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Functions concerned
Fonctions concernées

☐ Safety / Sécurité ☐ EMC / CEM ☐ Environment / Environnement ☐ Quality assurance / Assurance de la qualité

INTERNATIONAL ELECTROTECHNICAL COMMISSION COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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Title
IEC 62305-2 Ed. 1.0: Protection against lightning – Part 2: Risk management

Titre
CEI 62305-2 Ed. 1.0: Protection contre la foudre – Partie 2: Evaluation des risques

IEC CO note : Please read the important information on the Risk Assessment Calculator software given on page 1A.

ATTENTION
VOTE PARALLÈLE
CEI – CENELEC

L'attention des Comités nationaux de la CEI, membres du CENELEC, est attirée sur le fait que ce projet final de Norme internationale est soumis au vote parallèle. Un bulletin de vote séparé pour le vote CENELEC leur sera envoyé par le Secrétariat Central du CENELEC.

ATTENTION
IEC – CENELEC
PARALLEL VOTING

The attention of IEC National Committees, members of CENELEC, is drawn to the fact that this final Draft International Standard (DIS) is submitted for parallel voting. A separate form for CENELEC voting will be sent to them by the CENELEC Central Secretariat.

IEC 62305-2 - INFORMATION ON RISK ASSESSMENT CALCULATOR SOFTWARE

The Risk Assessment Calculator software is circulated as a zip file.

It can also be downloaded from an ftp server site set-up by the IEC CO for this purpose by using the link with username included as.
ftp://riskmem@ftp.iec.ch

Please note that:

- the data base of the software is password protected,
- the expiry date for the software has been set for 150 days,
- on the Toolbar of the software under “Library”, the user is able to obtain PDF copies of the English and French versions of the FDIS,
- the software will be taken off the ftp server site at the end of the voting period of the FDIS.

Upon the final publication, the ftp server site will be used to supply updates of the software for purchasers of the standard.

Finally please note: The software is purely provided to assist in a simplified implementation of the standard and should in no way be construed as a substitute for the written standard.

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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.

The IEC 62305 series (Parts 1 to 5), is produced in accordance with the New Publications Plan, approved by National Committees (81/171/RQ (2001-06-29)), which restructures and updates, in a more simple and rational form, the publications of the IEC 61024 series, the IEC 61312 series and the IEC 61663 series.

The text of this first edition of IEC 62305-2 is compiled from and replaces

– IEC 61662, first edition (1995) and its Amendment (1996).

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

FDIS	Report on voting
81/XX/FDIS	81/XX/RVD

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

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

IEC 62305 consists of the following parts, under the general title *Protection against lightning*:

Part 1: General principles

Part 2: Risk management

Part 3: Physical damage to structures and life hazard

Part 4: Electrical and electronic systems within structures

Part 5: Services

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date[1] 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.

[1] The National Committees are requested to note that for this publication the maintenance result date is 2010.

INTRODUCTION

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

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.

The hazard to services can result in

– damage to the service itself,
– failure of associated electrical and electronic equipment.

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 standard as the probable average annual loss in a structure and in a service due to lightning flashes, depends on:

– the annual number of lightning flashes influencing the structure and the service;
– 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 services (power, telecommunication lines, other services) or near the services.

Lightning flashes influencing the service may be divided into

– flashes terminating on the service,
– flashes terminating near the service or direct to a structure connected to the service.

Flashes to the structure or a connected service may cause physical damage and life hazards. Flashes near the structure or service as well as flashes to the structure or service 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 1 Malfunctioning of electrical and electronic systems is not covered by the IEC 62305 series. Reference should be made to IEC 61000-4-5 [1][2].

NOTE 2 Information on assessment of the risk due to switching overvoltages is given in Annex F.

2 Figures in square brackets refer to the bibliography.

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

The probability of lightning damage depends on the structure, the services, 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 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.

The assessment of risk due to all possible effects of lightning flashes to structures and services is given in this standard, which is a revised version of IEC 61662:1995 and its Amendment 1:1996.

The decision to provide lightning protection may be taken regardless of the outcome of any 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 or for a service 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 at 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 60079-10:2002, *Electrical apparatus for explosive gas atmosphere – Part 10: Classification of hazardous areas*

IEC 61241-10:2004, *Electrical apparatus for use in the presence of combustible dust – Part 10: Classification of areas where combustible dusts are or may be present*

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

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

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

IEC 62305-5, *Protection against lightning – Part 5: Services*

ITU-T Recommendation K.46:2000, *Protection of telecommunication lines using metallic symmetric conductors against lightning induced surges*

ITU-T Recommendation K.47:2000, *Protection of telecommunication lines using metallic conductors against direct lightning discharges*

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
object to be protected
structure or service to be protected against the effects of lightning

3.1.2
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 a part of a larger structure.

3.1.3
structures with risk of explosion
structures containing solid explosives materials or hazardous zones as determined in accordance with IEC 60079-10 and IEC 61241-10

NOTE For the purposes of this standard, only structures with hazardous zones type 0 or containing solid explosive materials are considered.

3.1.4
structures dangerous to the environment
structures which may cause biological, chemical and radioactive emission as a consequence of lightning (such as chemical, petrochemical, nuclear plants, etc).

3.1.5
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.

3.1.6
suburban environment
area with a medium density of buildings

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

3.1.7
rural environment
area with a low density of buildings.

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

3.1.8
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 overvoltages

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

3.1.9
electrical system
system incorporating low voltage power supply components

3.1.10
electronic system
system incorporating sensitive electronic components such as communication equipment, computer, control and instrumentation systems, radio systems, power electronic installations

3.1.11
internal systems
electrical and electronic systems within a structure

3.1.12
service to be protected
service connected to a structure for which protection is required against the effects of lightning in accordance with this standard

3.1.13
telecommunication lines
transmission medium intended for communication between equipment that may be located in separate structures, such as phone line and data line

3.1.14
power lines
transmission 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

3.1.15
pipes
piping intended to convey a fluid into or out of a structure, such as gas pipe, water pipe, oil pipe

3.1.16
dangerous event
lightning flash to the object to be protected or near the object to be protected

3.1.17
lightning flash to an object
lightning flash striking an object to be protected

3.1.18
lightning flash near an object
lightning flash striking close enough to an object to be protected that it may cause dangerous overvoltages

3.1.19
number of dangerous events due to flashes to a structure
$N_{\mathbf{D}}$
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 service
$N_{\mathbf{L}}$
expected average annual number of dangerous events due to lightning flashes to a service

3.1.21
number of dangerous events due to flashes near a structure
$N_{\mathbf{M}}$
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 service
N_I
expected average annual number of dangerous events due to lightning flashes near a service

3.1.23
lightning electromagnetic impulse
LEMP
electromagnetic effects of lightning current

NOTE It includes conducted surges as well as radiated impulse electromagnetic field effects.

3.1.24
surge
transient wave appearing as overvoltage and/or overcurrents caused by LEMP

NOTE Surges caused by LEMP can arise from (partial) lightning currents, from induction effects into installation loops and as remaining threats downstream of SPD.

3.1.25
node
point on a service line at a which surge propagation can be assumed to be neglected

NOTE Examples of nodes are a point on a power line branch distribution at a HV/LV transformer, a multiplexer on a telecommunication line or SPD installed along the line conforming to IEC 62305-5.

3.1.26
physical damage
damage to a structure (or to its contents) or to a service due to mechanical, thermal, chemical or explosive effects of lightning.

3.1.27
injury to living beings
injuries, including loss of life, to people or to animals due to touch and step voltages caused by lightning

3.1.28
failure of electrical and electronic systems
permanent damage of electrical and electronic systems due to LEMP

3.1.29
failure current
I_a
minimum peak value of lightning current that will cause damage in a line

3.1.30
probability of damage
P_X
probability that a dangerous event will cause damage to or in the object to be protected

3.1.31
loss
L_X
mean amount of loss (humans and goods) consequent to a specified type of damage due to a dangerous event, relative to the value (humans and goods) of the object to be protected

3.1.32
risk
R
value of probable average annual loss (humans and goods) due to lightning, relative to the total value (humans and goods) of the object to be protected

3.1.33
risk component
R_X
partial risk depending on the source and the type of damage

3.1.34
tolerable risk
R_T
maximum value of the risk which can be tolerated for the object to be protected

3.1.35
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

3.1.36
section of a service
S_S
part of a service with homogeneous characteristics where only one set of parameters is involved in the assessment of a risk component

3.1.37
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).

3.1.38
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.

3.1.39
protection measures
measures to be adopted in the object to be protected, in order to reduce the risk

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 system
LPMS
complete system of protection measures for internal systems against LEMP

3.1.42
shielding wire
metallic wire used to reduce physical damage due to lightning flashes to a service

3.1.43
magnetic shield
closed, metallic, grid-like or continuous screen enveloping the object to be protected, or part of it, used to reduce failures of electrical and electronic systems

3.1.44
lightning protective cable
special cable with increased dielectric strength, whose metallic sheath is in continuous contact with the soil either directly or by the use of conducting plastic covering

3.1.45
lightning protective cable duct
cable duct of low resistivity in contact with the soil (for example, concrete with interconnected structural steel reinforcements or a metallic duct)

3.1.46
surge protective device
SPD
device intended to limit transient overvoltages and divert surge currents. It contains at least one non-linear component

3.1.47
coordinated SPD protection
set of SPDs properly selected, coordinated and installed to reduce failures of electrical and electronic systems

3.2

Symbols and abbreviations

a	Amortization rate	Annex G
A_d	Collection area for flashes to an isolated structure	A.2
$A_d{}'$	Collection area attributed to an elevated roof protrusion	A.2.1
A_i	Collection area for flashes near a service	A.4; Table A.3
A_l	Collection area for flashes to a service	A.4; Table A.3
A_m	Area of influence for flashes near a structure	A.3
B	Building	A.2
c	Mean value of possible loss of the structure, in currency	C.4; C.5
C_A	Annual cost of the animals	Annex G
C_B	Annual cost of the building	Annex G
C_C	Annual cost of the contents	Annex G
C_d	Location factor	A.2; Table A.2
C_e	Environnemental factor	A.5; Table A.5
C_L	Annual cost of total loss in absence of protection measures	5.6; Annex G
C_{RL}	Annual cost of residual loss	5.6; Annex G
C_P	Cost of protection measures	Annex G
C_{PM}	Annual cost of selected protection measures	5.6; Annex G
c_t	Total value of the structure, in currency	C.4; C.5; E.3
C_S	Annual cost of systems in a structure	Annex G
C_t	Correction factor for a HV/LV transformer on the service	A.2;Table A.3

D_i	Lateral distance relevant to lightning flash near a service	A.5
D1	Injury to living beings	4.1.2
D2	Physical damage	4.1.2
D3	Failure of electrical and electronic systems	4.1.2
h	Factor increasing the loss when a special hazard is present	C.2;Table C.5
H	Height of the structure connected at end “a”of a service	A.4
H_a	Height of the structure connected at end “a” of a service	A.4
H_b	Height of the structure connected at end “b” of a service	A.4
H_c	Height of the service conductors above ground	A.4
i	Interest rate	Annex G
I_a	Failure current	D.1.1;D.1.2
K_d	Factor relevant to the characteristics of a service	D.1.1
K_{MS}	Factor relevant to the performance of protection measures against LEMP	B.4
K_p	Factor relevant to adopted protection measures in a service	D.1.1
K_{S1}	Factor relevant to the screening effectiveness of the structure	B.4
K_{S2}	Factor relevant to the screening effectiveness of shields internal to the structure	B.4
K_{S3}	Factor relevant to the characteristics of internal wiring	B.4
K_{S4}	Factor relevant to the impulse withstand voltage of a system	B.4
L	Length of structure	A.2
L_a	Length of the structure connected at end “a” of a service	A.4
L_A	Loss related to injury to living beings	6.2; Table 8
L_B	Loss to structure related to physical damage (flashes to structure)	6.2; Table 8
L'_B	Loss to service related to physical damage (flashes to service)	7.4; Table 10
L_c	Length of service section	A.4
L_C	Loss related to failure of internal systems (flashes to structure)	6.2; Table 8
L'_C	Loss related to failure of service equipment (flashes to structure)	7.4; Table 10
L_f	Loss to structure due to physical damage	C.1
L'_f	Loss to service due to physical damage	E.1
L_M	Loss related to failure of internal systems (flashes near structure)	6.3; Table 8
L_o	Loss to structure due to failure of internal systems	C.1
L'_o	Loss to service due to failure of internal systems	E.1
L_t	Loss due to injury by touch and step voltages	C.1
L_U	Loss related to injury of living beings (flashes to service)	6.4; Table 8
L_V	Loss to structure due to physical damage (flashes to service)	6.4; Table 8
L'_V	Loss to services due to physical damage (flashes to service)	7.2; Table 10
L_W	Loss related to failure of internal systems (flashes to service)	6.4; Table 8
L'_W	Loss related to failure of service equipment (flashes to service)	7.2; Table 10
L_X	Consequent loss of structure	6.1
L'_X	Consequent loss of service	7.1
L_Z	Loss related to failure of internal systems (flashes near a service)	6.5; Table 8
L'_Z	Loss related to failure of service equipment (flashes near a service)	7.3; Table 10
L1	Loss of human life in a structure	4.1.3
L2	Loss of service to the public in a structure	4.1.3
L′2	Loss of service to the public in a service	4.1.3
L3	Loss of cultural heritage in a structure	4.1.3
L4	Loss of economic value in a structure	4.1.3
L′4	Loss of economic value in a service	4.1.3

m	Maintenance rate	Annex G
n	Number of services connected to the structure	D.1.1
N_X	Number of dangerous events	6.1
N_D	Number of dangerous events due to flashes to a structure	A.2.3
N_{Da}	Number of dangerous events due to flashes to a structure at "a" end of line	A.2.4; Table 8
N_g	Lightning ground flash density	A.1
N_I	Number of dangerous events due to flashes near a service	A.5
N_L	Number of dangerous events due to flashes to a service	A.4
N_M	Number of dangerous events due to flashes near a structure	A.3
n_p	Number of possible endangered persons (victims or users not served)	C.2; C.3; E.2
n_s	Estimated or measured annual number of switching overvoltages	Annex F
N_s	Annual number of switching overvoltages in excess of 2,5 kV	Annex F
n_t	Expected total number of persons (or users served)in the structure	C.2; C.3; E.2
P	Probability of damage	3.29
P_A	Probability of injury to living beings (flashes to a structure)	6.2; Table 8
P_B	Probability of physical damage to a structure (flashes to a structure)	6.2; Table 8
P'_B	Probability of physical damage to a service (flashes to a structure)	7.4; Table 10
P_C	Probability of failure of internal systems (flashes to a structure)	6.2; Table 8
P'_C	Probability of failure of service equipment (flashes to a structure)	7.4; Table 10
P_{LD}	Probability of failure of internal systems (flashes to a connected service)	B.5; B.6; B.7
P_{LI}	Probability of failure of internal systems (flashes near a connected service)	B.8
P_M	Probability of failure of internal systems (flashes near a structure)	6.3; Table 8
P_{MS}	Probability of failure of internal systems (with protection measures)	B.4
P_{SPD}	Probability of failure of internal systems or a service when SPDs are installed	B.3;B.4
P_U	Probability of injury to living beings (flashes to a connected service)	6.4; Table 8
P_V	Probability of physical damage to a structure (flashes to a connected service)	6.4; Table 8
P'_V	Probability of physical damage to services (flashes to a service)	7.2; Table 10
P_W	Probability of failure of internal systems (flashes to a connected service)	6.4; Table 6
P'_W	Probability of failure of service equipment (flashes to a service)	7.2; Table 10
P_X	Probability of damage for a structure	6.1
P'_X	Probability of damage for a service	7.1
P_Z	Probability of failure of internal systems (flashes near a connected service)	6.5; Table 8
P'_Z	Probability of failure of service equipment (flashes near a service)	7.3; Table 10
r_p	Factor reducing the loss due to provisions against fire	C.2
R	Risk	3.32
r_a	Reduction factor associated with the type of surface of soil	C.2
r_u	Reduction factor associated with the type of surface of floor	C.2
R_A	Risk component (injury to living beings – flashes to a structure)	4.2.2
R_B	Risk component (physical damage to a structure – flashes to a structure)	4.2.2
R'_B	Risk component (physical damage to a service – flashes to a structure)	4.2.8
R_C	Risk component (failure of internal systems -flashes to a structure)	4.2.2
R'_C	Risk component (failure of service equipment – flashes to a structure)	4.2.8
R_D	Risk to a structure due to flashes to the structure	4.3.1

r_f	Factor reducing loss depending on risk of fire	C.2
R_F	Risk due to physical damage to a structure	4.3.2
R'_F	Risk due to physical damages to a service	4.4.2
R_I	Risk for a structure due to flashes not striking the structure	4.3.1
R_M	Risk component (failure of internal systems – flashes near a structure)	4.2.3
R'_M	Risk R_M when protection measures are adopted	Annex G
R_O	Risk due to failure of internal systems	4.3.2
R'_O	Risk due to failure of service equipment	4.4.2
R_s	Shield resistance per unit length of a cable	B.5;B.8; D.1
R_S	Risk due to injury to living beings	4.3.2
R_T	Tolerable risk	3.34
R_U	Risk component (injury to living being – flashes to a connected service)	4.2.4
R_V	Risk component (physical damage to structure – flashes to a connected service)	4.2.4
R'_V	Risk component (physical damage to service – flashes to the service)	4.2.6
R_W	Risk component (failure of internal systems – flashes to the connected service)	4.2.4
R'_W	Risk component (failure of service equipment – flashes to the service)	4.2.6
R_X	Risk component	3.33
R'_X	Risk component for a service	7.1
R_Z	Risk component (failure of internal systems – flashes near a service)	4.2.5
R'_Z	Risk component (failure of service equipment – flashes near the service)	4.2.7
R_1	Risk of loss of human life in a structure	4.2.1; 4.3
R_2	Risk of loss of service to the public in a structure	4.2.1; 4.3
R'_2	Risk of loss of service to the public in a service	4.2.1; 4.4
R_3	Risk of loss of cultural heritage in a structure	4.2.1; 4.3
R_4	Risk of loss of economic value in a structure	4.2.1; 4.3
R'_4	Risk of loss of economic value in a service	4.2.1; 4.4
S	Structure	A.2
S	Annual saving of money	Annex G
S_S	Section of a service	3.36
S1	Flashes to a structure	4.1.1
s	Thickness of a continuous metal sheath	B.4
S2	Flashes near a structure	4.1.1
S3	Flashes to a service	4.1.1
S4	Flashes near a service	4.1.1
t_p	Time in hours per year that persons are present in a dangerous place	C.2
t	Annual period of loss of service, in hours	C.3; E.2
T_d	Thunderstorm days per year	A.1
T_x	Transition points	Annex I
U_W	Rated impulse withstand voltage of a system	B.4
w	Mesh width	B.4
W	Width of structure	A.2
W_a	Width of the structure connected at end “a” of a service	A.4
Z_S	Zones of a structure	3.35

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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 strike attachment point (see Table 1):

S1: flashes to a structure;

S2: flashes near a structure;

S3: flashes to a service;

S4: flashes near a service.

4.1.2 Types of damage

A lightning flash may cause damage depending on the characteristics of the object 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 Tables 1 and 2):

D1: injury to living beings;

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).

Lightning affecting a service can cause damage to the physical means itself – line or pipe – used to provide the service, as well as to related electrical and electronic systems. The damage may also extend to internal systems connected to the service.

4.1.3 Types of loss

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

L1: loss of human life;

L2: loss of service to the public;

L3: loss of cultural heritage;

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

Type of loss which may be associated with a structure are as follows:

L1: loss of human life;

L2: loss of service to the public;

L3: loss of cultural heritage;

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

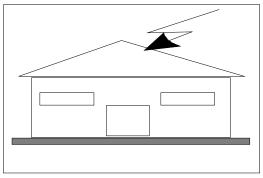
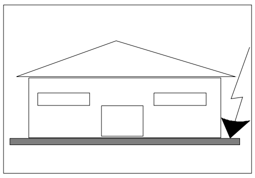
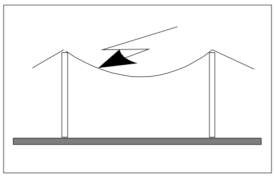
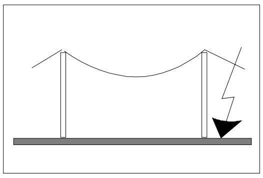
Type of loss which may be associated with a service are as follows:

L′2: loss of service to the public;

L′4: loss of economic value (service and loss of activity).

NOTE Loss of human life associated with a service is not considered in this standard.

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

		Structure		Service	
Point of strike	**Source of damage**	**Type of damage**	**Type of loss**	**Type of damage**	**Type of loss**
	S1	D1 D2 D3	L1, L4[2)] L1,L2, L3, L4 L1*, L2, L4	D2 D3	L`2, L`4 L`2, L`4
	S2	D3	L1[1)], L2 , L4		
	S3	D1 D2 D3	L1, L4[2)] L1, L2, L3, L4 L1[1)], L2, L4	D2 D3	L`2, L`4 L`2, L`4
	S4	D3	L1[1)], L2, L4	D3	L`2, L`4

1) Only for structures with risk of explosion, and for hospitals or other structures where failures of internal systems immediately endangers human life.

2) Only for properties where animals may be lost.

Table 2 – Risk in a structure for each type of damage and of loss

Damage \ Loss	L1 Loss of human life	L2 Loss of service to the public	L3 Loss of cultural heritage	L4 Loss of economic value
D1 Injury to living beings	R_S	–	–	R_S [1)]
D2 Physical damage	R_F	R_F	R_F	R_F
D3 Failure of electric or electronic systems	R_O [2)]	R_O	–	R_O

[1)] Only for properties where animals may be lost.

[2)] Only for structures with a risk of explosion, and for hospitals or other structures where failure of internal systems immediately endangers human life.

4.2 Risk and risk components

4.2.1 Risk

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

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

R_1: risk of loss of human life;

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.

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

R'_2: risk of loss of service to the public;

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 touch and step voltages in the zones up to 3 m outside the structure. Loss of type L1 and, in the case of agricultural properties, loss of type L4 with possible loss of animals may also arise;

NOTE 1 The risk component caused by touch and step voltages inside the structure due to flashes to the structure is not considered in this standard.

NOTE 2 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 standard.

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 service connected to the structure

R_U: Component related to injury to living beings caused by touch voltage inside the structure, due to lightning current injected in a line entering the structure. Loss of type L1 and, in the case of agricultural properties, losses 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 services. 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 The services taken into account in this assessment are only the lines entering the structure. 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 must also be considered.

