

Technical Seminar for Cathodic Protection to GOGC Design Unit Specialists

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WITHIN THE JURISDICTION OF THE MINISTRY OF ENVIRONMENT, ENERGY & CLIMATE CHANGE



Source of Development, Supplier of Energy



THE LIGHTNING PROTECTION INTERNATIONAL STANDARD

IEC 62305



Introduction

IEC standards are based on
scientifically proven theories and experimentation,
taking into account the **international expertise** in the matter.

- IEC 62305 lays down requirements for
- 1) the design and installation of LPS for structures and buildings,
 - 2) the protection against lightning of services entering the buildings and
 - 3) the protection of electrical and electronics systems.



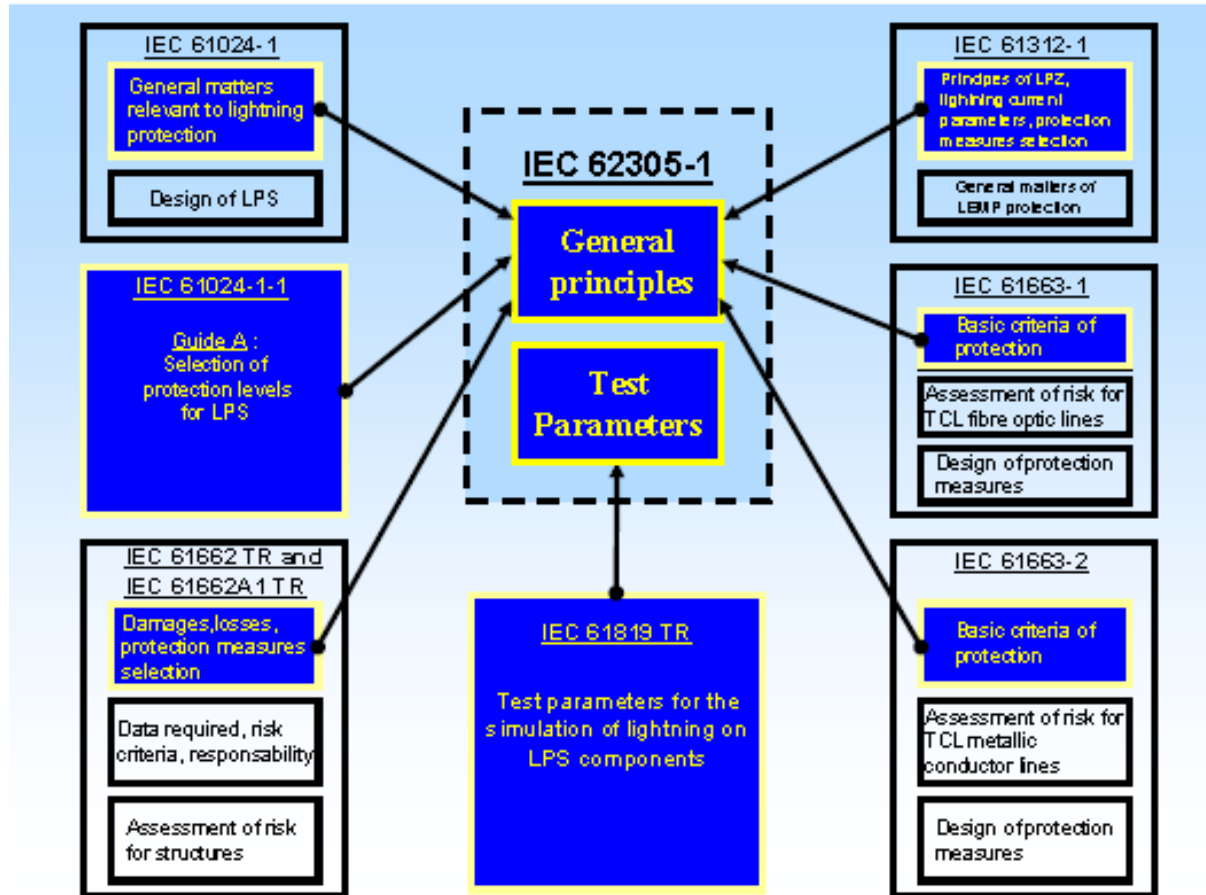
- IEC 62305-1 **Part 1 : General Principles**
 - 1-1 Protection against lightning
 - 1-2 Test parameters simulating the effects of lightning on LPS components

- IEC 62305-2 **Part 2 : Risk management**
 - 2-1 Risk assessment method
 - 2-2 Risk components for structures
 - 2-3 Risk components for services

- IEC 62305-3 **Part 3 : Physical damage and life hazard**
 - 3-1 Lightning protection system (LPS) = external + internal
 - 3-2 Protection measures against injuries of living beings due to touch and step voltages
 - 3-3 Design, installation, maintenance and inspection of LPS

- IEC 62305-4 **Part 4 : Electrical and electronic systems within structures**
 - 4-1 Protection against LEMP : general principles
 - 4-2 Earthing and bonding; magnetic shielding and line routing
 - 4-3 SPD system
 - 4-4 Management of an LPM system

- IEC 62305-5 **Part 5 : Services : cancelled out (Lannion, June 2006)**





Part 1

General principles



SCOPE

Protection against lightning of

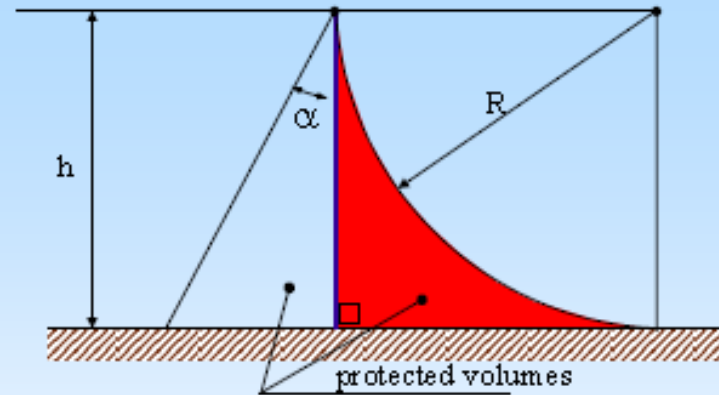
- structures including their installations and contents
as well as persons
- services connected to a structure

Outside:

- railway systems;
- vehicles, ships, aircraft, offshore installations;
- underground high pressure pipelines;
- pipe, power and telecommunication lines
not connected to a structure



