Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.

CONTENTS

FOREWORD.....	6
INTRODUCTION.....	8
1 Scope.....	10
2 Normative references	10
3 Terms and definitions	10
4 Lightning current parameters	17
5 Damage due to lightning.....	18
5.1 Damage to a structure	18
5.1.1 General	18
5.1.2 Effects of lightning on a structure	18
5.1.3 Sources and causes of damage to a structure	19
5.2 Types of loss	20
6 Need for lightning protection.....	21
6.1 Risk and frequency	21
6.2 Need for lightning protection for reduction of risk R	22
6.3 Need for lightning protection for reduction of frequency of damage F	22
7 Protection measures.....	23
7.1 General.....	23
7.2 Protection measures to reduce injury to human beings by electric shock.....	23
7.3 Protection measures to reduce physical damage.....	24
7.4 Protection measures to reduce failure of internal systems.....	24
7.5 Protection measures selection	24
8 Basic criteria for protection of structures.....	24
8.1 General.....	24
8.2 Lightning protection levels (LPLs)	25
8.3 Lightning protection zones (LPZs).....	27
8.4 Protection of structures	29
8.4.1 Protection to reduce physical damage and life hazard	29
8.4.2 Protection to reduce the failure of internal systems.....	30
Annex A (informative) Parameters of lightning current	31
A.1 Lightning flashes to earth.....	31
A.2 Lightning current parameters	34
A.3 Fixing the maximum lightning current parameters for LPL I	39
A.3.1 General	39
A.3.2 First positive stroke and long stroke	39
A.3.3 First negative stroke	40
A.3.4 Subsequent stroke.....	40
A.4 Fixing the minimum lightning current parameters	40
Annex B (informative) Time functions of the lightning current for analysis purposes.....	42
Annex C (informative) Simulation of the lightning current for test purposes	47
C.1 General.....	47
C.2 Simulation of the specific energy of the first positive stroke and the charge of the long stroke	47
C.3 Simulation of the front current steepness of the impulses.....	48

Annex D (informative) Test parameters simulating the effects of lightning current on LPS components.....	51
D.1 General.....	51
D.2 Current parameters relevant to the point of strike.....	51
D.3 Current sharing	52
D.4 Effects of lightning current causing possible damage	53
D.4.1 Thermal effects.....	53
D.4.2 Mechanical effects	57
D.4.3 Combined effects.....	61
D.4.4 Sparking	61
D.4.5 Soil ionization	61
D.5 LPS components, relevant problems and test parameters	61
D.5.1 General	61
D.5.2 Air terminations	61
D.5.3 Down conductors	62
D.5.4 Connecting components	63
D.5.5 Earth terminations	64
D.6 Surge protective devices (SPDs).....	64
D.6.1 General	64
D.6.2 SPD containing spark gaps.....	64
D.6.3 SPD containing metal-oxide varistors	65
D.7 Summary of the test parameters to be adopted in testing LPS components.....	66
Annex E (informative) Surge currents due to lightning at different installation points	67
E.1 General.....	67
E.2 Surge currents due to flashes to the structure (source of damage S1).....	67
E.2.1 Surge currents flowing through external conductive parts and lines connected to the structure	67
E.2.2 Factors influencing the sharing of the lightning current and related charge in power lines.....	67
E.2.3 Surge currents flowing through line conductors connected to the structure	68
E.2.4 Surge currents flowing through conductive parts and cables internal to the structure connected to LPS.....	69
E.2.5 Surge currents flowing through cables connected to different points of the earth-termination system within the same earth-termination system	70
E.3 Surge currents due to flashes to lines (source of damage S3).....	70
E.4 Surges due to flashes near the lines (source of damage S4).....	71
E.5 Surge currents due to induction effects (sources of damage S1 or S2).....	71
E.5.1 General	71
E.5.2 Surges inside an unshielded LPZ 1	72
E.5.3 Surges inside shielded LPZs.....	72
E.6 Conventional surge currents	72
Bibliography.....	75
Figure 1 – Connection between the various parts of the IEC 62305 series	9
Figure 2 – LPZ defined by an LPS (IEC 62305-3).....	28
Figure 3 – LPZ defined by LPS and SPM (IEC 62305-4)	29
Figure A.1 – Definitions of impulse current parameters according to IEC 62475 [7].....	31
Figure A.2 – Definitions of long duration stroke parameters	32

Figure A.3 – Schematic representation (not to scale) of possible components of downward flashes (typical in flat territory and to lower structures) and multiple strokes downward flashes	32
Figure A.4 – Schematic representation (not to scale) of possible components of upward flashes (typical of exposed or higher structures or both)	33
Figure A.5 – Cumulative frequency distribution of lightning current parameters (dotted line through 50 % value)	38
Figure B.1 – Shape of the current rise of the first positive stroke	43
Figure B.2 – Shape of the current tail of the first positive stroke	43
Figure B.3 – Shape of the current rise of the first negative stroke	44
Figure B.4 – Shape of the current tail of the first negative stroke	44
Figure B.5 – Shape of the current rise of the subsequent negative strokes	45
Figure B.6 – Shape of the current tail of the subsequent negative strokes	45
Figure B.7 – Amplitude density of the lightning current according to LPL I	46
Figure C.1 – Example test generator for the simulation of the specific energy of the first positive stroke and the charge of the long stroke	48
Figure C.2 – Definition of the current steepness in accordance with Table C.3.....	49
Figure C.3 – Example test generator for the simulation of the front steepness of the first positive stroke for large test items.....	49
Figure C.4 – Example test generator for the simulation of the front steepness of the subsequent negative strokes for large test items.....	50
Figure D.1 – General arrangement of two conductors for the calculation of electrodynamic force.....	58
Figure D.2 – Typical conductor arrangement in an LPS.....	59
Figure D.3 – Diagram of the stresses F for the configuration of Figure D.2	59
Figure D.4 – Force per unit length F' along the horizontal conductor of Figure D.2.....	60
Table 1 – Effects of lightning on typical structures	19
Table 2 – Sources of damage, causes of damage, types of loss according to the point of strike	21
Table 3 – Maximum values of lightning parameters according to LPLs	26
Table 4 – Minimum values of lightning parameters and related rolling sphere radius corresponding to LPLs	26
Table 5 – Probabilities for the limits of the lightning current parameters.....	26
Table A.1 – Tabulated values of lightning current parameters (CIGRE [9], [10], [11])	35
Table A.2 – Logarithmic normal distribution of lightning current parameters – Mean μ and dispersion $\sigma_{\log}$ calculated from 5 % and 95 % values (CIGRE [9], [10], [11]).....	36
Table A.3 – Values of probability P as function of the lightning current I peak value.....	37
Table B.1 – Parameters for Equation (B.1).....	42
Table C.1 – Test parameters of the first positive stroke.....	48
Table C.2 – Test parameters of the long stroke.....	48
Table C.3 – Test parameters of the strokes.....	49
Table D.1 – Summary of the lightning threat parameters to be considered in the calculation of the test values for the different LPS components and for the different LPLs	52
Table D.2 – Physical characteristics of typical materials used in LPS components	55

Table D.3 – Temperature rise for conductors of different sections as a function of W/R 55

Table E.1 – Conventional surge currents due to lightning flashes on low-voltage systems 73

Table E.2 – Conventional surge currents due to lightning flashes on telecommunication systems 74

INTERNATIONAL ELECTROTECHNICAL COMMISSION

PROTECTION AGAINST LIGHTNING –**Part 1: General 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 itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 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) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at <https://patents.iec.ch>. IEC shall not be held responsible for identifying any or all such patent rights.

IEC 62305-1 has been prepared by IEC technical committee 81: Lightning protection. It is an International Standard.

This third edition cancels and replaces the second edition published in 2010. This edition constitutes a technical revision.

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

- a) reference to the IEC 62561 series [1]¹ is made in Annex D to provide a link to relevant lightning protection system components according to the IEC 62561 series;

¹ Numbers in square brackets refer to the Bibliography.

- b) risk management introduces the concept of types of loss with public relevance;
- c) the concept of frequency of damage that can impair the availability of the internal systems within the structure has been introduced;
- d) surge currents due to lightning flashes have been more accurately specified for SPD dimensioning in low-voltage power systems and in telecommunication systems.

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

Draft	Report on voting
81/737/FDIS	81/756/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 62305 series, published under the general title *Protection against lightning*, can be found on the IEC website.

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

- reconfirmed,
- withdrawn, or
- revised.

INTRODUCTION

There are no devices or methods capable of modifying the natural weather phenomena to the extent that they can prevent lightning discharges. Lightning flashes to, or nearby, structures (or lines connected to the structures) are hazardous to people, to the structures themselves, their contents and installations as well as to lines. This is why the application of lightning protection measures is essential.

The need for protection, the economic benefits of installing protection measures, and the selection of adequate protection measures should be determined in terms of risk management. Risk management is the subject of IEC 62305-2 [2].

NOTE In Germany, the need for lightning protection is determined by, and the class of required LPS shall be selected according to, a national annex to the third edition of IEC 62305-1 (including an option for a risk assessment following the third edition of IEC 62305-2).

Protection measures considered in the IEC 62305 series have been proven to be effective in risk reduction.

All measures for protection against lightning form the overall lightning protection. For practical reasons the criteria for design, installation and maintenance of lightning protection measures are considered in two separate groups:

- the first group concerning protection measures to reduce physical damage and life hazard in a structure is given in IEC 62305-3;
- the second group concerning protection measures to reduce failures of electrical and electronic systems in a structure is given in IEC 62305-4.

The connection between the parts of the IEC 62305 series is illustrated in Figure 1.

NOTE The implementation of an IEC 62793 [3] compliant TWS in the protection measures for a structure can assist in reducing physical damage, life hazard, and failure of electrical and electronic systems.

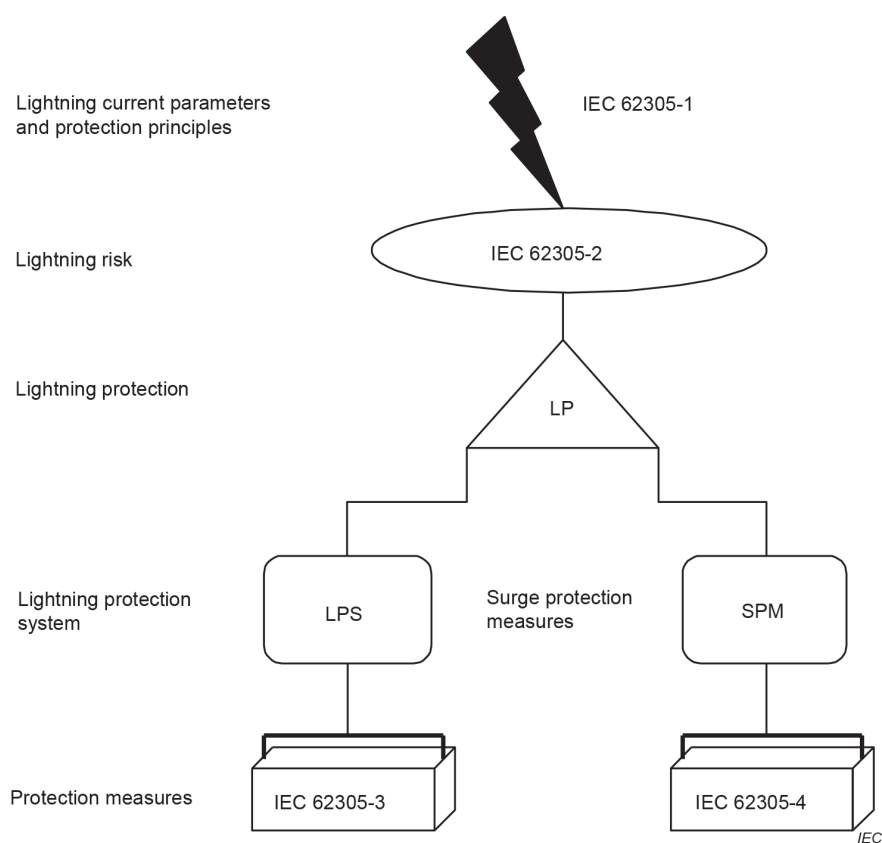


Figure 1 – Connection between the various parts of the IEC 62305 series

PROTECTION AGAINST LIGHTNING –

Part 1: General principles

1 Scope

This part of IEC 62305 provides general principles for the protection of structures against lightning, including their installations and contents, as well as persons.

The following cases are outside the scope of this document:

- railway systems;
- vehicles, ships, aircraft, offshore installations;
- underground high-pressure pipelines;
- pipe, power and telecommunication lines separated from the structure;
- nuclear power plants.

The IEC 62305 series should be considered as a minimum requirement for these structures.

Until any further information by CIGRE is available the lightning current parameters described in this document can be applied also for offshore installations.

NOTE 1 In these cases, structures usually fall under special regulations produced by various specialized authorities. For structures (subsidiary or others) not falling under such special regulations, the IEC 62305 series still applies.

