EEP17/8/21

IEC 62305-2

Edition 2.0 2010-12

INTERNATIONAL STANDARD

colour inside

Protection against lightning –
Part 2: Risk management

IEC 62305-2:2010(E)

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

About the IEC

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

About IEC publications

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

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

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 It also gives information on projects, withdrawn and replaced publications.

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

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

- Electropedia: www.electropedia.org

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

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

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

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

IEC 62305-2

Edition 2.0 2010-12

INTERNATIONAL STANDARD

colour inside

Protection against lightning –
Part 2: Risk management

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

PRICE CODE XC

ICS 29.020; 91.120.40

ISBN 978-2-88912-281-3

CONTENTS

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.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

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

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

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

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

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

6) Tables are provided to select the relative amount of loss in all cases.
7) Impulse withstand voltage level of equipments was extended down to 1 kV.

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

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

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

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

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

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

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

A bilingual version of this standard may be issued at a later date.

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

INTRODUCTION

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

The hazard to a structure can result in

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

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

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

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

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

Lightning flashes influencing the structure may be divided into

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

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

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

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

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

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

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

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

---

1 Figures in square brackets refer to the bibliography.

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

PROTECTION AGAINST LIGHTNING –

Part 2: Risk management

1 Scope

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

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

2 Normative references

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

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

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

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

3 Terms, definitions, symbols and abbreviations

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

3.1 Terms and definitions

3.1.1
structure to be protected
structure for which protection is required against the effects of lightning in accordance with this standard

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

3.1.2
structures with risk of explosion
structures containing solid explosives materials or hazardous zones as determined in accordance with IEC 60079-10-1[2] and IEC 60079-10-2[3]

3.1.3
structures dangerous to the environment
structures which may cause biological, chemical or radioactive emission as a consequence of lightning (such as chemical, petrochemical, nuclear plants, etc.)

3.1.4
urban environment
area with a high density of buildings or densely populated communities with tall buildings

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

3.1.5
suburban environment
area with a medium density of buildings

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

3.1.6
rural environment
area with a low density of buildings

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

3.1.7
rated impulse withstand voltage level
$U_{\mathbf{W}}$
impulse withstand voltage assigned by the manufacturer to the equipment or to a part of it, characterizing the specified withstand capability of its insulation against (transient) overvoltages

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

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

3.1.8
electrical system
system incorporating low voltage power supply components

3.1.9
electronic system
system incorporating sensitive electronic components such as telecommunication equipment, computer, control and instrumentation systems, radio systems, power electronic installations

3.1.10
internal systems
electrical and electronic systems within a structure

3.1.11
line
power line or telecommunication line connected to the structure to be protected

3.1.12
telecommunication lines
lines intended for communication between equipment that may be located in separate structures, such as phone lines and data lines

3.1.13
power lines
distribution lines feeding electrical energy into a structure to power electrical and electronic equipment located there, such as low voltage (LV) or high voltage (HV) electric mains

3.1.14
dangerous event
lightning flash to or near the structure to be protected, or to or near a line connected to the structure to be protected that may cause damage

3.1.15
lightning flash to a structure
lightning flash striking a structure to be protected

3.1.16
lightning flash near a structure
lightning flash striking close enough to a structure to be protected that it may cause dangerous overvoltages

3.1.17
lightning flash to a line
lightning flash striking a line connected to the structure to be protected

3.1.18
lightning flash near a line
lightning flash striking close enough to a line connected to the structure to be protected that it may cause dangerous overvoltages

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

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

3.1.23
lightning electromagnetic impulse
LEMP
all electromagnetic effects of lightning current via resistive, inductive and capacitive coupling, which create surges and electromagnetic fields

3.1.24
surge
transient created by LEMP that appears as an overvoltage and/or overcurrent

3.1.25
node
point on a line from which onward surge propagation can be assumed to be neglected

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

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

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

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

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

3.1.29
probability of damage
P_X
probability that a dangerous event will cause damage to or in the structure to be protected

3.1.30
loss
L_X
mean amount of loss (humans and goods) consequent on a specified type of damage due to a dangerous event, relative to the value (humans and goods) of the structure to be protected

3.1.31
risk
R
value of probable average annual loss (humans and goods) due to lightning, relative to the total value (humans and goods) of the structure to be protected

3.1.32
risk component
R_X
partial risk depending on the source and the type of damage

3.1.33
tolerable risk
R_T
maximum value of the risk which can be tolerated for the structure to be protected

3.1.34
zone of a structure
Z_S
part of a structure with homogeneous characteristics where only one set of parameters is involved in assessment of a risk component

3.1.35
section of a line
S_L
part of a line with homogeneous characteristics where only one set of parameters is involved in the assessment of a risk component

3.1.36
lightning protection zone
LPZ
zone where the lightning electromagnetic environment is defined

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

3.1.37
lightning protection level
LPL
number related to a set of lightning current parameters values relevant to the probability that the associated maximum and minimum design values will not be exceeded in naturally occurring lightning

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

3.1.38
protection measures
measures to be adopted in the structure to be protected, in order to reduce the risk

3.1.39
lightning protection
LP
complete system for protection of structures against lightning, including their internal systems and contents, as well as persons, in general consisting of an LPS and SPM

3.1.40
lightning protection system
LPS
complete system used to reduce physical damage due to lightning flashes to a structure

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

3.1.41
LEMP protection measures
SPM
measures taken to protect internal systems against the effects of LEMP

NOTE This is part of overall lightning protection

3.1.42

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

3.1.43
lightning protective cable
special cable with increased dielectric strength and whose metallic sheath is in continuous contact with the soil either directly or by use of conducting plastic covering

3.1.44
lightning protective cable duct
cable duct of low resistivity in contact with the soil

EXAMPLE Concrete with interconnected structural steel reinforcements or metallic duct.

3.1.45
surge protective device
SPD
device intended to limit transient overvoltages and divert surge currents; contains at least one non-linear component

3.1.46
coordinated SPD system
SPDs properly selected, coordinated and installed to form a system intended to reduce failures of electrical and electronic systems

3.1.47
isolating interfaces
devices which are capable of reducing conducted surges on lines entering the LPZ

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

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

3.1.48
lightning equipotential bonding
EB
bonding to LPS of separated metallic parts, by direct conductive connections or via surge protective devices, to reduce potential differences caused by lightning current

3.1.49
zone 0
place in which an explosive atmosphere consisting of a mixture of air and flammable substances in the form of gas, vapour or mist is present continuously or for long periods or frequently

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

3.1.50
zone 1
place in which an explosive atmosphere consisting of a mixture of air and flammable substances in the form of gas, vapour or mist is likely to occur in normal operation occasionally

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

3.1.51
zone 2
place in which an explosive atmosphere consisting of a mixture of air and flammable substances in the form of gas, vapour or mist is not likely to occur in normal operation but, if it does occur, will persist for a short period only

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

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

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

3.1.52
zone 20
place in which an explosive atmosphere, in the form of a cloud of combustible dust in air, is present continuously, or for long periods, or frequently

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

3.1.53
zone 21
place in which an explosive atmosphere, in the form of a cloud of combustible dust in air, is likely to occur in normal operation occasionally

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

3.1.54
zone 22
place in which an explosive atmosphere, in the form of a cloud of combustible dust in air, is not likely to occur in normal operation but, if it does occur, will persist for a short period only

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

3.2 Symbols and abbreviations

a	Amortization rate	Annex D
A_D	Collection area for flashes to an isolated structure	A.2.1.1
A_{DJ}	Collection area for flashes to an adjacent structure	A.2.5
A_D'	Collection area attributed to an elevated roof protrusion	A.2.1.2
A_I	Collection area for flashes near a line	A.5
A_L	Collection area for flashes to a line	A.4
A_M	Collection area for flashes striking near the structure	A.3
B	Building	A.2
C_D	Location factor	Table A.1
C_{DJ}	Location factor of an adjacent structure	A.2.5
C_E	Environmental factor	Table A.4
C_I	Installation factor of the line	Table A.2
C_L	Annual cost of total loss in absence of protection measures	5.5; Annex D
C_{LD}	Factor depending on shielding, grounding and isolation conditions of the line for flashes to a line	Annex B
C_{LI}	Factor depending on shielding, grounding and isolation conditions of the line for flashes near a line	Annex B
C_{LZ}	Cost of loss in a zone	Annex D
C_P	Cost of protection measures	Annex D
C_{PM}	Annual cost of selected protection measures	5.5; Annex D
C_{RL}	Annual cost of residual loss	5.5; Annex D
C_{RLZ}	Cost of residual loss in a zone	Annex D
C_T	Line type factor for a HV/LV transformer on the line	Table A.3
c_a	Value of the animals in the zone, in currency	C.6
c_b	Value of the building relevant to the zone, in currency	C.6
c_c	Value of the content in the zone, in currency	C.6
c_e	Total value of goods in dangerous place outside the structure, in currency	C.6
c_s	Value of the internal systems (including their activities) in the zone, in currency	C.6
c_t	Total value of the structure, in currency	C.5; C.6
c_z	Value of the cultural heritage in the zone, in currency	C.5
D1	Injury to living beings by electric shock	4.1.2
D2	Physical damage	4.1.2
D3	Failure of electrical and electronic systems	4.1.2

h_z	Factor increasing the loss when a special hazard is present	Table C.6
H	Height of the structure	A.2.1.1
H_J	Height of the adjacent structure	A.2.5
i	Interest rate	Annex D
K_{MS}	Factor relevant to the performance of protection measures against LEMP	B.5
K_{S1}	Factor relevant to the screening effectiveness of the structure	B.5
K_{S2}	Factor relevant to the screening effectiveness of shields internal to the structure	B.5
K_{S3}	Factor relevant to the characteristics of internal wiring	B.5
K_{S4}	Factor relevant to the impulse withstand voltage of a system	B.5
L	Length of structure	A.2.1.1
L_J	Length of the adjacent structure	A.2.5
L_A	Loss due to injury to living beings by electric shock (flashes to structure)	6.2
L_B	Loss in a structure related to physical damage (flashes to structure)	6.2
L_L	Length of line section	A.4
L_C	Loss related to failure of internal systems (flashes to structure)	6.2
L_E	Additional loss when the damage involves surrounding structures	C.3; C.6
L_F	Loss in a structure due to physical damage	Tables C.2, C8, C10, C12
L_{FE}	Loss due to physical damage outside the structure	C.3; C.6
L_{FT}	Total loss due to physical damage in and outside the structure	C.3; C.6
L_M	Loss related to failure of internal systems (flashes near structure)	6.3
L_O	Loss in a structure due to failure of internal systems	Tables C.2, C8, C12
L_T	Loss due to injury by electric shock	Tables C.2, C12
L_U	Loss due to injury of living beings by electric shock (flashes to line)	6.4
L_V	Loss in a structure due to physical damage (flashes to line)	6.4
L_W	Loss related to failure of internal systems (flashes to line)	6.4
L_X	Loss consequent to damages relevant to structure	6.1
L_Z	Loss related to failure of internal systems (flashes near a line)	6.5
L1	Loss of human life	4.1.3
L2	Loss of service to the public	4.1.3
L3	Loss of cultural heritage	4.1.3
L4	Loss of economic value	4.1.3
m	Maintenance rate	Annex D
N_X	Number of dangerous events per annum	6.1
N_D	Number of dangerous events due to flashes to structure	A.2.4
N_{DJ}	Number of dangerous events due to flashes to adjacent structure	A.2.5
N_G	Lightning ground flash density	A.1
N_I	Number of dangerous events due to flashes near a line	A.5
N_L	Number of dangerous events due to flashes to a line	A.4
N_M	Number of dangerous events due to flashes near a structure	A.3
n_z	Number of possible endangered persons (victims or users not served)	C.3; C.4
n_t	Expected total number of persons (or users served)	C.3; C.4
P	Probability of damage	Annex B
P_A	Probability of injury to living beings by electric shock (flashes to a structure)	6.2; B.2
P_B	Probability of physical damage to a structure (flashes to a structure)	Table B.2
P_C	Probability of failure of internal systems (flashes to a structure)	6.2; B.4
P_{EB}	Probability reducing P_U and P_V depending on line characteristics and	

withstand voltage of equipment when EB is installed .... Table B.7

P_{LD} Probability reducing P_U, P_V and P_W depending on line characteristics and withstand voltage of equipment (flashes to connected line)....................... Table B.8

P_{LI} Probability reducing P_Z depending on line characteristics and withstand voltage of equipment (flashes near a connected line) .... Table B.9

P_M Probability of failure of internal systems (flashes near a structure) .... 6.3; B 5

P_{MS} Probability reducing P_M depending on shielding, wiring and withstand voltage of equipment B.5

P_{SPD} Probability reducing P_C, P_M, P_W and P_Z when a coordinated SPD system is installed .... Table B.3

P_{TA} Probability reducing P_A depending on protection measures against touch and step voltages... Table B.1

P_U Probability of injury to living beings by electric shock (flashes to a connected line)... 6.4; B.6

P_V Probability of physical damage to a structure (flashes to a connected line)... 6.4; B.7

P_W Probability of failure of internal systems (flashes to connected line)................ 6.4; B.8

P_X Probability of damage relevant to a structure 6.1

P_Z Probability of failure of internal systems (flashes near a connected line).. 6.5; B.9

r_t Reduction factor associated with the type of surface C.3

r_f Factor reducing loss depending on risk of fire C.3

r_p Factor reducing the loss due to provisions against fire C.3

R Risk 4.2

R_A Risk component (injury to living beings – flashes to structure) 4.2.2

R_B Risk component (physical damage to a structure – flashes to a structure).......... 4.2.2

R_C Risk component (failure of internal systems –flashes to structure) 4.2.2

R_M Risk component (failure of internal systems – flashes near structure)............ 4.2.3

R_S Shield resistance per unit length of a cable... Table B.8

R_T Tolerable risk .... 5.3; Table 4

R_U Risk component (injury to living being – flashes to connected line) 4.2.4

R_V Risk component (physical damage to structure – flashes to connected line)....... 4.2.4

R_W Risk component (failure of internal systems – flashes to connected line)................ 4.2.4

R_X Risk component for a structure.. 6.1

R_Z Risk component (failure of internal systems – flashes near a line)..................... 4.2.5

R_1 Risk of loss of human life in a structure... 4.2.1

R_2 Risk of loss of service to the public in a structure 4.2.1

R_3 Risk of loss of cultural heritage in a structure... 4.2.1

R_4 Risk of loss of economic value in a structure 4.2.1

R'_4 Risk R_4 when protection measures are adopted .... Annex D

S Structure.. A.2.2

S_M Annual saving of money .... Annex D

S_L Section of a line... 6.8

S1 Source of damage – Flashes to a structure.. 4.1.1

S2 Source of damage – Flashes near a structure 4.1.1

S3 Source of damage – Flashes to a line 4.1.1

S4 Source of damage – Flashes near a line... 4.1.1

t_e Time in hours per year of presence of people in a dangerous place outside the structure.. C.3

t_z Time in hours per year that persons are present in a dangerous place C.2

T_D	Thunderstorm days per year	A.1
U_W	Rated impulse withstand voltage of a system	B.5
w_m	Mesh width	B.5
W	Width of structure	A.2.1.1
W_J	Width of the adjacent structure	A.2.5
X	Subscript identifying the relevant risk component	6.1
Z_S	Zones of a structure	6.7

4 Explanation of terms

4.1 Damage and loss

4.1.1 Source of damage

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

S1: flashes to a structure,

S2: flashes near a structure,

S3: flashes to a line,

S4: flashes near a line.

4.1.2 Types of damage

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

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

D1: injury to living beings by electric shock,

D2: physical damage,

D3: failure of electrical and electronic systems.