4 Lightning Protection Levels (LPL I, II, III, IV) with 4 types of relevant protection measures for the design of LPS are introduced

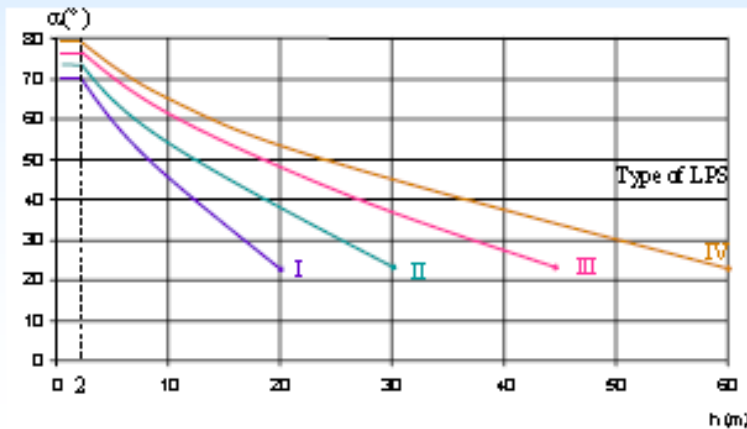


Level	R(m)	$\alpha(h = 20)$	$\alpha(h = 30)$	$\alpha(h = 45)$	$\alpha(h = 60)$	d(m)
I	20	25	*	*	*	5
II	30	35	25	*	*	10
III	45	45	35	25	*	15
IV	60	55	45	35	25	20



Table 2
Rolling sphere radius, mesh size and protection angle
corresponding to the type of LPS

Type of LPS	Protection method		
	Rolling sphere radius R m	Mesh size M m	Protection angle α°
I	20	5 × 5	See figure below
II	30	10 × 10	
III	45	15 × 15	
IV	60	20 × 20	



NOTE 1 - Not applicable beyond the values marked with *. Only rolling sphere and mesh methods apply in these cases

NOTE 2 - h is the height of air-termination above the area to be protected.

NOTE 3 - The angle will not change for values of h below 2 m



**Table 3 –
Maximum values of lightning parameters according to LPL**

First short stroke			LPL			
Current parameters	Symbol	Unit	I	II	III	IV
Peak current	I	kA	200	150	100	
Short stroke charge	Q _{short}	C	100	75	50	
Specific energy	W/R	kJ/Ω	10.000	5.625	2.500	
Time parameters	T ₁ / T ₂	μs / μs	10 / 350			
Subsequent short stroke			LPL			
Current parameters	Symbol	Unit	I	II	III	IV
Peak current	I	kA	50	37,5	25	
Average steepness	dI/dt	kA/μs	200	150	100	
Time parameters	T ₁ / T ₂	μs / μs	0,25 / 100			
Long stroke			LPL			
Current parameters	Symbol	Unit	I	II	III	IV
Long stroke charge	Q _{long}	C	200	150	100	
Time parameter	T _{long}	s	0,5			
Flash			LPL			
Current parameters	Symbol	Unit	I	II	III	IV
Flash charge	Q _{flash}	C	300	225	150	



Part 2

Risk management



SCOPE





**Risk assessment for a structure or for a service
due to lightning flashes to earth**

To provide a procedure to **evaluate this risk.**

Once an **upper tolerable limit** for the risk has been selected,
this procedure allows the selection of
appropriate protection measures to be adopted
to reduce the risk to or below the tolerable limit.



Table 1 - Damages and losses at different points of strike of lightning

Point of strike			Structure		Service	
			Type of damage	Type of loss	Type of damage	Type of loss
Structure		S1	D1 D2 D3	L1, L4** L1, L2, L3, L4 L1*, L2, L4	D2 D3	L'2, L'4 L'2, L'4
Ground near a structure		S2	D3	L1*, L2, L4		
Incoming line		S3	D1 D2 D3	L1, L4** L1, L2, L3, L4 L1*, L2, L4	D2 D3	L'2, L'4 L'2, L'4
Ground near a line		S4	D3	L1*, L2, L4	D3	L'2, L'4

Source of damages

- S1. Direct strike to the structure
- S2. Strike to ground near the structure
- S3. Direct strike to the incoming line
- S4. Strike to ground near the incoming line

Type of losses

- L1. Loss of human life
- L2. Loss of services to the public
- L3. Loss of cultural heritage
- L4. Losses of economic value

Type of damages

- D1. Injury to living beings
- D2. Physical damage (fire, explosion, mechanical destruction, chemical release due to mechanical and thermal effects)
- D3. Failure of electrical and electronic systems (overvoltages)

*In the case of hospitals and structures with risk of explosion or other structures with electronic systems which could endanger human life.

