

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Protection against lightning –
Part 2: Risk management**

**Protection contre la foudre –
Partie 2: Evaluation des risques**



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**Protection contre la foudre –
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COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

PROTECTION AGAINST LIGHTNING –

Part 2: Risk management

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.
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International Standard IEC 62305-2 has been prepared by IEC technical committee 81: Lightning protection.

This second edition cancels and replaces the first edition, published in 2006, and constitutes a technical revision.

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

- 1) Risk assessment for services connected to structures is excluded from the scope.
- 2) Injuries of living beings caused by electric shock inside the structure are considered.
- 3) Tolerable risk of loss of cultural heritage is lowered from 10^{-3} to 10^{-4} . The value of tolerable risk of loss of economic value ($R_T = 10^{-3}$) is introduced, to be used when data for cost/benefit analysis are not available.
- 4) Extended damage to surroundings structures or to the environment is considered.
- 5) Improved equations are provided for evaluation of

- collection areas relevant to flashes nearby a structure,
- collection areas relevant to flashes to and nearby a line,
- probabilities that a flash can cause damage,
- loss factors even in structures with risk of explosion,
- risk relevant to a zone of a structure,
- cost of loss.

6) Tables are provided to select the relative amount of loss in all cases.

7) Impulse withstand voltage level of equipments was extended down to 1 kV.

This bilingual version corresponds to the monolingual English version, published in 2010-12.

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

FDIS	Report on voting
81/371/FDIS	81/381/RVD

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

The French version of this standard has not been voted upon.

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

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

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

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

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

INTRODUCTION

Lightning flashes to earth may be hazardous to structures and to lines.

The hazard to a structure can result in

- damage to the structure and to its contents,
- failure of associated electrical and electronic systems,
- injury to living beings in or close to the structure.

Consequential effects of the damage and failures may be extended to the surroundings of the structure or may involve its environment.

To reduce the loss due to lightning, protection measures may be required. Whether they are needed, and to what extent, should be determined by risk assessment.

The risk, defined in this part of IEC 62305 as the probable average annual loss in a structure due to lightning flashes, depends on:

- the annual number of lightning flashes influencing the structure;
- the probability of damage by one of the influencing lightning flashes;
- the mean amount of consequential loss.

Lightning flashes influencing the structure may be divided into

- flashes terminating on the structure,
- flashes terminating near the structure, direct to connected lines (power, telecommunication lines,) or near the lines.

Flashes to the structure or a connected line may cause physical damage and life hazards. Flashes near the structure or line as well as flashes to the structure or line may cause failure of electrical and electronic systems due to overvoltages resulting from resistive and inductive coupling of these systems with the lightning current.

Moreover, failures caused by lightning overvoltages in users' installations and in power supply lines may also generate switching type overvoltages in the installations.

NOTE Malfunctioning of electrical and electronic systems is not covered by the IEC 62305 series. Reference should be made to IEC 61000-4-5 ^[1]1.

The number of lightning flashes influencing the structure depends on the dimensions and the characteristics of the structure and of the connected lines, on the environmental characteristics of the structure and the lines, as well as on lightning ground flash density in the region where the structure and the lines are located.

The probability of lightning damage depends on the structure, the connected lines and the lightning current characteristics, as well as on the type and efficiency of applied protection measures.

The annual mean amount of the consequential loss depends on the extent of damage and the consequential effects which may occur as a result of a lightning flash.

The effect of protection measures results from the features of each protection measure and may reduce the damage probabilities or the amount of consequential loss.

¹ Figures in square brackets refer to the bibliography.

The decision to provide lightning protection may be taken regardless of the outcome of risk assessment where there is a desire that there be no avoidable risk.

PROTECTION AGAINST LIGHTNING –

Part 2: Risk management

1 Scope

This part of IEC 62305 is applicable to risk assessment for a structure due to lightning flashes to earth.

Its purpose is to provide a procedure for the evaluation of such a risk. Once an upper tolerable limit for the risk has been selected, this procedure allows the selection of appropriate protection measures to be adopted to reduce the risk to or below the tolerable limit.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

IEC 62305-3:2010, *Protection against lightning – Part 3: Physical damage to structures and life hazard*

IEC 62305-4:2010, *Protection against lightning – Part 4: Electrical and electronic systems within structures*

3 Terms, definitions, symbols and abbreviations

For the purposes of this document, the following terms, definitions, symbols and abbreviations, some of which have already been cited in Part 1 but are repeated here for ease of reading, as well as those given in other parts of IEC 62305, apply.

3.1 Terms and definitions

3.1.1

structure to be protected

structure for which protection is required against the effects of lightning in accordance with this standard

NOTE A structure to be protected may be part of a larger structure.

3.1.2

structures with risk of explosion

structures containing solid explosives materials or hazardous zones as determined in accordance with IEC 60079-10-1^[2] and IEC 60079-10-2^[3]

3.1.3

structures dangerous to the environment

structures which may cause biological, chemical or radioactive emission as a consequence of lightning (such as chemical, petrochemical, nuclear plants, etc.)

3.1.4**urban environment**

area with a high density of buildings or densely populated communities with tall buildings

NOTE 'Town centre' is an example of an urban environment.

3.1.5**suburban environment**

area with a medium density of buildings

NOTE 'Town outskirts' is an example of a suburban environment.

3.1.6**rural environment**

area with a low density of buildings

NOTE 'Countryside' is an example of a rural environment.

3.1.7**rated impulse withstand voltage level**

U_W

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

[IEC 60664-1:2007, definition 3.9.2, modified] ^[4]

NOTE For the purposes of this part of IEC 62305, only the withstand voltage between live conductors and earth is considered.

3.1.8**electrical system**

system incorporating low voltage power supply components

3.1.9**electronic system**

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

3.1.10**internal systems**

electrical and electronic systems within a structure

3.1.11**line**

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

3.1.12**telecommunication lines**

lines intended for communication between equipment that may be located in separate structures, such as phone lines and data lines

3.1.13**power lines**

distribution lines 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

3.1.14

dangerous event

lightning flash to or near the structure to be protected, or to or near a line connected to the structure to be protected that may cause damage

3.1.15

lightning flash to a structure

lightning flash striking a structure to be protected

3.1.16

lightning flash near a structure

lightning flash striking close enough to a structure to be protected that it may cause dangerous overvoltages

3.1.17

lightning flash to a line

lightning flash striking a line connected to the structure to be protected

3.1.18

lightning flash near a line

lightning flash striking close enough to a line connected to the structure to be protected that it may cause dangerous overvoltages

3.1.19

number of dangerous events due to flashes to a structure

N_D

expected average annual number of dangerous events due to lightning flashes to a structure

3.1.20

number of dangerous events due to flashes to a line

N_L

expected average annual number of dangerous events due to lightning flashes to a line

3.1.21

number of dangerous events due to flashes near a structure

N_M

expected average annual number of dangerous events due to lightning flashes near a structure

3.1.22

number of dangerous events due to flashes near a line

N_I

expected average annual number of dangerous events due to lightning flashes near a line

3.1.23

lightning electromagnetic impulse

LEMP

all electromagnetic effects of lightning current via resistive, inductive and capacitive coupling, which create surges and electromagnetic fields

3.1.24

surge

transient created by LEMP that appears as an overvoltage and/or overcurrent

3.1.25

node

point on a line from which onward surge propagation can be assumed to be neglected

NOTE Examples of nodes are a point on a power line branch distribution at an HV/LV transformer or on a power substation, a telecommunication exchange or an equipment (e.g. multiplexer or xDSL equipment) on a telecommunication line.

3.1.26

physical damage

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

3.1.27

injury to living beings

permanent injuries, including loss of life, to people or to animals by electric shock due to touch and step voltages caused by lightning

NOTE Although living beings may be injured in other ways, in this part of IEC 62305 the term 'injury to living beings' is limited to the threat due to electrical shock (type of damage D1).

3.1.28

failure of electrical and electronic systems

permanent damage of electrical and electronic systems due to LEMP

3.1.29

probability of damage

P_X

probability that a dangerous event will cause damage to or in the structure to be protected

3.1.30

loss

L_X

mean amount of loss (humans and goods) consequent on a specified type of damage due to a dangerous event, relative to the value (humans and goods) of the structure to be protected

3.1.31

risk

R

value of probable average annual loss (humans and goods) due to lightning, relative to the total value (humans and goods) of the structure to be protected

3.1.32

risk component

R_X

partial risk depending on the source and the type of damage

3.1.33

tolerable risk

R_T

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

3.1.34

zone of a structure

Z_S

part of a structure with homogeneous characteristics where only one set of parameters is involved in assessment of a risk component

3.1.35

section of a line

S_L

part of a line with homogeneous characteristics where only one set of parameters is involved in the assessment of a risk component

3.1.36

lightning protection zone

LPZ

zone where the lightning electromagnetic environment is defined

NOTE The zone boundaries of an LPZ are not necessarily physical boundaries (e.g. walls, floor and ceiling).

3.1.37

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 Lightning protection level is used to design protection measures according to the relevant set of lightning current parameters.

3.1.38

protection measures

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

3.1.39

lightning protection

LP

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

3.1.40

lightning protection system

LPS

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

NOTE It consists of both external and internal lightning protection systems.

3.1.41

LEMP protection measures

SPM

measures taken to protect internal systems against the effects of LEMP

NOTE This is part of overall lightning protection

3.1.42

magnetic shield

closed, metallic, grid-like or continuous screen enveloping the structure to be protected, or part of it, used to reduce failures of electrical and electronic systems

3.1.43

lightning protective cable

special cable with increased dielectric strength and whose metallic sheath is in continuous contact with the soil either directly or by use of conducting plastic covering

3.1.44

lightning protective cable duct

cable duct of low resistivity in contact with the soil

EXAMPLE Concrete with interconnected structural steel reinforcements or metallic duct.

3.1.45**surge protective device**

SPD

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

3.1.46**coordinated SPD system**

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

3.1.47**isolating interfaces**

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

NOTE 1 These include isolation transformers with earthed screen between windings, metal-free fibre optic cables and opto-isolators.

NOTE 2 Insulation withstand characteristics of these devices are suitable for this application intrinsically or via SPD.

3.1.48**lightning equipotential bonding**

EB

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

3.1.49**zone 0**

place in which an explosive atmosphere consisting of a mixture of air and flammable substances in the form of gas, vapour or mist is present continuously or for long periods or frequently

(IEC 60050-426:2008, 426-03-03, modified) ^[5]

3.1.50**zone 1**

place in which an explosive atmosphere consisting of a mixture of air and flammable substances in the form of gas, vapour or mist is likely to occur in normal operation occasionally

(IEC 60050-426:2008, 426-03-04, modified) ^[5]

3.1.51**zone 2**

place in which an explosive atmosphere consisting of a mixture of air and flammable substances in the form of gas, vapour or mist is not likely to occur in normal operation but, if it does occur, will persist for a short period only

NOTE 1 In this definition, the word "persist" means the total time for which the flammable atmosphere will exist. This will normally comprise the total of the duration of the release, plus the time taken for the flammable atmosphere to disperse after the release has stopped.

NOTE 2 Indications of the frequency of the occurrence and duration may be taken from codes relating to specific industries or applications.

