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Titre du CE/SC: Protection contre la foudre	TC/SC Title: Lightning protection
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Also of interest to the following committees Intéresse également les comités suivants SC 37A, TC 64, TC 77	Supersedes documents Remplace les documents 81/213/CD – 81/222A/CC

Functions concerned
Fonctions concernées

☒ Safety Sécurité	☐ EMC CEM	☐ Environment Environnement	☐ Quality assurance Assurance qualité

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Titre : CEI 62305-2, Ed. 1: Protection contre la foudre - Partie 2: Evaluation du risque

Title : IEC 62305-2, Ed. 1: Protection against lightning - Part 2: Risk management

Note d'introduction

Introductory note

The French version of the CDV will be circulated later.

**** The closing date remains unchanged.**

This document cancels and replaces document 81/241/CDV due to modifications on the cover page.

This document has been prepared based on the decisions taken at the last TC 81 meeting, (see 81/236/RM item 8).
The simplified software for risk management (version 3.0.3) is attached in the accompanying zip file to the CDV.
Risk assessment performed with the help of this software will be fully in line with procedure and requirements of IEC 62305-2.
Please note that support for the software will be given via the TC81 Secretariat. Consequently all questions related to the software covering installation, requests for more information etc should be addressed to:

- G.B. LO PIPARO, lopiparo@rai.it
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ATTENTION	ATTENTION
CDV soumis en parallèle au vote (CEI) et à l'enquête (CENELEC)	**Parallel IEC CDV/CENELEC Enquiry**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

PROTECTION AGAINST LIGHTNING –

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FOREWORD

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International Standard IEC 62305-2 has been prepared by IEC technical committee 81: Protection against lightning.

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

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

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

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

The committee has decided that the contents of this publication will remain unchanged until ______. At this date, the publication will be

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

INTRODUCTION

Lightning flashes to earth are hazardous to structures and to services.
. The hazard to structure can result in:

- damages to the structure and to its contents
- failures of associated electrical and electronic systems
- injuries of living beings in or close to the structure

Consequential effects of the damages and failures may be extended to the surroundings of the structure or may involve its environment.
The hazard to services can result in:

- damages to the service itself
- failures 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 extend 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 striking the structure
- flashes striking near the structure and/or near the connected services (power, telecommunication lines, other services).

Lightning flashes influencing the service may be divided into:

- flashes striking the service
- flashes striking near the service or direct to a structure connected to the service.

Flashes striking the structure or the connected services may cause physical damages and life hazards. Flashes striking near the structure or service as well as flashes to the structure or service may cause failures 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 IEC 62305 series. Reference should be made to Publication IEC 61000-4-5.

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

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

The probability of lightning damages depends on the structure and the service and the lightning current characteristics as well as on the kind and efficiency of applied protection measures.
The annual mean amount of the consequential loss depends on the extent of damages 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 the risk due to all possible effects of lightning flashes to structures and services is presented in this document being a revised version of IEC 61662: 1995-04 and A1: 1996-05 TR 2, Ed. 1.

PROTECTION AGAINST LIGHTNING –

Part 1: Risk management

1. Scope and object

This part of IEC 62305 is applicable to risk assessment in a structure or in a service due to lightning flashes to ground.
The scope of this part of IEC 62305 is to provide a procedure for the evaluation of such a risk. Once an upper tolerable limit for the risk has been selected, this procedure allows the selection of appropriate protection measures to be adopted to reduce the risk at or below the tolerable limit.

2. Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were intended to substitute the ones indicated within brackets ( ); the latter are valid until the issuing of the former. All normative documents are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60364 series: Electrical installations of buildings;

IEC 60479 series: Effects of current on human beings and livestock;

IEC 61643-1: 1998, Surge protective devices connected to low voltage power distribution systems. Part 1 : performance, requirements and testing methods.

IEC 61643-12: 2001, Surge protective devices connected to low voltage power distribution systems. Part 12 : selection and application principles.

IEC 62305-1 : Protection against lightning. Part 1: General principles

IEC 62305-3: Protection against lightning. Part 3: Physical damages and life hazard in structures.

IEC 62305-4 : Protection against lightning. Part 4: Electrical and electronic systems within structures.

IEC 62305-5 : Protection against lightning. Part 5: Services

3. Terms and definitions

For the purpose of this part of IEC 62305, the following definitions as well as those given in other parts of IEC 62305 apply:

3.1 Object to be protected

Structure or service to be protected against the effects of lightning.

3.2 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.

3.3 Structures with risk of explosion

Structures containing hazardous zones as determined in IEC 60079-10.

NOTE - For the purposes of IEC 62305-2 only structures with hazardous zones type 0 or containing solid explosive materials are considered.

3.4 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.

3.5 Urban environment

Area with high density of buildings of densely populated communities with tall buildings.

NOTE – Town centre is an example of urban environment.

3.6 Suburban environment

Area with medium density of buildings.

NOTE – Town outskirts is an example of suburban environment.

3.7 Rural environment

Area with low density of buildings.

NOTE – Countryside is an example of rural environment.

3.8 Rated impulse withstand voltage (U_w)

An impulse withstand voltage assigned by the manufacturer to the equipment or to a part of it, characterising the specified withstand capability of its insulation against overvoltages [definition 1.3.9.2 of IEC 60664-1].

NOTE – For the purpose of IEC 62305-2 only common mode withstand voltage is considered.

3.9 Electrical system

A system incorporating low voltage power supply components and possibly also electronic components.

3.10 Electronic system

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

3.11 Internal system

Electrical and electronic systems within a structure.

3.12 Service to be protected

A service entering a structure for which protection is required against the effects of lightning in accordance with this standard.

NOTE – The service to be protected is the physical means comprising between:

- the switch telecommunication building and the user's building or two switch telecommunication buildings or two user`s buildings, 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.

3.13 Telecommunication lines

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

3.14 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.

3.15 Pipes

Piping intend to convey a fluid into or out of a structure, such as gas pipe, water pipe, oil pipe.

3.16 Dangerous event

A lightning flash striking the object to be protected or near the object to be protected.

3.17 Lightning flash to an object

Lightning flash striking an object to be protected.

3.18 Lightning flash near an object

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

3.19 Frequency of lightning flashes to a structure (N_D)

Expected annual number of lightning flashes to a structure.

3.20 Frequency of lightning flashes to a service (N_L)

Expected annual number of lightning flashes to a service.

3.21 Frequency of lightning flashes near a structure (N_M)

Expected annual number of lightning flashes near a structure.

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3.22 Frequency of lightning flashes near a service (N_I)

Expected annual number of lightning flashes near a service.

3.23 Lightning electromagnetic impulse (LEMP)

Electromagnetic effects of lightning current.

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

3.24 Surges

Transient wave appearing as overvoltages and /or overcurrents.

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

3.25 Physical damage

Damage to structure or to its contents due to mechanical, thermal, chemical and explosive effects of lightning.

3.26 Injuries of living beings

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

3.27 Failure of electrical and electronic system

Permanent damage of electrical and electronic system due to LEMP

3.28 Failure current (I_a)

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

3.29 Probability of damage

Probability that a lightning flash cause a damage to the object to be protected.

3.30 Loss

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.

3.31 Risk (R)

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

3.32 Risk component (R_x)

Partial risk depending on the source and the type of damage.

3.33 Tolerable risk (R_T)

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

3.34 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.

3.35 Section of a service (S_S)

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

3.36 Lightning Protection Zone (LPZ)

Zone where the lightning electromagnetic environment is defined.

3.37 Lightning protection level (LPL)

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

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

3.38 Protection measures

Measures to be adopted in the object to be protected to reduce the risk due to lightning.

3.39 Lightning protection system (LPS)

Complete system used to reduce physical damages due to lightning flashes striking a structure. It consists of both external and internal lightning protection systems.

3.40 LEMP protection system (LPM)

Complete system of protection measures for internal systems against LEMP.

3.41 Shielding wire

Metallic wire used to reduce physical damages due to lightning flashes striking a service.

3.42 Magnetic shield

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

3.43 Lightning cable

Shielded cable specially designed and constructed to reduce the electromagnetic effects of lightning current flowing into the shield

3.44 Surge protective device (SPD)

Device that is intended to limit transient overvoltages and divert surge currents. It contains at least one non linear component.

[definition 3.1 of IEC 61643-1].

3.45 Surge protective devices set (SPD set)

A set of SPD properly selected, co-ordinated and installed to reduce failures of electrical and electronic systems.

4. EXPLANATION OF TERMS

4.1 Damages and loss

4.1.1 Source of damage

The lightning current is the primary source of damage. The following sources are distinguished depending on the position of the point struck by flash (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 damages depending on the characteristics of the object to be protected; among the most important are: type of construction, contents and application, type of service and protection measures provided.

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

- D1 : Injuries to living beings;
- D2 : Physical damages ;
- D3 : Failures 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 whole 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 mean 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 Table1):

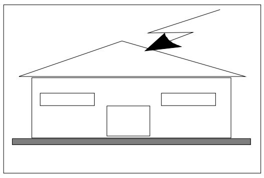
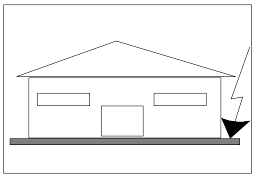
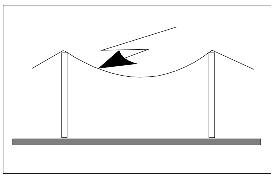
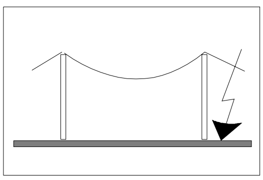
– L1: Loss of human life;
– L2: Loss of service to the public;
– L3: Loss of cultural heritage;
– L4: Loss of economic value (structure and its content, service and loss of activity).

Loss which may appear in a structure are:

– 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).

Loss which may appear in a service are:

– L2: Loss of service to the public;
– L4: Loss of economic value (service and loss of activity).

		STRUCTURE		SERVICE	
Point of strike	**Source of damage**	**Type of damage**	**Type of loss**	**Type of damage**	**Type of loss**
	S1	D1 D2 D3	L1, L4** L1,L2, L3,L4 L1*, L2, L4	D2 D3	L1***,L2,L4 L2,L4
	S2	D3	L1*,L2 , L4		
	S3	D1 D2 D3	L1,L4** L1,L2, L3,L4 L1*, L2, L4	D2 D3	L1***,L2,L4 D2,D4
	S4	D3	L1*,L2,L4	D3	L2,L4

(*) In the case of hospitals and of structures with risk of explosion;
(**) In the case of agricultural properties (loss of animals)
(***) In the case of pipelines, with not metallic gasket on flanges, conveying explosive fluid.

Table 1 – Sources of damages (S1, S2, S3, S4), types of damages (D1, D2, D3) and types of loss (L1, L2, L3, L4) selected according to the point of strike

Loss / **Damage**	**L1 Loss of human life**	**L2 Loss of service the public**	**L3 Loss of cultural heritage**	**L4 Loss of economic values**
D1 Shock of 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 of agricultural with possible loss of animals.

2 – Only for hospitals or other structures, where failures on internal systems immediately endanger human life.

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

4.2 Risk and risk components

4.2.1 Risk

The risk **R** is the measure of a 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:

- $\mathbf{R_1}$: Risk of loss of human life;
- $\mathbf{R_2}$: Risk of loss of service to the public;
- $\mathbf{R_3}$: Risk of loss of cultural heritage;
- $\mathbf{R_4}$: Risk of loss of economic value.

The risks to be evaluated in a service may be:

- $\mathbf{R'_1}$: Risk of loss of human life;

- $\mathbf{R'_2}$: 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 on the type of damage) shall be defined and calculated.
Each risk **R** is the sum of its risk components. In making addition 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 injuries of living beings caused by touch and step voltages in the zones up to 3 m outside the structure. Loss of type L1 and, in the case of agricultural properties, also loss L4 with possible loss of animals may arise;

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

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

R_C: component related to failure of internal systems caused by LEMP. Loss are 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 a flash near the structure

R_M: component related to failure of internal systems caused by LEMP. Loss are of type L2 and L4 could occur in all cases, along with type L1 in the case of structures with risk of explosion and of 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 injuries of 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, also loss L4 with possible loss of animals could occur;

R_V: component related to physical damages (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 are of type L2 and L4 could occur in all cases, along with type L1 in the case of structures with risk of explosion and of hospitals or other structures where failure of internal systems immediately endangers human life;

NOTE – Lightning flashes to or near pipes, do not cause damages to the structure, provided they are bonded to the equipotential bonding bar of the structure. Therefore such a source of damage is not considered in the assessment of risk for structures and the services to be taken into account are only the lines entering the structure.

4.2.5 Risk component for a structure due to a flash 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 are 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 – Lightning flashes to or near pipes, do not cause damages to the structure, provided they are bonded to the equipotential bonding bar of the structure. Therefore such a source of damage is not considered in the assessment of risk for structures and the services to be taken into account are only the lines entering the structure.

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

R'_V: component related to physical damages due to mechanical and thermal effects of lightning current. Loss of type L2and L4, along with type L1 in case of pipes, could occur;

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

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

R'_Z: component related to failure of lines and connected equipment caused by overvoltages induced on lines. Loss of type L2and L4 could occur;

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

R'_B: component related to physical damages due to mechanical and thermal effects of lightning current flowing along the line. Loss of type L2 and L4, along with type L1 in case of pipes, could occur;

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

4.3 Compositions of risk components related to the structure

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

$\mathbf{R}_1$: Risk of loss of human life;

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

NOTE 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.

$\mathbf{R}_2$: Risk of loss of service to the public;

$$\mathbf{R_2} = R_B + R_C + R_M + R_V + R_W + R_Z \qquad (2)$$

$\mathbf{R}_3$: Risk of loss of cultural heritage;

$$\mathbf{R_3} = R_B + R_V \qquad (3)$$

$\mathbf{R}_4$: Risk of loss of economic value.

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

NOTE 2- 2) Only for properties of agriculture with possible loss of animals

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

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

Source of damage	**Flash to structure** S_1			**Flash near a structure** S_2	**Flash to a line entering the structure** S_3			**Flash near a line entering the structure** S_4
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)
R_2		*	*	*		*		*
R_3		*					*	
R_4	* (2)	*	*	*	* (2)	*(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.
(2) Only for properties of agriculture with possible loss of animals

4.3.1 Composition of risk components with reference to the source of damage (Table 9)

$$\mathbf{R = R_D + R_I} \quad (5)$$

where:

$\mathbf{R_D}$ is the risk due to flashes striking the structure (source S1) and consists of the sum

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

$\mathbf{R_I}$ is the risk due to flashes not striking the structure (sources: S2, S3 and S4) but influencing it and may consists of the sum

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

4.3.2 Composition of risk components with reference to the type of damage (Table 9)

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

where:

$\mathbf{R_S}$ is the risk due to injuries of living beings and may consists of the sum

$$\mathbf{R_S} = R_A + R_U \quad (9)$$

$\mathbf{R_F}$ is the risk due to physical damages and may consists of the sum

$$\mathbf{R_F} = R_B + R_V \quad (10)$$

$\mathbf{R_O}$ is the risk due to failure of internal systems and may consists of the sum.

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

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

4.4 Compositions of risk components related to the services

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

R'_1: risk of loss of human life

$$\mathbf{R'_1} = R'_V + R'_B$$

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

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

R'_4 : risk of loss of economic value

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

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 S_3**		**Flash striking near the service S_4**	**Flash striking the structure S_1**	
Risk component	$R`_V$	$R`_W$	$R`_Z$	$R`_B$	$R`_C$
Risk for each type of loss					
$R`_1$(*)	*			*	
$R`_2$	*	*	*	*	*
$R`_4$	*	*	*	*	*
(*) Only for pipes with not metallic gasket on flanges, conveying explosive fluid.					

4.4.1 Composition of risk components with reference to the source of damage (Table 11)

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

where:

R'_D is the risk due to flashes striking the service (source S3) and consists of the sum

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

R'_I is the risk due to flashes not striking the service (sources S1 and S4) but influencing it and may consists of the sum

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

4.4.2 Composition of risk components with reference to the type of damage (Table 11)

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

where

R'$_F$ is the risk due to physical damages (D2) and may consists of the sum of the components R'$_V$ and R'$_B$

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

R'$_O$ is the risk due to failure of electrical and electronic systems (D3) and may consists of the sum of the components R'$_W$, R'$_Z$ and R'$_C$

.

$$\mathbf{R'_O} = R'_W + R'_Z + R'_C \quad (19)$$

For the compositions of risk components for a service as 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

	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 equipotentialisation	X							
LPS	X(1)	X	X(2)	X(2)	X(3)	X(3)		
SPD set			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

Characteristics of structure or of internal systems Protection measures Note 1 – Only where the structure's reinforcing members, or framework is used as down conductor system, or where physical restriction are provided. Note 2 - Only for grid-like external LPS Note 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

	$R`_V$	$R`_W$	$R`_Z$	$R`_B$	$R`_C$
Collection area	X	X	X	X	X
Cable shielding	X	X	X	X	X
Lightning cable	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
Characteristic of service Protection measure					

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 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;
- evaluation of need of protection, by comparison of risk $\mathbf{R_1}$, $\mathbf{R_2}$ and $\mathbf{R_3}$ for a structure ($\mathbf{R'_2}$ for a service) with the tolerable risk $\mathbf{R_T}$;
- evaluation of economic convenience of protection, by comparison of the costs of total loss with and without protection measures. In this case the assessment of components of risk $\mathbf{R_4}$ for a structure ($\mathbf{R'_4}$ for a service)(see Annex G) is to be done in order to evaluate such costs.

5.2 Structure to be considered for risk assessment

Structure to be protected 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 a 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 protected is the physical means comprising between:
- the switch telecommunication building and the user's building, 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 protected 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.
- two switch telecommunication buildings, for TLC lines;
- two user's buildings, for TLC and signal lines.

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 $\mathbf{R_T}$, where lightning flashes involve loss of human life or loss of social or cultural values, are reported in Table 7.

Table 5. Typical values of tolerable risk R_T

Types of loss	$\mathbf{R_T}$
Loss of human life	10^{-5}
Loss of service to the public	10^{-3}
Loss of cultural heritage	10^{-3}

NOTE - For more details on the background of these values reference can be made to BS 6651-1985 and to publications relevant to fatal accident rate

5.5 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 $\mathbf{R_1}$, $\mathbf{R_2}$ and $\mathbf{R_3}$ for a structure;
- risk $\mathbf{R'_1}$ and $\mathbf{R'_2}$ 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** ;
- identification of the tolerable risk $\mathbf{R_T}$;
- comparison of the risk **R** with the tolerable value $\mathbf{R_T}$

If **R ≤ R_T** lightning protection is not necessary.

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

The procedure to evaluate the need of protection is reported in Figure 1.