** Only in properties where animals may be lost.



Assessment of the average number of flashes to a structure

$$N_D = N_g A_d C_d 10^{-6}$$

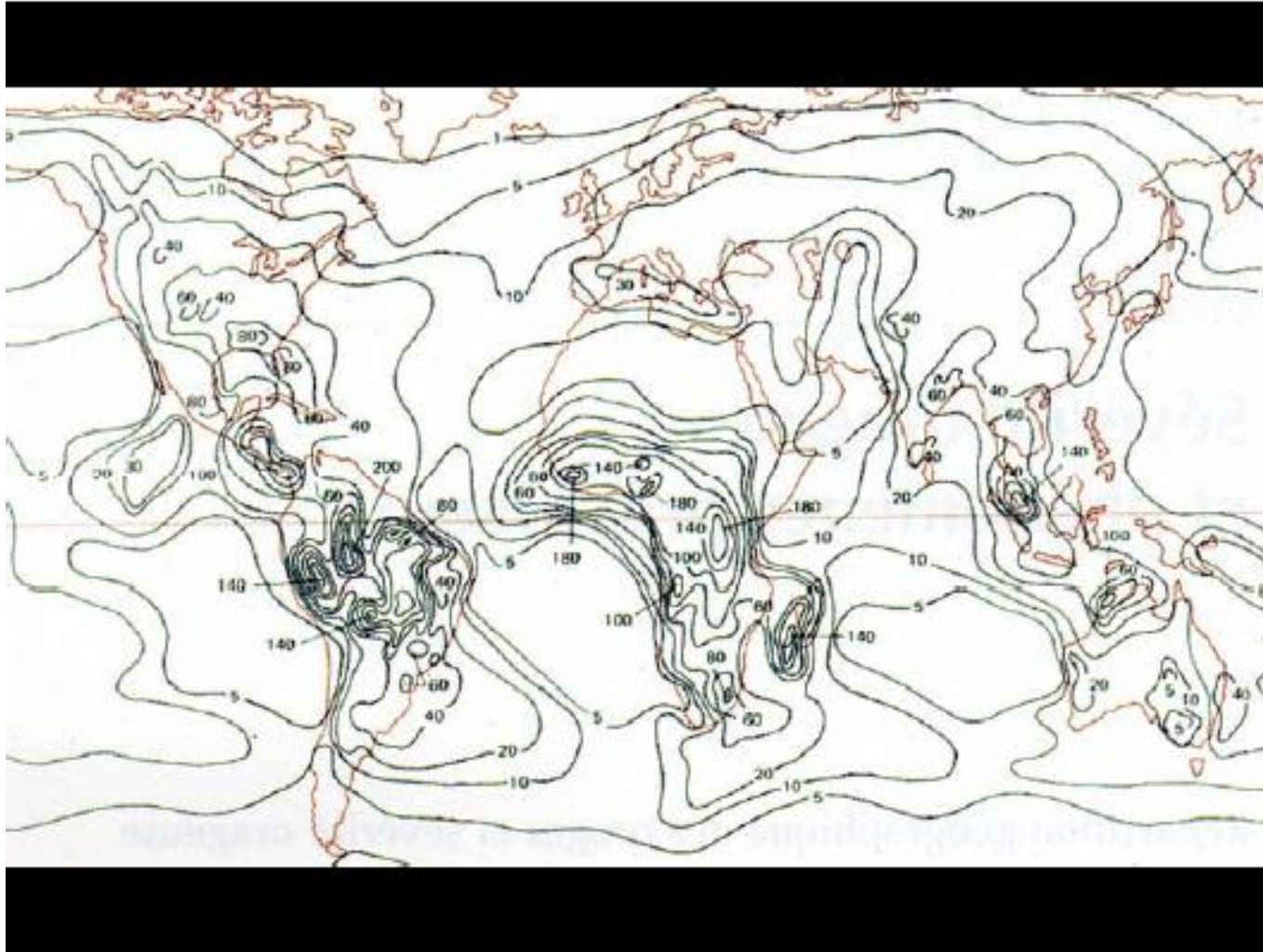
lightning
ground
flash
density

collection
area (m²)

relative
location

Table A.2 - Location factor C_d

Relative location	C _d
Object surrounded by other higher objects or trees	0.25
Object surrounded by other objects or trees (same h)	0.5
Isolated object: no other objects in the vicinity	1
Isolated object on a hilltop or a knoll	2

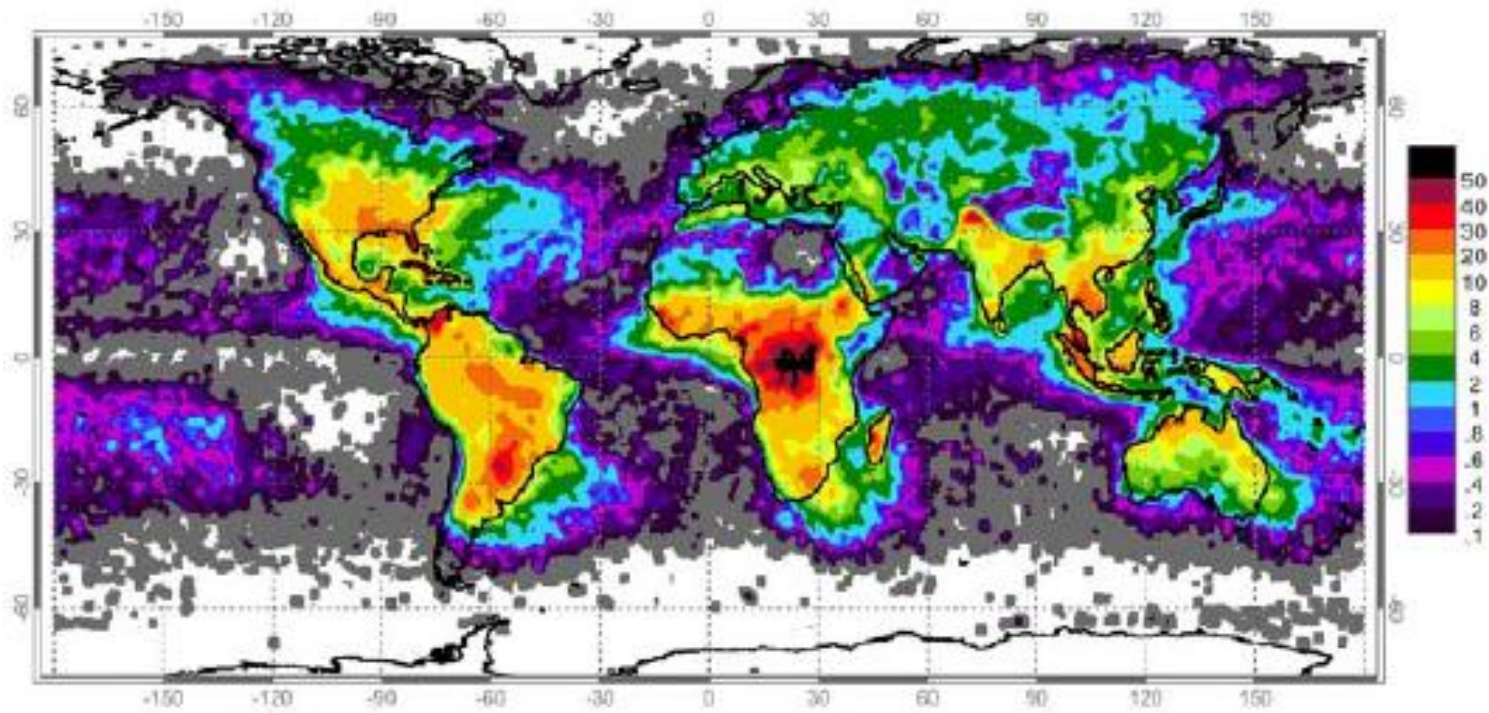




$$N_g = 0.04 T_d^{1.25} \text{ km}^2 \text{ year}^{-1}$$

$N_g = 0.1 \text{ km}^2 \text{ year}^{-1}$ on the oceans

$N_g = 8 \text{ to } 15 \text{ km}^2 \text{ year}^{-1}$ in Brazil, Florida,
Indonesia and Australia,
Central- and South-Africa.