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

4.1.3 Types of loss

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

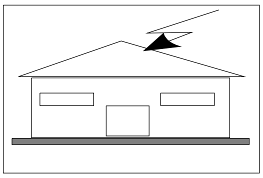
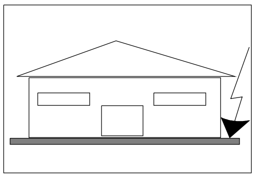
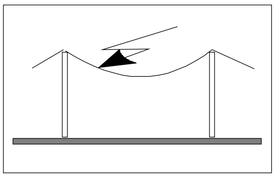
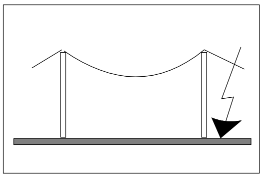
L1: loss of human life (including permanent injury);

L2: loss of service to the public;

L3: loss of cultural heritage;

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

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

Lightning flash		Structure	
Point of strike	**Source of damage**	**Type of damage**	**Type of loss**
	S1	D1 D2 D3	L1, L4[a] L1, L2, L3, L4 L1[b], L2, L4
	S2	D3	L1[b], L2 , L4
	S3	D1 D2 D3	L1, L4[a] L1, L2, L3, L4 L1[b], L2, L4
	S4	D3	L1[b], L2, L4

[a] Only for properties where animals may be lost.

[b] Only for structures with risk of explosion and for hospitals or other structures where failures of internal systems immediately endangers human life.

4.2 Risk and risk components

4.2.1 Risk

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

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

R_1: risk of loss of a human life (including permanent injury),

R_2: risk of loss of service to the public,

R_3: risk of loss of cultural heritage,

R_4: risk of loss of economic value.

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

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

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

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

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

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

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

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

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

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

R_U: Component related to injury to living beings caused by electric shock due to touch voltage inside the structure. Loss of type L1 and, in the case of agricultural properties, 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 lines. All types of loss (L1, L2, L3, L4) may occur.

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

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

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

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

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

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

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

4.3 Composition of risk components

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

R_1: Risk of loss of human life:

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

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

R_2: Risk of loss of service to the public:

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

R_3: Risk of loss of cultural heritage:

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

R_4: Risk of loss of economic value:

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

2) Only for properties where animals may be lost.

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

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

Source of damage	**Flash to a structure S1**			**Flash near a structure S2**	**Flash to a line connected to the structure S3**			**Flash near a line connected to the structure S4**
Risk component	R_A	R_B	R_C	R_M	R_U	R_V	R_W	R_Z
Risk for each type of loss								
R_1	*	*	* a	* a	*	*	* a	* a
R_2		*	*	*		*	*	*
R_3		*				*		
R_4	* b	*	*	*	*b	*	*	*

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

b Only for properties where animals may be lost.

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

Table 3 – Factors influencing the risk components

Characteristics of structure or of internal systems Protection measures	R_A	R_B	R_C	R_M	R_U	R_V	R_W	R_Z
Collection area	X	X	X	X	X	X	X	X
Surface soil resistivity	X							
Floor resistivity	X				X			
Physical restrictions, insulation, warning notice, soil equipotentialization	X				X			
LPS	X	X	X	X[a]	X[b]	X[b]		
Bonding SPD	X	X			X	X		
Isolating interfaces			X[c]	X[c]	X	X	X	X
Coordinated SPD system			X	X			X	X
Spatial shield			X	X				
Shielding external lines					X	X	X	X
Shielding internal lines			X	X				
Routing precautions			X	X				
Bonding network			X					
Fire precautions		X				X		
Fire sensitivity		X				X		
Special hazard		X				X		
Impulse withstand voltage			X	X	X	X	X	X

[a] Only for grid-like external LPS.

[b] Due to equipotential bonding.

[c] Only if they belong to equipment.

5 Risk management

5.1 Basic procedure

The following procedure shall be applied:

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

5.2 Structure to be considered for risk assessment

The structure to be considered includes:

- the structure itself;
- installations in the structure;

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

Protection does not include connected lines outside of the structure.

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

5.3 Tolerable risk R_T

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

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

Table 4 – Typical values of tolerable risk R_T

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

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

5.4 Specific procedure to evaluate the need of protection

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

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

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

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

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

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

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

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

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

5.5 Procedure to evaluate the cost effectiveness of protection

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

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

The procedure to ascertain the cost effectiveness of protection requires:

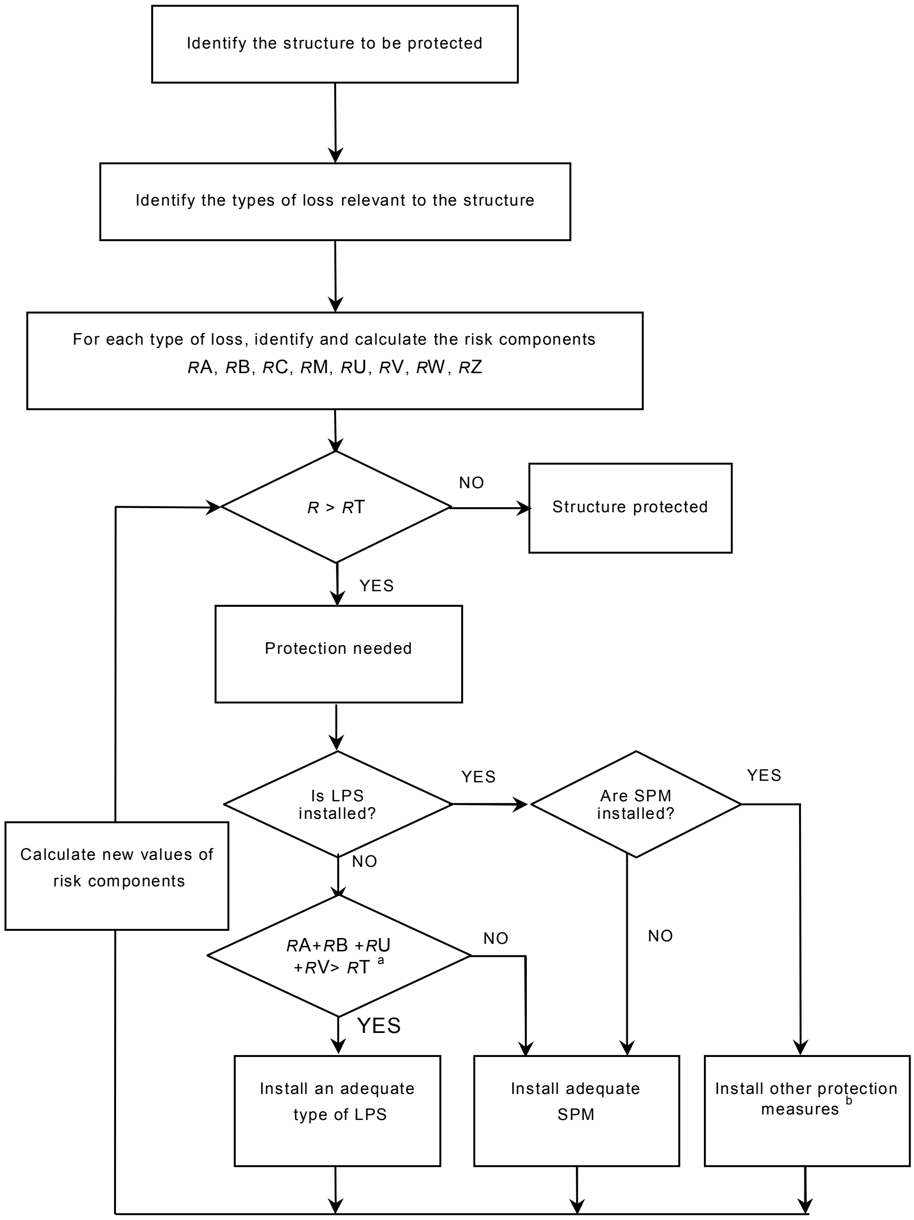
– identification of the components R_X which make up the risk R_4;
– calculation of the identified risk components R_X in absence of new/additional protection measures;
– calculation of the annual cost of loss due to each risk component R_X;
– calculation of the annual cost C_L of total loss in the absence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

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

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

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

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



IEC 2635/10

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

b See Table 3.

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

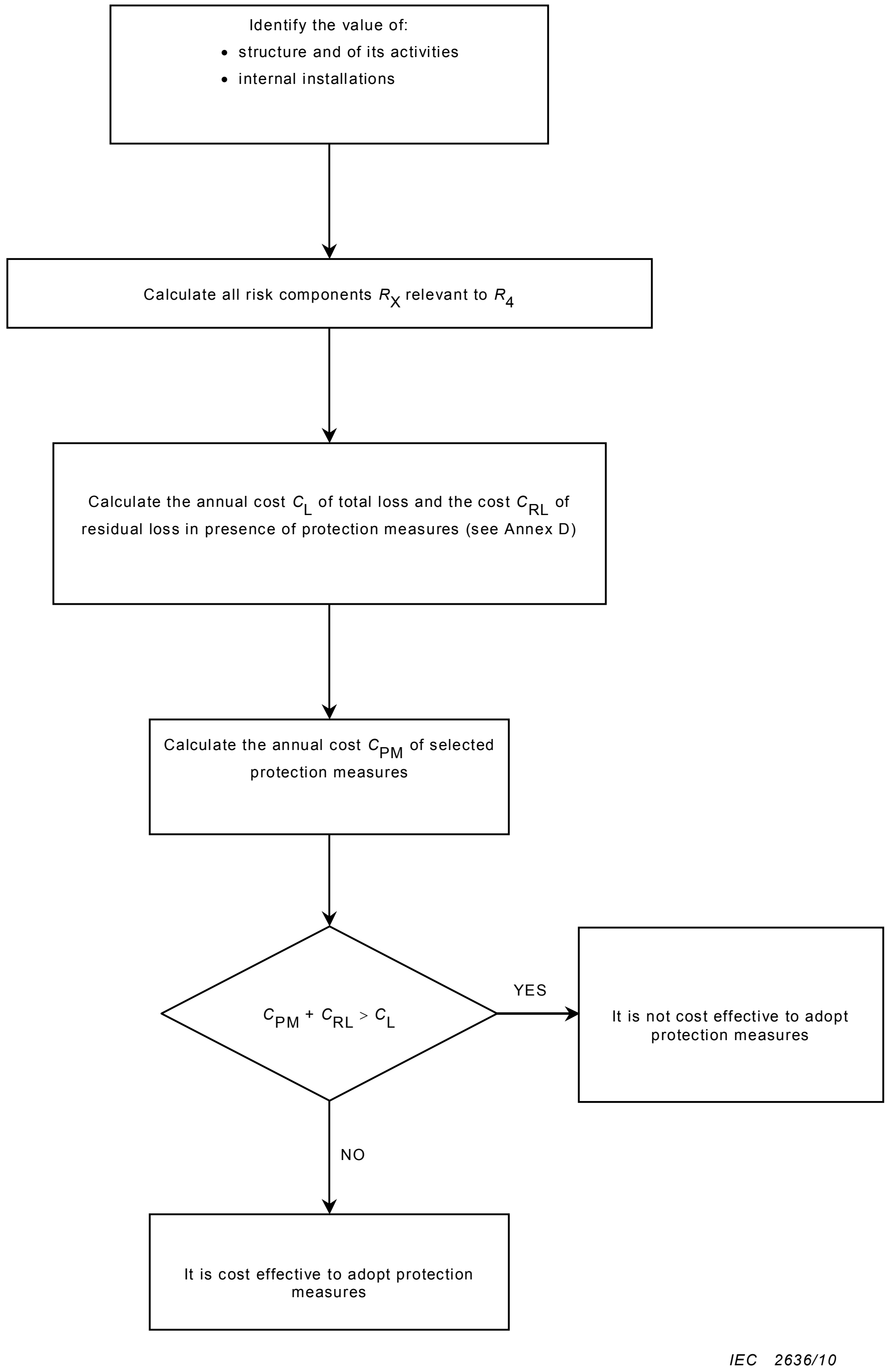


Figure 2 – Procedure for evaluating the cost-effectiveness of protection measures

5.6 Protection measures

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

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

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

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

5.7 Selection of protection measures

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

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

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

6 Assessment of risk components

6.1 Basic equation

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

$$R_X = N_X \times P_X \times L_X \tag{5}$$

where

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

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

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

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

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

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

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

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

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

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

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

– component related to physical damage (D2)

$$R_B = N_D \times P_B \times L_B \quad (7)$$

– component related to failure of internal systems (D3)

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

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

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

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

– component related to failure of internal systems (D3)

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

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

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

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

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

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

– component related to physical damage (D2)

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

– component related to failure of internal systems (D3)

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

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

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

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

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

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

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

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

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

– component related to failure of internal systems (D3)

$$R_Z = N_I \times P_Z \times L_Z \tag{13}$$

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

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

Table 5 – Parameters relevant to the assessment of risk components

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

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

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

6.6 Summary of risk components

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

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

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

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

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

6.7 Partitioning of a structure in zones Z_S

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

Zones Z_S are mainly defined by:

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

Further zones may be defined according to

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

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

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

6.8 Partitioning of a line into sections S_L

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

For all risk components, sections S_L are mainly defined by

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

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

6.9 Assessment of risk components in a structure with zones Z_S

6.9.1 General criteria

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

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

Moreover:

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

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

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

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

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

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

6.9.2 Single zone structure

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

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

6.9.3 Multi-zone structure

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

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

6.10 Cost-benefit analysis for economic loss (L4)

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

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

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

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

Annex A
(informative)

Assessment of annual number *N* of dangerous events

A.1 General

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

The lightning ground flash density N_G is the number of lightning flashes per 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:

$$N_G \approx 0{,}1\ T_D \tag{A.1}$$

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

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

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

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

A.2.1 Determination of the collection area A_D

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

A.2.1.1 Rectangular structure

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

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

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

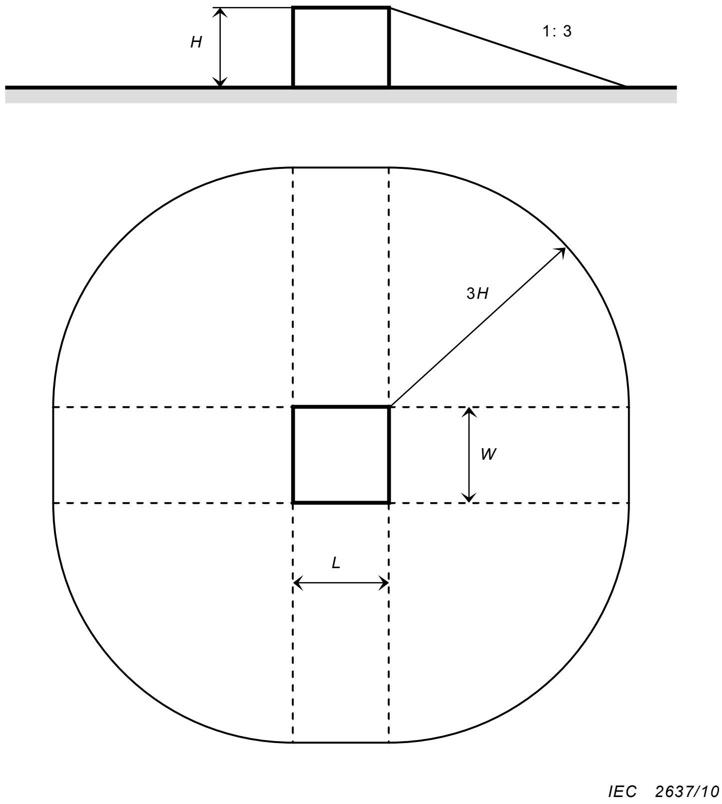


Figure A.1 – Collection area A_D of an isolated structure

A.2.1.2 Complex shaped structure

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

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

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

where H_P is the height of protrusion.

