BS EN 62305-2:2012

BSI Standards Publication

Protection against lightning

Part 2: Risk management

National foreword

This British Standard is the UK implementation of EN 62305-2:2012. It was derived from IEC 62305-2:2010. It supersedes BS EN 62305-2:2006, which will be withdrawn on 31 January 2014.

The CENELEC common modifications have been implemented at the appropriate places in the text. The start and finish of each common modification is indicated in the text by tags [C〉 〈C].

The UK participation in its preparation was entrusted to Technical Committee GEL/81, Protection against lightning.

The values assigned for certain parameters used as part of the risk evaluation process in this British Standard, are values proposed by IEC (specifically in Annexes B, C and the case studies in Annex E). It is recognized by IEC that these identified values may not be appropriate for application in all the countries that utilize this standard. Different values may be assigned by each national committee based upon each country's perception and importance they attribute to the relevant risk category.

The UK committee has reviewed the relevant parts of this standard and have provided appropriate UK interpretations which can be found in national annexes at the end of this standard. National Annex NF contains interpretations relating to Table 4 and reproduces the lightning flash density map for the British Isles together with the table and map showing the thunderstorm days throughout the world. Annexes B, C and E have been reproduced as National Annexes NB, NC and NE. The revised versions contain appropriate UK interpretations and in Annex NE two further examples, namely a heritage building and a bank computer centre, in order to provide a full representation of the four categories of risk and associated loss. These National Annexes should be used wherever and whenever the British Standard is adopted for designing lightning protection systems.

Due to the specific UK values outlined above, it is important to ensure that any software package used in conjunction with this standard is specifically designed to use the National Annexes in this document.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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CENELEC

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Foreword

This document (EN 62305-2:2012) consists of the text of IEC 62305-2:2010 prepared by IEC/TC 81, "Lightning protection", together with the common modifications prepared by CLC/TC 81X, "Lightning protection".

The following dates are fixed:

• latest date by which this document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2013-03-19
• latest date by which the national standards conflicting with this document have to be withdrawn	(dow)	2014-01-13

This document supersedes EN 62305-2:2006 + corrigendum November 2006.

EN 62305-2:2012 includes the following significant technical changes with respect to EN 62305-2:2006:

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};
4) extended damage to surroundings structures or to the environment is considered;
5) improved formulas 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.

Notes and tables, which are additional to those in IEC 62305-2:2010 are prefixed “Z”.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

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 EN 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 EN 62305 series. Reference should be made to EN 61000-4-5 [2] 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.

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.

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1) Figures in square brackets refer to the bibliography.

1 Scope

This part of EN 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 documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 62305-1:2011, *Protection against lightning – Part 1: General principles* (IEC 62305-1:2010, mod.)

EN 62305-3:2011, *Protection against lightning – Part 3: Physical damage to structures and life hazard* (IEC 62305-3:2010, mod.)

EN 62305-4:2011, *Protection against lightning – Part 4: Electrical and electronic systems within structures* (IEC 62305-4:2010, mod.)

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 EN 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 1 to entry: 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 EN 60079-10-1[3] and EN 60079-10-2[4]

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 1 to entry: 'Town centre' is an example of an urban environment.

3.1.5
suburban environment
area with a medium density of buildings

Note 1 to entry: 'Town outskirts' is an example of a suburban environment.

3.1.6
rural environment
area with a low density of buildings

Note 1 to entry: Countryside' is an example of a rural environment.

3.1.7
rated impulse withstand voltage level
U_W
impulse withstand voltage assigned by the manufacturer to the equipment or to a part of it, characterizing the specified withstand capability of its insulation against (transient) overvoltages

[C] [SOURCE: EN 60664-1:2007, definition 3.9.2, modified][5]

Note 1 to entry: For the purposes of this part of EN 62305, only the withstand voltage between live conductors and earth is considered. [C]

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 1 to entry: 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

[C] Note 1 to entry: Although living beings may be injured in other ways, in this part of EN 62305 the term ‘injury to living beings’ is limited to the threat due to electrical shock (type of damage D1). [C]

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

Note 2 to entry: 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

[SOURCE:IEC 60050-426:2008, 426-03-03, modified][6]

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

[SOURCE:IEC 60050-426:2008, 426-03-04, modified][6]

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

[SOURCE:IEC 60050-426:2008, 426-03-05, modified][6]

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

[C〉 [SOURCE:EN 60079-10-2:2009, 6.2, modified] [4] 〈C]

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

[SOURCE:EN 60079-10-2:2009, 6.2, modified] [4]

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

[SOURCE:EN 60079-10-2:2009, 6.2, modified] [4]

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
[C⟩ L_A	Loss related to injury to living beings by electric shock (flashes to structure)	6.2
L_B	Loss related to physical damage in a structure (flashes to structure)	6.2
L_{BE}	Additional loss related to physical damage outside the structure (flashes to structure)	C.3,C.6
L_{BT}	Total loss related to physical damage (flashes to structure)	C.3,C.6 ⟨C]
L_L	Length of line section	A.4

L_C	Loss related to failure of internal systems (flashes to structure)	6.2
Ⓒ L_F	Typical percentage of loss related to physical damage in a structure	Tables C.2, C8, C10, C12
L_{FE}	Typical percentage of loss related to physical damage outside the structure	C.3; C.6 Ⓒ
L_M	Loss related to failure of internal systems (flashes near structure)	6.3
Ⓒ L_O	Typical percentage of loss related to failure of internal systems	Tables C.2, C8, C12
L_T	Typical percentage of loss related to injury by electric shock	Tables C.2, C12
L_U	Loss related to injury of living beings by electric shock (flashes to line)	6.4
L_V	Loss related to physical damage in a structure (flashes to line)	6.4
L_{VE}	Additional loss related to physical damage outside the structure (flashes to line)	C.3,C.6
L_{VT}	Total loss related to physical damage (flashes to line)	C.3,C.6 Ⓒ
L_W	Loss related to failure of internal systems (flashes to line)	6.4
Ⓒ L_X	Loss consequent to damages	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.

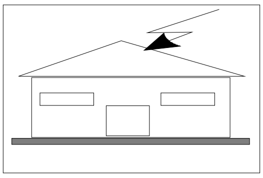
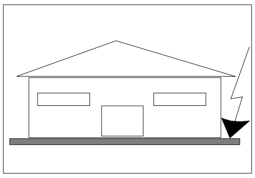
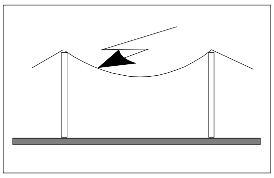
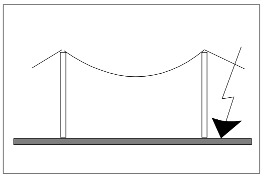
The damage to a structure due to lightning may be limited to a part of the structure or may extend to the entire structure. It may also involve surrounding structures or the environment (e.g. chemical or radioactive emissions).

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.

[C) 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 EN 62305. (C]

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:

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

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

R_2: Risk of loss of service to the public:

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

R_3: Risk of loss of cultural heritage:

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

R_4: Risk of loss of economic value:

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

NOTE 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.

C〉 NOTE Z1 Thunderstorm warning systems compliant with EN 50536 can also be used to reduce the risk. 〈C

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}

C〉 In principle, for loss of economic value (L4), the route to be followed is the cost/benefit comparison given in Annex D. 〈C

5.4 Specific procedure to evaluate the need of protection

According to EN 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.

C〉 NOTE 1 In cases where the risk cannot be reduced to a tolerable level in spite of having applied the most efficient protection means proposed (i.e. P_B = 0,001, P_{SPD}=0,001), the site owner should be informed. In these cases the use of a thunderstorm warning system is recommended. 〈C

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:

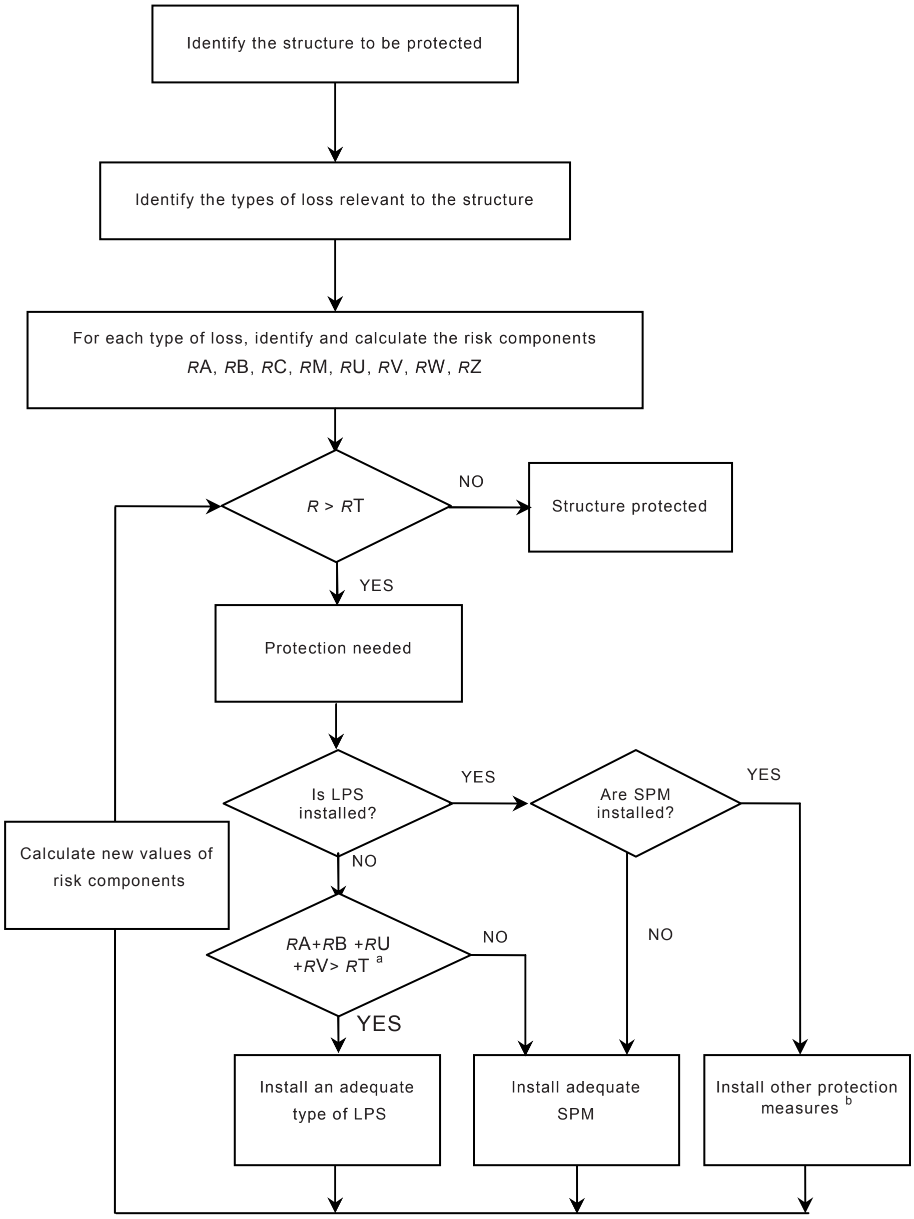
- identification of the components R_X which make up the risk R_4;
- calculation of the identified risk components R_X in absence of new/additional protection measures;
- calculation of the annual cost of loss due to each risk component R_X;
- calculation of the annual cost C_L of total loss in the absence 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.



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Key

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

[b] See Table 3.

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

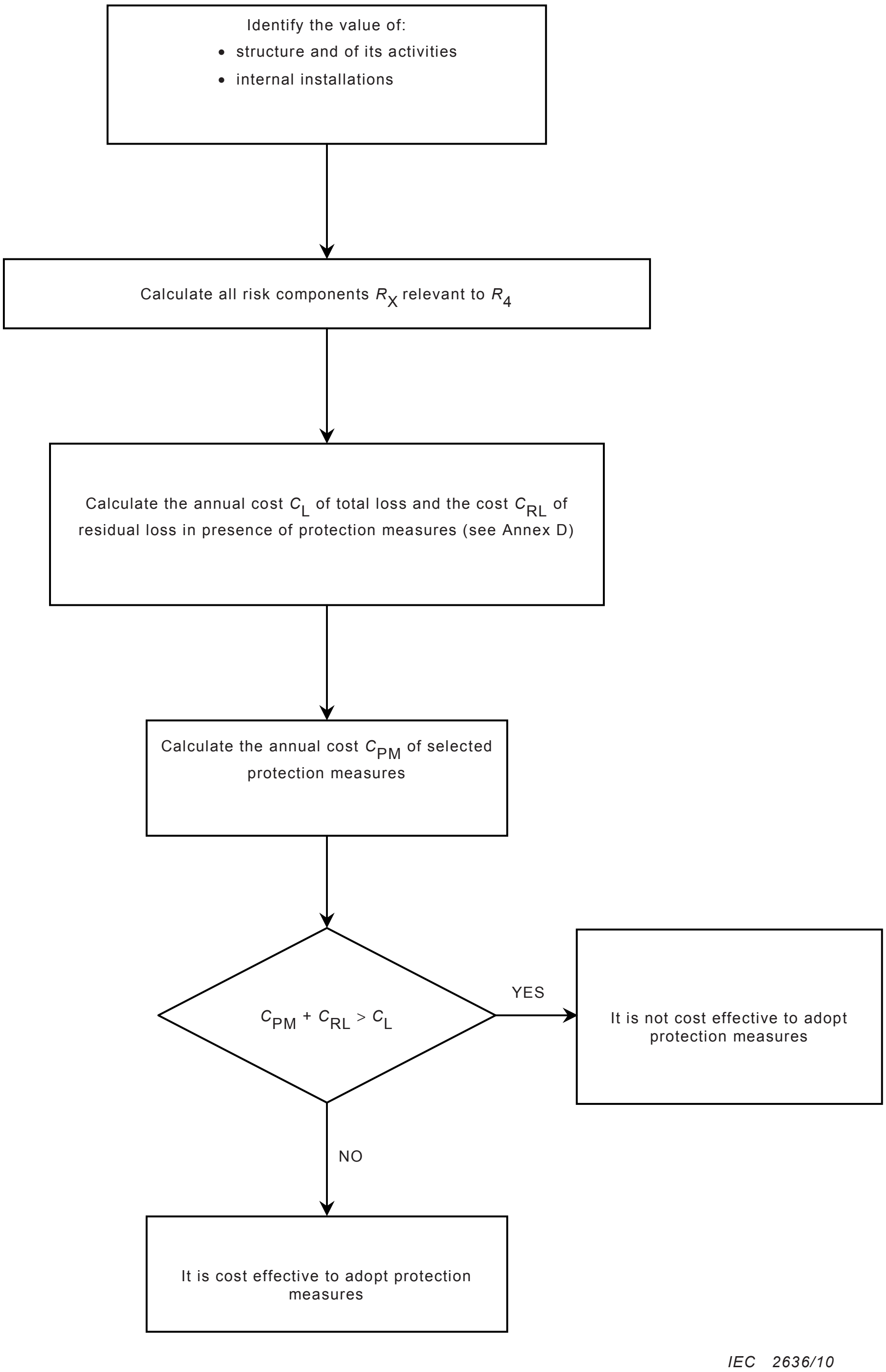


Figure 2 – Procedure for evaluating the cost-effectiveness of protection measures

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:

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

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 formula:

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

where

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

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

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

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

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

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

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

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

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

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

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

– component related to physical damage (D2)

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

– 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)

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

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

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

Table 5 – Parameters relevant to the assessment of risk components

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

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

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

6.6 Summary of risk components

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

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

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

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

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

6.7 Partitioning of a structure in zones Z_S

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

Zones Z_S are mainly defined by

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

Further zones may be defined according to

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

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

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

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.

[C› The cost of loss, the cost of the protection measures and the possible saving should be evaluated according to Annex D. ‹C]

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:

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

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

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

- flashes to the structure,
- flashes near the structure,
- flashes to a 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

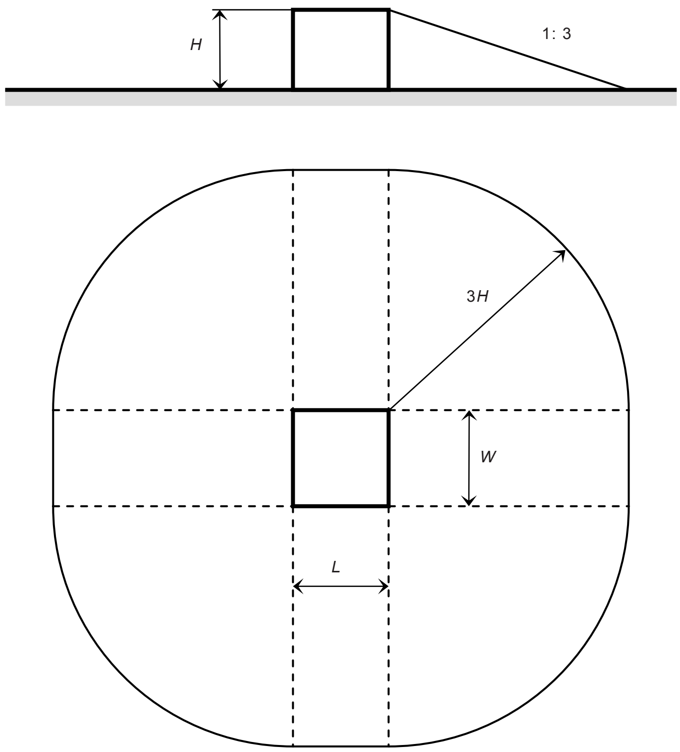
For isolated structures on flat ground, the collection area A_D is the area defined by the intersection between the ground surface and a straight line with 1/3 slope which passes from the upper parts of the structure (touching it there) and rotating around it. Determination of the value of A_D may be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

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

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



IEC 2637/10

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 Formula (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.