$$R_X = N P_X L_X \quad X = A, B, \dots$$

number of
dangerous events

probability
of damage

consequent
loss

for each type of loss L_1 to L_4
corresponding to a relevant risk (R_1 to R_4)
which is the sum of different risk components R_X

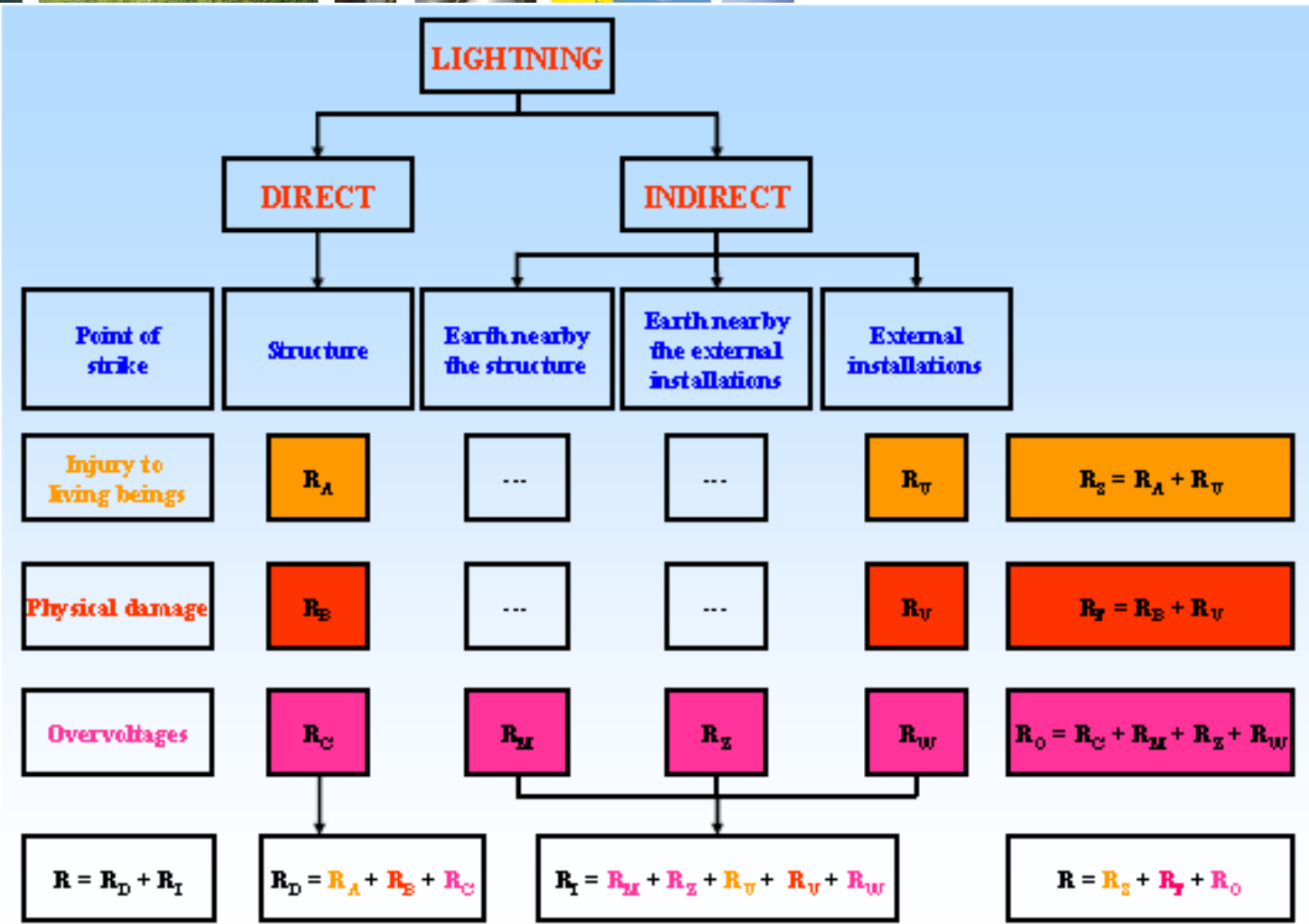
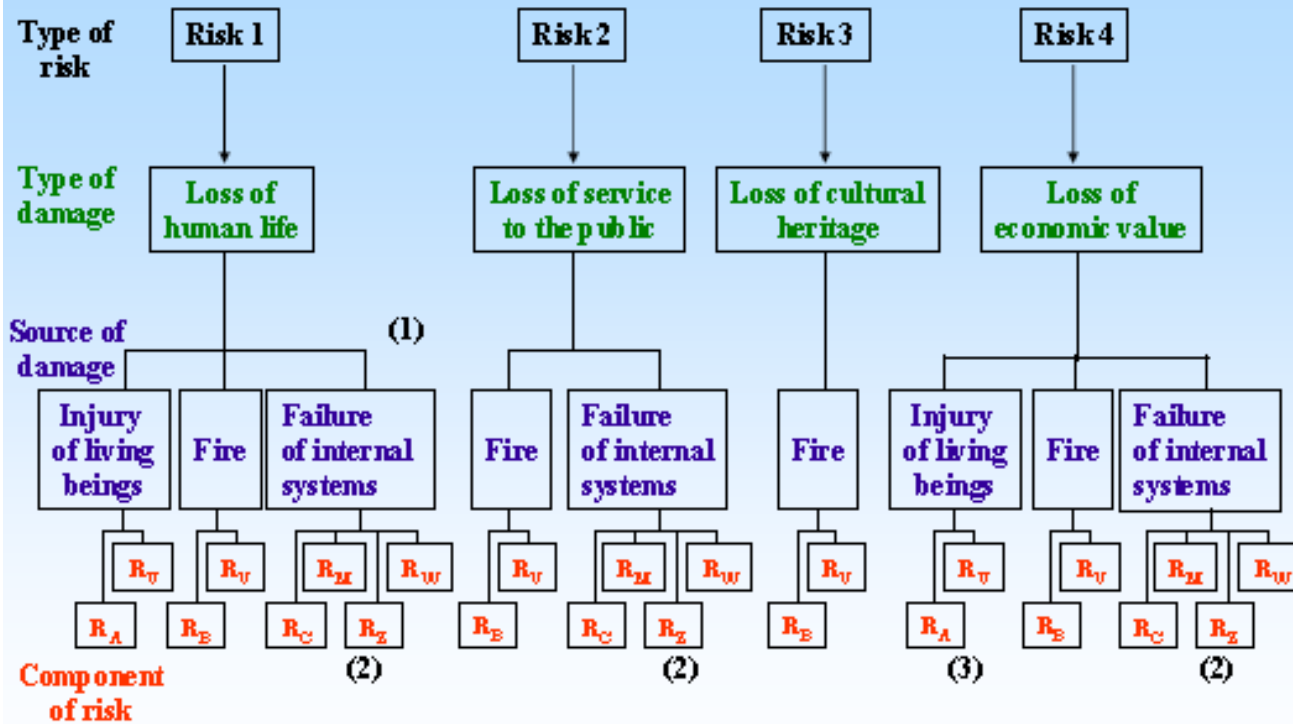




