ICLP 2006 Invited Lecture

Kanazawa (Japan), September 18th 2006

THE LIGHTNING PROTECTION INTERNATIONAL STANDARD

IEC 62305

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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 TC 81 : LIGHTNING PROTECTION

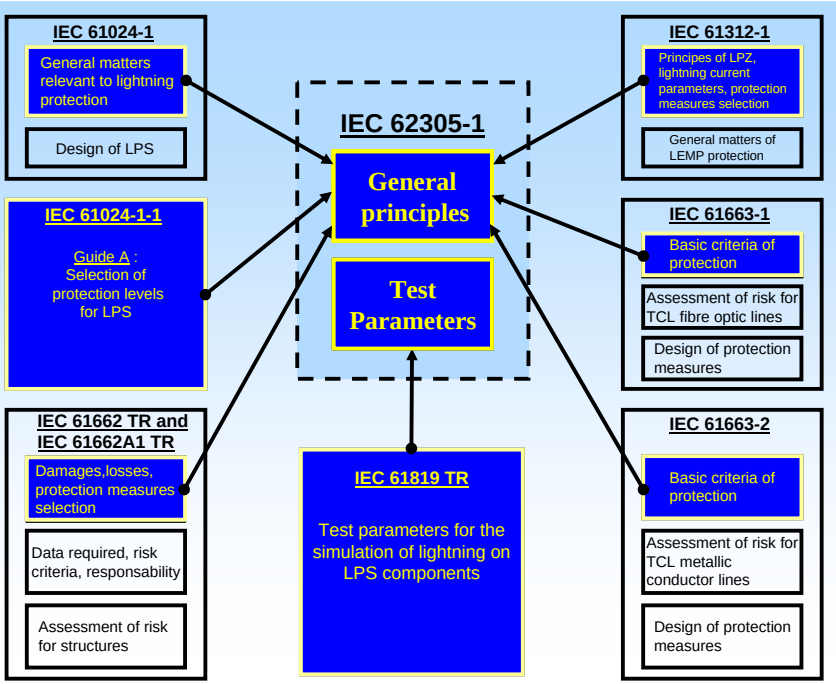
IEC 62305-1 Part 1 : General Principles
- 1-1 Protection against lightning
- 1-2 Test parameters simulating the effects of lightning on LPS components

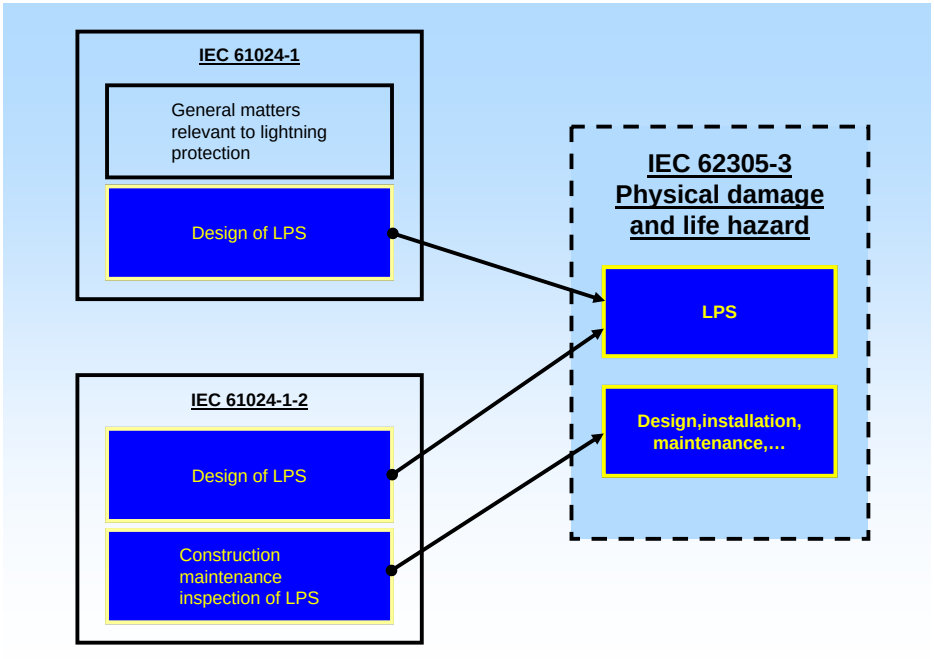
IEC 62305-2 Part 2 : Risk management
- 2-1 Risk assessment method
- 2-2 Risk components for structures
- 2-3 Risk components for services

