CENTRE for ELECTROMAGNETIC and LIGHTNING PROTECTION RESEARCH (CELP)

Lightning Protection of Buildings: Guidance to MS IEC 62305 and Updates from Working Group/Research Institute

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Chair, IEC TC 81: Lightning Protection (National Mirror Comm)

Immediate Past Chair, IEEE PES Malaysia Chapter

Chair, MNC-CIGRE C4: System Technical Performance

WG Committee: IEEE 1410; CIGRE C4.23, C4.27

- seen at few hundred meters
- less than 1 m to over 1 km
Return stroke current
Flashover
Coupling
P
Electromagnetic Field
z
Channel Base Current
Striking Distance

THE CIRCULAR

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Suruhanjaya Tenaga

www.st.gov.my

Ruj kami : ST(IP/JKE)PE/16/04/1 (3)
Tarikh : 17 Ogos 2011

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SENARAI SEPERTI EDARAN

Y. Bhg. Datuk/Dato'/Datin/Tuan/Puan,

PEKELILING BIL. 03/2011 - MENGENAI PENETAPAN KAEDAH PEMASANGAN SISTEM PERLINDUNGAN KILAT DI BANGUNAN-BANGUNAN

Dengan segala hormatnya saya merujuk kepada perkara diatas.

2. Untuk makluman Y. Bhg. Datuk/Dato'/Datin/Tuan/Puan, lanjutan mesyuarat mengenai penetapan kaedah pemasangan sistem perlindungan kilat di bangunan-bangunan yang telah diadakan pada 8 Mac 2011 lalu, ST dengan ini bersetuju supaya satu ketetapan bagi kaedah tersebut diadakan.

THE GUIDEBOOK

MS IEC 62305 (2007)

- MS IEC 62305-1 :2007 - *General principles*
- MS IEC 62305-2 :2007 - *Risk management*
- MS IEC 62305-3: 2007 - *Physical damage to structures and life hazard*
- MS IEC 62305-4 :2007 - *Electrical and electronic systems within structures*

PRESENTATION OUTLINES

- Origins of Lightning Protection Systems
- General Principle
- Risk Assessment
- Lightning Protection System
- Surge Protection
- Inspection and Maintenance of LPS
- Updates from WG/ Research Inst.
- Concluding Remarks

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ORIGINS OF LIGHTNING PROTECTION

- Earliest literature available: 1752 (Benjamin Franklin)

-He consequently published the first instruction for lightning protection:

"The method is this: Provide a small **iron rod** (maybe made of the rod iron used by the Nailers) but of such length, **that one end being three or four feet in the moist ground, the other maybe six or eight feet above the tallest part of the building**. **To the upper end of the rod, fasten about a foot of brass wire, the size of a common knitting needle, sharpened to a fine point; the rod maybe secured to the house by a few small staples. If the house be long, there maybe a rod and point each end and a middling wire along the ridge from one to the other**. A house thus furnished will not be damaged by lightning, it being attracted by the points and passing through the metal into the ground without hurting anything.." [1]

[1] B Franklin. "How to secure houses from lightning", *Poor Richards's Almanac*, reproduced in Benjamin Franklin's Experiments, edited by I. Bernard Cohen, Harvard University Press, 1941.

Early field trials and investigation of failures
Board House at Purfleet, Essex, England

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-Reported by Nickson [2] where lightning protection was installed and struck shortly thereafter. Yet the lightning rod was not struck.
-Investigation revealed another metallic object was struck and lightning conducted to ground.
-This incident caused the first reconsideration of lightning protection technology and it's techniques.

[2] E Nickson (Store-keeper at Purfleet), "XV. Sundry papers relative to an accident from lightning at Purfleet, May 15, 1777. Report to the Secretary of the Royal Society". *Phil. Trans., Royal Soc.*, **LXVIII,** for 1778, Part. 1, pp 232-235.