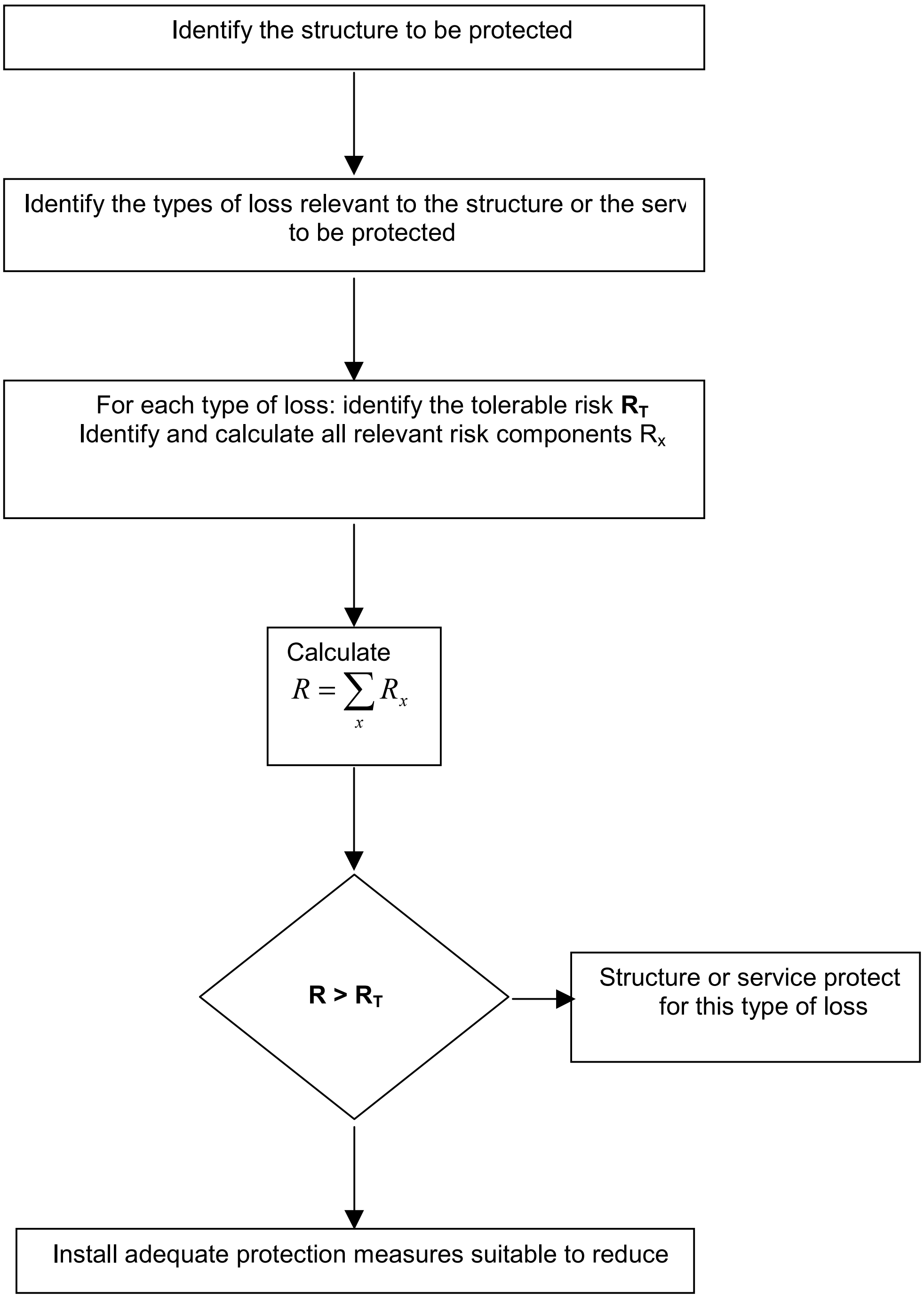


Figure 1 – Procedure for decision of the need of protection

EMBED 5.6 Procedure to evaluate the economic convenience of protection

Besides the need for lightning protection for a structure or for a service, it may useful to ascertain the economic benefits of installing protection measures in order to reduce the economic loss L4.
The assessment of components of risk $\mathbf{R_4}$ for a structure ($\mathbf{R'_4}$for a service) allows the user to evaluate the cost of the economic loss with and without the adopted protection measures, as reported in Annex G.

The procedure to ascertain the economic convenience of protection requires:

- identification of the components R_X which make up the risk $\mathbf{R_4}$ for a structure ($\mathbf{R'_4}$for a service);
- calculation of the identified risk components R_X in absence of protection measures;
- calculation of cost of loss due to each risk component R_X;
- calculation of cost $\mathbf{C_L}$ of total loss in absence of protection measures;
- adoption of selected protection measures;
- calculation of risk components R_X in presence of selected protection measures;
- calculation of cost of residual loss due to each risk component R_X in the protected structure or service;
- calculation of total cost $\mathbf{C_{RL}}$ of residual loss in presence of protection measures;
- calculation of annual cost $\mathbf{C_{PM}}$ of selected protection measures;
- comparison of costs.

If $\mathbf{C_L < C_{RL} + C_{PM}}$ lightning protection may not be deemed to b Is LPM ective.
installed

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

The procedure to evaluate the economical convenience of protection is outlined in Figure 2.

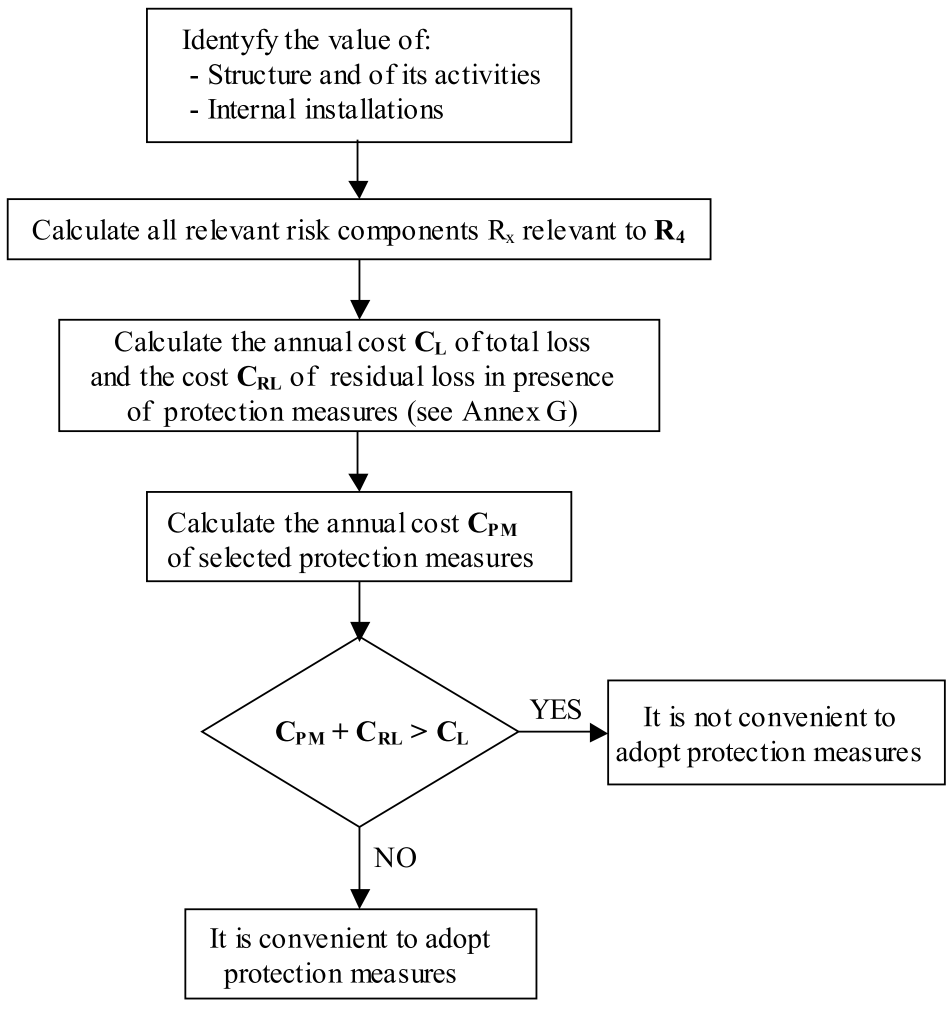


Figure 2 - Procedure for decision of the economic convenience of protection measures

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 comply with requirements of relevant standards:

- IEC 62305-3 for protection to reduce injuries of living beings and physical damages in a structure ;
- IEC 62305-4 for protection to reduce failures 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 economical aspects of the different protection measures.

Critical parameters have to 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 $\mathbf{R} \le \mathbf{R_T}$. The solution to be adopted shall be selected with allowance for technical and economic aspects. A simplified procedure for selection of protective measures is reported in the flow diagrams of Figure 6 for structures and of Figure 7 for services. In any case the installer or planner should identify the most critical risk components and reduce them, taking into account also economic aspects.

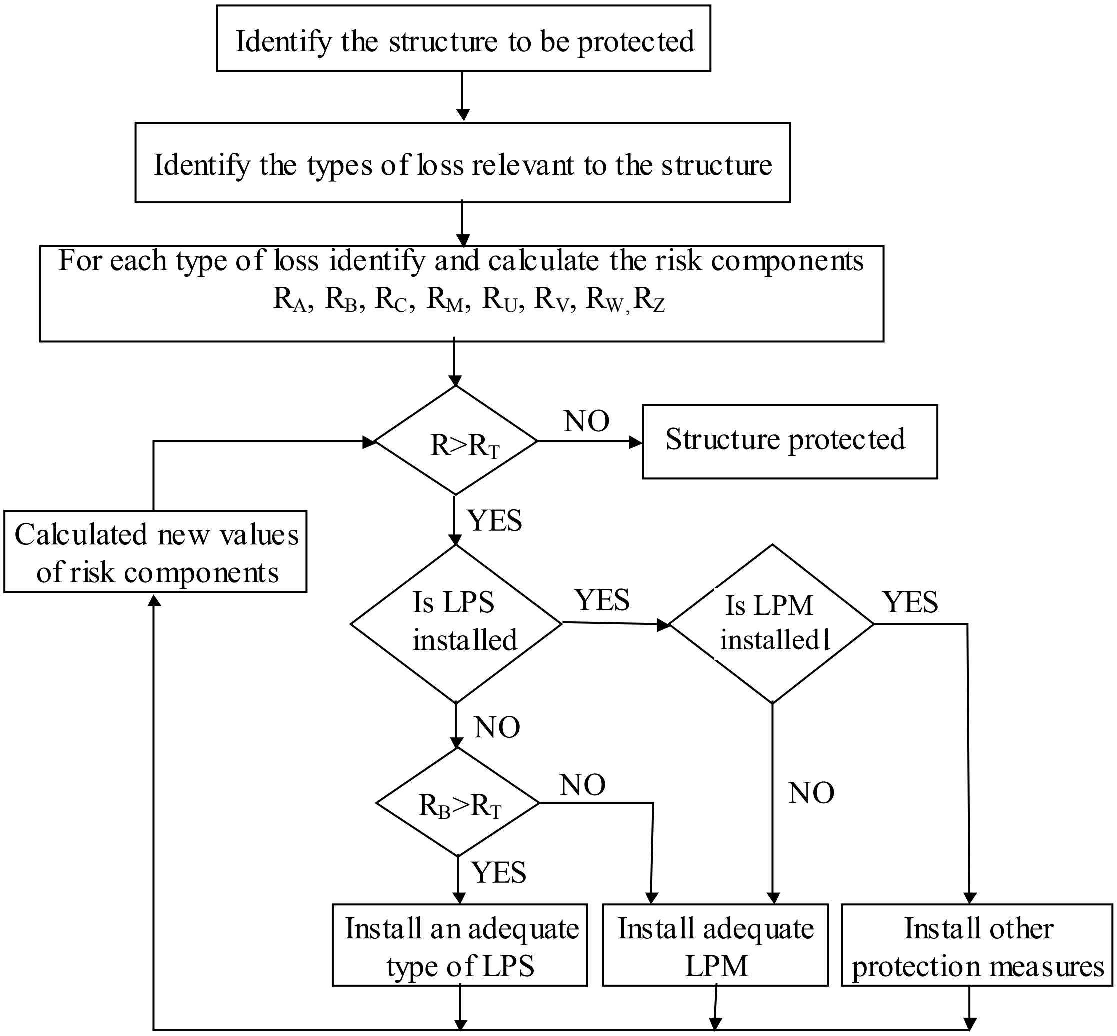


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Figure 3 - Procedure for selection of protection measures in the structures

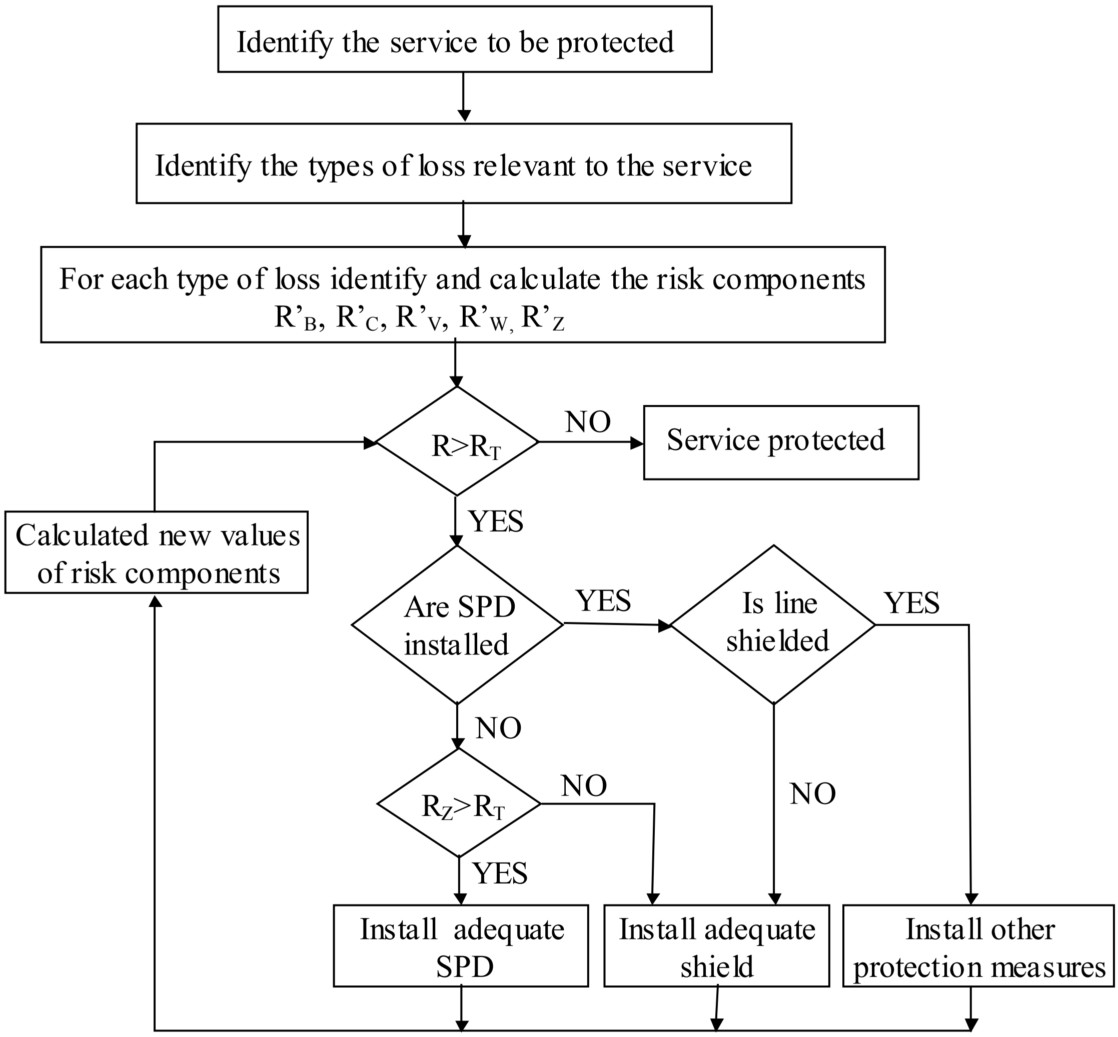

Figure 4 – Procedure for selection of protection measures in the services

6. ASSESSMENT OF RISK COMPONENTS FOR STRUCTURES

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 explained in the sub-clause 4, may be expressed by the following general equation

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

in which:
N_X - the number of dangerous events (see also Annex A),
P_X - the probability of damage (see also Annex B),
L_X - the consequent loss (see also Annex C)

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

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

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

6.2 Assessment of risk components due to flashes to the structure

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

- component related to injuries of living beings

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

- component related to physical damages

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

- component related to failure of internal systems

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

Parameters to assess these risk components are reported in Table 6.

6.3 Assessment of the risk component due to flash near the structure

For evaluation of risk component related to lightning flashes near the structure, the following relation apply:

- component related to failure of internal systems

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

Parameters to assess this risk component are reported in Table 6.

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

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

- component related to injuries of living beings

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

- component related to physical damages

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

- component related to failure of internal systems

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

Parameters to assess these risk components are reported in Table 6.

If the line has more than one section (overhead, underground, screened, unscreened), 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.

In the case of 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 flash near a line connected to the structure

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

- component related to failure of internal systems

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

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

If the line has more than one section (overhead, underground, screened, unscreened), the value of R_Z is the sum of the R_Z components relevant to each section of the line.

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

If $(N_I – N_L) < 0$, then $(N_I – N_L) = 0$ it is assumed.

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

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

NOTE – Values of loss L_t, L_f, L_o and factors r, r_a , r_f reducing the loss and factor h increasing the loss are reported in Annex C and Tables C.2, C.3, C.4 and C.5.

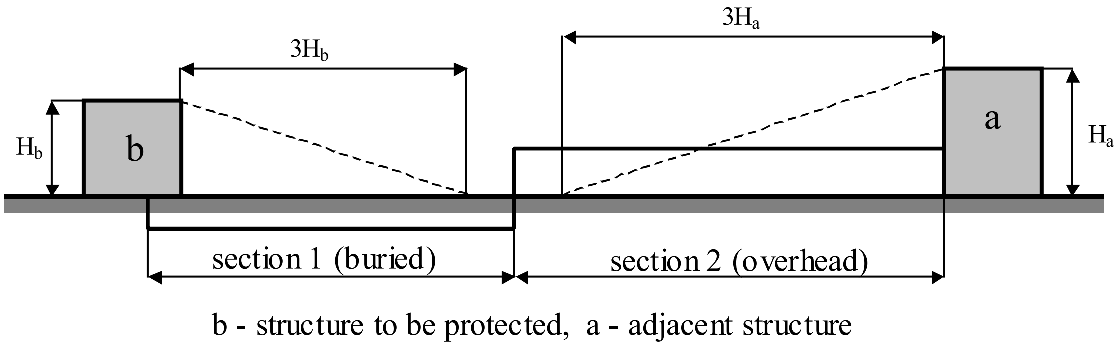

Figure 5 –Structures at line ends : to be protected (structure b) and at “a” end (structure a)

6.6 Summary of risk components in a structure

Risk components for structures are summarised 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 a incoming service	S4 Lightning flash near a service	**Resulting risk according to type of damage**
D1 shock of living beings	$R_A = N_D\ P_A\ r_a\ L_t$		$R_U = (N_L + N_{Da})\ P_U\ r_a\ L_t$		$\mathbf{R_S} = R_A + R_U$
D2 Physical damage	$R_B = N_D\ P_B\ r\ h\ r_f\ L_f$		$R_V = (N_L + N_{Da})\ P_V\ r\ h\ r_f\ L_f$		$\mathbf{R_F} = R_B + R_V$
D3 failure of electrical and electronic systems	$R_C = N_D\ P_c\ L_o$	$R_M = N_M\ P_M\ L_o$	$R_W = (N_L + N_{Da})\ P_W\ L_o$	$R_Z = (N_I - N_L)\ P_Z\ L_o$	$\mathbf{R_O}=R_C+R_M+R_W+R_Z$
Resulting risk according to the source of damage	$\mathbf{R_D} = R_A + R_B + R_C$	$\mathbf{R_I} = R_M + R_U + R_V + R_W + R_Z$			

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 zones Z_S which constitute the structure.