NOTE 2 Lightning protection of wind turbines is also covered by IEC 61400-24 [4].

2 Normative references

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

IEC 62305-3:2024, *Protection against lightning – Part 3: Physical damage to structures and life hazard*

IEC 62305-4:2024, *Protection against lightning – Part 4: Electrical and electronic systems within structures*

3 Terms and definitions

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

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

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

3.1**lightning flash to earth**

electrical discharge of atmospheric origin between cloud and earth consisting of one or more strokes

3.2**downward flash**

lightning flash initiated by a downward leader from cloud to earth

Note 1 to entry: A downward flash consists of a first current short stroke, which can be followed by other subsequent short strokes. One or more short strokes can be also followed by a long stroke.

3.3**upward flash**

lightning flash initiated by an upward leader from an earthed structure to cloud

Note 1 to entry: An upward flash consists of a first long stroke with or without multiple superimposed impulses. One or more impulses can be followed by a long stroke.

3.4**lightning stroke**

single electrical discharge in a lightning flash to earth

3.5**short stroke**

part of the lightning flash which corresponds to an impulse current

Note 1 to entry: The impulse current has a time T_2 to the half peak value on the tail typically less than 2 ms (see Figure A.1).

3.6**long stroke**

part of the lightning flash which corresponds to a continuing current

Note 1 to entry: The duration time T_{LONG} of this continuing current is typically more than 2 ms and less than 1 s (see Figure A.2).

3.7**multiple strokes lightning flash**

lightning flash consisting on average of three to four strokes, with a typical time interval between them of about 50 ms

Note 1 to entry: Events having up to a few dozen strokes with intervals between them ranging from 10 ms to 250 ms have been reported.

3.8**point of strike**

point where a lightning flash strikes the earth or a structure (e.g. building, LPS, line, tree)

Note 1 to entry: A lightning flash can have more than one point of strike.

3.9**lightning current**

i

current flowing at the point of strike

3.10**current peak value**

I

maximum value of the lightning current

3.11

average steepness of the current front

di/dt

maximum current of the impulse I divided by the front time of the impulse T_1

Note 1 to entry: See 3.10 and 3.12 and Figure A.1.

3.12

front time of impulse current

T_1

virtual parameter defined as 1,25 times the time interval between the instants when the 10 % and 90 % of the peak value are reached

SEE: Figure A.1.

3.13

virtual origin of impulse current

O_1

point of intersection with the time axis of a straight line drawn through the 10 % and the 90 % reference points on the stroke current front preceding by 0,1 T_1 that instant at which the current attains 10 % of its peak value

SEE: Figure A.1.

3.14

time to half value on the tail of impulse current

T_2

virtual parameter defined as the time interval between the virtual origin O_1 and the instant at which the current has decreased to half the peak value on the tail

SEE: Figure A.1.

3.15

flash duration

T

time for which the lightning current flows at the point of strike

3.16

duration of long stroke current

T_{LONG}

time duration during which the current in a long stroke is between 10 % of the peak value during the increase of the continuing current and 10 % of the peak value during the decrease of the continuing current

SEE: Figure A.2.

3.17

flash charge

Q_{FLASH}

value resulting from the time integral of the lightning current for the entire lightning flash duration

3.18

short stroke charge

Q_{SHORT}

value resulting from the time integral of the lightning current in an impulse

3.19
long stroke charge Q_{LONG}

value resulting from the time integral of the lightning current in a long stroke

3.20
specific energy W/R

value resulting from the time integral of the square of the lightning current for the entire flash duration

Note 1 to entry: The specific energy represents the energy dissipated by the lightning current in a unit resistance.

3.21
specific energy of the impulse current

value resulting from the time integral of the square of the lightning current for the duration of the impulse

Note 1 to entry: The specific energy in a long stroke current is negligible.

3.22
structure to be protected

any place, facility or building suitable to contain persons, animals, materials or systems

Note 1 to entry: A structure to be protected can be part of a larger structure.

3.23
line

external power line or telecommunication line connected to the structure to be protected

3.24
telecommunication line

line intended for communication between equipment that can be located in separate structures, such as a phone line and a data line

3.25
power line

distribution line feeding electrical energy into a structure to power electrical and electronic equipment located there, such as low voltage (LV) or high voltage (HV) electric mains

3.26
lightning flash to a structure
lightning flash striking a structure**3.27**
lightning flash near a structure
lightning flash striking close enough to a structure that it can cause dangerous overvoltages**3.28**
lightning flash to a line
lightning flash striking a line connected to a structure**3.29**
lightning flash near a line
lightning flash striking close enough to a line connected to a structure that it can cause dangerous overvoltages within the structure

3.30

dangerous event

lightning flash to or near a structure, or to or near a line connected to the structure that can cause damage within the structure

3.31

dangerous sparking

spark inside the structure where lightning current flows triggering fire or explosion or leading to mechanical and chemical effects which can also endanger the environment

3.32

electrical system

system incorporating low-voltage power supply components

3.33

electronic system

system incorporating sensitive electronic components such as telecommunication equipment, computer, control and instrumentation systems, radio systems, power electronic installations

3.34

internal systems

electrical and electronic systems of a structure

Note 1 to entry: Internal systems may for example be located on the roof of the structure provided they are connected internally to the structure.

3.35

physical damage

damage to a structure (or to its contents) due to mechanical, thermal, chemical and explosive effects of lightning

3.36

injury to human beings

injuries to, including loss of life of, people, resulting from lightning

3.37

failure of internal systems

damage of internal systems due to LEMP

3.38

lightning electromagnetic impulse

LEMP

fast time-varying electromagnetic field emitted by lightning which can create surges via resistive, inductive and capacitive coupling to circuits

3.39

surge

transient in lines and equipment created by LEMP that appears as overvoltage or overcurrent or both

3.40

lightning protection zone

LPZ

zone where the lightning electromagnetic environment is defined

Note 1 to entry: The zone boundaries of an LPZ are not necessarily physical boundaries (e.g. walls, floor and ceiling).

**3.41
frequency of damage** F

value of the annual number of damaging events due to LEMP which can occur to the internal systems of a structure

**3.42
tolerable frequency of damage** F_T

maximum value of the frequency of damage which can be tolerated for the internal systems of the structure or a zone to be protected

**3.43
loss** L

mean amount of a specified type of loss consequent to a dangerous event in the considered zone of a structure

**3.44
loss of public relevance**

loss which will result in consequences that will affect more than those involved in the decision-making process such as external consequences, injury to human beings, unavailability of services provided to the public, including physical damage, damage to the environment, and costs required to be paid by the public

EXAMPLE The costs of emergency measures to limit the damage, the costs resulting from loss of the structure and production, the costs of reconstruction.

**3.45
service**

function performed by the internal systems of the structure to supply a specific need

**3.46
service of public relevance**

service provided to the public as well as service where the heritage of cultural interest is involved

**3.47
risk** R

probable average annual loss due to lightning, in a structure or in a considered zone of the structure

**3.48
tolerable risk** R_T

maximum value of the risk which can be tolerated for the structure to be protected

**3.49
lightning protection level
LPL**

number related to a set of lightning current parameters values relevant to the probability that the associated maximum and minimum design values will not be exceeded in naturally occurring lightning

Note 1 to entry: The lightning protection level is used to design protection measures according to the relevant set of lightning current parameters.

3.50

protection measures

measures adopted for the structure to be protected in order to reduce the risk

3.51

lightning protection

LP

measures taken for the protection of structures against lightning, including their internal systems and contents, as well as persons, in general consisting of an LPS and SPM

3.52

lightning protection system

LPS

complete system used to reduce injury to human beings and physical damage due to lightning flashes to a structure

Note 1 to entry: A lightning protection system consists of both external and internal lightning protection systems. To protect internal systems against the effects of LEMP, measures according to IEC 62305-4 are necessary.

3.53

external lightning protection system

part of the LPS consisting of an air-termination system, a down-conductor system and an earth-termination system

3.54

internal lightning protection system

part of the LPS consisting of lightning equipotential bonding or electrical separation of an external LPS or both

3.55

air-termination system

part of an external LPS using metallic elements such as rods, masts, mesh conductors or catenary wires intended to intercept lightning flashes

3.56

down-conductor system

part of an external LPS intended to conduct lightning current from the air-termination system to the earth-termination system

3.57

earth-termination system

part of an external LPS which is intended to conduct and disperse lightning current into the earth

3.58

external conductive parts

extended metal items entering or leaving the structure to be protected such as pipe works, cable metallic elements, metal ducts which can carry a part of the lightning current

3.59

lightning equipotential bonding

EB

bonding to the LPS of separated metallic parts, by direct conductive connections or via surge protective devices, to reduce potential differences caused by lightning current

3.60

conventional earthing impedance

ratio of the peak values of the earth-termination voltage and the earth-termination current which, in general, do not occur simultaneously

3.61**surge protection measures****SPM**

measures taken to protect internal systems against the effects of LEMP

Note 1 to entry: Surge protection measures are part of the overall lightning protection.

3.62**electromagnetic shield**

screen of conductive material intended to reduce the penetration of a time-varying electromagnetic field into the structure or part of the structure to be protected, used to reduce failures of internal systems

3.63**surge protective device****SPD**

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

3.64**coordinated SPD system**

set of SPDs properly selected, coordinated and installed to form a system intended to reduce failures of internal systems

3.65**isolating interfaces**

devices which are capable of reducing conducted surges on lines entering the LPZ

Note 1 to entry: Isolating interfaces include isolation transformers with an earthed screen between windings, metal free fibre optic cables and opto-isolators.

Note 2 to entry: The insulation withstand characteristics of these devices should be suitable for this application either intrinsically or by SPD.

3.66**separation distance**

s

necessary distance between a conductor carrying full or partial lightning current and other conductive parts to avoid dangerous sparking

3.67**safety distance**

d_s

necessary distance between the internal systems and the shield of the LPZ, at which the shielding effect of the LPZ against the influence of the magnetic field is valid

4 Lightning current parameters

The lightning current parameters used in the IEC 62305 series are given in Annex A.

The time function of the lightning current to be used for analysis purposes is given in Annex B.

Information for simulation of lightning current for test purposes is given in Annex C.

The basic parameters to be used in laboratories to simulate the effects of lightning on LPS components are given in Annex D.

Information on surges due to lightning at different installation points is given in Annex E.

5 Damage due to lightning

5.1 Damage to a structure

5.1.1 General

Lightning affecting a structure can cause damage to the structure itself and to its occupants and contents, including failure of internal systems. The damages and failures can also extend to the surroundings of the structure and even involve the local environment. The scale of this extension depends on the characteristics of the structure and on the characteristics of the lightning flash.

5.1.2 Effects of lightning on a structure

The main characteristics of structures relevant to lightning effects include:

- construction (e.g. wood, brick, concrete, reinforced concrete, steel frame construction);
- function (dwelling house, office, farm, theatre, hotel, school, hospital, museum, church, prison, department store, bank, factory, industry plant, sports area);
- occupants and contents (persons and animals, presence of combustible or non-combustible materials, explosive or non-explosive materials, radioactive materials, hazardous biochemical materials, electrical and electronic systems with low or high rated impulse voltage);
- connected lines (power lines, telecommunication lines) pipelines;
- photovoltaic systems, vehicle charging systems, mobile phone installations;
- existing or provided protection measures (protection measures to reduce physical damage and life hazard, protection measures to reduce failure of internal systems);
- scale of the extension of danger (structure with difficulty of evacuation or structure where panic can be created, structure dangerous to the surroundings, structure dangerous to the environment).

Table 1 reports some examples of the effects of lightning on various types of structures.