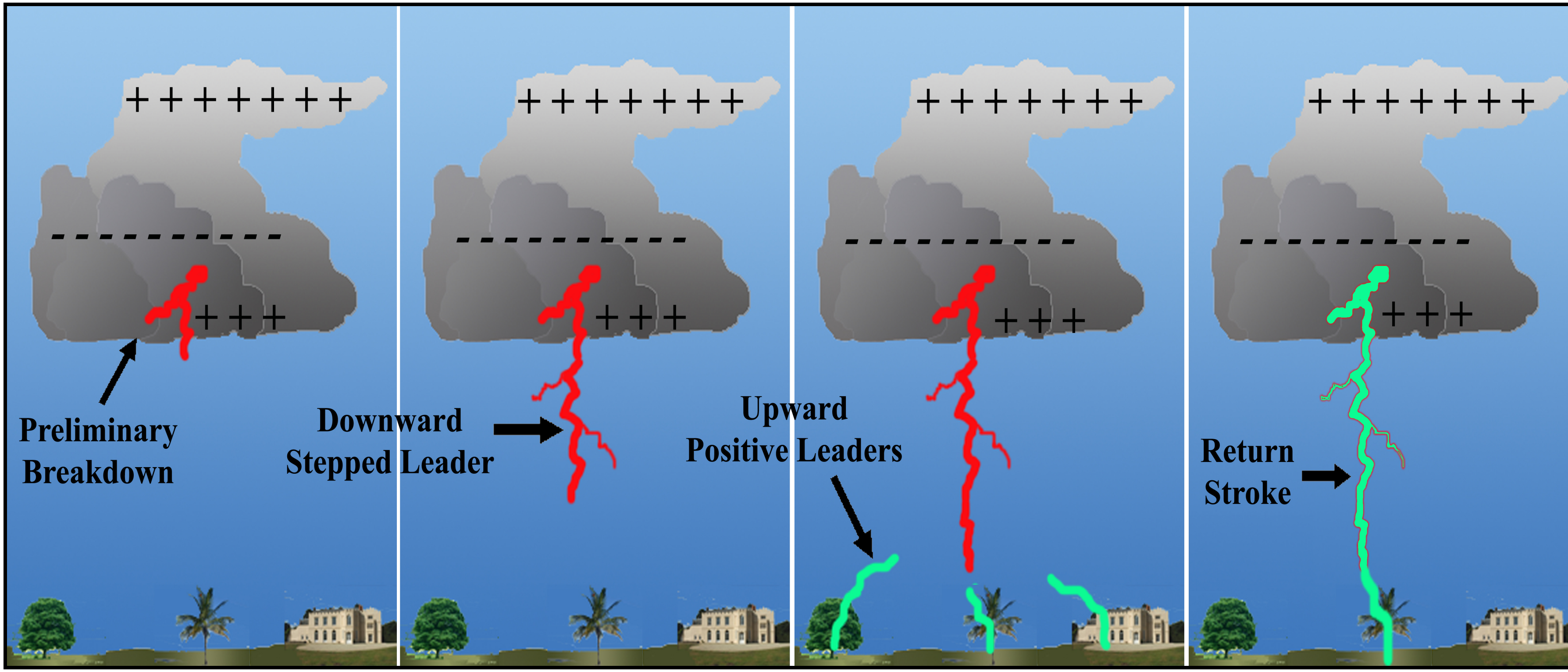
Knowledge gained from Purfleet incident

-Lightning-damaged corner of the Board House was not adequately protected by the closest lightning rod, installed above the centre of the 44-foot (13.5m) high building with a tip-height of 27 feet (~8m) above and horizontal distance of 37 feet (~11m) from the lightning strike point [3].

-This incident drove the first recommendations for lightning protection systems concerning bonding of incidental metal and the first consideration concerning the effective range of strike terminations. It also set off the blunt vs. pointed air terminal arguments.

[3] RH Golde, "Lightning", Vol. 2, Academic Press London, 1977, pp 546 provides a pictorial description of Purfleet..

GENERAL PRINCIPLE



The propagation of a downward stepped leader and the interception with a tree on earth

Lightning Current

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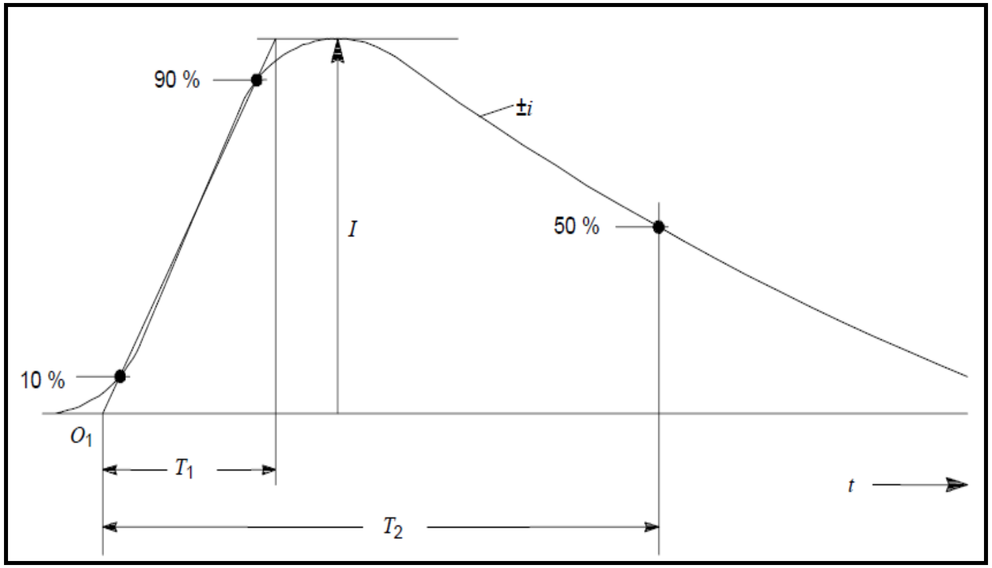
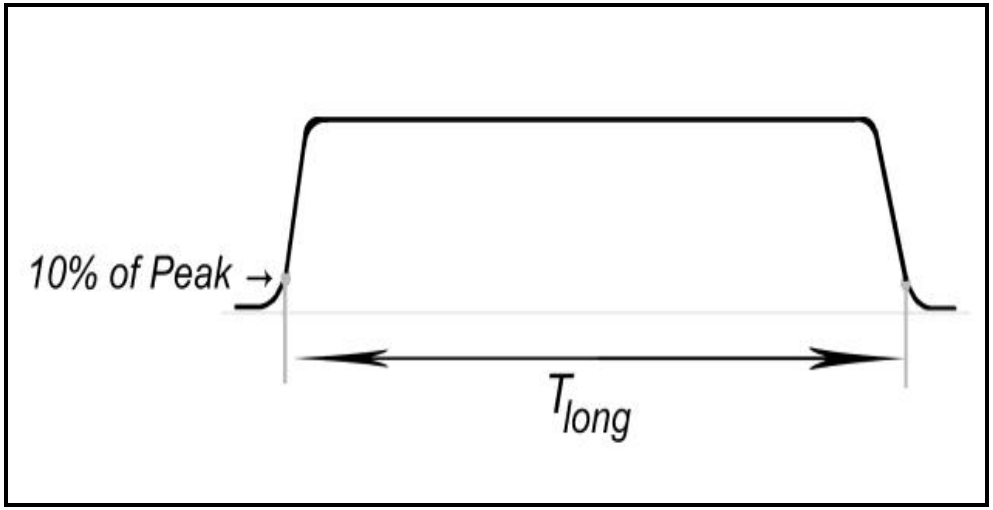