6.7 Partitioning of a structure in zones Z_S

To assess each risk component, structure could be divided in parts having homogeneous characteristics (zones) Z_S. 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, R_M, R_W and R_Z).

Further zones may be defined according to:

- Layout of internal systems;
- Protection measures existing or to be provided;
- Losses L values.

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

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

7. ASSESSMENT OF RISK COMPONENTS FOR SERVICES

7.1 Basic equation

Each risk component R'_V, R'_W, R'_Z, R'_B and R'_C, as explained in the sub-clause 4, may be expressed by the following general equation

$$R'_X = N'_X \, P'_X \, L'_X \qquad (29)$$

in which:
N_X - the number of dangerous events (see also Annex A),
P'_X - the probability of damage (see also Annex D),
L'_X - the consequent loss (see also Annex E)

7.2 Assessment of components due to flashes to the service

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

- component related to physical damages

$$R'_V = N_L \, P'_V \, L'_V \qquad (30)$$

- component related to failure of connected equipment

$$R'_W = N_L \, P'_W \, L'_W \qquad (31)$$

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

7.3 Assessment of risk component due to flashes near the service

For evaluation of risk component related to lightning flashes near the service, the following relation apply:

- component related to failure of connected equipments

$$R'_Z = (N_I - N_L) \, P'_Z \, L'_Z \qquad (32)$$

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

If $(N_I - N_L) < 0$, then $(N_I - N_L) = 0$ it is assumed.

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

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

- component related to physical damages

$R'_B = N_D\, P'_B\, L'_B$ (33)

- component related to failures of equipment

$R'_C = N_D\, P'_C\, L'_C$ (34)

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

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

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

7.5 Summary of risk components in a service

Risk components for a service are summarised in Table 11, according to different types of damage and different 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	$R'_V = N_{Li} P'_{Vi} L'_V$		$R'_B = N_{Di}\, P'_{Bi}\, L'_B$	$\mathbf{R_F} = R'_V + R'_B$
D3 Failure of electrical and electronic systems	$R'_W = N_{Li} P'_{Wi}\, L'_W$	$R'_Z = (N_{Ii} - N_{Li})\, P'_Z\, L'_Z$	$R'_C = N_{Di} P'_{Ci}\, L'_C$	$\mathbf{R_O} = R'_Z + R'_W + R'_C$
Resulting risk according to the source of damage	$\mathbf{R_D} = R'_V + R'_W$	$\mathbf{R_I} = R'_Z + R'_B + R'_C$		

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

The risk components $\mathbf{R'}_B$, $\mathbf{R'}_C$ 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 $\mathbf{R'}_B$, $\mathbf{R'}_C$, $\mathbf{R'}_V$, $\mathbf{R'}_W$, and $\mathbf{R'}_Z$.

7.6 Partitioning of a service in sections S_S

To assess each risk component, service could be divided in 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 zones may be defined according to:

- Type of connected apparatus;
- Protection measures existing or to be provided.

Partitioning of service in 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 damage. 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 annual number N of lightning flashes influencing an object to be protected depends on the thunderstorm activity of the region where the object is located and on object's physical characteristics. It is generally accepted to evaluate the number N by multiplying the lightning ground flash density (N_g) by an equivalent collection area of the object.

The lightning ground flash density, N_g, is number of lightning flashes per km^2 per year. This value is available from ground flash location networks in most area of the world.

NOTE - If the map of N_g is not available, it may be estimated by :
$N_g \approx 0,1\ T_d$
where T_d, the thunderstorm days per year, may 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 average annual number of flashes to a structure (N_D) and to a structure connected at "a" end of a line ($N_{D\,a}$)

N_D may be evaluated as the product :

$$N_D = N_g\ A_d\ C_d\ 10^{-6} \qquad \text{(A.1)}$$

with
- N_g lightning ground flash density (flash/km^2/year)
- A_d collection area of the isolated structure (m^2)
- C_d factor taking into account the influence of the relative location of object to be protected (see Table A.1).

Table A.1 Location factor C_d

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

For isolated structures on a 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 (see Figure A.1).

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

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

being *L,W* and *H* expressed in meters the dimensions of the structure considered.

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 3*H* from the structure.

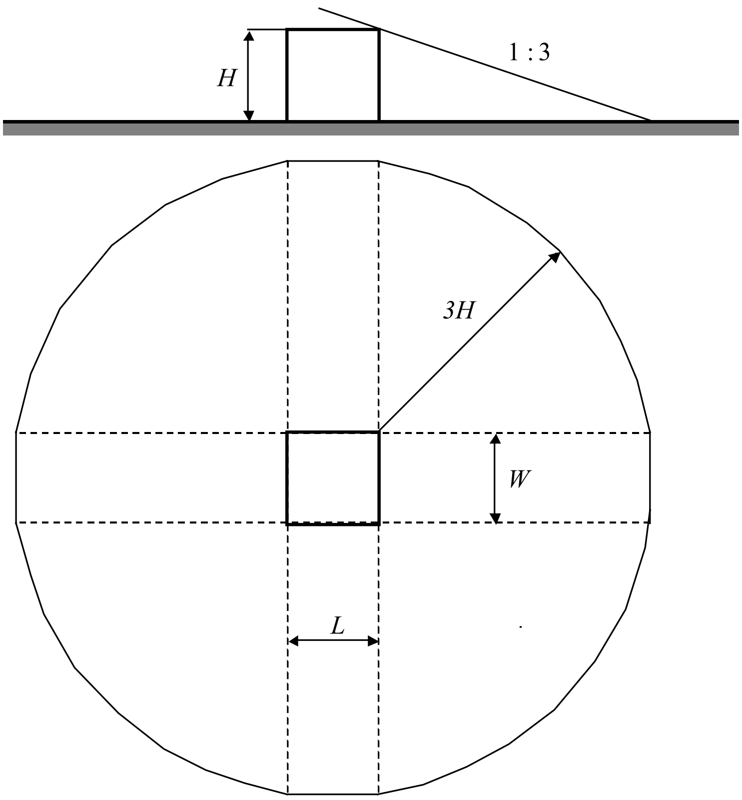

Figure A.1 – Collection area A_d of an isolated structure

Where the structure *S* to be considered consist of only a part of a building *B,* dimensions of structure *S* may be used in evaluation of A_d provided that the following conditions are fulfilled (see Fig. A.2):

- the structure *S* is a separated vertical part of the building *B*;
- the building *B* is a no risk of explosion structure;
- propagation of fire between the structure *S* and other parts of building *B* is avoided by means of walls with resistance to fire of 120 minutes (REI 120) or by means of other equivalent protection measure;
- propagation of overvoltages along common lines, if any, is avoided by means of SPD installed at the entrance point of such lines in the structure or by means of other equivalent protection measure.

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

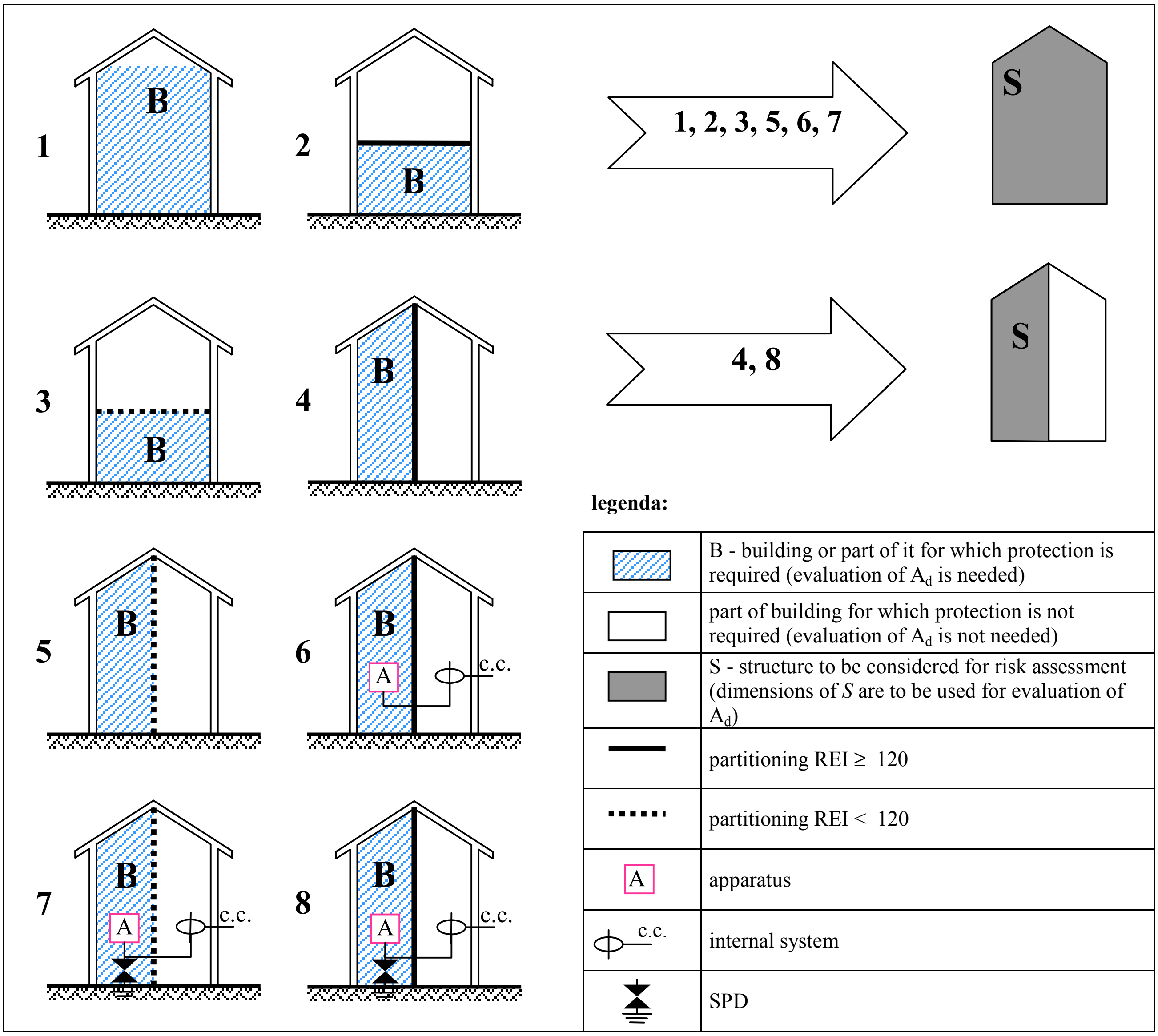

Figure A. 2 – Structure to be considered for evaluation of collection area A_d

The collection area of a structure at “a” end of a line N_{Da} may be evaluated as the product :

$$N_{Da} = N_D \, C_t \qquad \text{(A.3)}$$

with

- C_t correction factor for the presence of a HV/LV transformer on the service to which the structure is connected, located between the point of strike and the structure(see Table A.3)

A.3. Assessment of average annual number of flashes near a structure (N_M)

N_M may be evaluated as the product :

$$N_M = N_g\ A_m\ 10^{-6} \qquad (A.4)$$

with :
- N_g lightning ground flash density (flash/km ^{2}/year)
- A_m area of influence of the structure (m ^{2})

The area of influence of the structure A_m is defined as the area surrounding the structure where a lightning strike creates a magnetic field which may induce in a loop of 100 m^2, an overvoltage greater, or at least equal, to the impulse withstand voltage level of 1,5 kV of internal systems.
It extends to a line located at a distance of 250 m from the perimeter of the structure.

The area of influence A_m is calculated as the difference between the area enclosed by this line and the collection area $A_d\ C_d$ of the structure.

If $A_m < 0$, it is assumed $A_m = 0$

A.4 Assessment of average annual number of flashes to a service (N_L)

For one section service, N_L may be evaluated by :

$$N_L = N_g\ A_l\ C_d\ C_t 10^{-6} \qquad (A.5)$$

with
- N_g lightning ground flash density (flash/km^2.year)
- A_l collection area of flashes striking the service (m^2) (see Table A.2 and Figure A.3)
- C_d location factor of service (see Table A.1)
- C_t correction factor for the presence of a HV/LV transformer located between the point of strike and the structure(see Table A.3). This factor applies to line sections upstream the transformer respect to the structure.

TABLE A. 2 – Collection areas A_l and A_i depending on the service characteristics

	Aerial	Buried
A_l	$(L_c - 3(H_a + H_b))\ 6\ H_c$	$15\ (L_c - 3(H_a + H_b))$
A_i	$1000 L_c$	$500 L_c$

H_c = height (m) of the service conductors above ground ;
L_c = length (m) of the service - from the structure to the first distribution node (e.g. HV/LV station) or the first point where SPD, complying with IEC 62305-5, are installed on the service - with a maximum value of 1000 m ;
H_a = height (m) of the structure connected at end “a” of service ;
H_b = height (m) of the structure connected at end “b” of service.

For the purposes of this calculation :

– where the value of L_c is unknown, L_c = 1000 m is to be assumed;
– for underground cables running entirely within a highly meshed earth termination, the equivalent collection area $A_i = A_l = 0$ may be assumed;
– structure to be protected shall be assumed to be the one connected at “b” end of service.

Table A.3 Transformer factor C_t

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

NOTE 1 - A more precise evaluation of collection area A_i for buried cables could be carried out with the following equation

$$A_l = (L_c - 3(H_a + H_b))2D \quad \text{(A.6)}$$

where

D is the arcing distance which can be roughly evaluated as $D = 0.4\sqrt{\rho}$, or more precisely as follows:

$D = 0,482\sqrt{\rho}$ for $\rho \leq 100\ \Omega\text{m}$,

$D = 0,283\sqrt{\rho}$ for $\rho \geq 1\ 000\ \Omega\text{m}$,

$D = 0,191(\sqrt{\rho}-10)+4,82$ for $100\ \Omega\text{m} < \rho < 1\ 000\ \Omega\text{m}$;

ρ is the resistivity (Ωm) of the ground where the cable is buried.

NOTE 2 - A more precise evaluation of collection area A_i for buried cables could be carried out with the following equation

$$A_i = 46 L_c \sqrt{\rho} \quad \text{(A.7)}$$

for aerial lines,

$$A_i = 23 L_c \sqrt{\rho} \quad \text{(A.8)}$$

for buried lines,
where

ρ is the resistivity (Ωm) of the ground where the cable is buried.

A.5 Assessment of average annual number of flashes near a service (N_l)

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

$$N_l = N_g\ A_i\ C_e\ C_t\ 10^{-6} \quad \text{(A.9)}$$

with

- N_g lightning ground flash density (flash/km^2.year)
- A_i collection area of flashes to ground near the service(m^2) (see Table A.2 and Figure A.3)
- C_e environmental factor **(**see Table A.4).
- C_t correction factor for the presence of a HV/LV transformer located between the point of strike and the structure(see Table A.3). This factor applies to line sections upstream the transformer respect to the structure.
-

Table A.4 Environmental factor C_e

Environment	C_e
Urban	0
Suburban	0,5
Rural	1

NOTE -The collection area A_i of the service is defined by its length L_c and by the lateral distance D_i (see Figure A.3) at which a lightning strike near the service may cause induced overvoltages not lower than 1,5 kV.

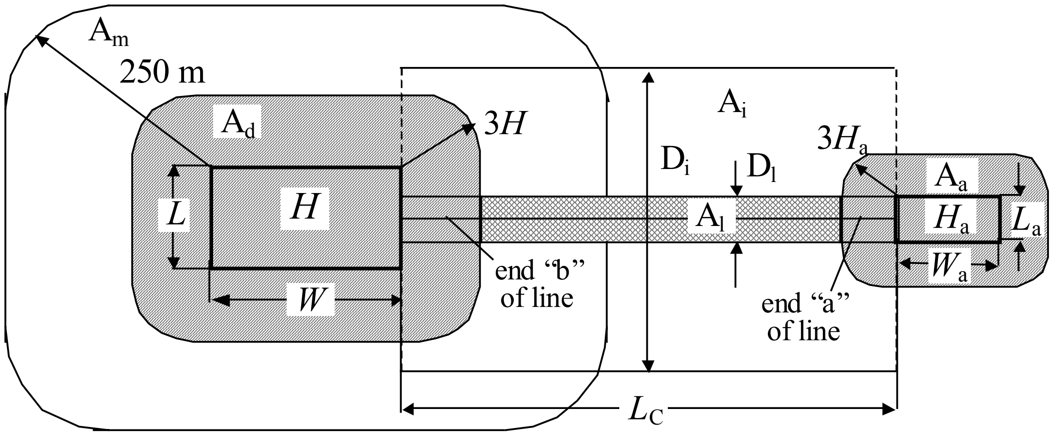

Figure A.3 – Collection areas (A_m, A_i, A_l)

ANNEX B

(Informative)

Assessment of probability P of damage for a structure

The probabilities given in this Annex are valid if protection measures comply with:

- IEC 62305-3 for protection measures to reduce injuries to living beings and for protection measures to reduce physical damages
- IEC 62305-4 for protection measures to reduce failures of internal systems

Other values may be chosen if justified.

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

B.1 Probability P_A that a lightning will cause injuries to living beings

The values of probability P_A of shock to human beings due to touch and step voltage by strike to the structure are reported in Table B.1 as a function of typical protection measures:

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

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

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

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

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

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

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

Table B.2 Values of P_B depending on the protection measures to reduce physical damages

Characteristics of structure	LPL	P_B
Structure not protected by an LPS	–	1
Structure protected by an LPS or structure with continuous metal or reinforced concrete framework acting as natural LPS, bonding and earthing included	IV	0,2
	III	0,1
	II	0,05
	I	0,02

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

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

$$P_C = P_{SPD} \quad (B.1)$$

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

Table B.3 – Value of the probability P_{SPD} depending on LPL for which SPD are designed

LPL	P_{SPD}
No SPD set	1
III-IV	0,03
II	0,02
I	0,01

NOTE 1 – Only an SPD set is suitable as protection measure to reduce P_C.

NOTE 2– Internal systems connected to external lines consisting in lightning cable or leaded into metallic conduit or tube, may not require the use of SPD at the entrance of the service.

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

The probability P_M that a lightning flash near a structure will cause failure of internal systems depends on the adopted lightning protection measures (LPM), according to factor K_{MS} (see Table B.4).

When LPM are provided, value of P_M is the lowest between P_{SPD} and P_{MS}.

The values of P_{MS} as function of K_{MS} are reported in Table B.4, where K_{MS} is a factor taking into account the performances of the adopted protection measures.

Table B.4 – Value of the probability P_M depending on factor K_M

K_{MS}	P_{MS}
≥ 0,4	1
0,15	0,9
0,07	0,5
0,035	0,1
0,021	0,01
0,016	0,005 (*)
0,015	0,003 (*)
0,014	0,001 (*)
≤ 0,013	0,0001 (*)
(*) Value of probability affected by poor accuracy	

For internal systems with equipment not complying with the relevant EMC immunity product standards P_{MS} = 1 shall be assumed.

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

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

where :

- K_{S1} takes into account the screening effectiveness of the structure, LPS or other shields at boundary LPZ 0/1;
- K_{S2} takes into account the screening effectiveness of shields internal to the structure at boundary LPZ X/Y (X>0,Y>1);
- K_{S3} takes into account the characteristics of internal wiring (Table B.5).
- K_{S4} takes into account the impulse withstand voltage of the system to be protected .

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

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

being w [m] the mesh width of grid-like spatial shield or of mesh type LPS down conductors or the spacing between the structure metal columns or between reinforced concrete framework acting as natural LPS.