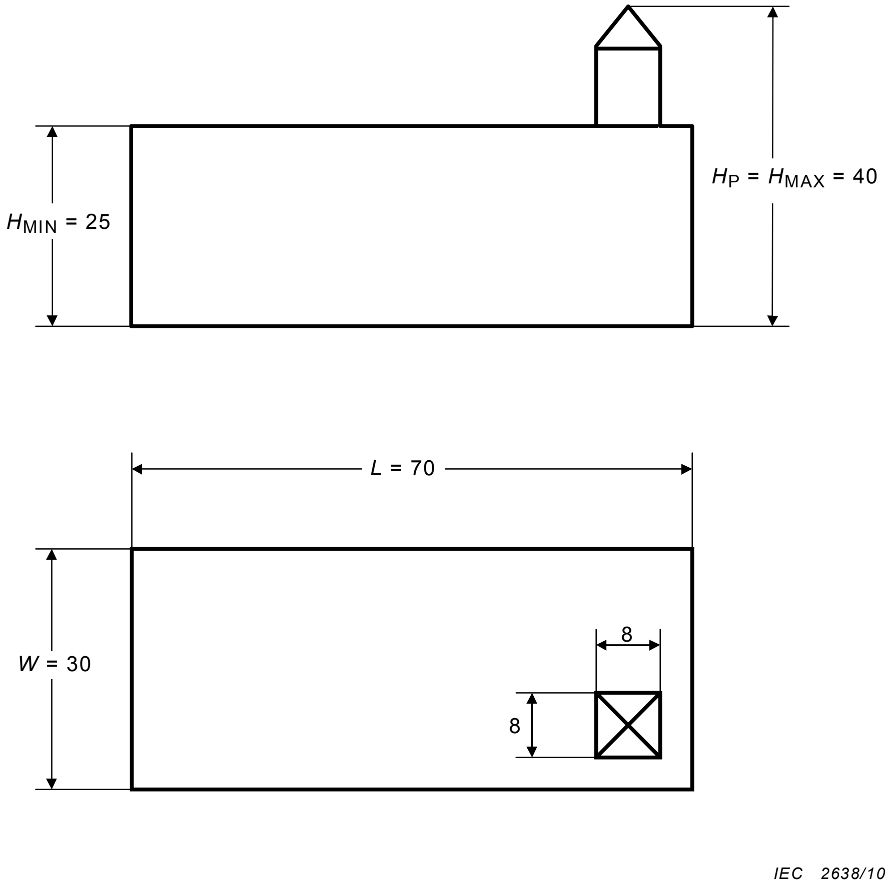


Figure A.2 – Complex shaped structure

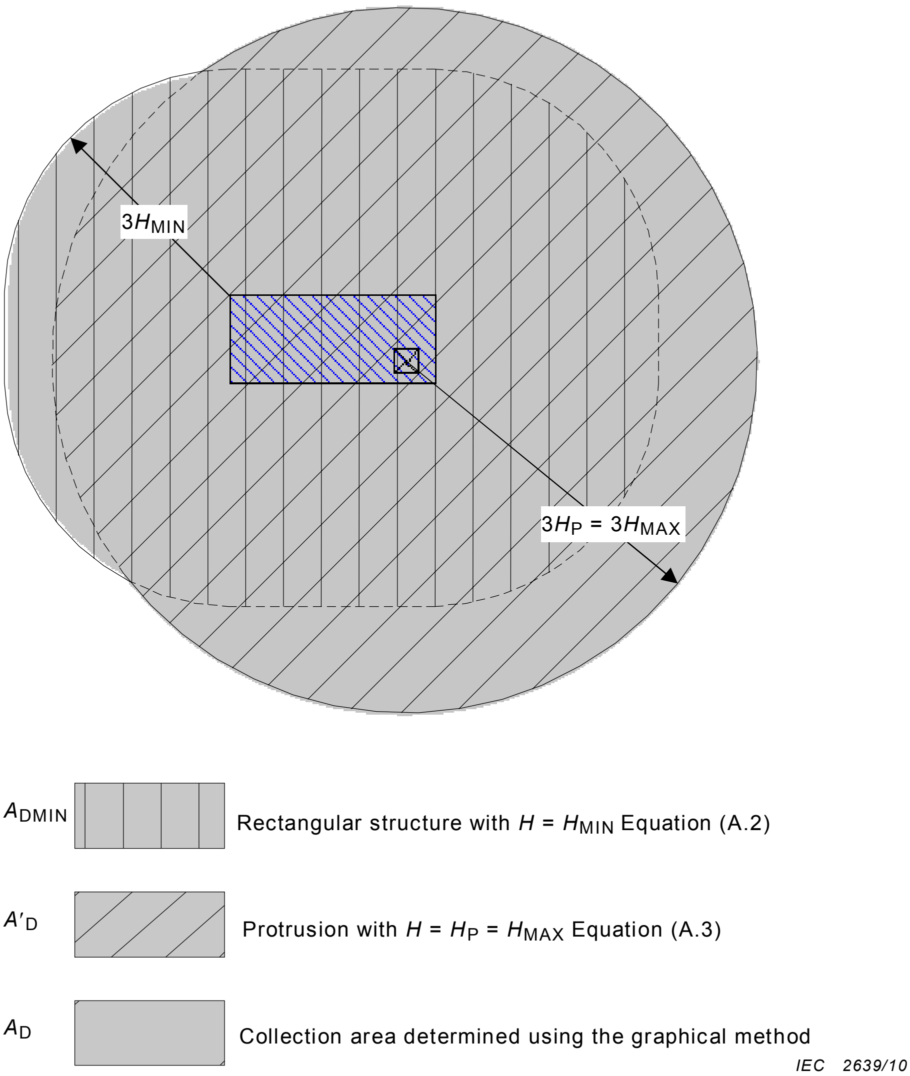


Figure A.3 – Different methods to determine the collection area for the given structure

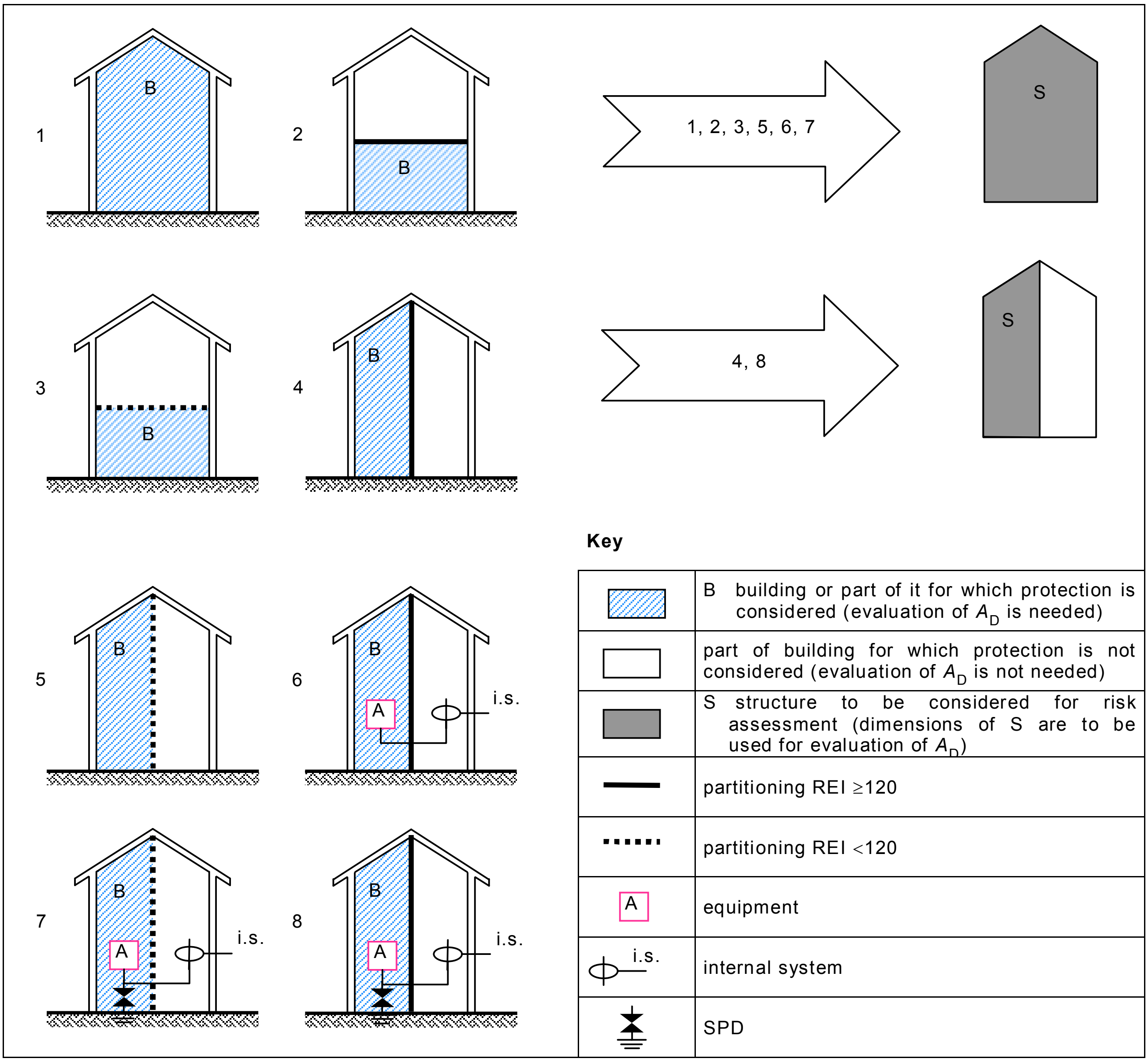
A.2.2 Structure as a part of a building

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

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

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

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



IEC 2640/10

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

A.2.3 Relative location of the structure

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

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

Table A.1 – Structure location factor C_D

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

A.2.4 Number of dangerous events N_D for the structure

N_D may be evaluated as the product:

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

where

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

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

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

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

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

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

where

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

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

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

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

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

N_M may be evaluated as the product:

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

where

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

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

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

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

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

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

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

where

- N_L is the number of overvoltages of amplitude not lower than 1 kV (1/year) on the line section)
- N_G is the lightning ground flash density (1/km^2 × year);
- A_L is the collection area of flashes striking the line (m^2) (see Figure A.5);
- C_I is the installation factor of the line (see Table A.2);
- C_T is the line type factor (see Table A.3);
- C_E is the environmental factor (see Table A.4);

with the collection area for flashes to a line:

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

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

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

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

Table A.2 – Line installation factor C_I

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

Table A.3 – Line type factor C_T

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

Table A.4 – Line environmental factor C_E

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

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

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

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

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

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

where

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

N_G is the lightning ground flash density (1/km^2 × year);

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

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

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

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

with the collection area for flashes near a line

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

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

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

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

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

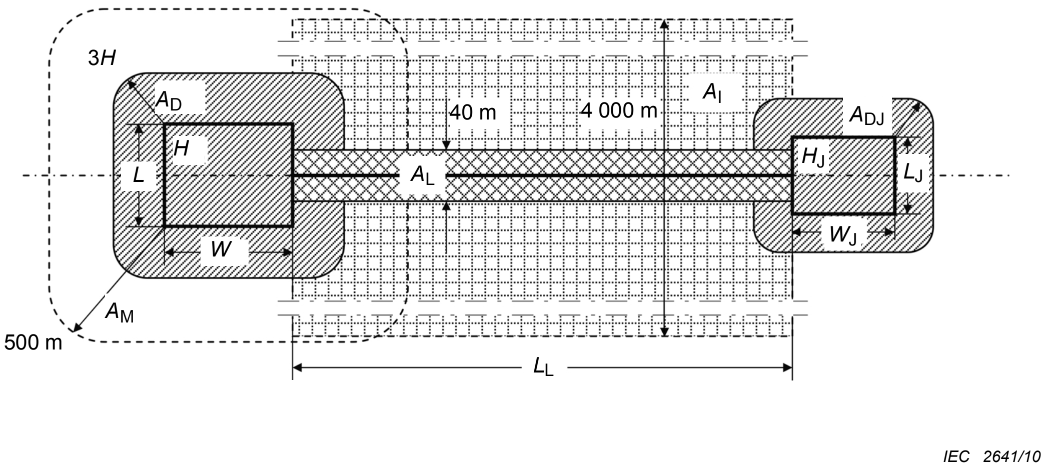


Figure A.5 – Collection areas (A_D, A_M, A_I, A_L)

Annex B
(informative)

Assessment of probability P_X of damage

B.1 General

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

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

Other values may be chosen, if justified.

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

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

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

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

where

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

NOTE 4 For non-shielded internal systems

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

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

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

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

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

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

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

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

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

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

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

where

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Type of internal wiring	K_{S3}
Unshielded cable – no routing precaution in order to avoid loops[a]	1
Unshielded cable – routing precaution in order to avoid large loops[b]	0,2
Unshielded cable – routing precaution in order to avoid loops[c]	0,01
Shielded cables and cables running in metal conduits[d]	0,0001

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

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

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

[d] Shields and the metal conduits bonded to an equipotential bonding bar at both ends and equipment is connected to the same bonding bar.

The factor K_{S4} is evaluated as:

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

where

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

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

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

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

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

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

The value of P_U is given by:

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

where

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The value of P_V is given by:

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

where

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

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

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

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

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

The value of P_W is given by:

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

where

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

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

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

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

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

The value of P_Z is given by:

$$P_Z = P_{SPD} \times P_{LI} \times C_{LI} \quad \text{(B.11)}$$

where

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

P_{LI} is the probability of failure of internal systems due to a flash near the connected line depending on the line and equipment characteristics. Values of P_{LI} are given in Table B.9;

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

Table B.9 – Values of the probability P_{LI} depending on the line type and the impulse withstand voltage U_W of the equipment

Line type	Withstand voltage U_W in kV				
	1	**1,5**	**2,5**	**4**	**6**
Power lines	1	0,6	0,3	0,16	0,1
TLC lines	1	0,5	0,2	0,08	0,04

NOTE More precise evaluation of P_{LI} can be found in IEC/TR 62066:2002 for power lines[11] and in ITU-T Recommendation K.46 [10] for telecommunication (TLC) lines.

Annex C
(informative)

Assessment of amount of loss L_X

C.1 General

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 of loss L_X in a structure given in this annex are merely values proposed by the IEC. Different values may be assigned by each national committee or after detailed investigation.

NOTE 1 When the damage to a structure due to lightning may also involve surrounding structures or the environment (e.g. chemical or radioactive emissions), a more detailed evaluation of L_X that takes into account this additional loss should be performed.

NOTE 2 It is recommended that the equations given in this annex be used as the primary source of values for L_X.

C.2 Mean relative amount of loss per dangerous event

The loss L_X refers to the mean relative amount of a particular type of damage for one dangerous event caused by a lightning flash, considering both its extent and effects.

The loss value L_X varies with the type of loss considered:

- L1 (Loss of human life, including permanent injury): the endangered number of persons (victims);
- L2 (Loss of public service): the number of users not served;
- L3 (Loss of cultural heritage): the endangered economic value of structure and content;
- L4 (Loss of economic values): the endangered economic value of animals, the structure (including its activities), content and internal systems,

and, for each type of loss, with the type of damage (D1, D2 and D3) causing the loss.

The loss L_X should be determined for each zone of the structure into which it is divided.

C.3 Loss of human life (L1)

The loss value L_X for each zone can be determined according to Table C.1, considering that:

- loss of human life is affected by the characteristics of the zone. These are taken into account by increasing (h_z) and decreasing (r_t, r_p, r_f) factors;
- the maximum value of loss in the zone shall be reduced by the ratio between the number of persons in the zone (n_z) versus the total number of persons (n_t) in the whole structure;
- the time in hours per year for which the persons are present in the zone (t_z), if it is lower than the total 8 760 h of a year, will also reduce the loss.