The short stroke current (impulse) as specified in MS IEC 62305-1-2007



The long stroke current (continuing current) specified in MS IEC 62305-1:2007. T_{long} can vary between 2 ms to 1000 ms.

Comparison of return-stroke peak currents (the largest peak, in kA) for first strokes in negative downward lightning

References	Location	Sample size	Percent exceeding tabulated value			$\sigma_{log}I$ (base 10)	Remarks
			95%	50%	5%		
Berger et al. (1975)	Switzerland	101	14	30 (~30)	80	0.26	Direct measurements on 70-m towers
Anderson and Eriksson (1980)	Switzerland	80	14	31	69	0.21	Direct measurements on 70-m towers
Dellera et al. (1985)	Italy	42	-	33	-	0.25	Direct measurements on 40-m towers
Geldenhuys et al. (1989)	South Africa	29	7*	33 (43)	162*	0.42	Direct measurements on a 60-m mast
Takami and Okabe (2007)	Japan	120	10	29**	85	0.28**	Direct measurements on 40- to 140-m transmission-line towers
Visacro et al. (2011)	Brazil	38	21	45	94	0.20	Direct measurements on a 60-m mast
Anderson and Eriksson (1980)	Switzerland (N=125), Australia (N=18), Czechoslovakia (N=123), Poland (N=3), South Africa (N=11), Sweden (N=14), and USA (N=44)	338	9*	30 (34)	101*	0.32	Combined direct and indirect (magnetic link) measurements
CIGRE Report 63 (1991)	Switzerland (N=125), Australia (N=18), Czechoslovakia (N=123), Poland (N=3), South Africa (N=81), Sweden (N=14), and USA (N=44)	408	-	31 (33)	-	0.21	Same as Anderson and Eriksson's (1980) sample plus 70 additional measurements from South Africa

The 95%, 50%, and 5% values are determined using the lognormal approximation to the actual data, with 50% values in the parentheses being based on the actual data.

$\sigma_{log}I$ is the standard deviation of the logarithm (base 10) of peak current in kA.

* As reported by Takami and Okabe (2007).