(IEC 60050-426:2008, 426-03-05, modified) ^[5]

3.1.52**zone 20**

place in which an explosive atmosphere, in the form of a cloud of combustible dust in air, is present continuously, or for long periods, or frequently

(IEC 60079-10-2:2009, 6.2, modified) ^[3]

3.1.53

zone 21

place in which an explosive atmosphere, in the form of a cloud of combustible dust in air, is likely to occur in normal operation occasionally

(IEC 60079-10-2:2009, 6.2, modified) ^[3]

3.1.54

zone 22

place in which an explosive atmosphere, in the form of a cloud of combustible dust in air, is not likely to occur in normal operation but, if it does occur, will persist for a short period only

(IEC 60079-10-2:2009, 6.2, modified) ^[3]

3.2 Symbols and abbreviations

a	Amortization rate.....	Annex D
A_D	Collection area for flashes to an isolated structure	A.2.1.1
A_{DJ}	Collection area for flashes to an adjacent structure	A.2.5
A_D'	Collection area attributed to an elevated roof protrusion	A.2.1.2
A_l	Collection area for flashes near a line	A.5
A_L	Collection area for flashes to a line	A.4
A_M	Collection area for flashes striking near the structure	A.3
B	Building.....	A.2
C_D	Location factor	Table A.1
C_{DJ}	Location factor of an adjacent structure.....	A.2.5
C_E	Environmental factor	Table A.4
C_l	Installation factor of the line	Table A.2
C_L	Annual cost of total loss in absence of protection measures	5.5; Annex D
C_{LD}	Factor depending on shielding, grounding and isolation conditions of the line for flashes to a line	Annex B
C_{LI}	Factor depending on shielding, grounding and isolation conditions of the line for flashes near a line	Annex B
C_{LZ}	Cost of loss in a zone.....	Annex D
C_P	Cost of protection measures.....	Annex D
C_{PM}	Annual cost of selected protection measures.....	5.5; Annex D
C_{RL}	Annual cost of residual loss.....	5.5; Annex D
C_{RLZ}	Cost of residual loss in a zone.....	Annex D
C_T	Line type factor for a HV/LV transformer on the line	Table A.3
c_a	Value of the animals in the zone, in currency	C.6
c_b	Value of the building relevant to the zone, in currency.....	C.6
c_c	Value of the content in the zone, in currency	C.6
c_e	Total value of goods in dangerous place outside the structure, in currency	C.6
c_s	Value of the internal systems (including their activities) in the zone, in currency	C.6
c_t	Total value of the structure, in currency	C.5; C.6
c_z	Value of the cultural heritage in the zone, in currency	C.5
$D1$	Injury to living beings by electric shock	4.1.2
$D2$	Physical damage	4.1.2

D3	Failure of electrical and electronic systems	4.1.2
h_z	Factor increasing the loss when a special hazard is present	Table C.6
H	Height of the structure	A.2.1.1
H_J	Height of the adjacent structure	A.2.5
i	Interest rate	Annex D
K_{MS}	Factor relevant to the performance of protection measures against LEMP	B.5
K_{S1}	Factor relevant to the screening effectiveness of the structure	B.5
K_{S2}	Factor relevant to the screening effectiveness of shields internal to the structure	B.5
K_{S3}	Factor relevant to the characteristics of internal wiring	B.5
K_{S4}	Factor relevant to the impulse withstand voltage of a system	B.5
L	Length of structure	A.2.1.1
L_J	Length of the adjacent structure	A.2.5
L_A	Loss due to injury to living beings by electric shock (flashes to structure)	6.2
L_B	Loss in a structure related to physical damage (flashes to structure)	6.2
L_L	Length of line section	A.4
L_C	Loss related to failure of internal systems (flashes to structure)	6.2
L_E	Additional loss when the damage involves surrounding structures	C.3; C.6
L_F	Loss in a structure due to physical damage	Tables C.2, C.8, C.10, C.12
L_{FE}	Loss due to physical damage outside the structure	C.3; C.6
L_{FT}	Total loss due to physical damage in and outside the structure	C.3; C.6
L_M	Loss related to failure of internal systems (flashes near structure)	6.3
L_O	Loss in a structure due to failure of internal systems	Tables C.2, C.8, C.12
L_T	Loss due to injury by electric shock	Tables C.2, C.12
L_U	Loss due to injury of living beings by electric shock (flashes to line)	6.4
L_V	Loss in a structure due to physical damage (flashes to line)	6.4
L_W	Loss related to failure of internal systems (flashes to line)	6.4
L_X	Loss consequent to damages relevant to structure	6.1
L_Z	Loss related to failure of internal systems (flashes near a line)	6.5
L1	Loss of human life	4.1.3
L2	Loss of service to the public	4.1.3
L3	Loss of cultural heritage	4.1.3
L4	Loss of economic value	4.1.3
m	Maintenance rate	Annex D
N_X	Number of dangerous events per annum	6.1
N_D	Number of dangerous events due to flashes to structure	A.2.4
N_{DJ}	Number of dangerous events due to flashes to adjacent structure	A.2.5
N_G	Lightning ground flash density	A.1
N_I	Number of dangerous events due to flashes near a line	A.5
N_L	Number of dangerous events due to flashes to a line	A.4
N_M	Number of dangerous events due to flashes near a structure	A.3
n_z	Number of possible endangered persons (victims or users not served)	C.3; C.4
n_t	Expected total number of persons (or users served)	C.3; C.4
P	Probability of damage	Annex B
P_A	Probability of injury to living beings by electric shock (flashes to a structure)	6.2; B.2
P_B	Probability of physical damage to a structure (flashes to a structure)	Table B.2

P_C	Probability of failure of internal systems (flashes to a structure)	6.2; B.4
P_{EB}	Probability reducing P_U and P_V depending on line characteristics and withstand voltage of equipment when EB is installed	Table B.7
P_{LD}	Probability of reducing P_U , P_V and P_W depending on line characteristics and withstand voltage of equipment (flashes to connected line)	Table B.8
P_{LI}	Probability of reducing P_Z depending on line characteristics and withstand voltage of equipment (flashes near a connected line)	Table B.9
P_M	Probability of failure of internal systems (flashes near a structure)	6.3; B.5
P_{MS}	Probability of reducing P_M depending on shielding, wiring and withstand voltage of equipment	B.5
P_{SPD}	Probability of reducing P_C , P_M , P_W and P_Z when a coordinated SPD system is installed	Table B.3
P_{TA}	Probability of reducing P_A depending on protection measures against touch and step voltages	Table B.1
P_U	Probability of injury to living beings by electric shock (flashes to a connected line)	6.4; B.6
P_V	Probability of physical damage to a structure (flashes to a connected line).....	6.4; B.7
P_W	Probability of failure of internal systems (flashes to connected line).....	6.4; B.8
P_X	Probability of damage relevant to a structure	6.1
P_Z	Probability of failure of internal systems (flashes near a connected line).....	6.5; B.9
r_t	Reduction factor associated with the type of surface	C.3
r_f	Factor reducing loss depending on risk of fire	C.3
r_p	Factor reducing the loss due to provisions against fire	C.3
R	Risk	4.2
R_A	Risk component (injury to living beings – flashes to structure).....	4.2.2
R_B	Risk component (physical damage to a structure – flashes to a structure)	4.2.2
R_C	Risk component (failure of internal systems – flashes to structure).....	4.2.2
R_M	Risk component (failure of internal systems – flashes near structure).....	4.2.3
R_S	Shield resistance per unit length of a cable	Table B.8
R_T	Tolerable risk	5.3; Table 4
R_U	Risk component (injury to living being – flashes to connected line).....	4.2.4
R_V	Risk component (physical damage to structure – flashes to connected line).....	4.2.4
R_W	Risk component (failure of internal systems – flashes to connected line).....	4.2.4
R_X	Risk component for a structure.....	6.1
R_Z	Risk component (failure of internal systems – flashes near a line).....	4.2.5
R_1	Risk of loss of human life in a structure	4.2.1
R_2	Risk of loss of service to the public in a structure	4.2.1
R_3	Risk of loss of cultural heritage in a structure	4.2.1
R_4	Risk of loss of economic value in a structure	4.2.1
R'_4	Risk R_4 when protection measures are adopted	Annex D
S	Structure	A.2.2
S_M	Annual saving of money	Annex D
S_L	Section of a line	6.8
S_1	Source of damage – Flashes to a structure	4.1.1
S_2	Source of damage – Flashes near a structure	4.1.1
S_3	Source of damage – Flashes to a line	4.1.1
S_4	Source of damage – Flashes near a line	4.1.1

t_e	Time in hours per year of presence of people in a dangerous place outside the structure.....	C.3
t_z	Time in hours per year that persons are present in a dangerous place	C.2
T_D	Thunderstorm days per year.....	A.1
U_W	Rated impulse withstand voltage of a system	B.5
w_m	Mesh width.....	B.5
W	Width of structure.....	A.2.1.1
W_J	Width of the adjacent structure.....	A.2.5
X	Subscript identifying the relevant risk component.....	6.1
Z_S	Zones of a structure	6.7

4 Explanation of terms

4.1 Damage and loss

4.1.1 Source of damage

The lightning current is the primary source of damage. The following sources are distinguished by the point of strike (see Table 1):

- S1: flashes to a structure,
- S2: flashes near a structure,
- S3: flashes to a line,
- S4: flashes near a line.

4.1.2 Types of damage

A lightning flash may cause damage depending on the characteristics of the structure to be protected. Some of the most important characteristics are: type of construction, contents and application, type of service and protection measures provided.

For practical applications of this risk assessment, it is useful to distinguish between three basic types of damage which can appear as the consequence of lightning flashes. They are as follows (see Table 1):

- D1: injury to living beings by electric shock;
- D2: physical damage;
- D3: failure of electrical and electronic systems.

The damage to a structure due to lightning may be limited to a part of the structure or may extend to the entire structure. It may also involve surrounding structures or the environment (e.g. chemical or radioactive emissions).

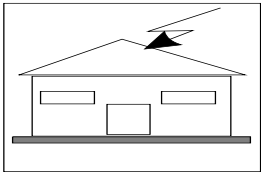
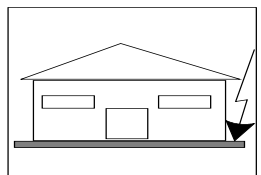
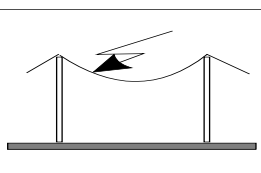
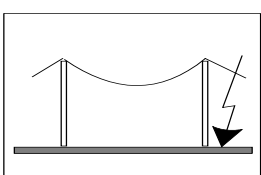
4.1.3 Types of loss

Each type of damage, alone or in combination with others, may produce a different consequential loss in the structure to be protected. The type of loss that may appear, depends on the characteristics of the structure itself and its content. The following types of loss shall be taken into account (see Table 1):

- L1: loss of human life (including permanent injury);
- L2: loss of service to the public;
- L3: loss of cultural heritage;

L4: loss of economic value (structure, content, and loss of activity).