Table 1 – Effects of lightning on typical structures

Type of structure according to function or contents or both	Effects of lightning
Dwelling house	Puncture of electrical installations, fire and material damage Damage normally limited to structures exposed to the point of strike or to the lightning current path Failure of electrical and electronic equipment and systems installed (e.g. TV sets, computers, modems, telephones)
Farm building	Primary risk of fire and hazardous step voltages as well as material damage Secondary risk due to loss of electric power, and life hazard to livestock due to failure of electronic control of ventilation and food supply systems, etc.
Theatre Hotel School Department store Sports area	Damage to the electrical installations (e.g. electric lighting) likely to cause panic Failure of fire alarms resulting in delayed fire-fighting measures
Bank Insurance company Commercial company, etc.	As all the types of structures listed above, plus problems resulting from loss of communication, failure of computers and loss of data
Hospital Nursing home Prison	As all the types of structures listed above, plus problems of people in intensive care, and the difficulties of rescuing immobile people
Industry	Additional effects depending on the contents of factories, ranging from minor to unacceptable damage and loss of production
Museums and archaeological site Church	Loss of irreplaceable cultural heritage
Telecommunication Power plants	Unacceptable loss of services to the public
Firework factory Munitions works	Consequences of fire and explosion to the plant and its surroundings
Surface mine	Risk of hazardous step voltages Risk of damage to plant and mobile machinery, including tyre explosions
Underground mine	Risk of hazardous step voltages Risk due to loss of electric power Risk of methane gas explosion or coal dust fire
Chemical plant Refinery Biochemical laboratories and plants	Fire and malfunction of the plant with detrimental consequences to the local and global environment

5.1.3 Sources and causes of damage to a structure

The lightning current is the source of damage. The following situations shall be taken into account, depending on the position of the point of strike relative to the structure considered:

S1: flashes to the structure;

S2: flashes near the structure;

S3: flashes to the lines connected to the structure;

S4: flashes near the lines connected to the structure.

a) Flashes to the structure can cause:

- immediate mechanical damage, fire or explosion or both due to the hot lightning plasma arc itself, due to the current resulting in ohmic heating of conductors (over-heated conductors), or due to the charge resulting in arc erosion (melted metal);
- fire or explosion of both triggered by sparks caused by overvoltages resulting from resistive and inductive coupling and to passage of part of the lightning currents;
- injury to human beings by electric shock resulting from direct strike or by resistive and inductive coupling;
- failure or malfunction of internal systems due to LEMP.

b) Flashes near the structure can cause:

- failure or malfunction of internal systems due to LEMP.

c) Flashes to a line connected to the structure can cause:

- fire or explosion or both triggered by sparks due to overvoltages and lightning currents transmitted through the connected line;
- injury to human beings by electric shock due to touch voltages inside the structure caused by lightning currents transmitted through the connected line;
- failure or malfunction of internal systems due to overvoltages appearing on connected lines and transmitted to the structure.

d) Flashes near a line connected to the structure can cause:

- failure or malfunction of internal systems due to overvoltages induced on connected lines and transmitted to the structure.

NOTE 1 Malfunctioning of internal systems is not covered by the IEC 62305 series. Refer to IEC 61000-4-5 [5].

NOTE 2 Only the sparks carrying lightning current (total or partial) are regarded as able to trigger fire.

NOTE 3 Lightning flashes, direct to or near the incoming pipelines, do not cause damages to the structure, provided that the pipelines are bonded to the equipotential bar of the structure (see IEC 62305-3).

As a result, four causes of damage can be distinguished:

D_{1T}: electric shock to human beings resulting from resistive and inductive coupling;

D_{1D}: electric shock to human beings resulting from direct strike to those beings;

D₂: dangerous sparking inside the structure triggering fire or explosion or leading to mechanical and chemical effects, or both, which can also endanger the environment;

D₃: surges due to all sources of damage causing failures of internal systems.

5.2 Types of loss

Each cause of damage relevant to the structure to be protected, alone or in combination with others, can produce different types of loss. The type of loss that can appear depends on the characteristics of the structure itself.

For the purposes of the IEC 62305 series, the following types of loss, which can appear as a consequence of lightning flashes, are considered:

L₁: loss due to injury to human beings; it is a consequence of causes D_{1D}, D_{1T}, D₂ and even D₃ in structures where failure of internal systems endangers human life, for example in structures with a risk of explosion and hospitals;

L₂: loss due to physical damage of the structure and its content. It is a consequence of cause D₂, and even D₃ in structures with a risk of explosion;

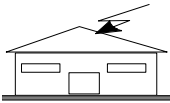
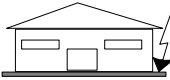
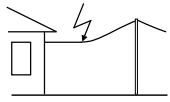
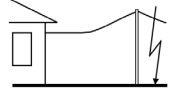
L₃: loss due to failure of internal systems. It is a consequence of cause D₃.

The risk calculation is applicable to all structures when types of loss L_1 , and L_2 , have public relevance.

The type of loss L_3 can unacceptably impair the services provided by internal systems of the structure and can also affect services of public relevance.

The relationship between sources of damage, causes of damage and types of loss is reported in Table 2.

Table 2 – Sources of damage, causes of damage, types of loss according to the point of strike

Point of strike		Source of damage	Cause of damage	Type of loss
Structure		S1	D_{1T}	L_1
			D_{1D}	L_1
			D_2	L_1, L_2
			D_3	L_1^a, L_2^b
Near the structure		S2	D_3	L_1^a, L_2^b
Lines connected to the structure		S3	D_{1T}	L_1
			D_2	L_1, L_2
			D_3	L_1^a, L_2^b
Near the lines connected to the structure		S4	D_3	L_1^a, L_2^b
^a Only for structures where failure of internal systems endangers human life, for example in structures with a risk of explosion and hospitals. ^b Only for structures with a risk of explosion.				

6 Need for lightning protection

6.1 Risk and frequency

The risk R shall be evaluated with reference to the safety of persons (type of loss L_1) and of the structure and its content (type of loss L_2).

The risk R is evaluated as the sum of its risk components depending on the source of damage or type of loss; each risk component may be expressed by the product of

- the number N of dangerous events per annum;
- the probability P of damage;
- the amount L of loss as a consequence of damage.

The frequency of damage F shall be evaluated for the equipment within the structure with reference to the availability of services provided (type of loss L_3).

The frequency of damage F may be evaluated as the sum of partial frequencies of damage depending on the source of damage; each partial frequency of damage is expressed by the product of number N of dangerous events per annum and the probability P of their damage.

NOTE Detailed information on the evaluation of risk, risk components, frequency and frequency components is reported in IEC 62305-2.

6.2 Need for lightning protection for reduction of risk R

Protection against lightning is needed if the risk R is higher than the tolerable level R_T .

$$R > R_T$$

In this case, protection measures shall be adopted in order to reduce the risk R to no more than the tolerable level R_T .

$$R \leq R_T$$

The values of tolerable risk R_T are the responsibility of the authorities having jurisdiction.

NOTE 1 Competent national bodies can provide guidance on whether the risk R is evaluated also in compliance with national laws and regulations.

NOTE 2 An authority having jurisdiction can specify the need for lightning protection for specific applications without requiring a risk assessment. In these cases, the required lightning protection level will be specified by the authority having jurisdiction.

NOTE 3 Detailed information on risk assessment and on the procedure for the selection of protection measures is reported in IEC 62305-2.

6.3 Need for lightning protection for reduction of frequency of damage F

Protection against lightning for the reduction of the frequency F is needed if the frequency of damage F is higher than the tolerable level F_T .

$$F > F_T$$

In this case, protection measures shall be adopted in order to reduce the frequency of damage F to no more than the tolerable level F_T .

$$F \leq F_T$$

The values of tolerable frequency of damage F_T are the responsibility of the authorities having jurisdiction when the service exploited is of public relevance.

In the other cases, evaluating whether or not to reduce the frequency F , as well as fixing the value of tolerable frequency F_T should be under the responsibility of the owner or the manager of the structure.

NOTE 1 Competent national bodies can provide guidance on whether the frequency of damage F is evaluated also in compliance with national laws and regulations.

NOTE 2 An authority having jurisdiction can specify the need for lightning protection for specific applications without requiring a risk assessment. In these cases, the required lightning protection level will be specified by the authority having jurisdiction.

NOTE 3 Detailed information on the frequency of damage assessment and on the procedure for the selection of protection measures is reported in IEC 62305-2.

7 Protection measures

7.1 General

Protection measures may be adopted in order to reduce the risk R and the frequency of damage F .

The most commonly used protection measures are:

- protection measures to reduce injury to human beings by electric shock (see 7.2);
- protection measures to reduce physical damage (see 7.3);
- protection measures to reduce failure of internal systems (see 7.4).

Moreover, provisions activated by means of a thunderstorm warning system (TWS) compliant with IEC 62793 [3] can be used as a preventive measure to reduce the risk R and the frequency F regardless of the type of loss, if appropriate protection measures are applied based on the warning given by a TWS.

NOTE 1 A TWS provides real-time information on atmospheric electrical activity. This provides for the reduction the risk R and the frequency of damage F by means of anticipated temporary preventive measures reducing the exposure time to the threat or cutting off lines conducting surges into the structure or both. In some cases of fast travelling or local formation T-storm, it is possible that the TWS will not always be fast enough to provide a warning signal.

Some examples of appropriate provisions are shown below:

- a) stopping dangerous activity;
- b) transferring people to a safe shelter;
- c) disconnection from external services and use of only local sources.

The circuit breaker disconnection (as from point c) should provide a withstand voltage high enough to avoid sparking-over when lightning surges occur.

If the voltage withstand of the circuit breaker is too low, then additional SPDs upstream of the circuit breaker are necessary. In addition, all lines shall be disconnected for N-conductors or PEN-conductors and this might not be possible due to wiring regulations. Inductive coupling in wiring loops due to S1 and S2 events cannot be reduced by this disconnection and this demands a specific study. In order to protect electrical and electronic systems in case of S3 and S4 events, the monitoring area of the TWS should be able to cover not only the structure but also the incoming lines.

NOTE 2 The advisability of implementing protection measures depends on the characteristics of the activity performed, the human presence in the zones exposed, and the possibility of taking effective preventive actions as a consequence of the information provided by the TWS.

NOTE 3 The reduction of the risk R and of the frequency of damage F by the use of a TWS and the amount of their reduction is evaluated by the lightning protection designer according to a plan of action of the protection measures to be undertaken in coordination with the TWS.

NOTE 4 More information on the provisions and actions to reduce different risk components is reported in IEC 62305-2:2024, Annex B.

7.2 Protection measures to reduce injury to human beings by electric shock

Possible protection measures include:

- lightning protection system (LPS);
- adequate insulation of exposed conductive parts;
- equipotentialization;
- physical restrictions and warning notices.

NOTE Equipotentialization and an increase in the contact resistance of the ground surface inside and outside the structure reduce the life hazard (see IEC 62305-3:2024, Clause 8).

7.3 Protection measures to reduce physical damage

Protection is achieved by the lightning protection system (LPS) complying with IEC 62305-3.

NOTE 1 When an LPS is installed, equipotentialization is a measure that reduces fire and explosion danger and life hazard. For more details see IEC 62305-3.

NOTE 2 Provisions limiting the development and propagation of the fire such as fireproof compartments, extinguishers, hydrants, fire alarms and fire extinguishing installations can reduce physical damage.

7.4 Protection measures to reduce failure of internal systems

Surge protection measures (SPM) complying with IEC 62305-4 include:

- earthing and bonding measures,
- electromagnetic shielding,
- line routing,
- isolating interfaces,
- coordinated SPD systems.

These measures may be used alone or in combination.

NOTE 1 When source of damage S1 is considered, protection measures are effective only in structures protected by an LPS or structures with continuous metal or reinforced concrete framework acting as a natural LPS.

NOTE 2 For sources of damage S1 and S3, the withstand level of the isolating interface can be inadequate in some cases.

7.5 Protection measures selection

The protection measures listed in 7.2, 7.3 and 7.4 together form the overall lightning protection.

Selection of the most suitable protection measures shall be made by the designer of the protection measures, the owner of the structure to be protected according to the type, the amount of each type of loss, the technical and economic aspects of the different protection measures and the results of risk assessment.

The criteria for risk R assessment, for frequency F assessment and for the selection of the most suitable protection measures are given in IEC 62305-2.

Protection measures are effective provided that they comply with the requirements of relevant standards and are able to withstand the stress expected in the place of their installation.

8 Basic criteria for protection of structures

8.1 General

An ideal protection for structures would be to enclose the structure to be protected within an earthed and perfectly conducting continuous shield of adequate thickness, and to provide adequate bonding at the entrance point into the shield of the lines connected to the structure.

This would prevent the penetration of lightning current and related electromagnetic field into the structure to be protected and prevent dangerous thermal and electrodynamic effects of current, as well as dangerous sparking and overvoltages for internal systems.

In practice, it is often neither possible nor cost effective to go to such measures to provide such full protection.

Lack of continuity of the shield or its inadequate thickness, or both, allows the lightning current to penetrate the shield causing:

- physical damage and life hazard;
- failure of internal systems.

8.2 Lightning protection levels (LPLs)

Protection measures, adopted to reduce such damages and relevant consequential loss, shall be designed for the defined set of lightning current parameters against which protection is required (lightning protection level).

For the purposes of the IEC 62305 series, four lightning protection levels (I to IV) are introduced. For each LPL, a set of maximum and minimum lightning current parameters is fixed.

The LPL is normally selected as the result of a risk assessment.

NOTE 1 Protection against lightning whose maximum and minimum lightning current parameters exceed those relevant to LPL I can require more efficient measures which are selected and erected on an individual basis but always following these standards.

NOTE 2 The probability of occurrence of lightning with minimum or maximum current parameters outside the range of values defined for LPL I is less than 2 %.