Table C.1 – Type of loss L1: Loss values for each zone

Type of damage	Typical loss	Equation
D1	$L_A = r_t \times L_T \times n_Z / n_t \times t_z / 8\,760$	(C.1)
D1	$L_U = r_t \times L_T \times n_Z / n_t \times t_z / 8\,760$	(C.2)
D2	$L_B = L_V = r_p \times r_f \times h_z \times L_F \times n_Z / n_t \times t_z / 8\,760$	(C.3)
D3	$L_C = L_M = L_W = L_Z = L_O \times n_Z / n_t \times t_z / 8\,760$	(C.4)

where

L_T is the typical mean relative numbers of victims injured by electric shock (D1) due to one dangerous event (see Table C.2);

L_F is the typical mean relative numbers of victims by physical damage (D2) due to one dangerous event (see Table C.2);

L_O is the typical mean relative numbers of victims by failure of internal systems (D3) due to one dangerous event (see Table C.2);

r_t is a factor reducing the loss of human life depending on the type of soil or floor (see Table C.3);

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.4);

r_f is a factor reducing the loss due to physical damage depending on the risk of fire or on the risk of explosion of the structure (see Table C.5);

h_z is a factor increasing the loss due to physical damage when a special hazard is present (see Table C.6);

n_z is the number of persons in the zone;

n_t is the total number of persons in the structure;

t_z is the time in hours per year for which the persons are present in the zone.

Table C.2 – Type of loss L1: Typical mean values of L_T, L_F and L_O

Type of damage	Typical loss value		Type of structure
D1 injuries	L_T	10^{-2}	All types
D2 physical damage	L_F	10^{-1}	Risk of explosion
		10^{-1}	Hospital, hotel, school, civic building
		5×10^{-2}	Public entertainment, church, museum
		2×10^{-2}	Industrial, commercial
		10^{-2}	Others
D3 failure of internal systems	L_O	10^{-1}	Risk of explosion
		10^{-2}	Intensive care unit and operation block of hospital
		10^{-3}	Other parts of hospital

NOTE 1 Values of Table C.2 refer to a continuous attendance of people in the structure.

NOTE 2 In case of a structure with risk of explosion, the values for L_F and L_O may need a more detailed evaluation, considering the type of structure, the risk explosion, the zone concept of hazardous areas and the measures to meet the risk.

When the damage to a structure due to lightning involves surrounding structures or the environment (e.g. chemical or radioactive emissions), additional loss (L_E) should be taken into account to evaluate the total loss (L_{FT}):

$$L_{FT} = L_F + L_E \qquad (C.5)$$

where

$$L_E = L_{FE} \times t_e/8\ 760 \qquad (C.6)$$

L_{FE} being the loss due to physical damage outside the structure;

t_e being the time of presence of people in the dangerous place outside the structure.

NOTE 3 If values of L_{FE} and t_e are unknown, $L_{FE} \times t_e/8\ 760 = 1$ should be assumed.

Table C.3 – Reduction factor r_t as a function of the type of surface of soil or floor

Type of surface[b]	Contact resistance k Ω[a]	r_t
Agricultural, concrete	≤ 1	10^{-2}
Marble, ceramic	1 – 10	10^{-3}
Gravel, moquette, carpets	10 – 100	10^{-4}
Asphalt, linoleum, wood	≥ 100	10^{-5}

[a] Values measured between a 400 cm^2 electrode compressed with a uniform force of 500 N and a point of infinity.

[b] A layer of insulating material, e.g. asphalt, of 5 cm thickness (or a layer of gravel 15 cm thick) generally reduces the hazard to a tolerable level.

Table C.4 – 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 compartments; escape routes	0,5
One of the following provisions: fixed automatically operated extinguishing installations; automatic alarm installations[a]	0,2

[a] 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 should be taken as the lowest of the relevant values.

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

Table C.5 – Reduction factor r_f as a function of risk of fire or explosion of structure

Risk	Amount of risk	r_f
Explosion	Zones 0, 20 and solid explosive	1
	Zones 1, 21	10^{-1}
	Zones 2, 22	10^{-3}
Fire	High	10^{-1}
	Ordinary	10^{-2}
	Low	10^{-3}
Explosion or fire	None	0

NOTE 4 In case of a structure with risk of explosion, the value for r_f may need a more detailed evaluation.

NOTE 5 Structures with a high risk of fire may be assumed to be structures made of combustible materials or structures with roofs made of combustible materials or structures with a specific fire load larger than 800 MJ/m^2.

NOTE 6 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 7 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 only a small amount of combustible material.

NOTE 8 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.

NOTE 9 For the purposes of this part of IEC 62305, structures containing hazardous zones or containing solid explosive materials should not be assumed to be structures with a risk of explosion if any one of the following conditions is fulfilled:

a) the time of presence of explosive substances is lower than 0,1 h/year;

b) the volume of explosive atmosphere is negligible according to IEC 60079-10-1[2] and IEC 60079-10-2[3];

c) the zone cannot be hit directly by a flash and dangerous sparking in the zone is avoided.

NOTE 10 For hazardous zones enclosed within metallic shelters, condition c) is fulfilled when the shelter, as a natural air-termination system, acts safely without puncture or hot-spot problems, and internal systems inside the shelter, if any, are protected against overvoltages to avoid dangerous sparking.

Table C.6 – Factor h_z increasing the relative amount of loss in presence of a special hazard

Kind of special hazard	h_z
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 immobile 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

C.4 Unacceptable loss of service to the public (L2)

The loss value L_X for each zone can be determined according to Table C.7, considering that:

– loss of public service is affected by the characteristics of the zone of the structure. These are taken into account by decreasing (r_f, r_p) factors;

– the maximum value of loss due to the damage in the zone must be reduced by the ratio between the number of users served by the zone (n_z) versus the total number of users (n_t) served by the whole structure.

Table C.7 – Type of loss L2: Loss values for each zone

Type of damage	Typical loss	Equation
D2	$L_B = L_V = r_p \times r_f \times L_F \times n_z/n_t$	(C.7)
D3	$L_C = L_M = L_W = L_Z = L_O \times n_z/n_t$	(C.8)

where

L_F is the typical mean relative number of users not served, resulting from physical damage (D2) due to one dangerous event (see Table C.8);

L_O is the typical mean relative numbers of users not served resulting from failure of internal systems (D3) due to one dangerous event (see Table C.8);

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.4);

r_f is a factor reducing the loss due to physical damage depending on the risk of fire (see Table C.5);

n_z is the number of users served by the zone;

n_t is the total number of users served by the structure.

Table C.8 – Type of loss L2: Typical mean values of L_F and L_O

Type of damage	Typical loss value		Type of service
D2 physical damage	L_F	10^{-1}	Gas, water, power supply
		10^{-2}	TV, telecommunications lines
D3 failure of internal systems	L_O	10^{-2}	Gas, water, power supply
		10^{-3}	TV, telecommunications lines

C.5 Loss of irreplaceable cultural heritage (L3)

The loss value L_X for each zone can be determined according to Table C.9, considering that:

– loss of cultural heritage is affected by the characteristics of the zone. These are taken into account by decreasing (r_f, r_p) factors;

– the maximum value of loss due to the damage of the zone must be reduced by the ratio between the value of the zone (c_z) versus the total value (c_t) of the whole structure (building and content).

Table C.9 – Type of loss L3: Loss values for each zone

Type of damage	Typical loss value	Equation
D2 physical damage	$L_B = L_V = r_p \times r_f \times L_F \times c_z / c_t$	(C.9)

where

L_F is the typical mean relative value of all goods damaged by physical damage (D2) due to one dangerous event (see Table C.10);

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.4);

r_f is a factor reducing the loss due to physical damage depending on the risk of fire (see Table C.5);

c_z is the value of cultural heritage in the zone;

c_t is the total value of building and content of the structure (sum over all zones).

Table C.10 – Type of loss L3: Typical mean value of L_F

Type of damage	Typical loss value		Type of structure or zone
D2 physical damage	L_F	10^{-1}	Museums, galleries

C.6 Economic loss (L4)

The loss value L_X for each zone can be determined according to Table C.11, considering that:

- loss of economic values is affected by the characteristics of the zone. These are taken into account by decreasing (r_t, r_p, r_f) factors;
- the maximum value of loss due to the damage of the zone must be reduced by the ratio between the relevant value in the zone versus the total value (c_t) of the whole structure (animals, building, content and internal systems including their activities). The relevant value of the zone depends on the type of damage:

  D1 (injuries of animals due to shock): c_a (value of animals only)

  D2 (physical damage): $c_a + c_b + c_c + c_s$ (value of all goods)

  D3 (failures of internal systems): c_s (value of internal systems and their activities only)

Table C.11 – Type of loss L4: Loss values for each zone

Type of damage	Typical loss	Equation
D1	$L_A = r_t \times L_T \times c_a / c_t$ [a]	(C.10)
D1	$L_U = r_t \times L_T \times c_a / c_t$ [a]	(C.11)
D2	$L_B = L_V = r_p \times r_f \times L_F \times (c_a + c_b + c_c + c_s) / c_t$ [a]	(C.12)
D3	$L_C = L_M = L_W = L_Z = L_O \times c_s / c_t$ [a]	(C.13)

[a] The ratios c_a / c_t and $(c_a + c_b + c_c + c_s) / c_t$ and c_s / c_t have only to be considered in the eq. (C.10) – (C.13), if the risk assessment is conducted in accordance with clause 6.10, using Annex D. In case of using a representative value for the tolerable risk R4 in accordance with Table 4, the ratios do not have to be taken into account. In these cases, the ratios have to be replaced by the value 1.

where

L_T is the typical mean relative value of all goods damaged by electric shock (D1) due to one dangerous event (see Table C.12);

L_F is the typical mean relative value of all goods damaged by physical damage (D2) due to one dangerous event (see Table C.12);

L_O is the typical mean relative value of all goods damaged by failure of internal systems (D3) due to one dangerous event (see Table C.12);

r_t is a factor reducing the loss of animals depending on the type of soil or floor (see Table C.3);

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.4);

r_f is a factor reducing the loss due to physical damage depending on the risk of fire or on the risk of explosion of the structure(see Table C.5);

c_a is the value of animals in the zone;

c_b is the value of building relevant to the zone;

c_c is the value of content in the zone;

c_s is the value of internal systems including their activities in the zone;

c_t is the total value of the structure (sum over all zones for animals, building, content and internal systems including their activities).

Table C.12 – Type of loss L4: Typical mean values of L_T, L_F and L_O

Type of damage	Typical loss value		Type of structure
D1 injuries due to shock	L_T	10^{-2}	All types where only animals are present
D2 physical damage	L_F	1	Risk of explosion
		0,5	Hospital, industrial, museum, agricultural
		0,2	Hotel, school, office, church, public entertainment, commercial
		10^{-1}	Others
D3 failure of internal systems	L_O	10^{-1}	Risk of explosion
		10^{-2}	Hospital, industrial, office, hotel, commercial
		10^{-3}	Museum, agricultural, school, church, public entertainment
		10^{-4}	Others

NOTE 1 In structures where there is a risk of explosion, the values for L_F and L_O may need more detailed evaluation, where consideration of the type of structure, the risk explosion, the zone concept of hazardous areas and the measures to meet the risk, etc. are addressed.

When the damage to a structure due to lightning involves surrounding structures or the environment (e.g. chemical or radioactive emissions), additional loss (L_E) should be taken into account to evaluate the total loss (L_{FT}):

$$L_{FT} = L_F + L_E \tag{C.14}$$

where

$$L_E = L_{FE} \times c_e / c_t \tag{C.15}$$

L_{FE} is the loss due to physical damage outside the structure;

c_e is the total value of goods in dangerous place outside the structure.

NOTE 2 If the value of L_{FE} is unknown, L_{FE} = 1 should be assumed.

Annex D
(informative)

Evaluation of costs of loss

The cost of loss C_{LZ} in a zone may be calculated by the following equation:

$$C_{LZ} = R_{4Z} \times c_t \tag{D.1}$$

where

R_{4Z} is the risk related to loss of value in the zone, without protection measures;

c_t is the total value of the structure (animals, building, content and internal systems including their activities in currency).

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

$$C_L = \sum C_{LZ} = R_4 \times c_t \tag{D.2}$$

where

$R_4 = \sum R_{4Z}$ is the risk related to loss of value, without protection measures.

The cost C_{RLZ} of residual loss in a zone in spite of protection measures may be calculated by means of the equation:

$$C_{RLZ} = R'_{4Z} \times c_t \tag{D.3}$$

where

R'_{4Z} is the risk related to loss of value in the zone, with protection measures.

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

$$C_{RL} = \sum C_{RLZ} = R'_4 \times c_t \tag{D.4}$$

where

$R'_4 = \sum R'_{4Z}$ is the risk related to loss of value in the structure, with protection measures.

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

$$C_{PM} = C_P \times (i + a + m) \tag{D.5}$$

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_M in money is:

$$S_M = C_L - (C_{PM} + C_{RL}) \tag{D.6}$$

Protection is justified if the annual saving $S_M > 0$.

Annex E
(informative)

Case study

E.1 General

In Annex E case studies relevant to a country house, an office building, a hospital and an apartment block are developed with the aim of showing

– how to calculate the 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 the risk,
– the method of selection from among different protection solutions taking into account the cost-effectiveness.

NOTE This annex presents hypothetical data for all cases. It is intended to provide information about risk evaluation in order to illustrate the principles contained in this part of IEC 62305. It is not intended to address the unique aspects of the conditions that exist in all facilities or systems.

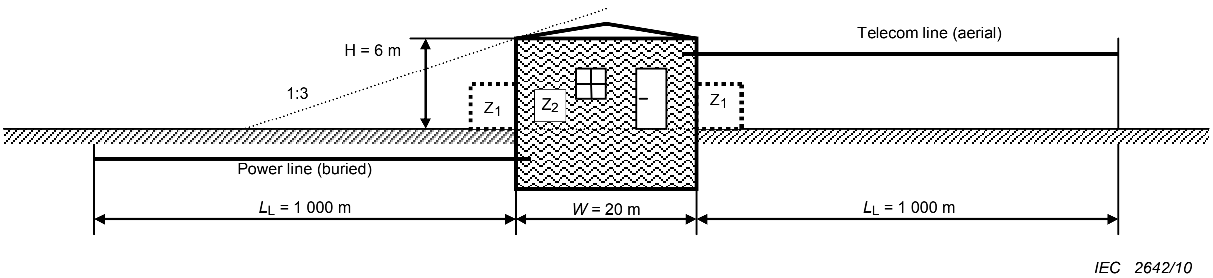
E.2 Country house

As a first case study a country house (Figure E.1) is considered.

Loss of human life (L1) and economic loss (L4) are relevant for this type of structure.

It is required to evaluate the need for protection. This implies the need to determine only the risk R_1 for loss of human life (L1) with the risk components R_A, R_B, R_U and R_V (according to Table 2) and to compare it with the tolerable risk $R_T = 10^{-5}$ (according to Table 4). Suitable protection measures to mitigate such risk will be selected.

Following the decision taken by the owner that an economic evaluation is not required, the risk R_4 for economic loss (L4) is not considered.



Key

Z_1: outside

Z_2: rooms block

Figure E.1 – Country house

E.2.1 Relevant data and characteristics

The country house is located in flat territory without any neighbouring structures. The lightning flash density is N_G = 4 flashes per km^2 per year. Five persons live in the house. This is also the total number of persons to be considered, because it is assumed that there is no person outside the house during thunderstorm.

Data for the house and its surroundings are given in Table E.1.

Data for the incoming lines and their internal systems connected to are given for the power line in Table E.2 and for the telecom line in Table E.3.

Table E.1 – Country house: Environment and structure characteristics

Input parameter	Comment	Symbol	Value	Reference
Ground flash density (1/km²/year)		N_G	4,0	
Structure dimensions (m)		L, W, H	15, 20, 6	
Location factor of structure	Isolated structure	C_D	1	Table A.1
LPS	None	P_B	1	Table B.2
Equipotential bonding	None	P_{EB}	1	Table B.7
External spatial shield	None	K_{S1}	1	Equation (B.5)

Table E.2 – Country house: Power line

Input parameter	Comment	Symbol	Value	Reference
Length (m)[a]		L_L	1 000	
Installation factor	Buried	C_I	0,5	Table A.2
Line type factor	LV line	C_T	1	Table A.3
Environmental factor	Rural	C_E	1	Table A.4
Shield of line	Unshielded	R_S	–	Table B.8
Shielding, grounding, isolation	None	C_{LD}	1	Table B.4
		C_{LI}	1	
Adjacent structure	None	L_J, W_J, H_J	–	
Location factor of structure	None	C_{DJ}	–	Table A.1
Withstand voltage of internal system (kV)		U_W	2,5	
	Resulting parameters	K_{S4}	0,4	Equation (B.7)
		P_{LD}	1	Table B.8
		P_{LI}	0,3	Table B.9

[a] As the length L_L of the line section is unknown, L_L = 1 000 m is assumed (Clause A.4 and Clause A.5).

