

Protection against lightning —

Part 2: Risk management

ICS 29.020; 91.120.40

National foreword

This British Standard is the UK implementation of EN 62305-2:2006. It is identical with IEC 62305-2:2006. This standard, together with BS EN 62305-1:2006, BS EN 62305-3:2006 and BS EN 62305-4:2006, supersedes BS 6651:1999, is withdrawn.

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

A list of organizations represented on GEL/81 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.

The values assigned for certain parameters used as part of the risk evaluation process in this British standard, are merely values proposed by the IEC (specifically in Annexes B, C and the case studies in Annex H).

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 (GEL/81) 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.

Annexes D and E are relevant to a service (service in this instance being part of telecommunications, power, water, gas and fuel distribution networks). This information was to be used in conjunction with IEC 62305-5 services. IEC TC81 decided not to publish part 5 therefore Annexes D and E do not form an integral part of BS EN 62305-2.

National Annex NK contains interpretations relating to Table 7 and reproduces the lightning flash density map for the British Isles together with the table and map showing the thunderstorm days throughout the world from BS 6651:1999. Annexes B, C and H have been reproduced as National Annexes NB, NC and NH. The revised versions contain appropriate UK interpretations. These national annexes should be used wherever and whenever the British Standard is adopted for designing Lightning Protection systems in the UK.

A software package, to complement IEC 62305-2:2006, and identified as the 'Simplified IEC Risk Assessment Calculator (SIRAC)' has been produced by IEC and was endorsed by CENELEC in October 2007.

Users should be aware that SIRAC has limited functionality and application. It is intended to help users of the standard to appreciate the principles of the risk-assessment calculations. SIRAC is, for example, unable to correctly perform the necessary calculations when using the UK National Parameters given in Annexes NB, NC and NH of BS EN 62305-2:2006 and therefore it is not recommended for such system design purposes in the UK.

Compliance with a British Standard cannot confer immunity from legal obligations.

Amendments/corrigenda issued since publication

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30 April 2009	Text added to the National foreword.

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**Protection against lightning
Part 2: Risk management
(IEC 62305-2:2006)**

Protection contre la foudre
Partie 2: Evaluation du risque
(CEI 62305-2:2006)

Blitzschutz
Teil 2: Risiko-Management
(IEC 62305-2:2006)

This European Standard was approved by CENELEC on 2006-02-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

The text of document 81/263/FDIS, future edition 1 of IEC 62305-2, prepared by IEC TC 81, Lightning protection, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 62305-2 on 2006-02-01.

The following dates were fixed:

- latest date by which the EN has to be implemented
at national level by publication of an identical
national standard or by endorsement (dop) 2006-11-01
- latest date by which the national standards conflicting
with the EN have to be withdrawn (dow) 2009-02-01

This European Standard makes reference to International Standards. Where the International Standard referred to has been endorsed as a European Standard or a home-grown European Standard exists, this European Standard shall be applied instead. Pertinent information can be found on the CENELEC web site.

Endorsement notice

The text of the International Standard IEC 62305-2:2006 was approved by CENELEC as a European Standard without any modification.

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INTRODUCTION

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

The hazard to a structure can result in

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

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

The hazard to services can result in

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

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

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

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

Lightning flashes influencing the structure may be divided into

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

Lightning flashes influencing the service may be divided into

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

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

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

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

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

¹ Figures in square brackets refer to the bibliography.

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

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

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

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

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

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

PROTECTION AGAINST LIGHTNING –

Part 2: Risk management

1 Scope

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

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

2 Normative references

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

IEC 60079-10:2002, *Electrical apparatus for explosive gas atmosphere – Part 10: Classification of hazardous areas*

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

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

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

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

IEC 62305-5, *Protection against lightning – Part 5: Services²*

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

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

3 Terms, definitions, symbols and abbreviations

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

² To be published

3.1 Terms and definitions

3.1.1

object to be protected

structure or service to be protected against the effects of lightning

3.1.2

structure to be protected

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

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

3.1.3

structures with risk of explosion

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

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

3.1.4

structures dangerous to the environment

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

3.1.5

urban environment

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

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

3.1.6

suburban environment

area with a medium density of buildings

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

3.1.7

rural environment

area with a low density of buildings.

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

3.1.8

rated impulse withstand voltage level

U_w

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

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

3.1.9

electrical system

system incorporating low voltage power supply components

3.1.10**electronic system**

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

3.1.11**internal systems**

electrical and electronic systems within a structure

3.1.12**service to be protected**

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

3.1.13**telecommunication lines**

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

3.1.14**power lines**

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

3.1.15**pipes**

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

3.1.16**dangerous event**

lightning flash to the object to be protected or near the object to be protected

3.1.17**lightning flash to an object**

lightning flash striking an object to be protected

3.1.18**lightning flash near an object**

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

3.1.19**number of dangerous events due to flashes to a structure**

N_D

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

3.1.20**number of dangerous events due to flashes to a service**

N_L

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

3.1.21

number of dangerous events due to flashes near a structure

N_M

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

3.1.22

number of dangerous events due to flashes near a service

N_I

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

3.1.23

lightning electromagnetic impulse

LEMP

electromagnetic effects of lightning current

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

3.1.24

surge

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

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

3.1.25

node

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

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

3.1.26

physical damage

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

3.1.27

injury to living beings

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

3.1.28

failure of electrical and electronic systems

permanent damage of electrical and electronic systems due to LEMP

3.1.29

failure current

I_a

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

3.1.30

probability of damage

P_x

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

3.1.31**loss** L_x

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

3.1.32**risk** R

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

3.1.33**risk component** R_x

partial risk depending on the source and the type of damage

3.1.34**tolerable risk** R_T

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

3.1.35**zone of a structure** Z_s

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

3.1.36**section of a service** S_s

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

3.1.37**lightning protection zone****LPZ**

zone where the lightning electromagnetic environment is defined

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

3.1.38**lightning protection level****LPL**

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

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

3.1.39**protection measures**

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

3.1.40

lightning protection system

LPS

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

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

3.1.41

LEMP protection measures system

LPMS

complete system of protection measures for internal systems against LEMP

3.1.42

shielding wire

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

3.1.43

magnetic shield

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

3.1.44

lightning protective cable

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

3.1.45

lightning protective cable duct

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

3.1.46

surge protective device

SPD

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

3.1.47

coordinated SPD protection

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

3.2

Symbols and abbreviations

a	Amortization rate	Annex G
A_d	Collection area for flashes to an isolated structure	A.2
A_d'	Collection area attributed to an elevated roof protrusion	A.2.1
A_i	Collection area for flashes near a service.....	A.4; Table A.3
A_l	Collection area for flashes to a service	A.4; Table A.3
A_m	Area of influence for flashes near a structure	A.3
B	Building.....	A.2