Table 1 – Sources of damage, types of damage and types of loss according to the point of strike

Lightning flash		Structure	
Point of strike	Source of damage	Type of damage	Type of loss
	S1	D1 D2 D3	L1, L4 ^a L1, L2, L3, L4 L1 ^b , L2, L4
	S2	D3	L1 ^b , L2, L4
	S3	D1 D2 D3	L1, L4 ^a L1, L2, L3, L4 L1 ^b , L2, L4
	S4	D3	L1 ^b , L2, L4
^a Only for properties where animals may be lost. ^b Only for structures with risk of explosion and for hospitals or other structures where failures of internal systems immediately endangers human life.			

4.2 Risk and risk components

4.2.1 Risk

The risk R is the relative value of a probable average annual loss. For each type of loss which may appear in a structure, the relevant risk shall be evaluated.

The risks to be evaluated in a structure may be as follows:

- R_1 : risk of loss of a human life (including permanent injury);
- R_2 : risk of loss of service to the public;
- R_3 : risk of loss of cultural heritage;
- R_4 : risk of loss of economic value.

To evaluate risks, R , the relevant risk components (partial risks depending on the source and type of damage) shall be defined and calculated.

Each risk, R , is the sum of its risk components. When calculating a risk, the risk components may be grouped according to the source of damage and the type of damage.

4.2.2 Risk components for a structure due to flashes to the structure

R_A : Component related to injury to living beings caused by electric shock due to touch and step voltages inside the structure and outside in the zones up to 3 m around down-conductors. Loss of type L1 and, in the case of structures holding livestock, loss of type L4 with possible loss of animals may also arise.

NOTE In special structures, people may be endangered by direct strikes (e.g. top level of garage parking or stadiums). These cases may also be considered using the principles of this part of IEC 62305.

R_B : Component related to physical damage caused by dangerous sparking inside the structure triggering fire or explosion which may also endanger the environment. All types of loss (L1, L2, L3 and L4) may arise.

R_C : Component related to failure of internal systems caused by LEMP. Loss of type L2 and L4 could occur in all cases along with type L1 in the case of structures with risk of explosion, and hospitals or other structures where failure of internal systems immediately endangers human life.

4.2.3 Risk component for a structure due to flashes near the structure

R_M : Component related to failure of internal systems caused by LEMP. Loss of type L2 and L4 could occur in all cases, along with type L1 in the case of structures with risk of explosion, and hospitals or other structures where failure of internal systems immediately endangers human life.

4.2.4 Risk components for a structure due to flashes to a line connected to the structure

R_U : Component related to injury to living beings caused by electric shock due to touch voltage inside the structure. Loss of type L1 and, in the case of agricultural properties, loss of type L4 with possible loss of animals could also occur.

R_V : Component related to physical damage (fire or explosion triggered by dangerous sparking between external installation and metallic parts generally at the entrance point of the line into the structure) due to lightning current transmitted through or along incoming lines. All types of loss (L1, L2, L3, L4) may occur.

R_W : Component related to failure of internal systems caused by overvoltages induced on incoming lines and transmitted to the structure. Loss of type L2 and L4 could occur in all cases, along with type L1 in the case of structures with risk of explosion, and hospitals or other structures where failure of internal systems immediately endangers human life.

NOTE 1 The lines taken into account in this assessment are only the lines entering the structure.

NOTE 2 Lightning flashes to, or near, pipes are not considered as a source of damage, based on the bonding of pipes to an equipotential bonding bar. If an equipotential bonding bar is not provided, such a threat should also be considered.

4.2.5 Risk component for a structure due to flashes near a line connected to the structure

R_Z : Component related to failure of internal systems caused by overvoltages induced on incoming lines and transmitted to the structure. Loss of type L2 and L4 could occur in all cases, along with type L1 in the case of structures with risk of explosion, and hospitals or other structures where failure of internal systems immediately endanger human life.

NOTE 1 The lines taken into account in this assessment are only the lines entering the structure.

NOTE 2 Lightning flashes to or near pipes are not considered as a source of damage, based on the bonding of pipes to an equipotential bonding bar. If an equipotential bonding bar is not provided, such a threat should also be considered.

4.3 Composition of risk components

Risk components to be considered for each type of loss in a structure are listed below:

R_1 : Risk of loss of human life:

$$R_1 = R_{A1} + R_{B1} + R_{C1}^{1)} + R_{M1}^{1)} + R_{U1} + R_{V1} + R_{W1}^{1)} + R_{Z1}^{1)} \quad (1)$$

¹⁾ Only for structures with risk of explosion and for hospitals with life-saving electrical equipment or other structures when failure of internal systems immediately endangers human life.

R_2 : Risk of loss of service to the public:

$$R_2 = R_{B2} + R_{C2} + R_{M2} + R_{V2} + R_{W2} + R_{Z2} \quad (2)$$

R_3 : Risk of loss of cultural heritage:

$$R_3 = R_{B3} + R_{V3} \quad (3)$$

R_4 : Risk of loss of economic value:

$$R_4 = R_{A4}^{2)} + R_{B4} + R_{C4} + R_{M4} + R_{U4}^{2)} + R_{V4} + R_{W4} + R_{Z4} \quad (4)$$

²⁾ Only for properties where animals may be lost.

The risk components corresponding to each type of loss are also combined in Table 2.

Table 2 – Risk components to be considered for each type of loss in a structure

Source of damage	Flash to a structure S1			Flash near a structure S2	Flash to a line connected to the structure S3			Flash near a line connected to the structure S4
	R_A	R_B	R_C		R_U	R_V	R_W	
Risk component	R_A	R_B	R_C	R_M	R_U	R_V	R_W	R_Z
Risk for each type of loss								
R_1	*	*	* a	* a	*	*	* a	* a
R_2		*	*	*		*	*	*
R_3		*				*		
R_4	* b	*	*	*	* b	*	*	*
^a Only for structures with risk of explosion, and for hospitals or other structures where failure of internal systems immediately endangers human life. ^b Only for properties where animals may be lost.								

Characteristics of the structure and of possible protection measures influencing risk components for a structure are given in Table 3.

Table 3 – Factors influencing the risk components

Characteristics of structure or of internal systems Protection measures	R_A	R_B	R_C	R_M	R_U	R_V	R_W	R_Z
Collection area	X	X	X	X	X	X	X	X
Surface soil resistivity	X							
Floor resistivity	X				X			
Physical restrictions, insulation, warning notice, soil equipotentialization	X				X			
LPS	X	X	X	X ^a	X ^b	X ^b		
Bonding SPD	X	X			X	X		
Isolating interfaces			X ^c	X ^c	X	X	X	X
Coordinated SPD system			X	X			X	X
Spatial shield			X	X				
Shielding external lines					X	X	X	X
Shielding internal lines			X	X				
Routing precautions			X	X				
Bonding network			X					
Fire precautions		X				X		
Fire sensitivity		X				X		
Special hazard		X				X		
Impulse withstand voltage			X	X	X	X	X	X
^a Only for grid-like external LPS. ^b Due to equipotential bonding. ^c Only if they belong to equipment.								

5 Risk management

5.1 Basic procedure

The following procedure shall be applied:

- identification of the structure to be protected and its characteristics;
- identification of all the types of loss in the structure and the relevant corresponding risk R (R_1 to R_4);
- evaluation of risk R for each type of loss R_1 to R_4 ;
- evaluation of need of protection, by comparison of risk R_1 , R_2 and R_3 with the tolerable risk R_T ;
- evaluation of cost effectiveness of protection by comparison of the costs of total loss with and without protection measures. In this case, the assessment of components of risk R_4 shall be performed in order to evaluate such costs (see Annex D).

5.2 Structure to be considered for risk assessment

The structure to be considered includes:

- the structure itself;
- installations in the structure;

- contents of the structure;
- persons in the structure or in the zones up to 3 m from the outside of the structure;
- environment affected by damage to the structure.

Protection does not include connected lines outside of the structure.

NOTE The structure to be considered may be subdivided into several zones (see 6.7).

5.3 Tolerable risk R_T

It is the responsibility of the authority having jurisdiction to identify the value of tolerable risk.

Representative values of tolerable risk R_T , where lightning flashes involve loss of human life or loss of social or cultural values, are given in Table 4.

Table 4 – Typical values of tolerable risk R_T

Types of loss		$R_T (y^{-1})$
L1	Loss of human life or permanent injuries	10^{-5}
L2	Loss of service to the public	10^{-3}
L3	Loss of cultural heritage	10^{-4}

In principle, for loss of economic value (L4), the route to be followed is the cost/benefit comparison given in Annex D. If the data for this analysis are not available, the representative value of tolerable risk $R_T = 10^{-3}$ may be used.

5.4 Specific procedure to evaluate the need of protection

According to IEC 62305-1, risks R_1 , R_2 and R_3 shall be considered in the evaluation of the need of protection against lightning.

For each risk to be considered the following steps shall be taken:

- identification of the components R_X which make up the risk;
- calculation of the identified risk components R_X ;
- calculation of the total risk R (see 4.3);
- identification of the tolerable risk R_T ;
- comparison of the risk R with the tolerable value R_T .

If $R \leq R_T$, lightning protection is not necessary.

If $R > R_T$, protection measures shall be adopted in order to reduce $R \leq R_T$ for all risks to which the structure is subjected.

The procedure to evaluate the need for protection is given in Figure 1.

NOTE 1 In cases where the risk cannot be reduced to a tolerable level, the site owner should be informed and the highest level of protection provided to the installation.

NOTE 2 Where protection against lightning is required by the authority having jurisdiction for structures with a risk of explosion, at least a class II LPS should be adopted. Exceptions to the use of lightning protection level II may be allowed when technically justified and authorized by the authority having jurisdiction. For example, the use of lightning protection level I is allowed in all cases, especially in those cases where the environments or contents within the structure are exceptionally sensitive to the effects of lightning. In addition, authorities having jurisdiction may choose to allow lightning protection level III systems where the infrequency of lightning activity and/or the insensitivity of the contents of the structure warrants it.

NOTE 3 When the damage to a structure due to lightning may also involve surrounding structures or the environment (e.g. chemical or radioactive emissions), additional protection measures for the structure and measures appropriate for these zones may be requested by the authorities having jurisdiction.

5.5 Procedure to evaluate the cost effectiveness of protection

Besides the need for lightning protection of a structure, it may be useful to ascertain the economic benefits of installing protection measures in order to reduce the economic loss L_4 .

The assessment of components of risk R_4 allows the user to evaluate the cost of the economic loss with and without the adopted protection measures (see Annex D).