Table E.3 – Country house: Telecom line (TLC)

Input parameter	Comment	Symbol	Value	Reference
Length (m)[a]		L_L	1 000 m	
Installation factor	Aerial	C_I	1	Table A.2
Line type factor	Telecom line	C_T	1	Table A.3
Environmental factor	Rural	C_E	1	Table A.4
Shield of line	Unshielded	R_S	–	Table B.8
Shielding, grounding, isolation	None	C_{LD}	1	Table B.4
		C_{LI}	1	
Adjacent structure	None	L_J, W_J, H_J	–	
Location factor of structure	Isolated structure	C_{DJ}	–	Table A.1
Withstand voltage of internal		U_W	1,5	

Input parameter	Comment	Symbol	Value	Reference
system (kV)				
	Resulting parameters	K_{S4}	0,67	Equation (B.7)
		P_{LD}	1	Table B.8
		P_{LI}	0,5	Table B.9
[a] As the length L_L of the line section is unknown, L_L = 1 000 m is assumed (Clause A.4 and Clause A.5).				

E.2.2 Definition of zones in the country house

The following main zones may be defined:

– Z_1 (outside the building);

– Z_2 (inside the building).

For zone Z_1 it is assumed, that no people are outside the building. Therefore the risk of shock of people R_A = 0. Because R_A is the only risk component outside the building, zone Z_1 can be disregarded completely.

Inside the building only one zone Z_2 is defined taking into account that

– both internal systems (power and telecom) extend throughout the building,

– no spatial shields exist,

– the structure is a unique fireproof compartment,

– losses are assumed to be constant in all the building and to correspond to the typical mean values of Table C.1.

The resulting factors valid for zone Z_2 are reported in Table E.4.

Table E.4 – Country house: Factors valid for zone Z_2 (inside the building)

Input parameter		Comment	Symbol	Value	Reference
Type of floor		Linoleum	r_t	10^{-5}	Table C.3
Protection against shock (flash to structure)		None	P_{TA}	1	Table B.1
Protection against shock (flash to line)		None	P_{TU}	1	Table B.6
Risk of fire		Low	r_f	10^{-3}	Table C.5
Fire protection		None	r_p	1	Table C.4
Internal spatial shield		None	K_{S2}	1	Equation (B.6)
Power	Internal wiring	Unshielded (loop conductors in the same conduit)	K_{S3}	0,2	Table B.5
	Coordinated SPDs	None	P_{SPD}	1	Table B.3
Telecom	Internal wiring	Unshielded (large loops >10 m^2)	K_{S3}	1	Table B.5
	Coordinated SPDs	None	P_{SPD}	1	Table B.3
L1: Loss of human life		Special hazard: none	h_z	1	Table C.6
		D1: due to touch and step voltage	L_T	10^{-2}	Table C.2
		D2: due to physical damage	L_F	10^{-1}	
		D3: due to failure of internal systems	L_O	-	

Input parameter	Comment	Symbol	Value	Reference
Factor for persons in zone	$n_z/n_t \times t_z/8\,760$ = 5/5 × 8 760/8 760	–	1	
	Resulting parameters	L_A	10^{-7}	Equation (C.1)
		L_U	10^{-7}	Equation (C.2)
		L_B	10^{-4}	Equation (C.3)
		L_V	10^{-4}	Equation (C.3)

E.2.3 Calculation of relevant quantities

Calculations are given in Table E.5 for the collection areas and in Table E.6 for the expected number of dangerous events.

Table E.5 – Country house: Collection areas of structure and lines

	Symbol	Result m^2	Reference Equation	Equation
Structure	A_D	$2{,}58 \times 10^3$	(A.2)	$A_D = L \times W + 2 \times (3 \times H) \times (L + W) + \pi \times (3 \times H)^2$
	A_M	–	(A.7)	Not relevant
Power line	$A_{L/P}$	$4{,}00 \times 10^4$	(A.9)	$A_{L/P} = 40 \times L_L$
	$A_{I/P}$	$4{,}00 \times 10^6$	(A.11)	$A_{L/P} = 4\,000 \times L_L$
	$A_{DJ/P}$	0	(A.2)	No adjacent structure
Telecom line	$A_{L/T}$	$4{,}00 \times 10^4$	(A.9)	$A_{L/T} = 40 \times L_L$
	$A_{I/T}$	$4{,}00 \times 10^6$	(A.11)	$A_{L/T} = 4\,000 \times L_L$
	$A_{DJ/T}$	0	(A.2)	No adjacent structure

Table E.6 – Country house: Expected annual number of dangerous events

	Symbol	Result 1/year	Reference Equation	Equation
Structure	N_D	$1{,}03 \times 10^{-2}$	(A.4)	$N_D = N_G \times A_D \times C_D \times 10^{-6}$
	N_M	–	(A.6)	Not relevant
Power Line	$N_{L/P}$	$8{,}00 \times 10^{-2}$	(A.8)	$N_{L/P} = N_G \times A_{L/P} \times C_{I/P} \times C_{E/P} \times C_{T/P} \times 10^{-6}$
	$N_{I/P}$	8,00	(A.10)	$N_{I/P} = N_G \times A_{I/P} \times C_{I/P} \times C_{E/P} \times C_{T/P} \times 10^{-6}$
	$N_{DJ/P}$	0	(A.5)	No adjacent structure
Telecom Line	$N_{L/T}$	$1{,}60 \times 10^{-1}$	(A.8)	$N_{L/T} = N_G \times A_{L/T} \times C_{I/T} \times C_{E/T} \times C_{T/T} \times 10^{-6}$
	$N_{I/T}$	16	(A.10)	$N_{I/T} = N_G \times A_{I/T} \times C_{I/T} \times C_{E/T} \times C_{T/T} \times 10^{-6}$
	$N_{DJ/T}$	0	(A.5)	No adjacent structure

E.2.4 Risk R_1 – Determination of need of protection

The risk R_1 can be expressed according to Equation (1) by the following sum of components:

$$R_1 = R_A + R_B + R_{U/P} + R_{V/P} + R_{U/T} + R_{V/T}$$

Risk components are to be evaluated according to Table 6.

Involved components and total risk evaluation are given in Table E.7

Table E.7 – Country house: Risk R_1 for the unprotected structure (values × 10^{-5})

	Symbol	Z_1	Z_2	Structure
D1 Injury	R_A	–	≈ 0	**≈ 0**
	$R_U = R_{U/P} + R_{U/T}$		0,002	**0,002**
D2 Physical damage	R_B		0,103	**0,103**
	$R_V = R_{V/P} + R_{V/T}$		2,40	**2,40**
Total		**–**	**2,51**	**R_1 = 2,51**
Tolerable		**$R_1 > R_T$: Lightning protection is required**		**R_T = 1**

Because R_1 = 2,51×10^{-5} is higher than the tolerable value R_T = 10^{-5}, lightning protection for the structure is required.

E.2.5 Risk R_1 – Selection of protection measures

According to Table E.7 the main contributions to the value of risk are given by:

– component R_V (lightning flash to lines) of 96 %;

– component R_B (lightning flash to structure) of 4 %.

To reduce the risk R_1 to a tolerable value, the protective measures influencing the components R_V and R_B should be considered. Suitable measures include:

a) installing SPDs of LPL IV at the line entrance (lightning equipotential bonding) to protect both power and telephone lines in the house. According to Table B.7 this reduces the value of P_{EB} (due to SPDs on connected lines) from 1 to 0,05 and the values of P_U and P_V by the same factor;

b) installing an LPS of class IV (including mandatory lightning equipotential bonding). According to Tables B.2 and B.7 this reduces the value of P_B from 1 to 0,2 and the value of P_{EB} (due to SPDs on connected lines) from 1 to 0,05 and finally the values of P_U and P_V by the same factor.

Inserting these values into the equations, new values of risk components are obtained, as shown in Table E.8.

Table E.8 – Country house: Risk components relevant to risk R_1 for protected structure

Type of damage	Symbol	Result case a) × (10^{-5})	Result case b) × (10^{-5})
D1 Injury due to shock	R_A	≈ 0	≈ 0
	$R_U = R_{U/P} + R_{U/T}$	≈ 0	≈ 0
D2 Physical damage	R_B	0,103	0,021
	R_V	0,120	0,120
Total	$\boldsymbol{R_1}$	**0,223**	**0,141**

The choice of solution is decided on economic and technical factors.

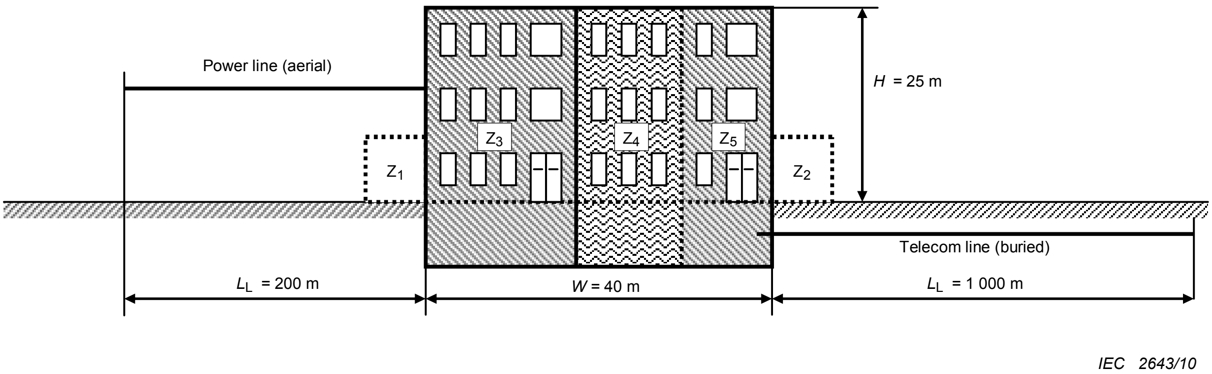
E.3 Office building

As a second case study, an office building with an archive, offices and a computer centre is considered (Figure E.2).

Loss of human life (L1) and economic loss (L4) are relevant for this type of structure.

It is required to evaluate the need for protection. This implies the determination of only the risk R_1 for loss of human life (L1) with the risk components R_A, R_B, R_U and R_V (according to Table 2) and to compare it with the tolerable risk $R_T = 10^{-5}$ (according to Table 4). Suitable protection measures will be selected to reduce the risk to or below the tolerable risk.

Following the decision taken by the owner an economic evaluation is not requested; therefore the risk R_4 for economic loss (L4) is not considered.



Key

Z_1: entrance (outside)

Z_2: garden (inside)

Z_3: archive

Z_4: offices

Z_5: computer centre

Figure E.2 – Office building

E.3.1 Relevant data and characteristics

The office building is located in flat territory without any neighbouring structures. The lightning flash density is N_G = 4 flashes per km^2 per year.

Data for the building and its surroundings are given in Table E.9.

Data for the incoming lines and their connected internal systems are given for the power line in Table E.10 and for the telecom line in Table E.11.

Table E.9 – Office building: Environment and structure characteristics

Input parameter	Comment	Symbol	Value	Reference
Ground flash density (1/km^2/year)		N_G	4,0	
Structure dimensions (m)		L, W, H	20, 40, 25	
Location factor of structure	Isolated structure	C_D	1	Table A.1
LPS	None	P_B	1	Table B.2
Equipotential bonding	None	P_{EB}	1	Table B.7
External spatial shield	None	K_{S1}	1	Equation (B.5)

Table E.10 – Office building: Power line

Input parameter	Comment	Symbol	Value	Reference
Length (m)		L_L	200	
Installation factor	Aerial	C_I	1	Table A.2
Line type factor	LV line	C_T	1	Table A.3
Environmental factor	Rural	C_E	1	Table A.4
Shield of line (Ω/km)	Unshielded	R_S	–	Table B.8
Shielding, grounding, isolation	None	C_{LD}	1	Table B.4
		C_{LI}	1	
Adjacent structure	None	L_J, W_J, H_J	–	
Location factor of adjacent structure	None	C_{DJ}	–	Table A.1
Withstand voltage of internal system (kV)		U_W	2,5	
	Resulting parameters	K_{S4}	0,4	Equation (B.7)
		P_{LD}	1	Table B.8
		P_{LI}	0,3	Table B.9

Table E.11 – Office building: Telecom line

Input parameter	Comment	Symbol	Value	Reference
Length (m)		L_L	1 000	
Installation factor	Buried	C_I	0,5	Table A.2
Line type factor	Telecom line	C_T	1	Table A.3
Environmental factor	Rural	C_E	1	Table A.4
Shield of line (Ω/km)	Unshielded	R_S	–	Table B.8
Shielding, grounding, isolation	None	C_{LD}	1	Table B.4
		C_{LI}	1	
Adjacent structure	None	L_J, W_J, H_J	–	
Location factor of adjacent structure	None	C_{DJ}	–	Table A.1
Withstand voltage of internal system (kV)		U_W	1,5	
	Resulting parameters	K_{S4}	0,67	Equation (B.7)
		P_{LD}	1	Table B.8
		P_{LI}	0,5	Table B.9

E.3.2 Definition of zones in the office building

The following zones are defined:

Z_1 (entrance area outside);

Z_2 (garden outside);

Z_3 (archive);

Z_4 (offices);

Z_5 (computer centre);

taking into account that:

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

– the structure is divided into two separate fireproof compartments: the first is the archive (Z_3) and the second is the offices together with the computer centre (Z_4 and Z_5);
– in all inner zones, Z_3, Z_4 and Z_5, internal systems connected to power as well as to telecom lines exist;
– no spatial shields exist.

In the different zones inside and outside the office building a total number of 200 persons shall be considered.

The number of persons related to each zone is different. The distribution into the individual zones is shown in Table E.12. These values are used later to subdivide the total loss values into fractions for each zone.

Table E.12 – Office building: Distribution of persons into zones

Zone	Number of persons	Time of presence
Z_1 (entrance outside)	4	8 760
Z_2 (garden outside)	2	8 760
Z_3 (archive)	20	8 760
Z_4 (offices)	160	8 760
Z_5 (computer centre)	14	8 760
Total	n_t **= 200**	**–**

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

– $L_T = 10^{-2}$ (outside the structure),
– $L_T = 10^{-2}$ (inside the structure),
– $L_F = 0,02$ classified as “commercial building”.

These global values were reduced for each zone according to the number of people endangered in the individual zone related to the total number of people considered.

The resulting characteristics of the zones Z_1 to Z_5 are given in the Tables E.13 to E.17.