c	Mean value of possible loss of the structure, in currency	C.4; C.5
C_A	Annual cost of the animals.....	Annex G
C_B	Annual cost of the building.....	Annex G
C_C	Annual cost of the contents.....	Annex G
C_d	Location factor	A.2; Table A.2
C_e	Environmental factor	A.5; Table A.5
C_L	Annual cost of total loss in absence of protection measures	5.6; Annex G
C_{RL}	Annual cost of residual loss	5.6; Annex G
C_P	Cost of protection measures	Annex G
C_{PM}	Annual cost of selected protection measures.....	5.6; Annex G
C_S	Annual cost of systems in a structure	Annex G
C_t	Correction factor for a HV/LV transformer on the service	A.4; Table A.4
c_t	Total value of the structure, in currency	C.4; C.5; E.3
D_i	Lateral distance relevant to lightning flash near a service	A.5
D1	Injury to living beings.....	4.1.2
D2	Physical damage	4.1.2
D3	Failure of electrical and electronic systems	4.1.2
h_z	Factor increasing the loss when a special hazard is present	C.2; Table C.5
H	Height of the structure	A.4
H_a	Height of the structure connected at end “a” of a service	A.4
H_b	Height of the structure connected at end “b” of a service	A.4
H_c	Height of the service conductors above ground	A.4
i	Interest rate	Annex G
I_a	Failure current.....	D.1.1; D.1.2
K_d	Factor relevant to the characteristics of a service.....	D.1.1
K_{MS}	Factor relevant to the performance of protection measures against LEMP.....	B.4
K_p	Factor relevant to adopted protection measures in a service.....	D.1.1
K_{S1}	Factor relevant to the screening effectiveness of the structure.....	B.4
K_{S2}	Factor relevant to the screening effectiveness of shields internal to the structure	B.4
K_{S3}	Factor relevant to the characteristics of internal wiring	B.4
K_{S4}	Factor relevant to the impulse withstand voltage of a system.....	B.4
L	Length of structure	A.2
L_a	Length of the structure connected at end “a” of a service	A.4
L_A	Loss related to injury to living beings	6.2; Table 8
L_B	Loss in a structure related to physical damage (flashes to structure)	6.2; Table 8
L'_B	Loss in a service related to physical damage (flashes to service).....	7.4; Table 10
L_c	Length of service section.....	A.4
L_C	Loss related to failure of internal systems (flashes to structure).....	6.2; Table 8
L'_C	Loss related to failure of service equipment (flashes to structure).....	7.4; Table 10

L_f	Loss in a structure due to physical damage.....	C.1
L'_f	Loss in a service due to physical damage	E.1
L_M	Loss related to failure of internal systems (flashes near structure).....	6.3; Table 8
L_o	Loss in a structure due to failure of internal systems	C.1
L'_o	Loss in a service due to failure of internal systems.....	E.1
L_t	Loss due to injury by touch and step voltages	C.1
L_U	Loss related to injury of living beings (flashes to service)	6.4; Table 8
L_V	Loss in a structure due to physical damage (flashes to service).....	6.4; Table 8
L'_V	Loss in a services due to physical damage (flashes to service).....	7.2; Table 10
L_W	Loss related to failure of internal systems (flashes to service)	6.4; Table 8
L'_W	Loss related to failure of service equipment (flashes to service)	7.2; Table 10
L_X	Consequent loss in a structure.....	6.1
L'_X	Consequent loss in a service	7.1
L_Z	Loss related to failure of internal systems (flashes near a service).....	6.5; Table 8
L'_Z	Loss related to failure of service equipment (flashes near a service).....	7.3; Table 10
L_1	Loss of human life in a structure	4.1.3
L_2	Loss of service to the public in a structure	4.1.3
L'_2	Loss of service to the public in a service	4.1.3
L_3	Loss of cultural heritage in a structure	4.1.3
L_4	Loss of economic value in a structure	4.1.3
L'_4	Loss of economic value in a service.....	4.1.3
m	Maintenance rate.....	Annex G
n	Number of services connected to the structure.....	D.1.1
N_X	Number of dangerous events per annum.....	6.1
N_D	Number of dangerous events due to flashes to a structure.....	A.2.3
N_{Da}	Number of dangerous events due to flashes to a structure at “a” end of line	A.2.4; Table 8
N_g	Lightning ground flash density	A.1
N_I	Number of dangerous events due to flashes near a service	A.5
N_L	Number of dangerous events due to flashes to a service	A.4
N_M	Number of dangerous events due to flashes near a structure.....	A.3
n_p	Number of possible endangered persons (victims or users not served) ...	C.2; C.3; E.2
n_s	Estimated or measured annual number of switching overvoltages.....	Annex F
N_s	Annual number of switching overvoltages in excess of 2,5 kV.....	Annex F
n_t	Expected total number of persons (or users served)in the structure	C.2; C.3; E.2