For shields of full continuous metal sheath $K_{S1} = K_{S2} = 10^{-4}$-$10^{-5}$ shall be assumed, ranging the thickness s of the shield from s=0,1mm to 0,5 mm.

Where induced loop is running close to the LPZ boundary screen conductors at distance to the shield shorter than the safety distance, the values of K_{S1} and K_{S2} are higher. For instance, for distances to the shield ranging from 0,1 w to 0,2 w the values of K_{S1} and K_{S2} have to be doubled.

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

NOTE – The maximum value of K_{S1} is limited to 1.

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

Type of internal wiring	K_{S3}
Unshielded cable- No routing precaution in order to avoid loops (*)	1
Unshielded cable- Routing precaution in order to avoid large loops (**)	0,2
Unshielded cable- Routing precaution in order to avoid loops (***)	0,02
Shielded cable with screen resistance (1) R ≥5 Ω / km	0,1
Shielded cable with screen resistance (1) 1 ≤ R < 5 Ω / km	0,02
Shielded cable with screen resistance (1) R <1 Ω / km	0,01
1) Cable with screen of resistance R (Ω / km) bonded to equipotential bonding bar at both ends and equipment connected to the same bonding bar. (*) Loop conductors with different routing in large buildings. (**) Loop conductors routing in the same conduit or loop conductors with different routing in small buildings. (***) Loop conductors routing in the same cable.	

For wiring running in continuous metal conduit bonded to equipotential bonding bar at both ends, K_{s3} values shall be multiplied by 0,1.

Factor K_{S4} shall be evaluated as:

$$K_{S4} = 1{,}5 / U_w \qquad \text{(B.4)}$$

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

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

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

The values of probability P_U of injuries to living beings due to touch voltage by a flash to a service entering the structure depend on the characteristics of service shield, on the impulse withstand voltage of internal systems connected to the service, on typical protection measures (physical restrictions, warning notices, etc. – see Table B.1) and on SPD provided at the entrance of the service (see Table B.6).

When SPD(s) are provided for equipotential bonding according to IEC 62305-3, the value of P_U is the lowest between P_{SPD} (Table B.3) and P_{LD}. Values of P_{LD} are reported in Table B.6.

NOTE – An entire SPD set according to IEC 62305-4 is not necessary here to reduce P_U. SPD(s)according to IEC 62305-3 are sufficient.

Table B.6 – Value of the probability P_{LD} depending on resistance R of the cable screen and the impulse withstand voltage U_w of the equipment.

U_w (kV)	$R_s \geq 5$ (Ω / km)	$5 > R_s \geq 1$ (Ω / km)	$R_s < 1$ (Ω / km)
1,5	1	0,9	0,8
2,5	0,4	0,1	0,04
4	0,2	0,05	0,006 (*)
6	0,05	0,02	0,003 (*)
R_s (Ω / km): resistance of the cable shield (*)Value of probability affected by poor accuracy			

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

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

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

The values of probability P_V of physical damages by a flash to a service entering the structure depend on the characteristics of service shield, on the impulse withstand voltage of internal systems connected to the service and on SPD provided (see Table B.6).

When an SPD(s) is provided for equipotential bonding according to IEC 62305-3, value of P_V is the lowest between P_{SPD} (Table B.3) and P_{LD}. Values of P_{LD} are reported in Table B.6.

NOTE – An entire SPD set according to IEC 62305-4 is not necessary here to reduce P_V. SPD(s)according to IEC 62305-3 are sufficient.

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

The values of probability P_W that a flash striking a service entering the structure will cause a failure of internal systems depend on the characteristics of service shielding, on the impulse withstand voltage of internal systems connected to the service and on SPD provided (see Table B.6).

When an SPD set is provided, value of P_W is the lowest between P_{SPD} (Table B.3) and P_{LD}. Values of P_{LD} are reported in Table B.6.

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

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

When an SPD set is provided, the value of P_Z is the lowest between P_{SPD} (Table B.3) and P_{LI}. Values of P_{LI} are reported in Table B.7.

Table B.7 – Value of the probability P_{LI} depending on resistance R of the cable screen and the impulse withstand voltage U_w of the equipment.

U_w (kV)	No screen	R_s ≥5 (Ω/km)	5 > R_s ≥1 (Ω/km)	R_s <1 (Ω/km)
1,5	1	1	0,9	0,8
2,5	0,6	0,4	0,1	0,04
4	0,4	0,2	0,05	0,006(*)
6	0,25	0,05	0,02	0,003(*)
R_s : resistance of the cable shield (Ω / km) (*) Value of probability affected by poor accuracy				

ANNEX C
(Informative)

Assessment of amount of loss L for a structure

The values given in this Annex are values proposed by IEC. Other values may be chosen if based on calculations and documented assumptions.

C.1. Average relative amount of loss per year

The loss L refers to the mean relative amount of a peculiar type of damage, its extent and the consequential effects , which may occur as the result of a lightning strike. Its value depends on:
- the number of persons and the time for which they remain in the hazardous place;
- the type and importance of the service provided to the public;
- the value of the goods affected by the damage.

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

L_t loss due to injuries by touch and step voltages
L_f loss due to physical damages
L_o loss due to failure of internal systems.

C.2. Loss of human life

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

$$L_x = n_p / n_t * t_p / 8760 \quad \text{(C.1)}$$

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

Typical mean values of L_t, L_f and $L_{o,}$ which may be assumed when the determination of n, n_t and t is uncertain or difficult, are reported in Table C.1.

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

Type of structure	L_t
All – Inside buildings	10^{-4}
All – Outside buildings	10^{-2}

Type of structure	L_f
Hospitals, Hotels, Civil buildings	10^{-1}
Industrial, Commercial, School	$5 \cdot 10^{-2}$
Public entertainment, Churches, Museum	$2 \cdot 10^{-2}$
Others	10^{-2}

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

Loss of human life are affected by structure characteristics which are taken into account by increasing (h) and decreasing ($r_{f,}$ r, r_a) factors as follows:

$$L_A = r_a L_t \qquad (C.2)$$

$$L_U = r_a L_t \qquad (C.3)$$

$$L_B = L_V = r\, h\, r_f L_f \qquad (C.4)$$

$$L_C = L_M = L_W = L_Z = L_o \qquad (C.5)$$

where

- r_a is a factor reducing the loss of human life depending on the type of soil or floor (see Table C.2)
- r is a factor reducing the loss due to physical damage depending on the provisions taken to reduce the consequences of fire (see Table C.3)
- r_f is a factor reducing the loss due to physical damage depending on the risk of fire of the structure (see Table C.4)
- h is a factor increasing the loss due to physical damage in presence of special hazard (see Table C.5)

Table C.2 – Values of reduction factor r_a depending on the type of soil or floor

Type of soil or floor	Contact resistance (k Ω)*	r_a
Agricultural, Concrete	≤ 1	10^{-2}
Marble, Ceramic	1 - 10	10^{-3}
Gravel, Moquette, Carpets	10 - 100	10^{-4}
Asphalt, Linoleum, Wood	≥ 100	10^{-5}
(*) Values measured between a 400 cm^2 electrode compressed with force of 500 N and a point of infinity.		

Table C.3 – Values of reduction factor r depending on provisions taken to reduce the consequence of fire

Provisions	r
No provisions	1
One of the following provisions: extinguishers, fixed manually operated extinguishing installations, manual alarm installations, hydrants, fire proof compartments, protected escape routes ;	0,5
One of the following provisions: fixed automatically operated extinguishing installations, , automatic alarm installations(*);	0,2
(*) only if protected against overvoltages or other damages and time of fire men operation is t < 10 min;.	

If more than one provision has been taken, the value of r is the lowest between the individual values. In structures with risk of explosion , r = 1 in all cases.

Table C.4 – Values of reduction factor r_f depending on risk of fire of structure

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

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

NOTE 2 - Structures with high risk of fire may be assumed **s**tructures made by combustible materials, or structures with roof made of combustible materials or structures with a specific fire load larger than 800 MJ/m2

NOTE 3 - Structures with ordinary risk of fire may be assumed structures with a specific fire load between 800 and 400 MJ/m2

NOTE 4 - Structures with low risk of fire may be assumed structures with a specific fire load less than 400 MJ/m2, or structures containing combustible materials only occasionally

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

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

Kind of special hazard	h
No special hazard	1
Low level of panic (structure limited to two floors and the number of persons not greater than 100)	2
Average level of panic (structures designed for cultural or sport events with a number of participants between 100 and 1000 persons)	5
Difficulty of evacuation (structures with immobilised persons)	5
High level of panic (structures designed for cultural or sport events with a number of participants greater than 1000 persons)	10
Hazard for surroundings or environment	20
Contamination of surroundings or environment	50

C.3. Unacceptable loss of service to the public

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

$$L_x = n_p / n_t * t / 8760 \qquad (C.6)$$

where

n_p is the mean number of possible endangered persons (users not served);
n_t is the total number of persons (users served);
t is the annual period of loss of service, in hours.

Typical mean values of Lf and Lo, which may be assumed when the determination of n, nt and t is uncertain or difficult, are reported in Table C.6.

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

Type of service	L_f	L_o
Gas, Water	10^{-1}	10^{-2}
TV, TLC, Power Supply	10^{-2}	10^{-3}

Loss of service to the public are affected by structure characteristics and by decreasing factors (r) as follows:

$$L_B = L_V = r\ r_f\ L_f \qquad (C.7)$$

$$L_C = L_M = L_W = L_Z = L_o \qquad (C.8)$$

being the values of factors reported in:

- r in Table C.3
- r_f in Table C.4

C.4. Loss of irreplaceable cultural heritage

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

$$L_x = c / c_t \qquad (C.9)$$

where

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

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

Typical mean values of L_f, which may be assumed when the determination of n, n_t and t for museum or gallery is uncertain or difficult is:

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

Loss of irreplaceable cultural heritage are affected by structure characteristics by decreasing factors (r) as follows:

$$L_B = L_V = r\ r_f\ L_f \qquad (C.10)$$

being the values of factors reported in:

- r in Table C.3
- r_f in Table C.4

C.5. Economic loss

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

$$L_x = c / c_t \qquad (C.11)$$

where

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

Typical mean values of L_t, L_f and L_o for all types of structures, which may be assumed when the determination of n, n_t and t is uncertain or difficult, are:

$$L_t = 10^{-2}$$
$$L_f = 10^{-1}$$
$$L_o = 10^{-3}$$

Loss of economical values are affected by structure characteristics by increasing (h) and decreasing (r, r_a, r_f) factors as follows:

$$L_A = r_a L_t \tag{C.12}$$

$$L_B = L_V = r\, r_f\, h\, L_f \tag{C.13}$$

$$L_C = L_M = L_W = L_Z = L_o \tag{C.14}$$

being the values of factors reported in:

- r_a in Table C.2
- r in Table C.3
- r_f in Table C.4
- h in Table C.5

ANNEX D

(Informative)

Assessment of probability P' of damage for a service

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

The probabilities given in this Annex are valid if protection measures comply with IEC 62305-5.

D.1 Lines with metallic conductors

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

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

For unshielded lines $I_a = 0$ shall be assumed.

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

$$I_a = 25\ n\ U_w / (R_s\ K_d\ K_p) \qquad (D.1)$$

being

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

NOTE 1 - For strikes to structures to which the line is connected, a more precise evaluation of the failure current (I_a) could be carried out with the following procedure:

a) unshielded line

– to calculate the current entering the conductor I_c, which causes damage to the cable, using the following equation:

$$I_c = 8\ S_c \ [kA] \qquad (D.2)$$

where S_c is the cross-section area of the conductor in square millimetres

– using this I_c value, the lightning current I_a is estimated as follows:

$$I_a = 2\ n\ m\ I_c = 16\ n\ m\ S_c \quad [kA] \qquad (D.3)$$

where m is the number of telecommunication line conductors.

– alternatively, using the breakdown voltage U_w value, the failure current I_a is estimated as follows:

$$I_a = 2\ n\ m\ U_w\ L_c\ (R_s\ l_c) \qquad (D.4)$$

where

R_s is the resistance per unit length [Ω/km]; and

L_c is the length of the service (distance between the structure and the closest earthing point of the conductor) [km];

b) shielded line

– to calculate the breakdown sheath current, I_s as follows:

$$I_s = U_w\ 106 / (R_s\ L_c) \quad [A] \qquad (D.5)$$

where

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

R_s is the resistance per unit length of the cable sheath [Ω/km]

L_c is the length of the cable (m); its value is the following:

$L_c = 8\sqrt{\rho}$ for the shield in contact with the soil having a resistivity of ρ [Ωm];

L_c is the distance between the structure and the closest earthing point of the shield.

– using this I_s value, the failure current, I_a, is estimated as follows:

$$I_a = 2\ n\ I_s = 2\ n\ U_w\ 106\ /\ (R_s\ L_c) \quad [A] \qquad (D.6)$$

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

Line	Aerial	Buried
Not shielded	1	1
Shielded	1	0,4

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

Protection measure	K_p
Additional shielding wires - One conductor	0,6
Additional shielding wires - Two conductors	0,4
Lightning cable	0,02
Additional shielding wires- Steel tube	0,01

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

Type of cable insulation	U_w (kV)
Paper	1,5
PVC, PE, etc.	5

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

Type of equipment	U_w (kV)
Electronic	1,5
Electrical	2,5

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

When SPD, complying with IEC 62305-5 are provided, values of P'_B and P'_C are the value of P_{SPD} (Table B.3) .

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

I_a (kA)	P'_B , P'_C, P'_V , P'_W
3	0,99
5	0,95

10	0,9
20	0,8
30	0,6
40	0,4
50	0,3
60	0,2
80	0,1
100	0,05
150	0,02
200	0,01
300	0,005(*)
400	0,002(*)
600	0,001(*)
(*)Value of probability affected by poor accuracy	

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

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

For unshielded lines $I_a = 0$ shall be assumed.

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

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

being

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

In evaluation of P'_V for telecommunication lines, maximum values of failure current I_a to be assumed are:

– I_a = 40 kA for cables with lead shield ;
– I_a = 20 kA for cables with aluminium shield.

NOTE 1– These values are a rough estimation of the test current (I_t) damaging typical telecommunication cables in the striking point. If there's any evidence that these values are not applicable for a given cable design, the tests described in the IEC 62305-5 standard should be used for the evaluation of the failure current.

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

NOTE 2 - For shielded cables a more precise evaluation of the failure current I_a may be carried out as follows:

$$I_a = 2\ I_s \qquad \text{(D.8)}$$

being I_s the sheath breakdown current evaluated according to the following procedure:

a) Buried cable

The sheath breakdown current (I_s) of the cable with metallic sheath, with or without an insulating protective covering, may be estimated with the following equation:

$$I_s = 10^3\ U_w\ L_c\ (8\ \ R_s\ \rho^{1/2}) \quad [\text{kA}] \qquad \text{(D.9)}$$

R_s is the sheath resistance per unit length [Ω/km]
U_w is the impulse withstand voltage of cable, (kV) (see Table D.3 for cables and Table D.4 for apparatus);
ρ is the soil resistivity (Ω.m)

b) Aerial cable

The sheath breakdown current (I_s) is calculated by the following equation:

$$I_s = 10^3 U_w L_c (K R_s \rho_e^{1/2}) \quad (D.10)$$

ρ_e is the effective earth resistivity in Ω.m, which is defined as:

$$\rho_e = \pi d R_g L_c \ln(2H_c / b) \quad (D.11)$$

d is the spacing between earthing points, in metres (d is assumed to be short, so that reflections occur long before the crest voltage or current is reached)
H_c is the height of the cable in metres
b is the radius of the cable in metres
R_g is the resistance of the earthing points in Ω.

When SPD, complying with IEC 62305-5 are provided, values of P'_V and P'_W are the value of P_{SPD} (Table B.3).

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

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

When SPD complying with IEC 62305-5 are provided, value of P'_Z is the lowest between P_{SPD} (Table B.3) and P_{LI} (see Table B.7).

D.2 Fibre optic lines

(Under consideration)

D.3 Pipes

(Under consideration)

ANNEX E
(Informative)

Assessment of amount of loss L' for a service

E.1. Average relative amount of loss per year

The loss L refers to the mean relative amount of a peculiar type of damage, its extent and the consequential effects , which may occur as the result of a lightning strike. Its value depends on:
- the type and importance of the service provided to the public;
- the value of the goods affected by the damage.

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

L'_f loss due to physical damages
L'_o loss due to failure of internal systems.

E.2. Unacceptable loss of service to the public

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

$$L'_x = n/ n_t * t/ 8760 \quad (E.1)$$

where
n is the mean number of users not served;
n_t is the total number of users served;
t is the annual period of loss of service, in hours.

Typical mean values of L'_f and L'_o, which may be assumed when the determination of n, n_t and t is uncertain or difficult, are reported in Table E.1.

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

Type of service	L'_f	L'_o
Gas, Water	10^{-1}	10^{-2}
TV, TLC, Power Supply	10^{-2}	10^{-3}

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

$$L'_B = L'_V = L'_f \quad (E.2)$$

$$L'_C = L'_W = L'_Z = L'_o \quad (E.3)$$

E.3. Economic loss

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

$$L'_x = c / c_t \quad (E.4)$$

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

c_t is the total value of the structure, its content and of relevant activities, in currency.

Typical mean values of L'_f and L'_o, which may be assumed for all types of services when the determination of n, n_t and t is uncertain or difficult, are:

$$L'_f = 10^{-1}$$

$$L'_o = 10^{-3}$$

Loss of economical values are affected by service characteristics as follows:

$$L'_B = L'_V = L'_f \quad (E.5)$$

$$L'_C = L'_W = L'_Z = L'_o \quad (E.6)$$

ANNEX F
(Informative)

Switching overvoltages

Internal overvoltages can appear due to different causes, but one of them is, for instance, a short circuit due to lightning sparkover, which often can lead to the temporary and switching overvoltages. For this reason and for the reason of general hazard the consideration on protection against internal overvoltages is justified.

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

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

As a matter of fact, there are two types of switching surges :

- the repetitive ones (volunteer operating of circuit breakers or alike, switching of capacitors banks...); they are occurring quite frequently based on regular decision from a human being or more often from an automatism. This frequency is ranging from 1 or 2 times per day to many times per day in case of an arc soldering machine for example. The frequency of occurrence and the magnitude of these surges (or their effect on electrical devices) are in general well known, especially based on experience.
  In such cases, most of the time, the decision to protect equipment or not is taken on a deterministic basis and no risk analysis is useful;

- the random ones (operating of circuit breakers or fuses to clear a fault, for example). In this case their frequency is by definition unknown and their amplitude and effect on the electrical equipments may be unknown as well.
  In this case, a risk assessment may help to decide if a protection is needed against this source of damage.

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

In low voltage systems switching overvoltages are expected to be lower than 4 kV and only 2 per 1000 have a magnitude exceeding 2.5 kV. Based on the total estimated or measured switching overvoltages which may happen per year (n_s), we can derived the total number N_s per year which is in excess of 2.5 kV (but lower than 4 kV) by the following equation:

$$N_s = 0{,}002\ n_s \qquad \text{(F.1)}$$

The probability of damage P, the factors K_{si} taking into account the effect of protection measures and the reduction factor r as well the amount of the damage L are the same as for the lightning induced surges (see item 3) and Annexes B and C apply.