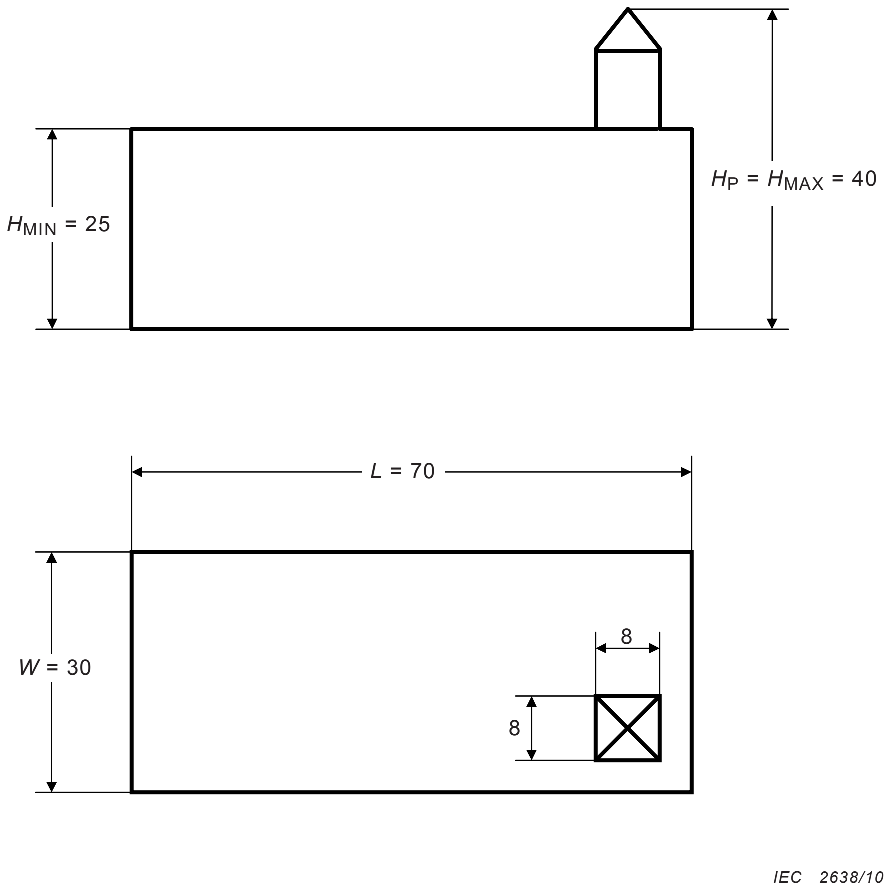


Figure A.2 – Complex shaped structure

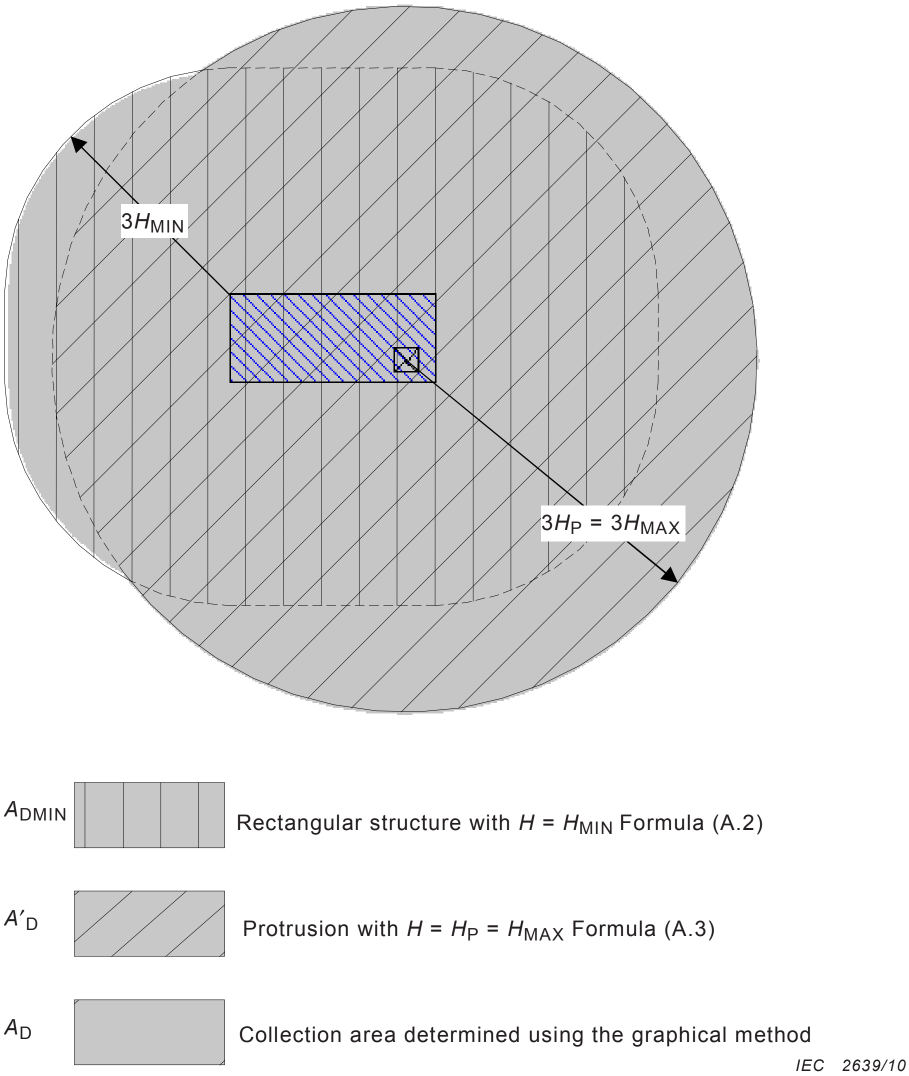


Figure A.3 – Different methods to determine the collection area for the given structure

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 [7].

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

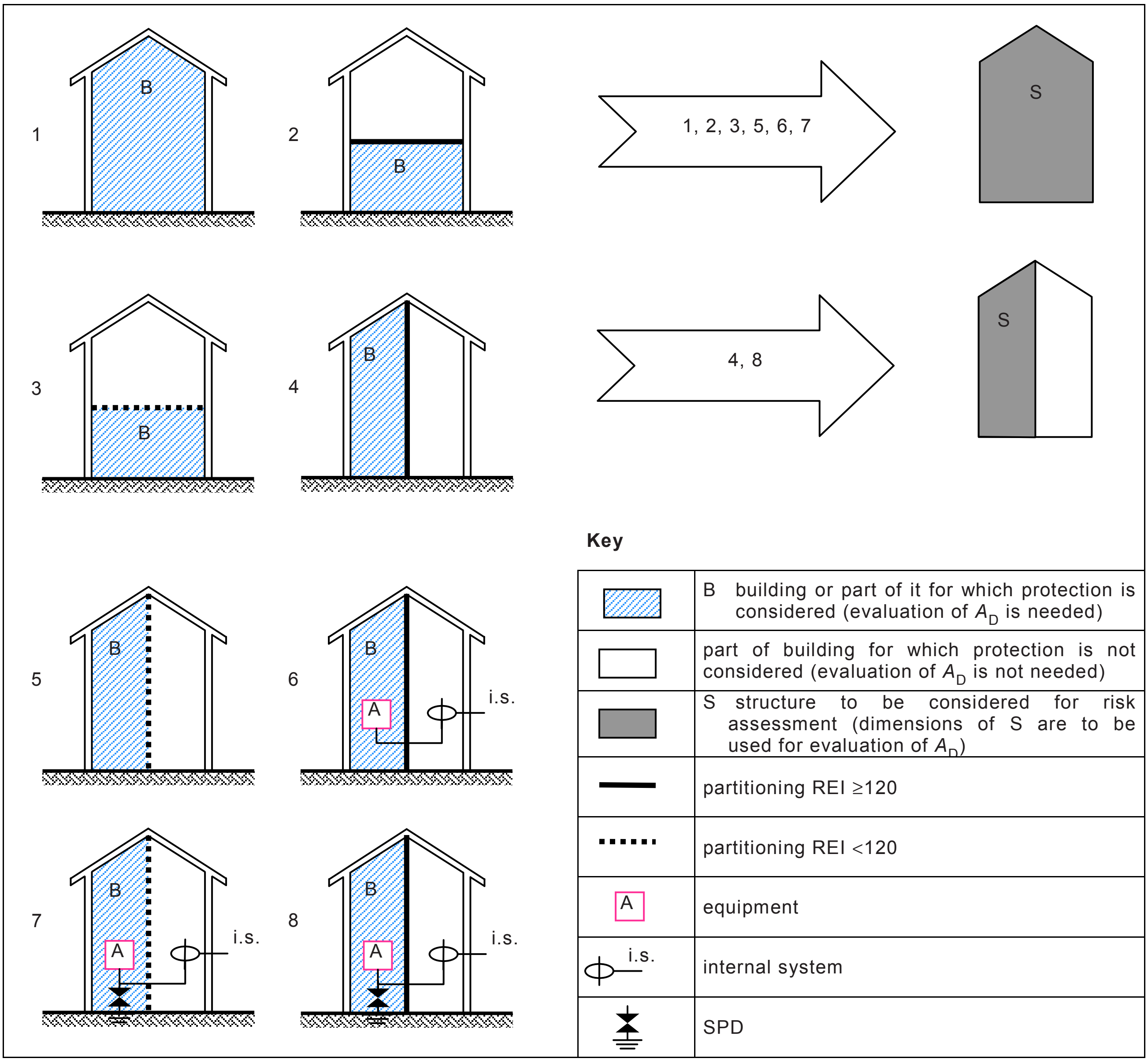


Figure A.4 – Structure to be considered for evaluation of collection area A_D

A.2.3 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/km^2 × 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/km^2 × 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/km^2 × year);

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

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

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

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

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

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

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:

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

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
[C) Buried cables running entirely within a meshed earth termination (5.2 of EN 62305-4:2011). (C]	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 [8].

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

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

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

where

- N_I is the number of overvoltages of amplitude not lower than 1 kV (1/year) on the line section;
- N_G is the lightning ground flash density (1/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

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

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

Where the length of a line section is unknown, L_L =1 000 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 [9] and 162 [10], 1995 for power lines and in ITU-T Recommendation K.46 [11] for telecommunications lines.

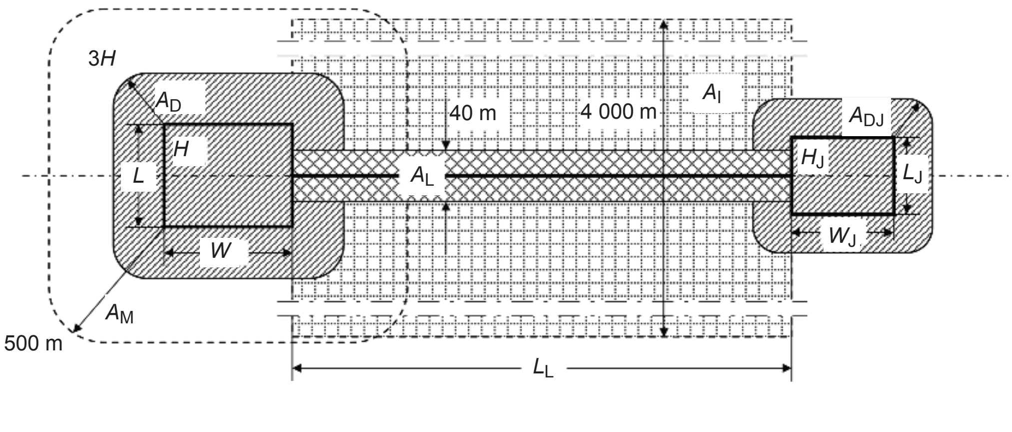


Figure A.5 – Collection areas (A_D, A_M, A_I, A_L)

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

- EN 62305-3 for protection measures to reduce injury to living beings and for protection measures to reduce physical damage,
- EN 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:

$$P_A = P_{TA} \times P_B \tag{B.1}$$

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 EN 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 EN 62305-3 are satisfied.

NOTE 2 For more information see 8.1 and 8.2 of EN 62305-3:2011.

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

[C) 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 EN 62305-1.

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

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:

$$P_C = P_{SPD} \times C_{LD} \tag{B.2}$$

[C) P_{SPD} depends on the coordinated SPD system conforming to EN 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]

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 EN 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 EN 62305-1:2011 for information on lightning current probabilities, and Annex E of EN 62305-1:2011 and Annex D of EN 62305-4:2011 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 EN 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 EN 62305-4 is not necessary to reduce P_C, provided that the induced voltage U_I is not higher than the withstand voltage U_W of the internal system ($U_I \leq U_W$). For evaluation of induced voltage U_I see Annex A of EN 62305-4:2011. Ⓒ

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.

〔C〉 When a coordinated SPD system meeting the requirements of EN 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 EN 62305-4 is provided, the value of P_M is given by: 〈C〕

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

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

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

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

where

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

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

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

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

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

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

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

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

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

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

〔C〉 NOTE 2 Where a meshed bonding network is provided according to EN 62305-4, values of K_{S1} and K_{S2} may be halved. 〈C〕

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

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

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

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

Type of internal wiring	K_{S3}
Unshielded cable – no routing precaution in order to avoid loops[a]	1
Unshielded cable – routing precaution in order to avoid large loops[b]	0,2
Unshielded cable – routing precaution in order to avoid loops[c]	0,01
Shielded cables and cables running in metal conduits[d]	0,000 1

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

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

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

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

The factor K_{S4} is evaluated as:

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

where

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

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

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

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

[C] 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 EN 62305-3.

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

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;

[C] P_{EB} depends on lightning equipotential bonding (EB) conforming to EN 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; [C]

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.

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

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

[C⟩ 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 EN 62305-1:2011 for information on lightning current probabilities, and Annex E of EN 62305-1:2011 and Annex D of EN 62305-4:2011 for lightning current sharing). The same annexes may be used for SPDs having higher probabilities P_{EB}. ⟨C]

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.

[C⟩ 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 EN 62305-3.

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

The value of P_V is given by:

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

where

- [C] P_{EB} depends on lightning equipotential bonding (EB) conforming to EN 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; [C]
- 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:

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

where

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

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

where

- [C] P_{SPD} depends on the coordinated SPD system conforming to EN 62305-4 and the lightning protection level (LPL) for which its SPDs are designed. Values of P_{SPD} are given in Table B.3; [C]
- 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[12] and in ITU-T Recommendation K.46 [11] 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 formulas given in this annex be used as the primary source of values for L_X.

[C› NOTE Z1 The typical mean values of loss L_X proposed by the IEC are referred to temperate regions. For other regions adjustment could be needed. ‹C]

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	Formula
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

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

L_F is the typical mean percentage of persons injured by physical damage (D2) due to one dangerous event (see Table C.2);

L_O is the typical mean percentage of persons injured by failure of internal systems (D3) due to one dangerous event (see Table C.2); (C]

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.

[C) NOTE Z1 When a structure is treated as a single zone the ratio n_z/n_t should equate to a value of 1.

NOTE Z2 Where the value of t_z is not known, the ratio $t_z/8\,760$ should equate to a value of 1. (C]

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.

[C⟩ When the damage to a structure due to lightning involves surrounding structures or the environment (e.g. chemical or radioactive emissions), additional loss (L_{BE} and L_{VE}) should be taken into account to evaluate the total loss (L_{BT} and L_{VT})

$$L_{BT} = L_B + L_{BE} \quad (C.5)$$
$$L_{VT} = L_V + L_{VE}$$

where

$$L_{BE} = L_{VE} = L_{FE} \times t_e/8\,760 \quad (C.6)$$

L_{FE} being the mean percentage of persons injured by 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 t_e is unknown, t_e /8 760 = 1 should be assumed. L_{FE} should be evaluated or based on the documents of the authorities having jurisdiction. ⟨C]

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.

[C› NOTE 9 For the purposes of this part of EN 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: ‹C]

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

[C› b) the volume of explosive atmosphere is negligible according to EN 60079-10-1[3] and EN 60079-10-2[4]; ‹C]

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	Formula
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

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

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

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	Formula
D2 physical damage	$L_B = L_V = r_p \times r_f \times L_F \times c_z / c_t$	(C.9)

where

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

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

C〉

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

〈C

where

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

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

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

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.

C⟩ When the damage to a structure due to lightning involves surrounding structures or the environment (e.g. chemical or radioactive emissions), additional losses (L_{BE} and L_{VE}) should be taken into account to evaluate the total loss (L_{BT} and L_{VT})

$$L_{BT} = L_B + L_{BE} \quad (C.14)$$
$$L_{VT} = L_V + L_{VE}$$

where

$$L_{BE} = L_{VE} = L_{FE} \times c_e / c_t \quad (C.15)$$

L_{FE} being the typical mean percentage of economic value of all goods damaged by physical damage outside the structure;

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

NOTE 2 L_{FE} should be evaluated or based on the documents of the authorities having jurisdiction.

The data related to the value c_a of animals, the value c_b of building, the value c_c of content and the value c_s of internal systems including their activities should be provided to the designer from the owner of the structure.
If such data are not provided, the values in Table C.Z1 and C.Z2 are proposed to assess these data.

Table C.Z1 – Values to assess the total value c_t

Type of structure	Reference values		Total for c_t	
non-industrial structures	**Total reconstruction costs** (not including loss of activities)	Low	**c_t per volume (€/m^3)**	300
		Ordinary		400
		High		500
industrial structures	**Total value of structure, including building, installations and content** (including loss of activities)	Low	**c_t per employee (k€/employee)**	100
		Ordinary		300
		High		500

⟨C

Table C.Z2 – Portions to assess the total values c_a, c_b, c_c, c_s

Condition	Portion for animals c_a / c_t	Portion for the building c_b / c_t	Portion for the content c_c / c_t	Portion for the internal systems c_s / c_t	Total for all goods (c_a+c_b+c_c+c_s)/ c_t
Without animals	0	75 %	10 %	15 %	**100 %**
With animals	10 %	70 %	5 %	15 %	**100 %**

If the data from Tables C.Z1 or C.Z2 are used, the following steps should be performed:

1. Determine the total value c_t in € for the whole structure from Table C.Z1
2. Determine the total values c_a, c_b, c_c and c_s for the whole structure from Table C.Z2
3. In case of more than one zone subdivide the total values of c_a, c_b, c_c and c_s in fractional values valid for each zone. The fractional factor could be

– volume of the zone / total volume for non-industrial structures,

– employees in the zone / total number of employees for industrial structures.

NOTE Z1 The typical mean values of costs given in Table C.Z1 and in Table C.Z2 are merely values proposed by the CENELEC. Different values may be assigned by each national committee or after detailed investigation.