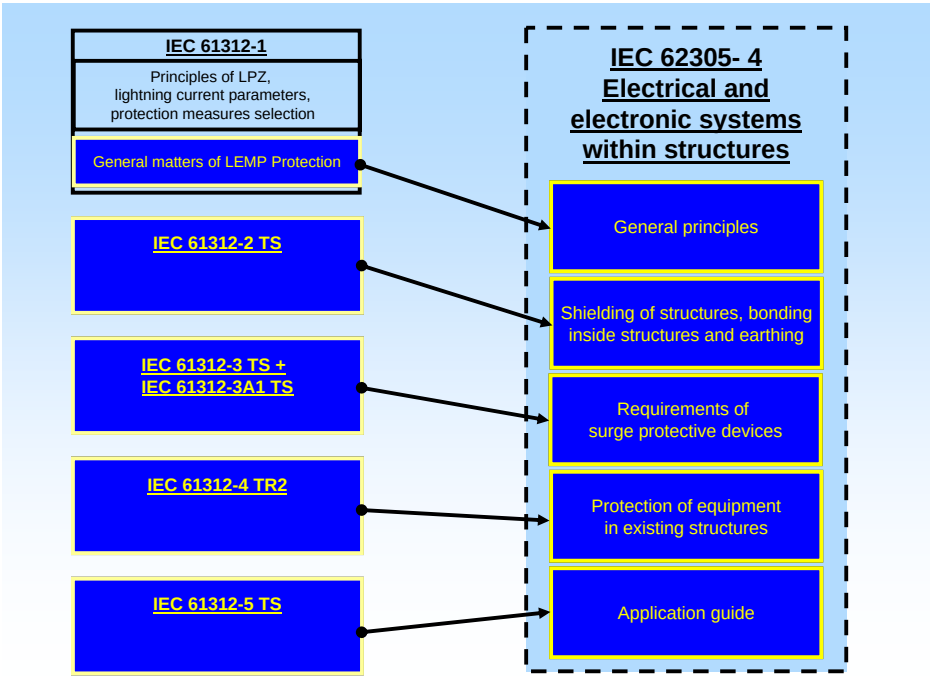
IEC 62305-3 Part 3 : Physical damage and life hazard
- 3-1 Lightning protection system (LPS) = external + internal
- 3-2 Protection measures against injuries of living beings due to touch and step voltages
- 3-3 Design, installation, maintenance and inspection of LPS

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

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	4-4 Management of an LPM system

SCOPE

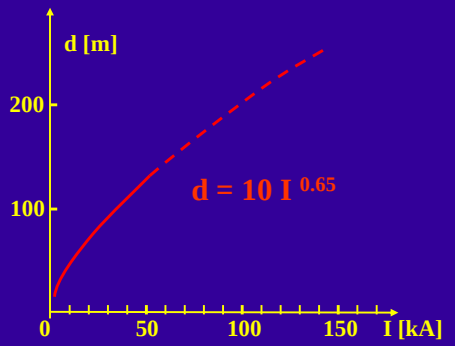
Protection against lightning of

- 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

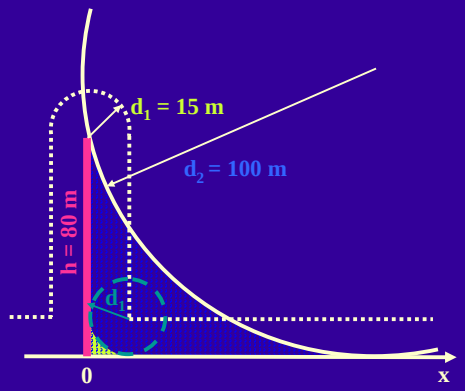
Electrogeometric Model (EGM)
Striking distance