Figure 1 Types of loss resulting from different types of damage



- (1) Only for hospitals and structures with risk of explosion
- (2) Only for structures with electronic systems
- (3) Only for properties of agricultural value (loss of animals)



Typical values of tolerable risk R_T

Type of damage	R_T
Loss of human life	10^{-5}
Loss of service to the public	10^{-3}
Loss of cultural heritage	10^{-3}

R_d (economic value)

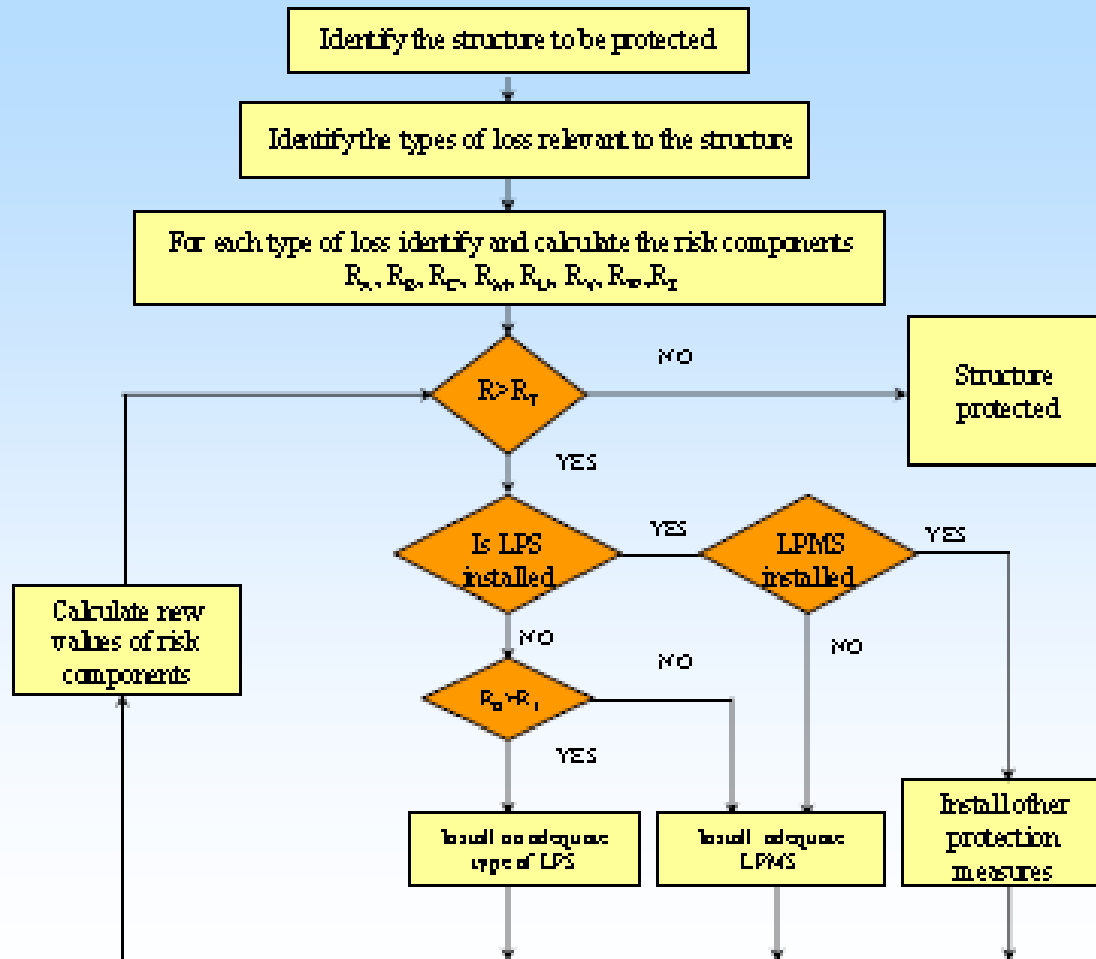
Protection measures convenient if $C_{RL} + C_{PM} < C_L$

with C_{RL} = residual loss when protection measures

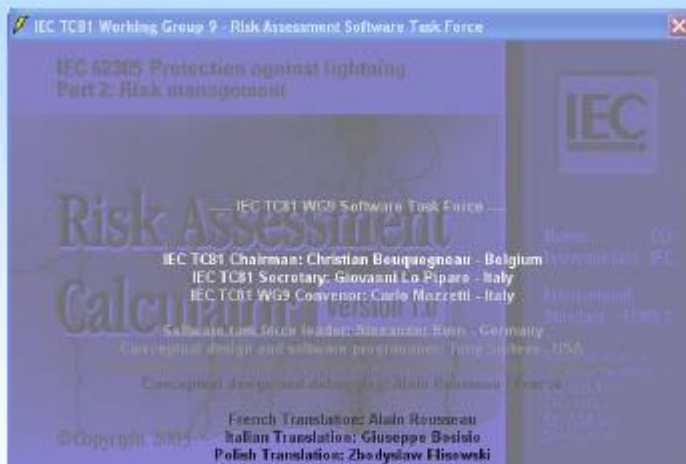
C_{PM} = cost of protection measures

C_L = cost of total loss without protection measures

Figure 3 - Procedure for selection of protection measures in a structure



LPMS = LEMP protection measures system.