**26 kA and 0.32 after compensation for the 9-kA lower measurement limit.

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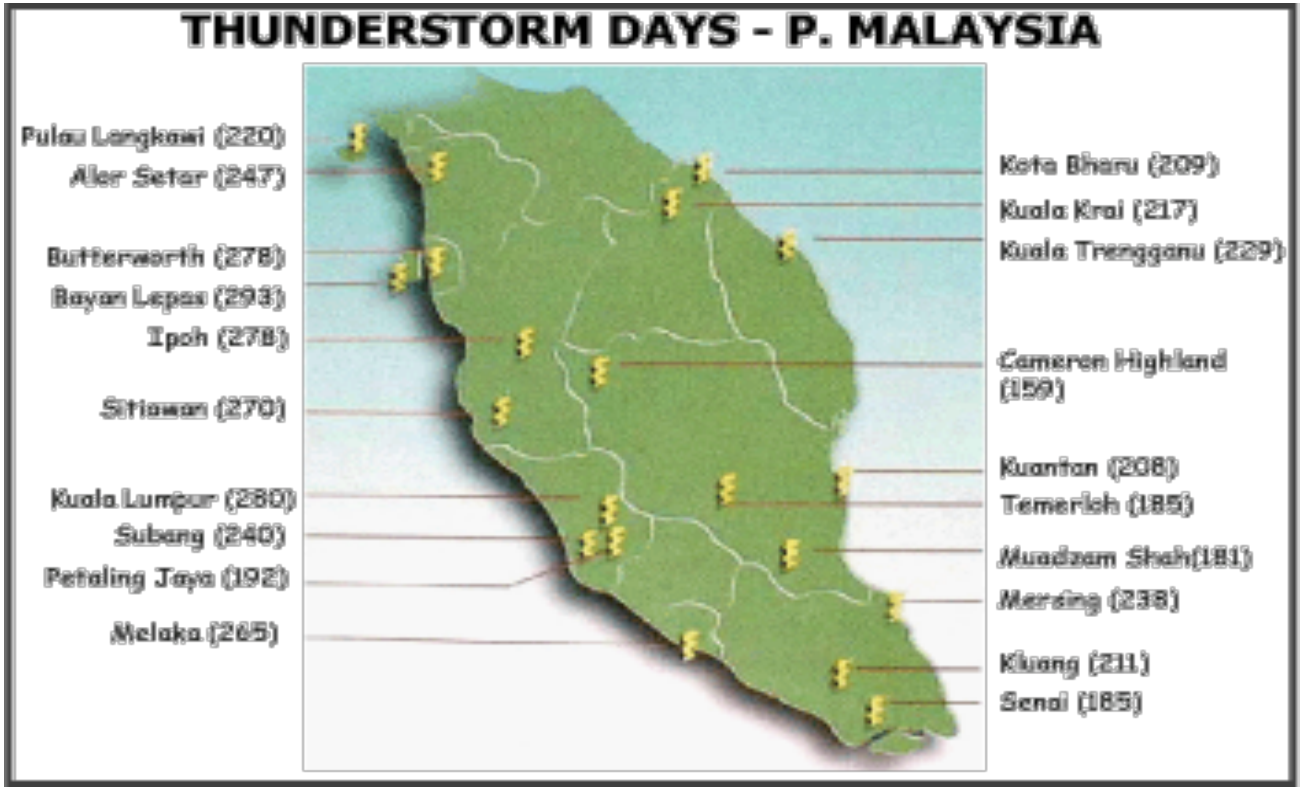
Lightning Severity



MS IEC 62305-2:2007 page 87, Annex A, specify approximate relationship of the lightning density N_g with keraunic level thunder days $\mathbf{T_d}$ **for temperate land only.**

$$N_g = 0.1\,T_d$$

where

$\mathbf{N_g}$ is the ground flash density in flashes per km^2 per year

$\mathbf{T_d}$ is the number of days with thunder per year

Injury Mechanisms

3-5%	Direct Strike
1-2%	Contact Injury
30-35%	Side Splash / Flash
50-55%	Ground Current
10-15%	Upward Streamer

Lightning Injuries/ Fatalities

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Based on the no of victims*

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2008	3	0	0	3	3	2	0	0	0	0	9	0	20
2009	0	0	0	0	13	6	0	0	0	8	0	5	32
2010	0	0	0	2	0	0	0	0	9	2	0	0	13
2011	1	2	1	0	0	3	3	12	2	1	4	1	30
2012	0	5	1	56	7	1	5	5	1	0	5	0	86
2013	0	12	1	2	0	0	2	1	2	0	0	0	20
2014	0	0	4	1	2	0	0	0	0	2	2	0	11
2015	0	0	0	12	4	0	1	1	5	0	0	0	23
Total	4	19	7	76	29	12	11	19	19	13	20	6	235