I [kA]	d [m]
2	15
5	27
10	45
30	91
50	127
100	(200)
150	(260)
200	(313)

$$I = 10.6\ Q^{0.7}$$

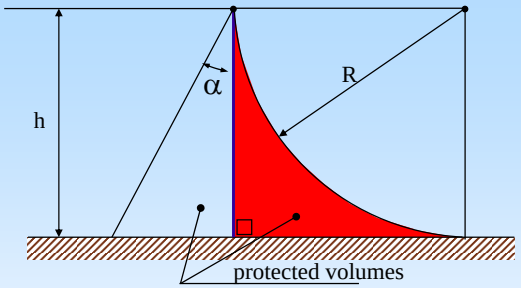
Electrogeometric model applied to a vertical rod



$$d = 10\ I^{0.65}$$

kA	m
2	15
10	45
35	100
100	200

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

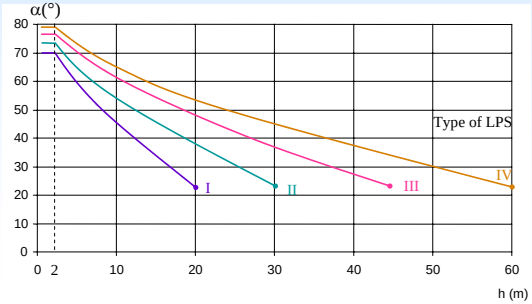


Level	R(m)	α(h = 20)	α(h = 30)	α(h = 45)	α(h = 60)	d(m)
I	20	25	*	*	*	5
II	30	35	25	*	*	10
III	45	45	35	25	*	15
IV	60	55	45	35	25	20

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 x 5	See figure below
II	30	10 x 10	
III	45	15 x 15	
IV	60	20 x 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	

Table 4

Minimum values of lightning parameters and related rolling sphere radius corresponding to LPL

Interception criteria			LPL			
	Symbol	Unit	I	II	III	IV
Minimum peak current	I	kA	3	5	10	16
Rolling sphere radius	R	m	20	30	45	60

Table 5

Probabilities for the limits of the lightning current parameters

Probability that lightning current parameters are	LPL			
	I	II	III	IV
smaller than the maxima defined in table 3	0,99	0,98	0,97	0,97
greater than the minima defined in table 4	0,99	0,97	0,91	0,84

- ~~ESE, French PDA...~~

no significant difference in the attractive distance !

- ~~Eliminators, repellers…~~

fancy devices !

IEC TC81

encourages scientific and technical progress;
the introduction of other devices in our standard is too early since, at the time being, these systems do not have scientifically and practically proven efficiency.

CIGRE 33.01.03

there is neither significant theoretical analysis nor substantial field data which support conclusive improvement in interception efficiency of non conventional lightning air terminals (ESE) with respect to the conventional ones (metallic air terminations).

ICLP

See cautionary message on the ICLP site.

Part 2

Risk management

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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 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)

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

*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.

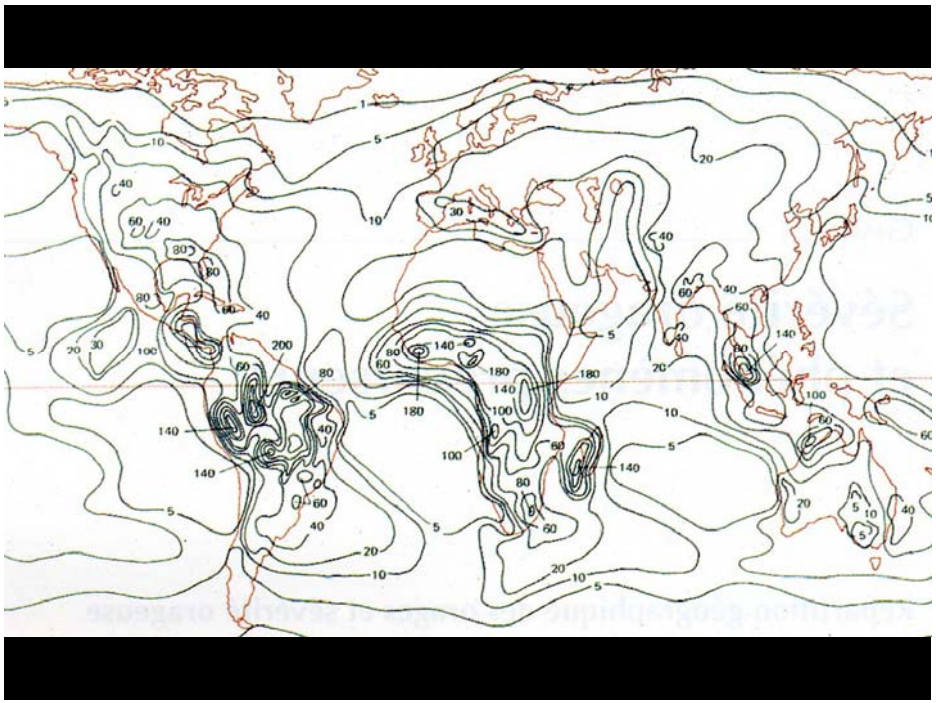
Assessment of the average number of flashes to a structure