ANNEX G
(Informative)

Evaluation of costs of loss

The cost of total loss $\mathbf{C_L}$ may be calculated by the following formula:

$$\mathbf{C_L} = (R_B + R_V)(C_B+C_S+C_C) + (R_C + R_M + R_W + R_Z)\, C_S \quad \text{(G.1)}$$

being

- R_B and R_V the risk components related to physical damages, without protection measures,
- R_C , R_M , R_W and R_Z the risk components related to failure of electrical and electronic systems, without protection measures,
- C_S the cost of systems in the structure,
- C_B the cost of the building,
- C_C the cost of the contents.

If $\mathbf{C_{RL}}$ is the total cost of residual loss in spite of protection measures, its value is:

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

being

- R'_B and R'_V the risk components related to physical damages, with protection measures,
- R'_C , R'_M , R'_W and R'_Z the risk components related to failure of electrical and electronic systems, with protection measures,

Assuming $\mathbf{C_{PM}}$ the annual cost of a protection measures to be adopted, protection is convenient if

$$\mathbf{C_L > C_{PM} + C_{RL}} \quad \text{(G.3)}$$

The annual cost of protection measure may be calculated by means of the formula:

$$\mathbf{C_{PM} = C_P (i_r + a_r + m_r)} \quad \text{(G.4)}$$

being

- $\mathbf{C_P}$ the cost of protection measures,
- $\mathbf{i_r}$ the interest, $\mathbf{a_r}$ the amortization and $\mathbf{m_r}$ the maintenance rates.

ANNEX H
(Informative)

Case study for structures

This Annex is divided in two parts.
In the first part – H.0 - general rules are presented for calculation of some quantities related to the risk assessment. In particular the following cases are considered:

- calculation of collection area A_d of a complex shape structure
- zones definition in a structure
- risk evaluation in a multi-zone structure.

In the second part – H.1 - case studies relevant to a dwelling house, an office building, a hospital and an apartment house, are developed with the aim to show:

- the way of calculation of the risk and to ascertain the need of protection;
- the contribution of different risk components to the overall risk;
- the effect of different protection measures to mitigate such risk;
- the way of selection among different protection solutions taking into account the economic convenience.

H.0 General rules

H.0.1 Collection area A_d of a complex shape structure

For isolated structures on a flat ground the collection area A_d is the area enclosed within the border line obtained from 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 (see Figure 6).

If the structure has a regular shape, a simple way to evaluate A_d is to assume as structure the parallelepiped shape enveloping it.
For an isolated parallelepiped structure with length *L*, width *W* and height *H* on a flat ground, the collection area is then equal to:

$$A_d = LW + 6\,H\,(L + W) + 9\pi\,(H)^2$$

being *L,W* and *H* expressed in meters.
Values of A_d evaluated in this way are, on safety side, greater those given by the standard way (see Table.H.0.1) .

If the structure has a complex shape, a graphic method should be used (see Fig.H.0.2), because the differences with the simplified method may be too high (see Table.H.0.1) .

As study case let evaluate the collection area A_d of a church (see Fig.H.0.1) having the following dimensions, in meters:

Nave: *L = 70; W = 30; H = 25*
Bell tower: *L = 8; W = 8; H = 40*

Values of A_d according to evaluation way are reported in Table H.0.1.

Table H. 0.1 – Values of A_d according to evaluation way

	Real shape	**Parallelepiped shape**
Structure dimensions ***(L, W, H)*** **(m)**	(see Fig.H.0.1)	70 · 30 · 40
A_d (m^2)	47700 (see Fig.H.0.2)	71316

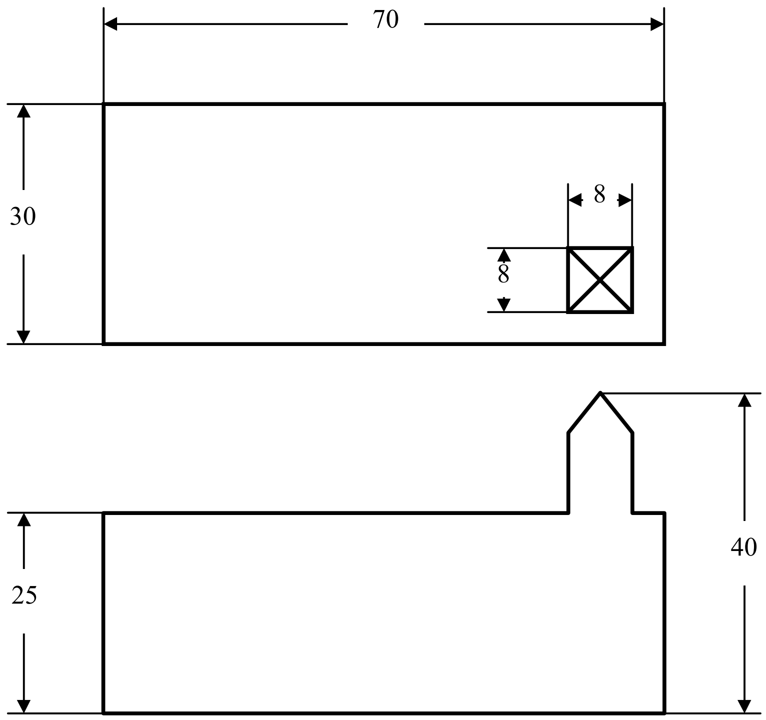

Fig. H.0.1 – Complex shape structure

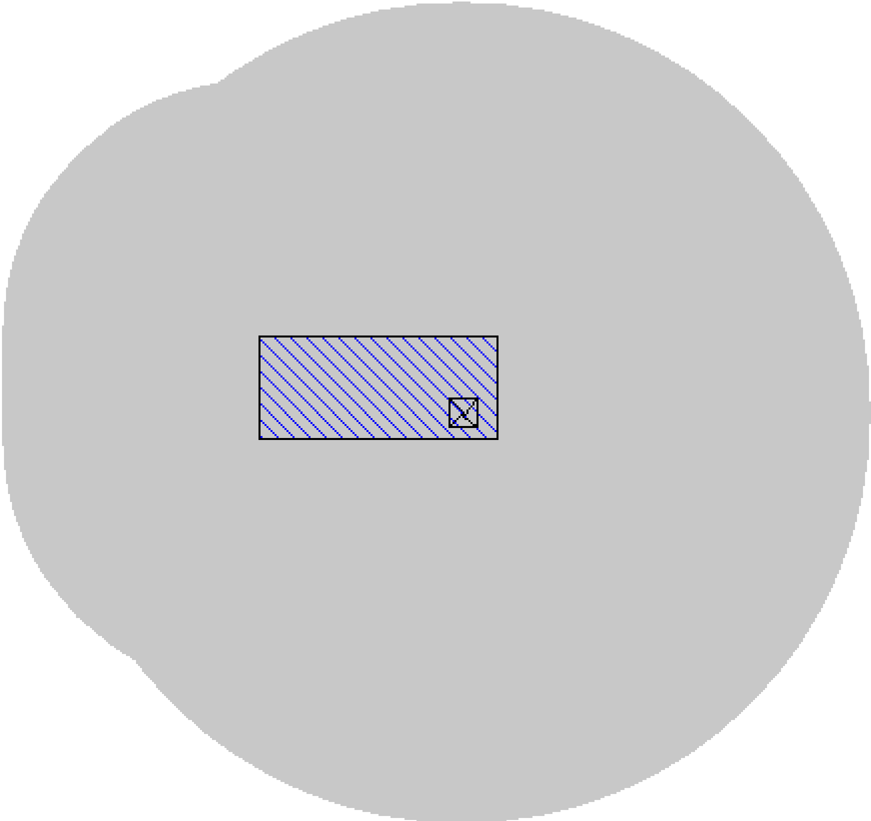

Fig. H.0.2 – Collection area A_d of structure of Fig.H.0.1

H.0.2 Zones definition in a structure

A zone (Z_S) of a structure is a part of a structure whit homogeneous characteristics where only one set of parameters is involved in assessment of a risk component (see 3.29).

Main zones should be defined by:

- Type of soil or of floor (components $\mathbf{R_A}$ and $\mathbf{R_U}$);
- Fire proof compartments (components $\mathbf{R_B}$ and $\mathbf{R_V}$);
- Spatial shields (components $\mathbf{R_C}$, $\mathbf{R_M}$, $\mathbf{R_W}$ and $\mathbf{R_Z}$).

Further zones may be defined according to:

- Layout of internal systems;
- Protection measures existing or to be provided;
- Losses L values.

H.0.3 Risk evaluation in a multi-zone structure

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

A) Risks R_1, R_2 and R_3

A1) Single zone structure

In this case only one zone Z_S is defined in the structure, which coincide with the whole structure itself. According to 6.7, risk **R** is the sum of risk components $\mathbf{R_x}$ in the structure. For the evaluation of risk components and the selection of the relevant parameters involved , the following rules apply :

- Parameters relevant to number N of dangerous event will be evaluated according to Annex A
- Parameters relevant to the probability P of damage will 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 involved parameter. Where more than one value is applicable, the highest one is to 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:

    $P_C = 1 – (1- P_{C1}) (1- P_{C2}) (1- P_{C3})$ …….
    $P_M = 1 – (1- P_{M1}) (1- P_{M2}) (1- P_{M3})$ ……

    being P_{Ci}, P_{Mi} parameters relevant to internal system i

- Parameters relevant to the amount L of loss

  Value of L should be evaluated according to Annex C.
  The typical mean values of Annex C may be assumed for the zone as default, according to the use of structure.

To assume the structure as a single zone may lead to expensive protection measures because it shall be extended to the whole structure.

A2) Multi-zone structure

In this case structure is divided in zones Z_S. According to 6.7 risk $\mathbf{R}_{(structure)}$ for the structure is the sum of the risks $\mathbf{R}_{(zone)}$ relevant to all zones of structure; in each zone, risk $\mathbf{R}_{(zone)}$ is the sum of the relevant risk components $\mathbf{R}_{\mathbf{x}(zone)}$ in the zone.
For the evaluation of risk components and the selection of the relevant parameters involved , the following rules apply :

- Parameters relevant to number N of dangerous event will be evaluated according to Annex A
- Parameters relevant to the probability P of damage will be evaluated according to Annex B
- Parameters relevant to the amount L of loss

Value of L should be evaluated according to Annex C for each zone.

To divide the structure in 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.

B) Risk R_4

Being the protection against lightning needed or not needed in order to reduce the 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 among :

- the whole structure ;
- a part of the structure ;
- an internal installation ;
- a part of an internal installation ;

an equipment ;
a peculiar good in the structure .

Cost of loss in a zone is to be evaluated according to Annex G; the cost of loss for the structure is the sum of cost of loss of zones of structure.

H.1 Case study for structures

The following structures with relevant risk components and tolerable risk values are considered:

H.1.1 Country house

H.1.2 Office building

H.1.3 Hospital

H.1.4 Apartment house

H.1 Country house

As first study case let us consider a country house for which the need of protection has to be evaluated.
For this aim risk R_1 of loss of human life (components of R_1 according to 4.2.1 and Table 1) shall be determined and compared with the tolerable value $R_T = 10^{-5}$ (according to 4.3.3 and Table 5).

H.1.1 Relevant data and characteristics

Data and characteristics of:

1) the house itself and its surroundings are presented in Table H.1.1;

2) internal electrical and electronic equipment and incoming services to which they are connected are presented in Table H.1.2.

Table H.1.1. Structure data and characteristics

Parameter	Comment	Symbol	Value	Reference
Dimensions (m)	-	(L_b, W_b, H_b)	15, 20, 6	
Location factor	Isolated[1)]	C_d	1	Table A.1
Floor type	Wood	r_a	0,00001	Table C.2
Soil surface type	Grass	r_a	0,01	Table C.2
Fire conditions	low	r_f	0,001	Table C.4
Special hazard	None	h	1	Table C.5
Fire protection	None	r	1	Table C.3
Injuries protection	None	P_A	1	Table B.1
LPS	None	P_B	1	Table B.2
People outside the house	None2)			
Lightning flash density	1/km2/year	Ng	4	-

[1)] flat territory, no neighbouring structures; [2)] risk of shock of people $R_A = 0$

Table H.1.2. Data and characteristics of incoming lines and internal equipment

Parameter	Comment	Symbol	Value	Reference
Lightning flash density	1/km²/year	N_g	4	-
Overhead LV power line and internal equipment				
Length (m)		L_c	1000	
Height (m)	buried	H_c	-	
Transformer	none	C_t	1	Table A.3
Line location factor[1)]	isolated	C_d	1	Table A.1
Line environment factor	rural	C_e	1	Table A.4
Line shielding	none	P_{LD}	1	Table B.6
		P_{LI}	0,6	Table B.7
Withstand of equipment[2)]	U_w = 2,5 kV	K_{S4}	0,6	Item B.3
Internal wiring precaution	none	K_{S3}	1	Table B. 4
SPD set	none	P_{SPD}	1	Table B.2
Overhead telecom line and internal electronic equipment				
Length (m)		L_c	1000	
Height (m)		H_c	6	
Line location factor[1)]	isolated	C_d	1	Table A.1
Line environment factor	rural	C_e	1	Table A.4
Line shielding	none	P_{LD}	1	Table B.6
		P_{LI}	1	Table B.7
Internal wiring precaution	none	K_{S3}	1	Table B.4
Withstand of equipment[2)]	U_w = 1,5 kV	K_{S4}	1	Item B.3
SPD set	none	P_{SPD}	1	Table B.2
Water pipes (non metallic and not taken into account)				

[1)] flat territory, lines insulated (no neighbouring structures, no adjacent structures connected to the external end (end “a”) of the lines (N_{Da} = 0); [2)] equipment connected to the lines;

H.1.1 Zone definition

Taking into account that:

- Type of soil is different outside and inside the structure;
- Structure is a unique fire proof compartment;
- No spatial shields exist;

the following main zone may be defined:

- **Z_1** (outside the building)
- **Z_2** (inside the building)

No further zones should be defined taking into account that:

– Both internal systems (Power and Telecom) cover all zone $Z_{2;}$
– Losses L are assumed to be constant in zone Z_2;

No people is attending in outside the building; risk $\mathbf{R_1}$ for zone $\mathbf{Z_1}$ may be disregarded.

H.1.2 Calculation of relevant quantities

1) calculations of collection areas are presented in Table H.1.3
2) calculations of expected numbers of dangerous events are in Table H.1.4;
3) assessment of expected annual loss are in Table H.1.5.

Table H.1.3 Collection areas of structure and lines

Symbol of area	Number of formula or Table	Formula for collection area	Data of Table	Value (m^2)
A_d	(A.2)	to the Structure: $A_d = [L_b W_b + 6H_b (L_b + W_b) + \pi (3H_b)^2]$	H.1.1	2578
$A_{l(P)}$	(Table A.2)	to the power line: $A_{l(P)} = 15 \cdot [L_c - 3H_b]$	H.1.2	14745
$A_{i(P)}$	(Table A.2)	near the power line: $A_{I(P)} = 500 \cdot L_c$	H.1.2	500000
$A_{l(T)}$	(Table A.2)	to the telecom line: $A_{l\,(T)} = 6H_c \cdot [L_c - 3H_b]$	H.1.2	28500
$A_{i(T)}$	(Table A.2)	near the telecom line: $A_{i\,(T)} = 1000 \cdot L_c$	H.1.2	1000000

Table H.1.4 – Expected annual number of dangerous events

Symbol of number	Number of formula	Formula for number of flashes	Data of Table	Value (1/year)
N_D	(A.1)	to the structure: $N_D = N_g A_d C_d 10^{-6}$	H.1.1 H.1.3	0,01
$N_{L(P)}$	(A.5)	to the power line: $N_{L(P)} = N_g A_{l\,(P)} C_{d(P)} C_{t(P)} 10^{-6}$	H.1.2 H.1.3	0,059
$N_{i(P)}$	(A.6)	near the power line: $N_{i(P)} = N_g A_{i(P)} C_{t(P)} C_{e(P)} \cdot 10^{-6}$	H.1.2 H.1.3	2
$N_{L(T)}$	(A.5)	to the telecom line: $N_{L(T)} = N_g A_{l(T)} C_{d(T)} C_{t(T)} \cdot 10^{-6}$	H.1.2 H.1.3	0,141
$N_{i(T)}$	(A.6)	near the telecom line: $N_{i(T)} = N_g A_{i(T)} C_{t(T)} C_{e(T)} \cdot 10^{-6}$	H.1.2 H.1.3	4

Table H.1.5 – Expected annual loss

Symbol	Value (1/year)	from	Assumption
L_t	0,0001	Table C.1	default values of Table C.1
L_f	0,1	Table C.1	default values of Table C.1

H.1.3. Risk calculation for decision on need of protection

In the case under consideration the component R_1 should be evaluated.
According to formula (9) it should be expressed by the following sum of components:

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

Involved components and total risk evaluation is reported in Table H.1.6

Table H.1.6 – Risk components involved and their calculation (values x 10^{-5})

Symbol of component	Number of formula or Table	Formula for component at flashes to	Data of Table	Value $\times(10^{-5})$
R_A	Table 7	the structure resulting in shock: $R_A = N_D\ P_A\ r_a\ L_t$	H.1.1 H.1.4 H.1.5	0
R_B	Table 7	the structure resulting in physical damages: $R_B = N_D\ P_B\ h\ r\ r_f\ L_f$		0,103
$R_{U(Power\ line)}$	Table 7	the power line resulting in shock: $R_U = (N_L + N_{Da})\ P_U\ r_a\ L_t$	H.1.1 H.1.2 H.1.4 H.1.5	0,000006
$R_{V(Power\ line)}$	Table 7	the power line resulting in physical damages: $R_V = (N_L + N_{Da})\ P_V\ h\ r\ r_f\ L_f$		0,59
$R_{U(Telecom.\ line)}$	Table 7	the phone line resulting in shock: $R_U = (N_L + N_{Da})\ P_U\ r_a\ L_t$		0,000014
$R_{V(Telecom.\ line)}$	Table 7	the phone line resulting in physical damages: $R_V = (N_L + N_{Da})\ P_V\ h\ r\ r_f\ L_f$		1,41
Total R_1	Table 7	$R_A + R_B + R_{U(p-l)} + R_{V(p-l)} + R_{U(t-l)} + R_{V(t-l)}$	H.1.6	2,11

H.1.4 Conclusion from R1 evaluation

Because R_1 = 2,11 10^{-5} is higher than the tolerable value R_T = 10^{-5} protection against lightning of the house is required.

H.1.5 Selection of protection measures

According to Table H.1.6 the main contributions to the value of risk are given by:

- component $R_{V\ (Telecom\ line)}$ (lightning flash to telecom line) for 48 %;
- component $R_{V\ (Power\ line)}$ (lightning flash to power line) for 28 %;
- component R_B (lightning flash to structure) for 5 %.

To reduce the risk R_1 to a tolerable value, the protective measures influencing the components R_V and the component R_B (Table H.1.6) should be considered. There are two most suitable cases:

a) the SPD of LPL IV at entrance point in the building of both power and telephone lines which – according to table B.3 – reduces the values of P_U and P_V (due to SPD on incoming lines) from 1 to 0,03;

b) the LPS of type IV, which – according to tables B.2 and B.3 – reduces the value of P_B from 1 to 0,2 and the values of P_U and P_V (due to SPD on incoming lines) from 1 to 0,03.

Inserting adequately these values to the formulae of Table H.1.6, one gets new values of risk components as shown in Table H.1.7.