IEC Risk Assessment Calculator Version 1.0.0

File Options Library Help

Structure's Dimensions:

Length of structure (m):

Width of structure (m):

Height of roof plane (m):

Height of highest roof protrusion (m):

* Measured from the ground

Collection area (m²):

Structure's Attributes:

Risk of physical damage (incl. fire):

Structure screening effectiveness:

Internal wiring type:

Environmental Influences:

Location factor:

Environmental factor:

Number thunderdays:

Annual ground flash density:

View isokeraunic map:

Conductive Electric Service Lines:

Power Lines:

Type of service to the structure:

Type of external cable:

Presence of MV /LV transformers:

Other Overhead Services:

Number of conductive services:

Type of external cable:

Other Underground Services:

Number of conductive services:

Type of external cable:

Protection Measures:

Class of LPS:

Fire protection provisions:

Surge protection:

Types of Loss:

Type 1 - Loss of Human Life:

Special hazards to life:

Life loss due to fire:

Life loss due to overvoltage:

Type 2 - Loss of Essential Public Services:

Services lost due to fire:

Services lost due to overvoltage:

Type 3 - Loss of Cultural Heritage:

Cultural heritage lost due to fire:

Type 4 - Economic Loss:

Special hazards to economics:

Economic loss due to fire:

Economic loss due to overvoltage:

Step/touch potential loss factor:

Tolerable risk of economic loss:

Calculated Risks:

	Tolerable Risk (Rt)	Direct Strike Risk (Rd)	Indirect Strike Risk (Ri)	Calculated Risk (R)
Loss of Human Life:	1.00E-05 =>	8.30E-05	+ 1.48E-04	= 2.31E-04
Loss of Public Services:	1.00E-03 =>	0.00E+00	+ 0.00E+00	= 0.00E+00
Loss of Cultural Heritage:	1.00E-03 =>	0.00E+00	+ 0.00E+00	= 0.00E+00
Economic Loss:	1.00E-03 =>	2.49E-04	+ 7.76E-04	= 1.02E-03

IEC

The IEC lightning risk assessment calculator is intended to assist in the analysis of various criteria to determine the risk of loss due to lightning. It is not possible to cover each special design element that may render a structure more or less susceptible to lightning damage. In special cases, personal and economic factors may be very important and should be considered in addition to the assessment obtained by use of this tool. It is intended that this tool be used in conjunction with the written standard IEC 62305-2.



Part 3

Physical Damage and Life Hazard



SCOPE

Requirements for protection of a structure against physical damage by means of an LPS and for protection against injury to living beings due to touch and step voltages in the vicinity of a lightning protection system

- 1) Design, installation, inspection and maintenance of an LPS for structures of any height.
- 2) Establishment of measures for protection against injury to living beings due to touch and step voltages.



Physical damage to structures and life hazard

Against physical damage :

- external + internal LPS.

Against injuries of living beings due to touch and step voltages :

- physical restrictions + warning notices ;
- insulation of exposed conductive parts ;
- increase of the surface soil resistivity.



External LPS

1) Interception of direct strikes :

- **air-termination system**

2) Conduction of the lightning current safely towards earth :

- **down-conductor system**

3) Dispersion of the current into the earth :

- **effective earth-termination system**



**Properly designed air termination system :
any combination of rods, catenary wires
and meshed conductors.**

Great care to exposed points, corners and edges (upper parts!)

3 methods used :

- **RSM (EG model ; always !)**
- **Protection angle method (limited : height !)**
- **Mesh method (plane surfaces)**



External and internal LPS Dangerous sparking !

Equipotential bonding

+

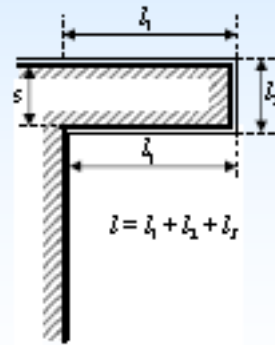
separation distance



bonding conductors or SPD
between internal system and LPS



$$s > k_i \frac{k_c}{k_m} l$$



k_i ← table 10



k_c ← table 11



k_m ← table 12



s depends on the LPL !

$l(m)$ = distance to the nearest equipotential bonding point





Table 10 – Isolation of external LPS – Values of coefficient k_1

Class of LPS	k_1
I	0.08
II	0.06
III, IV	0.04



Table 11 – Isolation of external LPS – Values of coefficient k_2

Number of down-conductors	k_2
1	1
2	1 ... 0.5
4, >4	1 ... 1/k



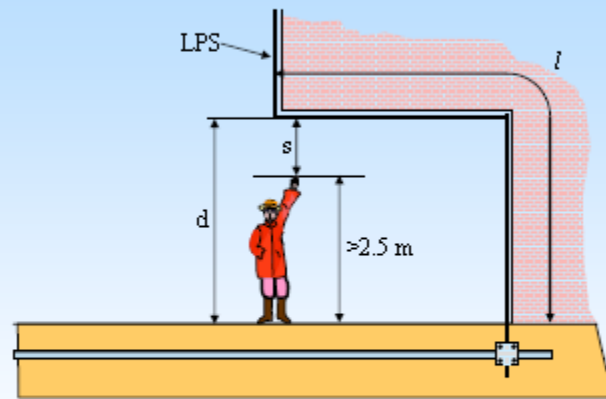
Table 12 – Isolation of External LPS – Values of coefficient k_m

Material	k_m
Air	1
Concrete, bricks	0.5





Lightning protection system design for a cantilevered part of a structure



$$d \geq 2.5 + s$$



Earth termination system ($R \ll 1$)

$R < 10 \Omega$ (low frequency)

Type A arrangement :

horizontal or vertical earth electrodes connected to each down conductor

length $> l_1$ (horizontal)

$0.5 l_1$ (vertical or inclined)



Type B arrangement :

ring conductor external to the structure in contact with the soil
(or foundation earth electrode)

mean radius of the area $r \geq l_1$

If $r < l_1$, add horizontal or vertical (or inclined) electrodes of length
 l_h (horizontal) and l_v (vertical) connected to the ring earth electrode such as