4.2.5 Risk component for a structure due to flashes near a service 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 The services taken into account in this assessment are only the lines entering the structure. 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 must also be considered.

4.2.6 Risk components for a service due to flashes to the service

R'_V: Component related to physical damage due to mechanical and thermal effects of lightning current. Loss of type L2 and L4 could occur;

R'_W: Component related to failure of connected equipment due to overvoltages by resistive coupling. Loss of type L2 and L4 could occur.

4.2.7 Risk component for a service due to flashes near the service

R'_Z: Component related to failure of lines and connected equipment caused by overvoltages induced on lines. Loss of type L2 and L4 could occur.

4.2.8 Risk components for a service due to flashes to the structure to which the service is connected

R'_B: Component related to physical damage due to mechanical and thermal effects of lightning current flowing along the line. Loss of type L2 and L4 could occur.

R'_C: Component related to failure of connected equipment due to overvoltages by resistive coupling. Loss of type L2 and L4 could occur.

4.3 Composition of risk components related to a structure

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

R_1:Risk of loss of human life:

$$R_1 = R_A + R_B + R_C{}^{1)} + R_M{}^{1)} + R_U + R_V + R_W{}^{1)} + R_Z{}^{1)} \quad (1)$$

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:

$$R_2 = R_B + R_C + R_M + R_V + R_W + R_Z \quad (2)$$

R_3: Risk of loss of cultural heritage:

$$R_3 = R_B + R_V \quad (3)$$

R_4: Risk of loss of economic value:

$$R_4 = R_A{}^{2)} + R_B + R_C + R_M + R_U{}^{2)} + R_V + R_W + R_Z \quad (4)$$

2) Only for properties where animals may be lost.

The risk components corresponding to each type of loss are also combined in Table 3.

Table 3 – 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
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	*	*	*1)	*1)	*	*	*1)	*1)
R_2		*	*	*		*	*	*
R_3		*				*		
R_4	* 2)	*	*	*	* 2)	**	*	*

1) Only for structures with risk of explosion, and for hospitals or other structures where failure of internal systems immediately endangers human life.

2) Only for properties where animals may be lost.

4.3.1 Composition of risk components with reference to the source of damage

$$R = R_D + R_I \tag{5}$$

where

R_D is the risk due to flashes striking the structure (source S1) which is defined as the sum:

$$R_D = R_A + R_B + R_C \tag{6}$$

where

R_I is the risk due to flashes influencing it but not striking the structure (sources: S2, S3 and S4). It is defined as the sum:

$$R_I = R_M + R_U + R_V + R_W + R_Z \tag{7}$$

For risk components and their compositions as given above see also Table 9.

4.3.2 Composition of risk components with reference to the type of damage

$$R = R_S + R_F + R_O \tag{8}$$

where

R_S is the risk due to injury to living beings which is defined as the sum:

$$R_S = R_A + R_U \tag{9}$$

R_F is the risk due to physical damage which is defined as the sum:

$$R_F = R_B + R_V \tag{10}$$

R_O is the risk due to failure of internal systems which is defined as the sum:

$$R_O = R_M + R_C + R_W + R_Z \tag{11}$$

For risk components and their compositions as given above see also Table 9.

4.4 Composition of risk components related to a service

Risk components to be considered for each type of loss in a service are listed below.

R'_2: risk of loss of service to the public:

$$R'_2 = R'_V + R'_W + R'_Z + R'_B + R'_C \quad (12)$$

R'_4: risk of loss of economic value:

$$R'_4 = R'_V + R'_W + R'_Z + R'_B + R'_C \quad (13)$$

Risk components to be considered for each type of loss in a service are given in Table 4.

Table 4 – Risk components to be considered for each type of loss in a service

Source of damage	Flash striking the service S3		Flash striking near the service S4	Flash striking the structure S1	
Risk component	R'_V	R'_W	R'_Z	R'_B	R'_C
Risk for each type of loss					
R'_2	*	*	*	*	*
R'_4	*	*	*	*	*

4.4.1 Composition of risk components with reference to the source of damage

$$R' = R'_D + R'_I \quad (14)$$

where

R'_D is the risk due to flashes striking the service (source S3); defined as the sum:

$$R'_D = R'_V + R'_W \quad (15)$$

R'_I is the risk due to flashes influencing the service without striking it (sources S1 and S4); defined as the sum:

$$R'_I = R'_B + R'_C + R'_Z \quad (16)$$

For the composition of risk components for a service as given above, see also Table 11.

4.4.2 Composition of risk components with reference to the type of damage

$$R' = R'_F + R'_O \quad (17)$$

where

R'_F is the risk of physical damage (D2); defined as the sum:

$$R'_F = R'_V + R'_B \quad (18)$$

R'_0 is the risk of failure of electrical and electronic systems (D3); defined as the sum

$$R'_O = R'_W + R'_Z + R'_C \tag{19}$$

For the composition of risk components for a service as given above see also Table 11.

4.5 Factors influencing the risk components

4.5.1 Factors influencing the risk components in a structure

Characteristics of the structure and of possible protection measures influencing risk components for a structure are given in Table 5.

Table 5 – Factors influencing the risk components in a structure

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			
Physical restrictions, insulation, warning notice, soil equipotentialization	X							
LPS	X[1)]	X	X[2)]	X[2)]	X[3)]	X[3)]		
Coordinated SPD protection			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

1) In the case of a “natural” or standardized LPS with down-conductor spacing of less than 10 m, or where physical restriction are provided, the risk related to injury to living beings caused by touch and step voltages is negligible.

2) Only for grid-like external LPS.

3) Due to equipotential bonding.

4.5.2 Factors influencing the risk components in a service

Characteristics of the service, of the connected structure and of possible protection measures influencing risk components are given in Table 6.

Table 6 – Factors influencing the risk components in a service

Characteristic of service Protection measure	R'_V	R'_W	R'_Z	R'_B	R'_C
Collection area	X	X	X	X	X
Cable shielding	X	X	X	X	X
Lightning protective cable	X	X	X	X	X
Lightning protective cable duct	X	X	X	X	X
Additional shielding conductors	X	X	X	X	X
Impulse withstand voltage	X	X	X	X	X
SPD	X	X	X	X	X

5 Risk management

5.1 Basic procedure

The decision to protect a structure or a service against lightning, as well as the selection of protection measures, shall be performed according to IEC 62305-1. The following procedure shall be applied:

– identification of the object to be protected and its characteristics;
– identification of all the types of loss in the object 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 for a structure (R'_2 for a service) 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 for a structure (R'_4 for a service) shall be performed in order to evaluate such costs (see Annex G).

5.2 Structure to be considered for risk assessment

Structure to be considered includes:

– the structure itself;
– installations in the structure;
– contents of the structure;
– persons in the structure or standing in the zones up to 3 m from the outside of the structure;
– environment affected by a damage to the structure.

Protection does not include connected services outside of the structure.

NOTE The structure to be considered may be subdivided into several zones (see Clause 6).

5.3 Service to be considered for risk assessment

The service to be considered is the physical connection between:

– the switch telecommunication building and the user′s building or two switch telecommunication buildings or two users′ buildings, for the telecommunication (TLC) lines;

– the switch telecommunication building or the user's building and a distribution node, or between two distribution nodes for the telecommunication (TLC) lines;
– the high voltage (HV) substation and the user's building, for the power lines;
– the main distribution station and the user's building, for pipes.

The service to be considered includes the line equipment and the line termination equipment, such as:

– multiplexer, power amplifier, optical network units, meters, line termination equipment, etc.;
– circuit-breakers, overcurrent systems, meters, etc.;
– control systems, safety systems, meters, etc.

Protection does not include the user's equipment or any structure connected at the ends of the service.

5.4 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 7.

Table 7 – Typical values of tolerable risk R_T

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

5.5 Specific procedure to evaluate the need of protection

According to IEC 62305-1, the following risks shall be considered in the evaluation of the need of protection against lightning for an object:

– risks R_1, R_2 and R_3 for a structure;
– risk R'_1 and R'_2 for a service .

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 object is subjected.

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

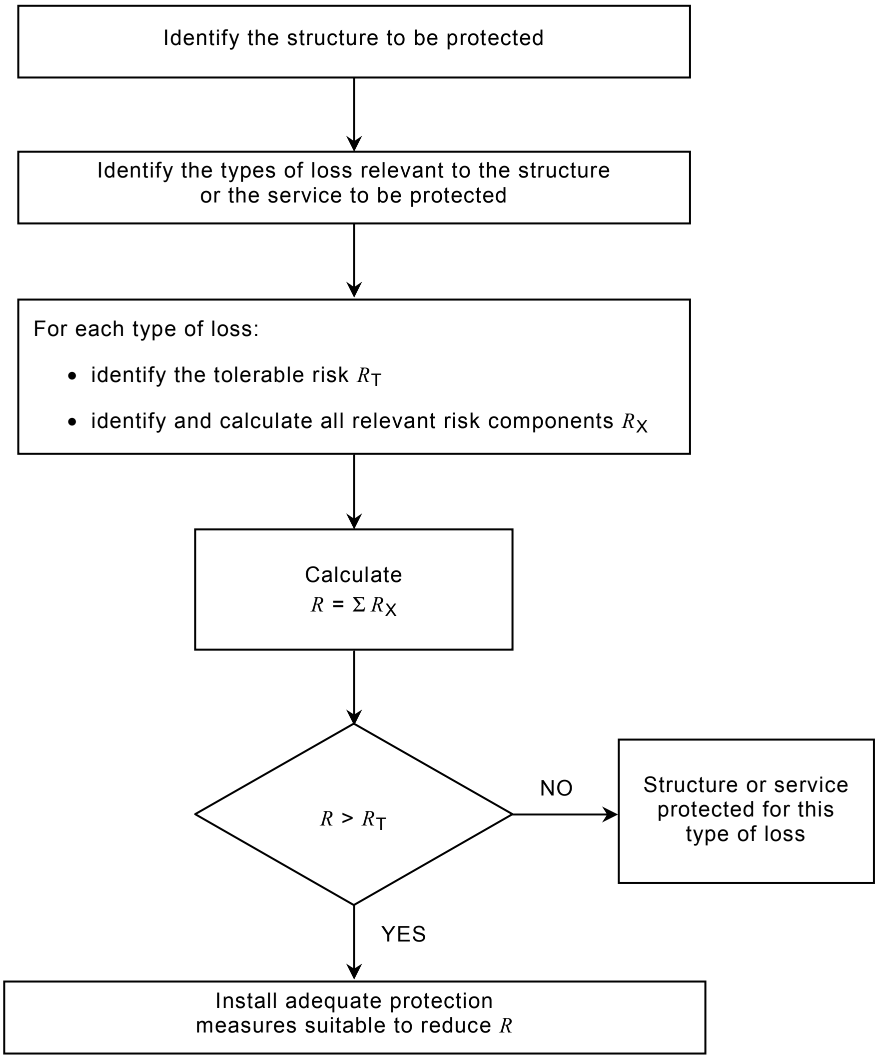


Figure 1 – Procedure for deciding the need of protection

5.6 Procedure to evaluate the cost effectiveness of protection

Besides the need of lightning protection for a structure or for a service, it may be useful to ascertain the economic benefits of installing protection measures in order to reduce the economic loss L4.

The assessment of components of risk R_4 for a structure (R'_4 for a service) allows the user to evaluate the cost of the economic loss with and without the adopted protection measures (see Annex G).

The procedure to ascertain the cost effectiveness of protection requires:

– identification of the components R_X which make up the risk R_4 for a structure (R'_4 for a service);
– calculation of the identified risk components R_X in 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 or service;
– 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 not be deemed 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.

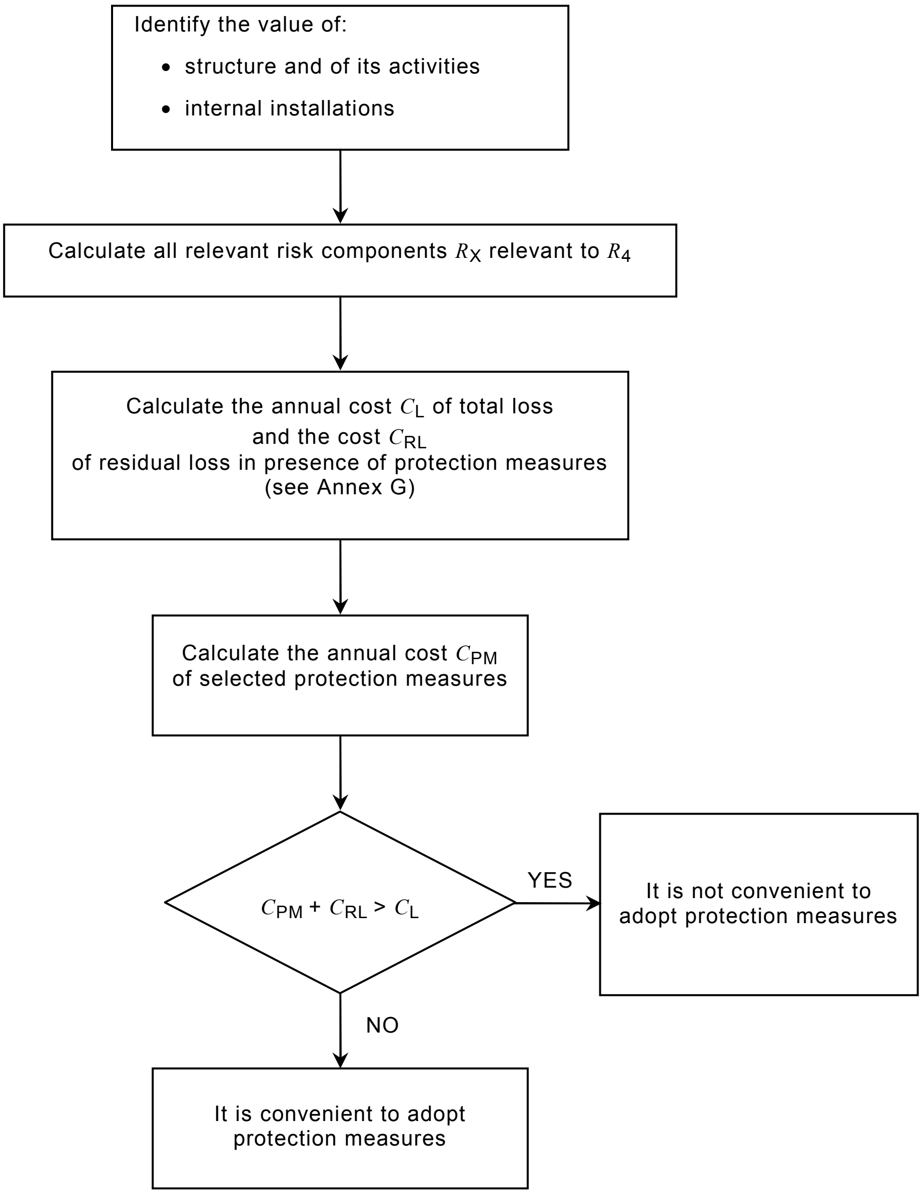


Figure 2 – Procedure for evaluating the cost-effectiveness of protection measures

5.7 Protection measures

Protection measures are directed to reduce 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 internal systems;
– IEC 62305-5 for protection of services

5.8 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 diagrams of Figure 3 for structures and Figure 4 for services. In any case the installer or planner should identify the most critical risk components and reduce them, also taking into account economic aspects.

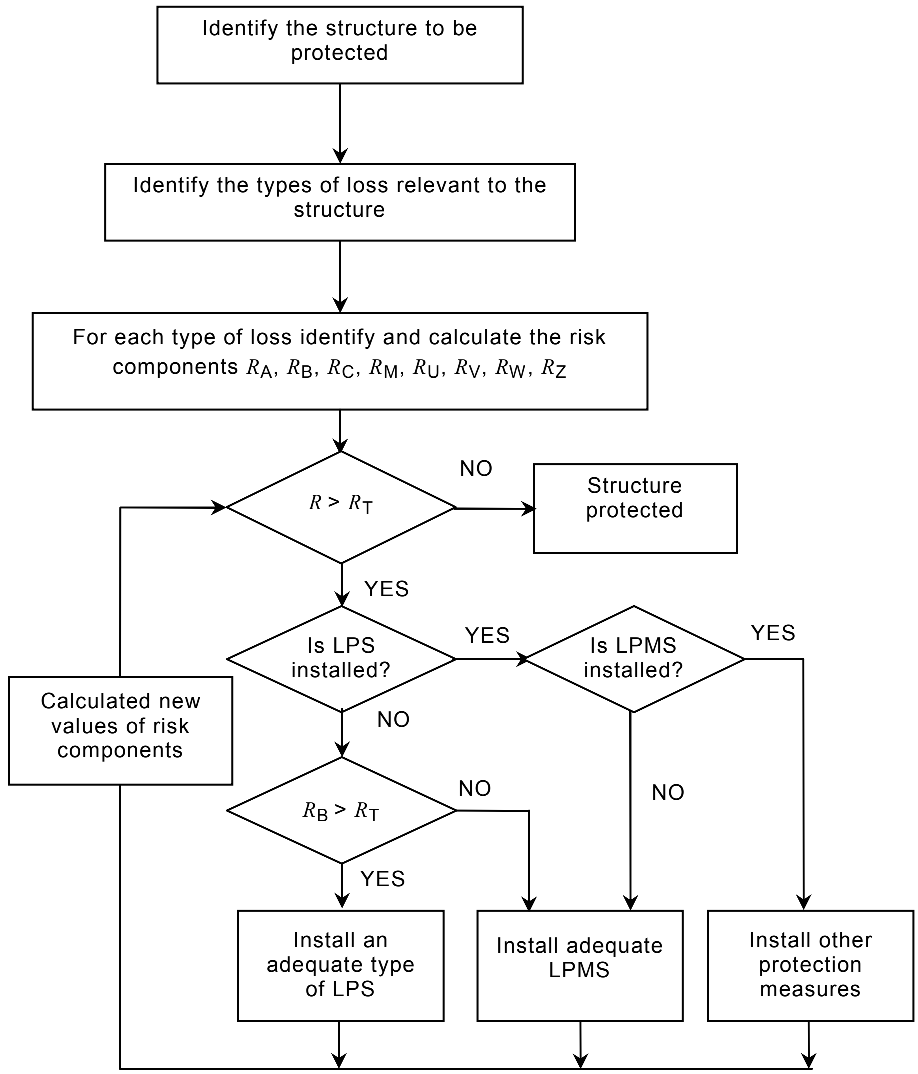


Figure 3 – Procedure for selecting protection measures in structures

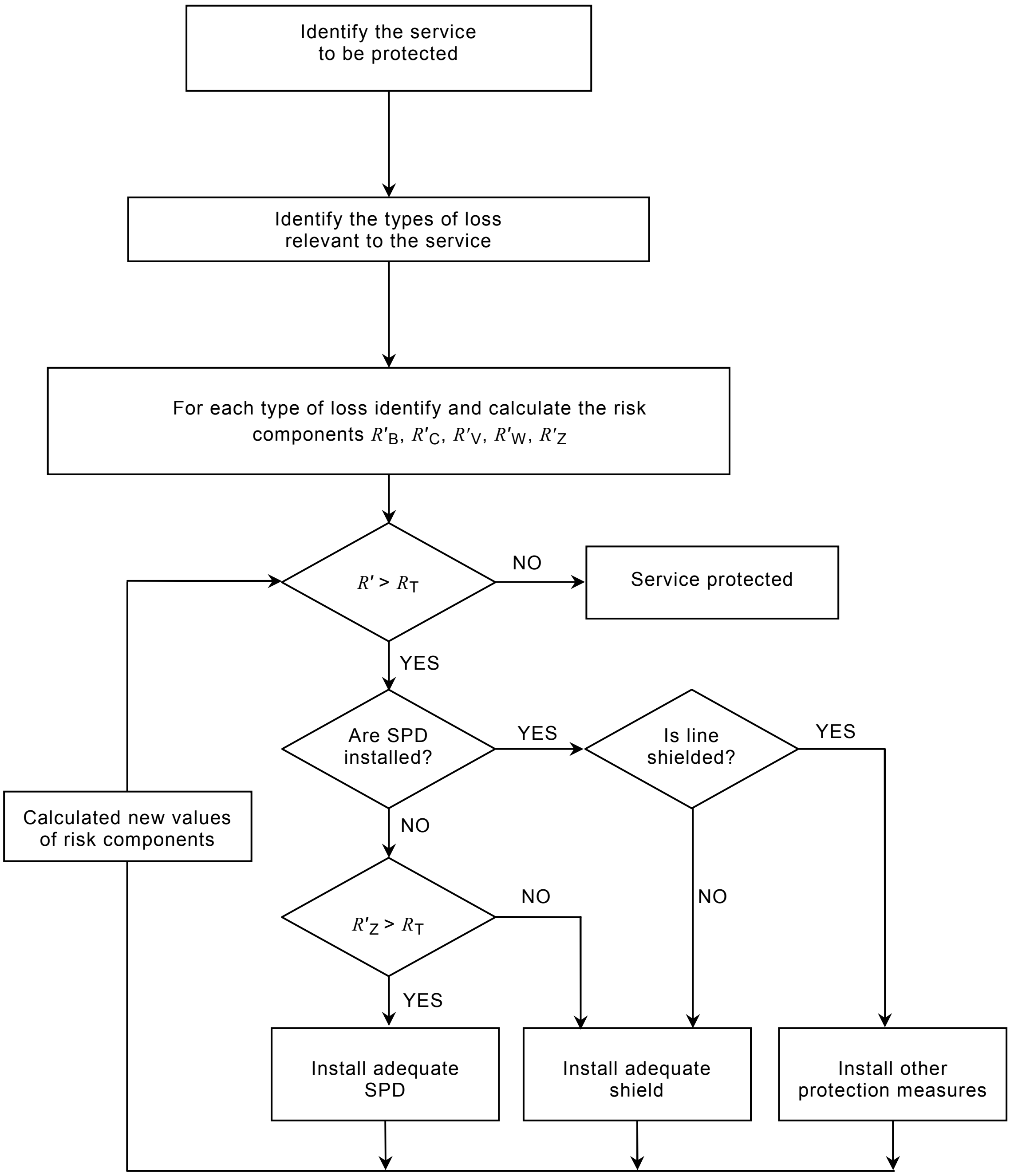


Figure 4 – Procedure for selecting protection measures in services

6 Assessment of risk components for a structure

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 Clause 4, may be expressed by the following general equation

$$R_X = N_X \times P_X \times L_X \tag{20}$$

where

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

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

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

NOTE 1 The number N_X of dangerous events is affected by lightning ground flash density (N_g) and by the physical characteristics of the object to be protected, its surroundings and the soil.