The maximum values of lightning current parameters relevant to LPL I are expected to be exceeded with a probability of no more than 1 %. Positive flashes are expected to exceed the given maximum values in no more than 10 % of positive flashes and those from negative flashes in no more than 1 % of negative flashes. On the assumption that positive flashes constitute no more than about 10 % of flashes (see Clause A.2), the combination of positive and negative flashes results in the expectation that no more than 1 % of flashes will exceed the tabled maximum values of parameters (see Clause A.3). The maximum values of lightning current parameters relevant to LPL I are reduced to 75 % for LPL II and to 50 % for LPL III and LPL IV (following a linear regression from LPL I values in I , Q and di/dt , but quadratic for W/R). The time parameters are unchanged.

NOTE 3 Lightning protection levels whose maximum lightning current parameters are lower than those relevant to LPL IV enable one to consider values of probability of damage higher than those presented in IEC 62305-2:2024, Annex B, and are useful for better tailoring of protection measures in order to avoid unjustified costs.

The maximum values of lightning current parameters for the different lightning protection levels are given in Table 3 and are used to design lightning protection components (e.g. cross-section of conductors, thickness of metal sheets, current capability of SPDs, separation distance against dangerous sparking) and to define test parameters simulating the effects of lightning on such components (see Annex D).

Table 3 – Maximum values of lightning parameters according to LPLs

Current parameters		Symbol	Unit	LPL			
				I	II	III	IV
First positive short stroke	Peak current	I	kA	200	150	100	
	Charge	Q_{SHORT}	C	100	75	50	
	Specific energy	W/R	MJ/Ω	10	5,6	2,5	
	Time parameters	T_1/T_2	μs/μs	10 / 350			
First negative short stroke ^a	Peak current	I	kA	100	75	50	
	Average steepness	di/dt	kA/μs	100	75	50	
	Time parameters	T_1/T_2	μs/μs	1 / 200			
Subsequent short stroke	Peak current	I	kA	50	37,5	25	
	Average steepness	di/dt	kA/μs	200	150	100	
	Time parameters	T_1/T_2	μs/μs	0,25 / 100			
Long stroke	Charge	Q_{LONG}	C	200	150	100	
	Time parameter	T_{LONG}	s	0,5			
Flash	Charge	Q_{FLASH}	C	300	225	150	

^a The first negative stroke relates only to calculations and not testing.

^a The first negative stroke relates only to calculations and not testing.

NOTE 4 For practical purposes each LPL has been assigned a probability value. Where a more detailed analysis, the values derived from the CIGRE in Clause A.2 can be used [6].

The minimum values of lightning peak current amplitude for the different LPLs are used to derive the rolling sphere radius (see Clause A.4) in order to define the lightning protection zone LPZ 0_B which is considered protected from a direct strike (see 8.3 and Figure 2 and Figure 3). The minimum values of lightning current parameters together with the related rolling sphere radius are given in Table 4. They are used for positioning of the air-termination system and to define the lightning protection zone LPZ 0_B (see 8.3).

Table 4 – Minimum values of lightning parameters and related rolling sphere radius corresponding to LPLs

Interception criteria			LPL			
	Symbol	Unit	I	II	III	IV
Minimum peak current	I	kA	3	5	10	16
Rolling sphere radius	r	m	20	30	45	60

From the statistical distributions given in Figure A.5, a weighted probability that the lightning current parameters are smaller than the maximum values and respectively greater than the minimum values defined for each protection level (see Table 5) can be determined.

Table 5 – Probabilities for the limits of the lightning current parameters

Probability that lightning current parameters	LPL			
	I	II	III	IV
– are smaller than the maximum values defined in Table 3	0,99	0,98	0,95	0,95
– are greater than the minimum values defined in Table 4	0,99	0,97	0,91	0,94

The protection measures specified in IEC 62305-3 and IEC 62305-4 are effective against lightning whose current parameters are in the range defined by the LPL assumed for design. Therefore, the efficiency of a protection measure is assumed to be equal to the probability with which lightning current parameters are inside such a range. For parameters exceeding this range, a residual risk of damage remains.

NOTE 5 The values in Table 5 reflect a conservative approach. Specific studies based on the rules and parameters of this document taking into account individual parameters (e.g. the real size of the structure, location and height of air-termination systems, current sharing) can lead to higher efficiency values.

8.3 Lightning protection zones (LPZs)

Protection measures such as LPSs, shielding wires, magnetic shields and SPDs determine lightning protection zones (LPZs).

LPZs downstream of the protection measure are characterized by significant reduction of LEMP compared to the LPZ upstream.

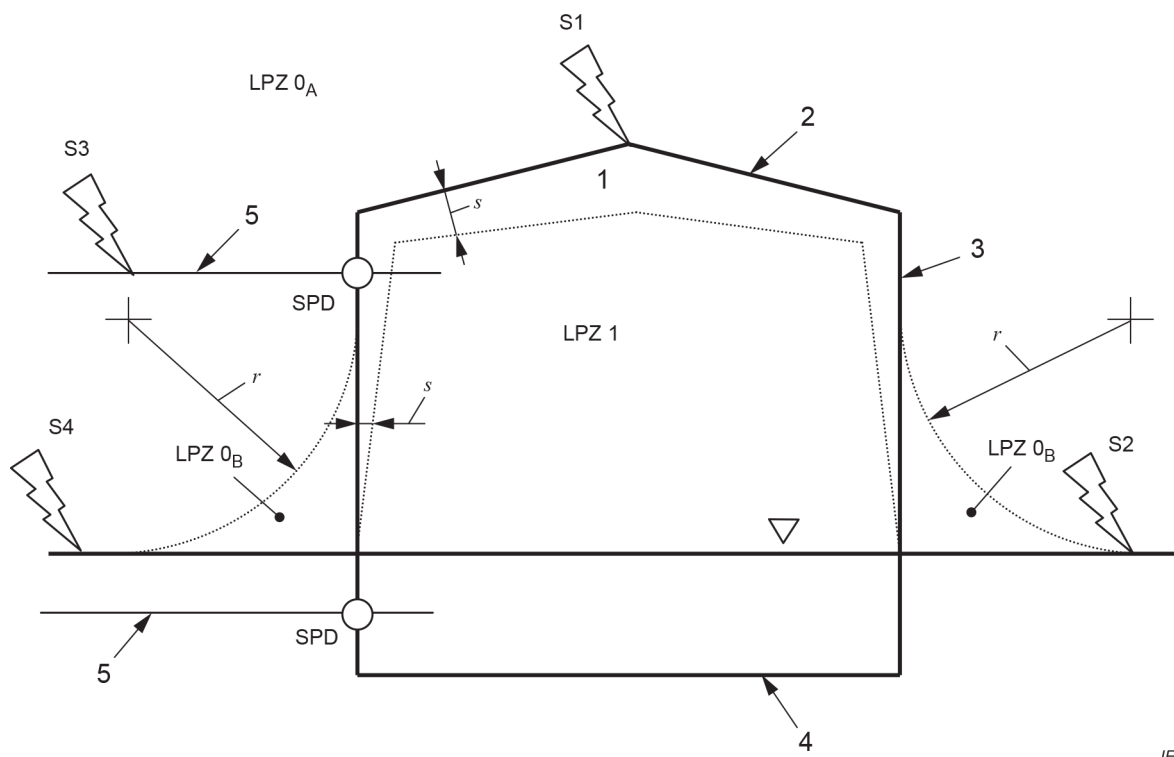
With respect to the threat of lightning, the following LPZs are defined (see Figure 2 and Figure 3):

- | | |
|----------------------|---|
| LPZ 0 _A | zone where the threat is due to the direct lightning flash and the full lightning electromagnetic field. The internal systems can be subjected to full or partial lightning surge current; |
| LPZ 0 _B | zone protected against direct lightning flashes but where the threat is the full lightning electromagnetic field. The internal systems can be subjected to partial lightning surge currents; |
| LPZ 1 | zone where the surge current is limited by current sharing and by isolating interfaces or SPDs at the boundary or both. Spatial shielding can attenuate the lightning electromagnetic field; |
| LPZ 2, ..., <i>n</i> | zone where the surge current can be further limited by current sharing and by isolating interfaces or additional SPDs at the boundary or both. Additional spatial shielding may be used to further attenuate the lightning electromagnetic field. |

NOTE 1 In general, the higher the number of an individual zone, the lower the electromagnetic environment parameters.

As a general rule for protection, the structure to be protected shall be in an LPZ whose electromagnetic characteristics are compatible with the capability of the structure to withstand stress causing the damage to be reduced (physical damage, failure of electrical and electronic systems due to overvoltages).

NOTE 2 For most electrical and electronic systems and apparatus, information about withstand level is supplied by the manufacturer.



IEC

Key

1	structure	S1	flash to the structure
2	air-termination system	S2	flash near the structure
3	down-conductor system	S3	flash to a line connected to the structure
4	earth-termination system	S4	flash near a line connected to the structure
5	incoming lines	r	rolling sphere radius
		s	separation distance against dangerous sparking (see IEC 62305-3:2024, 6.3 and Annex B)

▽ ground level

○ lightning equipotential bonding by means of SPD

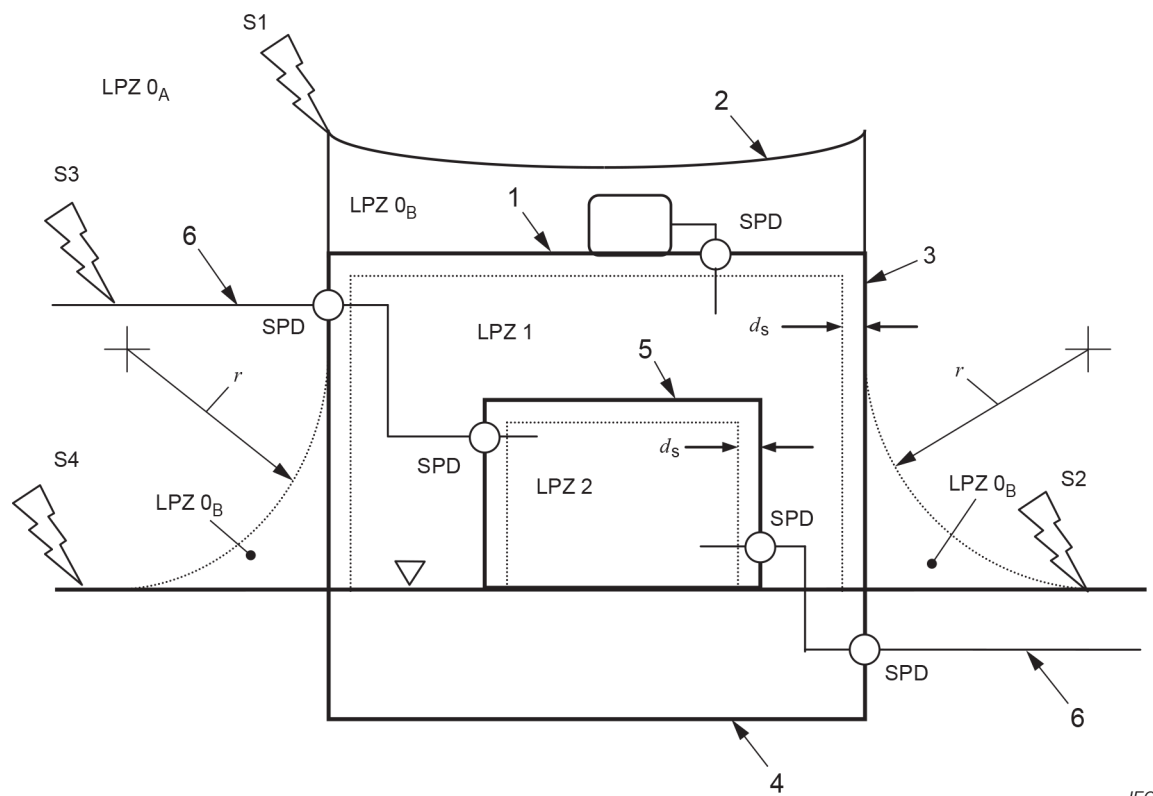
LPZ 0_A direct flash, full lightning current

LPZ 0_B no direct flash, partial lightning or induced current

LPZ 1 no direct flash, limited lightning or induced current

The protected volume inside LPZ 1 shall respect separation distance s .

Figure 2 – LPZ defined by an LPS (IEC 62305-3)



IEC

Key

1	structure (shield of LPZ 1)	S1	flash to the structure
2	air-termination system	S2	flash near to the structure
3	down-conductor system	S3	flash to a line connected to the structure
4	earth-termination system	S4	flash near a line connected to the structure
5	room (shield of LPZ 2)	r	rolling sphere radius
6	lines connected to the structure	d_s	safety distance against a too high magnetic field (see IEC 62305-4:2024, Annex A)



ground level



lightning equipotential bonding by means of SPD

LPZ 0_A direct flash, full lightning current, full magnetic fieldLPZ 0_B no direct flash, partial lightning or induced current, full magnetic field

LPZ 1 no direct flash, limited lightning or induced current, damped magnetic field

LPZ 2 no direct flash, induced currents, further damped magnetic field

Protected volumes inside LPZ 1 and LPZ 2 shall respect safety distances d_s .**Figure 3 – LPZ defined by LPS and SPM (IEC 62305-4)****8.4 Protection of structures****8.4.1 Protection to reduce physical damage and life hazard**

The structure to be protected shall be inside an LPZ 0_B or higher. This is achieved by means of a lightning protection system (LPS).