Annex D
(informative)

Evaluation of costs of loss

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

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

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 formula:

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

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 formula:

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

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 formula:

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

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 formula:

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

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 EN 62305. It is not intended to address the unique aspects of the conditions that exist in all facilities or systems.

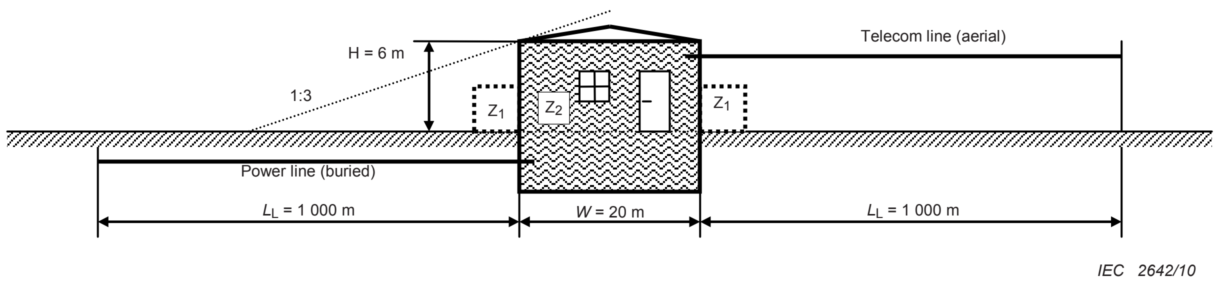
E.2 Country house

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/km^2/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	Formula (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	Formula (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 system (kV)		U_W	1,5	
	Resulting parameters	K_{S4}	0,67	Formula (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	Formula (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	-	
Factor for persons in zone		$n_z/n_t \times t_z/8\ 760 = 5/5 \times 8\ 760/8\ 760$	–	1	
		Resulting parameters	L_A	10^{-7}	Formula (C.1)
			L_U	10^{-7}	Formula (C.2)
			L_B	10^{-4}	Formula (C.3)
			L_V	10^{-4}	Formula (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 Formula	Formula
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 Formula	Formula
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 Formula (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 $\times 10^{-5}$)

	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 $R_1 = 2{,}51 \times 10^{-5}$ 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 formulas, 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.

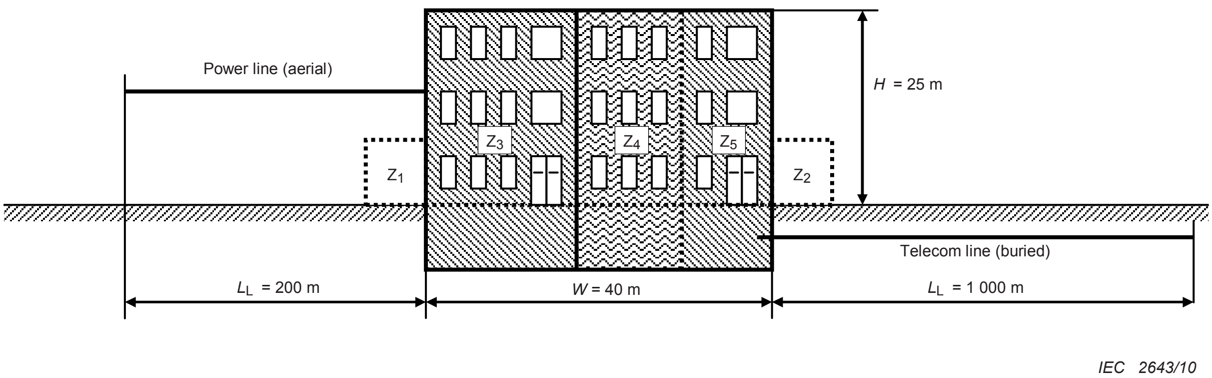
E.3 Office building

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	Formula (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	Formula (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	Formula (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	Formula (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	Formula (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	Formula (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 >10m²)	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	Formula (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 m²)	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		$n_z/n_t \times t_z/8\ 760 = 160/200 \times 8\ 760/8\ 760$	–	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	Formula (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		$n_z/n_t \times t_z/8\,760 = 14/200 \times 8\,760/8\,760$	–	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 m^2	Reference Formula	Formula
Structure	A_D	$2,75 \times 10^4$	(A.2)	$A_D = L \times W + 2 \times (3 \times H) \times (L + W) + \pi \times (3 \times H)^2$
	A_M	–	(A.7)	Not relevant
Power line	$A_{L/P}$	$8,00 \times 10^3$	(A.9)	$A_{L/P} = 40 \times L_L$
	$A_{I/P}$	$8,00 \times 10^5$	(A.11)	Not relevant
	$A_{DA/P}$	0	(A.2)	No adjacent structure
Telecom line	$A_{L/T}$	$4,00 \times 10^4$	(A.9)	$A_{L/P} = 40 \times L_L$
	$A_{I/T}$	$4,00 \times 10^6$	(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 Formula	Formula
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 $\times 10^{-5}$)

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**	**R_1 = 9,65**
Tolerable		**$R_1 > R_T$: Lightning protection is required**					**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

- [C] providing the whole building with an LPS conforming to EN 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}, [C]
- 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,
- [C] providing lightning equipotential bonding conforming to EN 62305-3 at the entrance of the building. This will reduce only the components R_U and R_V via probability P_{EB}. [C]

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 EN 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 EN 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})

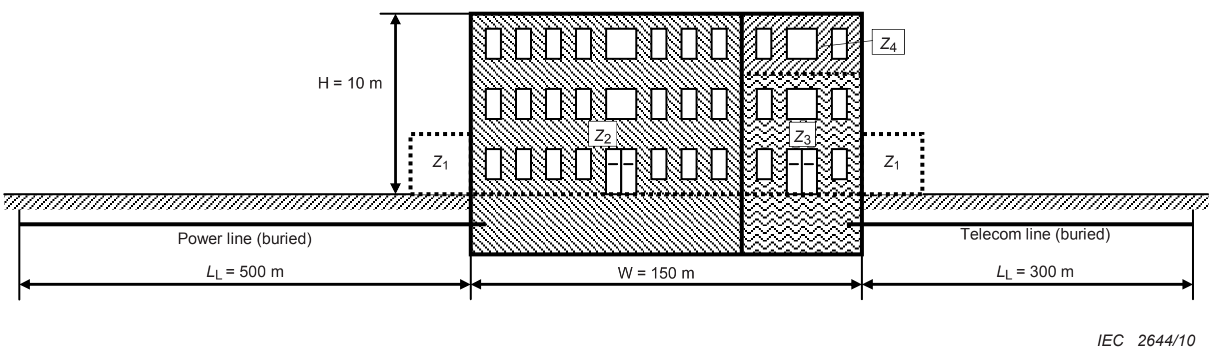
	Z_1	Z_2	Z_3	Z_4	Z_5	Total	Tolerable	Result
Solution a)	≈ 0	0	0,664	0,053	0,005	R_1 = **0,722**	R_T = **1**	$R_1 \le R_T$
Solution b)	≈ 0	0	0,552	0,089	0,008	R_1 = **0,648**	R_T = **1**	$R_1 \le R_T$

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	Formula (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	Formula (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 bonding bar as equipment.	C_{LD}	1	Table B.4
		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	Formula (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 Formulas (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 Formulas (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	Formula (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 × 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
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	Formula (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	Formula (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	Formula (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 = 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 m²	Reference Formula	Formula
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 Formula	Formula
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 Formula	Formula
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			0,006 4		(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 $\times 10^{-5}$)

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 systems	R_C		8,484	3,126	0,447	**12,057**
	R_M		2,413	0,889	0,127	**3,429**
	$R_W = R_{W/P} + R_{W/T}$		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 ≈ 61 % and R_V ≈ 13 % of the total risk),
- by failures of internal systems in the zones Z_2 and Z_3 (components R_C ≈ 12 % respectively R_C ≈ 5 %) of the total risk.

These dominant risk components can be reduced by

- C〉 providing the whole building with an LPS conforming to EN 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}, 〈C
- 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,
- C〉 providing zones Z_3 and Z_4 with a coordinated SPD protection conforming to EN 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 EN 62305-4. This will reduce the component R_M via the probability P_M. 〈C

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 = 0,1 m.

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 $\times 10^{-5}$)

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 Formula (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 $\times 10^{-5}$					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 Formula (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_m = 0,5 m)	100 000	10 000		
Zones Z_3 and Z_4 shielding (w_m = 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.

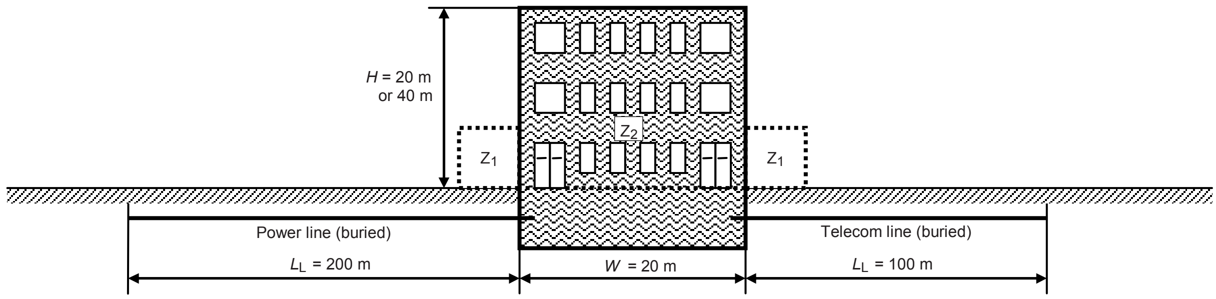
Table E.40 – Hospital: Annual saving of money (values in $)

	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 to 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	Formula (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 structure	None	C_{DJ}	–	Table A.1
Withstand voltage of internal system (kV)		U_W	2,5	
	Resulting parameters	K_{S4}	0,4	Formula (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	Formula (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)

<table>
<tr><th colspan="2">Input parameter</th><th>Comment</th><th>Symbol</th><th>Value</th><th>Reference</th></tr>
<tr><td colspan="2">Type of floor</td><td>Wood</td><td>r_t</td><td>10^{-5}</td><td>Table C.3</td></tr>
<tr><td colspan="2">Protection against shock (flash to structure)</td><td>None</td><td>P_{TA}</td><td>1</td><td>Table B.1</td></tr>
<tr><td colspan="2">Protection against shock (flash to line)</td><td>None</td><td>P_{TU}</td><td>1</td><td>Table B.6</td></tr>
<tr><td colspan="2">Risk of fire</td><td>Variable (see Table E.45)</td><td>r_f</td><td>–</td><td>Table C.5</td></tr>
<tr><td colspan="2">Fire protection</td><td>Variable (see Table E.45)</td><td>r_p</td><td>–</td><td>Table C.4</td></tr>
<tr><td colspan="2">Internal spatial shield</td><td>None</td><td>K_{S2}</td><td>1</td><td>Formula (B.6)</td></tr>
<tr><td rowspan="2">Power</td><td>Internal wiring</td><td>Unshielded (loop conductors in the same conduit)</td><td>K_{S3}</td><td>0,2</td><td>Table B.5</td></tr>
<tr><td>Coordinated SPDs</td><td>None</td><td>P_{SPD}</td><td>1</td><td>Table B.3</td></tr>
<tr><td rowspan="2">Telecom</td><td>Internal wiring</td><td>Unshielded (large loops > 10 m²)</td><td>K_{S3}</td><td>1</td><td>Table B.5</td></tr>
<tr><td>Coordinated SPDs</td><td>None</td><td>P_{SPD}</td><td>1</td><td>Table B.3</td></tr>
<tr><td colspan="2" rowspan="3">L1: Loss of human life</td><td>Special hazard: None</td><td>h_z</td><td>1</td><td>Table C.6</td></tr>
<tr><td>D1: due to touch and step voltage</td><td>L_T</td><td>10^{-2}</td><td rowspan="2">Table C.2</td></tr>
<tr><td>D2: due to physical damage</td><td>L_F</td><td>10^{-1}</td></tr>
<tr><td colspan="2">Factor for persons in zone</td><td>$n_z / n_t \times t_z$ / 8 760 = 200 / 200 × 8 760 / 8 760</td><td>–</td><td>1</td><td></td></tr>
</table>

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 $R_1 \le R_T$
	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

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

[3] EN 60079-10-1, *Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres* (IEC 60079-10-1)

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

[5] EN 60664-1:2007, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests* (IEC 60664-1:2007) 〈C]

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

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

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

[9] 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)

[10] 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)

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

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

Annex NB
(informative)

Assessment of probability P_X of damage

NB.1 General

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

— BS EN 62305-3 for protection measures to reduce injury to living beings and for protection measures to reduce physical damage,

— BS EN 62305-4 for protection measures to reduce failure of internal systems.

Other values may be chosen, if justified.

Tables NB.3 and NB.7 have been modified for clarity and to reflect the UK's interpretation relative to the assessment of probability of damage for a structure.

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.

NB.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:

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

where;

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

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

Table NB.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 BS EN 62305-3 are satisfied.

NOTE 2 For more information see 8.1 and 8.2 of BS EN 62305-3:2011.

NB.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 NB.2.

Table NB.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 NB.2 are possible if based on a detailed investigation taking into account the requirements of sizing and interception criteria defined in BS EN 62305-1.

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

NB.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:

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

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

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

LPL	SPD	P_{SPD}
No coordinated SPD system		1
III-IV	III-IV III-IV* (Note 2)	0,05 0,005
II	II II* (Note 2)	0,02 0,002
I	I I* (Note 2)	0,01 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 BS EN 62305-3 are satisfied.

NOTE 2 Smaller values of P_{SPD} are possible where SPDs have lower voltage protection levels (U_P) that further reduce the risk of injury to living beings, physical damage and failure of internal systems. Such SPDs are always required to ensure the protection and continuous operation of critical equipment. SPDs with low voltage protection levels also take account of the additive inductive voltage drops along the connecting leads of SPDs.

Unless stated, the susceptibility level (of equipment) is assumed to be twice its peak operating voltage. In this respect, installed SPDs with a voltage protection level greater than the susceptibility level but less than the impulse withstand voltage U_W (of equipment), equate to the standard value of P_{SPD} whereas installed SPDs with a voltage protection level less than the susceptibility level equate to the enhanced value (ie SPDs denoted by *).

For example, in the case for a 230 V mains supply an SPD fitted at the service entrance (for lightning equipotential bonding) should have a voltage protection level of no more than 1 600 V (4 kV withstand at the entrance of the installation, 20 % margin and a factor of 2 for the worse case doubling voltage as per IEC 61643-12: ((4 kV x 0,8)/2 = 1 600 V) when tested in accordance with BS EN 61643 series. Downstream SPDs (those that are located within another lightning protection zone) fitted as part of a coordinated set to ensure operation of critical equipment should have a voltage protection level of no more than 600 V ((1,5 kV x 0,8)/2) when tested in accordance with BS EN 61643 series (Class III test).

NOTE 3 The LPL governs the choice of the appropriate structural Lightning Protection System (LPS) and Surge Protection Measures (SPM), one option of which can include a set of coordinated SPDs. Typically, an LPS class II would require SPD II. If the indirect risk (R_1) was still greater than the tolerable risk (R_T) then SPD II* should be chosen.

When a risk assessment indicates that a structural LPS is not required, service lines connected to the structure (S3) are effectively protected against direct strikes when SPD III-IV or SPD III-IV* protection measures are applied.

Table NB.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 BS EN 62305-4	0	0

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

NOTE 5 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 BS EN 62305-4 is not necessary to reduce P_c, provided that the induced voltage U_I is not higher than the withstand voltage U_w of the internal system ($U_I \leq U_w$). For evaluation of induced voltage U_I see Annex A of BS EN 62305-4:2011.

NB.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 BS EN 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 BS EN 62305-4 is provided, the value of P_M is given by:

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

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

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

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

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 NB.5);

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

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

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

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

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

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 BS EN 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 NB.5 – Value of factor K_{S3} depending on internal wiring

Type of internal wiring	K_{S3}
Unshielded cable – no routing precaution in order to avoid loops[a]	1
Unshielded cable – routing precaution in order to avoid large loops[b]	0,2
Unshielded cable – routing precaution in order to avoid loops[c]	0,01
Shielded cables and cables running in metal conduits[d]	0,000 1

[a] Loop conductors with different routing in large buildings (loop area in the order of 50 m^2).
[b] Loop conductors routed in the same conduit or loop conductors with different routing in small buildings (loop area in the order of 10 m^2).
[c] Loop conductors routed in the same cable (loop area in the order of 0,5 m^2).
[d] Shields and the metal conduits bonded to an equipotential bonding bar at both ends and equipment is connected to the same bonding bar.

The factor KS4 is evaluated as:

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

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.

NB.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 BS EN 62305-3.

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

The value of P_U is given by:

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

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 NB.6;

P_{EB} depends on lightning equipotential bonding (EB) conforming to BS EN 62305-3 and on the lightning protection level (LPL) for which its SPDs are designed. Values of P_{EB} are given in Table NB.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 NB.8.

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

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

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

LPL	*SPD*	P_{EB}
No SPD		1
III-IV	III-IV III-IV* (Note 4)	0,05 0,005
II	II II* (Note 4)	0,02 0,002
I	I I* (Note 4)	0,01 0,001

NOTE 4 Smaller values of P_{EB} are possible where SPDs have lower voltage protection levels (U_P) that further reduce the risk of injury to living beings, physical damage and failure of internal systems. Such SPDs are always required to ensure the protection and continuous operation of critical equipment. SPDs with low voltage protection levels also take account of the additive inductive voltage drops along the connecting leads of SPDs.

Unless stated, the susceptibility level (of equipment) is assumed to be twice its peak operating voltage. In this respect, installed SPDs with a voltage protection level greater than the susceptibility level but less than the impulse withstand voltage U_W (of equipment), equate to the standard value of P_{EB} whereas installed SPDs with a voltage protection level less than the susceptibility level equate to the enhanced value (ie SPDs denoted by *).

For example, in the case for a 230 V mains supply an SPD fitted at the service entrance (for lightning equipotential bonding) should have a voltage protection level of no more than 1 600 V (4 kV withstand at the entrance of the installation, 20 % margin and a factor of 2 for the worse case doubling voltage as per IEC 61643-12: ((4 kV x 0,8)/2 = 1 600 V) when tested in accordance with BS EN 61643 series. Downstream SPDs (those that are located within another lightning protection zone) fitted as part of a coordinated set to ensure operation of critical equipment should have a voltage protection level of no more than 600 V ((1,5 kV x 0,8)/2) when tested in accordance with BS EN 61643 series (Class III test).