$$N_D = Ng\ A_d\ C_d\ 10^{-6}$$

- Ng: lightning ground flash density
- A_d: collection area (m^2)
- C_d: relative location

Table A.2 - **Location factor C_d**

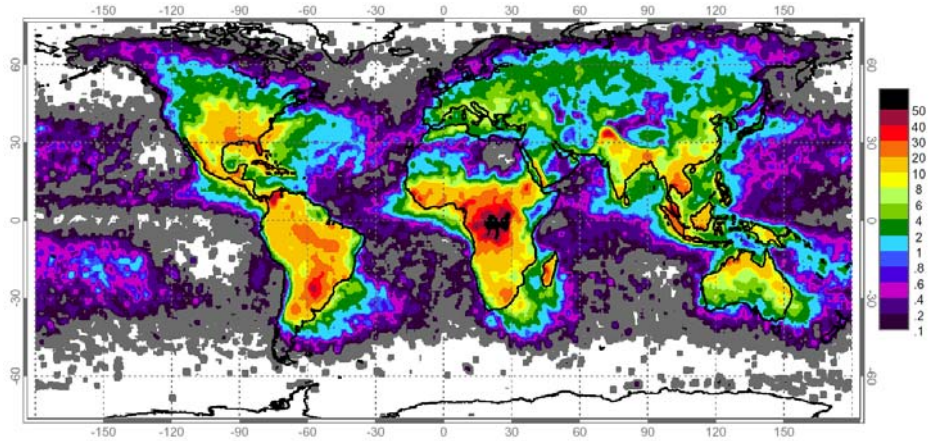
Relative location	C_d
Object surrounded by other higher objects or trees	0.25
Object surrounded by other objects or trees (same h)	0.5
Isolated object: no other objects in the vicinity	1
Isolated object on a hilltop or a knoll	2



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

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

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



$$R_X = N\ P_X\ L_X \qquad X = A,B,\ldots$$

- N: number of dangerous events
- P_X: probability of damage
- L_X: 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