An LPS consists of both external and internal lightning protection systems.

The functions of the external LPS are

- to intercept a lightning flash to the structure (with an air-termination system),
- to conduct the lightning current safely to earth (with a down-conductor system),
- to disperse it into the earth (with an earth-termination system).

NOTE Research indicates that the lightning channel termination point during a subsequent stroke can be up to a few metres away from the original (first stroke) termination point in some cases (multi-stroke flash, strong wind). However, the probability is low that a structure gets damaged by such a phenomenon when an LPS according to IEC 62305-3 is installed. A large continuing current flows right after the first stroke to keep the plasma channel alive. This phenomenon can be considered thanks to a specific study that includes wind direction and possible attachment points. Possible solutions are: additional air terminals, isolated LPS or increased length of air terminals.

The function of the internal LPS is to prevent dangerous sparking within the structure, using equipotential bonding or a separation distance, s , (and hence electrical isolation) between the LPS components and other electrically conducting elements internal to the structure.

Four classes of LPS (I, II, III and IV) are defined as a set of construction rules, based on the corresponding LPL. Each set includes level-dependent (e.g. rolling sphere radius, mesh width) and level-independent (e.g. cross-sections, materials) construction rules.

Where surface resistivity of the soil outside and of the floor inside the structure is low, life hazard due to touch and step voltages is reduced:

- outside the structure, by insulation of the exposed conductive parts, by equipotentialization of the soil by means of a meshed earthing system, by warning notices or by physical restrictions;
- inside the structure, by equipotential bonding of lines at the entrance points into the structure.

The LPS shall comply with the requirements of IEC 62305-3.

8.4.2 Protection to reduce the failure of internal systems

The protection against LEMP to reduce the frequency of failure of internal systems shall limit

- surges due to lightning flashes to the structure resulting from resistive and inductive coupling,
- surges due to lightning flashes near the structure resulting from inductive coupling,
- surges transmitted by lines connected to the structure due to flashes to or near the lines,
- electromagnetic fields directly coupling with the apparatus.

NOTE Failure of the apparatus due to electromagnetic fields directly radiated into the equipment is negligible provided that the apparatus complies with radiofrequency (RF) radiated emission and immunity tests defined by relevant EMC product standards (see IEC 62305-2 and IEC 62305-4).

The system to be protected shall be located inside an LPZ 1 or higher. This is achieved by means of electrical and electronic surge protection measures (SPM) consisting of magnetic shields attenuating the inducing magnetic field or suitable routing of wiring to reduce the induction loop, or both. Bonding shall be provided at the boundaries of an LPZ for metal parts and systems crossing the boundaries. This bonding may be accomplished by means of bonding conductors or, when necessary, by surge protective devices (SPDs).

The protection measures for any LPZ shall comply with IEC 62305-4.

Effective protection against overvoltages, causing failures of internal systems, may also be achieved by means of isolating interfaces or a coordinated SPD system, limiting overvoltages below the rated impulse voltage of the system to be protected, or both.

Isolating interfaces and SPDs shall be selected and installed according to the requirements of IEC 62305-4.

Annex A (informative)

Parameters of lightning current

A.1 Lightning flashes to earth

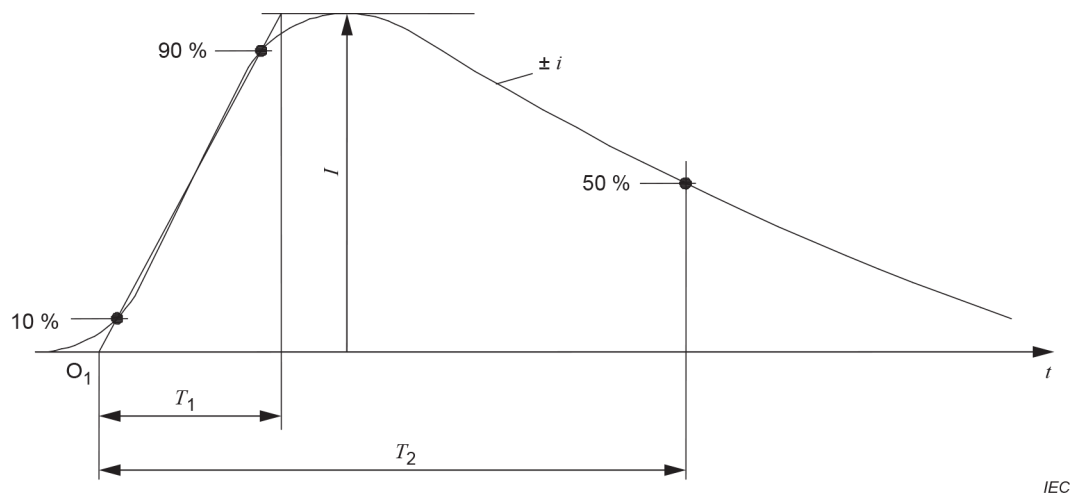
Two basic types of flashes exist:

- downward flashes initiated by a downward leader from cloud to earth;
- upward flashes initiated by an upward leader from an earthed structure to cloud.

Downward flashes occur mostly in flat territory, and to lower structures, whereas for exposed or higher structures, or both, upward flashes become dominant. With effective height, the probability of a direct strike to the structure increases (see IEC 62305-2:2024, Annex A) and the physical conditions change.

A lightning flash can consist of one or more different strokes:

- short strokes with a duration less than 2 ms (Figure A.1);
- long strokes with a duration longer than 2 ms (Figure A.2).



Key

O_1 virtual origin of impulse current (Point of intersection with the time axis of a straight line drawn through the 10 % and the 90 % reference points on the stroke current front; it precedes by $0,1 T_1$ that instant at which the current attains 10 % of its peak value)

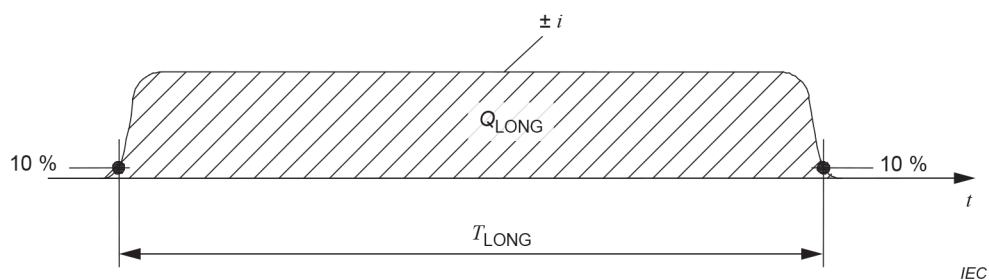
I peak current

i instantaneous value

T_1 front time of impulse current

T_2 time to half value on the tail of impulse current (typically $T_2 < 2$ ms)

Figure A.1 – Definitions of impulse current parameters according to IEC 62475 [7]



Key

T_{LONG} duration of long stroke current (typically $2 \text{ ms} < T_{\text{LONG}} < 1 \text{ s}$)

Q_{LONG} long stroke charge

Figure A.2 – Definitions of long duration stroke parameters

Further differentiation of strokes comes from their polarity (positive or negative) and from their position during the flash (first, subsequent, and superimposed). The schematic representation of possible components of the lightning current are shown in Figure A.3 for downward flashes and multiple strokes downward flashes, in Figure A.4 for upward flashes.

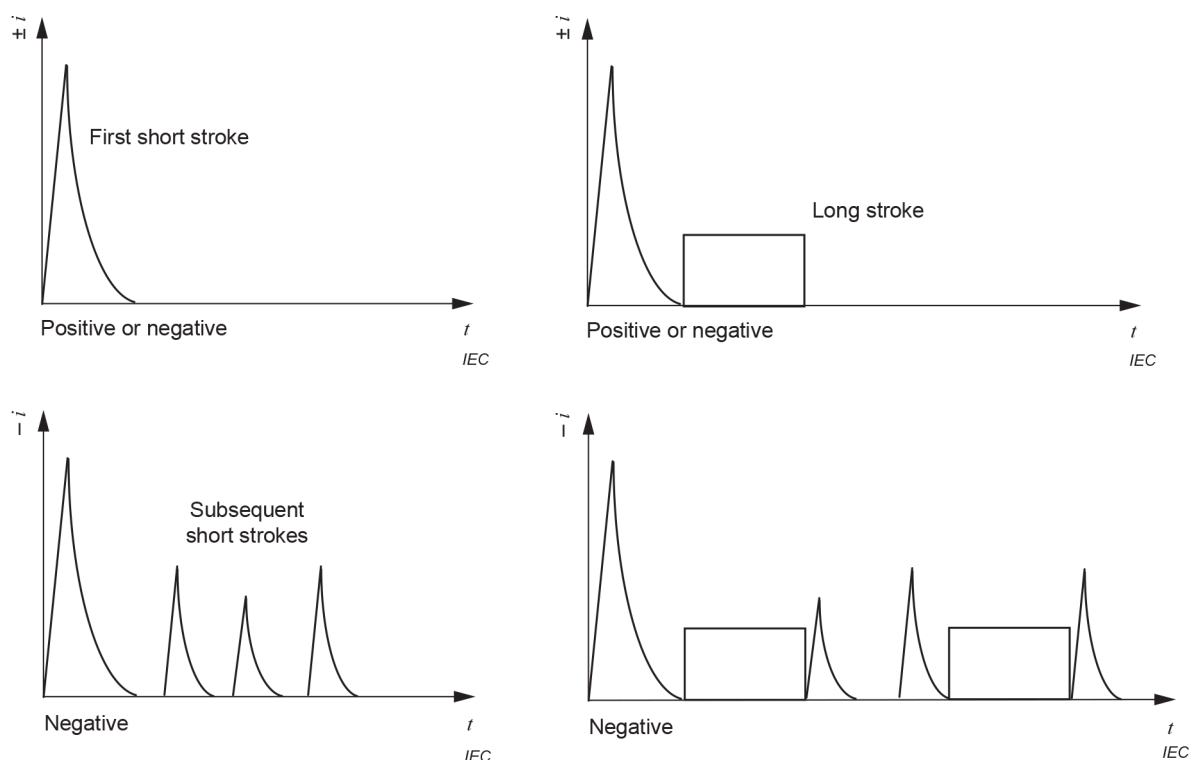


Figure A.3 – Schematic representation (not to scale) of possible components of downward flashes (typical in flat territory and to lower structures) and multiple strokes downward flashes

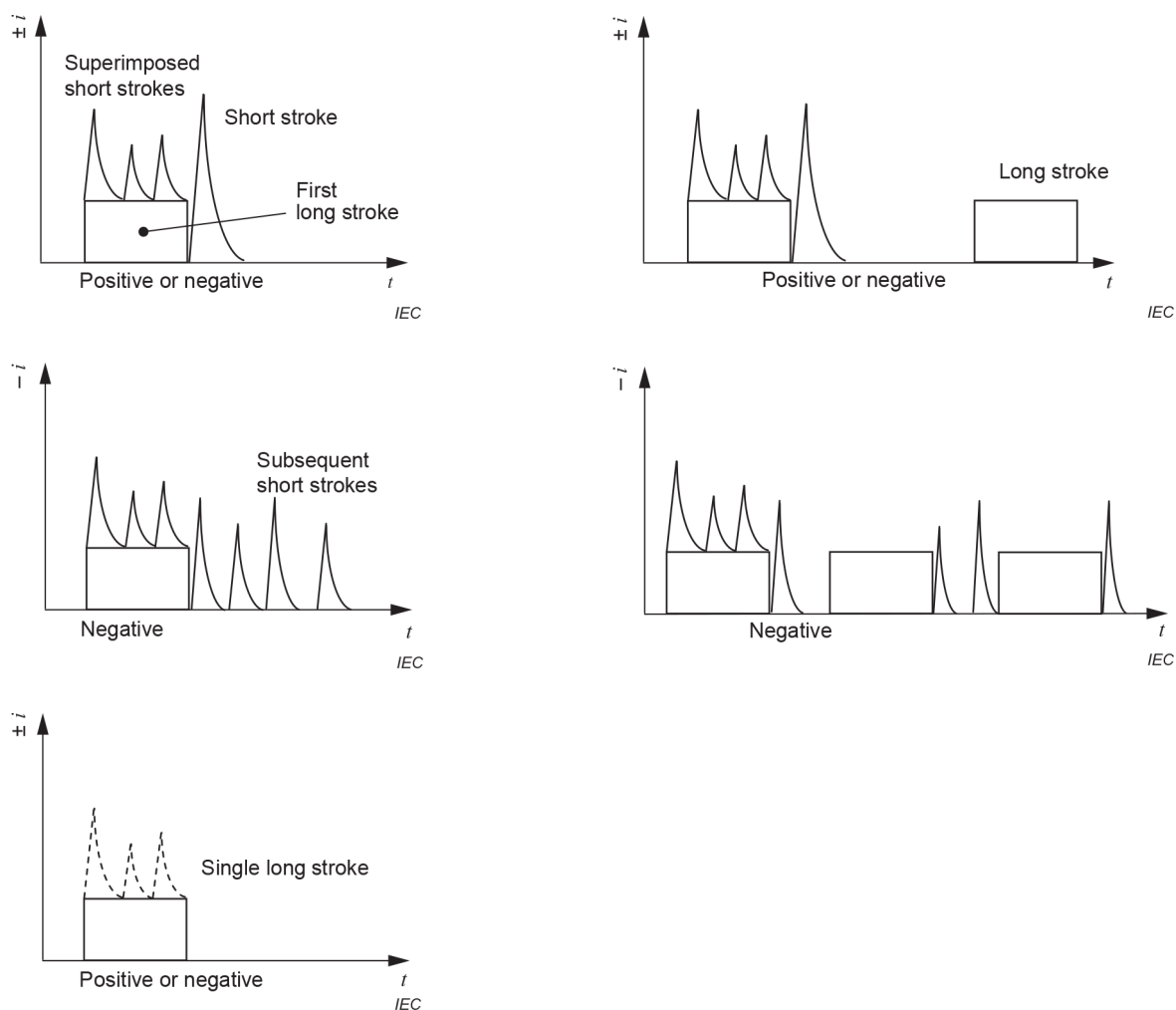


Figure A.4 – Schematic representation (not to scale) of possible components of upward flashes (typical of exposed or higher structures or both)