NOTE 5 The LPL governs the choice of the appropriate structural Lightning Protection System (LPS) and Surge Protection Measures (SPM), one option of which can include a set of coordinated SPDs. Typically, an LPS class II would require SPD II. If the indirect risk (R_1) was still greater than the tolerable risk (R_T) then SPD II* should be chosen.

When a risk assessment indicates that a structural LPS is not required, service lines connected to the structure (S3) are effectively protected against direct strikes when SPD III-IV or SPD III-IV* protection measures are applied.

Table NB.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.

NB.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 BS EN 62305-3.

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

The value of P_V is given by:

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

where;

P_{EB} depends on lightning equipotential bonding (EB) conforming to BS EN 62305-3 and on the lightning protection level (LPL) for which its SPDs are designed. Values of P_{EB} are given in Table NB.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 NB.8;

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

NB.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:

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

where;

- P_{SPD} depends on the coordinated SPD system conforming to BS EN 62305-4 and the lightning protection level (LPL) for which its SPDs are designed. Values of P_{SPD} are given in Table NB.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 NB.8;
- C_{LD} is a factor depending on shielding, grounding and isolation conditions of the line. Values of C_{LD} are given in Table NB.4.

NB.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:

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

where;

- P_{SPD} depends on the coordinated SPD system conforming to BS EN 62305-4 and the lightning protection level (LPL) for which its SPDs are designed. Values of P_{SPD} are given in Table NB.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 NB.9;
- C_{LI} is a factor depending on shielding, grounding and isolation conditions of the line. Values of C_{LI} are given in Table NB.4.

Table NB.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[12] and in ITU-T Recommendation K.46 [11] for telecommunication (TLC) lines.

Annex NC
(informative)

Assessment of amount of loss L_X

NC.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.

Tables NC.2, NC.5 and NC.8 have been modified for clarity and to reflect the UK's interpretation relative to the assessment of amount of loss in a structure.

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 formulas given in this annex be used as the primary source of values for L_X.

NOTE Z1 The typical mean values of loss L_X proposed by the IEC are referred to temperate regions. For other regions adjustment could be needed.

NC.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.

NC.3 Loss of human life (L1)

The loss value L_X for each zone can be determined according to Table NC.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 NC.1 – Type of loss L1: Loss values for each zone

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

where;

L_T is the typical mean percentage of persons injured by electric shock (D1) due to one dangerous event (see Table NC.2);

L_F is the typical mean percentage of persons injured by physical damage (D2) due to one dangerous event (see Table NC.2);

L_O is the typical mean percentage of persons injured by failure of internal systems (D3) due to one dangerous event (see Table NC.2);

r_t is a factor reducing the loss of human life depending on the type of soil or floor (see Table NC.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 NC.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 NC.5);

h_z is a factor increasing the loss due to physical damage when a special hazard is present (see Table NC.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.

NOTE Z1 When a structure is treated as a single zone the ratio n_z/n_t should equate to a value of 1.

NOTE Z2 Where the value of t_z is not known, the ratio $t_z/8\,760$ should equate to a value of 1.

Table NC.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	0,01	All types
D2 physical damage	L_F	1,00	Hospital
		1,00	Hotel
		1,00	Large House
		1,00	Block of flats
		1,00	Oil refinery/chemical plant
		1,00	Halls of residence
		1,00	Prison
		1,00	Police/ambulance station
		1,00	Farm building
		1,00	Nursing/children's home
		0,75	Factory
		0,75	Railway station
		0,75	Airport building

Type of damage	Typical loss value		Type of structure
D2 physical damage *(continued)*	L_F	0,67	Fuel/service station
		0,67	Leisure centre
		0,50	Shop/shopping centre
		0,50	Cathedral
		0,42	University
		0,42	Museum
		0,42	Commercial building/office block
		0,42	Department store
		0,42	Industrial warehouse
		0,33	Civic building
		0,33	Commercial centre
		0,33	Medical centre
		0,33	Telephone exchange
		0,33	Water treatment works
		0,33	Power station
		0,33	Substation
		0,33	School
		0,33	Gas Compound
		0,21	Theatre
		0,08	Church
		0,04	Sports stadium
		0,04	Base station
		0,04	Wind farm
		0,04	Ruins
		0,33	Others
D3 failure of internal systems	L_O	0,1	Risk of explosion
		0,001	Intensive care unit and operation block of hospital
		0,33	Other parts of hospital

NOTE 1 The above values of *L* are generic in nature; different specific values may be assigned, depending on the individual merits of each structure.

NOTE 2 The values of *L* are based on the assumption that the structure is treated as a single zone and the total numbers of persons in the structure are all in the zone. The time in hours (h) per year for which the persons are present has been evaluated for each individual case.

For example: Total number of persons in the structure = 200 (n_t)

Number of persons in the zone = 200 (n_z)

Number of hours per day spent in the office: = 10 h

Therefore t_z = 10 h × 365 days = 3 650 h

L = $(n_z / n_t) \times (t_z / 8\ 760)$

L = (200 / 200) × (3 650 / 8 760) = 0,42

NOTE 3 If further evaluation of *L* is required for a structure that is split into several zones, then the formula given in Table NC.1 should be applied.

NOTE 4 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 of 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_{BE} and L_{VE}) should be taken into account to evaluate the total loss (L_{BT} and L_{VT})

$$L_{BT} = L_B + L_{BE}$$
$$L_{VT} = L_V + L_{VE} \quad \text{(NC.5)}$$

where

$$L_{BE} = L_{VE} = L_{FE} \times t_e/8\,760 \quad \text{(NC.6)}$$

L_{FE} being the mean percentage of persons injured by physical damage outside the structure;

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

NOTE 5 If values of t_e is unknown, $t_e/8\,760 = 1$ should be assumed. L_{FE} should be evaluated or based on the documents of the authorities having jurisdiction.

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

Risk	Amount of risk	r_f	Type of structure[a]
Explosion	Zones 0, 20 and solid explosive	1	Petrochemical plant, ammunition store, gas compound, paper mill
	Zones 1, 21	10^{-1}	
	Zones 2, 22	10^{-3}	
Fire	High	10^{-1}	Paper mill, industrial warehouse with flammable stock
	Ordinary	10^{-2}	Office, school, theatre, hotel, museum, shop
	Low	10^{-3}	Sports stadium, railway station, telephone exchange
Explosion or fire	None	0	

[a] List of structures and Risk suggested are merely typical and not exhaustive.

NOTE 6 In case of a structure with risk of explosion, the value for r_f may need a more detailed evaluation.

NOTE 7 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 8 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 9 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 10 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 11 For the purposes of this part of BS EN 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 EN 60079-10-1[3] and EN 60079-10-2[4];

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

NOTE 12 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 NC.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

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

The loss value L_X for each zone can be determined according to Table NC.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 NC.7 – Type of loss L2: Loss values for each zone

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

where;

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

L_O is the typical mean percentage of users not served resulting from failure of internal systems (D3) due to one dangerous event (see Table NC.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 NC.4);

r_f is a factor reducing the loss due to physical damage depending on the risk of fire (see Table NC.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 NC.8 – Type of loss L2: Typical mean values of L_F and L_O

Service provider	L_F	L_O
Gas, water, power, communications, government, health, financial, manufacturing, retail, residential, leisure.	10^{-1}	10^{-2}

NOTE All of the above institutions/industries are service providers to the public and need to be considered when calculating R2 – Risk of unacceptable loss of service to the public.

NC.5 Loss of irreplaceable cultural heritage (L3)

The loss value L_X for each zone can be determined according to Table NC.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 NC.9 – Type of loss L3: Loss values for each zone

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

where;

L_F is the typical mean percentage of value of all goods damaged by physical damage (D2) due to one dangerous event (see Table NC.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 NC.4);

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

NC.6 Economic loss (L4)

The loss value L_X for each zone can be determined according to Table NC.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 NC.11 – Type of loss L4: Loss values for each zone

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

where;

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

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

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

r_t is a factor reducing the loss of animals depending on the type of soil or floor (see Table NC.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 NC.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 NC.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 NC.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 there is damage to a structure due to lightning involving surrounding structures or the environment (e.g. chemical or radioactive emissions), additional losses (L_{BE} and L_{VE}) should be taken into account to evaluate the total loss (L_{BT} and L_{VT})

$$L_{BT} = L_B + L_{BE}$$
$$L_{VT} = L_V + L_{VE} \quad \text{(NC.14)}$$

where

$$L_{BE} = L_{VE} = L_{FE} \times c_e / c_t \qquad \text{(NC.15)}$$

L_{FE} being the typical mean percentage of economic value of all goods damaged by physical damage outside the structure;

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

NOTE 2 L_{FE} should be evaluated or based on the documents of the authorities having jurisdiction.

The data related to the value c_a of animals, the value c_b of building, the value c_c of content and the value c_s of internal systems including their activities should be provided to the designer from the owner of the structure.

If such data are not provided, the values in Table NC.Z1 and NC.Z2 are proposed to assess these data.

Table NC.Z1 – Values to assess the total value c_t

Type of structure	Reference values		Total for c_t	
non-industrial structures	**Total reconstruction costs** (not including loss of activities)	Low	**c_t per volume (€/m³)**	300
		Ordinary		400
		High		500
industrial structures	**Total value of structure, including building, installations and content** (including loss of activities)	Low	**c_t per employee (k€/employee)**	100
		Ordinary		300
		High		500

Table NC.Z2 – Portions to assess the total values c_a, c_b, c_c, c_s

Condition	Portion for animals c_a / c_t	Portion for the building c_b / c_t	Portion for the content c_c / c_t	Portion for the internal systems c_s / c_t	Total for all goods $(c_a + c_b + c_c + c_s) / c_t$
Without animals	0	75 %	10 %	15 %	100 %
With animals	10 %	70 %	5 %	15 %	100 %

If the data from Tables NC.Z1 or NC.Z2 are used, the following steps should be performed:

a) Determine the total value c_t in € for the whole structure from Table NC.Z1.

b) Determine the total values c_a, c_b, c_c and c_s for the whole structure from Table NC.Z2.

c) In case of more than one zone subdivide the total values of c_a, c_b, c_c and c_s in fractional values valid for each zone. The fractional factor could be;
   - volume of the zone / total volume for non-industrial structures,
   - employees in the zone / total number of employees for industrial structures.

NOTE Z1 The typical mean values of costs given in Table NC.Z1 and in Table NC.Z2 are merely values proposed by the CENELEC. Different values may be assigned by each national committee or after detailed investigation.

Annex NE
(informative)

Case study

NE.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 BS EN 62305. It is not intended to address the unique aspects of the conditions that exist in all facilities or systems.

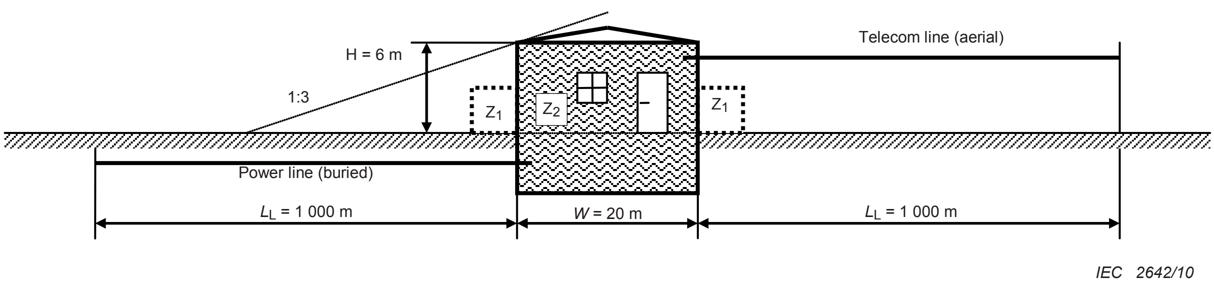
NE.2 Country house

As a first case study a country house (Figure NE.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 NF.1). 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 R4 for economic loss (L4) is not considered.



Key

Z_1: outside

Z_2: rooms block

Figure NE.1 – Country house

NE.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 = 0,7 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 NE.1.

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

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

Input parameter	Comment	Symbol	Value	Reference
Ground flash density (1/km^2/year)		N_G	0,7	
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 NB.2
Equipotential bonding	None	P_{EB}	1	Table NB.7
External spatial shield	None	K_{S1}	1	Formula (NB.5)

Table NE.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 NB.8
Shielding, grounding, isolation	None	C_{LD}	1	Table NB.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	Formula (NB.7)
		P_{LD}	1	Table NB.8
		P_{LI}	0,3	Table NB.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 NE.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 NB.8
Shielding, grounding, isolation	None	C_{LD}	1	Table NB.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 system (kV)		U_W	1,5	
	Resulting parameters	K_{S4}	0,67	Formula (NB.7)
		P_{LD}	1	Table NB.8
		P_{LI}	0,5	Table NB.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).

NE.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 NC.1.

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

Table NE.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 NC.3
Protection against shock (flash to structure)		None	P_{TA}	1	Table NB.1
Protection against shock (flash to line)		None	P_{TU}	1	Table NB.6
Risk of fire		Low	r_f	10^{-3}	Table NC.5
Fire protection		None	r_p	1	Table NC.4
Internal spatial shield		None	K_{S2}	1	Formula (NB.6)
Power	Internal wiring	Unshielded (loop conductors in the same conduit)	K_{S3}	0,2	Table NB.5
	Coordinated SPDs	None	P_{SPD}	1	Table NB.3
Telecom	Internal wiring	Unshielded (large loops >10 m²)	K_{S3}	1	Table NB.5
	Coordinated SPDs	None	P_{SPD}	1	Table NB.3
L1: Loss of human life		Special hazard: none	h_z	1	Table NC.6
		D1: due to touch and step voltage	L_T	10^{-2}	Table NC.2
		D2: due to physical damage	L_F	1	
		D3: due to failure of internal systems	L_O	–	
Factor for persons in zone		$n_z / n_t \times t_z / 8\,760 = 5/5 \times 8\,760 / 8\,760$	–	1	
		Resulting parameters	L_A	10^{-7}	Formula (NC.1)
			L_U	10^{-7}	Formula (NC.2)
			L_B	10^{-3}	Formula (NC.3)
			L_V	10^{-3}	Formula (NC.3)

NE.2.3 Calculation of relevant quantities

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

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

	Symbol	Result m²	Reference Formula	Formula
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 NE.6 – Country house: Expected annual number of dangerous events

	Symbol	Result 1/year	Reference Formula	Formula
Structure	N_D	1,8 × 10^{-3}	(A.4)	$N_D = N_G \times A_D \times C_D \times 10^{-6}$
	N_M	–	(A.6)	Not relevant
Power Line	$N_{L/P}$	1,4 × 10^{-2}	(A.8)	$N_{L/P} = N_G \times A_{L/P} \times C_{I/P} \times C_{E/P} \times C_{T/P} \times 10^{-6}$
	$N_{I/P}$	1,4	(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	$N_{L/T}$	2,8 × 10^{-2}	(A.8)	$N_{L/T} = N_G \times A_{L/T} \times C_{I/T} \times C_{E/T} \times C_{T/T} \times 10^{-6}$
	$N_{I/T}$	2,8	(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

NE.2.4 Risk R_1 – Determination of need of protection

The risk R_1 can be expressed according to Formula (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 NE.7.

Table NE.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**
	$R_U = R_{U/P} + R_{U/T}$		0,00042	**0,00042**
D2 Physical damage	R_B		0,1805	**0,1805**
	$R_V = R_{V/P} + R_{V/T}$		4,2	**4,2**
Total		–	**4,381**	**R_1 = 4,381**
Tolerable		**$R_1 > R_T$: Lightning protection is required**		**R_T = 1**

Because R_1 = 4,381 × 10^{-5} is higher than the tolerable value $R_T = 10^{-5}$, lightning protection for the structure is required.

NE.2.5 Risk R_1 – Selection of protection measures

According to Table NE.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 NB.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 NB.2 and NB.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 formulas, new values of risk components are obtained, as shown in Table NE.8.

Table NE.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	0,181	0,036
	R_V	0,21	0,21
Total	R_1	**0,391**	**0,246**

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

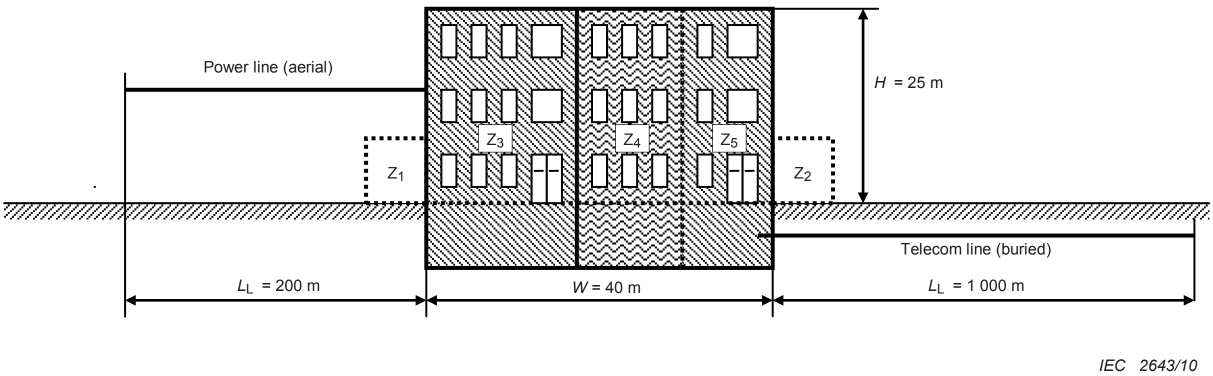
NE.3 Office building

As a second case study, an office building with an archive, offices and a computer centre is considered (Figure NE.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 NF.1). 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 (outside)
Z_3: archive
Z_4: offices
Z_5: computer centre

Figure NE.2 – Office building

NE.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 = 0,7 flashes per km^2 per year.