The procedure to ascertain the cost effectiveness of protection requires:

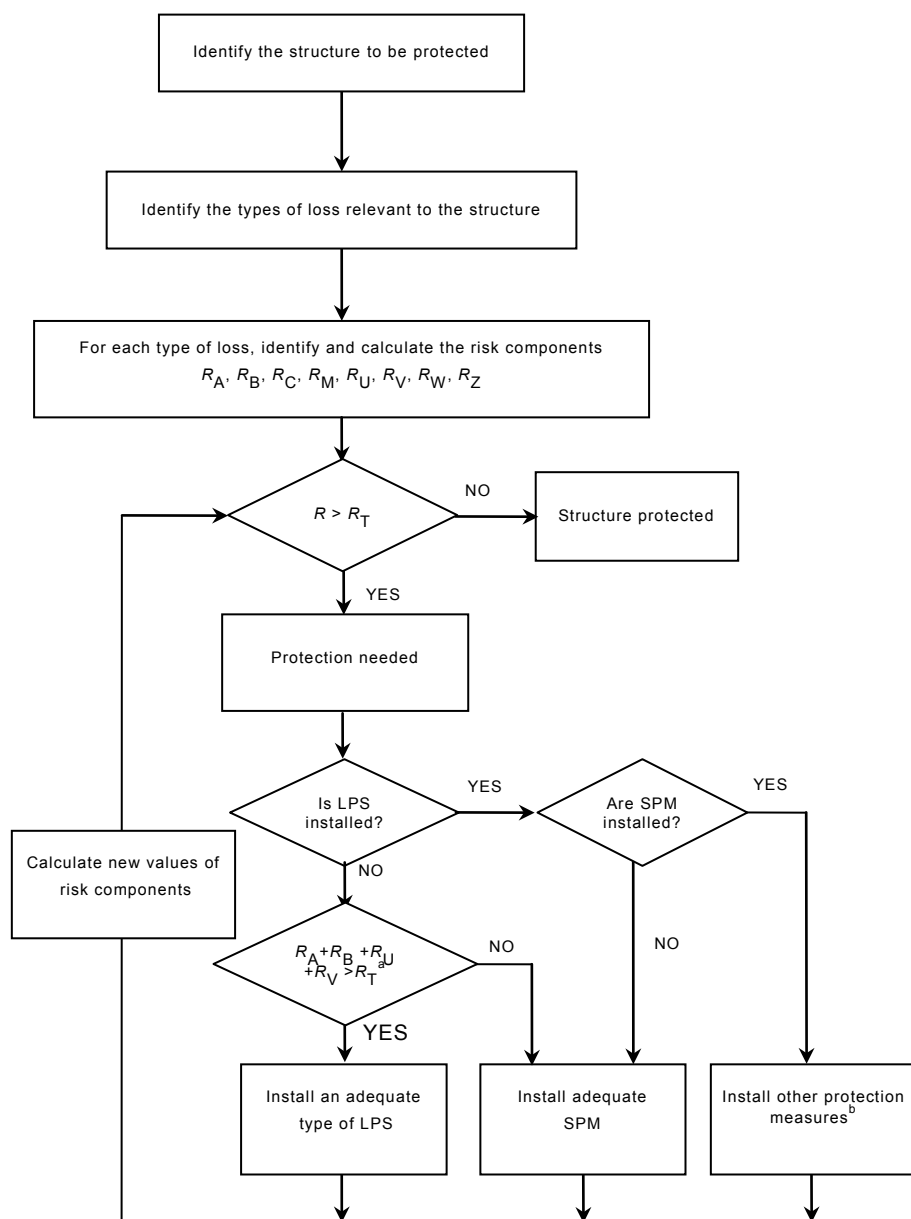
- identification of the components R_X which make up the risk R_4 ;
- calculation of the identified risk components R_X in the absence of new/additional protection measures;
- calculation of the annual cost of loss due to each risk component R_X ;
- calculation of the annual cost C_L of total loss in the absence of protection measures;
- adoption of selected protection measures;
- calculation of risk components R_X with selected protection measures present;
- calculation of the annual cost of residual loss due to each risk component R_X in the protected structure;
- calculation of the total annual cost C_{RL} of residual loss with selected protection measures present;
- calculation of the annual cost C_{PM} of selected protection measures;
- comparison of costs.

If $C_L < C_{RL} + C_{PM}$, lightning protection may be deemed not to be cost effective.

If $C_L \geq C_{RL} + C_{PM}$, protection measures may prove to save money over the life of the structure.

The procedure to evaluate the cost-effectiveness of protection is outlined in Figure 2.

It may be useful to evaluate some variants of combination of protection measures to find the optimal solution regarding the cost effectiveness.

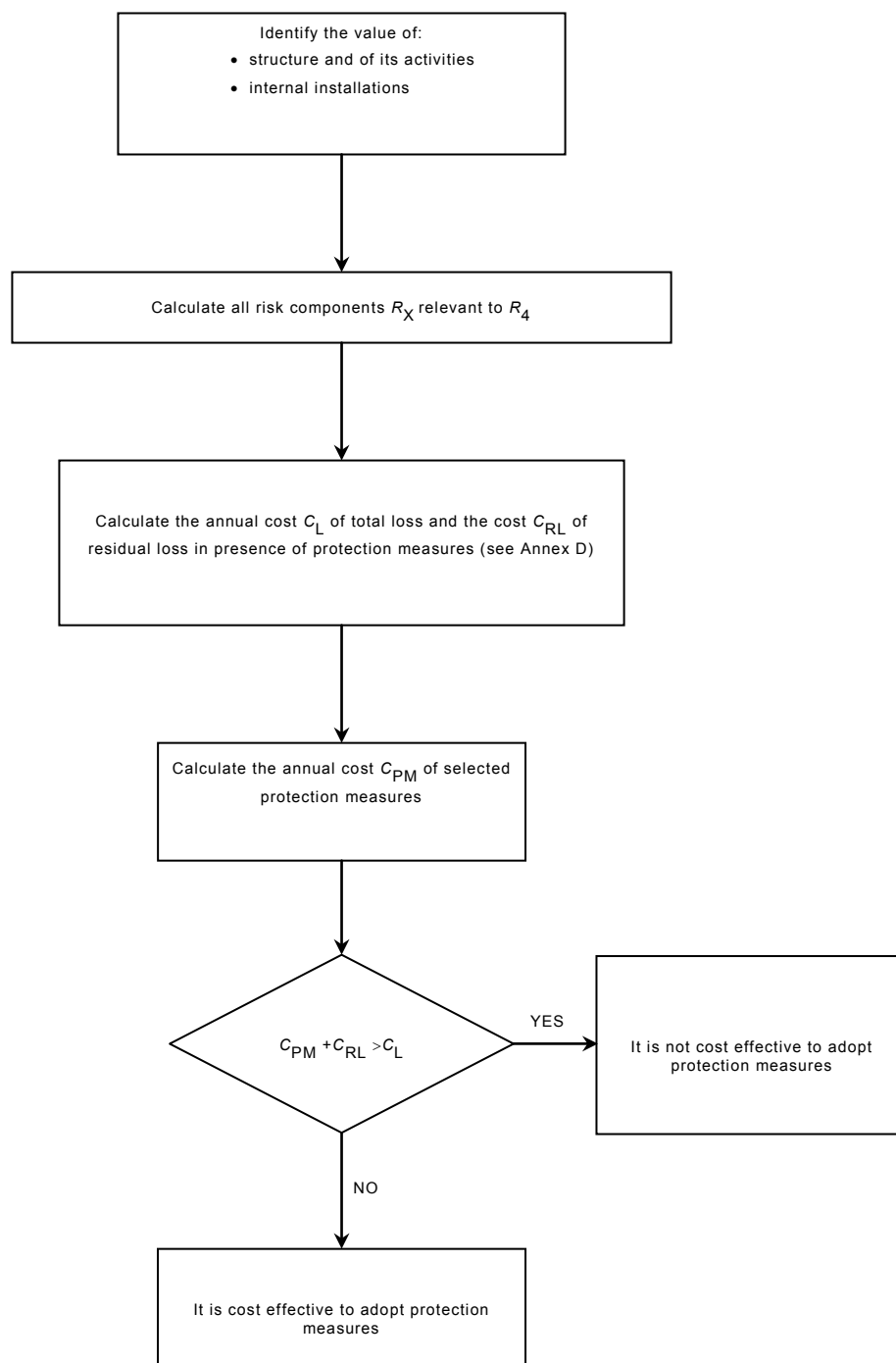


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^a If $R_A, R_B < R_T$, a complete LPS is not necessary; in this case SPD(s) according to IEC 62305-3 are sufficient.

^b See Table 3.

Figure 1 – Procedure for deciding the need of protection and for selecting protection measures



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Figure 2 – Procedure for evaluating the cost-effectiveness of protection measures

5.6 Protection measures

Protection measures are directed to reducing the risk according to the type of damage.

Protection measures shall be considered effective only if they conform to the requirements of the following relevant standards:

- IEC 62305-3 for protection against injury to living beings and physical damage in a structure;

- IEC 62305-4 for protection against failure of electrical and electronic systems.

5.7 Selection of protection measures

The selection of the most suitable protection measures shall be made by the designer according to the share of each risk component in the total risk R and according to the technical and economic aspects of the different protection measures.

Critical parameters shall be identified to determine the more efficient measure to reduce the risk R .

For each type of loss, there is a number of protection measures which, individually or in combination, make the condition $R \leq R_T$. The solution to be adopted shall be selected with allowance for technical and economic aspects. A simplified procedure for selection of protective measures is given in the flow diagram of Figure 1. In any case, the installer or planner should identify the most critical risk components and reduce them, also taking into account economic aspects.

6 Assessment of risk components

6.1 Basic equation

Each risk component R_A , R_B , R_C , R_M , R_U , R_V , R_W and R_Z , as described in 4.2.2, 4.2.3, 4.2.4 and 4.2.5 may be expressed by the following general equation:

$$R_X = N_X \times P_X \times L_X \quad (5)$$

where

N_X is the number of dangerous events per annum (see also Annex A);

P_X is the probability of damage to a structure (see also Annex B);

L_X is the consequent loss (see also Annex C).

The number N_X of dangerous events is affected by lightning ground flash density (N_G) and by the physical characteristics of the structure to be protected, its surroundings, connected lines and the soil.

The probability of damage P_X is affected by characteristics of the structure to be protected, the connected lines and the protection measures provided.

The consequent loss L_X is affected by the use to which the structure is assigned, the attendance of persons, the type of service provided to public, the value of goods affected by the damage and the measures provided to limit the amount of loss.

NOTE When the damage to a structure due to lightning may also involve surrounding structures or the environment (e.g. chemical or radioactive emissions), the consequent loss should be added to the value of L_X .

6.2 Assessment of risk components due to flashes to the structure (S1)

For evaluation of risk components related to lightning flashes to the structure, the following relationships apply:

- component related to injury to living beings by electric shock (D1)

$$R_A = N_D \times P_A \times L_A \quad (6)$$

- component related to physical damage (D2)

$$R_B = N_D \times P_B \times L_B$$

- component related to failure of internal systems (D3)

$$R_C = N_D \times P_C \times L_C \quad (8)$$

Parameters to assess these risk components are given in Table 5.

6.3 Assessment of the risk component due to flashes near the structure (S2)

For evaluation of the risk component related to lightning flashes near the structure, the following relationship applies:

- component related to failure of internal systems (D3)

$$R_M = N_M \times P_M \times L_M \quad (9)$$

Parameters to assess this risk component are given in Table 5.

6.4 Assessment of risk components due to flashes to a line connected to the structure (S3)

For evaluation of the risk components related to lightning flashes to an incoming line, the following relationships apply:

- component related to injury to living beings by electric shock (D1)

$$R_U = (N_L + N_{DJ}) \times P_U \times L_U \quad (10)$$

- component related to physical damage (D2)

$$R_V = (N_L + N_{DJ}) \times P_V \times L_V \quad (11)$$

- component related to failure of internal systems (D3)

$$R_W = (N_L + N_{DJ}) \times P_W \times L_W \quad (12)$$

NOTE 1 In many cases N_{DJ} may be neglected.