NOTE 2 The probability of damage P_X is affected by characteristics of the object to be protected and the protection measures provided.

NOTE 3 The consequent loss L_X is affected by the use to which the object 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.

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 relationship apply:

– component related to injury to living beings (D1)

$$R_A = N_D \times P_A \times L_A \tag{21}$$

– component related to physical damage (D2)

$$R_B = N_D \times P_B \times L_B \tag{22}$$

– component related to failure of internal systems (D3)

$$R_C = N_D \times P_C \times L_C \tag{23}$$

Parameters to assess these risk components are given in Table 8.

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)

$$R_M = N_M \times P_M \times L_M \tag{24}$$

Parameters to assess this risk component are given in Table 8.

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 (D1)

$$R_U = (N_L + N_{Da}) \times P_U \times L_U \tag{25}$$

– component related to physical damage (D2)

$$R_V = (N_L + N_{Da}) \times P_V \times L_V \tag{26}$$

– component related to failure of internal systems (D3)

$$R_W = (N_L + N_{Da}) \times P_W \times L_W \tag{27}$$

Parameters to assess these risk components are given in Table 8.

If the line has more than one section (see 7.6), 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 distribution node.

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

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 relationships applies:

– component related to failure of internal systems (D3)

$$R_Z = (N_I - N_L) \times P_Z \times L_Z \tag{28}$$

Parameters to assess this risk component are given in Table 8.

If the line has more than one section (see 7.6), 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 distribution node.

NOTE Detailed information for TLC lines are given in Recommendation ITU K.46.

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

For the purpose of this assessment, if $(N_I - N_L) < 0$, then assume $(N_I - N_L) = 0$.

Table 8 – Parameters relevant to the assessment of risk components for a structure

Symbol	Denomination	Value according to
Average annual number of dangerous events due to flashes		
N_D	– to the structure	Clause A.2
N_M	– near the structure	Clause A.3
N_L	– to a line entering the structure	Clause A.4
N_I	– near a line entering the structure	Clause A.4
N_{DA}	– to the structure at "a" end of the line (see Figure 5)	Clause A.2
Probability that a flash to the structure will cause		
P_A	– injury to living beings	Clause B.1
P_B	– physical damage	Clause B.2
P_C	– failure of internal systems	Clause B.3
Probability that a flash near the structure will cause		
P_M	– failure of internal systems	Clause B.4
Probability that a flash to a line will cause		
P_U	– injury to living beings	Clause B.5
P_V	– physical damage	Clause B.6
P_W	– failure of internal systems	Clause B.7
Probability that a flash near a line will cause		
P_Z	– failure of internal systems	Clause B.8
Loss due to		
$L_A = L_U = r_a \times L_t$	– injury to living beings	Clause C.2
$L_B = L_V = r_p \times r_f \times h_z \times L_f$	– physical damage	Clauses C.2, C.3, C.4, C.5
$L_C = L_M = L_W = L_Z = L_o$	– failure of internal systems	Clauses C.2, C.3, C.5
NOTE Values of loss L_t, L_f, L_o; factors r_p, r_a, r_u, r_f reducing the loss and factor h_z increasing the loss are given in Annex C and Tables C.2, C.3, C.4 and C.5.		

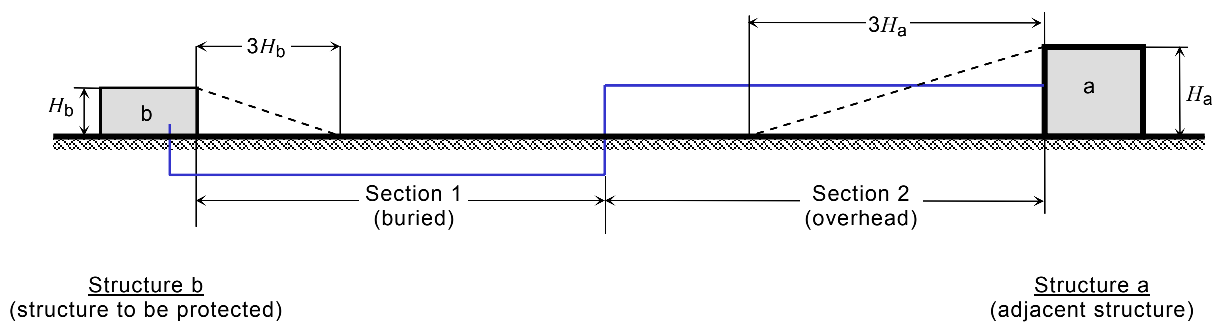


Figure 5 – Structures at line ends: at "b" end the structure to be protected (structure b) and at "a" end an adjacent structure(structure a)

6.6 Summary of risk components in a structure

Risk components for structures are summarized in Table 9, according to different types of damage and different sources of damage.

Table 9 – Risk components for a structure for different types of damage caused by different sources

Source of damage / Damage	S1 Lightning flash to a structure	S2 Lightning flash near a structure	S3 Lightning flash to an incoming service	S4 Lightning flash near a service	Resulting risk according to type of damage
D1 Injury to living beings	$R_A = N_D \times P_A \times r_a \times L_t$		$R_U = (N_L + N_{Da}) \times P_U \times r_u \times L_t$		$R_S = R_A + R_U$
D2 Physical damage	$R_B = N_D \times P_B \times r_p \times h_Z \times r_f \times L_f$		$R_V = (N_L + N_{Da}) \times P_V \times r_p \times h_Z \times r_f \times L_f$		$R_F = R_B + R_V$
D3 Failure of electrical and electronic systems	$R_C = N_D \times P_c \times L_o$	$R_M = N_M \times P_M \times L_o$	$R_W = (N_L + N_{Da}) \times P_W \times L_o$	$R_Z = (N_I - N_L) \times P_Z \times L_o$	$R_O = R_C + R_M + R_W + R_Z$
Resulting risk according to the source of damage	$R_D = R_A + R_B + R_C$	$R_I = R_M + R_U + R_V + R_W + R_Z$			

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),
– fire proof 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.

6.8 Assessment of risk components in a structure with zones Z_S

Rules to evaluate the risk components depends on the type of risk.

6.8.1 Risks R_1, R_2 and R_3

6.8.1.1 Single zone structure

In this case only one zone Z_S made up of the entire structure is defined. According to 6.7, the risk R is the sum of risk components R_X in the structure. 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 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 the zone, values of P_C and P_M are given by:

$$P_C = 1 - (1 - P_{C1}) \times (1 - P_{C2}) \times (1 - P_{C3}) \quad (29)$$

$$P_M = 1 - (1 - P_{M1}) \times (1 - P_{M2}) \times (1 - P_{M3}) \quad (30)$$

where $P_{Ci,}$ and P_{Mi} are parameters relevant to internal system i.

– Parameters relevant to the amount L of loss shall be evaluated according to Annex C.

The typical mean values derived from Annex C may be assumed for the zone, according to the use of the structure.

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.

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

6.8.1.2 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.

For the evaluation of risk components and the selection of the relevant parameters involved, the rules of 6.8.1.1 apply.

Dividing a structure into zones allows the designer to take into account the peculiar 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.

6.8.2 Risk R_4

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 convenience 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 in a zone shall be evaluated according to Annex G. The overall cost of loss for the structure is the sum of the cost of loss of all zones.

7 Assessment of risk components for a service

7.1 Basic equation

Each risk component R'_V, R'_W, R'_Z, R'_B and R'_C, as described in Clause 4, may be expressed by the following general equation:

$$R'_X = N_X \times P'_X \times L'_X \tag{31}$$

where

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

P'_X is the probability of damage to a service (see also Annex D);

L'_X is the consequent loss (see also Annex E).

7.2 Assessment of components due to flashes to the service (S3)

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

- component related to physical damage (D2)

$$R'_V = N_L \times P'_V \times L'_V \tag{32}$$

- component related to failure of connected equipment (D3)

$$R'_W = N_L \times P'_W \times L'_W \tag{33}$$

Parameters to assess these risk components are given in Table 10.

7.3 Assessment of risk component due to flashes near the service (S4)

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

– component related to failure of connected equipments (D3)

$$R'_Z = (N_I - N_L)\, P'_Z\, L'_Z \qquad (34)$$

Parameters to assess this risk component are given in Table 10.

For the purpose of this assessment, if $(N_I - N_L) < 0$, then $(N_I - N_L) = 0$ it shall be assumed.

7.4 Assessment of risk components due to flashes to structures to which the service is connected (S1)

For evaluation of risk components related to lightning flashes to each structure to which a service is connected, the following relationship applies for the section of service connected to the structure:

– component related to physical damage (D2)

$$R'_B = N_D\, P'_B\, L'_B \qquad (35)$$

– component related to failures of equipment (D3)

$$R'_C = N_D \times P'_C \times L'_C \qquad (36)$$

Parameters to assess this risk component are given in Table 10.

Table 10 – Parameters relevant to the assessment of risk components for a service

Symbol	Denomination	Value according to
Average annual number of flashes		
N_D	– to the structure connected to the service	Clause A.2
N_L	– to the service	Clause A.4
N_I	– near the service	Clause A.5
Probability that a flash to the adjacent structure will cause		
P'_B	– physical damage	Subclause D.1.1
P'_C	– failures of connected equipment	Subclause D.1.1
Probability that a flash to the service will cause		
P'_V	– physical damage	Subclause D.1.2
P'_W	– failures of connected equipment	Subclause D.1.2
Probability that a flash near a service will cause		
P'_Z	– failures of connected equipment	Subclause D.1.3
Loss due to		
$L'_B = L'_V = L'_f$	– physical damage	Table E.1, Equation (E.2)
$L'_C = L'_W = L'_Z = L'_0$	– failures of connected equipment	Table E.1, Equation (E.3)

7.5 Summary of risk components for a service

Risk components for a service are summarized in Table 11, according to different types and sources of damage.

Table 11 – Risk components for a service for different types of damage caused by different sources

Source of damage / Type of damage	S3 Lightning flash to a service	S4 Lightning flash near a service	S1 Lightning flash to a structure	Resulting risk according to the type of damage
D2 Physical damage	$R'_V = N_L \times P'_V \times L'_V$		$R'_B = N_D \times P'_B \times L'_B$	$R_F = R'_V + R'_B$
D3 Failure of electrical and electronic systems	$R'_W = N_L \times P'_W \times L'_W$	$R'_Z = (N_I - N_L) \times P'_Z \times L'_Z$	$R'_C = N_D \times P'_C \times L'_C$	$R_O = R'_Z + R'_W + R'_C$
Resulting risk according to the source of damage	$R_D = R'_V + R'_W$	$R_I = R'_Z + R'_B + R'_C$		

If the service is partitioned into sections S_S (see 7.6), the risk components R'_V, R'_W and R'_Z of the service shall be evaluated as the sum of the relevant risk components of each section of the service.

The risk component R'_Z shall be evaluated in each transition point (see IEC 62305-5) of the service and the highest value shall be assumed as the value of R'_Z.

NOTE Detailed information for TLC lines are given in Recommendation ITU K.46.

The risk components R'_B and R'_C of the service shall be evaluated as the sum of the relevant risk components of each structure connected to the service.

The total risk R of the service is the sum of risk components R'_B, R'_C, R'_V, R'_W and R'_Z.

7.6 Partitioning of a service into sections S_S

To assess each risk component, the service could be divided into sections S_S. However a service may be, or may be assumed to be, a single section.

For all risk components (R'_B, R'_C, R'_V, R'_W, R'_Z), sections S_S are mainly defined by:

– type of service (aerial or buried);
– factors affecting the collection area (C_d, C_e, C_t);
– characteristics of service (type of cable insulation, shield resistance).

Further sections may be defined according to:

– type of connected apparatus;
– protection measures existing or to be provided.

Partitioning of a service into sections should take into account the feasibility of implementation of the most suitable protection measures.

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.

The network operator or the owner of the service shall evaluate the relative amount of expected loss of service per year. If this evaluation cannot be carried out, representative values are suggested in Annex E.

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 an object to be protected depends on the thunderstorm activity of the region where the object is located and on the object′s physical characteristics. To calculate the number N, it is generally accepted to multiply the lightning ground flash density N_g by an equivalent collection area of the object and by taking into account correction factors for object′s physical characteristics.

The lightning ground flash density N_g is the number of lightning flashes per km^2 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:

$$N_g \approx 0,1\ T_d \qquad \text{(A.1)}$$

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

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

- flashes to the service,
- flashes near the service,
- flashes to the structure to which the service is connected.

A.2 Assessment of the average annual number of dangerous events due to flashes to a structure N_D and to a structure connected at “a” end of a line N_{Da}

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.

Rectangular structure

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

$$A_d = L \times W + 6 \times H \times (L + W) + 9 \times \pi \times (H)^2 \qquad \text{(A.2)}$$

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

NOTE A more precise evaluation could be obtained considering the relative height of the structure with respect to the surrounding objects or the soil within a distance of $3H$ from the structure.

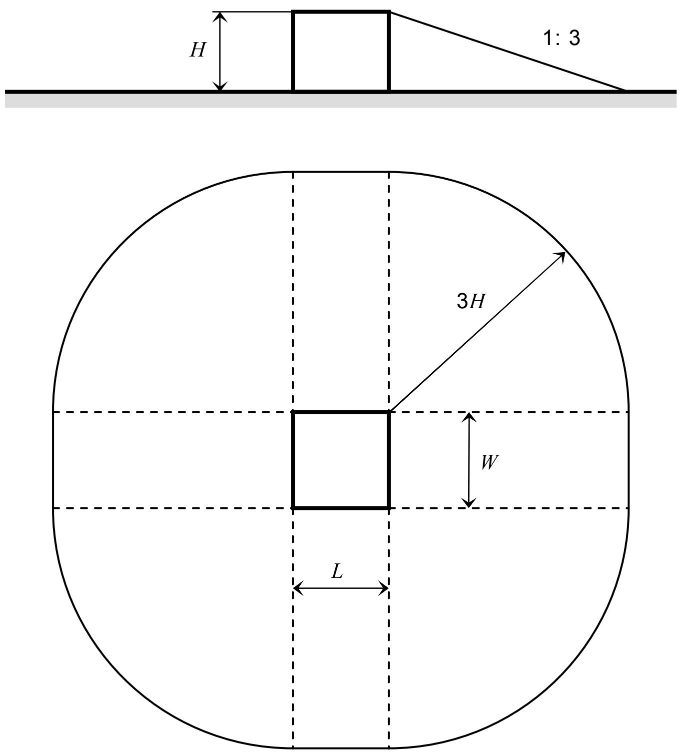


Figure A.1 – Collection area A_d of an isolated structure

A.2.1.1 Complex shaped structure

If the structure has a complex shape such as elevated roof protrusions (see Figure A.2), a graphic method should be used to evaluate A_d (see Figure A.3), because the differences may be too great if the maximum (A_{dmax}) or minimum (A_{dmin}) dimensions are used (see Table A.1)

An acceptable approximate value of the collection area is the maximum between A_{dmin} and the collection area attributed to the elevated roof protrusion A_d'. A_d' may be calculated by:

$$A_d' = 9\pi \times (H_p)^2 \qquad \text{(A.3)}$$

where H_p is the height of protrusion.

The different values of collection area according to the above methods are given in Table A.1.

Table A. 1 – Values of collection area depending on the evaluation method

	Graphic method	Structure (maximum dimensions)	Structure (minimum dimensions)	Protrusion H_p
Structure dimensions m (L, W, H)	See Figure A.2	70 × 30 × 40	70 × 30 × 25	40
m²	A_d = 47 700	A_{dmax} =71 316	A_{dmin} = 34 770 See Figure A.3	A_d' = 45 240 See Figure A.3

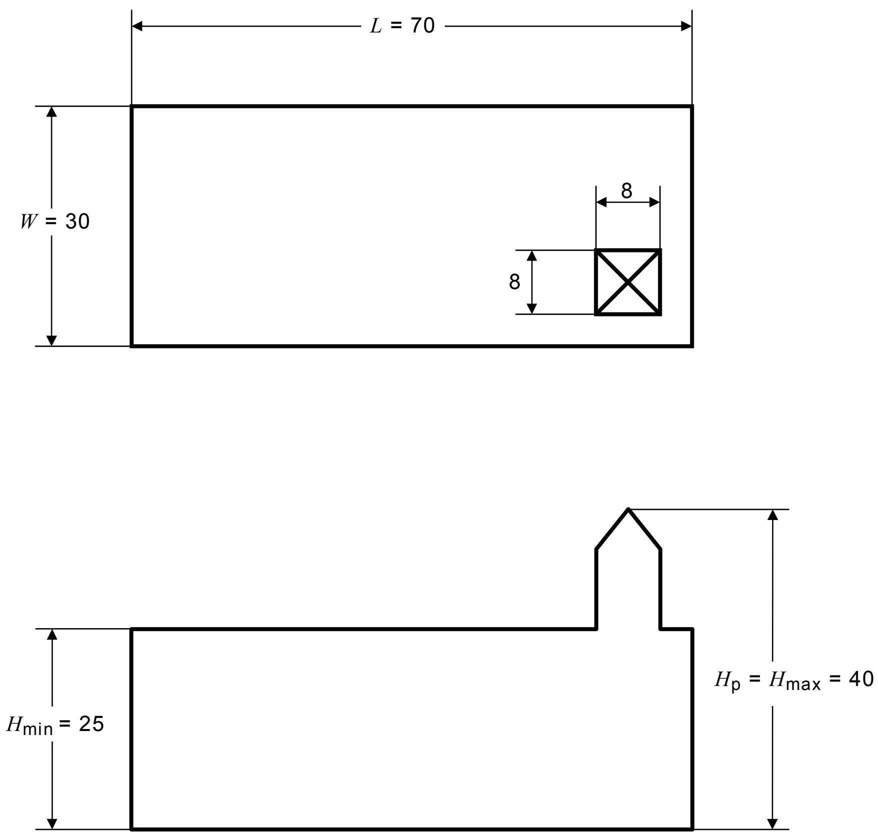
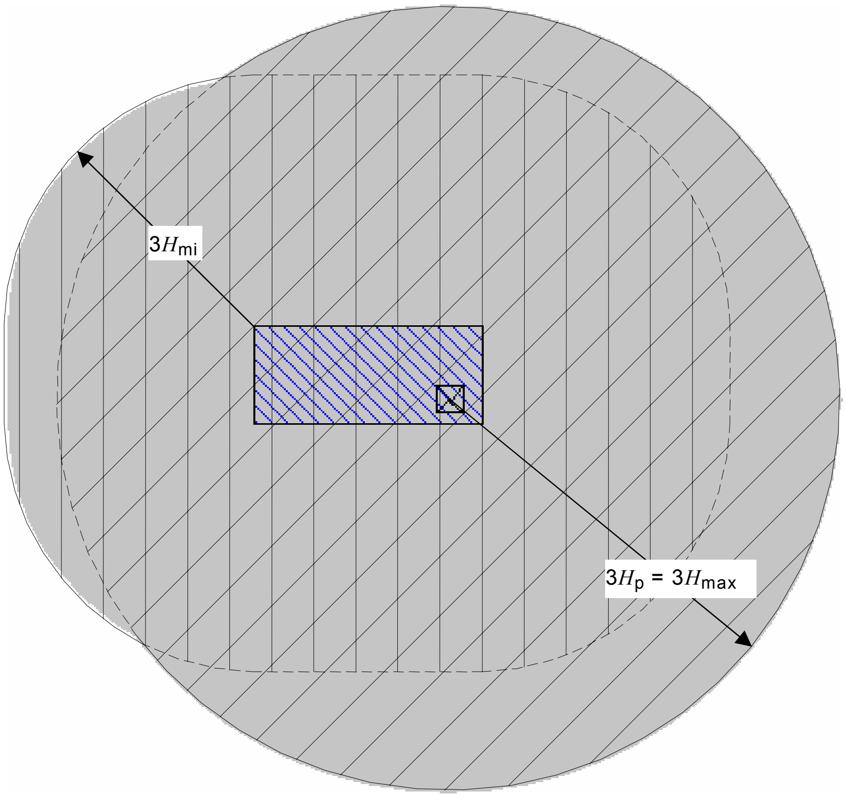


Figure A.2 – Complex shape structure



A_{dmin} Rectangular structure with $H = H_{min}$ Formula (A.3)

A'_d Protrusion with $H = H_p = H_{max}$ Formula (A.4)

A_d Collection area determined using the graphic method.

Figure A.3 – Different methods to determine the collection area for the structure of Figure A.2

A.2.1.2 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 SPD 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 Official Journal of European Union, 1994/28/02, n. C 62/63.

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

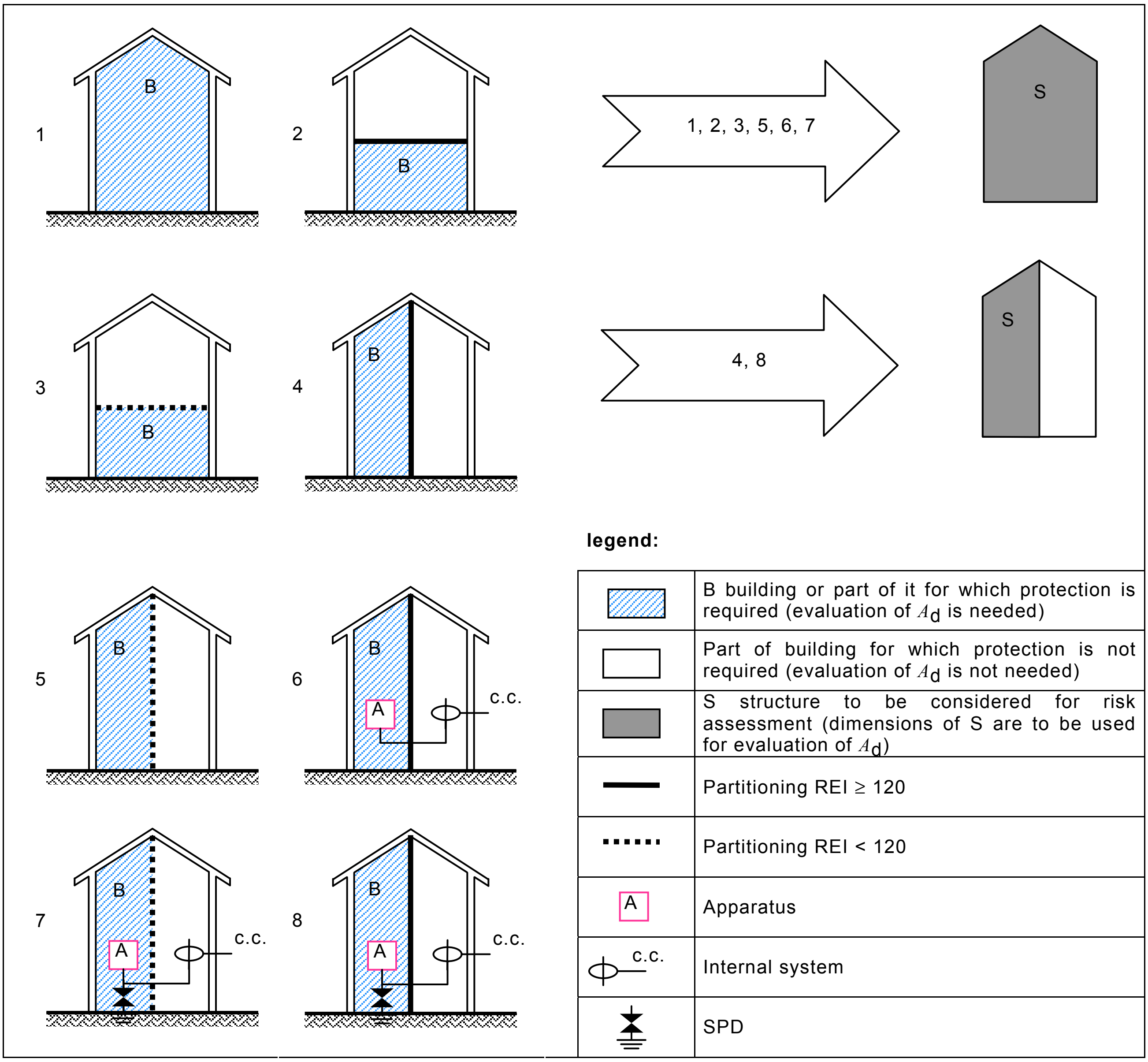


Figure A.4 – Structure to be considered for evaluation of collection area A_d

A.2.2 Relative location of the structure

The relative location of the structure, compensating for surrounding objects or an exposed location, will be taken into account by a location factor C_d (see Table A.2).