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

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

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

Input parameter	Comment	Symbol	Value	Reference
Ground flash density (1/km^2/year)		N_G	0,7	
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 NB.2
Equipotential bonding	None	P_{EB}	1	Table NB.7
External spatial shield	None	K_{S1}	1	Formula (NB.5)

Table NE.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 NB.8
Shielding, grounding, isolation	None	C_{LD}	1	Table NB.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	Formula (NB.7)
		P_{LD}	1	Table NB.8
		P_{LI}	0,3	Table NB.9

Table NE.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 NB.8
Shielding, grounding, isolation	None	C_{LD}	1	Table NB.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	Formula (NB.7)
		P_{LD}	1	Table NB.8
		P_{LI}	0,5	Table NB.9

NE.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 NE.12. These values are used later to subdivide the total loss values into fractions for each zone.

Table NE.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 NC.1) for the whole structure are:

- $L_T = 10^{-2}$ (outside the structure),
- $L_T = 10^{-2}$ (inside the structure),
- $L_F = 0,42$ 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 NE.13 to NE.17.

Table NE.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 NC.3
Protection against shock	None	P_{TA}	1	Table NB.1
Risk of fire	None	r_f	0	Table NC.5
Fire protection	None	r_p	1	Table NC.4
Internal spatial shield	None	K_{S2}	1	Formula (NB.6)
L1: Loss of human life	Special hazard: None	h_z	1	Table NC.6
	D1: due to touch and step voltage	L_T	10^{-2}	Table NC.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 × 8 760 / 8 760	–	0,02	

Table NE.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 NC.3
Protection against shock	Fence	P_{TA}	0	Table NB.1
Risk of fire	None	r_f	0	Table NC.5
Fire protection	None	r_p	1	Table NC.4
Internal spatial shield	None	K_{S2}	1	Formula (NB.6)
L1: Loss of human life	Special hazard: None	h_z	1	Table NC.6
	D1: due to touch and step voltage	L_T	10^{-2}	Table NC.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 × 8 760 / 8 760	–	0,01	

Table NE.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 NC.3
Protection against shock (flash to structure)		None	P_{TA}	1	Table NB.1
Protection against shock (flash to line)		None	P_{TU}	1	Table NB.6
Risk of fire		High	r_f	10^{-1}	Table NC.5
Fire protection		None	r_p	1	Table NC.4
Internal spatial shield		None	K_{S2}	1	Formula (NB.6)
Power	Internal wiring	Unshielded (loop conductors in the same conduit)	K_{S3}	0,2	Table NB.5
	Coordinated SPDs	None	P_{SPD}	1	Table NB.3
Telecom	Internal wiring	Unshielded (large loops >10m^2)	K_{S3}	1	Table NB.5
	Coordinated SPDs	None	P_{SPD}	1	Table NB.3
L1: Loss of human life		Special hazard: low panic	h_z	2	Table NC.6
		D1: due to touch and step voltage	L_T	10^{-2}	Table NC.2
		D2: due to physical damage	L_F	0,42	
		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 NE.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 NC.3
Protection against shock (flash to structure)		None	P_{TA}	1	Table NB.1
Protection against shock (flash to line)		None	P_{TU}	1	Table NB.6
Risk of fire		Low	r_f	10^{-3}	Table NC.5
Fire protection		None	r_p	1	Table NC.4
Internal spatial shield		None	K_{S2}	1	Formula (NB.6)
Power	Internal wiring	Unshielded (loop conductors in the same conduit)	K_{S3}	0,2	Table NB.5
	Coordinated SPDs	None	P_{SPD}	1	Table NB.3
Telecom	Internal wiring	Unshielded (large loops > 10 m^2)	K_{S3}	1	Table NB.5
	Coordinated SPDs	None	P_{SPD}	1	Table NB.3
L1: Loss of human life		Special hazard: low panic	h_z	2	Table NC.6
		D1: due to touch and step voltage	L_T	10^{-2}	Table NC.2
		D2: due to physical damage	L_F	0,42	
		D3: due to failure of internal systems	L_O	–	
Factor for persons in zone		$n_z / n_t \times t_z / 8\,760 = 160 / 200 \times 8\,760 / 8\,760$	–	0,80	

Table NE.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 NC.3
Protection against shock (flash to structure)		None	P_{TA}	1	Table NB.1
Protection against shock (flash to line)		None	P_{TU}	1	Table NB.6
Risk of fire		Low	r_f	10^{-3}	Table NC.5
Fire protection		None	r_p	1	Table NC.4
Internal spatial shield		None	K_{S2}	1	Formula (NB.6)
Power	Internal wiring	Unshielded (loop conductors in the same conduit)	K_{S3}	0,2	Table NB.5
	Coordinated SPDs	None	P_{SPD}	1	Table NB.3
Telecom	Internal wiring	Unshielded (large loops > 10 m²)	K_{S3}	1	Table NB.5
	Coordinated SPDs	None	P_{SPD}	1	Table NB.3
L1: Loss of human life		Special hazard: low panic	h_z	2	Table NC.6
		D1: due to touch and step voltage	L_T	10^{-2}	Table NC.2
		D2: due to physical damage	L_F	0,42	
		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	

NE.3.3 Calculation of relevant quantities

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

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

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

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

	Symbol	Result 1/year	Reference Formula	Formula
Structure	N_D	$1,92 \times 10^{-2}$	(A.4)	$N_D = N_G \times A_D \times C_D \times 10^{-6}$
	N_M	–	(A.6)	Not relevant
Power line	$N_{L/P}$	$5,6 \times 10^{-3}$	(A.8)	$N_{L/P} = N_G \times A_{L/P} \times C_{I/P} \times C_{E/P} \times C_{T/P} \times 10^{-6}$
	$N_{I/P}$	0.56	(A.10)	Not relevant
	$N_{DA/P}$	0	(A.5)	No adjacent structure
Telecom line	$N_{L/T}$	$1,4 \times 10^{-2}$	(A.8)	$N_{L/T} = N_G \times A_{L/T} \times C_{I/T} \times C_{E/T} \times C_{T/T} \times 10^{-6}$
	$N_{I/T}$	1,4	(A.10)	Not relevant
	$N_{DA/T}$	0	(A.5)	No adjacent structure

NE.3.4 Risk R_1 – Decision on need for protection

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

Table NE.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	0	≈ 0	≈ 0	≈ 0	**≈ 0**
	$R_U = R_{U/P} + R_{U/T}$			≈ 0	≈ 0	≈ 0	**≈ 0**
D2 Physical damage	R_B			16,15	1,292	0,113	**17,56**
	$R_V = R_{V/P} + R_{V/T}$			16,464	1,317	0,115	**17,896**
Total		≈ 0	**0**	**32,614**	**2,609**	**0,228**	**R_1 = 35,456**
Tolerable		**$R_1 > R_T$: Lightning protection is required**					**R_T = 1**

Because R_1 = 35,456 × 10^{-5} is higher than the tolerable value R_T = 10^{-5}, lightning protection for the structure is required.

NE.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 NE.20).

These dominant risk components can be reduced by;

— providing the whole building with an LPS conforming to BS EN 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 BS EN 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 II LPS conforming to BS EN 62305-3, to reduce component R_B (P_B = 0,05);

— this LPS includes the mandatory lightning equipotential bonding at the entrance with SPDs designed for LPL II* (P_{EB} = 0,002) and reduces components R_U and R_V.

Solution b):

— protect the building with a Class III LPS conforming to BS EN 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} = 0,005) 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 NE.20 will change to the reduced values reported in Table NE.21.

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

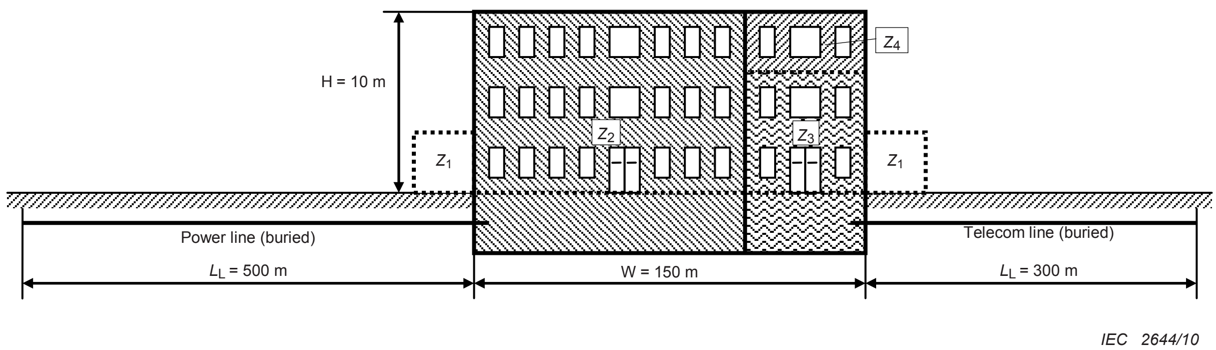
	Z_1	Z_2	Z_3	Z_4	Z_5	Total	Tolerable	Result
Solution a)	≈ 0	0	0,841	0,067	0,006	R_1 = 0,914	R_T = 1	$R_1 \leq R_T$
Solution b)	≈ 0	0	0,849	0,136	0,012	R_1 = 0,997	R_T = 1	$R_1 \leq R_T$

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.

NE.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 NE.3 – Hospital

NE.4.1 Relevant data and characteristics

The hospital is located in flat territory without any neighbouring structures. The lightning flash density is N_G = 0,7 flashes per km^2 per year.

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

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

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

Input parameter	Comment	Symbol	Value	Reference
Ground flash density (1/km^2/year)		N_G	0,7	
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 NB.2
Equipotential bonding	None	P_{EB}	1	Table NB.7
External spatial shield	None	K_{S1}	1	Formula (NB.5)

Table NE.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 NB.8
Shielding, grounding, isolation	Line shield bonded to the same bonding bar as equipment	C_{LD}	1	Table NB.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	Formula (NB.7)
		P_{LD}	0,2	Table NB.8
		P_{LI}	0,3	Table NB.9

Table NE.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 NB.8
Shielding, grounding, isolation	Line shield bonded to the same bonding bar as equipment.	C_{LD}	1	Table NB.4
		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	Formula (NB.7)
		P_{LD}	0,8	Table NB.8
		P_{LI}	0,5	Table NB.9

NE.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 NE.25. These values are used later to subdivide the total loss values into fractions for each zone.

Table NE.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 NC.2 and the increasing factor for special hazards according to Table NC.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;
— $L_F = 1$ 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 Z4 (intensive care unit).

These basic loss values were reduced for each zone according to the Formulas (NC.1) to (NC.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 NC.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 Formulas (NC.11) to (NC.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 NE.26 to NE.29.

Table NE.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 NC.3
Protection against shock	None	P_{TA}	1	Table NB.1
Risk of fire	None	r_f	0	Table NC.5
Fire protection	None	r_p	1	Table NC.4
Internal spatial shield	None	K_{S2}	1	Formula (NB.6)
L1: Loss of human life	Special hazard: None	h_z	1	Table NC.5
	D1: due to touch and step voltage	L_T	10^{-2}	Table NC.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 × 8 760 / 8 760	–	0,01	

Table NE.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 NC.3
Protection against shock (flash to structure)		None	P_{TA}	1	Table NB.1
Protection against shock (flash to line)		None	P_{TU}	1	Table NB.9
Risk of fire		Ordinary	r_f	10^{-2}	Table NC.5
Fire protection		None	r_p	1	Table NC.4
Internal spatial shield		None	K_{S2}	1	Formula (NB.6)
Power	Internal wiring	Unshielded (loop conductors in the same conduit)	K_{S3}	0,2	Table NB.5
	Coordinated SPDs	None	P_{SPD}	1	Table NB.3
Telecom	Internal wiring	Unshielded (loop conductors in the same cable)	K_{S3}	0,01	Table NB.5
	Coordinated SPDs	None	P_{SPD}	1	Table NB.3
L1: Loss of human life		Special hazard: difficulty of evacuation	h_z	5	Table NC.6
		D1: due to touch and step voltage	L_T	10^{-2}	Table NC.2
		D2: due to physical damage	L_F	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 NC.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 NE.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 NC.3
Protection against shock (flash to structure)		None	P_{TA}	1	Table NB.1
Protection against shock (flash to line)		None	P_{TU}	1	Table NB.9
Risk of fire		Low	r_f	10^{-3}	Table NC.5
Fire protection		None	r_p	1	Table NC.4
Internal spatial shield		None	K_{S2}	1	Formula (NB.6)
Power line	Internal wiring	Unshielded (loop conductors in the same conduit)	K_{S3}	0,2	Table NB.5
	Coordinated SPDs	None	P_{SPD}	1	Table NB.3
Telecom line	Internal wiring	Unshielded (loop conductors in the same cable)	K_{S3}	0,01	Table NB.5
	Coordinated SPDs	None	P_{SPD}	1	Table NB.3
L1: Loss of human life		Special hazard: difficulty of evacuation	h_z	5	Table NC.6
		D1: due to touch and step voltage	L_T	10^{-2}	Table NC.2
		D2: due to physical damage	L_F	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 NC.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 NE.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 NC.3
Protection against shock (flash to structure)		None	P_{TA}	1	Table NB.1
Protection against shock (flash to line)		None	P_{TU}	1	Table NB.9
Risk of fire		Low	r_f	10^{-3}	Table NC.5
Fire protection		None	r_p	1	Table NC.4
Internal spatial shield		None	K_{S2}	1	Formula (NB.6)
Power Line	Internal wiring	Unshielded (loop conductors in the same conduit)	K_{S3}	0,2	Table NB.5
	Coordinated SPDs	None	P_{SPD}	1	Table NB.3
Telecom Line	Internal wiring	Unshielded (loop conductors in the same cable)	K_{S3}	0,01	Table NB.5
	Coordinated SPDs	None	P_{SPD}	1	Table NB.3
L1: Loss of human life		Special hazard: difficulty of evacuation	h_z	5	Table NC.6
		D1: due to touch and step voltage	L_T	10^{-2}	Table NC.2
		D2: due to physical damage	L_F	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 = 5 / 1 000 × 8 760 / 8 760	–	0,005	
L4: Economic loss		D2: due to physical damage	L_F	0,5	Table NC.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	

NE.4.3 Calculation of relevant quantities

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

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

	Symbol	Result m²	Reference Formula	Formula
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 NE.31 – Hospital: Expected annual number of dangerous events

	Symbol	Result 1/year	Reference Formula	Formula
Structure	N_D	$1{,}56 \times 10^{-2}$	(A.4)	$N_D = N_G \times A_{D/B} \times C_{D/B} \times 10^{-6}$
	N_M	$6{,}9 \times 10^{-1}$	(A.6)	$N_M = N_G \times A_M \times 10^{-6}$
Power line	$N_{L/P}$	$7{,}00 \times 10^{-4}$	(A.8)	$N_{L/P} = N_G \times A_{L/P} \times C_{I/P} \times C_{E/P} \times C_{T/P} \times 10^{-6}$
	$N_{I/P}$	$7{,}00 \times 10^{-2}$	(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	$N_{L/T}$	$2{,}1 \times 10^{-3}$	(A.8)	$N_{L/T} = N_G \times A_{L/T} \times C_{I/T} \times C_{E/T} \times C_{T/T} \times 10^{-6}$
	$N_{I/T}$	$2{,}1 \times 10^{-1}$	(A.10)	$N_{I/T} = N_G \times A_{I/T} \times C_{I/T} \times C_{E/T} \times C_{T/T} \times 10^{-6}$
	$N_{DJ/T}$	$1{,}97 \times 10^{-3}$	(A.5)	$N_{DJ/T} = N_G \times A_{DJ/T} \times C_{DJ/T} \times C_{T/T} \times 10^{-6}$

NE.4.4 Risk R_1 – Decision on need for protection

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

Table NE.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 Formula	Formula
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		0,006 4			(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 NE.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	0,0016	0,000 1	≈0	≈0	**0,0017**
	$R_U = R_{U/P} + R_{U/T}$		≈0	≈0	≈0	**≈0**
D2 Physical damage	R_B		74,24	0,2735	0,0391	**74,55**
	$R_V = R_{V/P} + R_{V/T}$		16,115	0,594	0,0085	**16,1778**
D3 Failure of internal systems	R_C		1,485	0,547	0,0782	**2,11**
	R_M		0,4223	0,1556	0,0222	**0,6001**
	$R_W = R_{W/P} + R_{W/T}$		0,3222	0,1187	0,0170	**0,4579**
	$R_Z = R_{Z/P} + R_{Z/T}$					
Total		**0,0016**	**92,58**	**1,154**	**0,1649**	**R1 = 93,9**
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.

NE.4.5 Risk R_1 – Selection of protection measures

The risk R_1 is mainly influenced (see Table NE.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 BS EN 62305-3 reducing component R_B via probability P_{NB}. 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 BS EN 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 BS EN 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 II LPS (P_B = 0,05 including also P_{EB} = 0,02);
- install coordinated SPD protection on internal power and telecom systems (P_{SPD} = 0,02) 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 NE.33 will change to the reduced values reported in Table NE.34.

Table NE.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		0,7472	0,0137	0,0020	**0,7580**
	$R_V = R_{V/P} + R_{V/T}$		0,0644	0,0012	0,0002	**0,0658**
D3 Failure of internal systems	R_C		0,0588	0,0217	0,0031	**0,0836**
	R_M		0,0084	≈ 0	≈ 0	**0,0084**
	$R_W = R_{W/P} + R_{W/T}$		0,0064	0,0024	0,0003	**0,0092**
	$R_Z = R_{Z/P} + R_{Z/T}$					
Total		**≈ 0**	**0,8805**	**0,0389**	**0,0056**	**R_1 = 0,9251**
Tolerable		**$R_1 < R_T$: Structure is protected for this type of loss**				**R_T = 1**

Solution b):

— protect the building with a Class II LPS (P_B = 0,05);

— install enhanced coordinated SPD protection on internal power and telecom systems (P_{EB} = 0,002, 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).

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

Table NE.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		0,7424	0,0137	0,0020	**0,758**
	$R_V = R_{V/P} + R_{V/T}$		0,0064	≈ 0	≈0	**0,0064**
D3 Failure of internal systems	R_C		0,0059	0,0022	0,0003	**0,0084**
	R_M		0,0008	0,0003	≈0	**0,0012**
	$R_W = R_{W/P} + R_{W/T}$		0,0006	0,0002	≈ 0	**0,0009**
	$R_Z = R_{Z/P} + R_{Z/T}$					
Total		**≈ 0**	**0,7563**	**0,0165**	**0,0024**	**R_1 = 0,7752**
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.