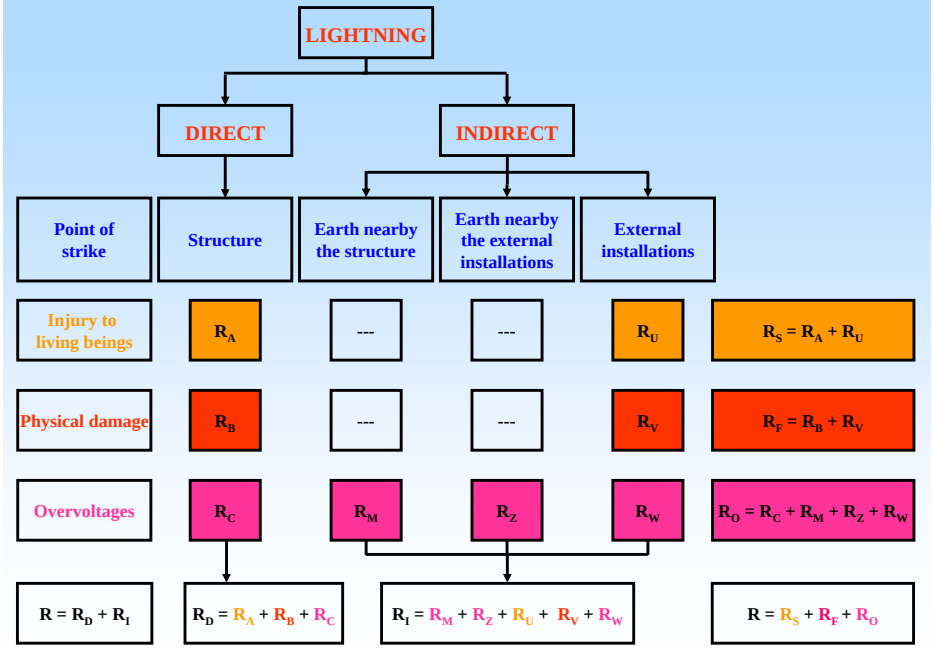
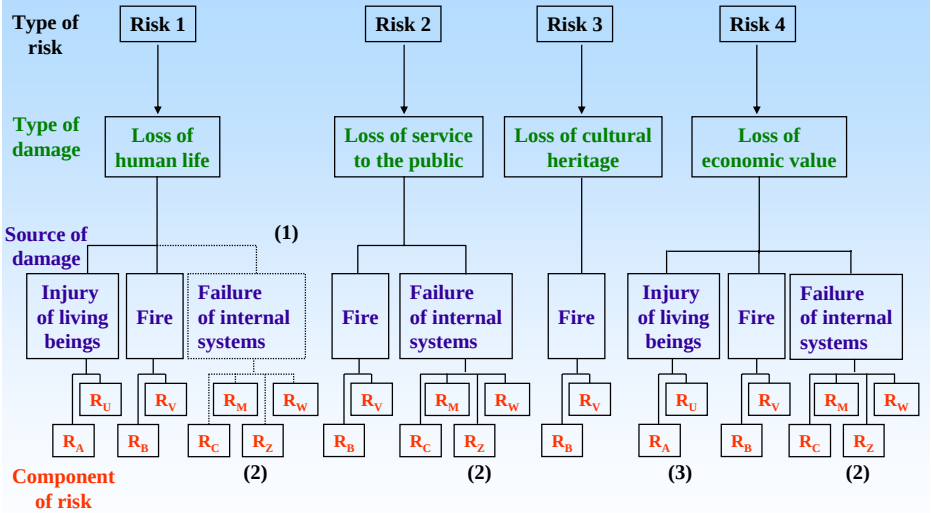


Figure 1 **Types of loss resulting from different types of damage**



(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_4 (economic value)

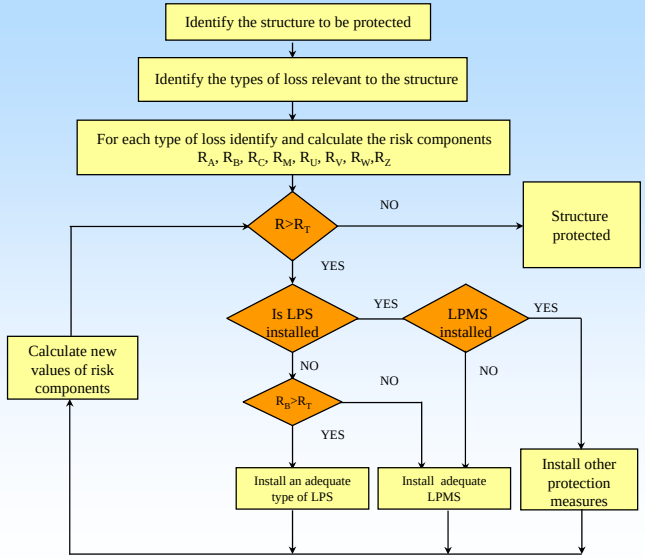
Protection measures convenient if $C_{RL} + C_{PM} < C_L$