Table E.13 – Office building: Factors valid for zone Z_1 (entrance area outside)

Input parameter	Comment	Symbol	Value	Reference
Ground surface	Marble	r_t	10^{-3}	Table C.3
Protection against shock	None	P_{TA}	1	Table B.1
Risk of fire	None	r_f	0	Table C.5
Fire protection	None	r_p	1	Table C.4
Internal spatial shield	None	K_{S2}	1	Equation (B.6)
L1: Loss of human life	Special hazard: None	h_z	1	Table C.6
	D1: due to touch and step voltage	L_T	10^{-2}	Table C.2
	D2: due to physical damage	L_F	–	
	D3: due to failure of internal systems	L_O	–	
Factor for persons in zone	$n_z/n_t \times t_z/8\ 760 = 4/200 \times 8\ 760/8\ 760$	–	0,02	

Table E.14 – Office building: Factors valid for zone Z_2 (garden outside)

Input parameter	Comment	Symbol	Value	Reference
Ground surface	Grass	r_t	10^{-2}	Table C.3
Protection against shock	Fence	P_{TA}	0	Table B.1
Risk of fire	None	r_f	0	Table C.5
Fire protection	None	r_p	1	Table C.4
Internal spatial shield	None	K_{S2}	1	Equation (B.6)
L1: Loss of human life	Special hazard: None	h_z	1	Table C.6
	D1: due to touch and step voltage	L_T	10^{-2}	Table C.2
	D2: due to physical damage	L_F	–	
	D3: due to failure of internal systems	L_O	–	
Factor for persons in zone	$n_z/n_t \times t_z/8\ 760 = 2/200 \times 8\ 760/8\ 760$	–	0,01	

Table E.15 – Office building: Factors valid for zone Z_3 (archive)

Input parameter		Comment	Symbol	Value	Reference
Type of floor		Linoleum	r_t	10^{-5}	Table C.3
Protection against shock (flash to structure)		None	P_{TA}	1	Table B.1
Protection against shock (flash to line)		None	P_{TU}	1	Table B.6
Risk of fire		High	r_f	10^{-1}	Table C.5
Fire protection		None	r_p	1	Table C.4
Internal spatial shield		None	K_{S2}	1	Equation (B.6)
Power	Internal wiring	Unshielded (loop conductors in the same conduit)	K_{S3}	0,2	Table B.5
	Coordinated SPDs	None	P_{SPD}	1	Table B.3
Telecom	Internal wiring	Unshielded (large loops $>10m^2$)	K_{S3}	1	Table B.5
	Coordinated SPDs	None	P_{SPD}	1	Table B.3
L1: Loss of human life		Special hazard: low panic	h_z	2	Table C.6
		D1: due to touch and step voltage	L_T	10^{-2}	Table C.2
		D2: due to physical damage	L_F	0,02	
		D3: due to failure of internal systems	L_O	–	
Factor for endangered persons		$n_z/n_t \times t_z/8\ 760 = 20/200 \times 8\ 760/8\ 760$	–	0,10	

Table E.16 – Office building: Factors valid for zone Z_4 (offices)

Input parameter		Comment	Symbol	Value	Reference
Type of floor		Linoleum	r_t	10^{-5}	Table C.3
Protection against shock (flash to structure)		None	P_{TA}	1	Table B.1
Protection against shock (flash to line)		None	P_{TU}	1	Table B.6
Risk of fire		Low	r_f	10^{-3}	Table C.5
Fire protection		None	r_p	1	Table C.4
Internal spatial shield		None	K_{S2}	1	Equation (B.6)
Power	Internal wiring	Unshielded (loop conductors in the same conduit)	K_{S3}	0,2	Table B.5

Input parameter		Comment	Symbol	Value	Reference
	Coordinated SPDs	None	P_{SPD}	1	Table B.3
Telecom	Internal wiring	Unshielded (large loops > 10 m^2)	K_{S3}	1	Table B.5
	Coordinated SPDs	None	P_{SPD}	1	Table B.3
L1: Loss of human life		Special hazard: low panic	h_z	2	Table C.6
		D1: due to touch and step voltage	L_T	10^{-2}	Table C.2
		D2: due to physical damage	L_F	0,02	
		D3: due to failure of internal systems	L_O	–	
Factor for persons in zone		$n_z/n_t \times t_z/8\,760$ = 160/200 × 8 760/8 760	–	0,80	

Table E.17 – Office building: Factors valid for zone Z_5 (computer centre)

Input parameter		Comment	Symbol	Value	Reference
Type of floor		Linoleum	r_t	10^{-5}	Table C.3
Protection against shock (flash to structure)		None	P_{TA}	1	Table B.1
Protection against shock (flash to line)		None	P_{TU}	1	Table B.6
Risk of fire		Low	r_f	10^{-3}	Table C.5
Fire protection		None	r_p	1	Table C.4
Internal spatial shield		None	K_{S2}	1	Equation (B.6)
Power	Internal wiring	Unshielded (loop conductors in the same conduit)	K_{S3}	0,2	Table B.5
	Coordinated SPDs	None	P_{SPD}	1	Table B.3
Telecom	Internal wiring	Unshielded (large loops > 10 m^2)	K_{S3}	1	Table B.5
	Coordinated SPDs	None	P_{SPD}	1	Table B.3
L1: Loss of human life		Special hazard: low panic	h_z	2	Table C.6
		D1: due to touch and step voltage	L_T	10^{-2}	Table C.2
		D2: due to physical damage	L_F	0,02	
		D3: due to failure of internal systems	L_O	–	
Factor for persons in zone		$n_z/n_t \times t_z/8\,760$ = 14/200 × 8 760/8 760	–	0,07	

E.3.3 Calculation of relevant quantities

Calculations are given in Table E.18 for the collection areas and in Table E.19 for the expected number of dangerous events.

Table E.18 – Office building: Collection areas of structure and lines

	Symbol	Result m²	Reference Equation	Equation
Structure	A_D	2,75 × 10^4	(A.2)	$A_D = L \times W + 2 \times (3 \times H) \times (L + W) + \pi \times (3 \times H)^2$
	A_M	–	(A.7)	Not relevant
Power line	$A_{L/P}$	8,00 × 10^3	(A.9)	$A_{L/P} = 40 \times L_L$
	$A_{I/P}$	8,00 × 10^5	(A.11)	Not relevant
	$A_{DA/P}$	0	(A.2)	No adjacent structure
Telecom line	$A_{L/T}$	4,00 × 10^4	(A.9)	$A_{L/P} = 40 \times L_L$
	$A_{I/T}$	4,00 × 10^6	(A.11)	Not relevant
	$A_{DA/T}$	0	(A.2)	No adjacent structure

Table E.19 – Office building: Expected annual number of dangerous events

	Symbol	Result 1/year	Reference Equation	Equation
Structure	N_D	$1{,}10 \times 10^{-1}$	(A.4)	$N_D = N_G \times A_D \times C_D \times 10^{-6}$
	N_M	–	(A.6)	Not relevant
Power line	$N_{L/P}$	$3{,}20 \times 10^{-2}$	(A.8)	$N_{L/P} = N_G \times A_{L/P} \times C_{I/P} \times C_{E/P} \times C_{T/P} \times 10^{-6}$
	$N_{I/P}$	3,20	(A.10)	Not relevant
	$N_{DA/P}$	0	(A.5)	No adjacent structure
Telecom line	$N_{L/T}$	$8{,}00 \times 10^{-2}$	(A.8)	$N_{L/T} = N_G \times A_{L/T} \times C_{I/T} \times C_{E/T} \times C_{T/T} \times 10^{-6}$
	$N_{I/T}$	8,00	(A.10)	Not relevant
	$N_{DA/T}$	0	(A.5)	No adjacent structure

E.3.4 Risk R_1 – Decision on need for protection

Values of the risk components for the unprotected structure are reported in Table E.20.

Table E.20 – Office building: Risk R_1 for the unprotected structure (values × 10^{-5})

Type of damage	Symbol	Z_1	Z_2	Z_3	Z_4	Z_5	Structure
D1 Injury due to shock	R_A	0,002	0	≈ 0	0,001	≈ 0	**0,003**
	$R_U = R_{U/P} + R_{U/T}$			≈ 0	0,001	≈ 0	**0,001**
D2 Physical damage	R_B			4,395	0,352	0,031	**4,778**
	$R_V = R_{V/P} + R_{V/T}$			4,480	0,358	0,031	**4,870**
Total		**0,002**	**0**	**8,876**	**0,712**	**0,062**	$\boldsymbol{R_1}$ **= 9,65**
Tolerable		$\boldsymbol{R_1 > R_T}$**: Lightning protection is required**					$\boldsymbol{R_T}$ **= 1**

Because $R_1 = 9{,}65 \times 10^{-5}$ is higher than the tolerable value $R_T = 10^{-5}$, lightning protection for the structure is required.

E.3.5 Risk R_1 – Selection of protection measures

The risk R_1 in the structure is mainly concentrated in zone Z_3 due to physical damages caused by lightning striking the structure or the connected lines (components R_B ≈ 49 % and R_V ≈ 50 % together cover 99 % of the total risk) (see Table E.20).

These dominant risk components can be reduced by:

– providing the whole building with an LPS conforming to IEC 62305-3 reducing component R_B via probability P_B. Lightning equipotential bonding at the entrance – a mandatory requirement of the LPS - reduces also the components R_U and R_V via probability P_{EB};

– providing zone Z_3 (archive) with protection measures against the consequences of fire (such as extinguishers, automatic fire detection system etc.). This will reduce the components R_B and R_V via the reduction factor r_p;

– providing lightning equipotential bonding conforming to IEC 62305-3 at the entrance of the building. This will reduce only the components R_U and R_V via probability P_{EB}.

Combining different elements of these protective measures the following solutions could be adopted:

Solution a)

– Protect the building with a Class III LPS conforming to IEC 62305-3, to reduce component R_B (P_B = 0,1).

– This LPS includes the mandatory lightning equipotential bonding at the entrance with SPDs designed for LPL III (P_{EB} = 0,05) and reduces components R_U and R_V.

Solution b)

– Protect the building with a Class IV LPS conforming to IEC 62305-3, to reduce component R_B (P_B = 0,2).
– This LPS includes the mandatory lightning equipotential bonding at the entrance with SPDs designed for LPL IV (P_{EB} = 0,05) and reduces components R_U and R_V.
– Use fire extinguishing (or detection) systems to reduce components R_B and R_V. Install a manual system in the zone Z3 (archive) (r_p = 0,5).

For both solutions, the risk values from Table E.20 will change to the reduced values reported in Table E.21.

Table E.21 – Office building: Risk R_1 for the protected structure (values × 10^{-5})

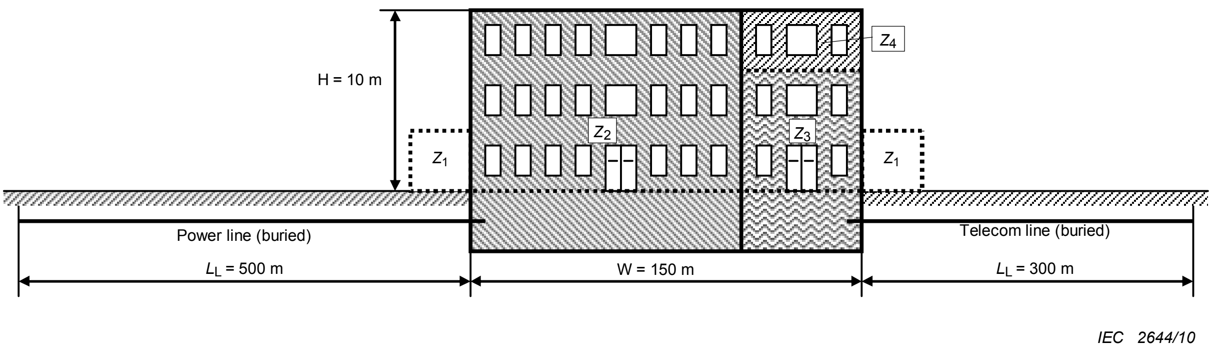
	Z_1	Z_2	Z_3	Z_4	Z_5	Total	Tolerable	Result
Solution a)	≈ 0	0	0,664	0,053	0,005	R_1 = 0,722	R_T = 1	$R_1 \le R_T$
Solution b)	≈ 0	0	0,552	0,089	0,008	R_1 = 0,648	R_T = 1	$R_1 \le R_T$

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.

E.4 Hospital

As a more complex case, this study considers a standard hospital facility with a rooms block, an operating block and an intensive care unit.

Loss of human life (L1) and economic loss (L4) are relevant for this type of facility. It is necessary to evaluate the need for protection and the cost effectiveness of protection measures; these require the evaluation of risks R_1 and R_4.



Key

Z_1: outside

Z_2: rooms block

Z_3: operation block

Z_4: intensive care unit

Figure E.3 – Hospital

E.4.1 Relevant data and characteristics

The hospital is located in flat territory without any neighbouring structures. The lightning flash density is N_G = 4 flashes per km^2 per year.

Data for the building and its surroundings are given in Table E.22.

Data for the incoming lines and their internal systems connected thereto are given for the power line in Table E.23 and for the telecom line in Table E.24.

Table E.22 – Hospital: Environment and global structure characteristics

Input parameter	Comment	Symbol	Value	Reference
Ground flash density (1/km^2/year)		N_G	4,0	
Structure dimensions (m)		L, W, H	50, 150, 10	
Location factor of structure	Isolated structure	C_D	1	Table A.1
LPS	None	P_B	1	Table B.2
Equipotential bonding	None	P_{EB}	1	Table B.7
External spatial shield	None	K_{S1}	1	Equation (B.5)

Table E.23 – Hospital: Power line

Input parameter	Comment	Symbol	Value	Reference
Length (m)		L_L	500	
Installation factor	Buried	C_I	0,5	Table A.2
Line type factor	HV power (with HV/LV transformer)	C_T	0,2	Table A.3
Environmental factor	Suburban	C_E	0,5	Table A.4
Shield of line (Ω/km)	Line shield bonded to the same bonding bar as equipment	R_S	$R_S \leq 1$	Table B.8
Shielding, grounding, isolation	Line shield bonded to the same bonding bar as equipment	C_{LD}	1	Table B.4
		C_{LI}	0	
Adjacent structure (m)	None	L_J, W_J, H_J	–	
Location factor of adjacent structure	None	C_{DJ}	–	Table A.1
Withstand voltage of internal system (kV)		U_W	2,5	
	Resulting parameters	K_{S4}	0,4	Equation (B.7)
		P_{LD}	0,2	Table B.8
		P_{LI}	0,3	Table B.9

Table E.24 – Hospital: Telecom line

Input parameter	Comment	Symbol	Value	Reference
Length (m)		L_L	300	
Installation factor	Buried	C_I	0,5	Table A.2
Line type factor	Telecom line	C_T	1	Table A.3
Environmental factor	Suburban	C_E	0,5	Table A.4
Shield of line (Ω/km)	Line shield bonded to the same bonding bar as equipment.	R_S	$1 < R_S \leq 5$	Table B.8
Shielding, grounding, isolation	Line shield bonded to the same	C_{LD}	1	Table B.4

Input parameter	Comment	Symbol	Value	Reference
	bonding bar as equipment.	C_{LI}	0	
Adjacent structure (m)	Length, width, height	L_J, W_J, H_J	20, 30, 5	
Location factor of adjacent structure	Isolated structure	C_{DJ}	1	Table A.1
Withstand voltage of internal system (kV)		U_W	1,5	
	Resulting parameters	K_{S4}	0,67	Equation (B.7)
		P_{LD}	0,8	Table B.8
		P_{LI}	0,5	Table B.9

E.4.2 Definition of zones in the hospital

The following zones are defined:

Z_1 (outside building);

Z_2 (rooms block);

Z_3 (operating block);

Z_4 (intensive care unit);

taking into account the following:

- the type of surface is different outside the structure from that inside the structure;
- two separate fire proof compartments exist: the first is the rooms block (Z_2) and the second is the operating block together with the intensive care unit (Z_3 and Z_4);
- in all inner zones Z_2, Z_3 and Z_4, internal systems connected to power as well as to telecom lines exist;
- no spatial shields exist;
- the intensive care unit contains extensive sensitive electronic systems and a spatial shield may be adopted as protection measure;

In the different zones inside and outside the hospital a total number of 1 000 persons shall be considered.

The number of persons, the times of presence and the economic values related to each zone are different. The distribution into the individual zones and the total values are shown in Table E.25. These values are used later to subdivide the total loss values into fractions for each zone.