NE.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 NE.22 through NE.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 NE.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 × 10^6 (Table NE.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 Formula (D.2) and (D.4)). The results are shown in Table NE.36.

Table NE.36 – 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	–	9,314	1,523	0,2829	**11,12**	**10 007**
Solution a)	–	0,1052	0,046	0,0086	**0,1598**	**144**
Solution b)	–	0.0727	0.0085	0.0018	**0.0829**	**75**

The values assumed for interest, amortization and maintenance rates relevant to the protection measures are given in Table NE.37.

Table NE.37 – Hospital: Rates relevant to the protection measures

Rate	Symbol	Value
Interest	*i*	0,02
Amortization	*a*	0,02
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 NE.38 (see Formula (D.5)).

Table NE.38 – 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)**
LPS class II	30 000	1 500	1 500
Automatic fire protection in zone Z_2	50 000	2 500	2 500
Zones Z_3 and Z_4 shielding (w_m = 0,5 m)	50 000	2 500	
Coordinated SPD set on power system (LPL II)	20 000	1 000	
Coordinated SPD set on power system (LPL II*)	30 000		1 500
Coordinated SPD set on TLC system (LPL II)	10 000	500	
Coordinated SPD set on TLC system (LPL II*)	15 000		750
Total annual cost C_{PM}		**8 000**	**6 250**

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 NE.39. It should be noted that consequential loss is not taken into account.

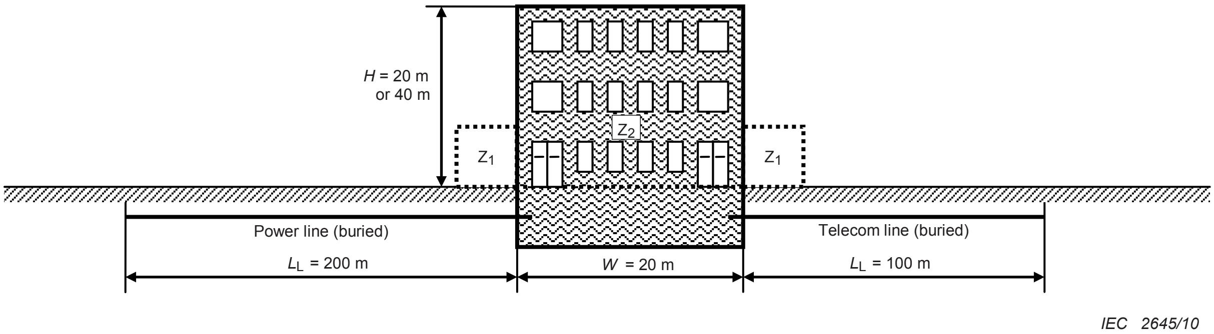
Table NE.39 – Hospital: Annual saving of money (values in £)

	Symbol	Solution a)	Solution b)
Loss for the unprotected structure	C_L	10 007	10 007
Residual loss for the protected structure	C_{RL}	144	75
Annual cost of protection	C_{PM}	8 000	6 250
Annual saving $S_M = C_L - (C_{RL} + C_{PM})$	S_M	**1 863**	**3 682**

NE.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, however, 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 to Table 2) will be determined and compared with the tolerable value $R_T = 10^{-5}$ (according to Table NF.1). 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 NE.4 – Apartment block

NE.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 = 0,7 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 NE.40.

Data for the incoming lines and their internal systems connected to are given for the power line in Table NE.41 and for the telecom line in Table NE.42.

Table NE.40 – Apartment block: Environment and global structure characteristics

Input parameter	Comment	Symbol	Value	Reference
Ground flash density (1/km^2/year)		N_G	0,7	
Structure dimensions (m)	*H* = 20 or 40 (see Table NE.44)	*L*, *W*	30, 20	
Location factor of structure	Isolated structure	C_D	1	Table A.1
LPS	Variable (see Table NE.44)	P_B	–	Table NB.2
Equipotential bonding	None	P_{EB}	1	Table NB.7
External spatial shield	None	K_{S1}	1	Formula (NB.5)

Table NE.41 – 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 NB.8
Shielding, grounding, isolation	None	C_{LD}	1	Table NB.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	2,5	
	Resulting parameters	K_{S4}	0,4	Formula (NB.7)
		P_{LD}	1	Table NB.8
		P_{LI}	0,3	Table NB.9

Table NE.42 – 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 NB.8
Shielding, grounding, isolation	None	C_{LD}	1	Table NB.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	Formula (NB.7)
		P_{LD}	1	Table NB.8
		P_{LI}	0,5	Table NB.9

NE.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 NC.1.

The resulting factors valid for zone Z_2 are reported in Table NE.43.

Table NE.43 – 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 NC.3
Protection against shock (flash to structure)		None	P_{TA}	1	Table NB.1
Protection against shock (flash to line)		None	P_{TU}	1	Table NB.6
Risk of fire		Variable (see Table NE.44)	r_f	–	Table NC.5
Fire protection		Variable (see Table NE.44)	r_p	–	Table NC.4
Internal spatial shield		None	K_{S2}	1	Formula (NB.6)
Power	Internal wiring	Unshielded (loop conductors in the same conduit)	K_{S3}	0,2	Table NB.5
	Coordinated SPDs	None	P_{SPD}	1	Table NB.3
Telecom	Internal wiring	Unshielded (large loops > 10 m^2)	K_{S3}	1	Table NB.5
	Coordinated SPDs	None	P_{SPD}	1	Table NB.3
L1: Loss of human life		Special hazard: None	h_z	1	Table NC.6
		D1: due to touch and step voltage	L_T	10^{-2}	Table NC.2
		D2: due to physical damage	L_F	1	
Factor for persons in zone		$n_z / n_t \times t_z$ / 8 760 = 200 / 200 × 8 760 / 8 760	–	1	

NE.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 NE.44, 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 L_{PS} adopted.

Table NE.44 – 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 $R_1 \le R_T$
	Type	r_f	Class	P_B	Type	r_p		
20	Low	0,001	None	1	None	1	**1,464**	No
	Ordinary	0,01	None	1	None	1	**14,637**	No
			II	0,05	None	1	**0,669**	Yes
			III	0,1	Manual	0,5	**0,679**	Yes
	High	0,1	None	1	None	1	**146,37**	No
			I	0,02	Automatic	0,2	**0,543**	Yes
			I*	0,01	None	1	**1,464**	No
			I*	0,1	Manual	0,5	**0,732**	Yes
40	Low	0,001	None	1	None	1	**4,259**	No
			None	1	Automatic	0,2	**0,852**	Yes
			IV	0,2	None	1	**0,82**	Yes
	Ordinary	0,01	None	1	None	1	**42,59**	No
			III	0,1	Automatic	0,2	**0,831**	Yes
			I	0,02	None	1	**0,831**	Yes
	High	0,1	None	1	None	1	**425,87**	No
			I*	0,1	Automatic	0,2	**0,852**	Yes

NE.6 Heritage building – ancient church

As a fifth case study the need for protection for an ancient church (Figure NE.5) is evaluated. This requires determination of the risk R_1 for loss of human life (L1) with the risk components R_{A1}, R_{B1}, R_{U1} and R_{V1}, and R_3 with the risk components, R_{B3} and R_{V3}, (according to BS EN 62305-2 Table 2) and to compare them with the respective tolerable risks $R_{T1} = 10^{-5}$ and $R_{T3} = 10^{-4}$ (according to Table NF.1). Suitable protection measures to reduce the risks R_1 and R_3 below the respective tolerable levels, as necessary, will be selected.

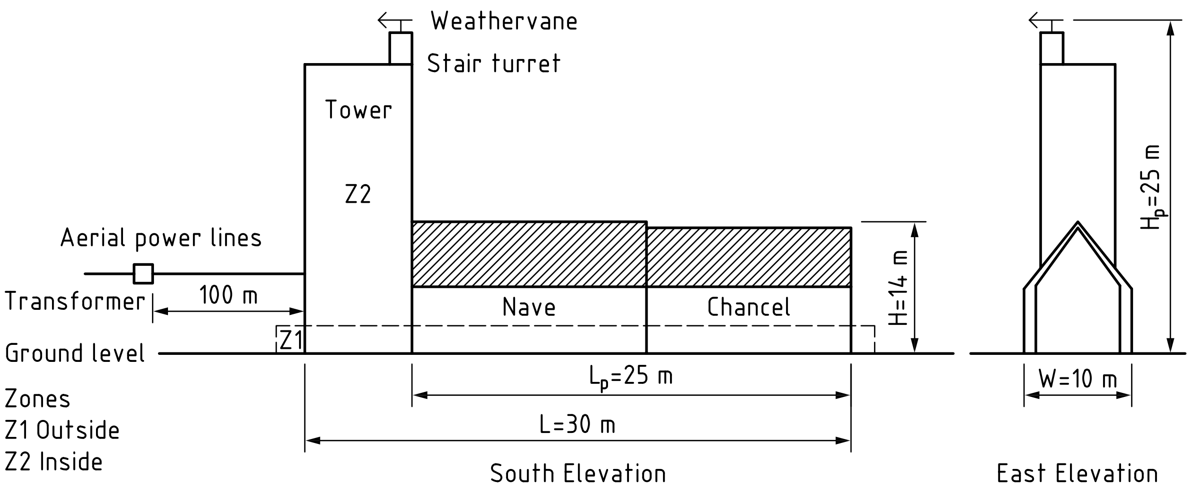


Figure NE.5 – Ancient church

NE.6.1 Relevant data and characteristics

The church is located in hilly territory with a few neighbouring structures of much lesser height. The lightning flash density is N_G = 1 flash per km^2 per year. The church is occupied for regular services on a Sunday and occasional services, such as weddings and funerals. There are also many other activities such as regular organ practice, bellringing practice, flower arranging and church cleaning and occasional activities such as concerts. The church is open to visitors at weekends in the summer. There are maintenance activities. Before and after weddings and funerals especially, people congregate outside the church. There is a large tarmac area outside the main door; people congregate in this area. Table NE.45 abbreviates the occupation assessment for people outside the church (within 3 m), zone 1, and inside the church, zone 2, showing the method of a detailed assessment and the average number of people during the time of occupation. Data for the church and its surroundings are given in Table NE.46. Data for the incoming line and the internal systems connected to it are given for the power line in Table NE.47.

Table NE.45 – Church occupation

Activity	Typical number of persons	Frequency of activity	Duration of activity – hours	Annual occupancy – hours [a]	Person hours
1	**2**	**3**	**4**	**5 = 3 x 4**	**6 = 2 x 5**
Main Sunday service	40	weekly	2,5	125	5 000
Weddings	60	6 y^{-1}	1,0	6	360
Christmas services	100	2 y^{-1}	2,0	4	400
Bellringing practice	10	weekly	2,0	100	1 000
Other activities not shown here individually				245	4 600
Total inside				**480**	**11 360**
Average occupancy inside	11 360/480 = **23,7**			480/8 760 = **0,05**	
Weddings	60	6 y^{-1}	0,75	4,5	270
Funerals	20	20 y^{-1}	0,75	15	300
Other				13,5	50
Total outside in Z_1				**33**	**620**
Average occupancy outside in Z_1	620/33 = **18,8**			33/8 760 = **0,004**	

[a] For ease of calculation a year is taken as 50 weeks

Table NE.46 – Environmental and whole structure characteristics

Parameter	Comment	Symbol	Value	Reference
Ground flash density (1/km^2/year)		N_G	1,0	
Structure dimensions 1		L, W, H	30 m, 10 m, 14 m	
Structure dimensions 2		L_P, H_P	25 m, 25 m	
Location factor of structure	Fairly isolated structure	C_D	0,8 [a]	Table A.1
LPS	None	P_B	1	Table NB.2
Equipotential bonding	None	P_{EB}	1	Table NB.7

[a] Interpolation of Table A.1

Table NE.47 – Power line characteristics

Input parameter	Comment	Symbol	Value	Reference
Length	Section 1 – from church to transformer	L_{LS1}	100 m	
	Section 2 – beyond transformer - unknown	L_{LS2}	1 000 m	
Installation factor	Section 1 – Aerial	C_{IS1}	1	Table A.2
	Section 2 – Aerial	C_{IS2}	1	Table A.2
Line type factor	Section 1 – LV line	C_{TS1}	1	Table A.3
	Section 2 – HV line with transformer	C_{TS2}	0,2	Table A.3
Environmental factor	Rural	C_E	1	Table A.4
Type of line	Power line – Single phase 100 A. TN-C-S (PME) system.	C_{LD}	1	Table NB.4
Shield of line	Unshielded (Not relevant to R_1 and R_3)	C_{LI}	0,2	Table NB.4
Adjacent structure	None	L_J, W_J, H_J	–	Figure A.5
Location factor of structure	None	C_{DJ}	–	Table A.1
Withstand of internal system		U_W	2,5 kV	
Shielding of internal cables	Mostly MICC (mineral insulated, copper clad)	Not applicable to R_1 and R_3		
Equipotential bonding SPDs	None	P_{EB}	1	Table NB.7
Protective value of internal cables	None	P_{LD}	1	Table NB.8

NE.6.2 Definition of zones in the church

The following zones are defined:

— Z_1 (outside the building and within 3 m of the building and the ground),
— Z_2 (inside the building).

The parameters valid for zone Z_1 are given in Table NE.48 and for zone Z_2 in Table E.49.

Table NE.48 – Factors valid for zone Z_1 (outside the building)

Input parameter	Comment	Symbol	Value	Reference
Type of surface	Asphalt in areas where people gather	r_{tZ1}	10^{-5}	Table NC.3
Protection against shock (flash to structure)	none	P_{TAZ1}	1	Table NB.6
L1: Loss of human life	D1: due to touch and step voltage	L_{T1Z1}	10^{-2}	Table NC.2
	D2: due to physical damage	L_{F1}	–	
	D3: due to failure of internal systems	L_{O1}	–	
Factor for endangered persons	$n_{Z1} / n_t \cdot t_Z / 8\,760 = 18{,}8 / 42{,}5 \times 33 / 8\,760$	–	$1{,}67 \times 10^{-3}$	Table NC.1
L3: Loss of cultural heritage	D2: due to physical damage	L_{F3}	–	Table NC.10

Table NE.49 – Factors valid for zone Z_2 (inside the building)

Input parameter	Comment	Symbol	Value	Reference
Type of floor	Mixture of brick tiles and wood	r_{tZ2}	10^{-2}	Table NC.3
Protection against shock (flash to structure)	none	P_{TAZ2}	1	Table NB.1
Protection against shock (flash to line)	none	P_{TUZ2}	1	Table NB.6
Risk of fire	High – timber roof	r_f	10^{-1}	Table NC.5
Fire protection	Manual fire extinguishers but low occupation – interpolated value used	r_p	0,9	Table NC.4
L1: Loss of human life	Special hazard: none	h_z	1	Table NC.6
	D1: due to touch and step voltage	L_{T1Z2}	10^{-2}	Table NC.2
	D2: due to physical damage	L_{F1}	8×10^{-2}	
	D3: due to failure of internal systems	L_{O1}	–	
Factor for endangered persons	$n_{Z2} / n_t \cdot t_{Z2}$ / 8 760 = 23,7 / 42,5 × 480 / 8 760	–	0,030	Table NC.1
L3: Loss of cultural heritage	D2: due to physical damage	L_{F3}	0,1	Table NC.10

NE.6.3 Calculation of relevant quantities

Calculations of the collection areas are given in Table NE.50 and of the expected number of dangerous events in Table NE.51

Table NE.50 – Collection areas of structure and lines

	Symbol	Value m²	Reference	Equation
Structure	A_D	$1,77 \times 10^4$	(A.3)	$A_D' = \pi \cdot (3 \cdot H_P)^2$ or, if $3 \cdot H_P < L_P + 3 \cdot H$; graphical determination may be preferable.
	A_M	–	(A.7)	Not relevant
Power Line	A_{LS1}	4×10^3	(A.9)	$A_{LS1} = 40 \cdot L_{LS1}$
	A_{LS2}	4×10^4	(A.9)	$A_{LS2} = 40 \cdot L_{LS2}$
	A_{IS1}	–	(A.11)	Not relevant
	A_{IS2}	–	(A.11)	Not relevant
	A_{DJ}	–	(A.5)	No adjacent structure

Table NE.51 – Expected annual number of dangerous events

	Symbol	Value 1/year	Reference	Equation
Structure	N_D	0,0141	(A.4)	$N_D = N_G \cdot A_D \cdot C_D \cdot 10^{-6}$
	N_M	–	(A.6)	Not relevant
Power Line	N_{LS1}	4×10^{-3}	(A.8)	$N_{LS1} = N_G \cdot A_{LS1} \cdot C_{IS1} \cdot C_E \cdot C_{TS1} \cdot 10^{-6}$
	N_{LS2}	8×10^{-3}	(A.8)	$N_{LS2} = N_G \cdot A_{LS2} \cdot C_{IS2} \cdot C_E \cdot C_{TS2} \cdot 10^{-6}$
	N_L	$1,2 \times 10^{-2}$	–	$N_L = N_{LS1} + N_{LS2}$
	N_{IS1}	–	(A.10)	Not relevant
	N_{IS2}	–	(A.10)	Not relevant
	N_I	–	–	$N_I = N_{IS1} + N_{IS2}$
	N_{DJ}	–	(A.5)	No adjacent structure

NE.6.4 Summary of probabilities and losses

For the unprotected structure all probabilities are 1. For the protected structure most probabilities remain at 1. For the protected structure, relevant probabilities are given in Table NE.55. Loss values, which are applicable to calculations for both the unprotected and the protected structure, are summarized in Table NE.52 below.