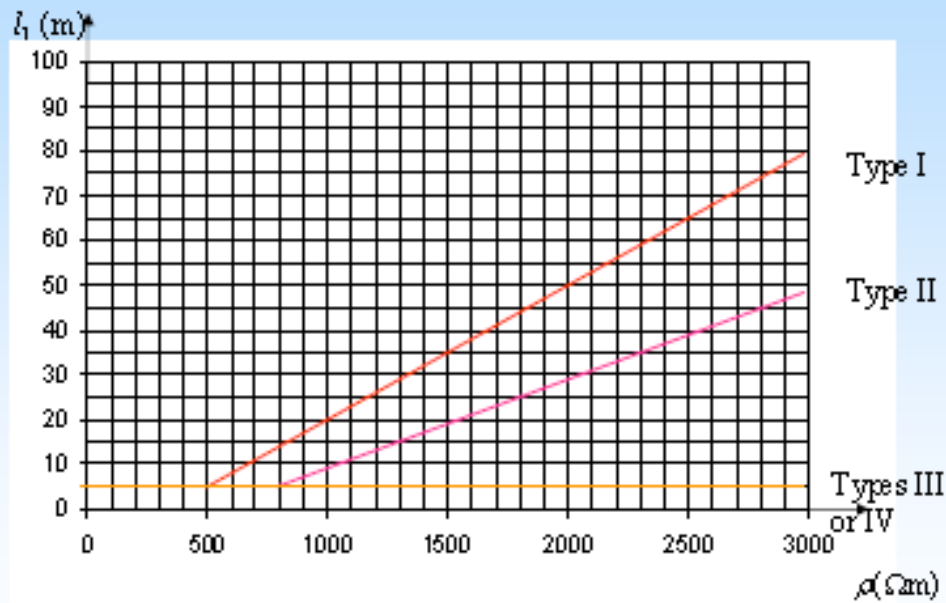
$$l_h = l_1 - r$$

and

$$l_v = 0.5 (l_1 - r)$$



Figure 2
Minimum length l_1 of each earth electrode
according to the type of LPS



NOTE Types III and IV are independent of soil resistivity.





Part 4

Electrical and electronic systems

within structures



SCOPE

Design, installation, inspection, maintenance and testing of a **LEMP protection measures system (LPM)** for electrical and electronic systems within a structure, able to reduce the risk of permanent failures due to lightning electromagnetic impulses.

Outside:

- protection against electromagnetic interference due to lightning ;
- detailed design of the electrical and electronic systems themselves.



Protection measures to reduce failure of electrical and electronic systems

For structures :

LEMP protection measures system (LPM) consisting of the following measures to be used alone or in combination :

- earthing and bonding measures ;
- magnetic shielding ;
- line routing ;
- coordinated SPD protection.

For services :

- SPDs at different locations
along the length of the line and at the line termination ;
- magnetic shields of cables.



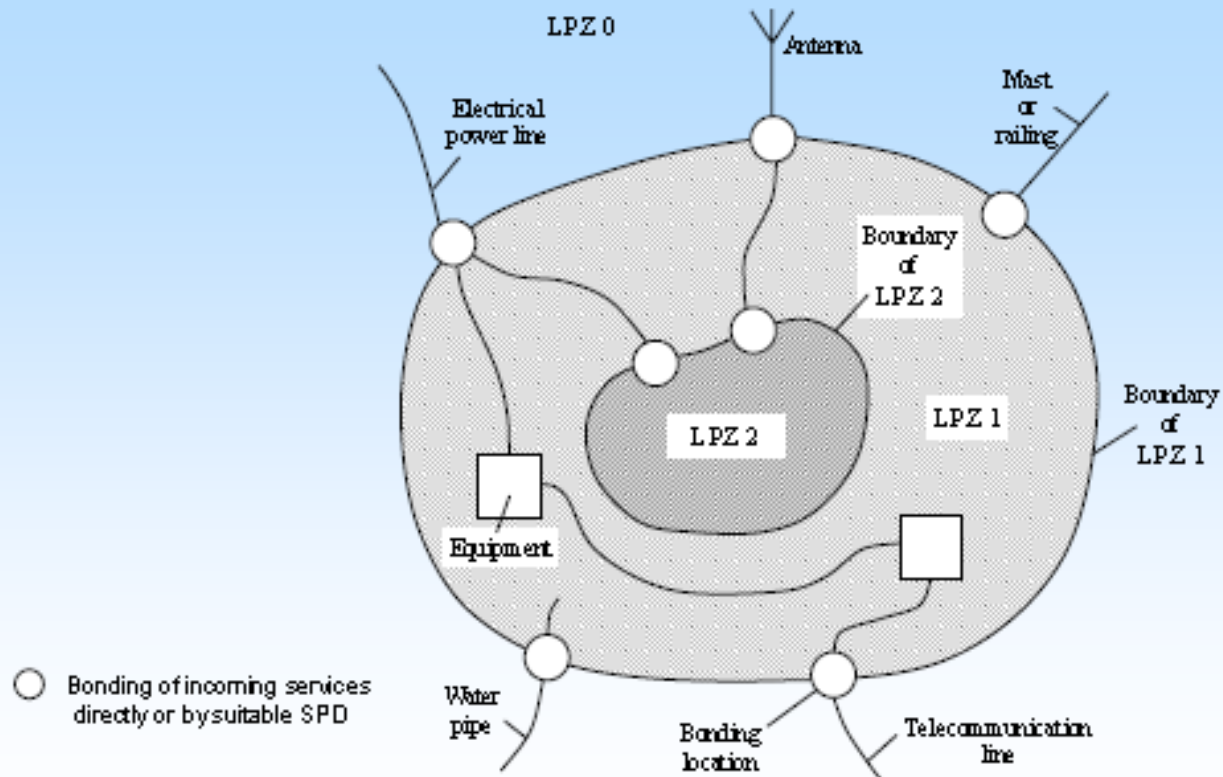
Lightning Protection Zones (LPZ)

Determined by protection measures such as LPS, shielding wires, magnetic shields and SPDs

- LPZ 0_A : **Exposed** to direct lightning strikes.
Full lightning current and exposed to full lightning EM field.
Internal systems may be subjected to full or partial lightning surge current.
- LPZ 0_B : **Protected** against direct lightning strikes.
Partial lightning or induced current and **exposed** to full lightning EM field.
- LPZ 1 : **Protected** against direct lightning strikes.
Surge current is limited by current sharing and by SPDs at the boundary.
Spatial shielding **may attenuate** the lightning EM field (damped EM field).
- LPZ 2, ..., n : as LPZ1, surge current is further limited by current sharing and by additional SPDs at the boundary.
Additional spatial shielding may be used to **further attenuate** the lightning EM field.