P	Probability of damage.....	3.1.29
P_A	Probability of injury to living beings (flashes to a structure).....	6.2; Table 8
P_B	Probability of physical damage to a structure (flashes to a structure)	6.2; Table 8
P'_B	Probability of physical damage to a service (flashes to a structure).....	7.4; Table 10
P_C	Probability of failure of internal systems (flashes to a structure).....	6.2; Table 8
P'_C	Probability of failure of service equipment (flashes to a structure).....	7.4; Table 10
P_{LD}	Probability of failure of internal systems (flashes to a connected service).....	B.5; B.6; B.7
P_{LI}	Probability of failure of internal systems (flashes near a connected service).....	B.8
P_M	Probability of failure of internal systems (flashes near a structure).....	6.3; Table 8
P_{MS}	Probability of failure of internal systems (with protection measures).....	B.4
P_{SPD}	Probability of failure of internal systems or a service when SPDs are installed	B.3; B.4
P_U	Probability of injury to living beings (flashes to a connected service)	6.4; Table 8
P_V	Probability of physical damage to a structure (flashes to a connected service)	6.4; Table 8
P'_V	Probability of physical damage to services (flashes to a service).....	7.2; Table 10
P_W	Probability of failure of internal systems (flashes to a connected service) ..	6.4; Table 6
P'_W	Probability of failure of service equipment (flashes to a service).....	7.2; Table 10
P_X	Probability of damage to a structure.....	6.1
P'_X	Probability of damage to a service	7.1
P_Z	Probability of failure of internal systems (flashes near a connected service)	6.5; Table 8
P'_Z	Probability of failure of service equipment (flashes near a service)	7.3; Table 10
r_a	Reduction factor associated with the type of surface of soil	C.2
r_u	Reduction factor associated with the type of surface of floor.....	C.2
r_p	Factor reducing the loss due to provisions against fire	C.2
R	Risk	3.1.32
R_A	Risk component (injury to living beings – flashes to a structure)	4.2.2
R_B	Risk component (physical damage to a structure – flashes to a structure).....	4.2.2
R'_B	Risk component (physical damage to a service – flashes to a structure)	4.2.8
R_C	Risk component (failure of internal systems -flashes to a structure).....	4.2.2
R'_C	Risk component (failure of service equipment – flashes to a structure)	4.2.8
R_D	Risk for a structure due to flashes to the structure.....	4.3.1

r_f	Factor reducing loss depending on risk of fire	C.2
R_F	Risk due to physical damage to a structure	4.3.2
R'_F	Risk due to physical damages to a service	4.4.2
R_I	Risk for a structure due to flashes not striking the structure	4.3.1
R_M	Risk component (failure of internal systems – flashes near a structure)	4.2.3
R'_M	Risk R_M when protection measures are adopted.....	Annex G
R_O	Risk due to failure of internal systems.....	4.3.2
R'_O	Risk due to failure of service equipment.....	4.4.2
R_s	Shield resistance per unit length of a cable	B.5;B.8; D.1
R_S	Risk due to injury to living beings.....	4.3.2
R_T	Tolerable risk	3.1.34
R_U	Risk component (injury to living being – flashes to a connected service).....	4.2.4
R_V	Risk component (physical damage to structure – flashes to a connected service).....	4.2.4
R'_V	Risk component (physical damage to service – flashes to the service).....	4.2.6
R_W	Risk component (failure of internal systems – flashes to the connected service)	4.2.4
R'_W	Risk component (failure of service equipment – flashes to the service)	4.2.6
R_X	Risk component for a structure	3.1.33
R'_X	Risk component for a service.....	7.1
R_Z	Risk component (failure of internal systems – flashes near a service).....	4.2.5
R'_Z	Risk component (failure of service equipment – flashes near the service)	4.2.7
R_1	Risk of loss of human life in a structure.....	4.2.1; 4.3
R_2	Risk of loss of service to the public in a structure	4.2.1; 4.3
R'_2	Risk of loss of service to the public in a service.....	4.2.1; 4.4
R_3	Risk of loss of cultural heritage in a structure	4.2.1; 4.3
R_4	Risk of loss of economic value in a structure	4.2.1; 4.3
R'_4	Risk of loss of economic value in a service	4.2.1; 4.4
S	Structure	A.2
S	Annual saving of money	Annex G
S_S	Section of a service	3.1.36
$S1$	Flashes to a structure	4.1.1
$S2$	Flashes near a structure	4.1.1
$S3$	Flashes to a service	4.1.1
$S4$	Flashes near a service	4.1.1
t	Annual period of loss of service, in hours	C.3; E.2
t_p	Time in hours per year that persons are present in a dangerous place.....	C.2
T_d	Thunderstorm days per year	A.1
T_x	Transition points.....	Annex I

U_W	Rated impulse withstand voltage of a system	B.4
w	Mesh width.....	B.4
W	Width of structure.....	A.2
W_a	Width of the structure connected at end “a” of a service	A.4
Z_S	Zones of a structure	3.1.35

4 Explanation of terms

4.1 Damage and loss

4.1.1 Source of damage

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

- S1: flashes to a structure;
- S2: flashes near a structure;
- S3: flashes to a service;
- S4: flashes near a service.

4.1.2 Types of damage

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

For practical applications of this risk assessment, it is useful to distinguish between three basic types of damage which can appear as the consequence of lightning flashes. They are as follows (see Tables 1 and 2):

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

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

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

4.1.3 Types of loss

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

- L1: loss of human life;
- L2: loss of service to the public;
- L3: loss of cultural heritage;
- L4: loss of economic value (structure and its content, service and loss of activity).

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

- L1: loss of human life;
- L2: loss of service to the public;
- L3: loss of cultural heritage;
- L4: loss of economic value (structure and its content).

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

- L'2: loss of service to the public;
- L'4: loss of economic value (service and loss of activity).

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

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

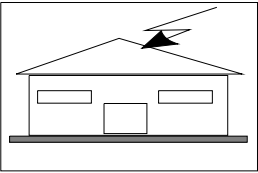
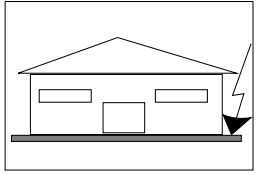
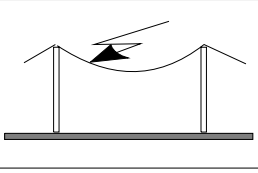
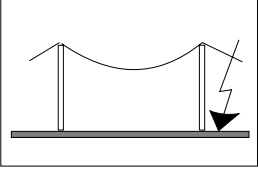
Point of strike	Source of damage	Structure		Service	
		Type of damage	Type of loss	Type of damage	Type of loss
	S1	D1 D2 D3	L1, L4 ²⁾ L1, L2, L3, L4 L1 ¹⁾ , L2, L4	D2 D3	L'2, L'4 L'2, L'4
	S2	D3	L1 ¹⁾ , L2, L4		
	S3	D1 D2 D3	L1, L4 ²⁾ L1, L2, L3, L4 L1 ¹⁾ , L2, L4	D2 D3	L'2, L'4 L'2, L'4
	S4	D3	L1 ¹⁾ , L2, L4	D3	L'2, L'4
1) Only for structures with risk of explosion, and for hospitals or other structures where failures of internal systems immediately endangers human life. 2) Only for properties where animals may be lost.					