The additional component in upward flashes is the first long stroke with or without up to some ten superimposed impulses. But all impulse current parameters of upward flashes are lower than those of downward flashes. A higher long stroke charge of upward flashes is not yet confirmed. Therefore, the lightning current parameters of upward flashes are considered to be covered by the maximum values given for downward flashes.

NOTE IEC 61400-24 [4] includes information about higher long stroke charge of upward flashes, especially in areas with high winter lightning activity. It includes a methodology to estimate the average annual flashes or strokes to wind turbines and upward lightning activity in wind turbines.

A.2 Lightning current parameters

The lightning current parameters in this document are based on the results of the International Council on Large Electrical Systems (CIGRE) data given in Table A.1. Their statistical distribution can be assumed to have a logarithmic normal distribution. The corresponding mean value μ and the dispersion $\sigma_{\log}$ are given in Table A.2 and the distribution function is shown in Figure A.5. On this basis, the probability of occurrence of any value of each parameter can be determined.

NOTE 1 Further information on lightning current parameters is contained in the ICLP 2008 paper by Heidler et al [8].

A polarity ratio of 10 % positive and 90 % negative flashes is assumed. The real polarity ratio is a function of the territory. If no local information is available, the ratio given herein should be used.

The value of the probability of occurrence of lightning current peak values of first negative short stroke and first positive short stroke exceeding the previously considered value are reported in Table A.3.

Table A.1 – Tabulated values of lightning current parameters (CIGRE [9], [10], [11])

Parameter	Fixed values for LPL I	Values			Type of stroke	Line in Figure A.5
		95 %	50 %	5 %		
I (kA)		4 ^a	20 ^a	90	First negative short ^b	1A + 1B
	50	4,9	11,8	28,6	Subsequent negative short ^b	2
	200	4,6	35	250	First positive short (single)	3
Q_{FLASH} (C)		1,3	7,5	40	Negative flash	4
	300	20	80	350	Positive flash	5
$Q_{\text{SHORT STROKE}}$ (C)		1,1	4,5	20	First negative short	6
		0,22	0,95	4	Subsequent negative short	7
	100	2	16	150	First positive short (single)	8
W/R (kJ/Ω)		6	55	550	First negative short	9
		0,55	6	52	Subsequent negative short	10
	10 000	25	650	15 000	First positive short	11
di/dt_{max} (kA/μs)		9,1	24,3	65	First negative short ^b	12
		9,9	39,9	161,5	Subsequent negative short ^b	13
	20	0,2	2,4	32	First positive short	14
$di/dt_{30\%/90\%}$ (kA/μs)	200	4,1	20,1	98,5	Subsequent negative short ^b	15
$Q_{\text{LONG STROKE}}$ (C)	200				Long	
$T_{\text{LONG STROKE}}$ (s)	0,5				Long	
Front duration (μs)		1,8	5,5	18	First negative short	
		0,22	1,1	4,5	Subsequent negative short	
		3,5	22	200	First positive short (single)	
Stroke duration (μs)		30	75	200	First negative short	
		6,5	32	140	Subsequent negative short	
		25	230	2 000	First positive short (single)	
Time interval between strokes (ms)		7	33	150	Multiple negative strokes	
Total flash duration (ms)		0,15	13	1 100	Negative flash (all)	
		31	180	900	Negative flash (without single)	
		14	85	500	Positive flash	

NOTE Values given for $Q_{\text{LONG STROKE}}$ and T_{LONG} are related to downward strikes only. $Q_{\text{LONG STROKE}} = Q_{\text{FLASH}} - Q_{\text{SHORT STROKE}}$, so there is no statistical values given in this Table A.1.

^a The values of $I = 4$ kA and $I = 20$ kA correspond to a probability of 98 % and 80 %, respectively.

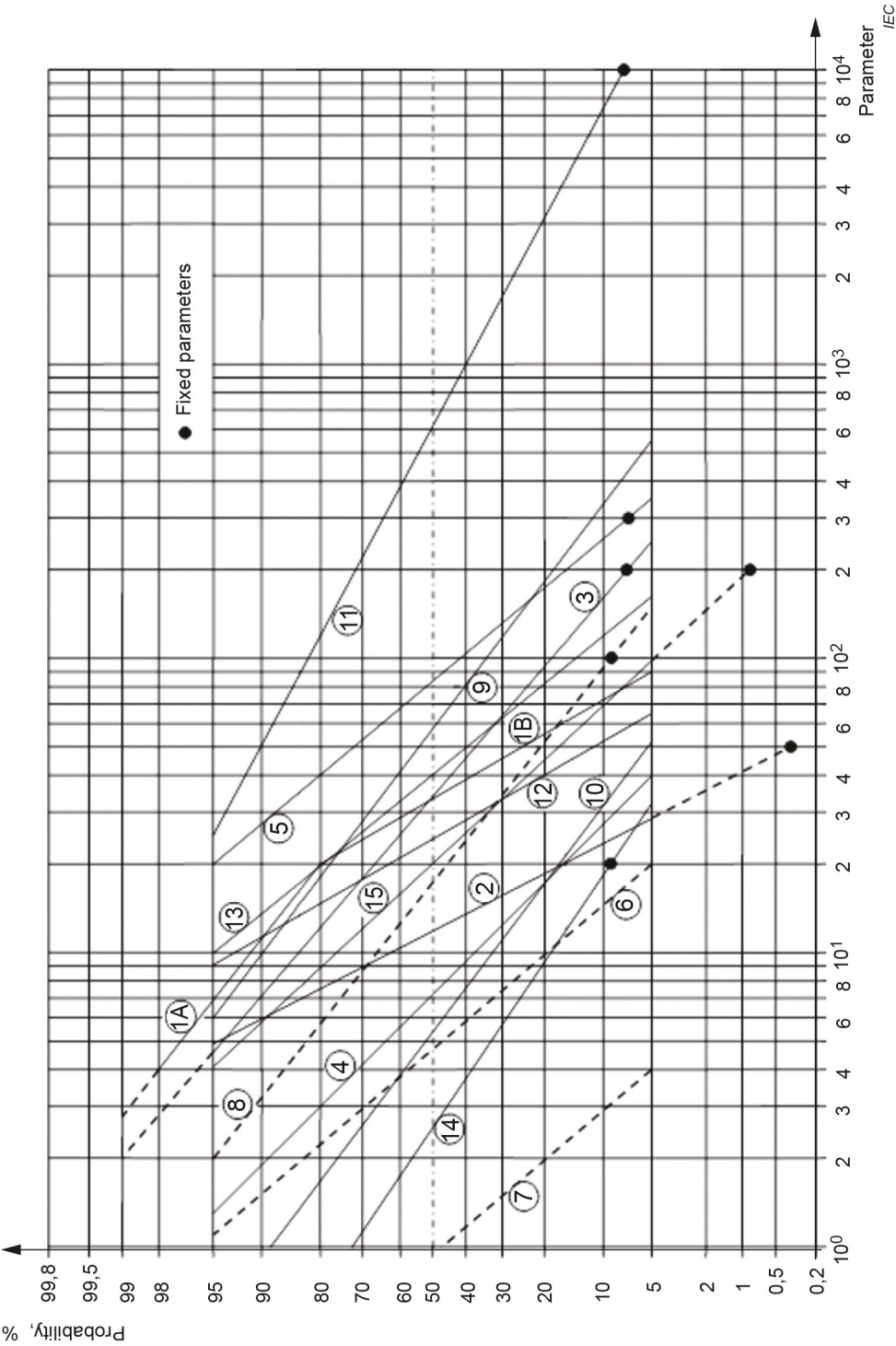
^b Parameters and relevant values are reported in [10].

Table A.2 – Logarithmic normal distribution of lightning current parameters – Mean μ and dispersion $\sigma_{\log}$ calculated from 5 % and 95 % values (CIGRE [9], [10], [11])

Parameter	Mean μ	Dispersion ^a $\sigma_{\log}$	Stroke type	Line in Figure A.5
I (kA)	(61,1)	0,576	First negative short (80 %) ^b	1A
	33,3	0,263	First negative short (80 %) ^b	1B
	11,8	0,233	Subsequent negative short ^b	2
	33,9	0,527	First positive short (single)	3
Q_{FLASH} (C)	7,21	0,452	Negative flash	4
	83,7	0,378	Positive flash	5
$Q_{\text{SHORT STROKE}}$ (C)	4,69	0,383	First negative short	6
	0,938	0,383	Subsequent negative short	7
	17,3	0,570	First positive short (single)	8
W/R (kJ/ Ω)	57,4	0,596	First negative short	9
	5,35	0,600	Subsequent negative short	10
	612	0,844	First positive short	11
di/dt_{max} (kA/ μ s)	24,3	0,260	First negative short ^b	12
	40,0	0,369	Subsequent negative short ^b	13
	2,53	0,670	First positive short	14
$di/dt_{30\%/90\%}$ (kA/ μ s)	20,1	0,420	Subsequent negative short ^b	15
$Q_{\text{LONG STROKE}}$ (C) ^c			Long	
$T_{\text{LONG STROKE}}$ (s) ^c			Long	
Front duration (μ s)	5,69	0,304	First negative short	
	0,995	0,398	Subsequent negative short	
	26,5	0,534	First positive short (single)	
Stroke duration (μ s)	77,5	0,250	First negative short	
	30,2	0,405	Subsequent negative short	
	224	0,578	First positive short (single)	
Time interval between strokes (ms)	32,4	0,405	Multiple negative strokes	
Total flash duration (ms)	12,8	1,175	Negative flash (all)	
	167	0,445	Negative flash (without single)	
	83,7	0,472	Positive flash	
^a $\sigma_{\log}$ is the value that indicates the dispersion around the logarithmic mean value of the log-normal distribution of the parameter. Integral $(-\sigma_{\log}, +\sigma_{\log})$ [log-normal distribution] = 68,2 %. ^b Parameters and relevant values are reported in [10]. ^c For the value refer to [12].				

Table A.3 – Values of probability P as function of the lightning current I peak value

I kA	P
0	1
3	0,99
5	0,95
10	0,91
20	0,8
30	0,6
35	0,5
40	0,4
50	0,3
60	0,2
80	0,1
100	0,05
150	0,02
200	0,01



NOTE For numbering of curves see Table A.1 and Table A.2.

Figure A.5 – Cumulative frequency distribution of lightning current parameters (dotted line through 50 % value)

All values fixed for LPLs given in this document relate to both downward and upward flashes.

NOTE 2 The value of lightning parameters is usually obtained from measurement taken on tall structures. Statistical distribution of roughly estimated lightning current peak values that does not consider the effect of tall structures is also available from lightning location systems.

A.3 Fixing the maximum lightning current parameters for LPL I

A.3.1 General

The mechanical effects of lightning are related to the peak value of the current (I), and to the specific energy (W/R). The thermal effects are related to the specific energy (W/R) when resistive coupling is involved and to the charge (Q) when arcs develop in the installation. Overvoltages and dangerous sparking caused by inductive coupling are related to the average steepness (di/dt) of the current front.

Each of the single parameters (I , Q , W/R , di/dt) tend to dominate each failure mechanism. This shall be taken into account when establishing test procedures.