General principle for the division into different LPZ



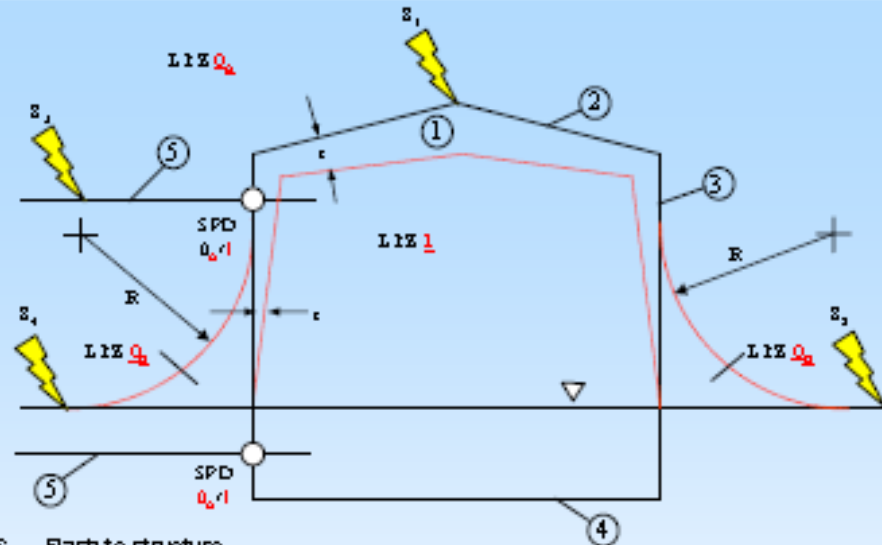
This figure shows an example for dividing a structure into inner LPZs.

All metal services entering the structure are bonded via bonding bars at the boundary of LPZ 1.

In addition, the metal services entering LPZ 2 (e.g. computer room) are bonded via bonding bars at the boundary of LPZ 2.



Figure 2
LPZ
defined
by an
LPS
(IEC 62305-3)



- | | | | |
|---|--------------------------|----------------|---|
| 1 | Structure | S ₁ | Flash to structure |
| 2 | Air-termination system | S ₂ | Flash near to the structure |
| 3 | Down-conductor system | S ₃ | Flash to service entering the structure |
| 4 | Earth-termination system | S ₄ | Flash near a service connected to the structure |
| 5 | Incoming services | R | Rolling sphere radius |
| | | s | Separation distance against dangerous sparking |

○ Lightning equipotential bonding (SPD)

LPZ 0₊ Direct flash, full lightning current

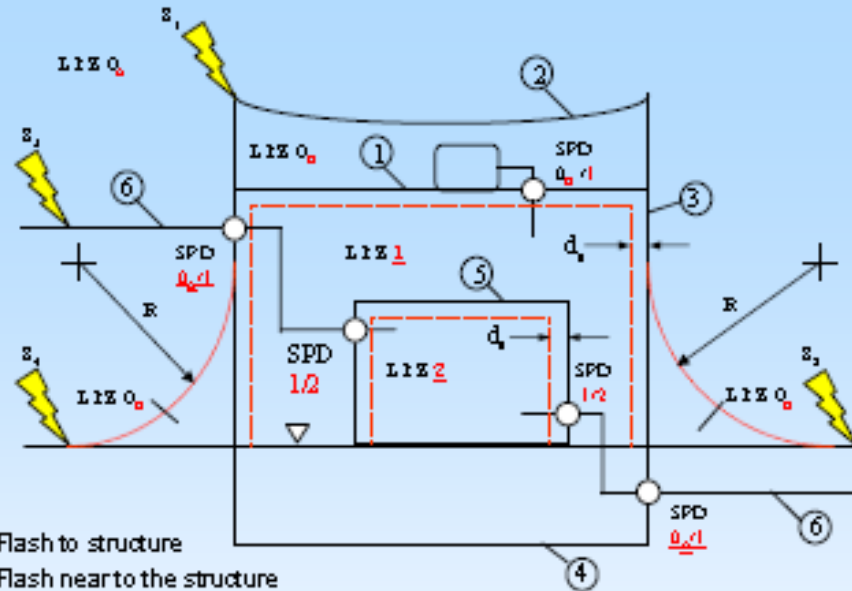
LPZ 0₋ No direct flash, partial lightning or induced current

LPZ 1 No direct flash, partial lightning or induced current

Protected volume inside LPZ 1 must respect separation distance *s*



Figure 3
LPZ
defined by
protection
measures
against
LEMP
(IEC 62305-4)



- 1 Structure (Shield of LPZ 1)
- 2 Air-termination system
- 3 Down-conductor system
- 4 Earth-termination system
- 5 Room (Shield of LPZ 2)
- 6 Services connected to the structure

- S_1 Flash to structure
- S_2 Flash near to the structure
- S_3 Flash to a service connected to the structure
- S_4 Flash near a service connected to the structure
- R Rolling sphere radius
- d_s Safety distance against too high magnetic field

○ Lightning equipotential bonding by means of SPDs

- LPZ 0_0 Direct flash, full lightning current, full magnetic field
 - LPZ 0_b No direct flash, partial lightning or induced current, full magnetic field
 - LPZ 1 No direct flash, limited lightning or induced current, damped magnetic field
 - LPZ 2 No direct flash, induced currents, further damped magnetic field
- Protected volumes inside LPZ 1 and LPZ 2 must respect safety distances d_s .



Protection to reduce the failure of internal systems (1)

Protection against LEMP to reduce the risk of failure of internal systems shall limit :

- overvoltages due to lightning flashes to the structure resulting from resistive and inductive coupling ;
- overvoltages due to lightning flashes near the structure resulting from inductive coupling ;
- overvoltages transmitted by lines connected to the structure due to flashes to or near the lines ;
- magnetic field directly coupling with internal systems.



Protection to reduce the failure of internal systems (2)

System to be protected inside a LPZ 1 or higher :

- magnetic shields to attenuate the inducing magnetic field
- suitable routing of wiring to reduce the induction loop

Bonding at the boundaries of LPZ for metal parts and systems crossing the boundaries (bonding conductors + SPDs)

Coordinated SPD protection

(overvoltages $<$ rated impulse withstand voltage)



Basic protection measures in an LPM

1) earthing and bonding :

earth-termination system + bonding network

Ex.: each conductive service incoming to the structure shall be bonded directly or via suitable SPD at the entrance point.

2) magnetic shielding and line routing :

- grid-like spatial shielding ;
- shielding of internal lines (shielded cables, cable ducts...);
- shielding of external lines entering the structure ;
- line routing of internal lines
(avoiding induction loops and reducing internal surges).

3) surge protective device system (SPD system) :

**limiting both external and internal surges
(coordinated set of SPDs).**