Table H.1.7 - Values of risk components relevant to risk R_1 (values 10^{-5}) for suitable cases

Risk components	Values $\times 10^{-5}$	
	case a)	**Case b)**
R_A	0	0
R_B	0,103	0,0206
$R_{U\ (Power\ line)}$	≈ 0	≈ 0
$R_{V\ (Power\ line)}$	0,018	0,018
$R_{U\ (Telecom\ line)}$	≈ 0	≈ 0
$R_{V\ (Telecom\ line)}$	0,042	0,042
TOTAL	***0,163***	***0,08***

Solution to be adopted is subjected to the best technical/economical convenience.

H.2 Office building

As second study case let us consider an office building for which the need of protection has to be evaluated.
For this aim risk $\mathbf{R_1}$ of loss of human life (components of $\mathbf{R_1}$ according to 4.2.1 and Table 1) shall be determined and compared with the tolerable value $\mathbf{R_T = 10^{-5}}$ (according to 4.3.3 and Table 5).

H.2.1 Relevant data and characteristics

Data and characteristics of:

1) the building itself and its surroundings are presented in Table H.2.1;
2) internal electrical systems and relevant incoming power line are presented in Table H.2.2;
3) of internal electronic systems and relevant incoming telecom line are presented in Table H.2.3.

Table H.2.1 – Structure characteristics

Parameter	Comment	Symbol	Value
Dimensions (m)	-	$(L_b \cdot W_b \cdot H_b)$	40· 20· 25
Location factor	Isolated	C_{db}	1
LPS	none	P_B	1
LPS shield	none	K_{S1}	1
Lightning flash density	1/km2/year	Ng	4

The two internal systems in the building are:
– power system : connected to a LV power line; no protection measures against failures (LEMP Protection Measures: LPM);
– telecom system : connected to a telephone line; no protection measures against failures (LPM).

There are also two non metallic services, namely water pipe and gas pipe, which are not taken into consideration in the following.

Table H.2.2 – Internal power system and relevant incoming power line characteristics

Parameter	Comment	Symbol	Value
Length (m)		L_c	1000
Aerial	yes		
Height (m)		H_c	6
HV/LV trafo	no	C_t	1
Line location factor	isolated	C_d	1
Line environment factor	rural	C_e	1
Line shielding	none	P_{LD}	1
		P_{LI}	0,6
Internal wiring precaution	none	K_{S3}	1
Equipment withstand voltage U_w	U_w = 2,5 kV	K_{S4}	0,6
SPD set	none	P_{SPD}	1
End “a” line structure dimensions (m)	none	(La·Wa·Ha)	-
Structure “a” location factor	-	C_{da}	-

Table H.2.3 – Internal telecom system and relevant incoming line characteristics

Parameter	Comment	Symbol	Value
Length (m)	-	L_c	1000
Aerial	buried	-	-
Height (m)	-	-	-
HV/LV trafo	no	C_t	1
Line location factor	isolated	C_d	1
Line environment factor	rural	C_e	1
Line shielding	none	P_{LD}	1
		P_{LI}	1
Internal wiring precaution	none	K_{S3}	1
Equipment withstand voltage U_w	U_w = 1,5 kV	K_{S4}	1
SPD system	none	P_{SPD}	1
End “a” line structure dimensions (m)	none	(La·Wa·Ha)	-
Structure “a” location factor	-	C_{da}	-

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

Taking into account that:

– Type of soil is different in the entrance area, in the garden and inside the structure;
– Structure and archive are fire proof compartments;
– No spatial shields exist;
– Losses L in the Computer center are assumed lower than those in Offices,

the following main zone may be defined:

- $\mathbf{Z_1}$ (Entrance area to building)
- $\mathbf{Z_2}$ (Garden)
- $\mathbf{Z_3}$ (Archive - it is separated fire-proof compartment)
- $\mathbf{Z_4}$ (Offices)
- $\mathbf{Z_5}$ (Computer centre)

Characteristics of zones are reported in Table H.2.4 for zone $\mathbf{Z_1}$, in TableH.2.5 for zone $\mathbf{Z_2}$, in Table H.2.6 for zone $\mathbf{Z_3}$, in Table H.2.7 for zone $\mathbf{Z_4}$ and in TableH.2.8 for zone $\mathbf{Z_5}$.

Table H.2.4 – Zone Z_1 (entrance area to the building) characteristics

Parameter	Comment	Symbol	Value
Soil type	marble	r_a	0,001
Risk of fire	none	r	0
Special hazard	none	h	1
Fire protection	none	r_f	1
Shock protection	none	P_A	1
Spatial shield	none	K_{S2}	1
Internal systems	none	-	-
Loss by touch and step voltages	yes	L_t	0,0002
Loss by physical damages	none	L_f	-
Loss by failure of internal systems	none	L_o	-

Table H.2.5 – Zone Z_2 (garden) characteristics

Parameter	Comment	Symbol	Value
Soil type	grass	r_a	0,01
Risk of fire	none	r	0
Special hazard	none	h	1
Fire protection	none	r_f	1
Shock protection	fence	P_A	0,001
Spatial shield	none	K_{S2}	1
Internal systems	none	-	-
Loss by touch and step voltages	yes	L_t	0,0001
Loss by physical damages	none	L_f	-
Loss by failure of internal systems	none	L_o	-

Table H.2.6 – Zone Z_3 (archive) characteristics

Parameter	Comment	Symbol	Value
Soil type	linoleum	r_a	0,00001
Risk of fire	high	r_f	0,1
Special hazard	low panic	h	2
Fire protection	none	r	1
Shock protection	none	-	-
Spatial shield	none	K_{S2}	1
Internal power systems	yes	Connected to LV power line	-
Internal telephone systems	yes	Connected to telecom line	-
Loss by touch and step voltages	yes	L_t	0,00001
Loss by physical damages	yes	L_f	0,001
Loss by failure of internal systems	none	L_o	-

Table H.2.7 – Zone Z_4 (offices) characteristics

Parameter	Comment	Symbol	Value
Soil type	linoleum	r_a	0,00001
Risk of fire	low	r_f	0,001
Special hazard	low panic	h	2
Fire protection	none	r	1
Shock protection	none	-	-
Spatial shield	none	K_{S2}	1
Internal power systems	yes	Connected to LV power line	-
Internal telephone systems	yes	Connected to telecom line	-
Loss by touch and	yes	L_t	0,00008

step voltages			
Loss by physical damages	yes	L_f	0,008
Loss by failure of internal systems	none	L_o	-

Table H.2.8 – Zone Z_5 (computer center) characteristics

Parameter	Comment	Symbol	Value
Soil type	linoleum	r_a	0,00001
Risk of fire	low	r_f	0,001
Special hazard	low panic	h	2
Fire protection	none	r	1
Shock protection	none	-	-
Spatial shield	none	K_{S2}	1
Internal power systems	yes	Connected to LV power line	-
Internal telephone systems	yes	Connected to telecom line	-
Loss by touch and step voltages	yes	L_t	0,000008
Loss by physical damages	yes	L_f	0,0008
Loss by failure of internal systems	none	L_o	-

H.2.3 Calculation of relevant quantities

1) calculations of collection areas are presented in Table H.2.9
2) calculations of expected numbers of dangerous events are in Table H.2.10;
3) assessment of expected annual loss are in Table H.2.11.

Table H.2.9 - Collection areas of structure and lines

Symbol	Value (m^2)
A_d	27471
$A_{l\ (Power)}$	33300
$A_{i\ (Power)}$	200000
$A_{l\ (Telecom)}$	13875
$A_{i\ (Telecom)}$	500000

Table H.2.10 - Expected annual number of dangerous events

Symbol	Value (1/year)
N_D	0,11
$N_{L\ (Power)}$	0,133
$N_{i\ (Power)}$	0,8
$N_{L\ (Telecom)}$	0,055
$N_{i\ (Telecom)}$	2

H.2.4. Risk calculation for decision on need of protection

Involved risk components for each zone and total risk evaluation is reported in Table H.2.11

Table H.2.11 - Risk R_1. Values of risk components according to zones (values · 10^{-5})

	Z_1 (entrance area)	Z_2 (garden)	Z_3 (archive)	Z_4 (offices)	Z_5 (computer center)	STRUCTURE
R_A	0,0022	0,011				*0,0132*
R_B			2,2	0,176	0,0176	*2,393*
R_U (Power line)			≈ 0	≈ 0	≈ 0	*≈ 0*
R_V (Power line)			2,66	0,213	0,0213	*2,894*
R_U (Telecom line)			≈ 0	≈ 0	≈ 0	*≈ 0*
R_V (Telecom line)			1,11	0,089	0,0089	*1,2*
TOTAL	*0,0022*	*0,011*	*5.97*	*0,478*	*0,0478*	***6,50***

For the structure risk $\mathbf{R_1} = 6,5 \cdot 10^{-5}$ is higher than the tolerable value $\mathbf{R_T} = 10^{-5}$; it essentially depends on physical damages (risk of fire) in the zone $\mathbf{Z_3}$ (≈ 92% of the total risk).

According to Table H.2.11 the main contributions to the value of risk in the zone $\mathbf{Z_3}$ are given by:

- component R_B (lightning flash to structure) for 34 %;
- component $R_{V\ (Power\ line)}$ (lightning flash to power line) for 41 %;
- component $R_{V\ (Telecom\ line)}$ (lightning flash to telecom line) for 17 %.

Inserting adequately these values to the formulae of Table H.1.6, one gets new values of risk components as shown in Table H.1.7.

H.2.5 Selection of protection measures

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

a) protect the building with an type IV LPS complying with IEC 62305-3, to reduce component R_B. LPS has not the characteristics of a grid-like spatial shield. Parameters in Table H.2.1, H.2.2, H.2.3 will change as follows:
   - P_B = 0,2
   - P_U = P_V = 0,03. (due to SPD on incoming lines)

b) install in the archive (zone **Z_3**)an automatic fire extinguishing (or detection) system, to reduce component R_B and R_V in this zone and SPD of LPL IV at entrance point in the building of both power and telephone lines. Parameters in Table H.2.2, H.2.3, H.2.6 will change as follows:
   - r = 0,2 only for zone **Z_3**
   - P_U = P_V = 0,03. (due to SPD on incoming lines)

Values of risk for each zone according to the solution chosen are reported in Table H.2.12.

Table H.2.12 - Values of risk R_1 according to solution chosen (values · 10^{-5})

	Z_1	Z_2	Z_3	Z_4	Z_5	TOTAL
Solution a)	0,0022	0,011	0,553	0,044	0,0041	***0,614***
Solution b)	0,0022	0,011	0,463	0,185	0,0185	***0,68***

Both solutions reduce the risk below the tolerable value.

Solution to be adopted is subject to the best technical /economical convenience.

H. 3 Hospital

The structure to be considered is a hospital. It includes standard hospital's facilities, an operating bloc and an intensive care unit.
Loss of human life (L1) and loss of economical value (L4) may affect this type of structure. It is required to evaluate the need of protection and the economic convenience of protection measures, so that the risks **R_1** and **R_4** shall be evaluated.

H.3.1 Relevant data and characteristics

Data and characteristics of:

1) the building itself and its surroundings are presented in Table H.3.1;
2) internal electrical systems and relevant incoming HV power line are presented in Table H.3.2;
3) internal electronic systems and relevant incoming telecom line are presented in Table H.3.3;
4) internal LAN not connected to the incoming telephone line are presented in Table H.3.4.

There are also two non metallic services, namely water pipe and gas pipe, which are not taken into consideration in the following.

Table H.3.1 – Structure characteristics

Parameter	Comment	Symbol	Value
Dimensions (m)	-	$(L_b \cdot W_b \cdot H_b)$	50 · 150 · 10
Location factor	Isolated	C_{db}	1
LPS	none	P_B	1
LPS shied	none	K_{S1}	1
Lightning flash density	1/km2/year	Ng	4

Table H.3.2 – – Internal power system and relevant incoming power line characteristics

Parameter	Comment	Symbol	Value
Length (m)		L_c	500
Aerial	buried	-	-
Height (m)	-	-	-
HV/LV trafo	yes	C_t	0,2
Line location factor	surrounded	C_d	0,5
Line environment factor	suburban	C_e	0,5
Line shielding	yes	P_{LD}	0,04
		P_{LI}	0,04
Internal wiring precaution	none	K_{S3}	1
Equipment withstand voltage U_w	U_w = 2,5 kV	K_{S4}	0,6
SPD set	none	P_{SPD}	1
End “a” line structure dimensions (m)	none	(La·Wa·Ha)	-
Structure “a” location factor	-	C_{da}	-

Table H.3.3 – Internal telecom system and relevant incoming line characteristics

Parameter	Comment	Symbol	Value
Length (m)	-	L_c	300
Aerial	buried		
Height (m)	-	-	-
HV/LV trafo	no	C_t	1
Line location factor	surrounded	C_d	0,5
Line environment factor	suburban	C_e	0,5
Line shielding	yes	P_{LD}	0,9
		P_{LI}	0,9
Internal wiring precaution	none	K_{S3}	1
Equipment withstand voltage U_w	U_w = 1,5 kV	K_{S4}	1
SPD set	none	P_{SPD}	1
End “a” line structure dimensions (m)	none	(La·Wa·Ha)	20 · 30 · 5
Structure “a” location factor	isolated	C_{da}	1

Table H.3.4 – Internal LAN system characteristics not connected to an incoming line

Parameter	Comment	Symbol	Value
Internal wiring precaution	yes	K_{S3}	0,2
Equipment withstand voltage U_w	U_w = 1,5 kV	K_{S4}	1
SPD set	none	P_{SPD}	1

H.3.2 Definition of zones in the office building and their characteristics

Taking into account that:

– Type of soil is different outside and inside the structure;
– Structure and operating bloc are fire proof compartments;
– No spatial shields exist;
– The intensive care unity is plenty of sensitive electronic systems and a spatial shield may be adopted as protection measure;
– In the intensive care unity losses L are assumed to be higher than the other parts of structure,

the following main zones may be defined:

- $\mathbf{Z_1}$ (Outside building)
- $\mathbf{Z_2}$ (Rooms bloc)
- $\mathbf{Z_3}$ (Operating bloc)
- $\mathbf{Z_4}$ (Intensive care unity)

Characteristics of zones are reported in Table H.3.5 for zone $\mathbf{Z_1}$, in Table H.3.6 for zone $\mathbf{Z_2}$, in Table H.3.7 for zone $\mathbf{Z_3}$, and in TableH.3.8 for zone $\mathbf{Z_4}$.

Table H.3.5 – Zone $\mathbf{Z_1}$ (Outside Building) **characteristics**

Parameter	Comment	Symbol	Value
Soil type	concrete	r_a	0,01
Risk of fire	none	r	-
Special hazard	none	h	-
Fire protection	none	r_f	-
Shock protection	none	P_A	1
Spatial shield	none	K_{S2}	1
Internal systems	none	-	-
Loss by touch and step voltages	yes	L_t	0,0001
Loss by physical damages	none	L_f	-
Loss by failure of internal systems	none	L_o	-

Table H.3.6 – Zone Z_2 (Rooms bloc) characteristics

Parameter	Comment	Symbol	Value
Soil type	linoleum	r_a	0,00001
Risk of fire	ordinary	r_f	0,01
Special hazard	Medium level of panic	h	5
Fire protection	none	r	1
Shock protection	none	-	-
Spatial shield	none	K_{S2}	1
Internal power systems	yes	Connected to HV power line trough a HV/LV transformer	-
Internal telephone systems	yes	Connected to telecom line	-
Loss by touch and step voltages (relevant to R_1)	yes	L_t	0,00009
Loss by physical damages (relevant to R_1)	yes	L_f	0,09
Loss by failure of internal systems (relevant to R_1)	none	L_o	-
Loss by touch and step voltages (relevant to R_4)	yes	L_t	-
Loss by physical damages (relevant to R_4)	yes	L_f	0,09
Loss by failure of internal systems (relevant to R_4)	yes	L_o	0,0009

Table H.3.7 – Zone Z_3 (Operating bloc) characteristics

Parameter	Comment	Symbol	Value
Soil type	Linoleum	r_a	0,00001
Risk of fire	low	r_f	0,001
Special hazard	Difficulty of evacuation	h	5
Fire protection	none	r	1
Shock protection	none	-	-
Spatial shield	none	K_{S2}	1
Internal power systems	yes	Connected to HV power line trough a HV/LV transformer	-
Internal telephone systems	yes	Connected to telecom line	-
Loss by touch and	yes	L_t	0,000008

step voltages (relevant to R_1)			
Loss by physical damages (relevant to R_1)	yes	L_f	0,08
Loss by failure of internal systems (relevant to R_1)	none	L_o	-
Loss by touch and step voltages (relevant to R_4)	yes	L_t	-
Loss by physical damages (relevant to R_4)	yes	L_f	0,008
Loss by failure of internal systems (relevant to R_4)	yes	L_o	0,00008

Table H.3.8 – Zone Z_4 (Intensive care unity) **characteristics**

Parameter	Comment	Symbol	Value
Soil type	linoleum	r_a	0,00001
Risk of fire	low	r_f	0,001
Special hazard	Difficulty of evacuation	h	5
Fire protection	none	r	1
Shock protection	none	-	-
Spatial shield	none	K_{S2}	1
Internal power systems	yes	Connected to HV power line trough a HV/LV transformer	-
Internal telephone systems	yes	Connected to telecom line	-
Internal LAN system	yes	Not connected to an incoming line	-
Loss by touch and step voltages (relevant to R_1)	yes	L_t	0,000001
Loss by physical damages (relevant to R_1)	yes	L_f	0,001
Loss by failure of internal systems (relevant to R_1)	none	L_o	0,00001
Loss by touch and step voltages (relevant to R_4)	yes	L_t	-
Loss by physical damages (relevant to R_4)	yes	L_f	0,001
Loss by failure of internal systems (relevant to R_4)	yes	L_o	0,00001

H.3.3 Expected annual number of dangerous events

Expected annual number of dangerous events is evaluated according to Annex A. Data are reported in Table H.3.9.

Table H.3.9 - Expected annual number of dangerous events

Symbol	Value (1/year)
N_D	0,0893
N_M	3,88
$N_{L\ (Power)}$	0,00282
$N_{i\ (Power)}$	0,1
$N_{L\ (telecom)}$	0,00765
$N_{i\ (telecom)}$	0,3

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

Parameters needed for evaluation of risk components are reported in Tables H.3.1 - H.3.9.

Values of risk components for unprotected structure are reported in Table H.3.10.

Table H.3.10 - Risk R_1. Values of risk components for unprotected structure according to zones (values · 10^{-5})

	Z_1	Z_2	Z_3	Z_4	Structure
R_A	0,009				*0,009*
R_B		40,2	3,57	0,0447	*43,6*
R_C				0,0893	*0,0893*
R_M				3,88	*3,88*
$R_{U\ (power\ line)}$		≈ 0	≈ 0	≈ 0	*≈ 0*
$R_{V\ (power\ line)}$		0,051	0,0045	≈ 0	*0,555*
$R_{W\ (power\ line)}$				≈ 0	≈ 0
$R_{Z (power\ line)}$				0,0039	*0,0039*
$R_{U\ (telecom\ line)}$		≈ 0	≈ 0	≈ 0	*≈ 0*
$R_{V\ (telecom\ line)}$		7,64	0,68	0,0085	*8,33*
$R_{W\ (telecom\ line)}$				0,017	*0,017*
$R_{Z\ (telecom\ line)}$				0,263	*0,263*
TOTAL	***0,009***	***47,9***	***4.26***	***4,33***	***56,5***

For the structure risk $\mathbf{R_1}$ = 56.5·10^{-5} is higher than the tolerable value $\mathbf{R_T}$ = 10^{-5}; it essentially depends on:

- physical damages (components R_B and R_V) in the zone $\mathbf{Z_2}$ (≈ 85% of the total risk) and in a lower measure in the zone $\mathbf{Z_3}$ (≈ 7,5% of the total risk)
- failures of internal systems caused by LEMP(component R_M) in the zone $\mathbf{Z_4}$ (≈ 7% of the total risk).