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

Loss Damage	L1 Loss of human life	L2 Loss of service to the public	L3 Loss of cultural heritage	L4 Loss of economic value
D1 Injury to living beings	R_S	–	–	R_S ¹⁾
D2 Physical damage	R_F	R_F	R_F	R_F
D3 Failure of electric or electronic systems	R_O ²⁾	R_O	–	R_O
¹⁾ Only for properties where animals may be lost. ²⁾ Only for structures with a risk of explosion, and for hospitals or other structures where failure of internal systems immediately endangers human life.				

4.2 Risk and risk components

4.2.1 Risk

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

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

- R_1 : risk of loss of human life;
- R_2 : risk of loss of service to the public;
- R_3 : risk of loss of cultural heritage;
- R_4 : risk of loss of economic value.

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

- R'_2 : risk of loss of service to the public;
- R'_4 : risk of loss of economic value.

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

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

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

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

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

NOTE 2 In special structures, people may be endangered by direct strikes (e.g. top level of garage parking or stadiums). These cases may also be considered using the principles of this standard.

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

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

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

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

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

R_U : Component related to injury to living beings caused by touch voltage inside the structure, due to lightning current injected in a line entering the structure. Loss of type L1 and, in the case of agricultural properties, losses of type L4 with possible loss of animals could also occur.

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

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

NOTE The services taken into account in this assessment are only the lines entering the structure. Lightning flashes to or near pipes are not considered as a source of damage based on the bonding of pipes to an equipotential bonding bar. If an equipotential bonding bar is not provided, such a threat must also be considered.

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

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

NOTE The services taken into account in this assessment are only the lines entering the structure. Lightning flashes to or near pipes are not considered as a source of damage based on the bonding of pipes to an equipotential bonding bar. If an equipotential bonding bar is not provided, such a threat must also be considered.

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

R'_V : Component related to physical damage due to mechanical and thermal effects of lightning current. Loss of type L'2 and L'4 could occur;

R'_W : Component related to failure of connected equipment due to overvoltages by resistive coupling. Loss of type L'2 and L'4 could occur.

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

R'_Z : Component related to failure of lines and connected equipment caused by overvoltages induced on lines. Loss of type L'2 and L'4 could occur.

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

R'_B : Component related to physical damage due to mechanical and thermal effects of lightning current flowing along the line. Loss of type L'2 and L'4 could occur.

R'_C : Component related to failure of connected equipment due to overvoltages by resistive coupling. Loss of type L'2 and L'4 could occur.

4.3 Composition of risk components related to a structure

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

R_1 : Risk of loss of human life:

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

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

R_2 : Risk of loss of service to the public:

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

R_3 : Risk of loss of cultural heritage:

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

R_4 : Risk of loss of economic value:

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

2) Only for properties where animals may be lost.

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

Table 3 – Risk components to be considered for each type of loss in a structure

Source of damage	Flash to a structure S1			Flash near a structure S2	Flash to a line connected to the structure S3			Flash near a line connected to the structure S4
Risk component	R_A	R_B	R_C	R_M	R_U	R_V	R_W	R_Z
Risk for each type of loss								
R_1	*	*	*1)	*1)	*	*	*1)	*1)
R_2		*	*	*		*	*	*
R_3		*				*		
R_4	* 2)	*	*	*	* 2)	*	*	*
¹⁾ Only for structures with risk of explosion, and for hospitals or other structures where failure of internal systems immediately endangers human life. ²⁾ Only for properties where animals may be lost.								

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

$$R = R_D + R_I \quad (5)$$

where

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

$$R_D = R_A + R_B + R_C \quad (6)$$

where

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

$$R_I = R_M + R_U + R_V + R_W + R_Z \quad (7)$$

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

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

$$R = R_S + R_F + R_O \quad (8)$$

where

R_S is the risk due to injury to living beings (D1) which is defined as the sum:

$$R_S = R_A + R_U \quad (9)$$

R_F is the risk due to physical damage (D2) which is defined as the sum:

$$R_F = R_B + R_V \quad (10)$$

R_O is the risk due to failure of internal systems (D3) which is defined as the sum:

$$R_O = R_M + R_C + R_W + R_Z \quad (11)$$

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

4.4 Composition of risk components related to a service

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

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

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

R'_4 : risk of loss of economic value:

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

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

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

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

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

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

where

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

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

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

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

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

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

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

where

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

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

R'_0 is the risk due to failure of internal systems (D3); defined as the sum

$$R'_0 = R'_W + R'_Z + R'_C \quad (19)$$

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

4.5 Factors influencing the risk components

4.5.1 Factors influencing the risk components in a structure

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

Table 5 – Factors influencing the risk components in a structure

Characteristics of structure or of internal systems Protection measures	R_A	R_B	R_C	R_M	R_U	R_V	R_W	R_Z
Collection area	X	X	X	X	X	X	X	X
Surface soil resistivity	X							
Floor resistivity					X			
Physical restrictions, insulation, warning notice, soil equipotentialization	X				X			
LPS	X ¹⁾	X	X ²⁾	X ²⁾	X ³⁾	X ³⁾		
Coordinated SPD protection			X	X			X	X
Spatial shield			X	X				
Shielding external lines					X	X	X	X
Shielding internal lines			X	X				
Routing precautions			X	X				
Bonding network			X					
Fire precautions		X				X		
Fire sensitivity		X				X		
Special hazard		X				X		
Impulse withstand voltage			X	X	X	X	X	X
1) In the case of a “natural” or standardized LPS with down-conductor spacing of less than 10 m, or where physical restriction are provided, the risk related to injury to living beings caused by touch and step voltages is negligible. 2) Only for grid-like external LPS. 3) Due to equipotential bonding.								

4.5.2 Factors influencing the risk components in a service

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

Table 6 – Factors influencing the risk components in a service

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

5 Risk management

5.1 Basic procedure

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

- identification of the object to be protected and its characteristics;
- identification of all the types of loss in the object and the relevant corresponding risk R (R_1 to R_4);
- evaluation of risk R for each type of loss (R_1 to R_4);
- evaluation of need of protection, by comparison of risk R_1 , R_2 and R_3 for a structure (R'_2 for a service) with the tolerable risk R_T ;
- evaluation of cost effectiveness of protection by comparison of the costs of total loss with and without protection measures. In this case, the assessment of components of risk R_4 for a structure (R'_4 for a service) shall be performed in order to evaluate such costs (see Annex G).

5.2 Structure to be considered for risk assessment

Structure to be considered includes:

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

Protection does not include connected services outside of the structure.