A.3.2 First positive stroke and long stroke

The values of I , Q (as flash charge and short stroke charge) and W/R related to mechanical and thermal effects are determined from positive flashes (because their 10 % values are much higher than the corresponding 1 % values of the negative flashes). From Figure A.5 (lines 3, 5, 8, 11 and 14) the following values with probabilities below 10 % can be taken:

I	= 200 kA
Q_{FLASH}	= 300 C
Q_{SHORT}	= 100 C
W/R	= 10 MJ/ Ω
di/dt	= 20 kA/ μ s

For a first positive stroke according to Figure A.1, the following values give a first approximation for the front time:

$$T_1 = I / (di/dt) = 10 \mu\text{s} \quad (T_1 \text{ is of minor interest})$$

For an exponentially decaying stroke, the following formulae for approximate charge and energy values apply ($T_1 \ll T_2$):

$$Q_{\text{SHORT}} = (1 / 0,7) \times I \times T_2$$

$$W/R = (1/2) \times (1 / 0,7) \times I^2 \times T_2$$

These formulae, together with the values given above, lead to a first approximation for the time to half value:

$$T_2 = 350 \mu\text{s}$$

For the long stroke, its charge can be approximately calculated from:

$$Q_{\text{LONG}} = Q_{\text{FLASH}} - Q_{\text{SHORT}} = 200 \text{ C}$$

Its duration time, according to Figure A.2, may be estimated from data in Table A.1 as:

$$T_{\text{LONG}} = 0,5 \text{ s}$$

A.3.3 First negative stroke

For some inductive coupling effects, the impact of the first negative stroke leads to the highest induced voltages due to high amplitude and long duration of current, e.g. for cables within cable ducts made of reinforced concrete. From Figure A.5 (lines 1 and 12) the following values with probabilities below 1 % can be taken:

$$I = 100 \text{ kA}$$

$$di/dt = 100 \text{ kA}/\mu\text{s}$$

For a first negative stroke according to Figure A.1, these values give a first approximation for its front time of:

$$T_1 = I / (di/dt) = 1,0 \mu\text{s}$$

Its time to half value may be estimated from the duration of first negative strokes:

$$T_2 = 200 \mu\text{s} \quad (T_2 \text{ is of minor interest}).$$

A.3.4 Subsequent stroke

The maximum value of the average steepness of the current front, di/dt , related to the dangerous sparking caused by inductive coupling is determined from subsequent strokes of negative flashes (because their 1 % values are somewhat higher than the 1 % values from first negative strokes or the corresponding 10 % values of the positive flashes). From Figure A.5 (lines 2 and 15) the following values with probabilities below 1 % can be taken:

$$I = 50 \text{ kA}$$

$$di/dt = 200 \text{ kA}/\mu\text{s}$$

For a subsequent stroke according to Figure A.1, these values give a first approximation for its front time of:

$$T_1 = I / (di/dt) = 0,25 \mu\text{s}$$

Its time to half value may be estimated from the duration of negative subsequent strokes:

$$T_2 = 100 \mu\text{s} \quad (T_2 \text{ is of minor interest}).$$

A.4 Fixing the minimum lightning current parameters

The interception efficiency of an air-termination system depends on the minimum lightning current parameters and on the related rolling sphere radius. The geometrical boundary of areas which are protected against direct lightning flashes can be determined using the rolling sphere method.

Following the electro-geometric model, the rolling sphere radius r (final jump distance) is correlated with the peak value of the first stroke current. In an IEEE working group report [13], the relation is given as

$$r = 10 \times I^{0,65} \quad (\text{A.1})$$

where

r is the rolling sphere radius (m);

I is the peak current (kA).

For a given rolling sphere radius r , it can be assumed that all flashes with peak values higher than the corresponding minimum peak value I will be intercepted by natural or dedicated air terminations. Therefore, the probability for the peak values of negative and positive first strokes from Figure A.5 (lines 1A and 3) is assumed to be the interception probability. Taking into account the polarity ratio of 10 % positive and 90 % negative flashes, the total interception probability can be calculated (see Table 5).

Annex B (informative)

Time functions of the lightning current for analysis purposes

The current shapes of

- the first positive impulse 10/350 µs,
- the first negative impulse 1/200 µs,
- the subsequent negative impulses 0,25/100 µs,

may be defined as:

$$i = \frac{I}{k} \times \frac{(t / \tau_1)^{10}}{1 + (t / \tau_1)^{10}} \times \exp(-t / \tau_2) \quad (\text{B.1})$$

where

I is the peak current;

k is the correction factor for the peak current;

t is the time;

τ_1 is the front time constant;

τ_2 is the tail time constant.

For the current shapes of the first positive stroke, the first negative stroke and the subsequent negative strokes for different LPLs, the parameters given in Table B.1 apply. The analytic curves as function of time are shown in Figure B.1 to Figure B.6.

NOTE 1 The maximum di/dt -values of the time functions are greater than the standardized values specified in Clause A.3 (see Figure B.1, Figure B.3 and Figure B.5).

Table B.1 – Parameters for Equation (B.1)

Parameters	First positive stroke			First negative stroke			Subsequent negative stroke		
	LPL			LPL			LPL		
	I	II	III to IV	I	II	III to IV	I	II	III to IV
I (kA)	200	150	100	100	75	50	50	37,5	25
k	0,93	0,93	0,93	0,986	0,986	0,986	0,993	0,993	0,993
τ_1 (µs)	19	19	19	1,82	1,82	1,82	0,454	0,454	0,454
τ_2 (µs)	485	485	485	285	285	285	143	143	143