* As of Sept 2015

Lightning Safety

NO PLACE OUTSIDE

is safe when thunderstorms are in the area

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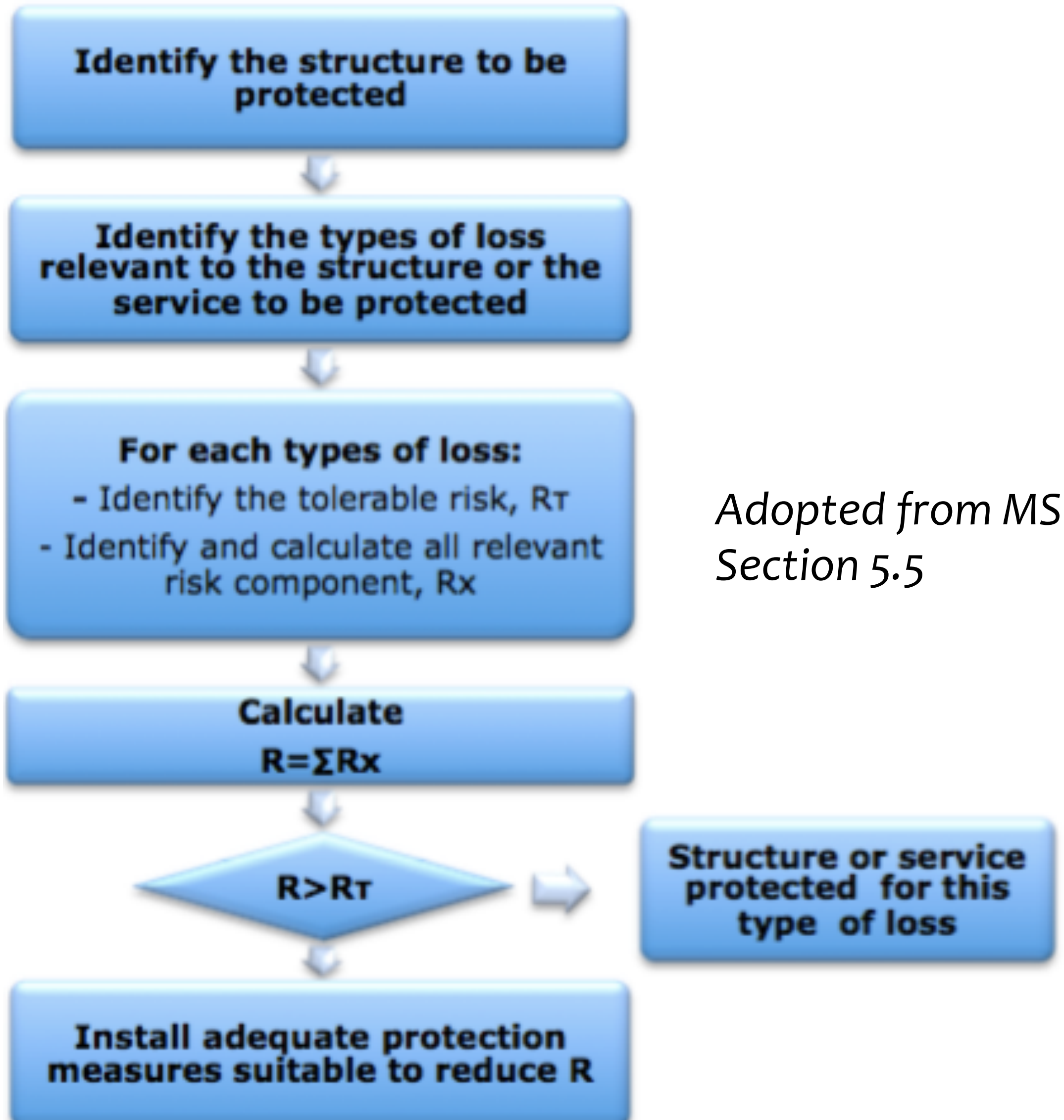
LIGHTNING RISK ASSESSMENT