Parameters to assess these risk components are given in Table 5.

If the line has more than one section (see 6.8), the values of R_U , R_V and R_W are the sum of the R_U , R_V and R_W values relevant to each section of the line. The sections to be considered are those between the structure and the first node.

In the case of a structure with more than one connected line with different routing, the calculations shall be performed for each line.

In the case of a structure with more than one connected line with the same routing, the calculations shall be performed only for the line with the worst characteristics, i.e. the line with the highest values of N_L and N_I connected to the internal system with the lowest value of U_W (telecom line versus power line, unscreened line versus screened line, LV power line versus HV power line with HV/LV transformer, etc.).

NOTE 2 In the case of lines for which there is an overlapping of the collection area, the overlapping area should be considered only once.

6.5 Assessment of risk component due to flashes near a line connected to the structure (S4)

For evaluation of the risk component related to lightning flashes near a line connected to the structure, the following relationship applies:

- component related to failure of internal systems (D3)

$$R_Z = N_I \times P_Z \times L_Z \quad (13)$$

Parameters to assess this risk component are given in Table 5.

If the line has more than one section (see 6.8), the value of R_Z is the sum of the R_Z components relevant to each section of the line. The sections to be considered are those between the structure and the first node.

Table 5 – Parameters relevant to the assessment of risk components

Symbol	Denomination	Value according to Clause
Average annual number of dangerous events due to flashes		
N_D	– to the structure	A.2
N_M	– near the structure	A.3
N_L	– to a line entering the structure	A.4
N_I	– near a line entering the structure	A.5
N_{DJ}	– to the adjacent structure (see Figure A.5)	A.2
Probability that a flash to the structure will cause		
P_A	– injury to living beings by electric shock	B.2
P_B	– physical damage	B.3
P_C	– failure of internal systems	B.4
Probability that a flash near the structure will cause		
P_M	– failure of internal systems	B.5
Probability that a flash to a line will cause		
P_U	– injury to living beings by electric shock	B.6
P_V	– physical damage	B.7
P_W	– failure of internal systems	B.8
Probability that a flash near a line will cause		
P_Z	– failure of internal systems	B.9
Loss due to		
$L_A = L_U$	– injury to living beings by electric shock	C.3
$L_B = L_V$	– physical damage	C.3, C.4, C.5, C.6
$L_C = L_M = L_W = L_Z$	– failure of internal systems	C.3, C.4, C.6

In the case of a structure with more than one connected line with different routing, the calculations shall be performed for each line.

In the case of a structure with more than one connected line with the same routing, the calculations shall be performed only for the line with the worst characteristics, i.e. the line with the highest values of N_L and N_I connected to the internal system with the lowest value of U_W (telecom line versus power line, unscreened line versus screened line, LV power line versus HV power line with HV/LV transformer, etc.)

6.6 Summary of risk components

Risk components for structures are summarized in Table 6 according to different types of damage and different sources of damage.

Table 6 – Risk components for different types of damage and source of damage

Damage	Source of damage			
	S1 Lightning flash to a structure	S2 Lightning flash near a structure	S3 Lightning flash to an incoming line	S4 Lightning flash near a line
D1 Injury to living beings by electric shock	$R_A = N_D \times P_A \times L_A$		$R_U = (N_L + N_{DJ}) \times P_U \times L_U$	
D2 Physical damage	$R_B = N_D \times P_B \times L_B$		$R_V = (N_L + N_{DJ}) \times P_V \times L_V$	
D3 Failure of electrical and electronic systems	$R_C = N_D \times P_C \times L_C$	$R_M = N_M \times P_M \times L_M$	$R_W = (N_L + N_{DJ}) \times P_W \times L_W$	$R_Z = N_I \times P_Z \times L_Z$

If the structure is partitioned in zones Z_S (see 6.7), each risk component shall be evaluated for each zone Z_S .

The total risk R of the structure is the sum of risks components relevant to the zones Z_S which constitute the structure.

6.7 Partitioning of a structure in zones Z_S

To assess each risk component, a structure could be divided into zones Z_S each having homogeneous characteristics. However, a structure may be, or may be assumed to be, a single zone.

Zones Z_S are mainly defined by:

- type of soil or of floor (risk components R_A and R_U);
- fireproof compartments (risk components R_B and R_V);
- spatial shields (risk components R_C and R_M).

Further zones may be defined according to

- layout of internal systems (risk components R_C and R_M),
- protection measures existing or to be provided (all risk components),
- losses L_X values (all risk components).

Partitioning of the structure in zones Z_S should take into account the feasibility of the implementation of the most suitable protection measures.

NOTE Zones Z_S according to this part of IEC 62305 may be LPZ in line with IEC 62305-4. However they may also be different from LPZs.

6.8 Partitioning of a line into sections S_L

To assess the risk components due to a flash to or near a line, the line could be divided into sections S_L . However a line may be, or may be assumed to be, a single section.

For all risk components, sections S_L are mainly defined by

- type of line (aerial or buried),
- factors affecting the collection area (C_D , C_E , C_T),
- characteristics of line (shielded or unshielded, shield resistance).

If more than one value of a parameter exists in a section, the value leading to the highest value of risk is to be assumed.

6.9 Assessment of risk components in a structure with zones Z_S

6.9.1 General criteria

For the evaluation of risk components and the selection of the relevant parameters involved, the following rules apply:

- parameters relevant to the number N of dangerous events shall be evaluated according to Annex A;
- parameters relevant to the probability P of damage shall be evaluated according to Annex B.

Moreover:

- for components R_A , R_B , R_U , R_V , R_W and R_Z , only one value is to be fixed in each zone for each parameter involved. Where more than one value is applicable, the highest one shall be chosen.
- for components R_C and R_M , if more than one internal system is involved in a zone, values of P_C and P_M are given by:

$$P_C = 1 - (1 - P_{C1}) \times (1 - P_{C2}) \times (1 - P_{C3}) \quad (14)$$

$$P_M = 1 - (1 - P_{M1}) \times (1 - P_{M2}) \times (1 - P_{M3}) \quad (15)$$

where P_{Ci} , and P_{Mi} are parameters relevant to internal system $i = 1, 2, 3, \dots$

- parameters relevant to the amount L of loss shall be evaluated according to Annex C.

With the exception made for P_C and P_M , if more than one value of any other parameter exists in a zone, the value of the parameter leading to the highest value of risk is to be assumed.

6.9.2 Single zone structure

In this case, only one zone Z_S made up of the entire structure is defined. The risk R is the sum of risk components R_X in this zone.

Defining the structure with a single zone may lead to expensive protection measures because each measure must extend to the entire structure.

6.9.3 Multi-zone structure

In this case, the structure is divided into multiple zones Z_S . The risk for the structure is the sum of the risks relevant to all zones of the structure; in each zone, the risk is the sum of all relevant risk components in the zone.

Dividing a structure into zones allows the designer to take into account the characteristics of each part of the structure in the evaluation of risk components and to select the most suitable protection measures tailored zone by zone, reducing the overall cost of protection against lightning.

6.10 Cost-benefit analysis for economic loss (L4)

Whether or not there is need to determine protection to reduce risks R_1 , R_2 , and R_3 , it is useful to evaluate the economic justification in adopting protection measures in order to reduce the risk R_4 of economic loss.

The items for which the assessment of risk R_4 is to be performed shall be defined from

- the whole structure,
- a part of the structure,
- an internal installation,
- a part of an internal installation,
- a piece of equipment,
- the contents in the structure.

The cost of loss, the cost of the protection measures and the possible saving should be evaluated according to Annex D. If the data for this analysis are not available, the representative value of tolerable risk $R_T = 10^{-3}$ may be used.

Annex A (informative)

Assessment of annual number N of dangerous events

A.1 General

The average annual number N of dangerous events due to lightning flashes influencing a structure to be protected depends on the thunderstorm activity of the region where the structure is located and on the structure's physical characteristics. To calculate the number N , one should multiply the lightning ground flash density N_G by an equivalent collection area of the structure, taking into account correction factors for the structure's physical characteristics.

The lightning ground flash density N_G is the number of lightning flashes per km² per year. This value is available from ground flash location networks in many areas of the world.

NOTE If a map of N_G is not available, in temperate regions it may be estimated by:

$$N_G \approx 0,1 T_D \quad (\text{A.1})$$

where T_D is the thunderstorm days per year (which can be obtained from isokeraunic maps).

Events that may be considered as dangerous for a structure to be protected are

- flashes to the structure,
- flashes near the structure,
- flashes to a line entering the structure,
- flashes near a line entering the structure,
- flashes to a another structure to which a line is connected.

A.2 Assessment of the average annual number of dangerous events N_D due to flashes to a structure and N_{DJ} to an adjacent structure

A.2.1 Determination of the collection area A_D

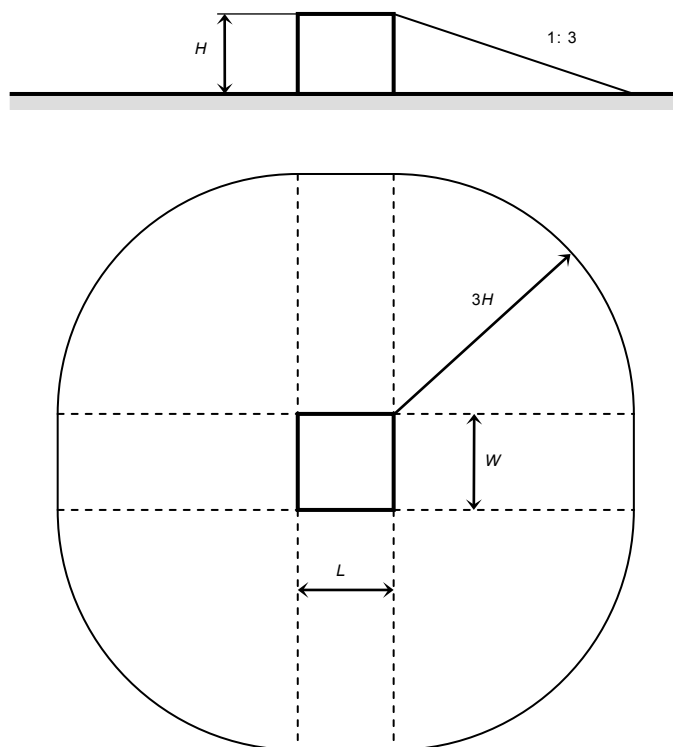
For isolated structures on flat ground, the collection area A_D is the area defined by the intersection between the ground surface and a straight line with 1/3 slope which passes from the upper parts of the structure (touching it there) and rotating around it. Determination of the value of A_D may be performed graphically or mathematically.

A.2.1.1 Rectangular structure

For an isolated rectangular structure with length L , width W , and height H on flat ground, the collection area is then equal to:

$$A_D = L \times W + 2 \times (3 \times H) \times (L + W) + \pi \times (3 \times H)^2 \quad (\text{A.2})$$

where L , W and H are expressed in metres (see Figure A.1).