Table A.2 – Location factor C_d

Relative location	C_d
Object surrounded by higher objects or trees	0,25
Object surrounded by objects or trees of the same heights or smaller	0,5
Isolated object: no other objects in the vicinity	1
Isolated object on a hilltop or a knoll	2

A.2.3 Number of dangerous events N_D for a structure (“b” end of a service)

N_D may be evaluated as the product:

$$N_D = N_g \times A_{d/b} \times C_{d/b} \times 10^{-6} \quad \text{(A.4)}$$

where

N_g is the lightning ground flash density (1/km²/year);

$A_{d/b}$ is the collection area of the isolated structure (m²) (see Figure A.1);

$C_{d/b}$ is the location factor of the structure (see Table A.2).

A.2.4 Number of dangerous events N_{Da} for an adjacent structure (“a” end of a service)

The average annual number of dangerous events due to flashes to a structure at “a” end of a line N_{Da} (see 6.5 and Figure 5) may be evaluated as the product:

$$N_{Da} = N_g \times A_{d/a} \times C_{d/a} \times C_t \times 10^{-6} \quad \text{(A.5)}$$

where

N_g is the lightning ground flash density (1/km²/year);

$A_{d/a}$ is the collection area of the isolated adjacent structure (m²) (see Figure A.1);

$C_{d/a}$ is the location factor of the adjacent structure (see Table A.2);

C_t is the correction factor for the presence of a HV/LV transformer on the service to which the structure is connected, located between the point of strike and the structure (see Table A.4). This factor applies to line sections upstream from the transformer with respect to the structure.

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

N_M may be evaluated as the product:

$$N_M = N_g \times (A_m - A_{d/b} C_{d/b}) \times 10^{-6} \quad \text{(A.6)}$$

where

N_g is the lightning ground flash density (flash/km²/year);

A_m is the collection area of flashes striking near the structure (m²).

The collection area A_m extends to a line located at a distance of 250 m from the perimeter of the structure (see Figure A.5).

If $N_M < 0$, $N_M = 0$ shall be used in the assessment.

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

For a one-section service, N_L may be evaluated by:

$$N_L = N_g \times A_l \times C_d \times C_t \times 10^{-6} \quad \text{(A.7)}$$

where

N_g is the lightning ground flash density (flash/km²/year);

A_l is the collection area of flashes striking the service (m²) (see Table A.3 and Figure A.5);

C_d is the location factor of service (see Table A.2);

C_t is the correction factor for the presence of a HV/LV transformer located between the point of strike and the structure(see Table A.4). This factor applies to line sections upstream from the transformer with respect to the structure.

Table A.3 – Collection areas A_l and A_i depending on the service characteristics

	Aerial	Buried
A_l	$(L_c - 3(H_a + H_b))\ 6\ H_c$	$(L_c - 3(H_a + H_b))\ \sqrt{\rho}$
A_i	$1\,000\ L_c$	$25\ L_c\sqrt{\rho}$

where

A_l is the collection area of flashes striking the service (m²);

A_i is the collection area of flashes to ground near the service(m²);

H_c is the height of the service conductors above ground (m);

L_c is the length of the service section from the structure to the first node (m). A maximum value L_c = 1 000 m should be assumed;

H_a is the height of the structure connected at end “a” of service (m);

H_b is the height of the structure connected at end “b” of service (m);

ρ is the resistivity of soil where the service is buried (Ωm). A maximum value ρ = 500 Ωm should be assumed.

For the purposes of this calculation:

– where the value of L_c is unknown, L_c = 1 000 m is to be assumed;
– where the value of soil resistivity is unknown, ρ = 500 Ωm is to be assumed;
– for underground cables running entirely within a highly meshed earth termination, $A_i = A_l = 0$ may be assumed for the equivalent collection area;
– the structure to be protected shall be assumed to be the one connected at “b” end of service.

NOTE More information on the collection areas A_l and A_i can be funded in ITU Recommendations K.46 and K.47.

Table A.4 – Transformer factor C_t

Transformer	C_t
Service with two windings transformer	0,2
Service only	1

A.5 Assessment of average annual number of dangerous events due to flashes near a service N_l

For a one-section (overhead, underground, screened, unscreened, etc.) service, the value of N_l may be evaluated by

$$N_l = N_g \times A_i \times C_e \times C_t \times 10^{-6} \tag{A.8}$$

where

N_g is the lightning ground flash density (flash/km²/year);

A_i is the collection area of flashes to ground near the service (m²) (see Table A.3 and Figure A.5);

C_e is the environmental factor (see Table A.5);

C_t is the correction factor for the presence of a HV/LV transformer located between the point of strike and the structure(see Table A.4). This factor applies to line sections upstream from the transformer with respect to the structure.

Table A.5 – Environmental factor C_e

Environment	C_e
Urban with tall buildings 1)	0
Urban 2)	0,1
Suburban 3)	0,5
Rural	1
1) Height of buildings higher than 20 m. 2) Height of buildings ranging between 10 m and 20 m. 3) Height of buildings lower than 10 m.	

NOTE The collection area A_i of the service is defined by its length L_c and by the lateral distance D_i (see Figure A.5) at which a flash near the service may cause induced overvoltages not lower than 1,5 kV.

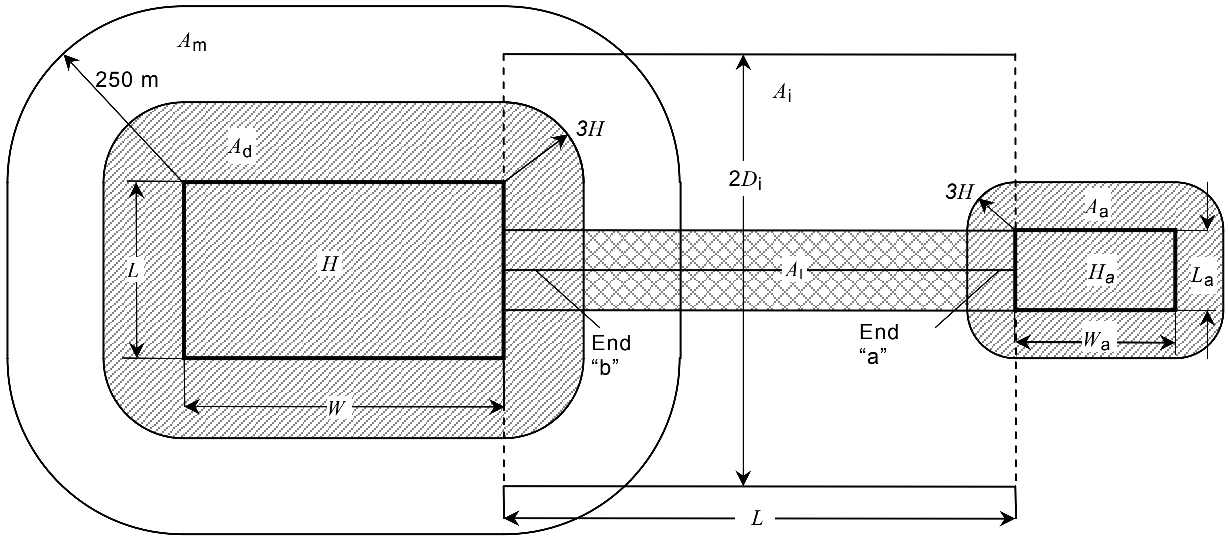


Figure A.5 – Collection areas (A_d, A_m, A_i, A_l)

Annex B
(informative)

Assessment of probability P_X of damage for a structure

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 only be selected 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.1 Probability P_A that a flash to the structure will cause injury to living beings

The values of probability P_A of shock to living beings due to touch and step voltage by a lightning flash to the structure, as a function of typical protection measures, are given in Table B.1.

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

Protection measure	P_A
No protection measures	1
Electrical insulation of exposed down-conductor (e.g. at least 3 mm cross-linked polyethylene)	10^{-2}
Effective soil equipotentialization	10^{-2}
Warning notices	10^{-1}

If more than one provision has been taken, the value of P_A is the product of the corresponding P_A values.

NOTE 1 For more information see 8.1 and 8.2 of IEC 62305-3.

NOTE 2 Where the structure's reinforcing members or framework is used as a down-conductor system, or where physical restrictions are provided, the value of probability P_A is negligible.

B.2 Probability P_B that a flash to a structure will cause physical damage

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

Table B.2 – Values of 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 or 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 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.

B.3 Probability P_C that a flash to a structure will cause failure of internal systems

The probability P_C that a flash to a structure will cause a failure of internal systems depends on the adopted coordinated SPD protection:

$$P_C = P_{SPD} \tag{B.1}$$

Values of P_{SPD} depend on lightning protection level (LPL) for which SPD are designed, as shown in Table B.3.

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 protection	1
III-IV	0,03
II	0,02
I	0,01
NOTE 3	0,005 – 0,001

NOTE 1 Only “coordinated SPD protection” is suitable as a protection measure to reduce P_C. Coordinated SPD protection is effective to reduce 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 Shielded internal systems connected to external lines consisting of lightning protective cable or systems with wiring in lightning protective cable ducts, metallic conduit, or metallic tubes; may not require the use of coordinated SPD protection.

NOTE 3 Smaller values of P_{SPD} are possible in the case of SPDs having better protection characteristics (higher current withstand capability, lower protective level, etc.) compared with the requirements defined for LPL I at the relevant installation locations.

B.4 Probability P_M that a flash near a structure will cause failure of internal systems

The probability P_M that a lightning flash near a structure will cause failure of internal systems depends on the adopted lightning protection measures (LPM), according to a factor K_{MS}.

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

The values of P_{MS} as a function of K_{MS} are given in Table B.4, where K_{MS} is a factor related to the performances of the adopted protection measures.

When coordinated SPD protection according to IEC 62305-4 is provided, the value of P_M is the lower value between P_{SPD} and P_{MS}.

Table B.4 – Value of the probability P_{MS} as a function of factor K_{MS}

K_{MS}	P_{MS}
≥ 0,4	1
0,15	0,9
0,07	0,5
0,035	0,1
0,021	0,01
0,016	0,005
0,015	0,003
0,014	0,001
≤ 0,013	0,000 1

For internal systems with equipment not conforming to the resistibility or withstand voltage level given in the relevant product standards P_{MS} = 1 shall be assumed.

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

$$K_{MS} = K_{S1} \times K_{S2} \times K_{S3} \times K_{S4} \qquad (B.2)$$

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 .

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

$$K_{S1} = K_{S2} = 0,12 \times w \qquad (B.3)$$

where w(m) is the mesh width of grid-like spatial shield, 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 shields with a full continuous metal sheath $K_{S1} = K_{S2} = 10^{-4}$ to 10^{-5} shall be as long as the thickness of the shield ranges from 0,1 mm to 0,5 mm.

NOTE 1 Where a meshed bonding network is provided according to IEC 62305-4, values of K_{S1} and K_{S2} may be reduced by a half.

Where the induction loop is running close 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* to 0,2 *w*.

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

NOTE 2 The maximum value of K_{S1} 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 [1]	1
Unshielded cable – routing precaution in order to avoid large loops [2]	0,2
Unshielded cable – routing precaution in order to avoid loops [3]	0,02
Shielded cable with shield resistance [4] $5 < R_S \leq 20$ Ω / km	0,001
Shielded cable with shield resistance [4] $1 < R_S \leq 5$ Ω / km	0,000 2
Shielded cable with shield resistance [4] $R_S \leq 1$ Ω / km	0,000 1

[1] Loop conductors with different routing in large buildings (loop area in the order of 50 m^2).

[2] Loop conductors routing in the same conduit or loop conductors with different routing in small buildings (loop area in the order of 10 m^2).

[3] Loop conductors routing in the same cable (loop area in the order of 0,5 m^2).

[4] Cable with shield of resistance R_S (Ω/km) bonded to equipotential bonding bar at both ends and equipment connected to the same bonding bar.

For wiring running in continuous metal conduit bonded to equipotential bonding bars at both ends, K_{S3} values shall be multiplied by 0,1.

The factor K_{S4} is evaluated as:

$$K_{S4} = 1{,}5/U_w \tag{B.4}$$

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

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

B.5 Probability P_U that a flash to a service will cause injury to living beings

The values of probability P_U of injury to living beings due to touch voltage by a flash to a service entering the structure depends on the characteristics of the service shield, the impulse withstand voltage of internal systems connected to the service, the typical protection measures (physical restrictions, warning notices, etc. (see Table B.1) and the SPD(s) provided at the entrance of the service.

When SPD(s) are not provided for equipotential bonding in accordance with IEC 62305-3, the value of P_U is equal to the value of P_{LD}, where P_{LD} is the probability of failure of internal systems due to a flash to the connected service.

Values of P_{LD} are given in Table B.6.

When SPD(s) are provided for equipotential bonding in accordance with IEC 62305-3, the value of P_U is the lower value between P_{SPD} (Table B.3) and P_{LD}.

NOTE Coordinated SPD protection according to IEC 62305-4 is not necessary to reduce P_U in this case. SPD(s) according to IEC 62305-3 are sufficient.

Table B.6 – 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

U_w kV	$5 < R_S \leq 20$ Ω/km	$1 < R_S \leq 5$ Ω/km	$R_S \leq 1$ Ω/km
1,5	1	0,8	0,4
2,5	0,95	0,6	0,2
4	0,9	0,3	0,04
6	0,8	0,1	0,02
R_S (Ω/km): resistance of the cable shield.			

For unshielded service P_{LD} = 1 shall be taken.

When protection measures, such as physical restrictions, warning notices, etc. are provided, probability P_U shall be further reduced by multiplying it by the values of probability P_A given in Table B.1.

B.6 Probability P_V that a flash to a service will cause physical damage

The values of probability P_V of physical damage by a flash to a service entering the structure depend on the characteristics of service shield, the impulse withstand voltage of internal systems connected to the service and the SPDs provided.

When SPD(s) are not provided for equipotential bonding according to IEC 62305-3, the value of P_V is equal to the value of P_{LD}, where P_{LD} is the probability of failure of internal systems due to a flash to the connected service.

Values of P_{LD} are given in Table B.6.

When SPD(s) are provided for equipotential bonding in accordance with IEC 62305-3, the value of P_V is the lower value between P_{SPD} (see Table B.3) and P_{LD}.

NOTE Coordinated SPD protection according to IEC 62305-4 is not necessary to reduce P_V in this case. SPD(s) according to IEC 62305-3 are sufficient.

B.7 Probability P_W that a flash to a service will cause failure of internal systems

The values of probability P_W that a flash to a service entering the structure will cause a failure of internal systems depend on the characteristics of service shielding, the impulse withstand voltage of internal systems connected to the service and the SPDs installed .

When coordinated SPD protection conforming to IEC 62305-4 is not provided, the value of P_W is equal to the value of P_{LD}, where P_{LD} is the probability of failure of internal systems due to a flash to the connected service.

Values of P_{LD} are given in Table B.6.

When coordinated SPD protection conforming to IEC 62305-4 is provided, the value of P_W is the lower value between P_{SPD} (see Table B.3) and P_{LD}.

B.8 Probability P_Z that a lightning flash near an incoming service will cause failure of internal systems

The values of probability P_Z that a lightning flash near a service entering the structure will cause a failure of internal systems depend on the characteristics of the service shield, the impulse withstand voltage of the system connected to the service and protection measures provided.

When coordinated SPD protection conforming to IEC 62305-4 is not provided, the value of P_Z is equal to the value of P_{LI}, where P_{LI} is the probability of failure of internal systems due to flash to the connected service.

Values of P_{LI} are given in Table B.7.

When coordinated SPD protection conforming to IEC 62305-4 is provided, the value of P_Z is the lower value between P_{SPD} (see Table B.3) and P_{LI}.

Table B.7 – Values of the probability P_{LI} depending on the resistance R_S of the cable screen and the impulse withstand voltage U_W of the equipment

U_w kV	No shield	Shield not bonded to equipotential bonding bar to which equipment is connected	Shield bonded to equipotential bonding bar and equipment connected to the same bonding bar		
			$5 < R_S \leq 20$ Ω/km	$1 < R_S \leq 5$ Ω/km	$R_S \leq 1$ Ω/km
1,5	1	0,5	0,15	0,04	0,02
2,5	0,4	0,2	0,06	0,02	0,008
4	0,2	0,1	0,03	0,008	0,004
6	0,1	0,05	0,02	0,004	0,002

R_s: resistance of the cable shield (Ω/km).

NOTE More precise evaluation of K_s for shielded and unshielded sections can be found in ITU Recommendation K.46.

Annex C
(informative)

Assessment of amount of loss L_X for a structure

The values of amount of loss L_X should be evaluated and fixed by the lightning protection designer (or the owner of the structure). The typical mean values given in this annex are merely values proposed by the IEC. Different values may be assigned by each national committee.

NOTE It is recommended that the equations given in this annex be used as the primary source of values for L_X.

C.1 Average relative amount of loss per year

The loss L_X refers to the mean relative amount of a particular type of damage which may be caused by a lightning flash, considering both its extent and effects.

Its value depends on:

– the number of persons and the time for which they remain in the hazardous place;
– the type and importance of the service provided to the public;
– the value of the goods affected by the damage.

The loss L_X varies with the type of loss (L1, L2, L3 and L4) considered and, for each type of loss, with the type of damage (D1, D2 and D3) causing the loss. The following symbols are used:

L_t is the loss due to injury by touch and step voltages;
L_f is the loss due to physical damage;
L_o is the loss due to failure of internal systems.

C.2 Loss of human life

The value of L_t, L_f and L_o may be determined in terms of the relative number of victims from the following approximate relationship:

$$L_X = (n_p / n_t) \times (t_p / 8\,760) \qquad \text{(C.1)}$$

where

n_p is the number of possible endangered persons (victims);
n_t is the expected total number of persons (in the structure);
t_p is the time in hours per year for which the persons are present in a dangerous place, outside of the structure (L_t only) or inside the structure (L_t , L_f and L_o).

Typical mean values of L_t, L_f and L_o, for use when the determination of n_p, n_t and t_p is uncertain or difficult, are given in Table C.1.

Table C.1 – Typical mean values of L_t, L_f and L_o

Type of structure	L_t
All types – (persons inside the building)	10^{-4}
All types – (persons outside the building)	10^{-2}

Type of structure	L_f
Hospitals, hotels, civil buildings	10^{-1}
Industrial, commercial, school	5×10^{-2}
Public entertainment, churches, museum	2×10^{-2}
Others	10^{-2}

Type of structure	L_o
Risk of explosion	10^{-1}
Hospitals	10^{-3}

Loss of human life is affected by the characteristics of a structure. These are taken into account by increasing (h_Z) and decreasing (r_f, r_p, r_a, r_u) factors as follows:

$$L_A = r_a \times L_t \quad \text{(C.2)}$$

$$L_U = r_u \times L_t \quad \text{(C.3)}$$

$$L_B = L_V = r \times h_Z \times r_f \times L_f \quad \text{(C.4)}$$

$$L_C = L_M = L_W = L_Z = L_o \quad \text{(C.5)}$$

where

r_a is a factor reducing the loss of human life depending on the type of soil (see Table C.2);

r_u is a factor reducing the loss of human life depending on the type of floor (see Table C.2);

r_p is a factor reducing the loss due to physical damage depending on the provisions taken to reduce the consequences of fire (see Table C.3);

r_f is a factor reducing the loss due to physical damage depending on the risk of fire of the structure (see Table C.4);

h_Z is a factor increasing the loss due to physical damage when a special hazard is present(see Table C.5).

Table C.2 – Values of reduction factors r_a and r_u as a function of the type of surface of soil or floor

Type of surface	Contact resistance k Ω[1)]	r_a and r_u
Agricultural, concrete	≤1	10^{-2}
Marble, ceramic	1 – 10	10^{-3}
Gravel, moquette, carpets	10 – 100	10^{-4}
Asphalt, linoleum, wood	≥100	10^{-5}
1) Values measured between a 400 cm^2 electrode compressed with force of 500 N at a point of infinity.		

Table C.3 – Values of reduction factor r_p as a function of provisions taken to reduce the consequences of fire

Provisions	r_p
No provisions	1
One of the following provisions: extinguishers; fixed manually operated extinguishing installations; manual alarm installations; hydrants; fire proof compartments; protected escape routes	0,5
One of the following provisions: fixed automatically operated extinguishing installations; automatic alarm installations[1)]	0,2
[1)] Only if protected against overvoltages and other damages and if firemen can arrive in less than 10 min.	

If more than one provision has been taken, the value of r_p shall be taken as the lowest of the relevant values.

In structures with risk of explosion, r_p = 1 for all cases.