- To reduce the potential for damage effectively and economically.

- The general steps in risk assessment analysis are described in below:

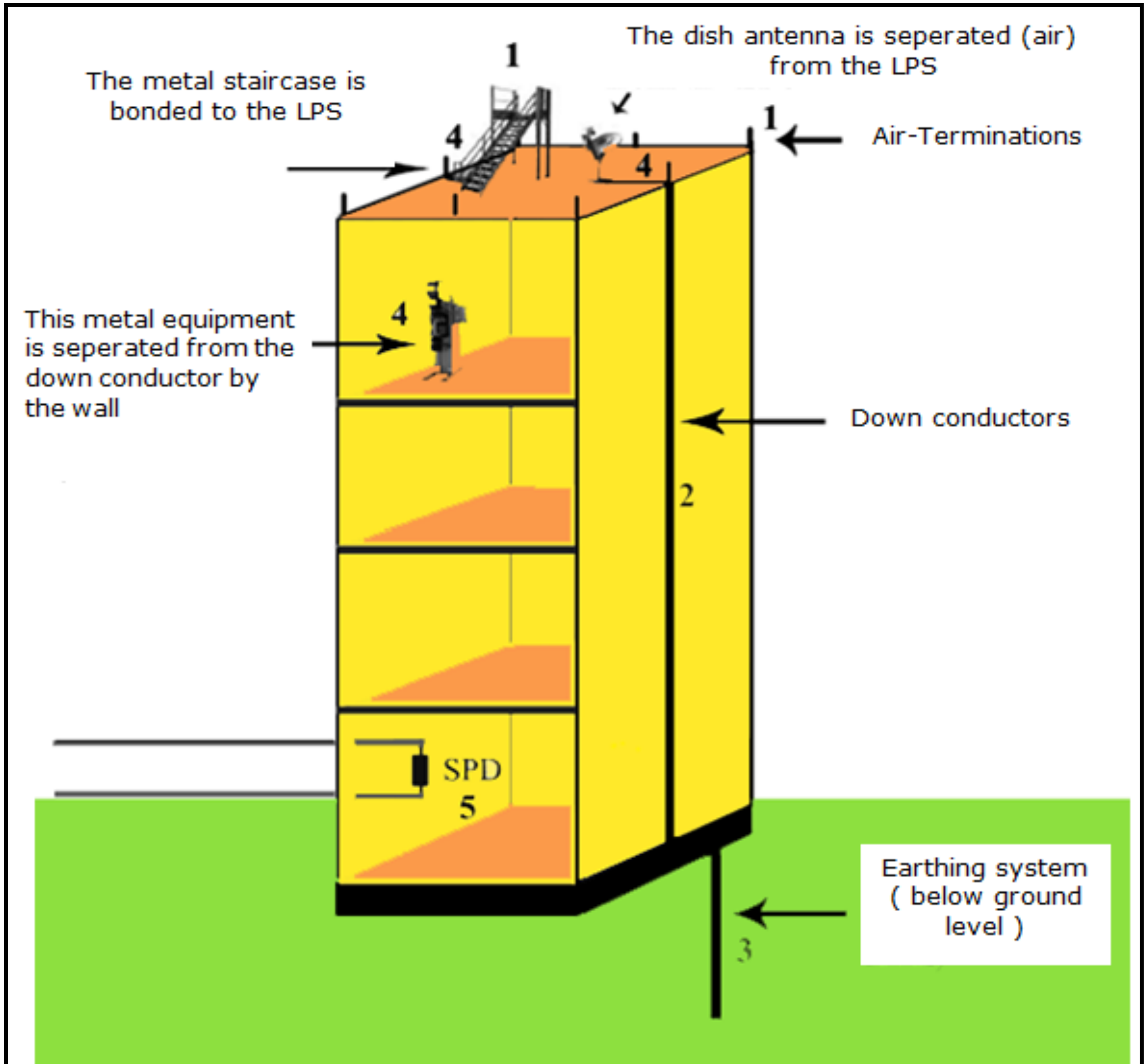
- **Damage and losses**
- **Risk and its components**
- **Risk assessment**
- **Risk management**