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

5.3 Service to be considered for risk assessment

The service to be considered is the physical connection between:

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

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

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

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

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

5.4 Tolerable risk R_T

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

Representative values of tolerable risk R_T , where lightning flashes involve loss of human life or loss of social or cultural values, are given in Table 7.

Table 7 – Typical values of tolerable risk R_T

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

NOTE See Table NK.1 in Annex NK for typical values of tolerable risk R_T as applied in the UK.

5.5 Specific procedure to evaluate the need of protection

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

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

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

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

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

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

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

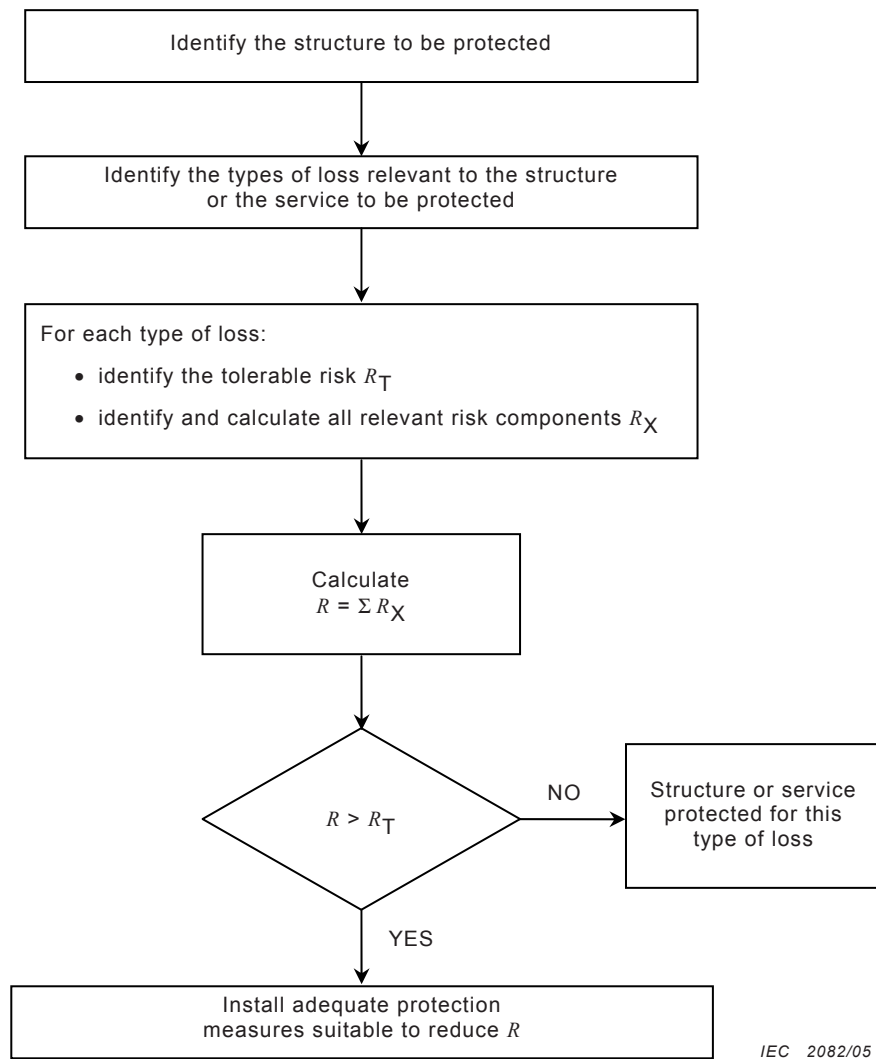


Figure 1 – Procedure for deciding the need of protection

5.6 Procedure to evaluate the cost effectiveness of protection

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

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

The procedure to ascertain the cost effectiveness of protection requires:

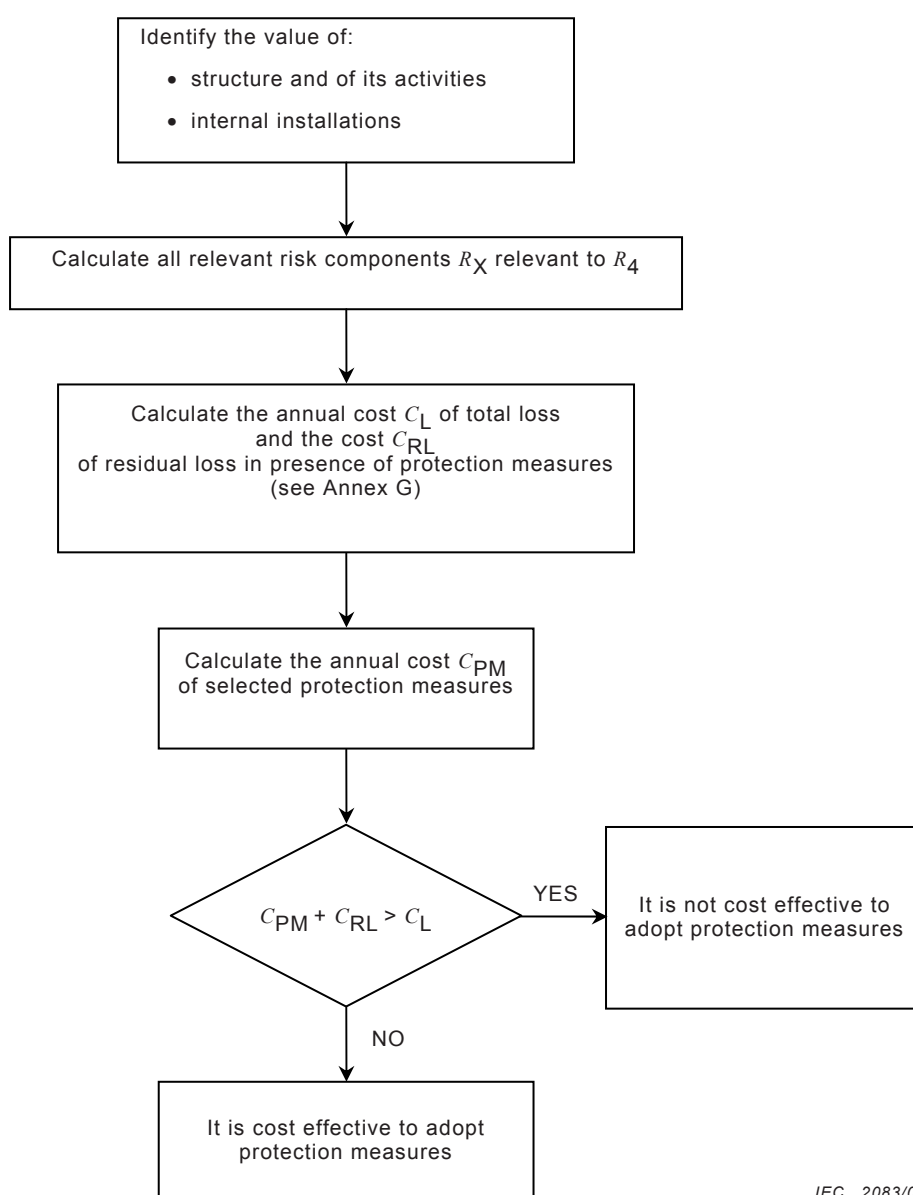
- identification of the components R_X which make up the risk R_4 for a structure (R'_4 for a service);
- calculation of the identified risk components R_X in absence of new/additional protection measures;
- calculation of the annual cost of loss due to each risk component R_X ;
- calculation of the annual cost C_L of total loss in the absence of protection measures;
- adoption of selected protection measures;