Table C.4 – Values of reduction factor r_f as a function of risk of fire of structure

Risk of fire	r_f
Explosion	1
High	10^{-1}
Ordinary	10^{-2}
Low	10^{-3}
None	0

NOTE 1 In the cases of a structure with risk of explosion and a structure containing explosive mixtures a more detailed evaluation of r_f may be necessary.

NOTE 2 Structures with a high risk of fire may be assumed to be structures made of combustible materials, structures with roof made of combustible materials or structures with a specific fire load larger than 800 MJ/m^2.

NOTE 3 Structures with an ordinary risk of fire may be assumed to be structures with a specific fire load between 800 MJ/m^2 and 400 MJ/m^2.

NOTE 4 Structures with a low risk of fire may be assumed to be structures with a specific fire load less than 400 MJ/m^2, or structures containing combustible materials only occasionally.

NOTE 5 Specific fire load is the ratio of the energy of the total amount of the combustible material in a structure and the overall surface of the structure.

Table C.5 – Values of factor h increasing the relative amount of loss in presence of a special hazard

Kind of special hazard	h
No special hazard	1
Low level of panic (e.g. a structure limited to two floors and the number of persons not greater than 100)	2
Average level of panic (e.g. structures designed for cultural or sport events with a number of participants between 100 and 1 000 persons)	5
Difficulty of evacuation (e.g. structures with immobilized persons, hospitals)	5
High level of panic (e.g. structures designed for cultural or sport events with a number of participants greater than 1 000 persons)	10
Hazard for surroundings or environment	20
Contamination of surroundings or environment	50

C.3 Unacceptable loss of service to the public

The values of L_f and L_o can be determined in term of the relative amount of possible loss from the following approximate relationship:

$$L_x = n_p / n_t \times t / 8\,760 \tag{C.6}$$

where

n_p is the mean number of possible endangered persons (users not served);

n_t is the total number of persons (users served);

t is the annual period of loss of service (in hours).

Typical mean values of L_f and L_o, for use when the determination of n_p, n_t and t is uncertain or difficult, are given in Table C.6.

Table C.6 – Typical mean values of L_f and L_o

Type of service	L_f	L_o
Gas, water	10^{-1}	10^{-2}
TV, TLC, power supply	10^{-2}	10^{-3}

Loss of service to the public is affected by structure characteristics and by a reduction factor (r_p) as follows:

$$L_B = L_V = r_p \times r_f \times L_f \tag{C.7}$$

$$L_C = L_M = L_W = L_Z = L_o \tag{C.8}$$

Values for factors r_p and r_f are given in Tables C.3 and C.4 respectively.

C.4 Loss of irreplaceable cultural heritage

The value of L_f can be determined in terms of the relative amount of possible loss from the following approximate relationship:

$$L_x = c / c_t \tag{C.9}$$

where

c is the mean value of possible loss of the structure (i.e. the insurable value of possible loss of goods) in currency;

c_t is the total value of the structure (i.e. the total insured value of all goods present in the structure) in currency

A typical mean value of L_f, for use when the determination of n, n_t and t for a museum or gallery is uncertain or difficult, is:

$$L_f = 10^{-1}$$

Loss of irreplaceable cultural heritage is affected by the characteristics of the structure by reduction factor r_p as follows:

$$L_B = L_V = r_p \times r_f \times L_f \tag{C.10}$$

Values for factors r_p and r_f are given in Tables C.3 and C.4, respectively.

C.5 Economic loss

The value of L_t, L_f and L_o can be determined in terms of the relative amount of possible loss from the following approximate relationship:

$$L_x = c / c_t \quad \text{(C.11)}$$

where

c is the mean value of possible loss of the structure (including its content and relevant activities and its consequences) in currency;

c_t is the total value of the structure (including its content and relevant activities) in currency.

Typical mean values of L_t, L_f and L_o for all types of structures, for use when the determination of n, n_t and t is uncertain or difficult, are given in Table C.7.

Table C.7 – Typical mean values of L_t, L_f and L_o

Type of structure	L_t
All types – Inside buildings	10^{-4}
All types – Outside buildings	10^{-2}
Type of structure	L_f
Hospital, industrial, museum, agriculture	0,5
Hotel, school, office, church, public entertainment, economic building	0,2
Others	0,1
Type of structure	L_o
Risk of explosion	10^{-1}
Hospital, industrial, office, hotel, economic building	10^{-2}
Museum, agriculture, school, church, public entertainment	10^{-3}
Others	10^{-4}

Loss of economical value is affected by the characteristics of the structure. These are taken into account by increasing (h_Z) and decreasing (r_p, r_a, r_f, r_u) factors as follows:

$$L_A = r_a \times L_t \quad \text{(C.12)}$$

$$L_U = r_u \times L_t \quad \text{(C.13)}$$

$$L_B = L_V = r_p \times r_f \times h_Z \times L_f \quad \text{(C.14)}$$

$$L_C = L_M = L_W = L_Z = L_O \quad \text{(C.15)}$$

Values of the factors r_a and r_u are given in Table C.2; r_p in Table C.3; r_f in Table C.4; and h_Z in Table C.5.

Annex D
(informative)

Assessment of probability P'_X of damage to a service

The probabilities given in this annex are values agreed by the IEC. Other values may be chosen if justified.

The probabilities given in this annex are valid if protection measures conform to IEC 62305-5.

D.1 Lines with metallic conductors

D.1.1 Probability P'_B and P'_C that a flash to the structure to which a line is connected will cause damages

The probability P'_B that a flash to the structure to which a line is connected will cause physical damages, and the probability P'_C that a flash to the structure to which the line is connected will cause failures of connected apparatus are related to the failure current I_a. I_a depends on the characteristics of the line, the number of incoming services to the structure and the adopted protection measures.

For unshielded lines I_a = 0 must be assumed.

For shielded lines, the failure current I_a (kA) shall be evaluated according to:

$$I_a = 25\ n \times U_w \,/\, (R_s \times K_d \times K_p) \quad \text{(D.1)}$$

where

- K_d is the factor depending on characteristics of line (see Table D.1);
- K_p is the factor taking into account the effect of the adopted protection measures (see Table D.2);
- U_w is the impulse withstand voltage, (kV) (see Table D.3 for cables and Table D.4 for apparatus);
- R_s is the shield resistance of the cable, (Ω/km);
- n is the number of services incoming to the structure.

NOTE 1 SPDs at entrance point into the structure increase the failure current I_a and may have a positive protection effect.

NOTE 2 Detailed information for TLC lines are given in Recommendation ITU K.47.

Table D.1 – Values of factor K_d as a function of the characteristics of the shielded line

Line	K_d
With shield in contact with the soil	1
With shield not in contact with the soil	0,4

Table D.2 – Values of the factor K_p as a function of the protection measures

Protection measure	K_p
No protection measures	1
Additional shielding wires – One conductor[1)]	0,6
Additional shielding wires – Two conductors[1)]	0,4
Lightning protective cable duct	0,1
Lightning protective cable	0,02
Additional shielding wires – steel tube	0,01

[1)] The shielding wire is installed about 30 cm above the cable; two shielding wires are located 30 cm above the cable symmetrically disposed in respect of the axis of the cable.

Table D.3 – Impulse withstand voltage U_w as a function of the type of cable

Type of cable	U_n kV	U_w kV
TLC- Paper insulated	–	1,5
TLC- PVC, PE insulated	–	5
Power	≤ 1	15
Power	3	45
Power	6	60
Power	10	75
Power	15	95
Power	20	125

Table D.4 – Impulse withstand voltage U_w as a function of the type of apparatus

Type of apparatus	U_w kV
Electronic	1,5
Electrical user apparatus (U_n <1 kV)	2,5
Electrical network apparatus (U_n <1 kV)	6

The values of P'_B and P'_C as function of values of the failure current I_a are given in Table D.5.

When SPDs, conforming to IEC 62305-5 are provided, values of P'_B and P'_C are to be assumed to be the value of P_{SPD} (see Table B.3).

Table D.5 – Values of probability P'_B, P'_C, P'_V and P'_W as a function of the failure current I_a

I_a kA	P'_B , P'_C, P'_V , P'_W
0	1
3	0,99
5	0,95
10	0,9
20	0,8
30	0,6
40	0,4
50	0,3
60	0,2
80	0,1
100	0,05
150	0,02
200	0,01
300	0,005
400	0,002
600	0,001

D.1.2 Probabilities P'_V and P'_W that a flash to a line will cause damages

The probability P'_V that a flash to a line will cause physical damages, and the probability P'_W that a flash to a line will cause failure of connected apparatus is related to the failure current I_a which, in turn, depends on the characteristics of the line and on the protection measures adopted.

For unshielded lines I_a = 0 must be assumed.

For shielded lines the failure current I_a shall be evaluated according to:

$$I_a = 25\ U_w / (R_s \times K_d \times K_p) \tag{D.7}$$

where

K_d is a factor depending on characteristics of the line (see Table D.1);

K_p is a factor taking into account the protection measures adopted (see Table D.2);

U_w is the impulse withstand voltage (in kV) (see Table D.3 for cables and Table D.4 for apparatus);

R_s is the shield resistance of the cable (in Ω/km).

When evaluating P'_V for telecommunication lines, the maximum values of failure current I_a to be assumed are as follows:

I_a = 40 kA for cables with a lead shield;

I_a = 20 kA for cables with an aluminium shield.

NOTE 1 These values are a rough estimation of the test current (I_t) damaging typical telecommunication cables at the striking point. If any evidence exists that these values are not applicable for a given cable design, other values may be used. In this case the tests described in IEC 62305-5 should be used for the evaluation of the failure current.

The values of P'_V and P'_W as a function of values of the failure current I_a are given in Table D.5.

NOTE 2 Detailed information for TLC lines is given in Recommendation ITU K.47.

D.1.3 Probability P'_Z that a flash near the line will cause damage

The probability P'_Z that a flash near the line will cause failure of connected apparatus depends on the characteristics of the line and on the protection measures adopted.

When SPDs conforming to IEC 62305-5 are not provided, the value of P'_Z is equal to the value of P_{LI}.
Values of P_{LI} are reported in Table B.7.

When SPDs conforming to IEC 62305-4 are provided, the value of P'_Z is the lower value between P_{SPD} (see Table B.3) and P_{LI}.

D.2 Fibre optic lines

Under consideration.

D.3 Pipes

Under consideration.

Annex E
(informative)

Assessment of the amount of loss L'_X for a service

E.1 Average relative amount of loss per year

The loss L'_X refers to the mean relative amount of a particular type of damage which may occur as the result of a lightning flash to a service, considering both the extent and consequential effects.

Its value depends on:

– the type and importance of the service provided to the public;
– the value of the goods affected by the damage.

The loss L'_X varies with the type of loss (L′1, L′2 and L′4) considered and, for each type of loss, with the type of damage (D2 and D3) causing the loss. The following symbols are used:

L'_f loss due to physical damage;

L'_o loss due to failure of internal systems.

E.2 Unacceptable loss of service to the public

The values of L'_f and L'_o can be determined in term of relative amount of possible loss from the approximate relationship:

$$L'_x = n_p / n_t \times t / 8\,760 \tag{E.1}$$

where

n_p is the mean number of users not served;

n_t is the total number of users served;

t is the annual period of loss of service (in hours).

Typical mean values of L'_f and L'_o, for use when the determination of n_p, n_t and t is uncertain or difficult, are given in Table E.1.

Table E.1 – Typical mean values of L'_f and L'_o

Type of service	L'_f	L'_o
Gas, water	10^{-1}	10^{-2}
TV, TLC, power supply	10^{-2}	10^{-3}

Loss of service to the public is affected by service characteristics as follows:

$$L'_B = L'_V = L'_f \tag{E.2}$$

$$L'_C = L'_W = L'_Z = L'_o \tag{E.3}$$

E.3 Economic loss

The value of L'_{f} and L'_{o} can be determined in term of the relative amount of possible loss from the approximate relationship:

$$L'_{\mathrm{x}} = c \,/\, c_{\mathrm{t}} \tag{E.4}$$

where

c is the mean value of possible loss of the structure, its content and relevant activities, in currency;

c_{t} is the total value of the structure, its content and relevant activities, in currency.

Typical mean values of L'_{f} and L'_{o}, for use for all types of services when the determination of n_{p}, n_{t} and t is uncertain or difficult, are as follows:

$$L'_{\mathrm{f}} = 10^{-1}$$

$$L'_{\mathrm{o}} = 10^{-3}$$

The loss of economic values is affected by service characteristics as follows:

$$L'_{\mathrm{B}} = L'_{\mathrm{V}} = L'_{\mathrm{f}} \tag{E.5}$$

$$L'_{\mathrm{C}} = L'_{\mathrm{W}} = L'_{\mathrm{Z}} = L'_{\mathrm{o}} \tag{E.6}$$

Annex F
(informative)

Switching overvoltages

Internal overvoltages can occur for different reasons. One possible cause is a short-circuit due to lightning sparkover, which can often lead to temporary and switching overvoltages. For this reason, consideration of protection against internal overvoltages is justified.

In most cases, switching overvoltages are less damaging than lightning ones and the means of protection (namely SPDs) effective to protect against lightning surges also protect efficiently against switching surges. Therefore, the decision to protect equipment against lightning surges covers in general the question of the need of protection against switching surges.

When the study of switching surges is relevant, the procedure to assess this risk is very close to the one used in the case of surges induced by lightning on the lines as the effects on equipment are very similar. However, there is a difference regarding the number N_S of overvoltages per year.

Switching surges can be divided into two types:

– Repetitive surges (operation of circuit-breakers, switching of capacitors banks, etc.). These occur quite frequently due to a regular decision from a human being or more often due to automatic functioning of equipment. The frequency of occurrence ranges from one or two times per day to many times per day in the case of an arc soldering machine for example. The frequency of occurrence and the magnitude of these surges (and their effect on electrical devices) are, in general, well known. Risk analysis is not often useful in the decision to protect equipment in such cases.
– Random surges (i.e. operating of circuit-breakers or fuses to clear a fault). In this case, their frequency is, by definition, unknown and their amplitude and effect on electrical equipment may also be unknown. In this case, a risk assessment may help to decide if protection is needed against this source of damage.

The magnitude of switching overvoltages can only be assessed by detailed measurements of specific electrical installations and statistical processing of the data. In general, the frequency of occurrence of switching overvoltages decreases with magnitude; fulfilling a third power law (the probability is inversely proportional to the third power of its magnitude).

In low voltage systems, switching overvoltages are expected to be lower than 4 kV and only 2 per 1 000 have a magnitude exceeding 2,5 kV. Based on the total estimated or measured switching overvoltages which may happen per year (n_S), we can derive the total number N_S per year which is in excess of 2,5 kV (but lower than 4 kV) by the following equation:

$$N_S = 0{,}002 \times n_S \qquad \text{(F.1)}$$

The probability of damage P and the consequent loss L are the same as those for lightning induced surges (see Annexes B and C).

Annex G
(informative)

Evaluation of costs of loss

The cost of total loss C_L may be calculated by the following equation:

$$C_L = (R_A + R_u) \times C_A + (R_B + R_V) \times (C_A + C_B + C_S + C_C) + (R_C + R_M + R_W + R_Z) \times C_S \quad \text{(G.1)}$$

where

R_A and R_u are the risk components related to loss of animals, without protection measures;

R_B and R_V are the risk components related to physical damage, without protection measures;

R_C, R_M, R_W, R_Z are the risk components related to failure of electrical and electronic systems, without protection measures;

C_A is the cost of the animals;

C_S is the cost of systems in the structure;

C_B is the cost of the building;

C_C is the cost of the contents.

The total cost C_{RL} of residual loss in spite of protection measures may be calculated by means of the formula:

$$C_{RL} = (R'_A + R'_U) \times C_A + (R'_B + R'_V) \times (C_A + C_B + C_S + C_C) + (R'_C + R'_M + R'_W + R'_Z) \times C_S \quad \text{(G.2)}$$

where

R'_A and R'_U are the risk components related to loss of animals, with protection measures;

R'_B and R'_V are the risk components related to physical damages, with protection measures;

R'_C, R'_M, R'_W, R'_Z are the risk components related to the failure of electrical and electronic systems, with protection measures.

The annual cost C_{PM} of protection measure may be calculated by means of the equation:

$$C_{PM} = C_P \times (i + a + m) \quad \text{(G.3)}$$

where

C_P is the cost of protection measures;

i is the interest rate;

a is the amortization rate;

m is the maintenance rate.

The annual saving S of money is:

$$S = C_L - (C_{PM} + C_{RL}) \quad \text{(G.4)}$$

Protection is convenient if the annual savings S >0.

Annex H
(informative)

Case study for structures

In this annex, case studies relevant to a country house, an office building, a hospital and an apartment house are developed with the aim of showing:

- how to calculate risk and determine the need for protection;
- the contribution of different risk components to the overall risk;
- the effect of different protection measures to mitigate against such risk;
- the method of selection from among different protection solutions, taking into account cost-effectiveness.

NOTE This annex presents hypothetical data for a country house, an office building, a hospital and an apartment house. This annex is intended to provide information about the evaluation of the risk to illustrate the principles contained in this standard. It is not intended to address the unique aspects of the conditions that exist in all facilities or systems.

H.1 Country house

As a first case study, let us consider a country house for which the need for protection has to be evaluated.

For this example, the risk R_1 of loss of human life (components of R_1 according to 4.3 and Table 3) shall be determined and compared with the tolerable value R_T = 10^{-5} (according to 5.5 and Table 7). The protection measures to mitigate such risk will be selected.

H.1.1 Relevant data and characteristics

The following data and characteristics apply:

1) the house itself and its surroundings are given in Table H.1;
2) internal systems and incoming lines to which they are connected are given in Table H.2.

Table H.1 – Structure data and characteristics

Parameter	Comment	Symbol	Value	Reference
Dimensions (m)	-	(L_b, W_b, H_b)	15, 20, 6	
Location factor	Isolated[1)]	C_d	1	Table A.1
LPS	None	P_B	1	Table B.2
Shield at structure boundary	None	K_{S1}	1	Equation (B.3)
Shield internal to structure	None	K_{S2}	1	Equation (B.3)
People present outside the house	None[2)]			
Lightning flash density	1/km²/year	N_g	4	–

1) Flat territory, no neighboring structures.

2) Risk of shock of people R_A = 0.

Table H.2 – Data and characteristics of lines and connected internal systems

Parameter	Comment	Symbol	Value	Reference
Soil resistivity	Ωm	ρ	500	
LV power line and its internal system				
Length (m)		L_c	1 000	
Height (m)	Buried	H_c	-	
Transformer	None	C_t	1	Table A.3
Line location factor [1)]	Isolated	C_d	1	Table A.1
Line environment factor	Rural	C_e	1	Table A.4
Line shielding	None	P_{LD}	1	Table B.6
Internal wiring precaution	None	K_{S3}	1	Table B. 5
Withstand of internal system	U_w = 2,5 kV	K_{S4}	0,6	Equation (B.4)
Coordinated SPD protection	None	P_{SPD}	1	Table B.3
Telecom line and its internal system				
Length (m)		L_c	1 000	
Height (m)		H_c	6	
Line location factor [1)]	Isolated	C_d	1	Table A.1
Line environment factor	Rural	C_e	1	Table A.4
Line shielding	None	P_{LD}	1	Table B.6
Internal wiring precaution	None	K_{S3}	1	Table B.5
Withstand of internal system	U_w = 1,5 kV	K_{S4}	1	Equation (B.4)
Coordinated SPD protection	None	P_{SPD}	1	Table B.3
[1)] Flat territory, line isolated (no neighbouring structures, no adjacent structures connected to the far end (end “a”) of the line (N_{Da} = 0).				

Taking into account that

– the type of surface is different outside from the one inside the structure,

– the structure is a unique fire proof compartment,

– no spatial shields exist,

the following main zone may be defined:

- Z_1 (outside the building);
- Z_2 (inside the building).

No further zones need be defined assuming that:

– both internal systems (power and telecom) are in zone Z_2;

– losses L are assumed to be constant in zone Z_2.

If there are no people outside the building, risk R_1 for zone Z_1 may be disregarded and the risk assessment is to be performed only for zone Z_2.

Characteristics of zone Z_2 are reported in Table H.3.

Following the evaluation of the lightning protection designer, the typical mean values of relative amount of loss per year relevant to risk R_1 were assumed (see Table C.1).

Table H.3 – Zone Z_2 (inside the building) characteristics

Parameter	Comment	Symbol	Value	Reference
Floor surface type	Wood	r_u	10^{-5}	Table C.2
Risk of fire	Low	r_f	10^{-3}	Table C.4
Special hazard	None	h_Z	1	Table C.5
Fire protection	None	r_p	1	Table C.3
Spatial shield	None	K_{S2}	1	
Internal power systems	Yes	Connected to LV power line	–	
Internal telephone systems	Yes	Connected to telecom line	–	
Loss by touch and step voltages	Yes	L_t	10^{-4}	Table C.1
Loss by physical damages	Yes	L_f	10^{-1}	Table C.1

H.1.2 Calculation of relevant quantities

Calculations of collection areas are given in Table H.4. Calculations of expected number of dangerous events are given in Table H.5.

Table H.4 – Collection areas of structure and lines

Symbol of area	Formula/Table reference	Formula for collection area	Data from table	Value m²
A_d	(A.2)	To the structure: $A_d = [L_b\ W_b + 6H_b \times (L_b + W_b + \pi \times (3\ H_b)^2]$	H.1	$2{,}58 \times 10^3$
$A_{l(P)}$	Table A.3	To the power line: $A_{l(P)} = \sqrt{\rho} \times [L_c - 3H_b]$	H.2	$2{,}2 \times 10^4$
$A_{i(P)}$	Table A.3	Near the power line: $A_{l(P)} = 25 \times \sqrt{\rho} \times L_c$	H.2	$5{,}6 \times 10^5$
$A_{l(T)}$	Table A.3	To the telecom line: $A_{l(T)} = 6\ H_c \times [L_c - 3\ H_b]$	H.2	$3{,}5 \times 10^4$
$A_{i(T)}$	Table A.3	Near the telecom line: $A_{i(T)} = 1\ 000 \times L_c$	H.2	10^6

Table H.5 – Expected annual number of dangerous events

Symbol of number	Formula reference	Formula for number of flashes	Data from table	Value (1/year)
N_D	(A.1)	To the structure: $N_D = N_g \times A_d \times C_d \cdot \times 10^{-6}$	H.1 H.4	$1{,}03 \times 10^{-2}$
$N_{L(P)}$	(A.5)	To the power line: $N_{L(P)} = N_g \times A_{l\ (P)} \times C_{d(P)} \times C_{t(P)} \times 10^{-6}$	H.1 H.2 H.4	$8{,}78 \times 10^{-2}$
$N_{i(P)}$	(A.6)	Near the power line: $N_{i(P)} = N_g \times A_{i(P)} \times C_{t(P)} \times C_{e(P)} \times 10^{-6}$	H.1 H.2 H.4	2,24
$N_{L(T)}$	(A.5)	To the telecom line: $N_{L(T)} = N_g \times A_{l(T)} \times C_{d(T)} \times 10^{-6}$	H.1 H.2 H.4	$1{,}41 \times 10^{-1}$
$N_{i(T)}$	(A.6)	Near the telecom line: $N_{i(T)} = N_g \times A_{i(T)} \times C_{e(T)} \times 10^{-6}$	H.1 H.2 H.4	4

H.1.3 Risk calculation to make a decision on the need for protection

In the case under consideration, the risk $\boldsymbol{R_1}$ should be evaluated.