Table E.25 – Hospital: Distribution of persons and of economic values into zones

Zone	Number of persons	Time of presence (h/y)	Economic values in $ x 10^6				
			Animals c_a	Building c_b	Content c_c	Internal systems c_s	Total c_t
Z_1 (outside building)	10	8 760	–	–	–	–	**–**
Z_2 (rooms block)	950	8 760	–	70	6	3,5	**79,5**
Z_3 (operating block)	35	8 760	–	2	0,9	5,5	**8,4**
Z_4 (intensive care unit)	5	8 760	–	1	0,1	1,0	**2,1**
Total	**n_t = 1 000**	**–**	**0**	**73**	**7**	**10**	**90,0**

For risk R_1, following the evaluation by the lightning protection designer, the basic loss values (typical mean values of relative amount of loss per year) according to Table C.2 and the increasing factor for special hazards according to Table C.6 are as follows:

- $L_T = 10^{-2}$ in zone Z_1 outside the structure;
- $L_T = 10^{-2}$ in zones Z_2, Z_3, Z_4 inside the structure;
- $L_F = 10^{-1}$ in zones Z_2, Z_3, Z_4 inside the structure;
- $h_z = 5$ in zones Z_2, Z_3, Z_4 inside the structure due to difficulty of evacuation;
- $L_O = 10^{-3}$ in zone Z_2 (rooms block);
- $L_O = 10^{-2}$ in zone Z_3 (operating block) and zone Z_4 (intensive care unit).

These basic loss values were reduced for each zone according to the Equations (C.1) to (C.4) taking into account the number of people endangered in the individual zone related to the total number of people considered and the time when people are present.

For risk R_4 the basic loss values according to Table C.12 are as follows:

- $L_T = 0$ no animals endangered;
- $L_F = 0{,}5$ in zones Z_2, Z_3, Z_4 inside the structure;
- $L_O = 10^{-2}$ in zones Z_2, Z_3, Z_4 inside the structure.

These basic loss values were reduced for each zone according to Equations (C.11) to (C.13) taking into account the value endangered in the individual zone related to the total value of the structure (animals, building, content, internal systems and activities) considered. The value endangered in an individual zone depends on the type of damage:

- D1 (injury by electric shock): value c_a of animals only;
- D2 (physical damage): sum of all values $c_a + c_b + c_c + c_s$;
- D3 (failure of internal system): value c_s of internal systems and their activities only.

The resulting characteristics of the zones Z_1 to Z_4 are given in Tables E.26 to E.29.

Table E.26 – Hospital: Factors valid for zone Z_1 (outside the building)

Input parameter	Comment	Symbol	Value	Reference
Ground surface	Concrete	r_t	10^{-2}	Table C.3
Protection against shock	None	P_{TA}	1	Table B.1
Risk of fire	None	r_f	0	Table C.5
Fire protection	None	r_p	1	Table C.4
Internal spatial shield	None	K_{S2}	1	Equation (B.6)
L1: Loss of human life	Special hazard: None	h_z	1	Table C.5
	D1: due to touch and step voltage	L_T	10^{-2}	Table C.2
	D2: due to physical damage	L_F	0	
	D3: due to failure of internal systems	L_O	0	
Factor for persons in zone	$n_z / n_t \times t_z / 8\,760 = 10 / 1\,000 \times 8\,760 / 8\,760$	–	0,01	

Table E.27 – Hospital: Factors valid for zone Z_2 (rooms block)

Input parameter	Comment	Symbol	Value	Reference
Type of floor	Linoleum	r_t	10^{-5}	Table C.3
Protection against shock (flash to structure)	None	P_{TA}	1	Table B.1

Input parameter		Comment	Symbol	Value	Reference
Protection against shock (flash to line)		None	P_{TU}	1	Table B.9
Risk of fire		Ordinary	r_f	10^{-2}	Table C.5
Fire protection		None	r_p	1	Table C.4
Internal spatial shield		None	K_{S2}	1	Equation (B.6)
Power	Internal wiring	Unshielded (loop conductors in the same conduit)	K_{S3}	0,2	Table B.5
	Coordinated SPDs	None	P_{SPD}	1	Table B.3
Telecom	Internal wiring	Unshielded (loop conductors in the same cable)	K_{S3}	0,01	Table B.5
	Coordinated SPDs	None	P_{SPD}	1	Table B.3
L1: Loss of human life		Special hazard: difficulty of evacuation	h_z	5	Table C.6
		D1: due to touch and step voltage	L_T	10^{-2}	Table C.2
		D2: due to physical damage	L_F	10^{-1}	
		D3: due to failure of internal systems	L_O	10^{-3}	
Factor for persons in zone		$n_z / n_t \times t_z$ / 8 760 = 950 / 1 000 × 8 760 / 8 760	–	0,95	
L4: Economic loss		D2: due to physical damage	L_F	0,5	Table C.12
		D2: Factor $(c_a + c_b + c_c + c_s)/ c_t$ = 79,5 / 90	–	0,883	
		D3: due to failure of internal systems	L_O	10^{-2}	
		D3: Factor c_s / c_t = 3,5 / 90	–	0,039	

Table E.28 – Hospital: Factors valid for zone Z_3 (operating block)

Input parameter		Comment	Symbol	Value	Reference
Type of floor		Linoleum	r_t	10^{-5}	Table C.3
Protection against shock (flash to structure)		None	P_{TA}	1	Table B.1
Protection against shock (flash to line)		None	P_{TU}	1	Table B.9
Risk of fire		Low	r_f	10^{-3}	Table C.5
Fire protection		None	r_p	1	Table C.4
Internal spatial shield		None	K_{S2}	1	Equation (B.6)
Power line	Internal wiring	Unshielded (loop conductors in the same conduit)	K_{S3}	0,2	Table B.5
	Coordinated SPDs	None	P_{SPD}	1	Table B.3
Telecom line	Internal wiring	Unshielded (loop conductors in the same cable)	K_{S3}	0,01	Table B.5
	Coordinated SPDs	None	P_{SPD}	1	Table B.3
L1: Loss of human life		Special hazard: difficulty of evacuation	h_z	5	Table C.6
		D1: due to touch and step voltage	L_T	10^{-2}	Table C.2
		D2: due to physical damage	L_F	10^{-1}	
		D3: due to failure of internal systems	L_O	10^{-2}	
Factor for persons in zone		$n_z / n_t \times t_z$ / 8 760 = 35 / 1 000 × 8 760 / 8 760	–	0,035	
L4: Economic loss		D2: due to physical damage	L_F	0,5	Table C.12
		D2: Factor $(c_a + c_b + c_c + c_s) / c_t$ = 8,4 / 90	–	0,093	
		D3: due to failure of internal systems	L_O	10^{-2}	
		D3: Factor c_s / c_t = 5,5 / 90	–	0,061	

Table E.29 – Hospital: Factors valid for zone Z_4 (intensive care unit)

Input parameter		Comment	Symbol	Value	Reference
Type of floor		Linoleum	r_t	10^{-5}	Table C.3
Protection against shock (flash to structure)		None	P_{TA}	1	Table B.1
Protection against shock (flash to line)		None	P_{TU}	1	Table B.9
Risk of fire		Low	r_f	10^{-3}	Table C.5
Fire protection		None	r_p	1	Table C.4
Internal spatial shield		None	K_{S2}	1	Equation (B.6)
Power Line	Internal wiring	Unshielded (loop conductors in the same conduit)	K_{S3}	0,2	Table B.5
	Coordinated SPDs	None	P_{SPD}	1	Table B.3
Telecom Line	Internal wiring	Unshielded (loop conductors in the same cable)	K_{S3}	0,01	Table B.5
	Coordinated SPDs	None	P_{SPD}	1	Table B.3
L1: Loss of human life		Special hazard: difficulty of evacuation	h_z	5	Table C.6
		D1: due to touch and step voltage	L_T	10^{-2}	Table C.2
		D2: due to physical damage	L_F	10^{-1}	
		D3: due to failure of internal systems	L_O	10^{-2}	
Factor for persons in zone		n_z / n_t × t_z / 8 760 = 5 / 1 000 × 8 760 / 8 760	–	0,005	
L4: Economic loss		D2: due to physical damage	L_F	0,5	Table C.12
		D2: Factor (c_a + c_b + c_c + c_s) / c_t = 2,1 / 90	–	0,023	
		D3: due to failure of internal systems	L_O	10^{-2}	
		D3: Factor c_s / c_t = 1,0 / 90	–	0,011	

E.4.3 Calculation of relevant quantities

Calculations are given in Table E.30 for the collection areas and in Table E.31 for the expected number of dangerous events.

Table E.30 – Hospital: Collection areas of structure and lines

	Symbol	Result m^2	Reference Equation	Equation
Structure	A_D	$2{,}23 \times 10^4$	(A.2)	$A_D = L \times W + 2 \times (3 \times H) \times (L + W) + \pi \times (3 \times H)^2$
	A_M	$9{,}85 \times 10^5$	(A.7)	$A_M = 2 \times 500 \times (L+W) + \pi \times 500^2$
Power line	$A_{L/P}$	$2{,}00 \times 10^4$	(A.9)	$A_{L/P} = 40 \times L_L$
	$A_{I/P}$	$2{,}00 \times 10^6$	(A.11)	$A_{L/P} = 4\,000 \times L_L$
	$A_{DJ/P}$	0	(A.2)	No adjacent structure
Telecom line	$A_{L/T}$	$1{,}20 \times 10^4$	(A.9)	$A_{L/P} = 40 \times L_L$
	$A_{I/T}$	$1{,}20 \times 10^6$	(A.11)	$A_{L/P} = 4\,000 \times L_L$
	$A_{DJ/T}$	$2{,}81 \times 10^3$	(A.2)	$A_{DJ/T} = L_J \times W_J + 2 \times (3 \times H_J) \times (L_J + W_J) + \pi \times (3 \times H_J)^2$

Table E.31 – Hospital: Expected annual number of dangerous events

	Symbol	Result 1/year	Reference Equation	Equation
Structure	N_D	$8,93 \times 10^{-2}$	(A.4)	$N_D = N_G \times A_{D/B} \times C_{D/B} \times 10^{-6}$
	N_M	3,94	(A.6)	$N_M = N_G \times A_M \times 10^{-6}$
Power line	$N_{L/P}$	$4,00 \times 10^{-3}$	(A.8)	$N_{L/P} = N_G \times A_{L/P} \times C_{I/P} \times C_{E/P} \times C_{T/P} \times 10^{-6}$
	$N_{I/P}$	$4,00 \times 10^{-1}$	(A.10)	$N_{I/P} = N_G \times A_{I/P} \times C_{I/P} \times C_{E/P} \times C_{T/P} \times 10^{-6}$
	$N_{DJ/P}$	0	(A.5)	No adjacent structure
Telecom line	$N_{L/T}$	$1,20 \times 10^{-2}$	(A.8)	$N_{L/T} = N_G \times A_{L/T} \times C_{I/T} \times C_{E/T} \times C_{T/T} \times 10^{-6}$
	$N_{I/T}$	1,20	(A.10)	$N_{I/T} = N_G \times A_{I/T} \times C_{I/T} \times C_{E/T} \times C_{T/T} \times 10^{-6}$
	$N_{DJ/T}$	$1,12 \times 10^{-2}$	(A.5)	$N_{DJ/T} = N_G \times A_{DJ/T} \times C_{DJ/T} \times C_{T/T} \times 10^{-6}$

E.4.4 Risk R_1 – Decision on need for protection

Values of the probabilities P_X are given in Table E.32 and the risk components for the unprotected structure are reported in Table E.33.

Table E.32 – Hospital: Risk R_1 – Values of probability P for the unprotected structure

Type of damage	Symbol	Z_1	Z_2	Z_3	Z_4	Reference Equation	Equation
D1 Injury due to shock	P_A	1	1				
	$P_{U/P}$		0,2				
	$P_{U/T}$		0,8				
D2 Physical damage	P_B		1				
	$P_{V/P}$		0,2				
	$P_{V/T}$		0,8				
D3 Failure of internal systems	P_C		1			(14)	$P_C = 1 - (1 - P_{C/P}) \times (1 - P_{C/T}) =$ $= 1 - (1 - 1) \times (1 - 1)$
	P_M		0,0064			(15)	$P_M = 1 - (1 - P_{M/P}) \times (1 - P_{M/T}) =$ $= 1 - (1 - 0,006\ 4) \times (1 - 0,000\ 04)$
	$P_{W/P}$		0,2				
	$P_{W/T}$		0,8				
	$P_{Z/P}$		0				
	$P_{Z/T}$		0				

Table E.33 – Hospital: Risk R_1 for the unprotected structure (values × 10^{-5})

Type of damage	Symbol	Z_1	Z_2	Z_3	Z_4	Structure
D1 Injury due to shock	R_A	0,009	0,000 9	≈0	≈0	**0,010**
	$R_U = R_{U/P} + R_{U/T}$		≈0	≈0	≈0	**≈0**
D2 Physical damage	R_B		42,4	0,156	0,022	**42,6**
	$R_V = R_{V/P} + R_{V/T}$		9,21	0,034	0,005	**9,245**
D3 Failure of internal	R_C		8,484	3,126	0,447	**12,057**
	R_M		2,413	0,889	0,127	**3,429**

Type of damage	Symbol	Z_1	Z_2	Z_3	Z_4	Structure
systems	$R_W = R_{W/P} + R_{W/T}$		1,841	0,678	0,097	**2,616**
	$R_Z = R_{Z/P} + R_{Z/T}$					
Total		**0,009**	**64,37**	**4,89**	**0,698**	R_1 **= 69,96**
Tolerable		$R_1 > R_T$: **Lightning protection is required**				R_T **= 1**

Because $R_1 = 69{,}96 \times 10^{-5}$ is higher than the tolerable value $R_T = 10^{-5}$, lightning protection for the structure is required.

E.4.5 Risk R_1 – Selection of protection measures

The risk R_1 is mainly influenced (see Table E.33):

- by physical damage in the zone Z_2 (components $R_B \approx 61$ % and $R_V \approx 13$ % of the total risk);
- by failures of internal systems in the zones Z_2 and Z_3 (components $R_C \approx 12$ % respectively $R_C \approx 5$ %) of the total risk.

These dominant risk components can be reduced by:

- providing the whole building with an LPS conforming to IEC 62305-3 reducing component R_B via probability P_B. The mandatory-included lightning equipotential bonding at the entrance reduces also the components R_U and R_V via probability P_{EB};
- providing zone Z_2 with protection measures against the consequences of fire (such as extinguishers, automatic fire detection system, etc.). This will reduce the components R_B and R_V via the reduction factor r_p;
- providing zones Z_3 and Z_4 with a coordinated SPD protection conforming to IEC 62305-4 for the internal power and telecom systems. This will reduce the components R_C, R_M, R_W via the probability P_{SPD}.
- providing zones Z_3 and Z_4 with an adequate spatial grid-like shield conforming to IEC 62305-4. This will reduce the component R_M via the probability P_M.

Combining different elements of these protective measures the following solutions could be adopted:

Solution a)

- protect the building with a Class I LPS ($P_B = 0{,}02$ including also $P_{EB} = 0{,}01$);
- install coordinated SPD protection on internal power and telecom systems for (1,5 x) better than LPL I ($P_{SPD} = 0{,}005$) in zones Z_2, Z_3, Z_4;
- provide zone Z_2 with an automatic fire protection system ($r_p = 0{,}2$ for zone Z_2 only);
- provide zone Z_3 and Z_4 with a meshed shield with $w_m = 0{,}5$ m.

Using this solution, the risk values from Table E.33 will change to the reduced values reported in Table E.34.

Table E.34 – Hospital: Risk R_1 for the protected structure according to solution a) (values × 10^{-5})

Type of damage	Symbol	Z_1	Z_2	Z_3	Z_4	Structure
D1 Injury due to shock	R_A	≈ 0	≈ 0	≈ 0	≈ 0	**≈ 0**
	$R_U = R_{U/P} + R_{U/T}$		≈ 0	≈ 0	≈ 0	**≈ 0**
D2 Physical damage	R_B		0,170	0,003	≈ 0	**0,173**
	$R_V = R_{V/P} + R_{V/T}$		0,018	≈ 0	≈ 0	**0,018**
D3 Failure of internal systems	R_C		0,085	0,031	0,004	**0,12**
	R_M		0,012	≈ 0	≈ 0	**0,012**
	$R_W = R_{W/P} + R_{W/T}$		0,009	0,003	≈ 0	**0,004**
	$R_Z = R_{Z/P} + R_{Z/T}$					
Total		**≈ 0**	**0,294**	**0,038**	**0,005**	**R_1 = 0,338**
Tolerable		**$R_1 < R_T$: Structure is protected for this type of loss**				**R_T = 1**

Solution b)

- Protect the building with a Class I LPS (P_B = 0,02 including also P_{EB} = 0,01).
- Install coordinated SPD protection on internal power and telecom systems for (3 x) better than LPL I (P_{SPD} = 0,001) in zones Z_2, Z_3, Z_4.
- Provide zone Z_2 with an automatic fire protection system (r_p = 0,2 for zone Z_2 only).