- calculation of risk components R_X with selected protection measures present;
- calculation of the annual cost of residual loss due to each risk component R_X in the protected structure or service;
- calculation of the total annual cost C_{RL} of residual loss with selected protection measures present;
- calculation of the annual cost C_{PM} of selected protection measures;
- comparison of costs.

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

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

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



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

5.7 Protection measures

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

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

- IEC 62305-3 for protection against injury to living beings and physical damage in a structure;
- IEC 62305-4 for protection against failure of internal systems;
- IEC 62305-5 for protection of services

5.8 Selection of protection measures

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

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

For each type of loss, there is a number of protection measures which, individually or in combination, make the condition $R \leq R_T$. The solution to be adopted shall be selected with allowance for technical and economic aspects. A simplified procedure for selection of protective measures is given in the flow diagrams of Figure 3 for structures and Figure 4 for services. In any case the installer or planner should identify the most critical risk components and reduce them, also taking into account economic aspects.

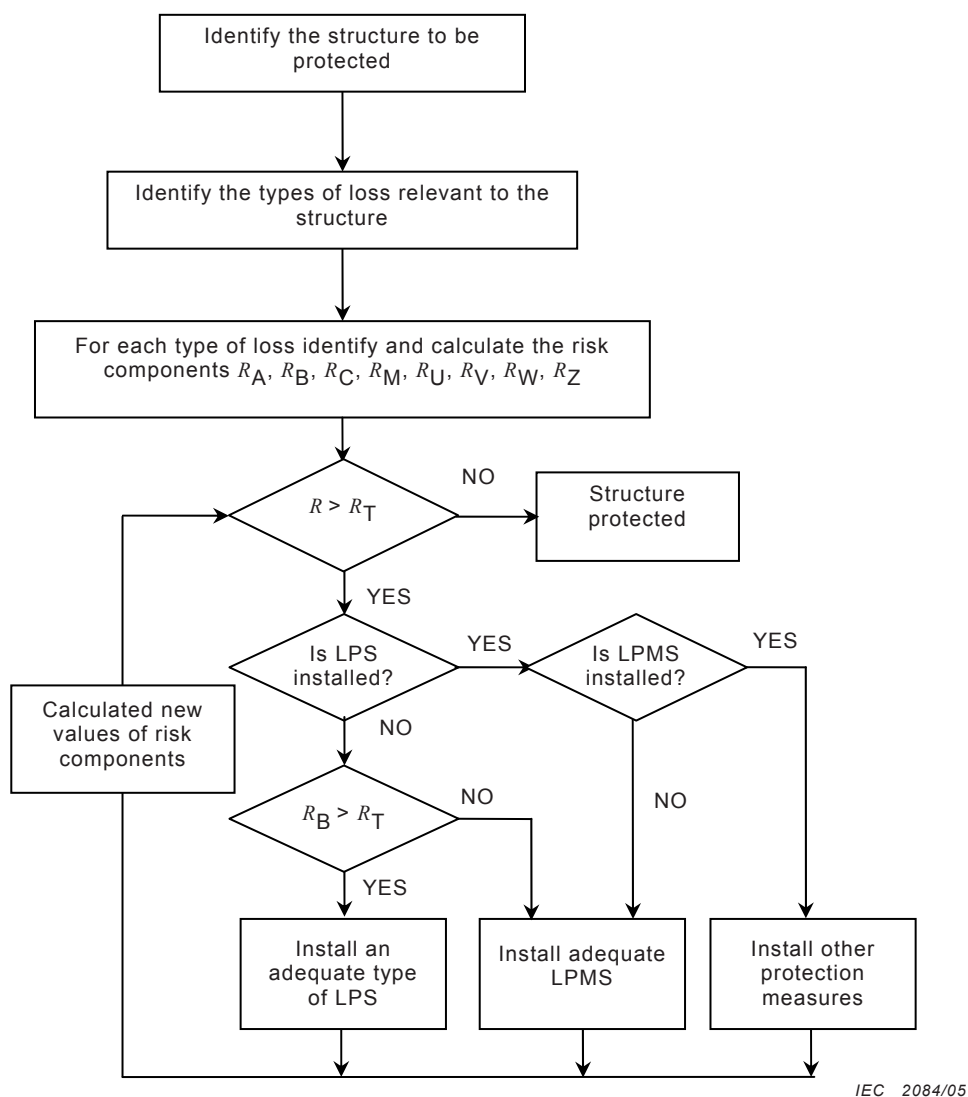


Figure 3 – Procedure for selecting protection measures in structures

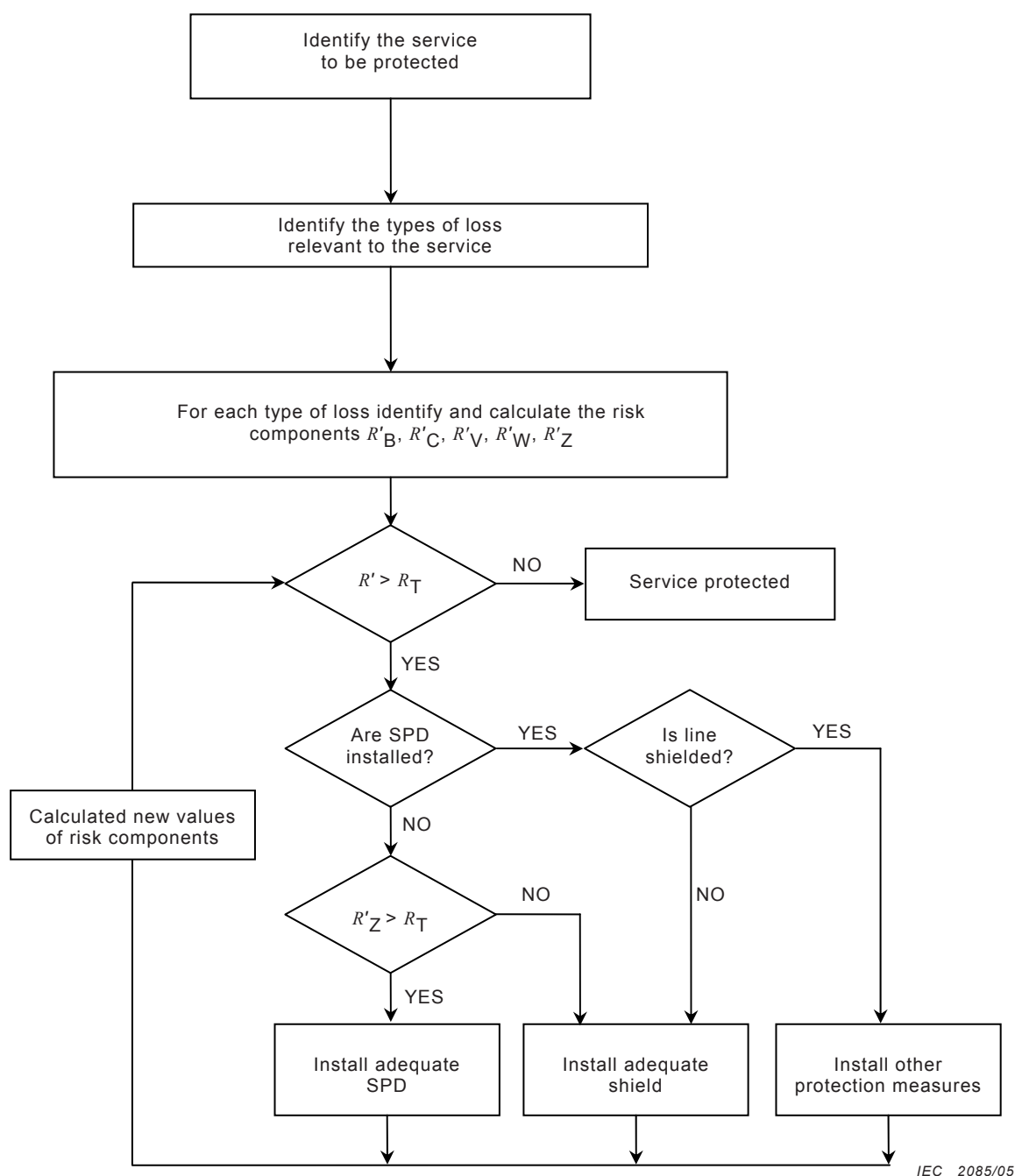


Figure 4 – Procedure for selecting protection measures in services

6 Assessment of risk components for a structure

6.1 Basic equation

Each risk component R_A , R_B , R_C , R_M , R_U , R_V , R_W and R_Z , as described in Clause 4, may be expressed by the following general equation

$$R_X = N_X \times P_X \times L_X \quad (20)$$

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).

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

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

NOTE 3 The consequent loss L_X is affected by the use to which the object is assigned, the attendance of persons, the type of service provided to public, the value of goods affected by the damage and the measures provided to limit the amount of loss.

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