with C_{RL} = residual loss when protection measures

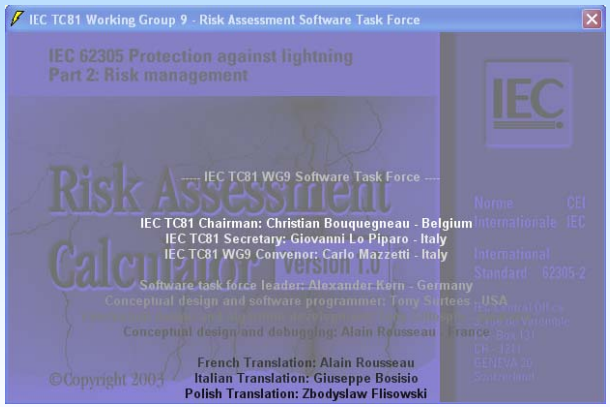
C_{PM} = cost of protection measures

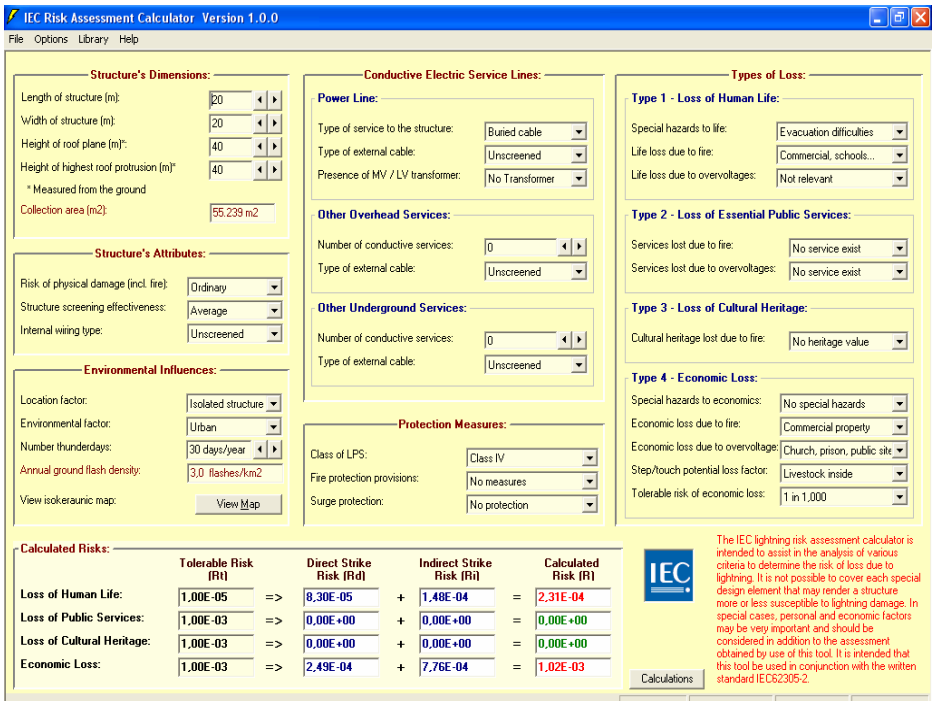
C_L = cost of total loss without protection measures

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



LPMS = LEMP protection measures system





Part 3

Physical Damage and Life Hazard

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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 :

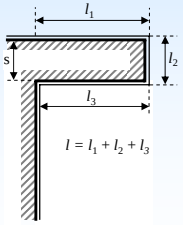
- RSM (EG model ; always !)
- Protection angle method (limited : height !)
- Mesh method (plane surfaces)

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_i

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

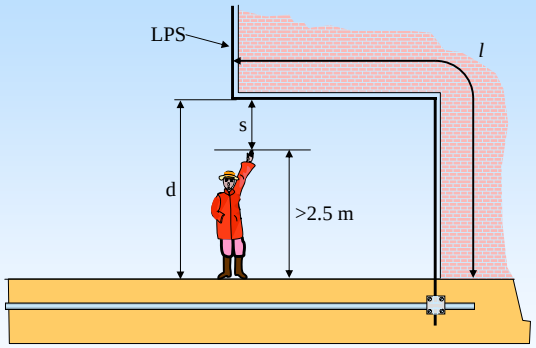
Table 11 – Isolation of external LPS – Values of coefficient k_c

Number n of down-conductors	k_c
1	1
2	1 ... 0.5
4, >4	1 ... 1/n

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 > 2.5 + s

Earth termination system (R<< !)

R < 10 Ω (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)

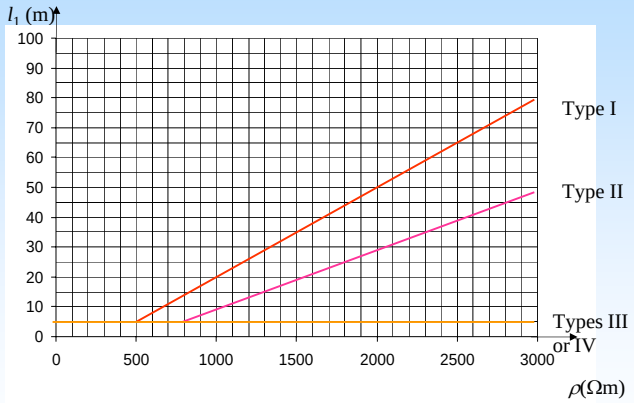
mean radius of the area $r \geq l_1$

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

$$l_r = l_1 - r \quad \text{and} \quad l_v = 0.5\,(l_1 - r)$$

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

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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