Adopted from MS IEC 62305-2:2007 Section 5.5

LIGHTNING PROTECTION SYSTEM

Basic Concept



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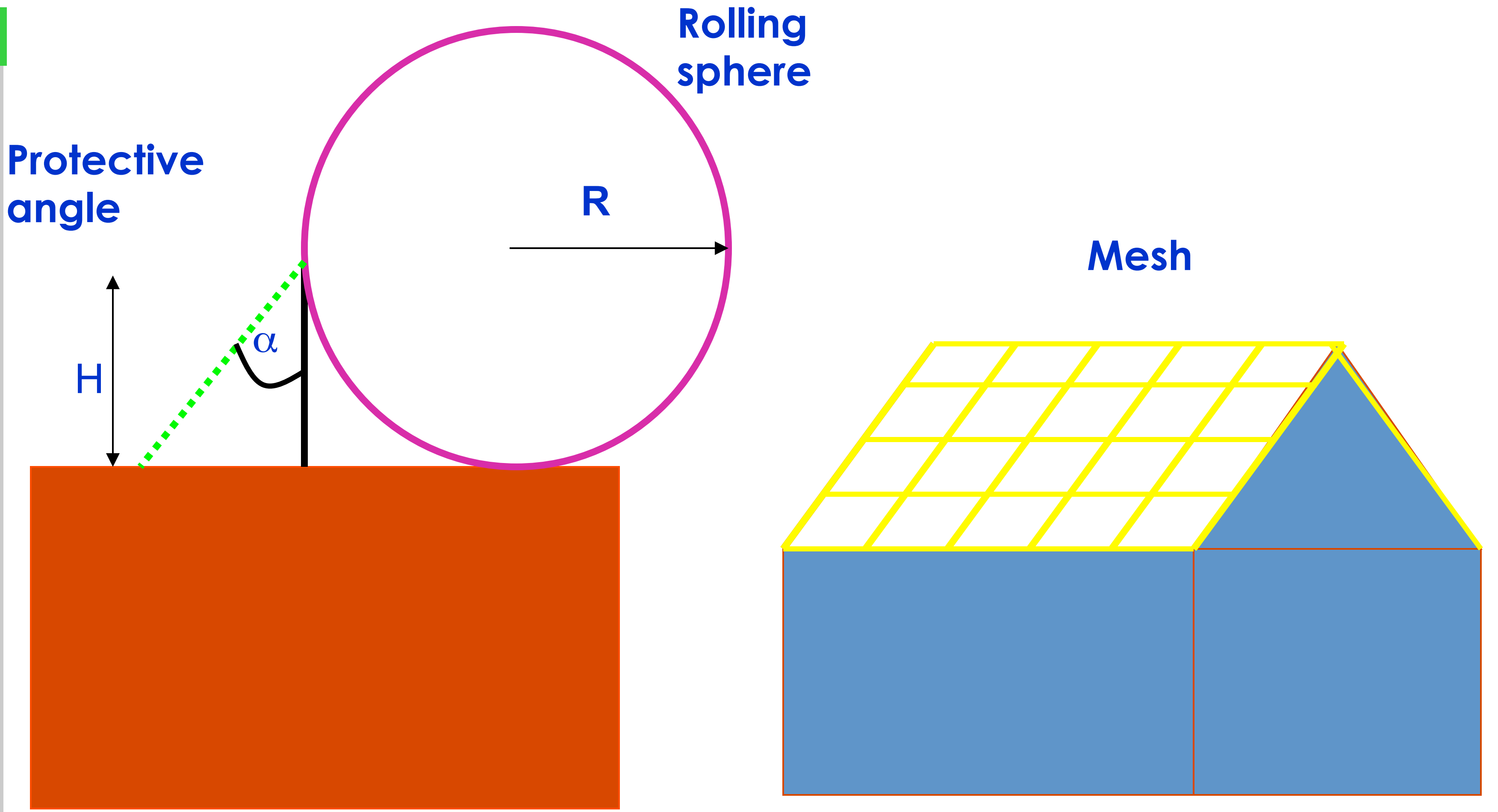
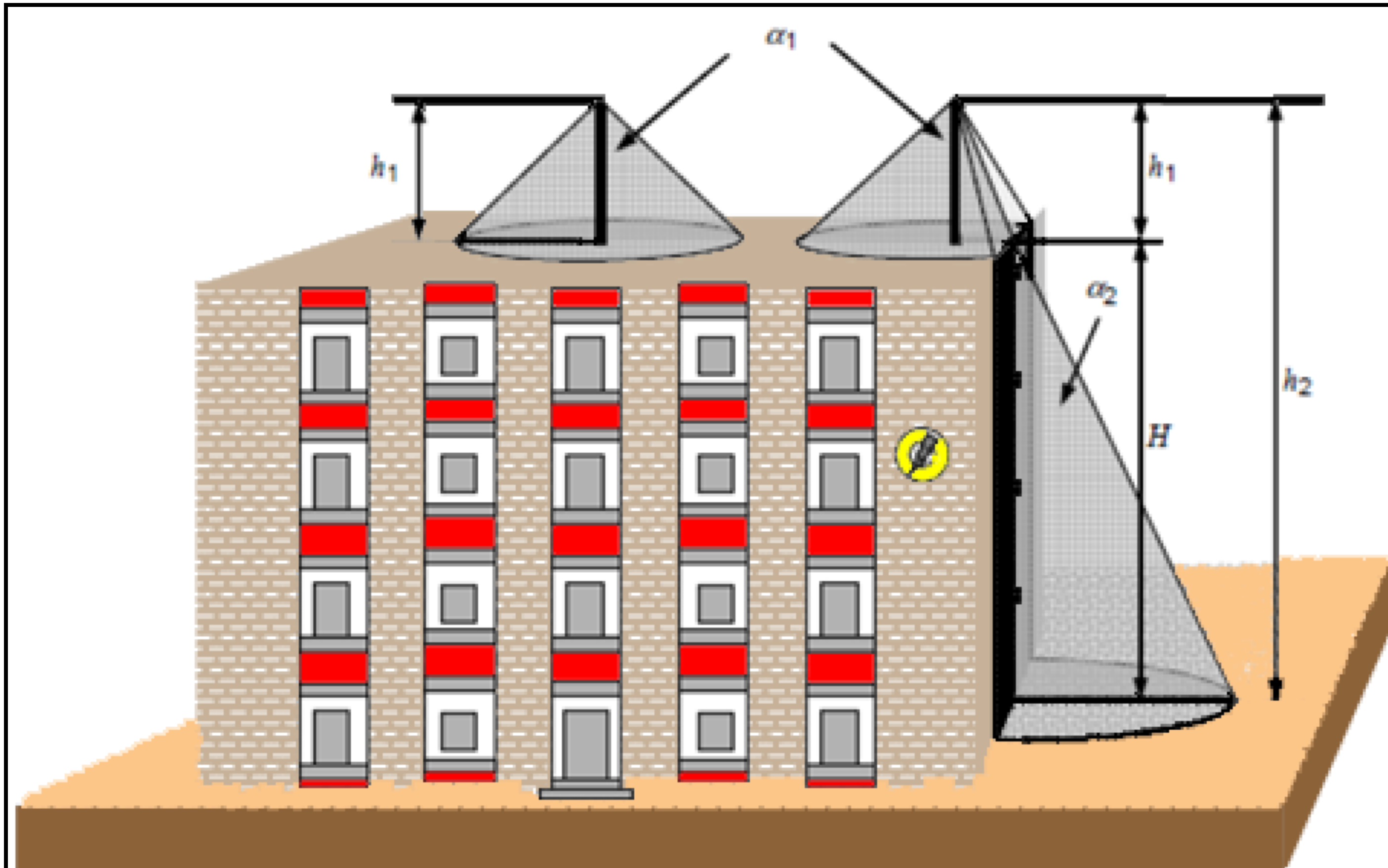
Air Termination System