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

- component related to injury to living beings (D1)

$$R_A = N_D \times P_A \times L_A \quad (21)$$

- component related to physical damage (D2)

$$R_B = N_D \times P_B \times L_B \quad (22)$$

- component related to failure of internal systems (D3)

$$R_C = N_D \times P_C \times L_C \quad (23)$$

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

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

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

- component related to failure of internal systems (D3)

$$R_M = N_M \times P_M \times L_M \quad (24)$$

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

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

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

- component related to injury to living beings (D1)

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

- component related to physical damage (D2)

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

- component related to failure of internal systems (D3)

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

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

If the line has more than one section (see 7.6), the values of R_U , R_V and R_W are the sum of the R_U , R_V and R_W values relevant to each section of the line. The sections to be considered are those between the structure and the first distribution node.

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

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

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

- component related to failure of internal systems (D3)

$$R_Z = (N_I - N_L) \times P_Z \times L_Z \quad (28)$$

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

If the line has more than one section (see 7.6), the value of R_Z is the sum of the R_Z components relevant to each section of the line. The sections to be considered are those between the structure and the first distribution node.

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

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

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

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

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

NOTE Values of loss L_t , L_f , L_o ; factors r_p , r_a , r_u , r_f reducing the loss and factor h_z increasing the loss are given in Annex C and Tables C.2, C.3, C.4 and C.5.

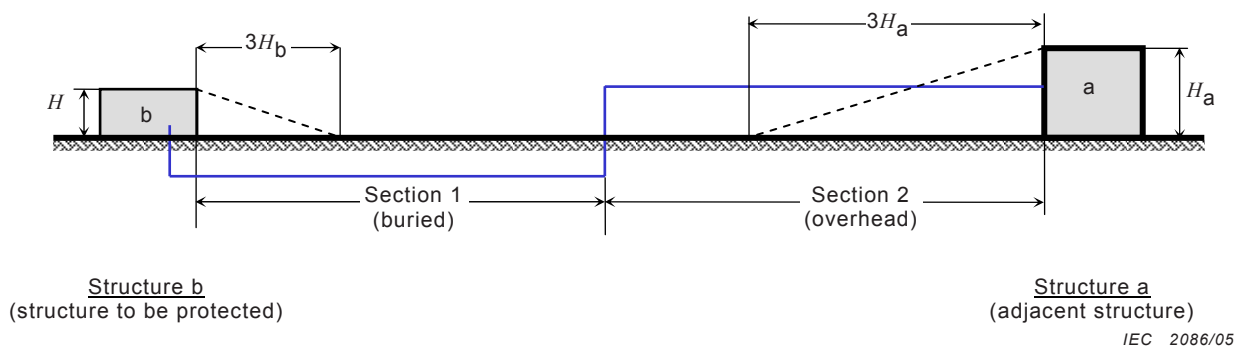


Figure 5 – Structures at line ends: at “b” end the structure to be protected (structure b) and at “a” end an adjacent structure (structure a)