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Figure A.1 – Collection area A_D of an isolated structure

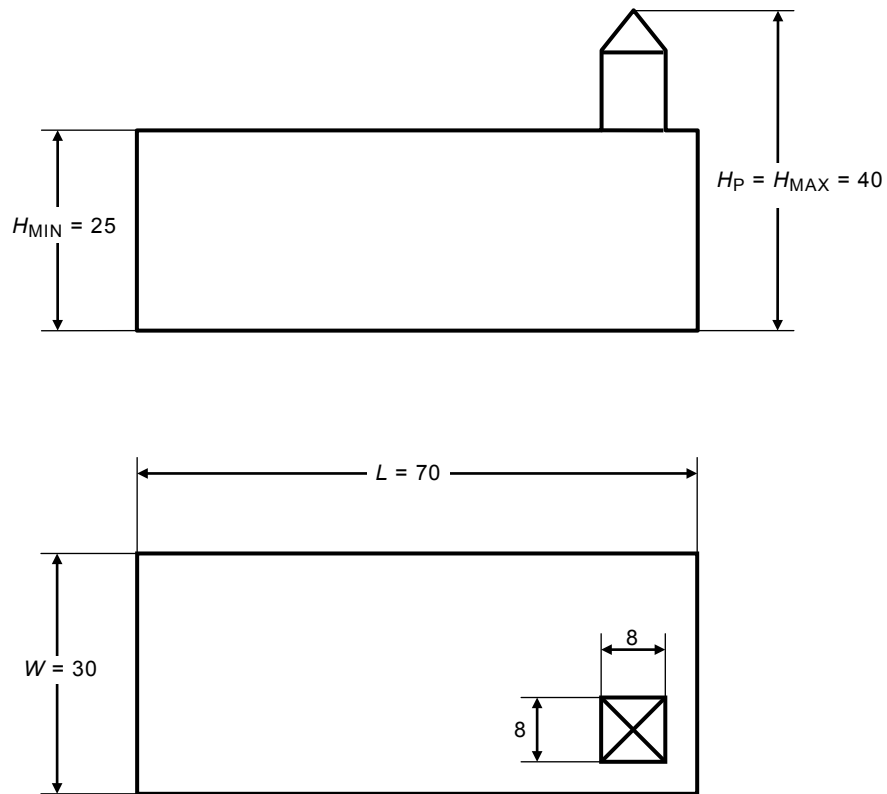
A.2.1.2 Complex shaped structure

If the structure has a complex shape such as elevated roof protrusions (see Figure A.2), a graphical method should be used to evaluate A_D (see Figure A.3).

An acceptable approximate value of the collection area is the greater between the collection area $A_{D\text{MIN}}$ evaluated with Equation (A.2) taking the minimum height H_{MIN} of the structure, and the collection area attributed to the elevated roof protrusion A_D' . A_D' may be calculated by:

$$A_D' = \pi \times (3 \times H_P)^2 \quad (\text{A.3})$$

where H_P is the height of protrusion.



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Figure A.2 – Complex shaped structure

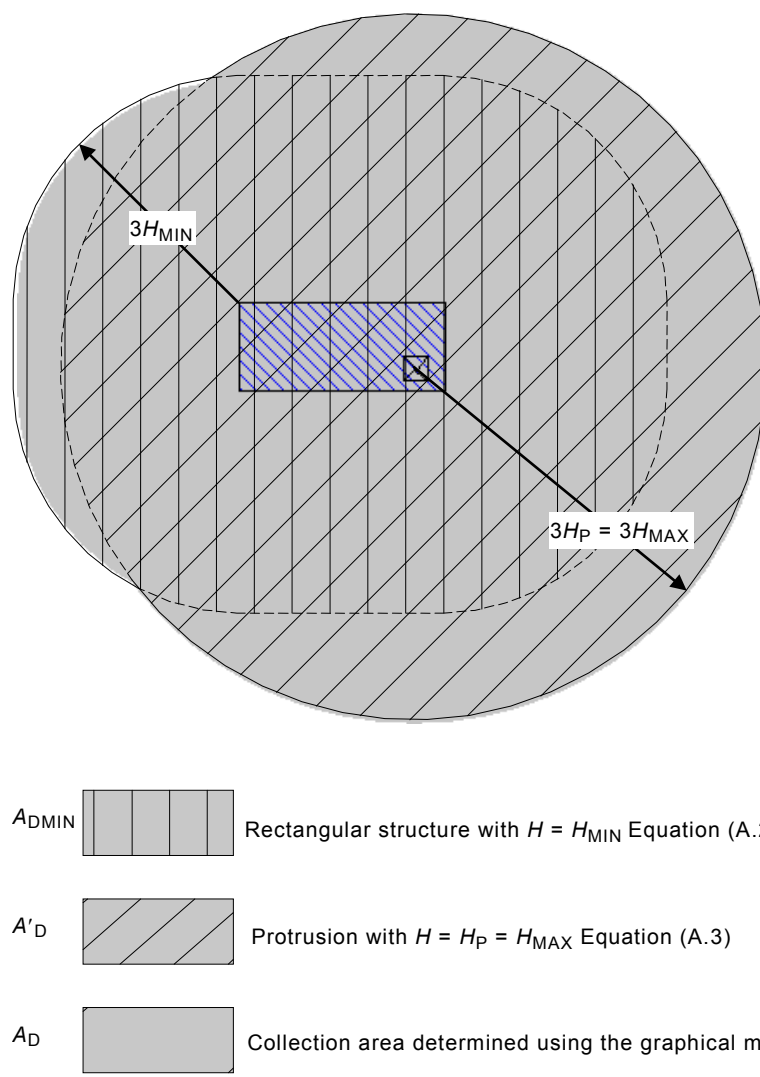


Figure A.3 – Different methods to determine the collection area for the given structure

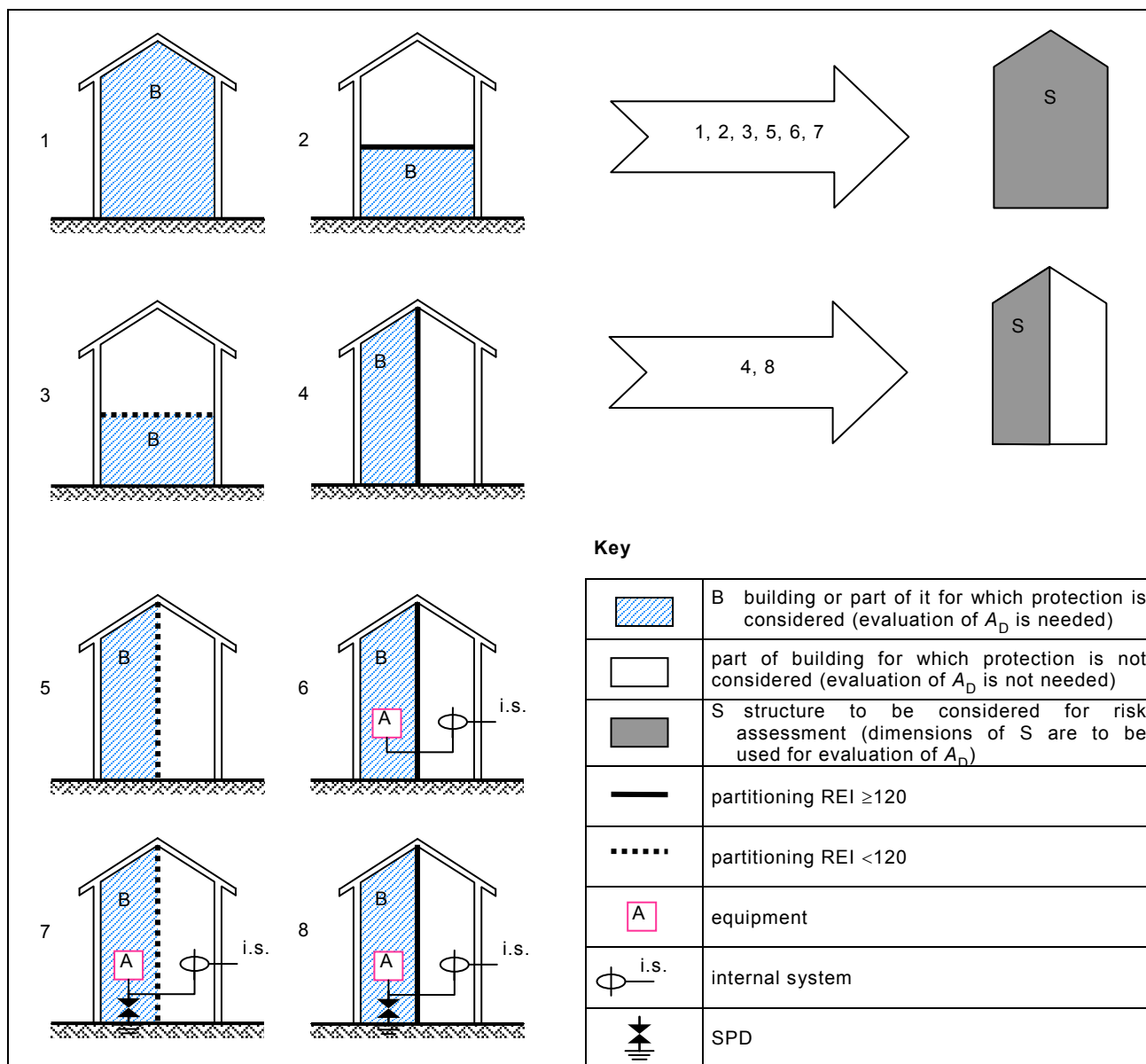
A.2.2 Structure as a part of a building

Where the structure S to be considered consists of only a part of a building B, the dimensions of structure S may be used in evaluation of A_D provided that the following conditions are fulfilled (see Figure A.4):

- the structure S is a separated vertical part of the building B;
- the building B does not have a risk of explosion;
- propagation of fire between the structure S and other parts of the building B is avoided by means of walls with resistance to fire of 120 min (REI 120) or by means of other equivalent protection measures;
- propagation of overvoltages along common lines, if any, is avoided by means of SPDs installed at the entrance point of such lines in the structure or by means of other equivalent protection measure.

NOTE For definition and information on REI, see [6].

Where these conditions are not fulfilled, the dimensions of the whole building B should be used.



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Figure A.4 – Structure to be considered for evaluation of collection area A_D

A.2.3 Relative location of the structure

The relative location of the structure, compensating for surrounding structures or an exposed location, will be taken into account by a location factor C_D (see Table A.1).

A more precise evaluation of the surrounding objects' influence can be obtained considering the relative height of the structure with respect to the surrounding objects or the ground within a distance of $3 \times H$ from the structure and assuming $C_D = 1$.

Table A.1 – Structure location factor C_D

Relative location	C_D
Structure surrounded by higher objects	0,25
Structure surrounded by objects of the same height or smaller	0,5
Isolated structure: no other objects in the vicinity	1
Isolated structure on a hilltop or a knoll	2

A.2.4 Number of dangerous events N_D for the structure

N_D may be evaluated as the product:

$$N_D = N_G \times A_D \times C_D \times 10^{-6} \quad (\text{A.4})$$

where

N_G is the lightning ground flash density ($1/\text{km}^2 \times \text{year}$);

A_D is the collection area of the structure (m^2) (see Figure A.5);

C_D is the location factor of the structure (see Table A.1).