Table NE.52 – Summary table of loss values

Loss	Value	Equation	Table
L_{A1}	3,1 × 10^{-6}	(NC.1)	NC.1
L_{B1}	2,2 × 10^{-4}	(NC.3)	
L_{U1}	3,1 × 10^{-6}	(NC.2)	
L_{V1}	2,2 × 10^{-4}	(NC.3)	
L_{B3}	9,0 × 10^{-3}	(NC.9)	NC.9
L_{V3}	9,0 × 10^{-3}	(NC.9)	

NE.6.5 Risk Calculation – R_1

The risk R_1 can be expressed according to BS EN 62305-2 equation (1) by the following sum of components:

$$R_1 = R_{A1Z1} + R_{A1Z2} + R_{B1} + R_{U1} + R_{V1} \quad \text{(NE.1)}$$

The risk components and total risk evaluation are given in Table NE.53

Table NE.53 – Risk R_1 for the unprotected structure (values × 10^{-5})

	Symbol	Z_1	Z_2	Structure	Reference	Equation
D1 Injury	R_{A1}	2,4 × 10^{-7}	0,004	0,004	(NB.1), (NC.1)	$R_{A1ZN} = N_D \cdot P_{TAZN} \cdot P_B \cdot r_{tZN} \cdot L_{T1} \cdot n_{ZN}/n_t \cdot t_{ZN}/ 8\,760$
	R_{U1}	-	0,004	0,004	(NB.8), (NC.2)	$R_{U1} = N_L \cdot P_{TU} \cdot P_{EB} \cdot P_{LD} \cdot C_{LD} \cdot r_{tZ2} \cdot L_{T1Z2} \cdot n_{ZN}/n_t \cdot t_{Z2}/8\,760$
D2 Physical damage	R_{B1}	-	0,311	0,311	(NC.3)	$R_{B1} = N_D \cdot P_B \cdot r_p \cdot r_f \cdot h_z \cdot L_{F1} \cdot n_{ZN}/n_t \cdot t_{Z2}/8\,760$
	R_{V1}	-	0,264	0,264	(NB.9), (NC.3)	$R_{V1} = N_L \cdot P_{EB} \cdot P_{LD} \cdot C_{LD} \cdot r_p \cdot r_f \cdot h_z \cdot L_{F1} \cdot n_{ZN}/n_t \cdot t_{Z2}/ 8\,760$
Total	$\boldsymbol{R_1}$			**0,583**		
Tolerable	$\boldsymbol{R_{T1}}$			**1,0**	**$R_1 < R_{T1}$: lightning protection is not required**	
NOTE Where a suffix $_{ZN}$ is shown then the particular value of parameter for either zone 1 or 2 should be used.						

NE.6.6 Risk Calculation – R_3

The risk R_3 can be expressed according to BS EN 62305-2 equation (1) by the following sum of components:

$$R_3 = R_{B3} + R_{V3} \quad \text{(NE.2)}$$

The risk components and total risk evaluation are given in Table NE.54

Table NE.54 – Risk R_3 for the unprotected structure (values × 10^{-4})

	Symbol	Value	Reference	Equation
D2 Physical damage	R_{B3}	1,27	(NC.9)	$R_{B3} = N_D \cdot P_B \cdot r_p \cdot r_f \cdot L_{F3}$
	R_{V3}	1,08	(NB.9), (NC.9)	$R_{V3} = N_L \cdot P_{EB} \cdot P_{LD} \cdot C_{LD} \cdot r_p \cdot r_f \cdot L_{F3}$
Total	R_3	**2,35**	–	
Tolerable	R_{T3}	**1,0**	**$R_3 > R_{T3}$: Lightning protection is required**	

NE.6.7 Selection of protection measures

Both components of R_3 are just above the tolerable risk. Therefore an external lightning protection system with equipotential bonding is required. The total risk R_1 is less than the tolerable risk, R_{T1}. Application of measures to reduce R_3 below R_{T3} will also reduce R_1. The parameters changed by the protection measures are given in Table NE.55.

Table NE.55 – Parameter values with protection measures

Parameter	Comment	Symbol	Value	Reference
Protective measures against shock	Outside – none	P_{TAZ1}	1	Table NB.1
	Inside – none	P_{TAZ2}	1	Table NB.1
LPS with equipotential bonding	LPS Class IV	P_B	0,2	Table NB.2
	Bond with SPD Type 1	P_{EB}	0,05	Table NB.7

Risks are re-calculated for the application of an external LPS to Class IV, including mandatory bonding with an SPD as well as an LPS to neutral bond and are given in Table NE.56.

Table NE.56 – Risks with LPS Class IV

Risk	Source of damage	Symbol	Value
R_1	S1 Structure	R_{A1}	0,004 × 10^{-5}
		R_{B1}	0,062 × 10^{-5}
	S3 Lines	R_{U1}	~ 0
		R_{V1}	0,013 × 10^{-5}
	Total	R_1	**0,080 × 10^{-5}**
R_3	S1 Structure	R_{B3}	0,26 × 10^{-4}
	S3 Lines	R_{V3}	0,05 × 10^{-4}
	Total	R_3	**0,31 × 10^{-4}**

Both risks are less than the relevant tolerable risks by a considerable margin. The application of an LPS Class IV including equipotential bonding with direct connection of the LPS and the incoming earth/neutral line at the main earthing terminal of the supply and a single phase SPD Type1 between line and neutral at the main switchboard is considered the appropriate, most economical solution to the protection of the church.

NE.7 Bank computer centre

NE.7.1 General

In this case the example of the Office building (NE.3) will be studied further in order to illustrate the calculations for loss of public service (L2).

The risk of loss of human life (R_1) has already been determined for the structure as detailed in example (NE.3). The following calculations are based on the premise that protection solution a) of example NE.3 has been applied in order to reduce the risk of loss of human life (R_1) to a tolerable level.

The office building is to be operated as a Banking computer centre. This example requires the determination of the risk R_2 only (comprising the risk components R_{B2}, R_{V2}, R_{C2}, R_{M2}, R_{W2} and R_{Z2} according to Table 2) and to compare it with the UK tolerable risk $R_{T2} = 10^{-4}$ (according to Table NF.1).

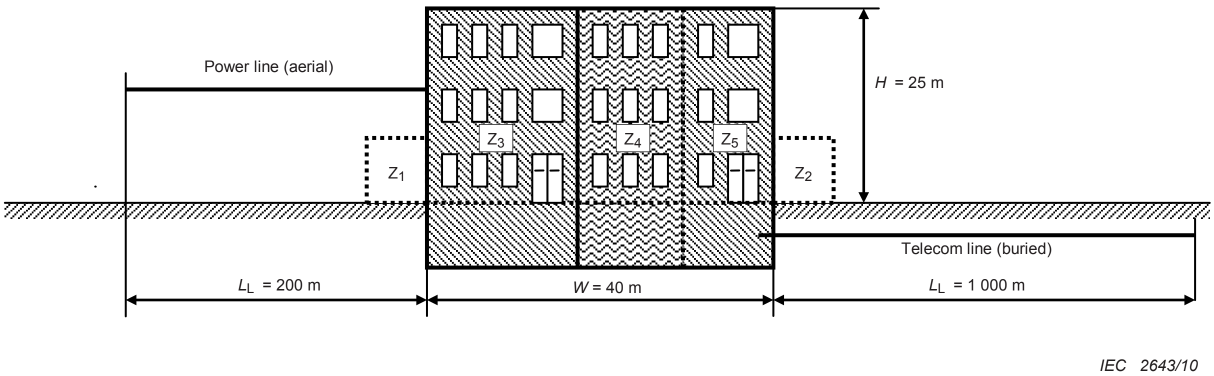


Figure NE.6 – Bank computer centre – Zone 5

NE.7.2 Relevant data and characteristics

The bank computer centre is located in flat territory without any neighbouring structures. The lightning flash density is N_G = 0,7 flashes per km^2 per year.

Data for the building and its surroundings are given in Table NE.57.

Data for the incoming lines and their connected internal systems are given for the power line in Table NE.58 and for the telecom line in Table NE.59.

Table NE.57 – Environmental and whole structure characteristics

Input parameter	Comment	Symbol	Value	Reference
Ground flash density (1/km^2/year)		N_G	0,7	
Structure dimensions (m)		L, W, H	20, 40, 25	
Location factor of structure	Isolated structure	C_D	1	Table A.1
LPS	Class II	P_B	0,05	Table NB.2
Equipotential bonding	Level II*	$P_{EB/P}$ and $P_{EB/T}$	0,002	Table NB.7
External spatial shield	None	K_{S1}	1	Equation (NB.5)

Table NE.58 – Power line characteristics

Input parameter	Comment	Symbol	Value	Reference
Length (m)		$L_{L/P}$	200	
Installation factor	Aerial	$C_{I/P}$	1	Table A.2
Line type factor	LV line	$C_{T/P}$	1	Table A.3
Environmental factor	Rural	$C_{E/P}$	1	Table A.4
Shield of line (Ω/km)	Unshielded	$R_{S/P}$	–	Table NB.8
Shielding, grounding, isolation	None	$C_{LD/P}$	1	Table NB.4
		$C_{LI/P}$	1	
Adjacent structure	None	$L_{J/P}$, $W_{J/P}$, $H_{J/P}$	–	
Location factor of adjacent structure	None	$C_{DJ/P}$	–	Table A.1
Withstand voltage of internal system (kV)		$U_{W/P}$	2,5	
Reciprocal of impulse withstand voltage	Resulting parameters	$K_{S4/P}$	0,4	Equation (NB.7)
Probability of failure of internal systems due to a flash to the line		$P_{LD/P}$	1	Table NB.8
Probability of failure of internal systems due to a flash near the line		$P_{LI/P}$	0,3	Table NB.9

Table NE.59 – Telecom line characteristics

Input parameter	Comment	Symbol	Value	Reference
Length (m)		$L_{L/T}$	1 000	
Installation factor	Buried	$C_{I/T}$	0,5	Table A.2
Line type factor	Telecom line	$C_{T/T}$	1	Table A.3
Environmental factor	Rural	$C_{E/T}$	1	Table A.4
Shield of line (Ω/km)	Unshielded	$R_{S/T}$	–	Table NB.8
Shielding, grounding, isolation	None	$C_{LD/T}$	1	Table NB.4
		$C_{LI/T}$	1	
Adjacent structure	None	$L_{J/T}$, $W_{J/T}$, $H_{J/T}$	–	
Location factor of adjacent structure	None	$C_{DJ/T}$	–	Table A.1
Withstand voltage of internal system (kV)		$U_{W/T}$	1,5	
Reciprocal of impulse withstand voltage	Resulting parameters	$K_{S4/T}$	0,67	Equation (NB.7)
Probability of failure of internal systems due to a flash to the line		$P_{LD/T}$	1	Table NB.8
Probability of failure of internal systems due to a flash near the line		$P_{LI/T}$	0,5	Table N B.9

NE.7.3 Definition of zones in the bank computer centre

With reference to example NE.3 the following zones are defined:

— Z_1 (entrance area outside);

— Z_2 (garden outside);

— Z_3 (archive);

— Z_4 (offices);

— Z_5 (computer centre);

For the purposes of this example it has been assumed that the critical business systems that ensure the continuity of service are provided by the computer centre (Z_5) of example NE.3.

Therefore, for the determination of the risk R_2 the structure will be treated as a single zone with the parameters of that zone based on the computer centre (Z_5).

The typical mean values of relative amount of loss per year relevant to risk R_2 for the whole structure are the values in Table NC.8:

— $L_{F2} = 10^{-1}$
— $L_{O2} = 10^{-2}$

The characteristics of zone Z_5 are given in Table NE.60.

Table NE.60 –Bank computer centre: factors for whole structure

Input parameter		Comment	Symbol	Value	Reference
Risk of fire		Low	r_f	10^{-3}	Table NC.5
Fire protection		None	r_p	1	Table NC.4
Internal spatial shield		None	K_{S2}	1	Equation (NB.6)
Power	Internal wiring	Unshielded (loop conductors in the same conduit)	$K_{S3/P}$	0,2	Table NB.5
	Coordinated SPDs	None	$P_{SPD/P}$	1	Table NB.3
Telecom	Internal wiring	Unshielded (large loops > 10 m^2)	$K_{S3/T}$	1	Table NB.5
	Coordinated SPDs	None	$P_{SPD/T}$	1	Table NB.3
L2: Loss of service to the public		D2: due to physical damage	L_{F2}	10^{-1}	Table NC.8
		D3: due to failure of internal systems	L_{O2}	10^{-2}	Table NC.8
Factor for number of users served by the zone		Not applicable	–	–	

NE.7.4 Calculation of relevant quantities

Calculations are given in Table NE.61 for the collection areas and in Table NE.62 for the expected number of dangerous events. Probability values are given in Table NE.63

Table NE.61 – Bank computer centre: Collection areas of structure and lines

	Symbol	Value m^2	Reference	Equation
Structure	A_D	$2{,}75 \times 10^4$	Equation (A.2)	$A_D = L \cdot W + 2 \times (3 \times H) \cdot (L + W) + \pi \cdot (3 \times H)^2$
	A_M	$8{,}45 \times 10^5$	Equation (A.7)	$A_M = 2 \times 500 \times (L + W) + \pi \times 500^2$
Power line	$A_{L/P}$	$8{,}00 \times 10^3$	Equation (A.9)	$A_{L/P} = 40 \times L_{LP}$
	$A_{I/P}$	$8{,}00 \times 10^5$	Equation (A.11)	$A_{I/P} = 4\,000 \times L_{LP}$
	$A_{DJ/P}$	0	Equation (A.2)	No adjacent structure
Telecom line	$A_{L/T}$	$4{,}00 \times 10^4$	Equation (A.9)	$A_{L/T} = 40 \times L_{LT}$
	$A_{I/T}$	$4{,}00 \times 10^6$	Equation (A.11)	$A_{I/T} = 4\,000 \times L_{LT}$
	$A_{DJ/T}$	0	Equation (A.2)	No adjacent structure

Table NE.62 – Bank computer centre: Expected annual number of dangerous events

	Symbol	Value 1/year	Reference	Equation
Structure	N_D	1,925 × 10^{-2}	Equation (A.4)	$N_D = N_G \cdot A_D \cdot C_D \cdot 10^{-6}$
	N_M	5,915 × 10^{-1}	Equation (A.6)	$N_M = N_G \cdot A_M \cdot 10^{-6}$
Power line	$N_{L/P}$	5,60 × 10^{-3}	Equation (A.8)	$N_{L/P} = N_G \cdot A_{L/P} \cdot C_{I/P} \cdot C_{E/P} \cdot C_{T/P} \cdot 10^{-6}$
	$N_{I/P}$	5,60 × 10^{-1}	Equation (A.10)	$N_{I/P} = N_G \cdot A_{I/P} \cdot C_{I/P} \cdot C_{E/P} \cdot C_{T/P} \cdot 10^{-6}$
	$N_{DJ/P}$	0	Equation (A.5)	No adjacent structure
Telecom line	$N_{L/T}$	1,40 × 10^{-2}	Equation (A.8)	$N_{L/T} = N_G \cdot A_{L/T} \cdot C_{I/T} \cdot C_{E/T} \cdot C_{T/T} \cdot 10^{-6}$
	$N_{I/T}$	1,40	Equation (A.10)	$N_{I/T} = N_G \cdot A_{I/T} \cdot C_{I/T} \cdot C_{E/T} \cdot C_{T/T} \cdot 10^{-6}$
	$N_{DJ/T}$	0	Equation (A.5)	No adjacent structure

Table NE.63 – Bank computer centre: Risk R_2 – Values of probability

	Symbol	Value	Reference	Equation
D2 Physical damage	P_B	0,05	Table NB.2	
	$P_{V/P}$	0,002	Tables NB.7, NB.8, Clause NB.4	$P_{V/P} = P_{EB/P} \cdot P_{LD/P} \cdot C_{LD/P}$
	$P_{V/T}$	0,002		$P_{V/T} = P_{EB/T} \cdot P_{LD/T} \cdot C_{LD/T}$
D3 Failure of internal systems	P_C	1	Eqn. (14) Tables NB.3, NB.4	$P_C = 1 - (1 - P_{C/P}) \cdot (1 - P_{C/T}) = 1 - (1 - P_{SPD/P} \cdot C_{LD/P}) \cdot (1 - P_{SPD/T} \cdot C_{LD/T})$ $= 1 - (1 - 1 \times 1) \cdot (1 - 1 \times 1) = 1$
	$P_{MS/P}$	0,0064	Eqns. (NB.4), (NB.5), (NB.6), (NB.7)	$P_{MS/P} = (K_{S1/P} \cdot K_{S2/P} \cdot K_{S3/P} \cdot K_{S4/P})^2 = (1 \times 1 \times 0,2 \times 0,4)^2$
	$P_{MS/T}$	0,444		$P_{MS/T} = (K_{S1/T} \cdot K_{S2/T} \cdot K_{S3/T} \cdot K_{S4/T})^2 = (1 \times 1 \times 1 \times 0,667)^2$
	P_M	0,448	Eqn. (15), Table NB.3	$P_M = 1 - (1 - P_{M/P}) \cdot (1 - P_{M/T}) = 1 - (1 - P_{SPD/P} \cdot P_{MS/P}) \cdot (1 - P_{SPD/T} \cdot P_{MS/T})$ $= 1 - (1 - 0,0064) \cdot (1 - 0,444)$
	$P_{W/P}$	1	Tables NB.3, NB.8 Clause NB.4	$P_{W/P} = P_{SPD/P} \cdot P_{LD/P} \cdot C_{LD/P}$
	$P_{W/T}$	1		$P_{W/T} = P_{SPD/T} \cdot P_{LD/T} \cdot C_{LD/T}$
	$P_{Z/P}$	0,3	Tables NB.3, NB.9, and NB.4	$P_{Z/P} = P_{SPD/P} \cdot P_{LI/P} \cdot C_{LI/P}$
	$P_{Z/T}$	0,5		$P_{Z/T} = P_{SPD/T} \cdot P_{LI/T} \cdot C_{LI/T}$

Table NE.64 Summary table of loss values

Loss	Value	Reference	Equation
L_{B2}	10^{-5}	NC.7 and NC.8	$L_{B2} = r_p \cdot r_f \cdot L_{F2} = 1 \text{ x } 10^{-3} \times 10^{-2} = 10^{-5}$
L_{C2}	10^{-2}		$L_{C2} = L_{O2} = 10^{-2}$
L_{V2}	10^{-5}		$L_{V2} = r_p \cdot r_f \cdot L_{F2} = 1 \text{ x } 10^{-3} \times 10^{-2} = 10^{-5}$
L_{M2}	10^{-2}		$L_{M2} = L_{O2} = 10^{-2}$
L_{W2}	10^{-2}		$L_{W2} = L_{O2} = 10^{-2}$
L_{Z2}	10^{-2}		$L_{Z2} = L_{O2} = 10^{-2}$

NE.7.5 Risk calculation R_2

The risk R_2 can be expressed according to BS EN 62305-2 equation (2) by the following sum of components:

$$R_2 = R_{B2} + R_{C2} + R_{M2} + R_{V2} + R_{V2} + R_{Z2} \qquad \text{(NE.3)}$$

The risk components and total risk evaluation are given in Table NE.65.