According to Equation (1), it should be expressed by the following sum of components:

$$R_1 = R_B + R_{U(\text{Power line})} + R_{V\ (\text{Power line})} + R_{U\ (\text{Telecom line})} + R_{V\ (\text{Telecom line})}$$

Involved components and total risk evaluation are given in Table H.6

Table H.6 – Risk components involved and their calculation (values x 10^{-5})

Symbol of component	Formula/Table reference	Formula for component with flashes to	Data from table	Value $\times(10^{-5})$
R_B	Table 9	the structure resulting in physical damages: $R_B = N_D \times P_B \times h_Z \times r_p \times r_f \times L_f$	H.1 H.3	0,103
$R_{U(\text{Power line})}$	Table 9	the power line resulting in shock: $R_U = (N_L + N_{Da}) \times P_U \times r_a \times L_t$	H.1 H.2 H.4	0,000 009
$R_{V(\text{Power line})}$	Table 9	the power line resulting in physical damages: $R_V = (N_L + N_{Da}) \times P_V \times h_Z \times r_p \times r_f \times L_f$		0,878
$R_{U(\text{Telecom line})}$	Table 9	the phone line resulting in shock: $R_U = (N_L + N_{Da}) \times P_U \times r_a \times L_t$		0,000 014
$R_{V(\text{Telecom line})}$	Table 9	the phone line resulting in physical damages: $R_V = (N_L + N_{Da}) \times P_V \times h_Z \times r_p \times r_f \times L_f$		1,41
Total $\boldsymbol{R_1}$	Table 9	$R_A + R_B + R_{U(\text{Power line})} + R_{V(\text{Power line})} + R_{U(\text{Telecom line})} + R_{V(\text{Telecom line})}$	H.6	**2,39**

H.1.4 Conclusion from R_1 evaluation

Because R_1 = 2,39×10^{-5} is higher than the tolerable value R_T = 10^{-5}, lightning protection for the structure is required.

H.1.5 Selection of protection measures

The composition of risk components (see 4.3.1 and 4.3.2) results as follows:

$R_D = R_A + R_B + R_C = R_B = 0{,}103 \times 10^{-5}$

$R_I = R_M + R_U + R_V + R_W + R_Z = R_U + R_V \approx 2{,}287 \times 10^{-5}$

$R_S = R_A + R_U = R_U \approx 0$

$R_F = R_B + R_V \approx 2{,}39 \times 10^{-5}$

$R_O = R_M + R_C + R_W = 0$

where

R_D is the risk due to flashes striking the structure (source S1);

R_I is the risk due to flashes not striking the structure but influencing it (sources: S2, S3 and S4);

R_S is the risk due to injury of living beings;

R_F is the risk due to physical damage;

R_O is the risk due to failure of internal systems.

This composition shows that the risk for the structure is mainly due to physical damage caused by lightning striking the connected lines.

According to Table H.6 the main contributions to the value of risk are given by:

– component $R_{V\ (Telecom\ line)}$ (lightning flash to telecom line) for 59 %;
– component $R_{V\ (Power\ line)}$ (lightning flash to power line) for 37 %;
– component R_B (lightning flash to structure) for 4 %.

To reduce the risk R_1 to a tolerable value, the protective measures influencing the components R_V and the component R_B (see Table H.6) should be considered. Suitable measures are as follows:

a) installing SPD of LPL IV at the service entrance to protect both power and telephone lines. According to Table B.3 this reduces the values of P_U and P_V (due to SPD on connected lines) from 1 to 0,03;
b) installing a LPS of class IV, which, according to Tables B.2 and B.3, reduces the value of P_B from 1 to 0,2 and the values of P_U and P_V (due to SPD on connected lines) from 1 to 0,03.

Inserting these values into the equations of Table H.6, new values of risk components are obtained, as shown in Table H.7.

Table H.7 – Values of risk components relevant to risk R_1 values × 10^{-5}) for suitable cases

Risk components	Values × 10^{-5}	
	Case a)	Case b)
R_A	0	0
R_B	0,103	0,020 6
$R_{U\ (Power\ line)}$	≈ 0	≈ 0
$R_{V\ (Power\ line)}$	0,026 3	0,026 3
$R_{U\ (Telecom\ line)}$	≈ 0	≈ 0
$R_{V\ (Telecom\ line)}$	0,042 3	0,042 3
TOTAL	0,171 6	0,089 2

The solution to be adopted is subject to the best technical/economic compromise..

H.2 Office building

As a second case study let us consider an office building for which the need for protection has to be evaluated.

In this aim, the risk R_1 of loss of human life (components of R_1 according to 4.3 and Table 3) shall be determined and compared with the tolerable value R_T = 10^{-5} (according to 5.5 and Table 7). The protection measures to mitigate such risk will be selected. Following the decision taken by the owner, the cost effectiveness of the adopted protection measures will not be evaluated.

H.2.1 Relevant data and characteristics

The following data and characteristics apply:

1) the building itself and its surroundings, given in Table H.8;
2) internal electrical systems and relevant incoming power line, given in Table H.9;
3) internal electronic systems and relevant incoming telecom line, given in Table H.10.

Table H.8 – Structure characteristics

Parameter	Comment	Symbol	Value
Dimensions (m)	–	$L_b \times W_b \times H_b$	40 × 20 × 25
Location factor	Isolated	C_d	1
LPS	None	P_B	1
Shield at structure boundary	None	K_{S1}	1
Shield internal to structure	None	K_{S2}	1
Lightning flash density	1/km²/year	N_g	4
People present in the structure	Inside and outside the structure	n_t	200

Table H.9 – Internal power system and connected power line characteristics

Parameter	Comment	Symbol	Value
Length (m)		L_c	200
Height (m)	Aerial	H_c	6
HV/LV transformer	No	C_t	1
Line location factor	Isolated	C_d	1
Line environment factor	Rural	C_e	1
Line shielding	None	P_{LD}	1
		P_{LI}	0,4
Internal wiring precaution	None	K_{S3}	1
Equipment withstand voltage U_w	U_w = 2,5 kV	K_{S4}	0,6
Coordinated SPD protection	None	P_{SPD}	1
End "a" line structure dimensions (m)	None	$L_a \times W_a \times H_a$	–

Table H.10 – Internal telecom system and connected TLC line characteristics

Parameter	Comment	Symbol	Value
Soil resistivity	Ωm	ρ	250
Length (m)	–	L_c	1 000
Height (m)	Buried	–	–
Line location factor	Isolated	C_d	1
Line environment factor	Rural	C_e	1
Line shielding	None	P_{LD}	1
		P_{LI}	1
Internal wiring precaution	None	K_{S3}	1
Equipment withstand voltage U_w	U_w = 1,5 kV	K_{S4}	1
Coordinated SPD protection	None	P_{SPD}	1
End "a" line structure dimensions (m)	None	$(L_a \times W_a \times H_a)$	–

H.2.2 Definition and characteristics of zones in the office building

Taking into account that

– the type of soil surface is different in the entrance area, in the garden and inside the structure,

– the structure and the archive are fire proof compartments,

– no spatial shields exist,

– losses L in the computer centre are assumed lower than those in the offices,

the following main zones may be defined:

– Z_1 entrance area to building;

– Z_2 garden;

- Z_3 archive – it is separated in a fire-proof compartment;
- Z_4 offices;
- Z_5 computer centre.

Characteristics of zones are given in Table H.11 for zone Z_1, in Table H.12 for zone Z_2, in Table H.13 for zone Z_3, in Table H.14 for zone Z_4 and in Table H.15 for zone Z_5.

Following the evaluation of the lightning protection designer, the typical mean values of relative amount of loss per year relevant to risk R_1 (see Table C.1)

- $L_t = 10^{-2}$ outside the structure,
- $L_t = 10^{-4}$ inside the structure,
- $L_f = 10^{-2}$,

were reduced, for each zone, taking into account the number of people potentially in danger in the zone of the structure versus the total number of people present in the structure.

Table H.11 – Zone Z_1 (entrance area to the building) characteristics

Parameter	Comment	Symbol	Value
Soil surface type	Marble	r_a	10^{-3}
Shock protection	None	P_A	1
Loss by touch and step voltages	Yes	L_t	2×10^{-4}
People potentially in danger in the zone			4

Table H.12 – Zone Z_2 (garden) characteristics

Parameter	Comment	Symbol	Value
Soil surface type	Grass	r_a	10^{-2}
Shock protection	Fence	P_A	0
Loss by touch and step voltages	Yes	L_t	10^{-4}
People potentially in danger in the zone			2

Table H.13 – Zone Z_3 (archive) characteristics

Parameter	Comment	Symbol	Value
Floor surface type	Linoleum	r_u	10^{-5}
Risk of fire	High	r_f	10^{-1}
Special hazard	Low panic	h_Z	2
Fire protection	None	r_p	1
Spatial shield	None	K_{S2}	1
Internal power systems	Yes	Connected to LV power line	–
Internal telephone systems	Yes	Connected to telecom line	–
Loss by touch and step voltages	Yes	L_t	10^{-5}
Loss by physical damage	Yes	L_f	10^{-3}
People potentially in danger in the zone			20

Table H.14 – Zone Z_4 (offices) characteristics

Parameter	Comment	Symbol	Value
Floor surface type	Linoleum	r_u	10^{-5}
Risk of fire	Low	r_f	10^{-3}
Special hazard	Low panic	h_Z	2
Fire protection	None	r_p	1
Spatial shield	None	K_{S2}	1
Internal power systems	Yes	Connected to LV power line	–
Internal telephone systems	Yes	Connected to telecom line	–
Loss by touch and step voltages	Yes	L_t	8×10^{-5}
Loss by physical damage	Yes	L_f	8×10^{-3}
People potentially in danger in the zone			160

Table H.15 – Zone Z_5 (computer centre) characteristics

Parameter	Comment	Symbol	Value
Floor surface type	Linoleum	r_u	10^{-5}
Risk of fire	Low	r_f	10^{-3}
Special hazard	Low panic	h_Z	2
Fire protection	None	r_p	1
Spatial shield	None	K_{S2}	1
Internal power systems	Yes	Connected to LV power line	–
Internal telephone systems	Yes	Connected to telecom line	–
Loss by touch and step voltages	Yes	L_t	7×10^{-6}
Loss by physical damage	Yes	L_f	7×10^{-4}
People potentially in danger in the zone			14

H.2.3 Calculation of relevant quantities

Calculations of collection areas are given in Table H.16, calculations of expected numbers of dangerous events are given in Table H.17 and assessment of expected annual losses are given in Table H.18.

Table H.16 – Collection areas of structure and lines

Symbol	Value m^2
A_d	$2,7 \times 10^4$
$A_{l\ (Power)}$	$4,5 \times 10^3$
$A_{i\ (Power)}$	2×10^5
$A_{l\ (Telecom)}$	$1,45 \times 10^4$
$A_{i\ (Telecom)}$	$3,9 \times 10^5$

Table H.17 – Expected annual number of dangerous events

Symbol	Value (1/year)
N_D	$1,1 \times 10^{-1}$
$N_{L\ (Power)}$	$1,81 \times 10^{-2}$
$N_{i\ (Power)}$	8×10^{-1}
$N_{L\ (Telecom)}$	$5,9 \times 10^{-2}$
$N_{i\ (Telecom)}$	1,581

H.2.4 Risk calculation for decision on need for protection

Involved risk components for each zone and total risk evaluation are given in Table H.18.

Table H.18 – Risk R_1- Values of risk components according to zones (values × 10^{-5})

Symbol	Z_1 Entrance area	Z_2 Garden	Z_3 Archive	Z_4 Offices	Z_5 Computer centre	Structure
R_A	0,002	0				0,002
R_B			2,21	0,177	0,016	2,403
$R_{U\ (Power\ line)}$			≈ 0	≈ 0	≈ 0	≈ 0
$R_{V\ (Power\ line)}$			0,362	0,029	0,002	0,393
$R_{U\ (Telecom\ line)}$			≈ 0	≈ 0	≈ 0	≈ 0
$R_{V\ (Telecom\ line)}$			1,18	0,094	0,008	1,282
TOTAL	0,002	0	3,752	0,3	0,026	**4,08**

H.2.5 Conclusion from R_1 evaluation

Because R_1 = 4,08 × 10^{-5} is higher than the tolerable value R_T = 10^{-5}, lightning protection for the structure is necessary.

H.2.6 Selection of protection measures

The composition of risk components (see 4.3.1 and 4.3.2) is given in Table H.19.

Table H.19 – Composition of risk R_1 components according to zones (values × 10^{-5})

Symbol	Z_1 Entrance area	Z_2 Garden	Z_3 Archive	Z_4 Offices	Z_5 Computer centre	Structure
R_D	0,002	0	2,21	0,177	0,016	2,405
R_I	0	0	1,542	0,123	0,01	1,673
TOTAL	0,002	0	3,752	0,3	0,026	**4,08**
R_S	0,002	0	≈ 0	≈ 0	≈ 0	0,002
R_F	0	0	3,752	0,3	0,026	4,312
R_O	0	0	0	0	≈ 0	0
TOTAL	0,002	0	3,752	0,3	0,026	**4,08**

where

$R_D = R_A + R_B + R_C$

$R_I = R_M + R_U + R_V + R_W + R_Z$

$R_S = R_A + R_U$

$R_F = R_B + R_V$

$R_O = R_M + R_C + R_W$

and

R_D is the risk due to flashes striking the structure (source S1);

R_I is the risk due to flashes not striking the structure but influencing it (sources: S2, S3 and S4);

R_S is the risk due to injury of living beings;

R_F is the risk due to physical damage;

R_O is the risk due to failure of internal systems.

This composition shows that the risk for the structure is mainly due to physical damage in the zone Z_3 caused by lightning striking the structure or the connected lines; the risk of fire (physical damage) in the zone Z_3 is 92 % of the total risk.

According to Table H.18, the primary contributing factors to the value of risk R_1 in zone Z_3 are due to:

- component R_B (lightning flash to structure) for 54 %;
- component $R_{V\ (Power\ line)}$ (lightning flash to power line) for ≈ 9 %;
- component $R_{V\ (Telecom\ line)}$ (lightning flash to telecom line) for ≈ 29 %.

To reduce the risk to the tolerable value the following protective measures could be adopted:

a) protect the building with a Class IV LPS conforming to IEC 62305-3 to reduce component R_B. This LPS does not have the characteristics of a grid-like spatial shield. Parameters in Table H.8, H.9, and H.10 will change as follows:
   - P_B = 0,2;
   - $P_U = P_V$ = 0,03 (due to SPDs on incoming lines).

b) install in the archive (zone Z_3) an automatic fire extinguishing (or detection) system, to reduce component R_B and R_V in this zone and SPDs of LPL IV at the entrance point in the building on both the power and telephone lines. Parameters in Table H.9, H.10 and H.13 will change as follows:

   r_p = 0,2 only for zone Z_3;

   $P_U = P_V$ = 0,03 (due to SPDs on incoming lines).

Values of risk for each zone are given in Table H.20.

Table H.20 – Values of risk R_1 according to solution chosen (values × 10^{-5})

	Z_1	Z_2	Z_3	Z_4	Z_5	TOTAL
Solution a)	0,002	0	0,488	0,039	0,003	**0,532**
Solution b)	0,002	0	0,451	0,18	0,015 8	**0,649**

Both solutions reduce the risk below the tolerable value.

The solution to be adopted is subject to both the best technical criteria and the most cost-effective solution.

H.3 Hospital

This next case study includes a standard hospital facility with an operating block and an intensive care unit.

Loss of human life (L1) and loss of economical value (L4) are components applicable to this type of facility. It is necessary to evaluate the need for protection and the cost effectiveness of protection measures, so risks R_1 and R_4 are evaluated.

H.3.1 Relevant data and characteristics

Data and characteristics of:

1) the building itself and its surroundings are given in Table H.21;
2) internal electrical systems and relevant incoming HV power line are given in Table H.22;
3) internal electronic systems and relevant incoming telecom line are given in Table H.23.

Table H.21 – Structure characteristics

Parameter	Comment	Symbol	Value
Dimensions (m)	–	$L_b \times W_b \times H_b$	50 × 150 × 10
Location factor	Isolated	C_d	1
LPS	None	P_B	1
Shield at structure boundary	None	K_{S1}	1
Shield internal to structure	None	K_{S2}	1
Lightning flash density	1/km^2/year	N_g	4
People present in the structure	Inside and outside the structure	n_t	1 000

Table H.22 – Internal power system and relevant incoming power line characteristics

Parameter	Comment	Symbol	Value
Soil resistivity	Ωm	ρ	200
Length (m)	–	L_c	500
Height (m)	Buried	–	–
HV/LV transformer	At building entrance	C_t	0,2
Line location factor	Surrounded by smaller objects	C_d	0,5
Line environment factor	Suburban	C_e	0,5
Line shield: bonded to equipotential bonding bar and equipment connected to the same bonding bar	R_S ≤1 (Ω/km)	P_{LD}	0,2
		P_{LI}	0,008
Internal wiring precaution	Unshielded cable – Routing precaution in order to avoid large loops	K_{S3}	0,2
Equipment withstand voltage U_w	U_w = 2,5 kV	K_{S4}	0,6
Coordinated SPD protection	None	P_{SPD}	1
End “a” line structure dimensions (m)	None	$L_a \times W_a \times H_a$	–

Table H.23 – Internal telecom system and relevant incoming line characteristics

Parameter	Comment	Symbol	Value
Soil resistivity	Ωm	ρ	200
Length (m)	–	L_c	300
Height (m)	Buried	–	–
Line location factor	Surrounded by smaller objects	C_d	0,5
Line environment factor	Suburban	C_e	0,5
Line shield: bonded to equipotential bonding bar and equipment connected to the same bonding bar	1 <R_S ≤5 (Ω/km)	P_{LD}	0,8
		P_{LI}	0,04
Internal wiring precaution	Unshielded cable – Routing precaution in order to avoid loops	K_{S3}	0,02
Equipment withstand voltage U_w	U_w = 1,5 kV	K_{S4}	1
Coordinated SPD protection	None	P_{SPD}	1
End “a” line structure dimensions (m)	None	$L_a \times W_a \times H_a$	20 × 30 × 5
Structure “a” location factor	Isolated	C_{da}	1

H.3.2 Definition and characteristics of zones in the hospital

Taking into account that

- the type of surface is different outside the structure from that inside of the structure;
- the structure and operating block are fire proof compartments;
- no spatial shields exist;
- the intensive care unity contains extensive sensitive electronic systems and a spatial shield may be adopted as protection measure;
- in the intensive care unity losses L are assumed to be higher than those in the other parts of the structure,

the following zones are defined:

Z_1 (outside building);

Z_2 (rooms block);

Z_3 (operating block);

Z_4 (intensive care unity).

Characteristics of these zones are given in Table H.24 for zone Z_1, in Table H.25 for zone Z_2, in Table H.26 for zone Z_3 and in Table H.27 for zone Z_4.

Following the evaluation of the lightning protection designer, the typical mean values of relative amount of losses per year relevant to risk R_1 (see Table C.1),

$L_t = 10^{-2}$ (outside the structure),

$L_t = 10^{-4}$ (inside the structure),

$L_f = 10^{-1}$,

$L_o = 10^{-3}$,

were reduced, for zones Z_1, Z_2 and Z_3. For zone Z_4 the default value, without reduction, was assumed, due to the particular characteristics of this zone: $L_o = 10^{-3}$.

For risk R_4 the typical mean values of relative amount of losses (see Table C.1) were assumed:

- $L_f = 5 \times 10^{-1}$
- $L_o = 10^{-2}$

Table H.24 – Zone Z_1 (outside building) characteristics

Parameter	Comment	Symbol	Value
Soil surface type	Concrete	r_a	1×10^{-2}
Shock protection	None	P_A	1
Loss by touch and step voltages	Yes	L_t	1×10^{-4}
People potentially in danger in the zone			10

Table H.25 – Zone Z_2 (rooms block) characteristics

Parameter	Comment	Symbol	Value
Floor surface type	Linoleum	r_u	1×10^{-5}
Risk of fire	Ordinary	r_f	1×10^{-2}
Special hazard (relevant to R_1)	Difficulty of evacuation	h_Z	5
Special hazard (relevant to R_4)	None	h_Z	1
Fire protection	None	r_p	1
Spatial shield	None	K_{S2}	1
Internal power systems	Connected to power line	–	–
Internal telecom systems	Connected to telecom line	–	–
Loss by touch and step voltages (relevant to R_1)	Yes	L_t	$9,5 \times 10^{-5}$
Loss by physical damage (relevant to R_1)	Yes	L_f	$9,5 \times 10^{-2}$
Loss by failure of internal systems (relevant to R_1)	None	L_o	–
People potentially in danger in the zone			950
Loss by physical damage (relevant to R_4)	Yes	L_f	5×10^{-1}
Loss by failure of internal systems (relevant to R_4)	Yes	L_o	1×10^{-2}

Table H.26 – Zone Z_3 (operating block) characteristics

Parameter	Comment	Symbol	Value
Floor surface type	Linoleum	r_u	1×10^{-5}
Risk of fire	Low	r_f	1×10^{-3}
Special hazard (relevant to R_1)	Difficulty of evacuation	h_Z	5
Special hazard (relevant to R_4)	None	h_Z	1
Fire protection	None	r_p	1
Spatial shield	None	K_{S2}	1
Internal power systems	Connected to power line	–	–
Internal telecom systems	Connected to telecom line	–	–
Loss by touch and step voltages (relevant to R_1)	Yes	L_t	$3,5 \times 10^{-6}$
Loss by physical damage (relevant to R_1)	Yes	L_f	$3,5 \times 10^{-3}$
Loss by failure of internal systems (relevant to R_1)	None	L_o	1×10^{-3}
People potentially in danger in the zone			35
Loss by physical damage (relevant to R_4)	Yes	L_f	5×10^{-1}
Loss by failure of internal systems (relevant to R_4)	Yes	L_o	1×10^{-2}

Table H.27 – Zone Z_4 (intensive care unity) characteristics

Parameter	Comment	Symbol	Value
Floor surface type	Linoleum	r_u	10^{-5}
Risk of fire	Low	r_f	10^{-3}
Special hazard (relevant to R_1)	Difficulty of evacuation	h_Z	5
Special hazard (relevant to R_4)	None	h_Z	1
Fire protection	None	r_p	1
Spatial shield	None	K_{S2}	1
Internal power systems	Connected to power line	–	–
Internal telecom systems	Connected to telecom line	-	-
Loss by touch and step voltages (relevant to R_1)	Yes	L_t	5×10^{-7}
Loss by physical damage (relevant to R_1)	Yes	L_f	5×10^{-4}
Loss by failure of internal systems (relevant to R_1)	Yes	L_o	1×10^{-3}
People potentially in danger in the zone			5
Loss by physical damage (relevant to R_4)	Yes	L_f	5×10^{-1}
Loss by failure of internal systems (relevant to R_4)	Yes	L_o	1×10^{-2}

H.3.3 Expected annual number of dangerous events

The expected annual number of dangerous events is evaluated according to Annex A. The resulting data is given in Table H.28.