A.2.5 Number of dangerous events N_{DJ} for an adjacent structure

The average annual number of dangerous events due to flashes to a structure connected at the far end of a line, N_{DJ} (see 6.5 and Figure A.5) may be evaluated as the product:

$$N_{DJ} = N_G \times A_{DJ} \times C_{DJ} \times C_T \times 10^{-6} \quad (\text{A.5})$$

where

N_G is the lightning ground flash density ($1/\text{km}^2 \times \text{year}$);

A_{DJ} is the collection area of the adjacent structure (m^2) (see Figure A.5);

C_{DJ} is the location factor of the adjacent structure (see Table A.1);

C_T is the line type factor (see Table A.3);

A.3 Assessment of the average annual number of dangerous events N_M due to flashes near a structure

N_M may be evaluated as the product:

$$N_M = N_G \times A_M \times 10^{-6} \quad (\text{A.6})$$

where

N_G is the lightning ground flash density ($1/\text{km}^2 \times \text{year}$);

A_M is the collection area of flashes striking near the structure (m^2).

The collection area A_M extends to a line located at a distance of 500 m from the perimeter of the structure (see Figure A.5):

$$A_M = 2 \times 500 \times (L + W) + \pi \times 500^2 \quad (\text{A.7})$$

A.4 Assessment of the average annual number of dangerous events N_L due to flashes to a line

A line may consist of several sections. For each section of line, the value of N_L may be evaluated by:

$$N_L = N_G \times A_L \times C_I \times C_E \times C_T \times 10^{-6} \quad (\text{A.8})$$

where

N_L is the number of overvoltages of amplitude not lower than 1 kV (1/year) on the line section)

N_G is the lightning ground flash density ($1/\text{km}^2 \times \text{year}$);

A_L is the collection area of flashes striking the line (m^2) (see Figure A.5);

C_I is the installation factor of the line (see Table A.2);

C_T is the line type factor (see Table A.3);

C_E is the environmental factor (see Table A.4);

with the collection area for flashes to a line:

$$A_L = 40 \times L_L \quad (\text{A.9})$$

L_L is the length of the line section (m).

Where the length of a line section is unknown, $L_L = 1\,000$ m is to be assumed.

NOTE 1 National committees may improve this information in order to better meet national conditions of power and telecommunication lines.

Table A.2 – Line installation factor C_I

Routing	C_I
Aerial	1
Buried	0,5
Buried cables running entirely within a meshed earth termination (5.2 of IEC 62305-4:2010).	0,01

Table A.3 – Line type factor C_T

Installation	C_T
LV power, telecommunication or data line	1
HV power (with HV/LV transformer)	0,2

Table A.4 – Line environmental factor C_E

Environment	C_E
Rural	1
Suburban	0,5
Urban	0,1
Urban with tall buildings ^a	0,01
^a Buildings higher than 20 m.	

NOTE 2 The ground resistivity affects the collection area A_L of buried sections. In general, the larger the ground resistivity, the larger the collection area (A_L proportional to $\sqrt{\rho}$). The installation factor of Table A.2 is based on $\rho = 400 \Omega\text{m}$.

NOTE 3 More information on the collection areas A_I for telecommunication lines can be found in ITU-T Recommendation K.47 ^[7].

A.5 Assessment of average annual number of dangerous events N_I due to flashes near a line

A line may consist of several sections. For each section of line, the value of N_I may be evaluated by

$$N_I = N_G \times A_I \times C_I \times C_E \times C_T \times 10^{-6} \quad (\text{A.10})$$

where

N_I is the number of overvoltages of amplitude not lower than 1 kV (1/year) on the line section;

N_G is the lightning ground flash density ($1/\text{km}^2 \times \text{year}$);

A_I is the collection area of flashes to ground near the line (m^2) (see Figure A.5);

C_I is the installation factor (see Table A.2);

C_T is the line type factor (see Table A.3);

C_E is the environmental factor (see Table A.4).

with the collection area for flashes near a line

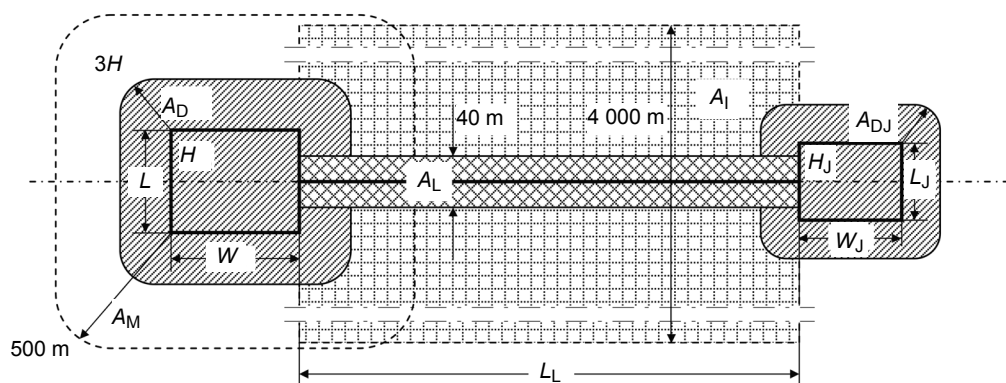
$$A_I = 4\,000 \times L_L \quad (\text{A.11})$$

where L_L is the length of the line section (m).

Where the length of a line section is unknown, $L_L = 1\,000 \text{ m}$ is to be assumed.

NOTE 1 National committees can improve this information in order to better meet national conditions of power and telecommunication lines.

NOTE 2 A more precise evaluation of A_I can be found in Electra n. 161 ^[8] and 162 ^[9], 1995 for power lines and in ITU-T Recommendation K.46 ^[10] for telecommunications lines.



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Figure A.5 – Collection areas (A_D , A_M , A_I , A_L)

Annex B (informative)

Assessment of probability P_X of damage

B.1 General

The probabilities given in this annex are valid if protection measures conform to:

- IEC 62305-3 for protection measures to reduce injury to living beings and for protection measures to reduce physical damage;
- IEC 62305-4 for protection measures to reduce failure of internal systems.

Other values may be chosen, if justified.

Values of probabilities P_X less than 1 may be selected only if the measure or characteristic is valid for the entire structure or zone of structure (Z_S) to be protected and for all relevant equipment.

B.2 Probability P_A that a flash to a structure will cause injury to living beings by electric shock

The values of probability P_A of shock to living beings due to touch and step voltage by a lightning flash to the structure, depend on the adopted LPS and on additional protection measures provided:

$$P_A = P_{TA} \times P_B \quad (\text{B.1})$$

where

P_{TA} depends on additional protection measures against touch and step voltages, such as those listed in Table B.1. Values of P_{TA} are given in Table B.1.

P_B depends on the lightning protection level (LPL) for which the LPS conforming to IEC 62305-3 is designed. Values of P_B are given in Table B.2.

Table B.1 – Values of probability P_{TA} that a flash to a structure will cause shock to living beings due to dangerous touch and step voltages

Additional protection measure	P_{TA}
No protection measures	1
Warning notices	10^{-1}
Electrical insulation (e.g. at least 3 mm cross-linked polyethylene) of exposed parts (e.g. down-conductors)	10^{-2}
Effective soil equipotentialization	10^{-2}
Physical restrictions or building framework used as a down-conductor system	0

If more than one provision has been taken, the value of P_{TA} is the product of the corresponding values.

NOTE 1 Protection measures are effective in reducing P_A only in structures protected by an LPS or structures with continuous metal or reinforced concrete framework acting as a natural LPS, where bonding and earthing requirements of IEC 62305-3 are satisfied.

NOTE 2 For more information see 8.1 and 8.2 of IEC 62305-3:2010.

B.3 Probability P_B that a flash to a structure will cause physical damage

An LPS is suitable as a protection measure to reduce P_B .

The values of probability P_B of physical damage by a flash to a structure, as a function of lightning protection level (LPL) are given in Table B.2.

Table B.2 – Values of probability P_B depending on the protection measures to reduce physical damage

Characteristics of structure	Class of LPS	P_B
Structure not protected by LPS	–	1
Structure protected by LPS	IV	0,2
	III	0,1
	II	0,05
	I	0,02
Structure with an air-termination system conforming to LPS I and a continuous metal or reinforced concrete framework acting as a natural down-conductor system		0,01
Structure with a metal roof and an air-termination system, possibly including natural components, with complete protection of any roof installations against direct lightning strikes and a continuous metal or reinforced concrete framework acting as a natural down-conductor system		0,001

NOTE 1 Values of P_B other than those given in Table B.2 are possible if based on a detailed investigation taking into account the requirements of sizing and interception criteria defined in IEC 62305-1.

NOTE 2 The characteristics of LPS, including those of SPD for lightning equipotential bonding, are reported in IEC 62305-3.

B.4 Probability P_C that a flash to a structure will cause failure of internal systems

A coordinated SPD system is suitable as a protection measure to reduce P_C .

The probability P_C that a flash to a structure will cause a failure of internal systems is given by:

$$P_C = P_{SPD} \times C_{LD} \quad (B.2)$$

P_{SPD} depends on the coordinated SPD system conforming to IEC 62305-4 and to the lightning protection level (LPL) for which its SPDs are designed. Values of P_{SPD} are given in Table B.3.

C_{LD} is a factor depending on shielding, grounding and isolation conditions of the line to which the internal system is connected. Values of C_{LD} are given in Table B.4.

Table B.3 – Value of the probability P_{SPD} as a function of LPL for which SPDs are designed

LPL	P_{SPD}
No coordinated SPD system	1
III-IV	0,05
II	0,02
I	0,01
NOTE 2	0,005 – 0,001

NOTE 1 A coordinated SPD system is effective in reducing P_C only in structures protected by an LPS or structures with continuous metal or reinforced concrete framework acting as a natural LPS, where bonding and earthing requirements of IEC 62305-3 are satisfied.

NOTE 2 The values of P_{SPD} may be reduced for SPDs having better protection characteristics (higher nominal current I_N , lower protective level U_P , etc.) compared with the requirements defined for LPL I at the relevant installation locations (see Table A.3 of IEC 62305-1:2010 for information on lightning current probabilities, and Annex E of IEC 62305-1:2010 and Annex D of IEC 62305-4:2010 for lightning current sharing). The same annexes may be used for SPDs having higher probabilities P_{SPD} .

Table B.4 – Values of factors C_{LD} and C_{LI} depending on shielding, grounding and isolation conditions

External line type	Connection at entrance	C_{LD}	C_{LI}
Aerial line unshielded	Undefined	1	1
Buried line unshielded	Undefined	1	1
Multi grounded neutral power line	None	1	0,2
Shielded buried line (power or TLC)	Shield not bonded to the same bonding bar as equipment	1	0,3
Shielded aerial line (power or TLC)	Shield not bonded to the same bonding bar as equipment	1	0,1
Shielded buried line (power or TLC)	Shield bonded to the same bonding bar as equipment	1	0
Shielded aerial line (power or TLC)	Shield bonded to the same bonding bar as equipment	1	0
Lightning protective cable or wiring in lightning protective cable ducts, metallic conduit, or metallic tubes	Shield bonded to the same bonding bar as equipment	0	0
(No external line)	No connection to external lines (stand-alone systems)	0	0
Any type	Isolating interface according to IEC 62305-4	0	0

NOTE 3 In the evaluation of probability P_C , values of C_{LD} in Table B.4 refer to shielded internal systems; for unshielded internal systems, $C_{LD} = 1$ should be assumed.