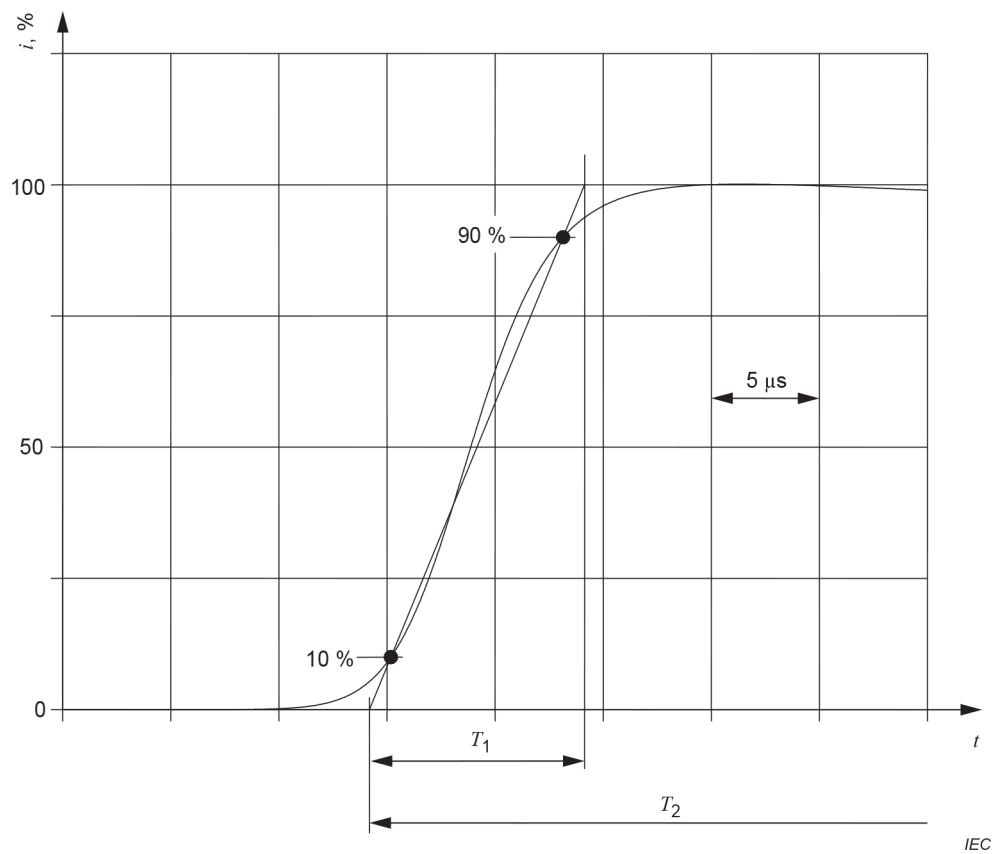


Figure B.1 – Shape of the current rise of the first positive stroke

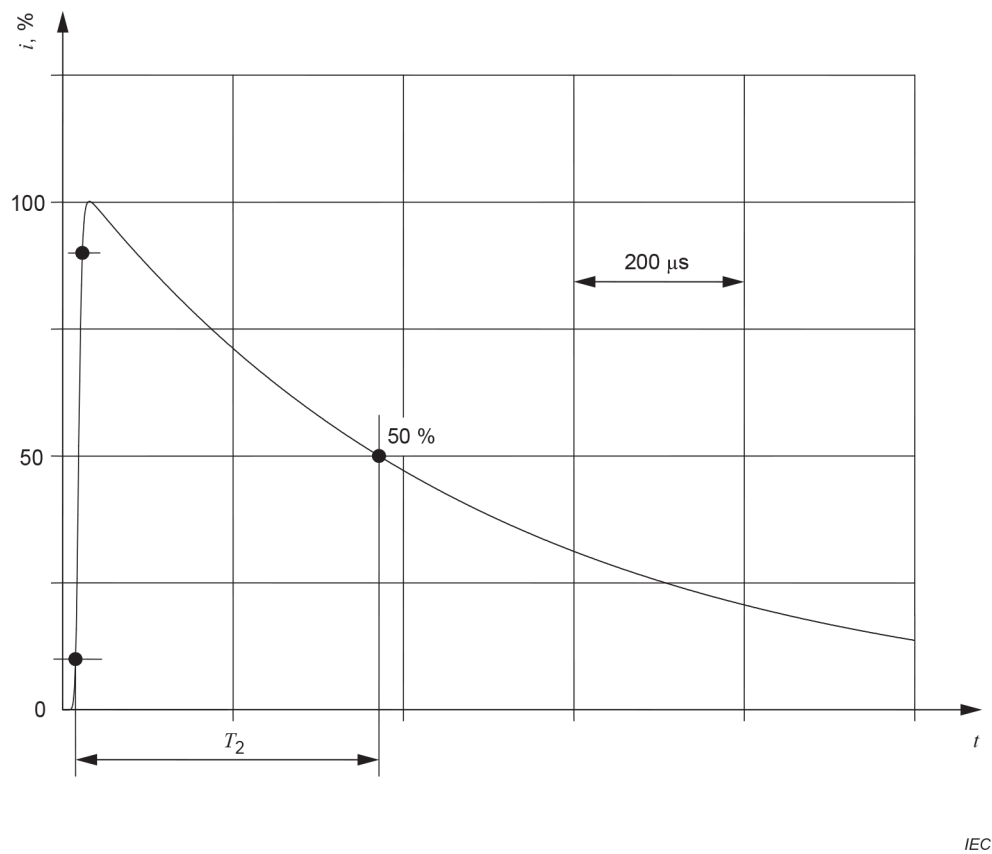


Figure B.2 – Shape of the current tail of the first positive stroke

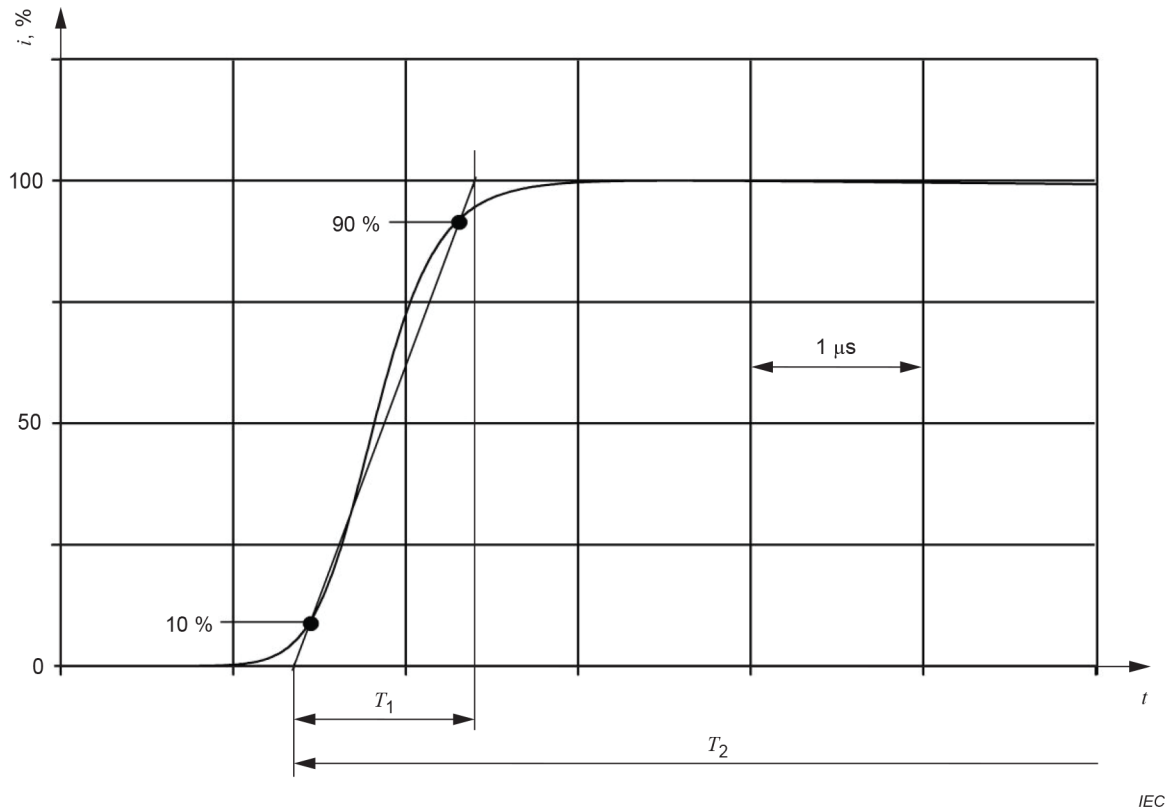


Figure B.3 – Shape of the current rise of the first negative stroke

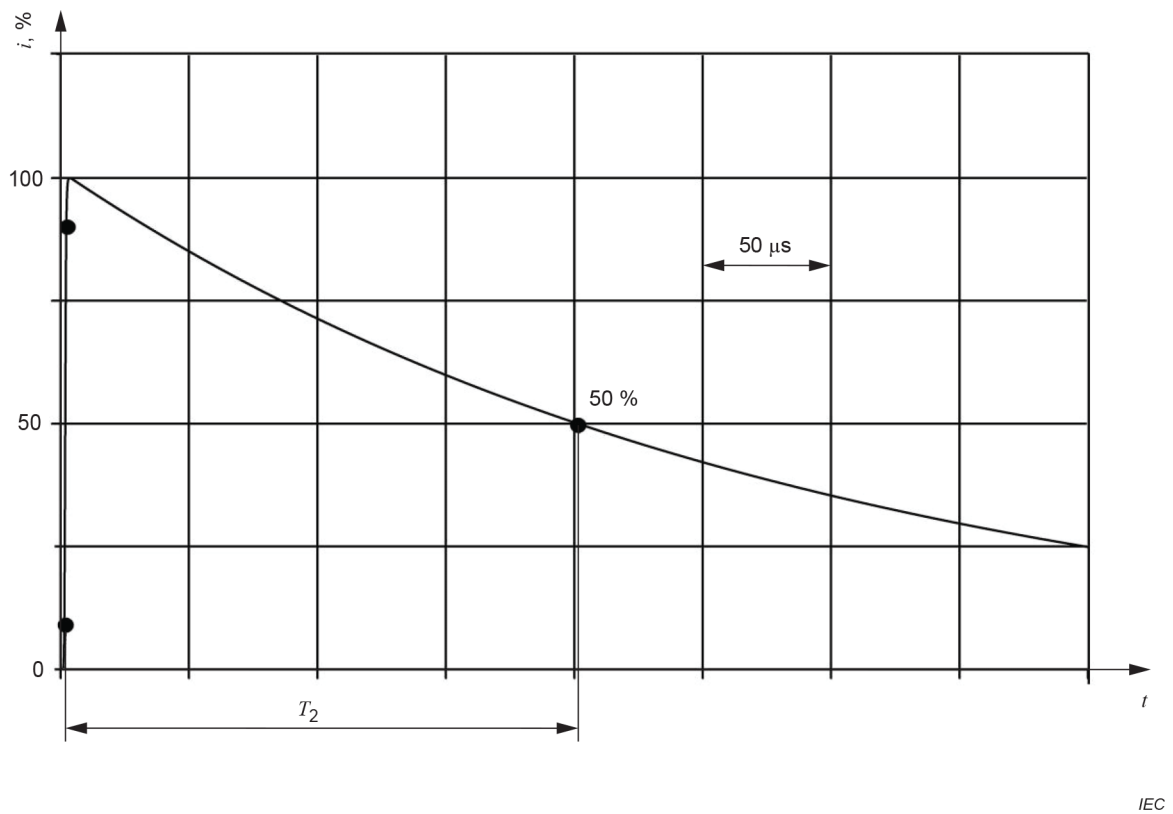


Figure B.4 – Shape of the current tail of the first negative stroke

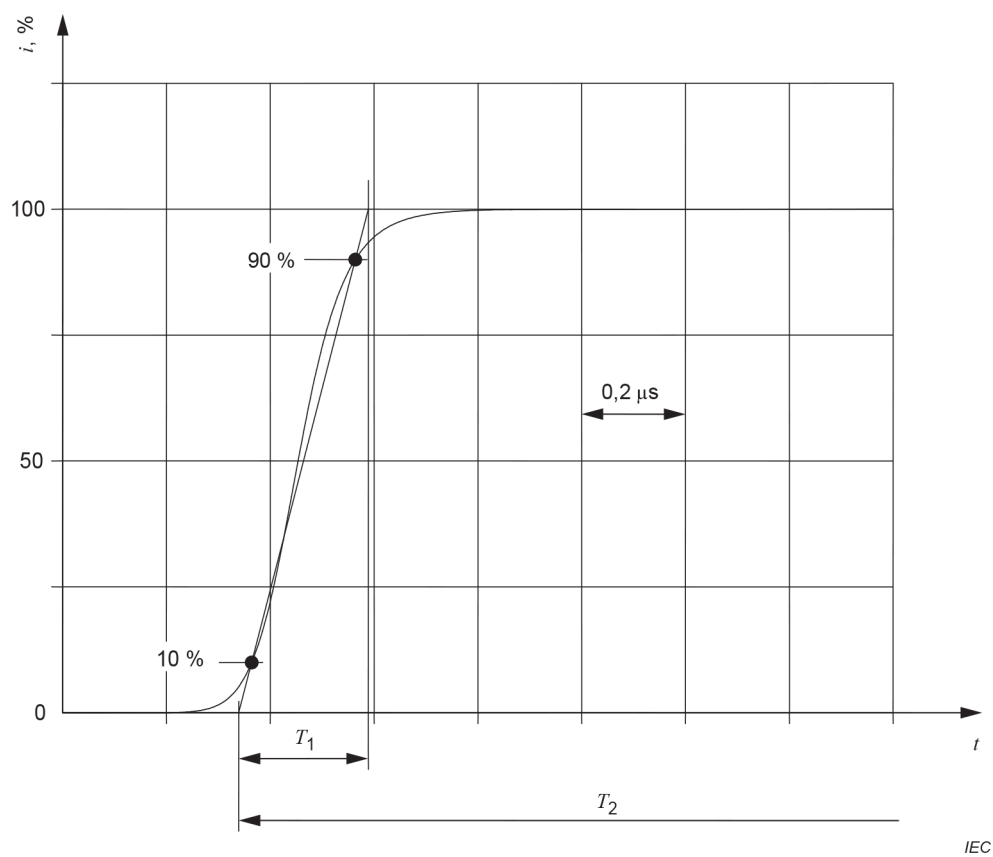


Figure B.5 – Shape of the current rise of the subsequent negative strokes

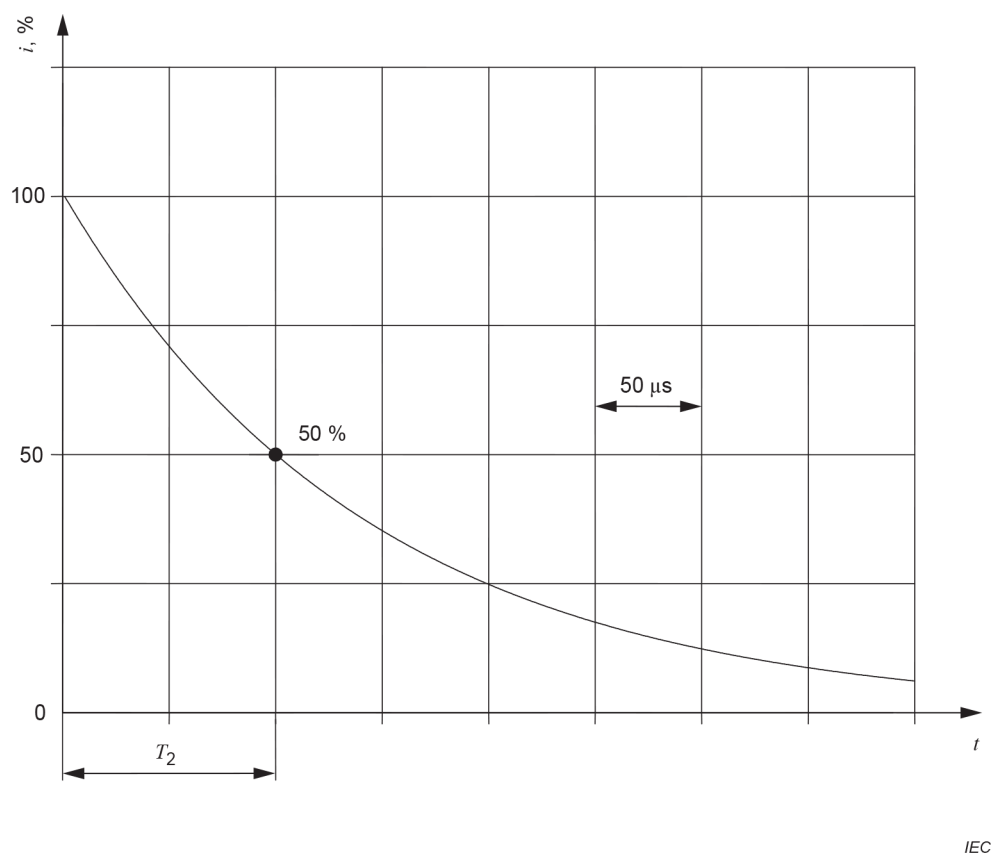


Figure B.6 – Shape of the current tail of the subsequent negative strokes

The long stroke can be described by a rectangular waveshape with an average current I and a duration T_{LONG} according to Table 3.

From the analytic curves as function of time, the amplitude density of the lightning current (Figure B.7) can be derived.

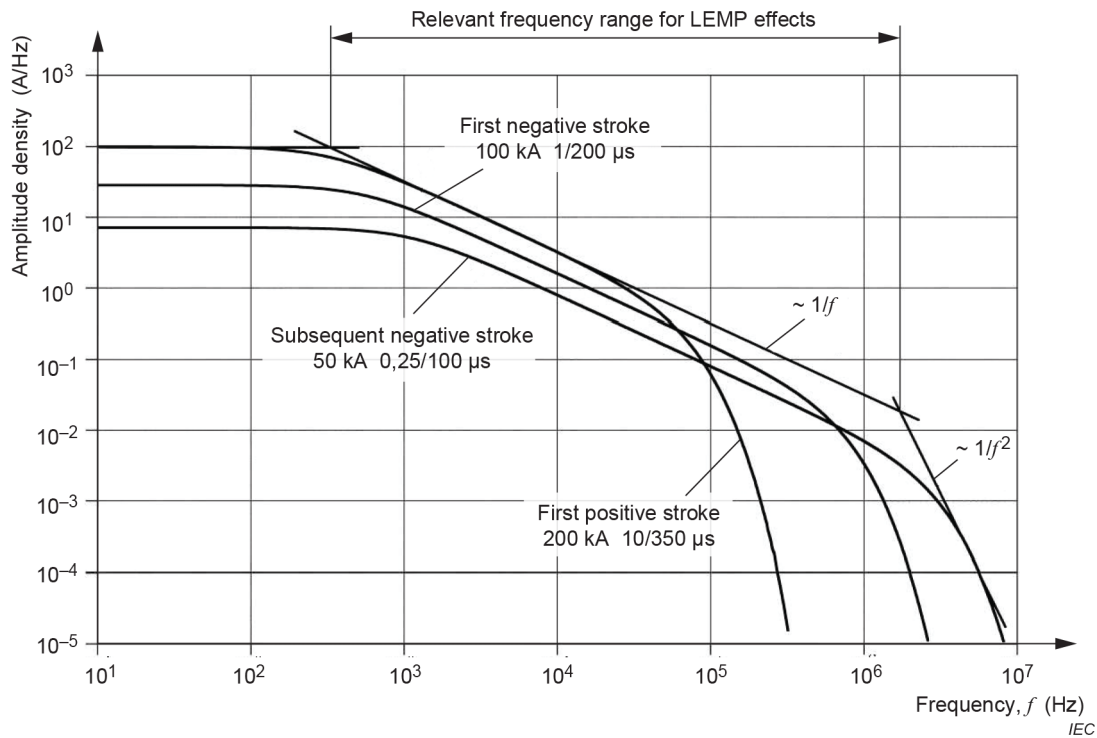


Figure B.7 – Amplitude density of the lightning current according to LPL I