Table H.28 – Expected annual number of dangerous events

Symbol	Value (1/year)
N_D	$8,98 \times 10^{-2}$
N_M	1,13
$N_{L\ (Power)}$	$2,67 \times 10^{-3}$
$N_{i\ (Power)}$	$7,1 \times 10^{-2}$
$N_{L\ (Telecom)}$	$7,26 \times 10^{-3}$
$N_{i\ (Telecom)}$	$2,13 \times 10^{-1}$
$N_{Da\ (Telecom)}$	$1,13 \times 10^{-2}$

H.3.4 Assessment of risk of loss of human life: R_1

Parameters required for the evaluation of risk components are given in Tables H.21 to H.29.

Risk components to be evaluated are given in Table H.29.

Values of probability P are given in Table H.30.

Table H.29 – Risk R_1 – Risk components to be considered according to zones

Symbol	Z_1	Z_2	Z_3	Z_4
R_A	X			
R_B		X	X	X
R_C			X	X
R_M			X	X
$R_{U(Power\ line\ )}$		X	X	X
$R_{V(Power\ line)}$		X	X	X
$R_{W(Power\ line)}$			X	X
$R_{Z(Power\ line)}$			X	X
$R_{U(Telecom\ line)}$		X	X	X
$R_{V(Telecom\ line)}$		X	X	X
$R_{W(Telecom\ line)}$			X	X
$R_{Z(Telecom\ line)}$			X	X

Table H.30 – Risk R_1 – Values of probability P for unprotected structure

Probability	Z_1	Z_2	Z_3	Z_4
P_A	1	–		
P_B	–	1		
$P_{C(power\ system)}$	–	1		
$P_{C(telecom\ system)}$	–	1		
P_C	–	1		
$P_{M(power\ system)}$	–	0,75		
$P_{M(telecom\ system)}$	–	0,009		
P_M	–	0,752		
$P_{U(power\ line)}$	–	0,2		
$P_{V(power\ line)}$	–	0,2		
$P_{W(power\ line)}$	–	0,2		
$P_{Z(power\ line)}$	–	0,008		
$P_{U(telecom\ line)}$	–	0,8		
$P_{V(telecom\ line)}$	–	0,8		
$P_{W(telecom\ line)}$	–	0,8		
$P_{Z(telecom\ line)}$	–	0,04		

Values of risk components for unprotected structure are reported in Table H.31.

Table H.31 – Risk R_1 – Values of risk components for unprotected structure according to zones (values × 10^{-5})

Symbol	Z_1	Z_2	Z_3	Z_4	Structure
R_A	0,009				0,009
R_B		42,7	0,157	0,022	44,01
R_C			8,98	8,98	8,98
R_M			85,2	85,2	85,2
$R_{U(\text{Power line})}$		≈0	≈0	≈0	≈0
$R_{V(\text{Power line})}$		0,25	≈0	≈0	0,26
$R_{W(\text{Power line})}$			0,053	0,053	0,053
$R_{Z(\text{Power line})}$			0,055	0,055	0,055
$R_{U(\text{Telecom line})}$		≈0	≈0	≈0	≈0
$R_{V(\text{Telecom line})}$		7,05	0,026	0,004	7,278
$R_{W(\text{Telecom line})}$			1,48	1,48	1,48
$R_{Z(\text{Telecom line})}$			0,825	0,825	0,825
TOTAL	**0,009**	**50**	**96,8**	**96,62**	**243,4**

H.3.5 Conclusion from R_1 evaluation

Because R_1 = 243,4 × 10^{-5} is higher than the tolerable value R_T = 10^{-5}, lightning protection for the structure is required.

H.3.6 Selection of protection measures

The composition of risk components (see 4.3.1 and 4.3.2) is given in Table H.32.

Table H.32 – Composition of risk R_1 components according to zones (values × 10^{-5})

Symbol	Z_1	Z_2	Z_3	Z_4	Structure
R_D	0,009	42,7	9,14	9,02	53,02
R_I	0	7,3	87,66	87,6	95,13
TOTAL	**0,009**	**50**	**96,8**	**96,62**	**243,4**
R_S	0,009	0	≈ 0	≈ 0	0,009
R_F	0	50	0,2	0,026	50,22
R_O	0	0	96,6	96,6	193,2
TOTAL	**0,009**	**50**	**96,8**	**96,62**	**243,4**

with

$R_D = R_A + R_B + R_C$

$R_I = R_M + R_U + R_V + R_W + R_Z$

$R_S = R_A + R_U$

$R_F = R_B + R_V$

$R_O = R_M + R_C + R_W$

where

R_D is the risk due to flashes striking the structure (source S1);

R_I is the risk due to flashes not striking the structure but influencing it (sources: S2, S3 and S4);

R_S is the risk due to injury of living beings;

R_F is the risk due to physical damage;

R_O is the risk due to failure of internal systems.

This composition shows that the risk R_1 for the structure is mainly due to failure of internal systems in zones Z_3 and Z_4 caused by lightning near the structure.

The risk R_1 is influenced by

- failures of internal systems in zones Z_3 and Z_4 (components R_M ≈57 % and R_C ≈6 % of the total risk),
- physical damages in the zone Z_2 (components R_B ≈ 27 % and R_V ≈ 4 % of the total risk).

Component R_B may be reduced either by

- an LPS conforming to IEC 62305-3 for the whole building,
- providing zone Z_2 with protection measures to reduce the consequences of fire (such as extinguishers, automatic fire detection system, etc.).

Components R_C and R_V may be reduced by providing the internal power and telecom systems with a coordinated SPD protection conforming to IEC 62305-4.

Component R_M in zones Z_3 and Z_4 may be reduced by:

- providing internal power and telecom systems with a coordinated SPD protection conforming to IEC 62305-4;
- providing zones Z_3 and Z_4 with an adequate spatial grid-like shield conforming to IEC 62305-4.

For protective measures the following solutions could be adopted:

a) First solution
   - Protect the building with a Class I LPS.
   - Install enhanced (1,5x) coordinated SPD protection with P_{SPD} = 0,005 on internal power and telecom systems.
   - Provide zone Z_2 with an automatic fire detection system.
   - Provide zones Z_3 and Z_4 with a meshed shield with w = 0,5 m.

   Using this solution, the parameters in Table H.25 will change, leading to the probabilities reported in Table H.33. The factor reducing the loss due to provisions against fire will change to r_p = 0,2 for zone Z_2.

Table H.33 – Risk R_1 – Values of probability P for the protected structure according to solution a)

Probability	Z_1	Z_2	Z_3	Z_4
P_A	1	–		
P_B	–	0,02		
$P_{C(Power\ system)}$	–		0,005	
$P_{C(Telecom\ system)}$	–		0,005	
P_C	–		0,001 99	
$P_{M(Power\ system)}$	–		0,000 1	
$P_{M(Telecom\ system)}$	–		0,000 1	
P_M	–		0,0 002	
$P_{U\ (power\ line)}$	–	0,005		
$P_{V\ (power\ line)}$	–	0,005		
$P_{W\ (power\ line)}$	–		0,005	
$P_{Z\ (power\ line)}$	–		0,005	
$P_{U\ (telecom\ line)}$	–	0,005		
$P_{V\ (telecom\ line)}$	–	0,005		
$P_{W\ (telecom\ line)}$	–		0,005	
$P_{Z\ (telecom\ line)}$	–		0,005	

b) Second solution

- Protect the building with a Class I LPS.
- Install enhanced (3x) coordinated SPD protection with P_{SPD} = 0,001 on internal power and telecom systems.
- Provide zone Z_2 with an automatic fire detection system.

Using this solution, the parameters in Table H.25 will change, leading to the probabilities reported in Table H.34. The factor reducing the loss due to provisions against fire will change to r_p = 0,5 for zone Z_2.

Table H.34 – Risk R_1 – Values of probability P for protected structure according to solution b)

Probability	Z_1	Z_2	Z_3	Z_4
P_A	1	–		
P_B	–	0,02		
$P_{C\ (power\ system)}$	–	0,001		
$P_{C\ (telecom\ system)}$	–	0,001		
P_C	–	0,002		
$P_{M\ (power\ system)}$	–	0,001		
$P_{M\ (telecom\ system)}$	–	0,001		
P_M	–	0,002		
$P_{U\ (power\ line)}$	–	0,001		
$P_{V\ (power\ line)}$	–	0,001		
$P_{W\ (power\ line)}$	–	0,001		
$P_{Z\ (power\ line)}$	–	0,001		
$P_{U\ (telecom\ line)}$	–	0,001		
$P_{V\ (telecom\ line)}$	–	0,001		
$P_{W\ (telecom\ line)}$	–	0,001		
$P_{Z\ (telecom\ line)}$	–	0,001		

c) Third solution

– Protect the building with a Class I LPS.

– Install enhanced (2x) coordinated SPD protection with P_{SPD} = 0,002 on internal power and telecom systems.

– Provide zone Z_2 with an automatic fire detection system.

– Provide zones Z_3 and Z_4 with a meshed shield having w = 0,1 m.

Using this solution, the parameters in Table H.25 will change, leading to the probabilities reported in Table H.35. The factor reducing the loss due to provisions against fire will change to r_p = 0,2 for zone Z_2.

Table H.35 – Risk R_1 – Values of probability P for the protected structure according to solution c)

Probability	Z_1	Z_2	Z_3	Z_4
P_A	1	-		
P_B	–	0,02		
$P_{C(Power\ system)}$	–		0,002	
$P_{C(Telecom\ system)}$	–		0,002	
P_C	–		0,004	
$P_{M(Power\ system)}$	–		0,000 1	
$P_{M(Telecom\ system)}$	–		0,000 1	
P_M	–		0,000 2	
$P_{U(Power\ line)}$	–	0,002		
$P_{V(Power\ line)}$	–	0,002		
$P_{W(Power\ line)}$	–		0,002	
$P_{Z(Power\ line)}$	–		0,002	
$P_{U(Telecom\ line)}$	–	0,002		
$P_{V(Telecom\ line)}$	–	0,002		
$P_{W(Telecom\ line)}$	–		0,002	
$P_{Z(Telecom\ line)}$	–		0,002	

Values of risk for each zone according to the solution selected are given in Table H.36.

Table H.36 – Risk R_1 – Values of risk according to solution chosen (values × 10^{-5})

	Z_1	Z_2	Z_3	Z_4	TOTAL
Solution a)	0,009	0,181	0,263	0,261	**0,714**
Solution b)	0,009	0,173	0,277	0,274	**0,733**
Solution c)	0,009	0,175	0,121	0,118	**0,423**

All solutions reduce the risk below the tolerable level.

The solution to be adopted is subject to both the best technical criteria and the most cost-effective solution.

H.3.7 Data for cost benefits analysis

The cost of total loss C_L may be calculated by Equation (G.1) of Annex G.

Economical values, including loss of activity, are given in Table H.37 for each zone.

Table H.37 – Values of costs of loss relevant to zones (values in \$ $\times 10^6$)

Symbol	Building B	Contents I	Power system A	Telecom system A	Total
Z_1	–	–	–		–
Z_2	70	6	3	0,5	**79,5**
Z_3	2	0,9	5	0,5	**8,4**
Z_4	1	0,1	0,015	1	**2,1**
Total	**73**	**7**	**8**	**2**	**90**

The values assumed for interest, amortization and maintenance rates relevant to the protection measures are given in Table H.38.

Table H.38 – Values relevant to rates

Rate	Symbol	Value
Interest	i	0,04
Amortization	a	0,05
Maintenance	m	0,01

H.3.8 Assessment of risk of economic loss: R_4

Parameters required for evaluating risk components are given in Tables H.31 through H.39.

Values of risk components for the unprotected structure are given in Table H.39.

Table H.39 – Risk R_4 – Values of risk components for unprotected structure according to zones (values $\times 10^{-5}$)

Symbol	Z_2	Z_3	Z_4
R_B	44,9	4,49	4,49
$R_{C(\text{Power line})}$	89,8	89,8	89,8
$R_{C(\text{Telecom line})}$	89,8	89,8	89,8
$R_{M(\text{Power line})}$	849	849	849
$R_{M(\text{Telecom line})}$	10,2	10,2	10,2
$R_{V(\text{Power line})}$	0,27	0,027	0,027
$R_{W(\text{Power line})}$	0,53	0,53	0,53
$R_{Z(\text{Power line})}$	0,55	0,55	0,55
$R_{V(\text{Telecom line})}$	7,42	0,74	0,74
$R_{W(\text{Telecom line})}$	14,8	14,8	14,8
$R_{Z(\text{Telecom line})}$	8,25	8,25	8,25

H.3.9 Cost benefits analysis

The cost of residual loss C_{RL} may be calculated using Equation (G.2) of Annex G once the new values of risk components have been evaluated according to selected protection measures (see H.3.4 – solutions a), b) and c)).

Values of the costs of loss C_L for the unprotected structure and of residual loss C_{RL} for structure protected in accordance with solutions a), b), and c) are given in Table H.40.

Table H.40 – Amount of losses C_L and C_{RL} (values in $)

Symbol	C_L (unprotected)	C_{RL} (protected) Solution a)	C_{RL} (protected) Solution b)	C_{RL} (protected) Solution c)
Z_2	68 801	3 503	3 325	4 066
Z_3	47 779	2 293	5 011	202
Z_4	1 430	27	927	64
Total	**118 010**	**5 824**	**9 262**	**4 332**

The cost C_P and the annual cost C_{PM} of protection measures are given in Table H.41 (see Equation (G.4) of Annex G).

Table H.41 – Costs C_P and C_{PM} of protection measures (values in $)

Protection measures	C_P	C_{PM}
LPS class I	100 000	10 000
Fire detection system	50 000	5 000
Zones Z_3 and Z_4 shielding (w = 0,5)	100 000	10 000
Zones Z_3 and Z_4 shielding (w = 0,1)	110 000	11 000
SPD (1,5x) on power system	20 000	2 000
SPD (2x) on power system	24 000	2 400
SPD (3x) on power system	30 000	3 000
SPD (1,5x) on TLC system	10 000	1 000
SPD (2x) on TLC system	12 000	2 000
SPD (3x) on TLC system	15 000	1 500

Annual saving of money

$$S = C_L - (C_{RL} + C_{PM})$$

is given in Table H.42.

Table H.42 – Annual saving of money (values in $)

Solution a)	84 186
Solution b)	89 248
Solution c)	84 078

H.4 Apartment house

As for the previous study case, the risk R_1 for an apartment house located in a region with a lightning flash density N_g = 4 flashes per km^2 per year will be evaluated.

According to Table 3 risk components R_B, R_U and R_V shall be evaluated.

The building is isolated: there are no other neighbouring structures.

Incoming services are as follows:

– LV power line;
– telephone line;

Structure characteristics are given in Table H.43.

Table H.43 – Structure characteristics

Parameter	Comment	Symbol	Value
Dimensions (m)	–	$L_b \times W_b \times H_b$	30 × 20 × 20
Location factor	Isolated	C_d	1
LPS	None	P_B	1
Lightning flash density	1/km²/year	N_g	4

The following zones can be defined:

- Z_1 (outside the building);
- Z_2 (inside the building).

There are no people located outside the building; risk R_1 for zone Z_1 may be therefore disregarded.

Economic evaluation is not required.

Parameters of zone Z_2 are given in Table H.44.

Table H.44 – Zone Z_2 parameters

Parameter	Comment	Symbol	Value
Floor surface type	Wood	r_u	10^{-5}
Risk of fire	Variable	r_f	–
Special hazard	None	h_Z	1
Fire protection	None	r_p	1
Shock protection	None	–	–
Internal power systems	Connected to LV power line	–	–
Internal telephone systems	Connected to telecom line	–	–
Loss by touch and step voltages (relevant to R_1)	Yes	L_t	10^{-4}
Loss by physical damages (relevant to R_1)	Yes	L_f	10^{-1}

Characteristics of internal systems and of relevant incoming lines are given in Table H.45 for a power system and in Table H.46 for a telecommunication system.

Table H.45 – Internal power system and relevant incoming line parameters

Parameter	Comment	Symbol	Value
Soil resistivity	Ωm	ρ	250
Length (m)	–	L_c	200
Height (m)	Buried	–	–
HV/LV transformer	None	C_t	1
Line location factor	Surrounded by smaller objects	C_d	0,5
Line environment factor	Suburban	C_e	0,5
Line shield	Unshielded	P_{LD}	1
		P_{LI}	0,4
Equipment withstand voltage U_w	U_w = 2,5 kV	K_{S4}	0,6
Coordinated SPD protection	None	P_{SPD}	1
End “a” line structure dimensions (m)	None	$L_a \times W_a \times H_a$	–

Table H.46 – Internal telecom system and relevant incoming line parameters

Parameter	Comment	Symbol	Value
Soil resistivity	(Ωm)	ρ	250
Length (m)	–	L_c	100
Height (m)	Buried	-	-
Line location factor	Surrounded by smaller objects	C_d	0,5
Line environment factor	Suburban	C_e	0,5
Line shielding	None	P_{LD}	1
		P_{LI}	1
Equipment withstand voltage U_w	U_w = 1,5 kV	K_{S4}	1
Coordinated SPD Protection	None	P_{SPD}	1
End “a” line structure dimensions (m)	None	$(L_a \times W_a \times H_a)$	-

Risk R_1 values and protection measures to be adopted to reduce the risk to the tolerable level $R_T = 10^{-5}$ are given in Table H.47 according to the height of the building and its risk of fire.

Table H.47 – Protection measures to be adopted according to the height of the building and its risk of fire

Risk of fire	Height m	LPS type	Anti-fire protection	R_1 (×10^{-5})	Structure protected
Low	20	–	–	0,77	x
Ordinary		–	–	7,7	No
		III	–	0,74	x
		IV	(2)	0,73	x
High		–	–	77	No
		II	(3)	0,74	x
		I	–	1,49	No
		I	(1)	0,74	x
Low	40	–	–	2,33	No
		–	(3)	0,46	x
		IV	–	0,46	x
Ordinary		–	–	23,3	No
		IV	(3)	0,93	x
		I	–	0,46	x
High		–	–	233	No
		I	(3)	0,93	x

(1) Extinguishers.

(2) Hydrants.

(3) Automatic alarm.

Annex I
(informative)

Case study for services – Telecommunication line

I.1 General

The service to be considered is a telecommunication line using metallic conductors. Loss of public service (L2) and loss of economical value (L4) may affect this type of service so that the corresponding risks R'_2 and R'_4 should be evaluated, but following the request of the network operator, only risk R'_2 will be considered.

I.2 Basic data

The line, located in a region with N_g = 4 flashes per km^2 per year, is shown in Figure I.1 (no equipment is installed along the line).

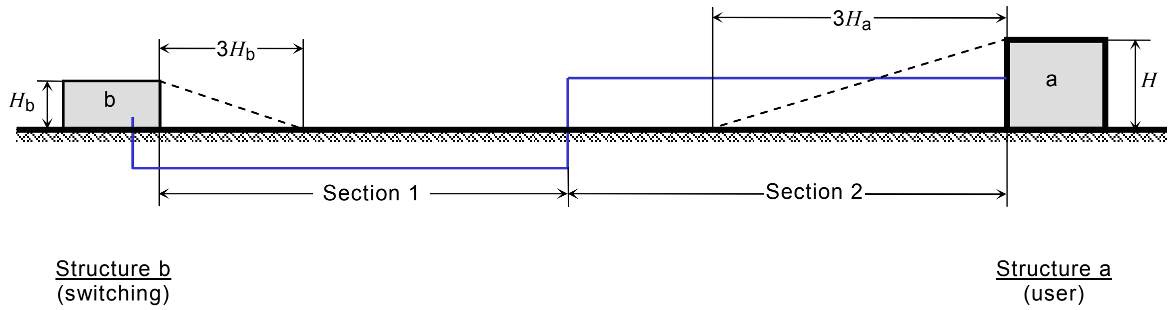


Figure I.1 – Telecommunication line to be protected

I.3 Line characteristics

The line consists of 2 sections:

— section S_1: buried shielded line connected to switching building: no protection measures are installed in this section;

— section S_2: aerial unshielded line connected to customer's building: no protection measures are installed in this section;

and 3 transition points:

— T_b: at the entrance of section S_1 into building "b" (i.e. the switching building): no protection measures are installed in this point;

— $T_{1/2}$: between section S_1 and section S_2: no protection measures are installed in this point;

— T_a: at the entrance of section S_2 into building "a" (i.e. the customer's building): no protection measures are installed in this point.

The shield of section S_1 is connected to earth at both ends (i.e. at the bonding bar in the switching building (T_b) and at the transition point $T_{1/2}$) with an earth resistance value of some tens of ohms.

Characteristics of the line are given in Table I.1 for section S_1 and in Table I.2 for section S_2.

Table I.1 – Section S_1 of line characteristics

Parameter	Comment	Symbol	Value
Soil resistivity	Ωm	ρ	500
Length (m)	–	L_c	600
Height (m)	Buried	–	–
Line location factor	Surrounded	C_d	0,5
Line environment factor	Rural	C_e	1
Line shielding resistance (Ω/km)	–	R_S	0,5
Type of line shield	Lead	–	–
Shield characteristics	No contact with soil	K_d	0,4
Type of line insulation	Paper	U_w (kV)	1,5
Type of equipment in transition point T_b	Electronic	U_w (kV)	1,5 (1)
Type of equipment in transition point $T_{1/2}$	None	–	–
Protection measures	None	K_p	1
(1) Enhanced level of ITU-T Recommendation K.20 [4].			