6.6 Summary of risk components in a structure

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

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

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

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

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

6.7 Partitioning of a structure in zones Z_S

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

Zones Z_S are mainly defined by

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

Further zones may be defined according to

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

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

6.8 Assessment of risk components in a structure with zones Z_S

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

6.8.1 Risks R_1 , R_2 and R_3

6.8.1.1 Single zone structure

In this case only one zone Z_S made up of the entire structure is defined. According to 6.7, the risk R is the sum of risk components R_X in the structure. For the evaluation of risk components and the selection of the relevant parameters involved, the following rules apply:

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

Moreover:

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

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

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

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

- Parameters relevant to the amount L of loss shall be evaluated according to Annex C.
The typical mean values derived from Annex C may be assumed for the zone, according to the use of the structure.

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

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

6.8.1.2 Multi-zone structure

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

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

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

6.8.2 Risk R_4

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

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

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

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

7 Assessment of risk components for a service

7.1 Basic equation

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

$$R'_X = N_X \times P'_X \times L'_X \quad (31)$$

where

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

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

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

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

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

- component related to physical damage (D2)

$$R'_V = N_L \times P'_V \times L'_V \quad (32)$$

- component related to failure of connected equipment (D3)

$$R'_W = N_L \times P'_W \times L'_W \quad (33)$$

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

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

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

- component related to failure of connected equipments (D3)

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

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

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

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

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

- component related to physical damage (D2)

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

- component related to failures of equipment (D3)

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

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

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

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

7.5 Summary of risk components for a service

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

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

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

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

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

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

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

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

7.6 Partitioning of a service into sections S_S

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

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

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

Further sections may be defined according to:

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

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

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

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

Annex A (informative)

Assessment of annual number N of dangerous events

A.1 General

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

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

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

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

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

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

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

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

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

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

A.2.1 Determination of the collection area A_d

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

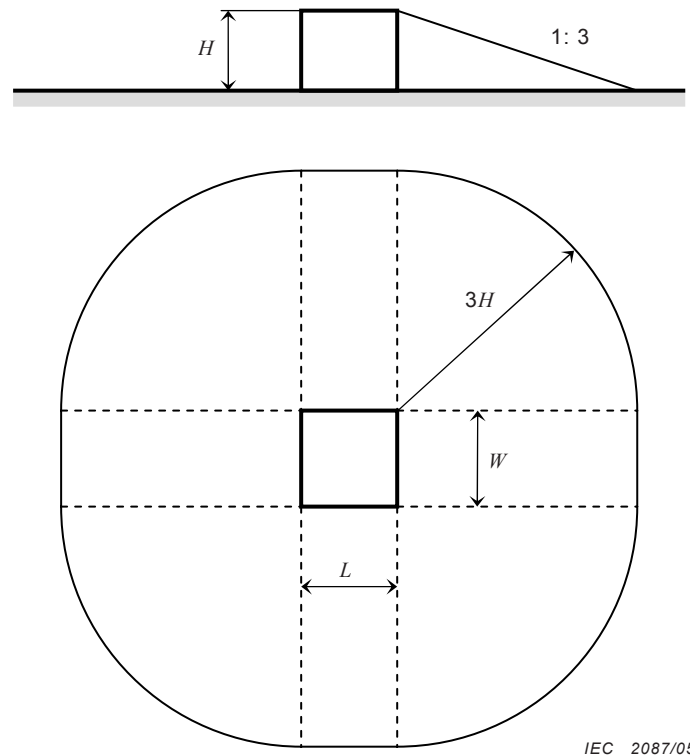
Rectangular structure

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

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

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

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



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

A.2.1.1 Complex shaped structure

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

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

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

where H_p is the height of protrusion.

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

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

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

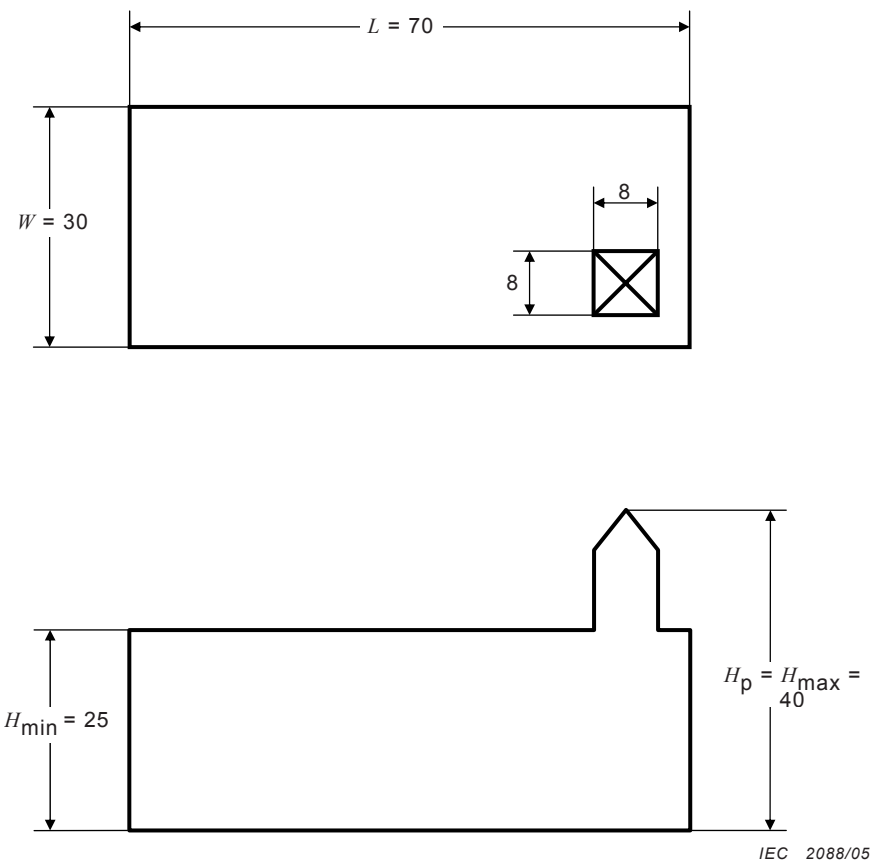


Figure A.2 – Complex shape structure