NOTE 4 For non-shielded internal systems

- not connected to external lines (stand-alone systems), or
- connected to external lines through isolating interfaces, or
- connected to external lines consisting of lightning protective cable or systems with wiring in lightning protective cable ducts, metallic conduit, or metallic tubes, bonded to the same bonding bar as equipment,

a coordinated SPD system according to IEC 62305-4 is not necessary to reduce P_C provided that the induced voltage U_I is not higher than the withstand voltage U_w of the internal system ($U_I \leq U_w$). For evaluation of induced voltage U_I see Annex A of IEC 62305-4:2010.

B.5 Probability P_M that a flash near a structure will cause failure of internal systems

A grid-like LPS, screening, routing precautions, increased withstand voltage, isolating interfaces and coordinated SPD systems are suitable as protection measures to reduce P_M .

The probability P_M that a lightning flash near a structure will cause failure of internal systems depends on the adopted SPM measures.

When a coordinated SPD system meeting the requirements of IEC 62305-4 is not provided, the value of P_M is equal to the value of P_{MS} .

When a coordinated SPD system according to IEC 62305-4 is provided, the value of P_M is given by:

$$P_M = P_{SPD} \times P_{MS} \quad (\text{B.3})$$

For internal systems with equipment not conforming to the resistibility or withstand voltage level given in the relevant product standards, $P_M = 1$ should be assumed.

The values of P_{MS} are obtained from the product:

$$P_{MS} = (K_{S1} \times K_{S2} \times K_{S3} \times K_{S4})^2 \quad (\text{B.4})$$

where

K_{S1} takes into account the screening effectiveness of the structure, LPS or other shields at boundary LPZ 0/1;

K_{S2} takes into account the screening effectiveness of shields internal to the structure at boundary LPZ X/Y ($X > 0$, $Y > 1$);

K_{S3} takes into account the characteristics of internal wiring (see Table B.5);

K_{S4} takes into account the impulse withstand voltage of the system to be protected.

NOTE 1 When equipment provided with isolating interfaces consisting of isolation transformers with earthed screen between windings, or of fibre optic cables or optical couplers is used, $P_{MS} = 0$ should be assumed.

Inside an LPZ, at a safety distance from the boundary screen at least equal to the mesh width w_m , factors K_{S1} and K_{S2} for LPS or spatial grid-like shields may be evaluated as

$$K_{S1} = 0,12 \times w_{m1} \quad (\text{B.5})$$

$$K_{S2} = 0,12 \times w_{m2} \quad (\text{B.6})$$

where w_{m1} (m) and w_{m2} (m) are the mesh widths of grid-like spatial shields, or of mesh type LPS down-conductors or the spacing between the structure metal columns, or the spacing between a reinforced concrete framework acting as a natural LPS.

For continuous metal shields with thicknesses not lower than 0,1 mm, $K_{S1} = K_{S2} = 10^{-4}$.

NOTE 2 Where a meshed bonding network is provided according to IEC 62305-4, values of K_{S1} and K_{S2} may be halved.

Where the induction loop is running closely to the LPZ boundary screen conductors at a distance from the shield shorter than the safety distance, the values of K_{S1} and K_{S2} will be higher. For instance, the values of K_{S1} and K_{S2} should be doubled where the distance to the shield ranges from 0,1 w_m to 0,2 w_m .

For a cascade of LPZs the resulting K_{S2} is the product of the relevant K_{S2} of each LPZ.

NOTE 3 The maximum value of K_{S1} and K_{S2} is limited to 1.

Table B.5 – Value of factor K_{S3} depending on internal wiring

Type of internal wiring	K_{S3}
Unshielded cable – no routing precaution in order to avoid loops ^a	1
Unshielded cable – routing precaution in order to avoid large loops ^b	0,2
Unshielded cable – routing precaution in order to avoid loops ^c	0,01
Shielded cables and cables running in metal conduits ^d	0,000 1
^a Loop conductors with different routing in large buildings (loop area in the order of 50 m ²). ^b Loop conductors routed in the same conduit or loop conductors with different routing in small buildings (loop area in the order of 10 m ²). ^c Loop conductors routed in the same cable (loop area in the order of 0,5 m ²). ^d Shields and the metal conduits bonded to an equipotential bonding bar at both ends and equipment is connected to the same bonding bar.	

The factor K_{S4} is evaluated as:

$$K_{S4} = 1/U_W \quad (\text{B.7})$$

where

U_W is the rated impulse withstand voltage of system to be protected, in kV.

NOTE 4 The maximum value of K_{S4} is limited to 1.

If there is equipment with different impulse withstand levels in an internal system, the factor K_{S4} relevant to the lowest impulse withstand level should be selected.

B.6 Probability P_U that a flash to a line will cause injury to living beings by electric shock

The values of probability P_U of injury to living beings inside the structure due to touch voltage by a flash to a line entering the structure depends on the characteristics of the line shield, the impulse withstand voltage of internal systems connected to the line, the protection measures like physical restrictions or warning notices and the isolating interfaces or SPD(s) provided for equipotential bonding at the entrance of the line according to IEC 62305-3.

NOTE 1 A coordinated SPD system according to IEC 62305-4 is not necessary to reduce P_U ; in this case SPD(s) according to IEC 62305-3 are sufficient.

The value of P_U is given by:

$$P_U = P_{TU} \times P_{EB} \times P_{LD} \times C_{LD} \quad (\text{B.8})$$

where

P_{TU} depends on protection measures against touch voltages, such as physical restrictions or warning notices. Values of P_{TU} are given in Table B.6;

P_{EB} depends on lightning equipotential bonding (EB) conforming to IEC 62305-3 and on the lightning protection level (LPL) for which its SPDs are designed. Values of P_{EB} are given in Table B.7;

P_{LD} is the probability of failure of internal systems due to a flash to the connected line depending on the line characteristics. Values of P_{LD} are given in Table B.8.

C_{LD} is a factor depending on shielding, grounding and isolation conditions of the line. Values of C_{LD} are given in Table B.4.

NOTE 2 When SPD(s) according to IEC 62305-3 are provided for equipotential bonding at the entrance of the line, earthing and bonding according to IEC 62305-4 may improve protection.

Table B.6 – Values of probability P_{TU} that a flash to an entering line will cause shock to living beings due to dangerous touch voltages

Protection measure	P_{TU}
No protection measures	1
Warning notices	10^{-1}
Electrical insulation	10^{-2}
Physical restrictions	0

NOTE 3 If more than one provision has been taken, the value of P_{TU} is the product of the corresponding values.

Table B.7 – Value of the probability P_{EB} as a function of LPL for which SPDs are designed

LPL	P_{EB}
No SPD	1
III-IV	0,05
II	0,02
I	0,01
NOTE 3	0,005 – 0,001

NOTE 4 The values of P_{EB} may be reduced for SPDs having better protection characteristics (higher nominal current I_N , lower protective level U_P , etc.) compared with the requirements defined for LPL I at the relevant installation locations (see Table A.3 of IEC 62305-1:2010 for information on lightning current probabilities, and Annex E of IEC 62305-1:2010 and Annex D of IEC 62305-4:2010 for lightning current sharing). The same annexes may be used for SPDs having higher probabilities P_{EB} .

Table B.8 – Values of the probability P_{LD} depending on the resistance R_S of the cable screen and the impulse withstand voltage U_W of the equipment

Line type	Routing, shielding and bonding conditions		Withstand voltage U_W in kV				
			1	1,5	2,5	4	6
Power lines or Telecom lines	Aerial or buried line, unshielded or shielded whose shield is not bonded to the same bonding bar as equipment		1	1	1	1	1
	Shielded aerial or buried whose shield bonded to the same bonding bar as equipment	$5\Omega/\text{km} < R_S \leq 20\ \Omega/\text{km}$	1	1	0,95	0,9	0,8
		$1\Omega/\text{km} < R_S \leq 5\ \Omega/\text{km}$	0,9	0,8	0,6	0,3	0,1
		$R_S \leq 1\ \Omega/\text{km}$	0,6	0,4	0,2	0,04	0,02

NOTE 5 In suburban/urban areas, an LV power line uses typically unshielded buried cable whereas a telecommunication line uses a buried shielded cable (with a minimum of 20 conductors, a shield resistance of $5\ \Omega/\text{km}$, a copper wire diameter of 0,6 mm). In rural areas an LV power line uses an unshielded aerial cable whereas a telecommunication line uses an aerial unshielded cable (copper wire diameter: 1 mm). An HV buried power line uses typically a shielded cable with a shield resistance in the order of $1\Omega/\text{km}$ to $5\ \Omega/\text{km}$. National committees may improve this information in order to better meet national conditions of power and telecommunication lines.

B.7 Probability P_V that a flash to a line will cause physical damage

The values of probability P_V of physical damage by a flash to a line entering the structure depend on the characteristics of the line shield, the impulse withstand voltage of internal systems connected to the line and the isolating interfaces or the SPDs provided for equipotential bonding at the entrance of the line according to IEC 62305-3.

NOTE A coordinated SPD system according to IEC 62305-4 is not necessary to reduce P_V ; in this case, SPDs according to IEC 62305-3 are sufficient.

The value of P_V is given by:

$$P_V = P_{EB} \times P_{LD} \times C_{LD} \quad (\text{B.9})$$

where

P_{EB} depends on lightning equipotential bonding (EB) conforming to IEC 62305-3 and on the lightning protection level (LPL) for which its SPDs are designed. Values of P_{EB} are given in Table B.7;

P_{LD} is the probability of failure of internal systems due to a flash to the connected line depending on the line characteristics. Values of P_{LD} are given in Table B.8;

C_{LD} is a factor depending on shielding, grounding and isolation conditions of the line. Values of C_{LD} are given in Table B.4.

B.8 Probability P_W that a flash to a line will cause failure of internal systems

The values of probability P_W that a flash to a line entering the structure will cause a failure of internal systems depend on the characteristics of line shielding, the impulse withstand voltage of internal systems connected to the line and the isolating interfaces or the coordinated SPD system installed.

The value of P_W is given by:

$$P_W = P_{SPD} \times P_{LD} \times C_{LD} \quad (\text{B.10})$$

where

P_{SPD} depends on the coordinated SPD system conforming to IEC 62305-4 and the lightning protection level (LPL) for which its SPDs are designed. Values of P_{SPD} are given in Table B.3;

P_{LD} is the probability of failure of internal systems due to a flash to the connected line depending on the line characteristics. Values of P_{LD} are given in Table B.8;

C_{LD} is a factor depending on shielding, grounding and isolation conditions of the line. Values of C_{LD} are given in Table B.4.

B.9 Probability P_Z that a lightning flash near an incoming line will cause failure of internal systems

The values of probability P_Z that a lightning flash near a line entering the structure will cause a failure of internal systems depend on the characteristics of the line shield, the impulse withstand voltage of the system connected to the line and the isolating interfaces or the coordinated SPD system provided.

The value of P_Z is given by:

$$P_Z = P_{SPD} \times P_{LI} \times C_{LI}$$