Table NE.65 – Bank computer centre: Risk R_2 with R_1 protection only (values × 10^{-4})

	Symbol	Value	Equation
D2 Physical damage	R_{B2}	0,00096	$R_{B2} = N_D \cdot P_B \cdot r_p \cdot r_f \cdot L_{F2}$
	$R_{V2/P}$	0,000011	$R_{V2/P} = N_{L/P} \cdot P_{EB/P} \cdot P_{LD/P} \cdot C_{LD/P} \cdot r_p \cdot r_f \cdot L_{F2}$
	$R_{V2/T}$	0,000028	$R_{V2/T} = N_{L/T} \cdot P_{EB/T} \cdot P_{LD/T} \cdot C_{LD/T} \cdot r_p \cdot r_f \cdot L_{F2}$
D3 Failure of electrical and electronic equipment	R_{C2}	1,923	$R_{C2} = N_D \cdot P_C \cdot L_{O2}$
	R_{M2}	26,51	$R_{M2} = N_M \cdot P_M \cdot L_{O2}$
	$R_{W2/P}$	0,56	$R_{W2/P} = N_{L/P} \cdot P_{SPD/P} \cdot C_{LD/P} \cdot L_{O2}$
	$R_{W2/T}$	1,4	$R_{W2/T} = N_{L/T} \cdot P_{SPD/T} \cdot C_{LD/T} \cdot L_{O2}$
	$R_{Z2/P}$	16,63	$R_{Z2/P} = N_{I/P} \cdot P_{SPD/P} \cdot P_{LI/P} \cdot C_{LI/P} \cdot L_{O2}$
	$R_{Z2/T}$	69,3	$R_{Z2/T} = N_{I/T} \cdot P_{SPD/T} \cdot P_{LI/T} \cdot C_{LI/T} \cdot L_{O2}$
Total risk	$\mathbf{R_2}$	**116,33**	**$R_2 > R_{T2}$: Additional lightning protection is required**
Tolerable risk	$\mathbf{R_{T2}}$	**1**	

NE.7.6 Risk R2 – Selection of protection measures

The risk R_2 is mainly influenced (see Table NE.65) by failures of internal systems in the structure. Component risks R_Z and R_M contributing 74 % and 23 % (respectively) to the total risk.

These dominant risk components can be reduced by;

— providing all internal systems connected to the incoming power and telecom lines with coordinated SPD protection conforming to BS EN 62305-4. This will reduce the components R_C, R_M, R_W via the probability P_{SPD},

The following solution could be adopted in conjunction with protection provided by solution (a) of the office example in NE.3:

— install enhanced type coordinated SPD protection on all internal systems connected to the incoming power and telecom lines (P_{SPD} = 0,002) in zone Z_5;

Using this solution, the probability values from Table NE.63 will change to the reduced values reported in Table NE.66. Risk values from Table NE.65 will change to the reduced values reported in Table NE.67.

Table NE.66 – Bank computer centre: Risk R_2 – Values of probability P changed by addition of R_2 protection

	Symbol	Value	Reference	Equation
	P_C	$3,996 \times 10^{-3}$	Eqn. (14) Tables NB.3, NB.4	$P_C = 1 - (1 - P_{C/P})\cdot(1 - P_{C/T}) =$ $1 - (1 - P_{SPD/P}\cdot C_{LD/P})\cdot(1 - P_{SPD/T}\cdot C_{LD/T}) =$ $1 - (1 - 0,002 \times 1)\cdot(1 - 0,002 \times 1) = 3,996 \times 10^{-3}$
D3 Failure of internal systems	$P_{MS/P}$	0,0064	Eqns. (NB.4), (NB.5), (NB.6), (NB.7)	$P_{MS/P} = (K_{S1/P}\cdot K_{S2/P}\cdot K_{S3/P}\cdot K_{S4/P})^2$ – no change
	$P_{MS/T}$	0,444		$P_{MS/T} = (K_{S1/T}\cdot K_{S2/T}\cdot K_{S3/T}\cdot K_{S4/T})^2$ – no change
	P_M	$8,889 \times 10^{-4}$	Eqn. (15), Table NB.3	$P_M = 1 - (1 - P_{M/P})\cdot(1 - P_{M/T}) =$ $1 - (1 - P_{SPD/P}\cdot P_{MS/P})\cdot(1 - P_{SPD/T}\cdot P_{MS/T}) =$ $1 - (1 - 0,002 \times 0,0064)\cdot(1 - 0,002 \times 0,444) =$ $1 - (1 - 1,28 \times 10^{-5})\cdot(1 - 0,00088) = 8,889 \times 10^{-4}$
	$P_{W/P}$	0,002	Tables NB.3, NB.8 Clause NB.4	$P_{W/P} = P_{SPD/P}\cdot P_{LD/P}\cdot C_{LD/P} = 0,002 \times 1 \times 1 = 0,002$
	$P_{W/T}$	0,002		$P_{W/T} = P_{SPD/T}\cdot P_{LD/T}\cdot C_{LD/T} = 0,002 \times 1 \times 1 = 0,002$
	$P_{Z/P}$	0,0006	Tables NB.3, NB.9, and NB.4	$P_{Z/P} = P_{SPD/P}\cdot P_{LI/P}\cdot C_{LI/P} = 0,002 \times 0,3 \times 1 = 0,0006$
	$P_{Z/T}$	0,001		$P_{Z/T} = P_{SPD/T}\cdot P_{LI/T}\cdot C_{LI/T} = 0,002 \times 0,5 \times 1 = 0,001$

The re-calculated risks as shown in Table NE.67

Table NE.67 – Bank computer centre: Risk R_2 for the protected structure (values × 10^{-4})

	Symbol	Value	Equation
D2 Physical damage	R_{B2}	0,00096	$R_{B2} = N_D\cdot P_B\cdot r_p\cdot r_f\cdot L_{F2}$ as above
	$R_{V2/P}$	0,0000112	$R_{V2/P} = N_{L/P}\cdot P_{EB/P}\cdot P_{LD/P}\cdot C_{LD/P}\cdot r_p\cdot r_f\cdot L_{F2}$ as above
	$R_{V2/T}$	0,000028	$R_{V2/T} = N_{L/T}\cdot P_{EB/T}\cdot P_{LD/T}\cdot C_{LD/T}\cdot r_p\cdot r_f\cdot L_{F2}$ as above
D3 Failure of electrical and electronic equipment	R_{C2}	0,007684	$R_{C2} = N_D\cdot P_C\cdot L_{O2} = 1,925 \times 10^{-2} \times 3,996 \times 10^{-3} \times 10^{-2}$
	R_{M2}	0,05336	$R_{M2} = N_M\cdot P_M\cdot L_{O2} = 0,5915 \times 8,889 \times 10^{-4} \times 10^{-2}$
	$R_{W2/P}$	0,00112	$R_{W2/P} = N_{L/P}\cdot P_{SPD/P}\cdot C_{LD/P}\cdot L_{O2} = 5,60 \times 10^{-3} \times 0,002 \times 1 \times 10^{-2}$
	$R_{W2/T}$	0,0028	$R_{W2/T} = N_{L/T}\cdot P_{SPD/T}\cdot C_{LD/T}\cdot L_{O2} = 1,4 \times 10^{-2} \times 0,002 \times 1 \times 10^{-2}$
	$R_{Z2/P}$	0,03326	$R_{Z2/P} = N_{I/P}\cdot P_{SPD/P}\cdot P_{LI/P}\cdot C_{LI/P}\cdot L_{O2} = 5,60 \times 10^{-1} \times 0,002 \times 0,3 \times 1 \times 10^{-2}$
	$R_{Z2/T}$	0,1386	$R_{Z2/T} = N_{I/T}\cdot P_{SPD/T}\cdot P_{LI/T}\cdot C_{LI/T}\cdot L_{O2} = 1,40 \times 0,002 \times 0,5 \times 1 \times 10^{-2}$
Total risk	$\mathbf{R_2}$	**0.238**	**$R_2 < R_{T2}$: The lightning protection measures are adequate.**
Tolerable risk	$\mathbf{R_{T2}}$	**1**	

The addition of enhanced type coordinated SPD protection on all internal systems (connected to the incoming power and telecom lines) to the protection provided by the Type 1 SPDs of solution (a) in example NE.3 is adequate to provide the required protection. In practice it may be cheaper to provide a combined enhanced Type 1 and Type 2 SPD unit on both the incoming power and telecoms lines. Because of the size of the building it will be necessary to provide Type 2 SPDs not only at the entrance of the power and telecoms services but at positions where equipment is more than 10 m from the service entrances and from subsequent downstream SPDs.

Annex NF
(informative)

Values determined at National level where permitted

NF.1 General

Certain values in BS EN 62305-2 can be determined at National level. This permission is given in places where the values proposed by the IEC are representative or illustrative. The UK committee (GEL/81) has reviewed the sections of the standard where this national determination is permitted and has provided appropriate interpretation.

NF.2 UK interpretations

NF.2.1 Table 4 modified

Sub clause 5.3 of BS EN 62305-2 states that it is the responsibility of the authority having jurisdiction to identify the value of tolerable risk. The values provided in Table 4 are representative. The UK committee therefore recommends the values in Table NF.1 for use in the UK.

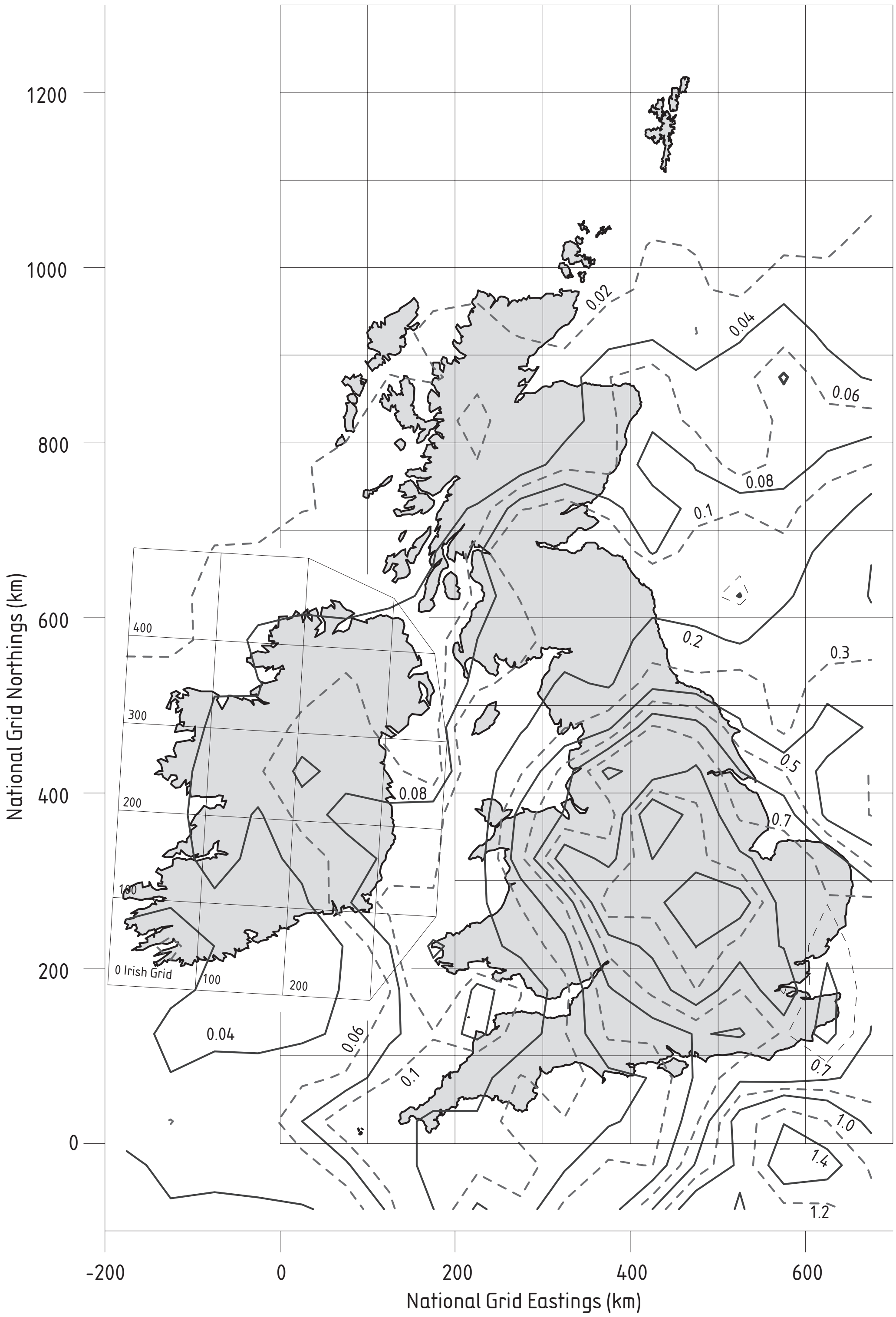
Table NF.1 – Typical values of tolerable risk R_T

Type of Loss	RT (y^{-1})
Loss of human life or permanent injury	10^{-5}
Loss of service to the public	10^{-4}
Loss of cultural heritage	10^{-4}

NOTE 1 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.

Table NF.2 – Relationship between thunderstorm days per year and lightning flashes per square kilometre per year

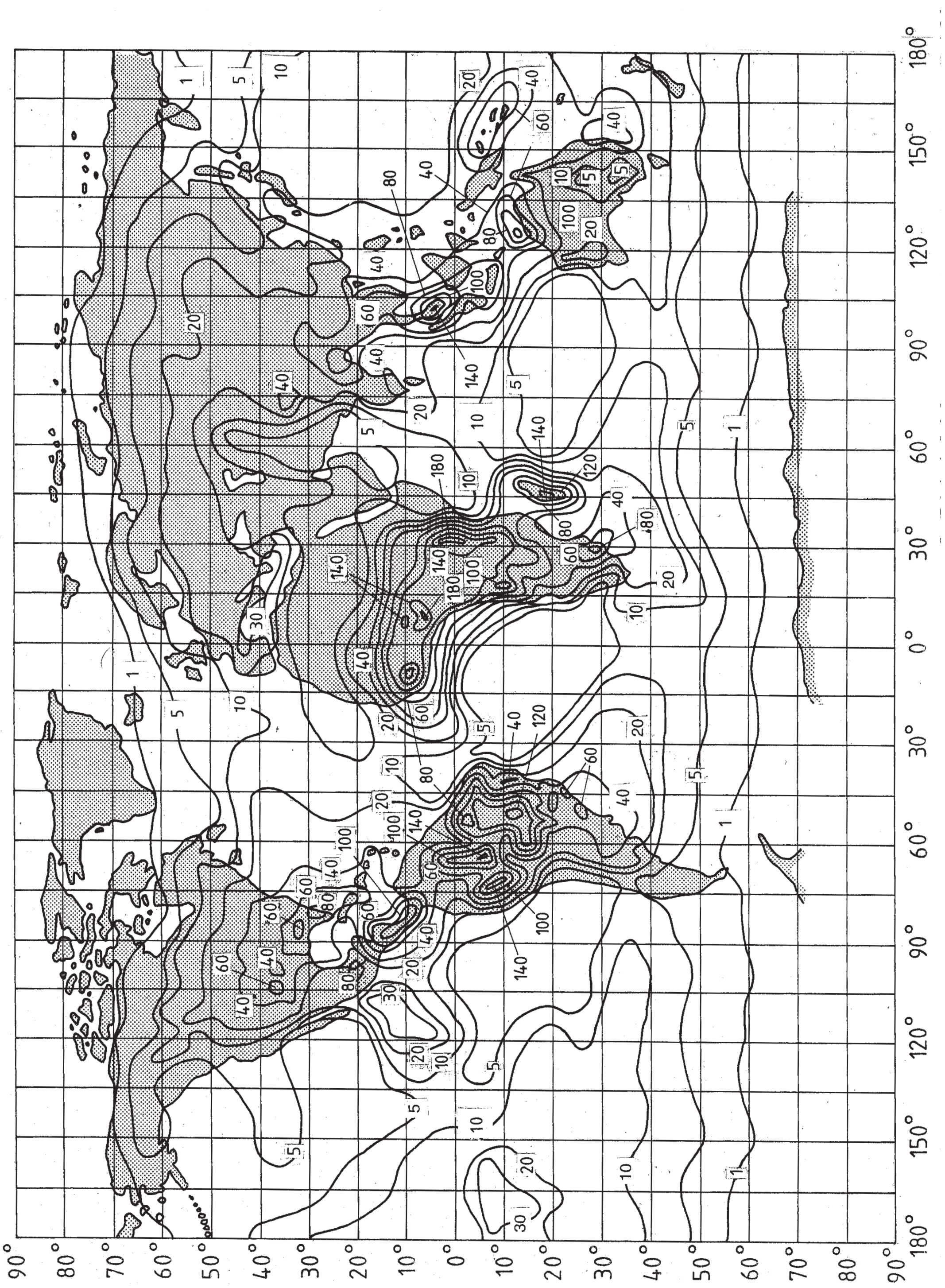
Thunderstorm days per year	Flashes per square kilometre per year	
	Mean	Limits
5	0,2	0,1 to 0,5
10	0,5	0,15 to 1
20	1,1	0,3 to 3
30	1,9	0,6 to 5
40	2,8	0,8 to 8
50	3,7	1,2 to 10
60	4,7	1,8 to 12
80	6,9	3 to 17
100	9,2	4 to 20
NOTE The data for this table has been extracted from information in Conference Internationale des Grands Rèseaux Electriques (CIGRE), *Lightning Parameters for Engineering Application* […]		



NOTE 1 This lightning density map was compiled by E.A. Technology Ltd. from data accumulated over 10 years

NOTE 2 A linear interpolation should be used to determine the value of the lightning flash density, N_g, for a location between two contour lines.

Figure NF.1 – Lightning flash density to ground (N_G) per square kilometre per year for the British Isles



NOTE This map is based on information from the World Meteorological Organization records for 1955.

Figure NF.2 – Map showing thunderstorm days per year throughout the world

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