Using this solution, the risk values from Table E.33 will change to the reduced values reported in Table E.35.

Table E.35 – Hospital: Risk R_1 for the protected structure according to solution b) (values × 10^{-5})

Type of damage	Symbol	Z_1	Z_2	Z_3	Z_4	Structure
D1 Injury due to shock	R_A	≈ 0	≈ 0	≈ 0	≈ 0	**≈ 0**
	$R_U = R_{U/P} + R_{U/T}$		≈ 0	≈ 0	≈ 0	**≈ 0**
D2 Physical damage	R_B		0,170	0,003	0,001	**0,174**
	$R_V = R_{V/P} + R_{V/T}$		0,018	≈ 0	≈0	**0,018**
D3 Failure of internal systems	R_C		0,017	0,006	0,001	**0,024**
	R_M		0,002	0,001	≈0	**0,003**
	$R_W = R_{W/P} + R_{W/T}$		0,002	0,001	≈ 0	**0,003**
	$R_Z = R_{Z/P} + R_{Z/T}$					
Total		**≈ 0**	**0,209**	**0,011**	**0,002**	**R_1 = 0,222**
Tolerable		**$R_1 < R_T$: Structure is protected for this type of loss**				**R_T = 1**

Solution c)

- Protect the building with a Class I LPS (P_B = 0,02 including also P_{EB} = 0,01).
- Install coordinated SPD protection on internal power and telecom systems for (2 x) better than LPL I (P_{SPD} = 0,002) in zones Z_2, Z_3, Z_4.
- Provide zone Z_2 with an automatic fire protection system (r_p = 0,2 for zone Z_2 only).
- Provide zone Z_3 and Z_4 with a meshed shield with w_m = 0,1m.

Using this solution, the risk values from Table E.33 will change to the reduced values reported in Table E.36.

Table E.36 – Hospital: Risk R_1 for the protected structure according to solution c) (values × 10^{-5})

Type of damage	Symbol	Z_1	Z_2	Z_3	Z_4	Structure
D1 Injury due to shock	R_A	≈ 0	≈ 0	≈ 0	≈ 0	**≈ 0**
	$R_U = R_{U/P} + R_{U/T}$		≈ 0	≈ 0	≈ 0	**≈ 0**
D2 Physical damage	R_B		0,170	0,003	≈ 0	**0,173**
	$R_V = R_{V/P} + R_{V/T}$		0,018	≈ 0	≈ 0	**0,018**
D3 Failure of internal systems	R_C		0,034	0,012	0,002	**0,048**
	R_M		≈ 0	≈ 0	≈ 0	**≈ 0**
	$R_W = R_{W/P} + R_{W/T}$		0,004	0,001	≈ 0	**0,005**
	$R_Z = R_{Z/P} + R_{Z/T}$					
Total		**≈ 0**	**0,226**	**0,016**	**0,002**	**R_1 = 0,244**
Tolerable		**$R_1 < R_T$: Structure is protected for this type of loss**				**R_T = 1**

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.

E.4.6 Risk R_4 – Cost benefit analysis

For the economic loss L4 the corresponding risk R_4 can be evaluated in the same way as before. All parameters required for evaluating the risk components are given in Tables E.22 through E.29, where the loss values L_X for economic loss L4 only are valid. Therefore only the zones Z_2, Z_3 and Z_4 are relevant, whereas zone Z_1 is disregarded (It could be relevant only in case of loss of animals).

The economic values (animals, building, internal systems and activities) were given above in Table E.25 for each zone and in total.

From the risk values R_4 or R'_4 and from the total value of the structure $c_t = 90 \times 10^6$ $ (Table E.25) the annual cost of loss $C_L = R_4 \times c_t$ for the unprotected and $C_{RL} = R'_4 \times c_t$ for the protected structure can be calculated (see Equation (D.2) and (D.4)). The results are shown in Table E.37.

Table E.37 – Hospital: Cost of loss C_L(unprotected) and C_{RL}(protected)

Protection	Risk R_4 values × 10^{-5}					Cost of loss $
	Z_1	Z_2	Z_3	Z_4	Structure	C_L or C_{RL}
Unprotected	–	53,2	8,7	1,6	**63,5**	**57 185**
Solution a)	–	0,22	0,07	0,01	**0,30**	**271**
Solution b)	–	0,18	0,02	0,005	**0,21**	**190**
Solution c)	–	0,19	0,03	0,007	**0,23**	**208**

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

Table E.38 – Hospital: Rates relevant to the protection measures

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

A list of cost C_P for possible protection measures and the annual cost C_{PM} of the protection measures adopted in solution a), b) or c) are given in Table E.39 (see Equation (D.5)).

Table E.39 – Hospital: Cost C_P and C_{PM} of protection measures (values in $)

Protection measure	Cost C_P	Annual cost $C_{PM} = C_P (I + a + m)$		
		Solution a)	**Solution b)**	**Solution c)**
LPS class I	100 000	10 000	10 000	10 000
Automatic fire protection in zone Z_2	50 000	5 000	5 000	5 000
Zones Z_3 and Z_4 shielding (w = 0,5 m)	100 000	10 000		
Zones Z_3 and Z_4 shielding (w = 0,1 m)	110 000			11 000
SPD on power system (1,5 × LPL I)	20 000	2 000		
SPD on power system (2 × LPL I)	24 000			2 400
SPD on power system (3 × LPL I)	30 000		3 000	
SPD on TLC system (1,5 × LPL I)	10 000	1 000		
SPD on TLC system (2 × LPL I)	12 000			1 200
SPD on TLC system (3 × LPL I)	15 000		1 500	
Total annual cost C_{PM}		**28 000**	**19 500**	**29 600**

The annual saving of money S_M can be evaluated by comparison of the annual cost of loss C_L for the unprotected structure with the sum of the residual annual cost of loss C_{RL} for the protected structure and the annual cost of the protection measures C_{PM}. The results for solution a), b) and c) are given in Table E.40.

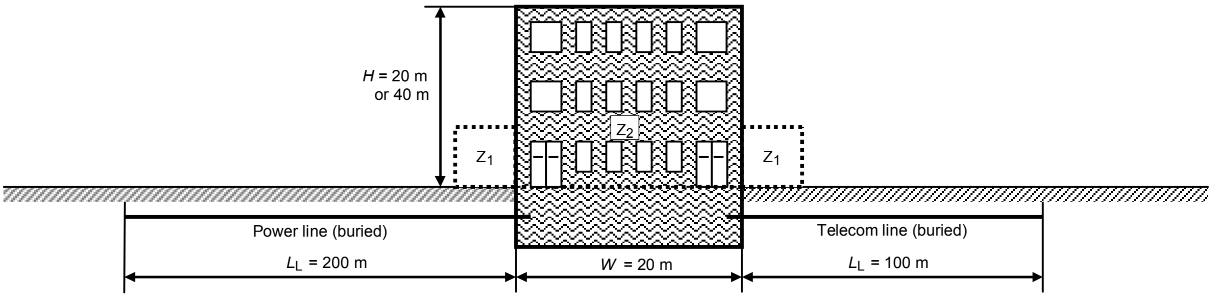
Table E.40 – Hospital: Annual saving of money (values in $)

	Symbol	Solution a)	Solution b)	Solution c)
Loss for the unprotected structure	C_L	57 185	57 185	57 185
Residual loss for the protected structure	C_{RL}	271	190	208
Annual cost of protection	C_{PM}	28 000	19 500	29 600
Annual saving $S_M = C_L - (C_{RL} + C_{PM})$	S_M	**28 914**	**37 495**	**27 377**

E.5 Apartment block

This case study compares different solutions for lightning protection for an apartment block. The results show that some solutions may not be not sufficient, whereas several suitable solutions can be chosen from different combinations of protection measures.

Only the risk R_1 for loss of human life (L1) with the risk components R_A, R_B, R_U and R_V (according Table 2) will be determined and compared with the tolerable value $R_T = 10^{-5}$ (according to Table 4). Economic evaluation is not required, therefore the risk R_4 for economic loss (L4) is not considered.



Key

Z_1: outside

Z_2: inside

Figure E.4 – Apartment block

E.5.1 Relevant data and characteristics

The apartment block is located in flat territory without any neighboring structures. The lightning flash density is N_G = 4 flashes per km^2 per year. 200 persons live in the block. This is also the total number of persons to be considered, because outside the building no people are assumed to be present during a thunderstorm.

Data for the block and its surroundings are given in Table E.41.

Data for the incoming lines and their internal systems connected to are given for the power line in Table E.42 and for the telecom line in Table E.43.

Table E.41 – Apartment block: Environment and global structure characteristics

Input parameter	Comment	Symbol	Value	Reference
Ground flash density (1/km^2/year)		N_G	4,0	
Structure dimensions (m)	H = 20 or 40 (see Table E.45)	L, W	30, 20	
Location factor of structure	Isolated structure	C_D	1	Table A.1
LPS	Variable (see Table E.45)	P_B	–	Table B.2
Equipotential bonding	None	P_{EB}	1	Table B.7
External spatial shield	None	K_{S1}	1	Equation (B.5)

Table E.42 – Apartment block: Power line

Input parameter	Comment	Symbol	Value	Reference
Length (m)		L_L	200	
Installation factor	Buried	C_I	0,5	Table A.2
Line type factor	LV line	C_T	1	Table A.3
Environmental factor	Suburban	C_E	0,5	Table A.4
Shield of line (Ω/km)	Unshielded	R_S	–	Table B.8
Shielding, grounding, isolation	None	C_{LD}	1	Table B.4
		C_{LI}	1	
Adjacent structure (m)	None	L_J, W_J, H_J	–	
Location factor of adjacent	None	C_{DJ}	–	Table A.1

Input parameter	Comment	Symbol	Value	Reference
structure				
Withstand voltage of internal system (kV)		U_W	2,5	
	Resulting parameters	K_{S4}	0,4	Equation (B.7)
		P_{LD}	1	Table B.8
		P_{LI}	0,3	Table B.9

Table E.43 – Apartment block: Telecom line

Input parameter	Comment	Symbol	Value	Reference
Length (m)		L_L	100	
Installation factor	Buried	C_I	0,5	Table A.2
Line type factor	Telecom line	C_T	1	Table A.3
Environmental factor	Suburban	C_E	0,5	Table A.4
Shield of line (Ω/km)	Unshielded	R_S	–	Table B.8
Shielding, grounding, isolation	None	C_{LD}	1	Table B.4
		C_{LI}	1	
Adjacent structure (m)	None	L_J, W_J, H_J	–	
Location factor of adjacent structure	None	C_{DJ}	–	Table A.1
Withstand voltage of internal system (kV)		U_W	1,5	
	Resulting parameters	K_{S4}	0,67	Equation (B.7)
		P_{LD}	1	Table B.8
		P_{LI}	0,5	Table B.9

E.5.2 Definition of zones in the apartment block

The following zones may be defined:

– Z_1 (outside the building);

– Z_2 (inside the building).

For zone Z_1 it is assumed that no people are outside the building. Therefore the risk of shock to people R_A = 0. Because R_A is the only risk component outside the building, zone Z_1 can be disregarded completely.

The zone Z_2 is defined taking into account the following:

– the structure is classified as a "civil building";

– both internal systems (power and telecom) exist in this zone;

– no spatial shields exist;

– the structure is a single fireproof compartment;

– losses are assumed to correspond to the typical mean values of Table C.1.

The resulting factors valid for zone Z_2 are reported in Table E.44.

Table E.44 – Apartment block: Factors valid for zone Z_2 (inside the building)

Input parameter		Comment	Symbol	Value	Reference
Type of floor		Wood	r_t	10^{-5}	Table C.3
Protection against shock (flash to structure)		none	P_{TA}	1	Table B.1
Protection against shock (flash to line)		none	P_{TU}	1	Table B.6
Risk of fire		Variable (see Table E.45)	r_f	–	Table C.5
Fire protection		Variable (see Table E.45)	r_p	–	Table C.4
Internal spatial shield		none	K_{S2}	1	Equation (B.6)
Power	Internal wiring	Unshielded (loop conductors in the same conduit)	K_{S3}	0,2	Table B.5
	Coordinated SPDs	None	P_{SPD}	1	Table B.3
Telecom	Internal wiring	Unshielded (large loops > $10 m^2$)	K_{S3}	1	Table B.5
	Coordinated SPDs	None	P_{SPD}	1	Table B.3
L1: Loss of human life		Special hazard: None	h_z	1	Table C.6
		D1: due to touch and step voltage	L_T	10^{-2}	Table C.2
		D2: due to physical damage	L_F	10^{-1}	
Factor for persons in zone		n_z / n_t × t_z / 8 760 = 200 / 200 × 8 760 / 8 760	–	1	

E.5.3 Risk R_1 – Selection of protection measures

Risk R_1 values and the protection measures selected to reduce the risk to the tolerable level $R_T = 10^{-5}$ are given in Table E.45, depending on the following parameters:

– height of the building H;

– reduction factor r_f for the risk of fire;

– reduction factor r_p reducing the consequences of fire;

– probability P_B depending on the class of LPS adopted.

Table E.45 – Apartment block: Risk R_1 for the apartment block depending on protection measures

Height H m	Risk of fire		LPS		Fire protection		Risk R_1 Values × 10^{-5}	Structure protected $R_1 \leq R_T$
	Type	r_f	**Class**	P_B	**Type**	r_p		
20	Low	0,001	None	1	None	1	**0,837**	Yes
	Ordinary	0,01	None	1	None	1	**8,364**	No
			III	0,1	None	1	**0,776**	Yes
			IV	0,2	Manual	0,5	**0,747**	Yes
	High	0,1	None	1	None	1	**83,64**	No
			II	0,05	Automatic	0,2	**0,764**	Yes
			I	0,02	None	1	**1,553**	No
			I	0,02	Manual	0,5	**0,776**	Yes
40	Low	0,001	None	1	None	1	**2,436**	No
			None	1	Automatic	0,2	**0,489**	Yes
			IV	0,2	None	1	**0,469**	Yes
	Ordinary	0,01	None	1	None	1	**24,34**	No
			IV	0,2	Automatic	0,2	**0,938**	Yes
			I	0,02	None	1	**0,475**	Yes
	High	0,1	None	1	None	1	**243,4**	No
			I	0,02	Automatic	0,2	**0,949**	Yes

Bibliography

[1] IEC 61000-4-5:1995*, Electromagnetic compatibility (EMC) – Part 4-5: Testing and measuring techniques – Surge immunity test*

[2] IEC 60079-10-1, *Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres*

[3] IEC 60079-10-2:2009, *Explosive atmospheres – Part 10-2: Classification of areas – Combustible dust atmospheres*

[4] IEC 60664-1:2007, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

[5] IEC 60050-426:2008, *International Electrotechnical Vocabulary – Part 426: Equipment for explosive atmospheres*

[6] Official Journal of European Union, 1994/28/02, n. C 62/63.

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

[8] NUCCI C.A., *Lightning induced overvoltages on overhead power lines. Part I: Return stroke current models with specified channel-base current for the evaluation of return stroke electromagnetic fields.* CIGRE Electra No 161 (August 1995)

[9] NUCCI C.A., *Lightning induced overvoltages on overhead power lines. Part II: Coupling models for the evaluation of the induced voltages.* CIGRE Electra No 162 (October 1995)

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

[11] IEC/TR 62066:2002, *Surge overvoltages and surge protection in low-voltage a.c. power systems - General basic information*

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

3, rue de Varembé
PO Box 131
CH-1211 Geneva 20
Switzerland

Tel: + 41 22 919 02 11
Fax: + 41 22 919 03 00
info@iec.ch
www.iec.ch