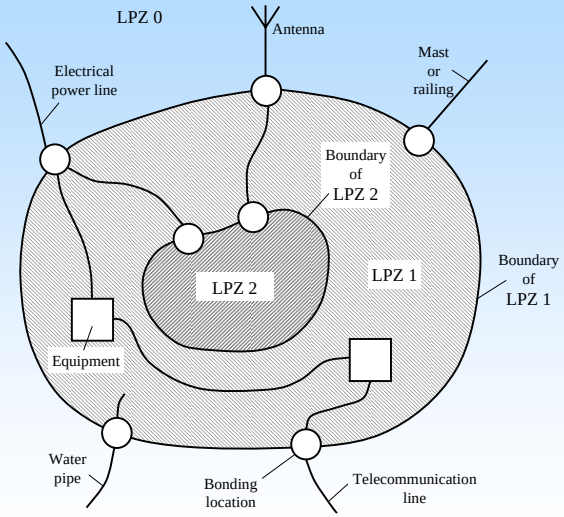
– LPZ 0_A : **Exposed** to direct lightning strikes.
Full lightning current and exposed to full lightning EM field.
Internal systems may be subjected to full or partial lightning surge current.

– 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.

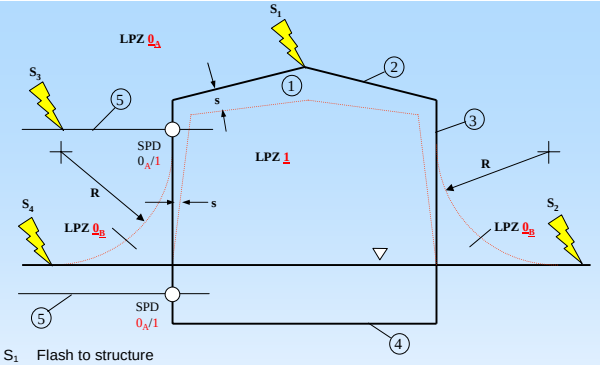
General principle for the division into different LPZ



○ Bonding of incoming services directly or by suitable SPD

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)

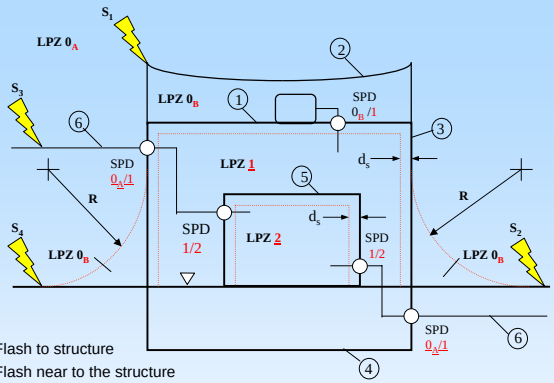


1	Structure	S_1	Flash to structure
2	Air-termination system	S_2	Flash near to the structure
3	Down-conductor system	S_3	Flash to service entering the structure
4	Earth-termination system	S_4	Flash near a service connected to the structure
5	Incoming services	R	Rolling sphere radius
		s	Separation distance against dangerous sparking

○ Lightning equipotential bonding (SPD)

LPZ 0_A	Direct flash, full lightning current
LPZ 0_B	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)	S_1	Flash to structure
2	Air-termination system	S_2	Flash near to the structure
3	Down-conductor system	S_3	Flash to a service connected to the structure
4	Earth-termination system	S_4	Flash near a service connected to the structure
5	Room (Shield of LPZ 2)	R	Rolling sphere radius
6	Services connected to the structure	d_s	Safety distance against too high magnetic field

○ Lightning equipotential bonding by means of SPDs

LPZ 0_A	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).

CONCLUSION

IEC TC 81 (+ CLC TC 81X)

STANDARD TO BE IMPROVED
during the maintenance period (2006-2010)

NATIONAL COMMITTEES
should avoid to promote fancy devices
which do not comply with it.