Component R_B may be reduced either by:

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

Component R_V may be reduced providing internal power and telephone system with an SPD set complying with IEC 62305-4.

Component R_M in zone **Z_4** (Intensive care unity) may be reduced:

- providing internal power, telecom and LAN systems with an SPD set complying with IEC 62305-4
- adopting suitable shielding of cables for LAN system,
- providing zone **Z_4** with an adequate spatial grid-like shield complying with IEC 62305-4.

For protective measures the following solutions could be adopted:

a)

- protect the building with a type I LPS;
- install LPL I SPD set on internal power and telecom systems;
- provide internal LAN system with a shield having resistance R < 1 Ω / km;
- provide zone **Z_2** with an automatic fire detection system;

LPS acts as grid-like shield with w = 10 m.

b)

- protect the building with a type I LPS;
- install LPL I SPD set on internal power and telecom systems;
- provide internal LAN system with a LPL I SPD set;
- provide zone **Z_2** with extinguishers;

LPS acts as grid-like shield with w = 10 m.

c)

- protect the building with a type II LPS;
- install LPL II SPD set on internal power and telecom systems;
- provide zone **Z_2** with an automatic fire detection system;
- provide zone **Z_4** with a meshed shield having w = 0,1 m;

LPS acts as grid-like shield with w = 15 m.

Values of risk for each zone according to the solution chosen are reported in Table H.3.11.

Table H.3.11 - Risk R_1. Values of risk according to solution chosen (values · 10^{-5})

	Z_1	**Z_2**	**Z_3**	**Z_4**	**TOTAL**
Solution a)	0,009	0,18	0,08	0,172	***0,441***
Solution b)	0,009	0,451	0,08	0,122	***0,662***
Solution c)	0,009	0,441	0,196	0,101	***0,747***

All solutions reduce the risk below the tolerable one.

Solution to be adopted is subject to the best technical /economical convenience.

H.3.5 Data for cost benefits analysis

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

Economical values, including loss of activity, are reported in Table H.3.12 for each zone

.

Table H.3.12 –Values of costs of loss relevant to zones in M$

	Building (B)	**Contents I**	**Power system (A)**	**Telecom system (A)**	**LAN network (A)**	***Total***
Z_1	-	-	-			**-**
Z_2	70	6	3	0,5		***79,5***
Z_3	2	0,9	5	0,5		***8,4***
Z_4	1	0,1	0,005	0,01	1	***2,1***
Total	***73***	***7***	***8***	***1***	***1***	***90***

The values assumed for interest, amortization and maintenance rates relevant to the protection measures are reported in Table H.3.13

Table H.3.13 –Values relevant to rates

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

H.3.6 Assessment of risk of economic loss : R_4

Parameters needed for evaluation of risk components are reported in Tables H.3.1 – H.3.9.

Values of risk components for unprotected structure are reported in Table H.3.14.

Table H.3.14 - Risk R_4. Values of risk components for unprotected structure according to zones (values · 10^{-5}) ***(Table H.3.14 has to be prepared)***

	Z_2	**Z_3**	**Z_4**
R_A	-	-	-
R_B	8,04	0,0714	0,0089
$R_{C\ (power\ line)}$	8,04	0,71	0,089
$R_{C\ (telecom\ line)}$	8,04	0,71	0,089
$R_{C\ (LAN)}$			0,089
$R_{M\ (power\ line)}$	349	31,4	3,88
$R_{M\ (telecom\ line)}$	349	31,4	3,88
$R_{M\ (LAN)}$	-	-	3,49
$R_{V\ (power\ line)}$	0,1	≈ 0	≈ 0
$R_{W\ (power\ line)}$	0,1	0,001	0,0001
$R_{Z(power\ line)}$	0,35	0,031	0,0039
$R_{V\ (telecom\ line)}$	1,53	0,014	0,0017
$R_{W\ (telecom\ line)}$	1,53	0,136	0,017
$R_{Z\ (telecom\ line)}$	23,7	2,1	0,263

H.3.7 Cost benefits analysis

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

Values of costs of loss $\mathbf{C_L}$ for unprotected structure and of residual loss $\mathbf{C_{RL}}$ for structure protected according to solution a), b), and c) are reported in Table H.3.15.

Table H.3.15 – Amount of losses C_L and C_{RL} ($)

	C_L (unprotected)	C_{RL} (protected) Solution a)	C_{RL} (protected) Solution b)	C_{RL} (protected) Solution c)
Z_2	19925	435	476	567
Z_3	1763	57	57	75
Z_4	37	1	1,3	1
Total	***21725***	***493***	***534***	***676***

The cost C_P and the annual cost C_{PM} of protection measures is reported in Table H.3.16 (see formula G.4 of Annex G).

Table H.3.16 – Costs C_P and C_{PM} of protection measures ($)

Protection measures	C_P	C_{PM}
LPS type I	100000	10000
LPS type II	75000	7500
Fire detection system	50000	5000
Extinguishers	10000	1000
Zone Z_4 shielding	20000	2000
LAN cables shielded	5000	500
SPD on power system	20000	2000
SPD on Tlc system	10000	1000

Annual saving **S** money

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

Is reported in Table H.3.17.

Table H.3.17 - Annual saving money ($)

Solution a)	2732
Solution b)	6190
Solution c)	3549

H.4. Apartment house

As the last study case for structures let evaluate risk $\mathbf{R_1}$ for an apartment house located in a region with a lightning flash density:

N_g = 4 flashes per km^2 per year.

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

Incoming services are:
- LV power line;
- Telephone line;
- Water pipe (non metallic).

Structure characteristics are reported in Table H.4.1.

Table H.4.1 – Structure characteristics

Parameter	Comment	Symbol	Value
Dimensions (m)	-	$(L_b \cdot W_b \cdot H_b)$	30· 20· 20
Location factor	Isolated	C_{db}	1
LPS	none	P_B	1
Lightning flash density	1/km2/year	Ng	4

The following zones are defined :

- $\mathbf{Z_1}$ (outside the building)
- $\mathbf{Z_2}$ (inside the building)

No people is attending in outside the building; risk R_1 for zone $\mathbf{Z_1}$ may be disregarded.
Economic evaluation is not required.
Parameters of zone $\mathbf{Z_2}$ are reported in Table H.4.2.

Table H.4.2 – Zone Z_2 parameters

Parameter	Comment	Symbol	Value
Soil type	wood	r_a	0,00001
Risk of fire	variable	r_f	-
Special hazard	none	h	1
Fire protection	none	r	1
Injuries protection	none	-	-
Spatial shield	none	K_{S2}	1
Internal power systems	yes	Connected to LV power line	-
Internal telephone systems	yes	Connected to telecom line	-
Loss by touch and step voltages (relevant to R_1)	yes	L_t	0,0001
Loss by physical damages (relevant to R_1)	yes	L_f	0,1
Loss by failure of internal systems (relevant to R_1)	none	L_o	-

Characteristics of internal systems and of relevant incoming lines are reported in Table H.4.3 for power system and in Table H.4.4 for telecommunication system.

Table H.4.3 – Internal power system and relevant incoming line parameters

Parameter	Comment	Symbol	Value
Length (m)		L_c	100
Overhead	buried		
Height (m)		H_c	-
HV/LV trafo	none	C_t	1
Line location factor	surrounded	C_d	0,5
Line environment factor	suburban	C_e	0,5
Line shielding	none	P_{LD}	1
		P_{LI}	0,6
Internal wiring precaution	none	K_{S3}	1
Equipment withstand voltage U_w	U_w = 2,5 kV	K_{S4}	0,6
SPD set	none	P_{SPD}	1
End “a” line structure dimensions (m)	none	(La·Wa·Ha)	-
Structure “a” location factor	isolated	C_{da}	1

Table H.4.4 – Internal telecom system and relevant incoming line parameters

Parameter	Comment	Symbol	Value
Length (m)		L_c	200
Overhead	buried		
Height (m)		H_c	-
HV/LV trafo	none	C_t	1
Line location factor	surrounded	C_d	0,5
Line environment factor	suburban	C_e	0,5
Line shielding	none	P_{LD}	1
		P_{LI}	1
Internal wiring precaution	none	K_{S3}	1
Equipment withstand voltage U_w	U_w = 1,5 kV	K_{S4}	1
SPD set	none	P_{SPD}	1
End “a” line structure dimensions (m)	none	(La·Wa·Ha)	-
Structure “a” location factor	isolated	C_{da}	1

Risk $\mathbf{R_1}$ values and protection measures to be adopted to reduce the risk to the tolerable level $\mathbf{R_T} = 10^{-5}$ are reported in Table H.4.5 according the height of the building and its risk of fire.

Table H.4.5 - Protection measures to be adopted according the height of the building and its risk of fire.

Risk of fire	Height (m)	LPS type	Anti-fire protection	R_1 ($\cdot 10^{-5}$)	Structure protected
low	20	-	-	0,77	x
ordinary		-	-	7,7	no
		III	-	0,74	x
		IV	(2)	0,73	x
high		-	-	77	no
		II	(3)	0,74	x
		I	-	1,49	no
		I	(1)	0,74	x
low	40	-	-	2,33	no
		-	(3)	0,46	x
		IV	-	0,46	x
ordinary		-	-	23,3	no
		IV	(3)	0,93	x
		I	-	0,46	x
high		-	-	233	no
		I	(3)	0,93	x

(1) Extinguishers
(2) Hydrants
(3) Automatic alarm

ANNEX I
(Informative)

Case study for services

I.1 Telecommunication line with metallic conductors

I.1.1 General

The service to be considered is the telecommunication line using metallic conductors shown in Figure H.1. Loss of public service (L2) and loss of economical value (L4) may affect this type of service so that the corresponding risks $\mathbf{R_2}$ and $\mathbf{R_4}$ should be evaluated, but following the request of the network operator, only risk $\mathbf{R_2}$ will be considered.

I.1.2 Basic data

The line is located in a region with a lightning flash density :

N_g = 4 flashes per km^2 per year.

It is a 2 sections line as shown in Figure I.1.

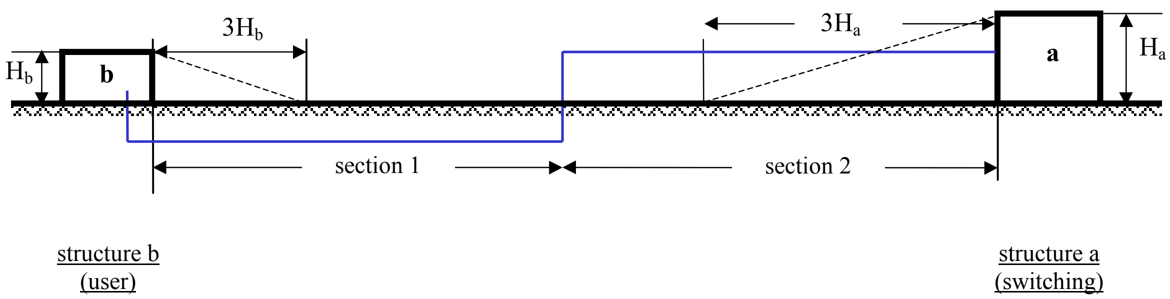

Figure I.1 – Telecommunication line to be protected

I.1.2.1 Line characteristics

The line consists of 2 sections:

- Section 1: buried shielded line connected to user building; no protection measures against failures;
- Section 2: buried shielded line connected to switching building; no protection measures against failures.

Characteristics of line are reported in Table I.1.1 for section 1 and in Table I.1.2 for section 2.

Table I.1.1 – Section 1 of line characteristics

Parameter	Comment	Symbol	Value
Length (m)		L_c	600
Aerial	no	-	-
Height (m)	-	-	-
2 windings transformer	no	C_t	1
Line location factor	surrounded	C_d	0,5
Line environment factor	suburban	C_e	0,5
Line shielding resistance R (Ω/km)	R = 2	P_{LI}	0,9
Type of line sheet	Lead	-	-
Type of line insulation	Paper	U_w	1,5 kV
Type of equipment	Electronic	U_w	1,5 kV
SPD set	none	P_{SPD}	1

Table I.1.2 – Section 2 of line characteristics

Parameter	Comment	Symbol	Value
Length (m)	-	L_c	1200
Aerial	yes	-	-
Height (m)	-	H_c	4
2 windings transformer	no	C_t	1
Line location factor	surrounded	C_d	0,5
Line environment factor	suburban	C_e	0,5
Line shielding resistance R (Ω/km)	R = 0,5	P_{LI}	0,45
Type of line sheet	Aluminium	-	-
Type of line insulation	plastic	U_w	5 kV
Type of equipment	none	U_w	-
SPD set	none	P_{SPD}	1

I.1.2.2 End of line structure characteristics

Characteristics of end of line structures are reported in Table I.1.3.

Table I.1.3 – End of line structure characteristics

Structure	Dimensions (m) (L · W · H)	Location factor C_d	Number n of services to structure
“a”	25 · 20 ·15	2	10
“b”	20 · 30 · 10	0,5	3

I.1.3 Study case 1: line without end line structures

I.1.3.1 Expected annual number of dangerous events

Expected annual number of dangerous events is evaluated according to Annex A.
Data are reported in Table I.1.4.

Table I.1.4 - Expected annual number of dangerous events

Symbol	Value (1/year)
$N_{L\ (S1)}$	0,018
$N_{i\ (S1)}$	0,6
$N_{L\ (S2)}$	0,048
$N_{i\ (S2)}$	2

I.1.3.2 Risk components

Risk components involved in each section are reported in Table I.1.5 for risk R_2.

Table I.1.5 - Risk components relevant to sections for risk R_2

	S_1	S_2
R'_B	-	-
R'_C	-	-
R'_V	x	x
R'_W	x	-
R'_Z	x	-

Failure currents and probabilities needed for evaluation of risk components are reported in Tables I.1.6.

Table I.1.6 - Failure currents and probabilities for evaluation of risk components

	S_1	S_2
$I_{a\ (V,W)}$ (kA)	47	20$^{(1)}$
P'_V	0,45	0,8
P'_W	0,45	-
P'_Z	0,9	-
(1) Limited to 20 kA because Aluminium shield		

I.1.3.2 Assessment of risk R_2

Values of risk components for unprotected line are reported in Table I.1.7.

Table I.1.7 - Risk R_2. Values of risk components for unprotected line according to sections (values · 10^{-3})

	S_1	S_2	Line
R'_V	0,081	0,462	*0,543*
R'_W	0,0081	-	*0,0081*
R'_Z	0,54	-	*0,54*
R_2	***0,63***	***0,462***	***1,092***

R_2 being higher than the tolerable value **R_T**= 10^{-3}, protection against lightning is needed for the line. Providing the line with class I tested SPD complying with IEC 62305-5, in Table I.1.6 will be $P'_V = P'_W = P'_Z = P'_{SPD} = 0{,}01$ for both sections.

Values of risk components for protected line are reported in Table I.1.8.

Table I.1.8 - Risk R_2. Values of risk components for protected line according to sections (values · 10^{-3})

	S_1	S_2	Line
R'_V	0,0018	0,0058	*0,0076*
R'_W	0,00018	-	*0,00018*
R'_Z	0,006	-	*0,006*
R_2	**-**	**-**	***0,0138***

R_2 being lower than the tolerable value $R_T = 10^{-3}$, no protection against lightning is needed for the line.

I.1.4 Study case 2: line with end line structures

I.1.4.1 Expected annual number of dangerous events

Expected annual number of dangerous events is evaluated according to Annex A.
Data are reported in Table I.1.9.

Table I.1.9 - Expected annual number of dangerous events

Symbol	Value (1/year)
N_{Da}	0,0873
N_{Db}	0,0129
$N_{L\ (S1)}$	0,0171
$N_{i\ (S1)}$	0,6
$N_{L\ (S2)}$	0,0458
$N_{i\ (S2)}$	2

I.1.4.2 Risk components

Risk components involved in each section are reported in Table I.1.10.

Table I.1.10 - Risk components relevant to sections for risk R_2

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

Failure currents and probabilities needed for evaluation of risk components are reported in Tables I.1.11.

Table I.1.11 - Failure currents and probabilities for evaluation of risk components

	S_1	S_2
$I_{a\ (B,C)}$ (kA)	140	>600
$I_{a\ (V)}$ (kA)	40(1)	20(2)
$I_{a\ (W)}$ (kA)	47	-
$P'_{B(a)}$	-	0,001
$P'_{B(b)}$	0,02	-
$P'_{C(a)}$	-	-
$P'_{C(b)}$	0,02	-
P'_V	0,4	0,8
P'_W	0,32	-
P'_Z	0,9	-
a. Limited to 40 kA because Lead shield		
b. Limited to 20 kA because Aluminium shield		

I.1.4.3 Assessment of risk R_2

Values of risk components for unprotected line are reported in Table I.1.12.

Table I.1.12 - Risk R_2. Values of risk components for unprotected line according to sections (values · 10^{-3})

	S_1	S_2	Line
$R'_{B(a)}$	-	0,001	***0,01***
$R'_{B(b)}$	0,00258	-	***0,00258***
$R'_{C(a)}$	-	-	***-***
$R'_{C(b)}$	0,000258	-	***0,000258***
R'_V	0,067	0,366	***0,433***
R'_W	0,00546	-	***0,00546***
R'_Z	0,54	-	***0,54***
R_2	**0,615**	**0,367**	***0,982***

R_2 being lower than the tolerable value **R_T** = 10^{-3}, protection, the line is protected against lightning.
The end line structures reduce the collection areas of the line: in this case this effect is greater than the increased risk due to lightning flashes to structures.

ANNEX J
*(Informative***)**

Simplified software for risk assessment

J.1 Fundamentals

The Simplified IEC Risk Assessment Calculator is a software tool based on calculations and methods given in IEC 62305-2 and intended to assist in the calculation of the risk components of simple structures. It is intended to support the application of the standard IEC 62305-2 as the risk management method for lightning protection purposes. It is important to note that this tool is a simplified implication of the more rigorous treatment of risk management found in the written standard. The tool is designed to be relatively intuitive for users who wish to obtain an initial assessment of risk sensitivity.

It is important to understand the intended purpose and limitations of the Simplified IEC Risk Assessment Calculator. These include :

- To enable more general users of the standard IEC 62305-2 to conduct calculations on typical structures without requiring that they have an indepth knowledge of details and methodologies covered in the body of the standard.
- To promote the application of the standard and adoption of the risk assessment method detailed there-in to a wider readership and range of users. It is believed that such a user-friendly tool will also serve to increase the acceptance of the standard in the wider lightning protection community.
- To provide a tool specifically tailored to the calculation of risk in typical, non-complicated, structures and more general situations. To achieve this aim, certain parameters are defaulted to fixed values and the user only required to make selections from a more limited subset.
- The software does not implement the full functionality of the written standard – such an implementation would have added unintended complexity to the tool. Users are encouraged to use the written standard for a more detailed treatment of risk when assessing complicated structures or special circumstances.
- It is not intended for the calculation of risk components to services.

The Simplified IEC Risk Assessment Calculator should be viewed as a companion tool to the standard and will be supported through an on-line update function to an IEC FTP server where downloads will be available as changes are required.