Table I.2 – Section S_2 of line characteristics

Parameter	Comment	Symbol	Value
Soil resistivity	Ωm	ρ	500
Length (m)	–	L_c	800
Height (m)	Aerial	H_c	6
Line location factor	Surrounded	C_d	0,5
Line environment factor	Rural	C_e	1
Line shielding resistance (Ω/km)	Unshielded	–	–
Type of line insulation	Plastic	U_w (kV)	5
Type of equipment in transition point T_a	Electronic	U_w (kV)	1,5 (1)
Type of equipment in transition point $T_{1/2}$	None	-	-
Protection measures	None	K_p	1
(1) Enhanced level of ITU-T Recommendation K.20.			

I.4 End of line structure characteristics

Characteristics of end of line structures are given in Table I.3.

Table I.3 – End of line structure characteristics

Structure	Dimensions m $L \times W \times H$	Location factor C_d	Number n of services to structure
"a"	25 × 20 ×15	2	3
"b"	20 × 30 × 10	0,5	10

I.5 Expected annual number of dangerous events

Expected annual number of dangerous events is evaluated according to Annex A.

Data are reported in Table I.4.

Table I.4 – Expected annual number of dangerous events

Parameter	Value (1/year)
N_{Da}	0,087 3
N_{Db}	0,012 9
$N_{L\ (S1)}$	0,023 5
$N_{I\ (S1)}$	0,617
$N_{L\ (S2)}$	0,052 2
$N_{I\ (S2)}$	1,6

I.6 Risk components

Risk components involved in each section are given in Table I.5.

Table I.5 – Risk R'_2 – Risk components relevant to sections S of the line

Parameter	S_1	S_2
$R'_{B(a)}$	–	x
$R'_{B(b)}$	x	–
$R'_{C(a)}$	–	x
$R'_{C(b)}$	x	–
R'_V	x	x
R'_W	x	x
R'_Z	x	x

Failure currents and probabilities needed for evaluation of risk components are given in Table I.6.

Table I.6 – Risk R'_2 – Values of failure currents and probabilities P' for unprotected structure

Parameter	S_1	S_2
$I_{a(B,C)}$ (kA)	>600(1)	0(2)
$I_{a(V)}$ (kA)	40(3)	0(2)
$I_{a(W)}$ (kA)	125(4)	0(2)
$P'_{B(a)(Ia(B))}$	-	1(5)
$P'_{B(b)(Ia(B))}$	0,001(5)	–
$P'_{C(a)(Ia(C))}$	–	1(5)
$P'_{C(b)(Ia(C))}$	0,001(5)	–
$P'_{V(Ia(V))}$	0,4	1
$P'_{W(Ia(W))}$	0,035	1
$P'_{Z(Ta)}$ (for equipment in transition point T_a, U_w = 1,5 kV) (6)	0,5(8)	1(8)
$P'_{Z(Tb)}$ (for equipment in transition point T_b, U_w = 1,5 kV) (6)	0,02(7)	1(8)
$P'_{Z(T1/2)}$ (for breakdown insulation of buried cable, U_w = 1,5 kV) (6)	0,5(9)	1(8)

(1) $I_a = 25\, n\, U_w / (R_s \times K_d \times K_p)$ with K_p = 1 and K_d = 0,4 (see Annex D.1 and Table D.1).

(2) I_a = 0 for unshielded line (see Annex D.1).

(3) Limited to 40 kA because lead shield (see D.1.2).

(4) $I_a = 25\, U_w / (R_s \times K_d \times K_p)$) with K_p = 1 and K_d = 0,4 (see Annex D.1.2 and Table D.1).

(5) See Table D.5.

(6) Values of P'_Z are reported in Table B.7. The rule to use Table B.7 for shielded section is the following:

When the considered transition point is between two shielded sections or the shielded section is entering the structure and is connected to the bonding bar where the equipment is connected, the values of Table B.7 given in the columns "Shield bonded to …" apply to shielded sections.

In all the other cases, the values of Table B.7 given in the columns "Shield not bonded to …" apply to shielded sections, if the shield is connected to earth at least at both ends with earth resistance value of some tens of ohms. Otherwise the shielded section shall be considered as unshielded ones.

(7) Values of Table B.7 under the columns "Shield bonded to …".

(8) Values of Table B.7 under the column "No shield".

(9) Values of Table B.7 under the column "Shield not bonded …".

I.7 Assessment of risk R'_2

Following the evaluation of the lightning protection designer based on network operator's experience, the following mean values of relative amount of loss per year relevant to risk R_2 were assumed:

$L_f = 3 \times 10^{-3}$

$L_o = 10^{-3}$ (default value – see Table E.1).

Values of risk components for the unprotected line are given in Table I.7.

Table I.7 – Risk R'_2 – Values of risk components for unprotected line according to sections S of the line (values ×10^{-3})

Parameter	S_1	S_2	Line
$R'_{B(a)}$ (1)	–	0,261	0,261
$R'_{B(b)}$ (1)	≅0	–	≅0
$R'_{C(a)}$ (2)	–	0,087 3	0,0873
$R'_{C(b)}$ (2)	≅0	–	≅0
R'_V	0,028 2	0,156 6	0,184 8
R'_W	0,000 8	0,052 2	0,053
$R' = R'_{B(a)} + R'_{B(b)} + R'_{C(a)} + R'_{C(b)} + R'_V + R'_W$			0,586 1
$R'_{Z(Ta)}$ (5)	0,296 7	1,547 8	1,845
$R'_{Z(Tb)}$ (6)	0,011 9	1,547 8	1,59
$R'_{Z(T1/2)}$ (7)	0,296 7	1,547 8	1,845
$R_{2(Ta)} = R' + R'_{Z(Ta)}$			**2,431 1**
$R_{2(Tb)} = R' + R'_{Z(Tb)}$			2,176 1
$R_{2(T1/2)} = R' + R'_{Z(T1/2)}$			**2,431 1**

(1) $R'_B = N_D \times P'_B \times L'_f$

(2) $R'_C = N_D \times P'_C \times L'_0$

(3) $R'_V = N_L \times P'_V \times L'_f$

(4) $R'_W = N_L \times P'_W \times L'_0$

(5) $R'_{Z(Ta)} = (N_I - N_L) \times P'_{Z(Ta)} \times L'_0$

(6) $R'_{Z(Tb)} = (N_I - N_L) \times P'_{Z(Tb)} \times L'_0$

(7) $R'_{Z(T1/2)} = (N_I - N_L) \times P'_{Z(T1/2)} \times L'_0$

The value of the risk R'_2 = 3,508 ×10^{-3} is greater than the tolerable value R_T = 10^{-3}, therefore the line needs to be protected against lightning.

Table I.7 shows that, due to the risk component R'_Z in section S_2, the risk R'_2 overcame the tolerable value in transition points T_a, T_b and $T_{1/2}$. Therefore this risk component must be reduced. Because the line is already installed (therefore it is not possible to use, for example, a shielded section instead of the unshielded one), SPDs conforming to IEC 62305-5 shall be used as protective measure.

In order to reduce the risk R'_2 below the tolerable value, it is enough to select SPDs in accordance with LPL III, i.e. P_{SDP} = 0,03 (see Table B.3).

The SPD installation at transition points T_a and $T_{1/2}$:

– reduces the probabilities $P'_{Z(Ta)}$ and $P'_{Z(T1/2)}$ to the value P_{SPD};

– does not affect the probabilities P'_V and P'_W (see D.1.2);

– does not affect the probabilities P'_B and P'_C relevant to section S_2 because it is aerial (see D.1.1);

– does not affect the probabilities P'_B and P'_C relevant to section S_1 because they are lower than P_{SPD} (see D.1.1).

Moreover, according to definition 3.25 and Clause A.4, with the SPDs installed in the transition point $T_{1/2}$, $T_{1/2}$ becomes a “node” for the transition point T_b and section S_2 of the line not longer contributes longer to the value of risk component $R'_{Z(Tb)}$ (see Annex A of IEC 62305-5).

Values of probabilities P' for the protected line are given in Table I.8.

Table I.8 – Risk R'_2 – Values of probabilities P' for the protected line

Parameter	S_1	S_2
$P'_{B(a)(Ia(B))}$	–	1
$P'_{B(b)(Ia(B))}$	0,001	–
$P'_{C(a)(Ia(C))}$	–	1
$P'_{C(b)(Ia(C))}$	0,001	–
$P'_{V(Ia(V))}$	0,4	1
$P'_{W(Ia(W))}$	0,035	1
$P'_{Z(Ta)}$ (for equipment in transition point T_a, U_w = 1,5 kV)	0,03	0,03
$P'_{Z(Tb)}$ (for equipment in transition point T_b, U_w = 1,5 kV)	0,02	–
$P'_{Z(T1/2)}$ (for breakdown insulation of buried cable, U_w = 1,5 kV)	0,03	0,03

Values of risk components for the protected line are reported in Table I.9 which shows that the risk R'_2 is lower that the tolerable value; therefore the protection of the line against lightning is achieved.

Table I.9 – Risk R'_2 – Values of risk components for the line protected with SPDs installed in the transition point $T_{1/2}$ and T_a with P_{SPD} = 0,03 (values × 10^{-3})

Parameter	S_1	S_2	Line
$R'_{B(a)}$	–	0,261	0,261
$R'_{B(b)}$	≅0	–	≅0
$R'_{C(a)}$	–	0,087 3	0,087 3
$R'_{C(b)}$	≅0	–	≅0
R'_V	0,028 2	0,156 6	0,184 8
R'_W	0,000 8	0,052 2	0,053
$R' = R'_{B(a)} + R'_{B(b)} + R'_{C(a)} + R'_{C(b)} + R'_V + R'_W$			0,586 1
$R'_{Z(T_a)}$	0,017 8	0,055 3	0,073 1
$R'_{Z(T_b)}$	0,011 9	–	0,011 9
$R'_{Z(T_{1/2})}$	0,017 8	0,055 3	0,073 1
$R_{2(T_a)} = R' + R'_{Z(T_b)}$			**0,659 2**
$R_{2(T_b)} = R' + R'_{Z(T_a)}$			0,598
$R_{2(T_{1/2})} = R' + R'_{Z(T_{1/2})}$			**0,659 2**

Annex J
(informative)

Simplified software for risk assessment for structures

J.1 Fundamentals

The Simplified IEC Risk Assessment Calculator (SIRAC) is a software tool based on calculations and methods given in IEC 62305-2 and assists in the calculation of the risk components of simple structures. It is intended to support the application of IEC 62305-2 as the risk management method for lightning protection purposes. It is important to note that this tool is a simplified implementation of the more rigorous treatment of risk management described elsewhere in this standard. The calculator is designed to be relatively intuitive for users wishing to obtain an initial assessment of risk sensitivity.

The purpose and limitations of SIRAC are as follows:

– To enable more general users of the standard IEC 62305-2 to conduct calculations on typical structures without requiring them to possess in-depth knowledge of details and methodologies covered in the body of the standard.
– To promote the application of IEC 62305-2 and adoption of its risk assessment method by a wider readership and range of users. It is believed that such a user-friendly tool will also serve to increase the acceptance of the standard in the wider lightning protection community.
– To provide a tool specifically tailored to the calculation of risk in typical, non-complicated, structures and more general situations. To achieve this aim, certain parameters are defaulted to fixed values and the user required only to make selections from a more limited subset.
– The software does not implement the full functionality of this standard; such an implementation would have added unintended complexity to the tool. Users are encouraged to use the written standard for a more detailed treatment of risk when assessing complicated structures or special circumstances.
– it is applicable only for the calculation of single-zone structures.
– SIRAC should be viewed as a companion tool to IEC 62305-2 and will be supported through an on-line update function to an IEC FTP server where downloads will be available as the tool is updated.

J.2 Description of parameters

Parameters important to the calculation of the risk components in the software tool are divided into three categories:

– parameters, which the user is required to select in accordance with definitions and possibilities provided in the standard (see Table J.1);
– parameters, where the user’s choice is limited to a subset of those provided in the standard (see Table J.2);
– parameters, which are fixed in code and which the user cannot alter (see Table J.3).

Table J.1 – Parameters for the user to change freely

Parameter	Abbreviation/ Symbol
Length, width and height of structure to be protected	L, W, H
Lightning ground flash density	N_g
Location factor	C_d
Environmental factor	C_e
Type of service (power line, other overhead services, other underground services) Remark: A transformer is only possible for the power line	
Lightning protection system according to IEC 62305-3	P_B
Surge (overvoltage) protection for the services - only at the entrance (equipotential bonding SPD) - or a coordinated SPD protection according to IEC 62305-4 for the whole internal system connected to the services Remark: The user may only select one value for the surge protection. This value is valid for all services and for the entire structure to be protected	P_{SPD}
Risk of fire or physical damage to the structure	r_f
Fire protection	r_p
Special hazards	h_Z
Choice of the relevant losses (loss types)	

Table J.2 – Limited subset of parameters to be changed by the user

Parameter	Abbreviation/ Symbol
Structure screening effectiveness	K_{S1}
Internal wiring type	K_{S3}
Screening of external services (type of external cabling)	P_{LD}, P_{LI}
Loss factors due to fire: the user is asked for the type of structure to be protected Remark: A calculation of L_f for all four loss types, as defined in Annex C, is not possible. The user has to select the type of structure to be protected out of the given list	L_f
Loss factors due to overvoltages Remark: A calculation of L_o for all four loss types, as defined in Annex C, is not possible. The user has to select the type of structure to be protected out of the given list	L_o
For losses of type L4, economic loss, there is no implementation of the investigation of the cost-effectiveness of protection measures in this simplified software solution. If this is required, the user has to select a tolerable risk of economic loss	

Table J.3 – Fixed parameters (not to be altered by the user)

Parameter	Symbol	Fixed value
Length of the services	L_c	1 000 m
In case of overhead services: height	H_c	6 m
No adjacent building is taken into account	N_{Da}	0
No screening effectiveness of zones internal to the structure is taken into account	K_{S2}	1
Impulse withstand voltage of the internal equipment connected to this service (1,5 kV)	K_{S4}	1
Probability for shock to living beings	P_A	1
Type of soil or floor	r_a	10-2
For loss of type L1, loss of human life, loss factor for step and touch voltages inside and up to 3 m outside the structure to be protected	L_t	0,01

NOTE Further information concerning parameter values can be found directly in SIRAC (contact the arrow of the click-down menu with the mouse).

J.3 Example of screen shot

Screen shots for the example described in Clause H.1 (country house) are given in Figure J.1 (no protection measures provided) and in Figure J.2 (protection measures provided as described in Clause H.1, namely LPS Class IV and SPDs at the service entrances).

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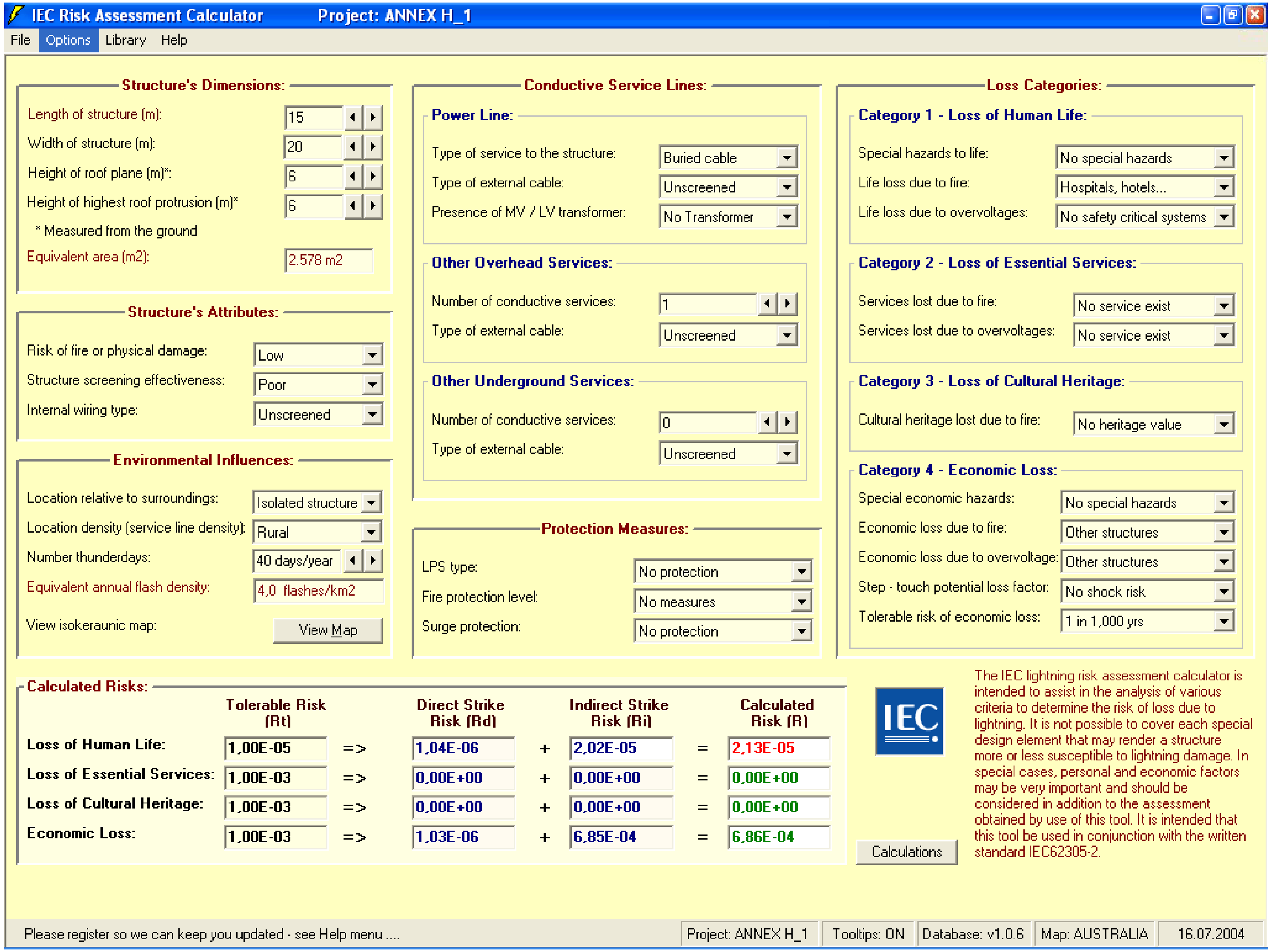

Figure J.1 – Example for a country house (see Clause H.1 – no protection measures provided)

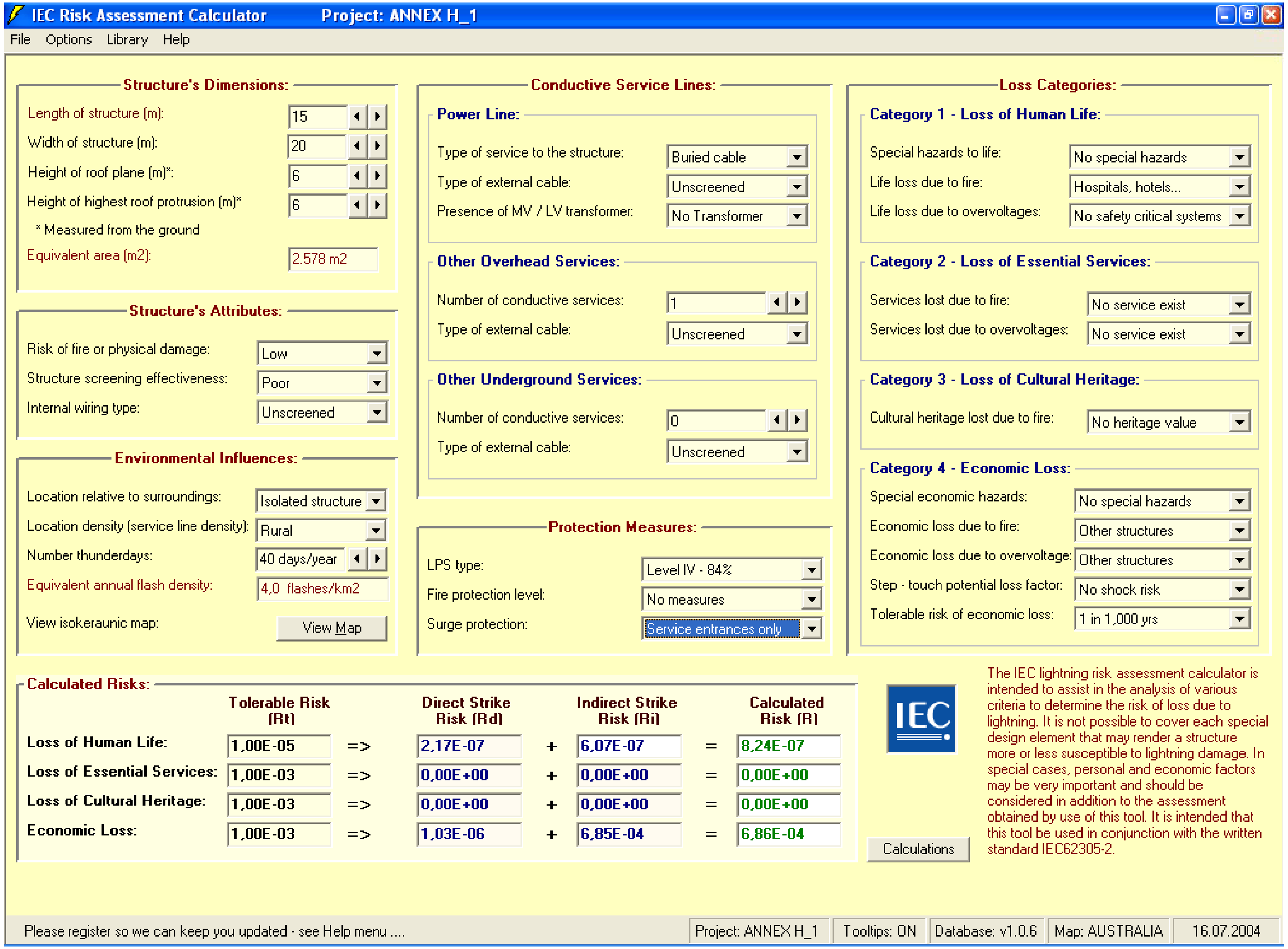

Figure J.2 – Example for a country house (see Clause H.1 – protection measures provided)

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[4] ITU-T Recommendation K.20:2003, *Resistibility of telecommunication equipment installed in a telecommunications centre to overvoltages and overcurrents*

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