J.2 Description of parameters

Parameters important to the calculation of the risk components in the software tool are divided into three categories:

- Parameters, which the user is required to select in accordance with definitions and possibilities provided in the standard (Table J.1);
- Parameters, where the user’s choice is limited to a subset of those provided in the standard (Table J.2);
- Parameters, which are fixed in code and unavailable to the user to alter (Table J.3).

Table J.1 - Parameters for the user free to select

Parameter	Abbreviation
Length, Width and Height of structure to be protected	L, W, H
Lightning ground flash density	N_g
Location factor	C_d
Environmental factor	C_e
Type of service (power line, other overhead services, other underground services) Remark: A transformer is only possible for the power line	
Lightning protection system acc. to 62305-3	P_B
Surge (overvoltage) protection for the services - only at the entrance (equipotential bonding SPD) - or a SPD set according to IEC 62305-4 for the whole internal system connected to the services Remark: The user may only select one value for the surge protection. This value is valid for all services and for the entire structure to be protected.	P_{EB} P_{SPD}
Risk of fire or physical damage of the structure	r_f
Fire protection	r
Special hazards	h
Choice of the relevant losses (loss types)	

Table J.2 - Parameters with limited user's choice

Parameter	Abbreviation
Structure screening effectiveness	K_{S1}
Internal wiring type	K_{S3}
Screening of external services (type of external cabling)	P_{LD}, P_{LI}
Loss factors due to fire: the user is asked for the type of structure to be protected Remark: A calculation of L_f for all four loss types, like defined in annex C of the standard, is not possible. The user has to select the type of structure to be protected out of the given list.	L_f
Loss factors due to overvoltages Remark: A calculation of L_o for all four loss types, like defined in annex C of the standard, is not possible. The user has to select the type of structure to be protected out of the given list.	L_o
For type of loss L4 - economic loss - there is no implementation of the investigation of the economic convenience of protection measures in this simplified software solution. For that the user has to select a tolerable risk of economic loss.	

Table J.3 - Fixed parameters (not to change by the user)

Parameter	Abbreviation	Fixed value
Length of the services	L_c	1000 m
In case of overhead services: Height	H_c	6 m
No adjacent building is taken into account	A_d	0 m^2
No screening effectiveness of zones internal to the structure is taken into account	K_{S2}	1
Impulse withstand voltage of the internal equipment connected to this service (1.5 kV)	K_{S4}	1
Probability for shock of living beings	P_A	1
Type of soil or floor	r_a	10^{-2}
For type of loss L1 - loss of human life – loss factor for step and touch voltages inside and up to 3 m outside the structure to be protected	L_t	0.01

Remark: Further informations about parameter values can be found directly in the Simplified IEC Risk Assessment Calculator (contact the arrow of the click-down menu with the mouse).

J.3 Example of screen shot

Example of screen shot are reported in Fig. J.1 (no protection measures provided) and in Fig. J.2 (protection measures provided e.g. LPS type III, SPD at entrance of services and manual fire protection measures).

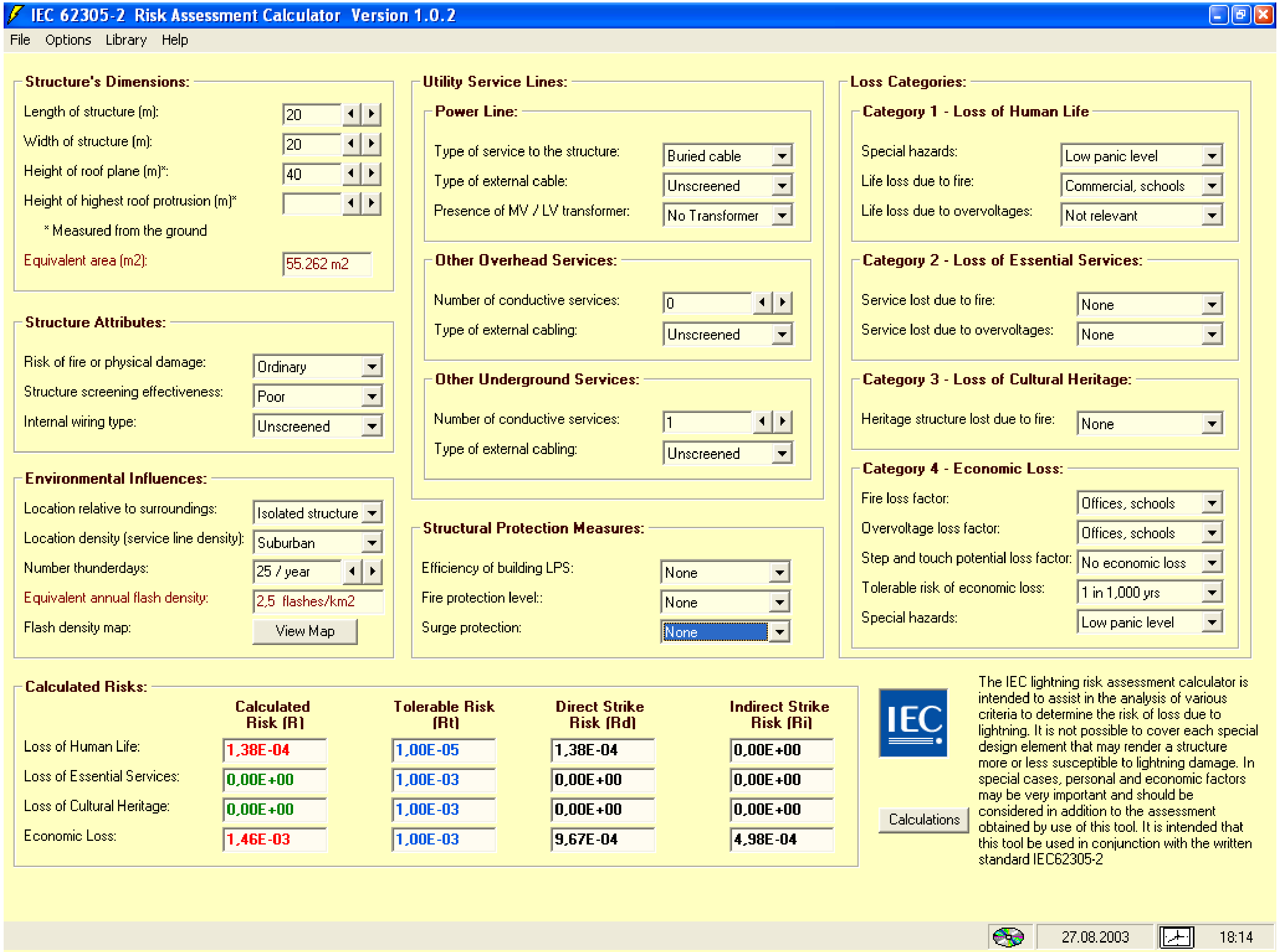

Fig. J.1: Example for a structure without protection measures (screen shot)

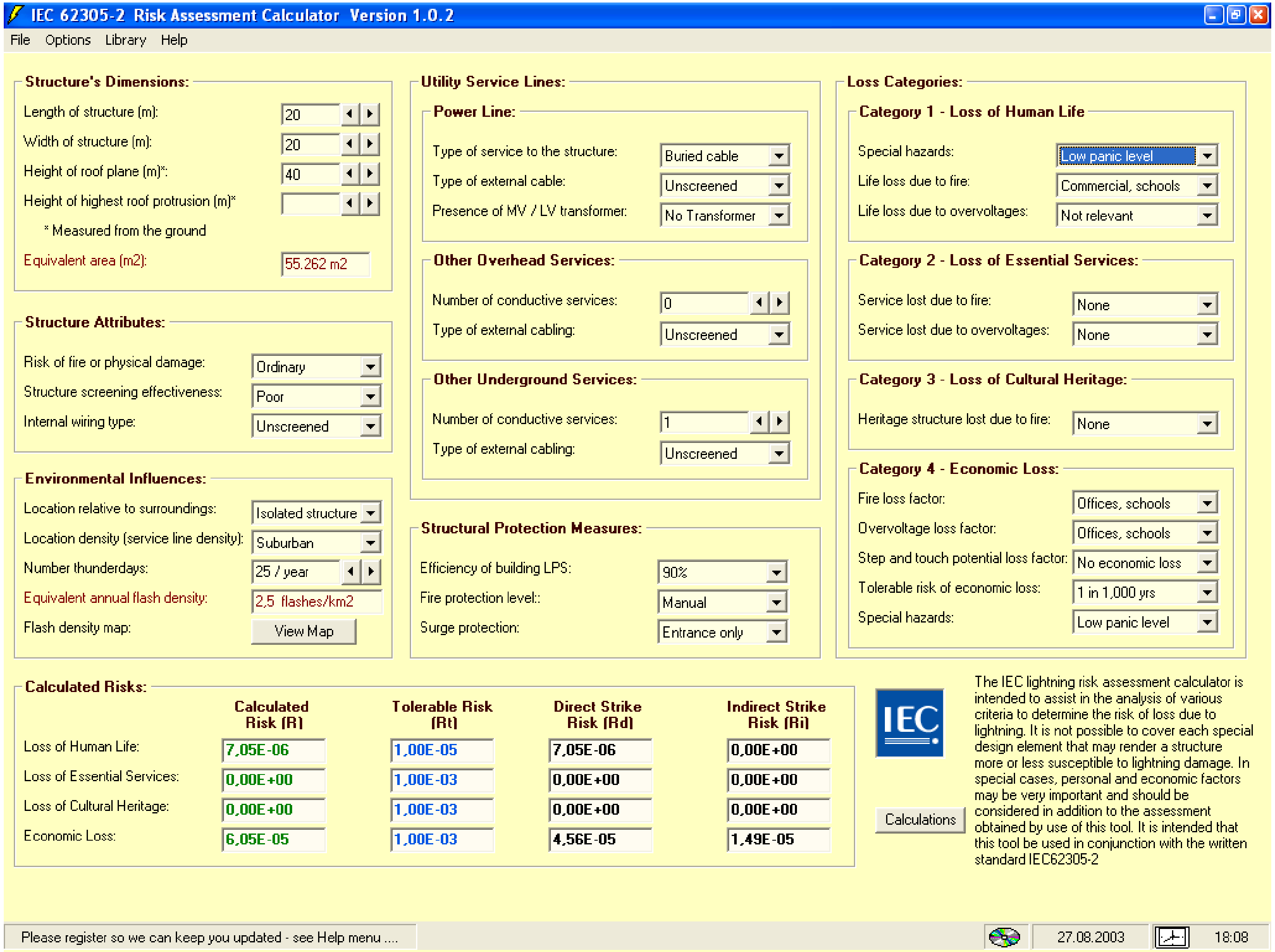

Fig. J.2: Example for a structure with protection measures provided (screen shot)

Annex K

List of Acronyms / Symbols

(Informative)

a_r	Amortization rate	Annex G
A_d	Collection area for flashes to an isolated structure	A.2
A_i	Collection area for flashes near a service	A.4; Table A.2
A_l	Collection area for flashes to a service	A.4
A_m	Area of influence for a structure	A.3
b	Radius of the cable	D.1.2
B	Building	A.2
c	Mean value of possible loss of the structure, in currency	C.4; C.5
C_B	Cost of the building	Annex G
C_C	Cost of the contents	Annex G
C_d	Location factor	A.2
C_e	Environmental factor	A.5
C_L	Cost of total loss in absence of protection measures	5.5
C_{RL}	Cost of residual loss	5.5; Annex G
C_P	Cost of protection measures	Annex G
C_{PM}	Annual cost of selected protection measures	5.5
c_t	Total value of the structure, in currency	C.4; C.5; E.3
C_S	Cost of systems in a structure	Annex G
C_t	Correction factor for the presence of a HV/LV transformer on the service	A.2
d	Spacing between earthing points	D.1.2
D	Arcing distance in the earth	A.4
D_i	lateral distance relevant to lightning flash near a service	A.5
D1	Injuries to living beings	4.1.2
D2	Physical damages	4.1.2
D3	Failures of electrical and electronic systems	4.1.2
h	Factor increasing the loss due to physical damage in presence of a special hazard	C.2
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; D.1.2
i_r	interest rate	Annex G
I_a	Failure current	3.23
I_c	Current entering a conductor	D.1.1
I_S	Breakdown sheath current	D.1.1
K_d	Factor associated with characteristics of a service	D.1.1
K_{MS}	Factor relevant to performances of protection measures against LEMP	B.4
K_p	Factor associated with adopted protection measures in a service	D.1.1
K_{S1}	Factor associated with the screening effectiveness of the structure	B.4
K_{S2}	Factor associated with the screening effectiveness of shields internal to the structure	B.4
K_{S3}	Factor associated with the characteristics of internal wiring	B.4
K_{S4}	Factor associated with the impulse withstand voltage of a system	B.4
L	Length of structure	A.2

L_A	Loss related to injuries of living beings	6.2; Table 6
L_B	Loss to structure related to physical damages	6.2; Table 6
L'_B	Loss to service related to physical damages	7.4; Table 8
l_c	Distance between the structure and the closest earthing point of the conductor	D.1.1
L_c	Length of service	A.4; D.1.1
L_C	Loss related to failure of internal systems	6.2; Table 6
L'_C	Loss related to failure of service equipment	7.4; Table 8
L_f	Loss to structure due to physical damages	C.1
L'_f	Loss to service due to physical damages	E.1
L_M	Loss related to failure of internal systems	6.3; Table 6
L_o	Loss due to failure of internal systems	C.1
L'_o	Loss to services due to failure of internal systems	E.1
L_t	Loss due to injuries by touch and step voltages	C.1
L_U	Loss related to injuries of living beings	6.4; Table 6
L_V	Loss to structure due to physical damages	6.4; Table 6
L'_V	Loss to services due to physical damages	7.2; Table 8
L_W	Loss related to failure of internal systems	6.3; Table 6
L'_W	Loss related to failure of service equipment	7.2; Table 8
L_X	Consequent loss	6.1
L'_X	Consequent loss of service	7.1
L_Z	Loss related to failure of internal systems due to flash near a service	6.5; Table 6
L'_Z	Loss related to failure of service equipment due to flash near the service	7.3; Table 8
L1	Loss of human life in a structure	4.1.3
L2	Loss of service to the public in a structure	4.1.3
L'1	Loss of human life in a service	
L'2	Loss of service to the public in a service	E.1
L3	Loss of cultural heritage	4.1.3
L4	Loss of economic value (structure and its content, service and loss of activity)	4.1.3
L'4	Loss of economic value (service and loss of activity)	E.1
m	Number of line conductors	D.1.1
m_r	Maintenance costs	Annex G
n	Number of services incoming to the structure	D.1.1
N	Annual number of lightning flashes influencing an object	A.1
N_D	Frequency of lightning flashes to a structure	3.13
N_{Da}	Frequency of lightning flashes to a structure at “a” end of line	Fig 8; Table 6; A.2
N_g	Lightning ground flash density	A.1
N_I	Frequency of lightning flashes near a service	3.16; 7.3
N_L	Frequency of lightning flashes to a service	3.14; 7.2
N_M	Frequency of lightning flashes near a structure	3.15
n_p	Number of possible endangered persons (victims or users not served)	C.2; C.3; E.2
n_s	Estimated or measured yearly number of switching overvoltages	Annex F
N_s	Yearly 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
N_X	Number of dangerous events	6.1
P	Probability of damage	3.24
P_A	Probability of injury of living beings	6.2; Table 6
P_B	Probability of physical damages to a structure	6.2; Table 6
P'_B	Probability of physical damages to a service	7.4; Table 8
P_C	Probability of failure of internal systems due to flash to structure	6.2; Table 6
P'_C	Probability of failure of service equipment	7.4; Table 8
P_i	Values of probabilities	Annex B

P_{LD}	Probability of failure of internal systems due to flash to connected service	B.5; B.6; B.7
P_{LI}	Probability of failureof internal systems due to flash near the connected service	B.8
P_M	Probability of failure of internal systems due to flash near a structure	6.3; Table 6
P_{MS}	Probability of failure of internal systems when lightning protection measures are applied	B.4
P_{SPD}	Probability of failure of internal systems or a service with the installation of SPDs	B.3
P_U	Probability of injuries of living beings in a structure	6.4; Table 6
P_V	Probability of physical damages to a structure	6.4; Table 6
P'_V	Probability of physical damages to services	7.2; Table 8
P_W	Probability of failure of internal systems in a structure	6.4; Table 6
P'_W	Probability of failure of internal systems in a service	7.2; Table 8
P_X	Probability of damage to a structure	6.1
P'_X	Probability of damage to service	7.1
P_Z	Probability of failure of internal systems due to flash near a service	6.5; Table 6
P'_Z	Probability of failure of service equipment due to flash near a service	7.3; Table 8
r	Factor reducing the loss due to physical damage associate with provisions taken to reduce the consequences of fire	C.2
R	Risk	3.26
R'	Risk for services	4.4.1; 4.4.2
r_a	Reduction factor associated with the type of soil or floor	C.2
R_A	Risk related to injuries of living beings caused by touch and step voltages (due to direct strike)	4.2.2
R_B	Risk related to physical damages to the structure (due to direct strike)	4.2.2
R'_B	Risk related to physical damages to service due to direct strike to the connected structure	4.2.8
R_C	Risk related to failure of internal systems caused by LEMP (due to direct strike)	4.2.2
R'_C	Risk related to failure of service equipment due to flash to connected structure	4.2.8
R_D	Risk for a structure due to flashes to the structure	4.3.1
r_f	Factor reducing the loss due to physical damage associated with risk of fire in the structure	C.2
R_F	Risk of physical damage to structure	Fig 2; 4.3.2
R'_F	Risk of physical damages to service	4.4.2
R_g	Resistance of earthing points	D.1.2
R_I	Risk for a structure due to flashes not striking the structure	4.3.1
R_M	Risk related to failure of internal systems caused by LEMP (due to flash near the structure)	4.2.3
R'_M	Risk related to failure of service equipment caused by LEMP (due to strike near service)	Annex G
R_O	Risk of failure of internal systems	Fig 2; 4.3.2
R'_O	Risk of 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 of injury to living beings	Fig 2; 4.3.2
R_T	Tolerable risk	3.28; 5.3
R_U	Risk of injury to living being caused by touch voltage (due to a flash to service)	4.2.4
R_V	Risk related to physical damages due to flash to a connected service	4.2.4
R'_V	Risk to service related to physical damages due to flash to service	4.2.6
R_W	Risk related to failure of internal systems	4.2.4

	due to flash to the connected service	
R'_W	Risk related to failure of service equipment due to flash to service	4.2.6
R_x	Risk component	3.27
R'_x	Risk component for service	7.1
R_Z	Risk related to failure of internal systems due to flash near a service	4.2.5
R'_Z	Risk related to failure of service equipment due to flash near the service	4.2.7
R1	Risk of loss of human life in a structure	4.2.1; 4.3
R'1	Risk of loss of human life in a service	4.2.1; 4.4
R2	Risk of loss of service to the public in a structure	4.2; 4.3
R'2	Risk of loss of service to the public in a service	4.2.1; 4.4
R3	Risk of loss of cultural heritage in a structure	4.2.1; 4.3
R4	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_c	Cross-section area of a conductor	D.1.1
S_S	Section of a service	3.30
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_p	Time in hours per year that persons are present in a dangerous place	C.2
t	Annual period of loss of service, in hours	C.3; E.2
T_d	Thunderstorm days per year	A.1
U_w	Rated impulse withstand voltage of a system	B.4
w	Mesh width	B.5
W	Width of structure	A.2
Z_S	Zones of a structure	3.29