Protective Angle Method



Mesh Method

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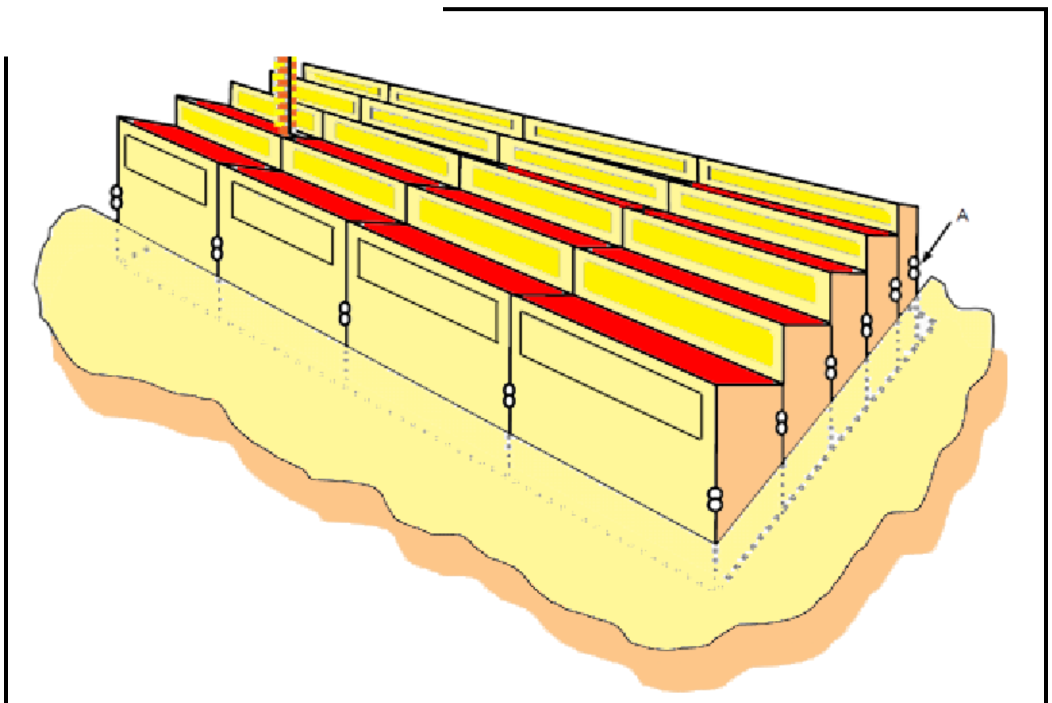
Level of Protection	Mesh size for a square arrangement in (L x L)
I	5mx 5m
II	10mx 10 m
III	15mx 15 m
IV	20mx 20 m



Rolling Sphere Method

- Rolling sphere method is suitable for any type of building, especially high rise building with complex plan.
- Should consider an imaginary sphere of radius R where the value of R depends on the level of protection

Level of Protection	Rolling Sphere radius (m)
I	20
II	30
III	45
IV	60

Rolling Sphere Method

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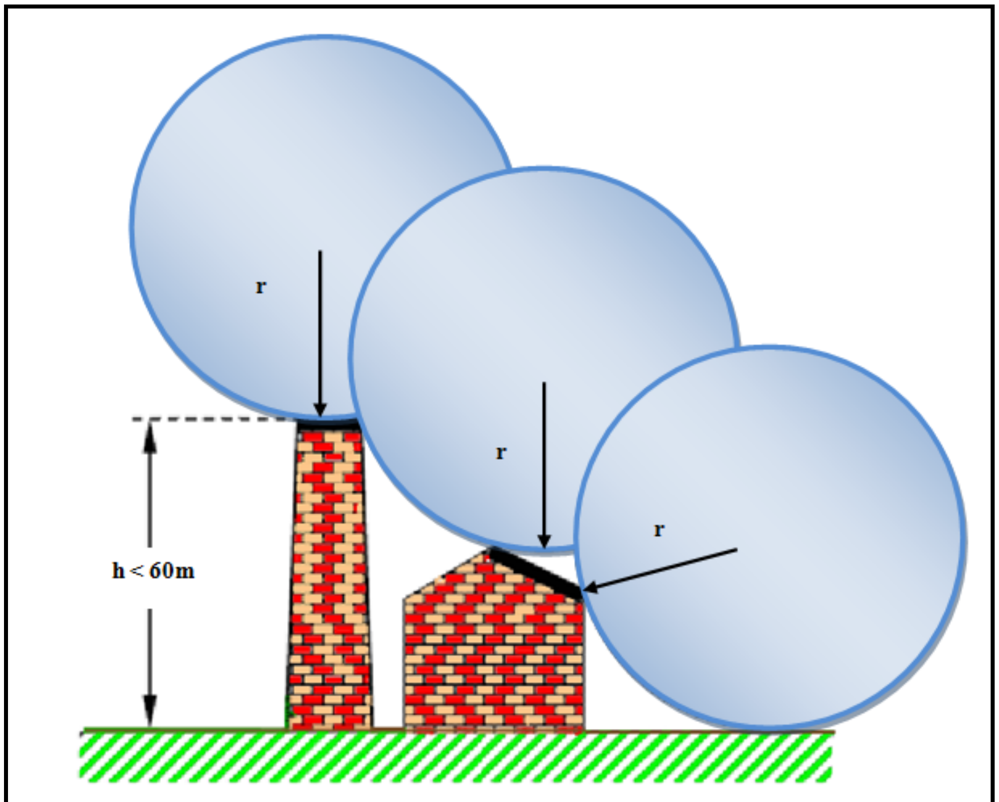
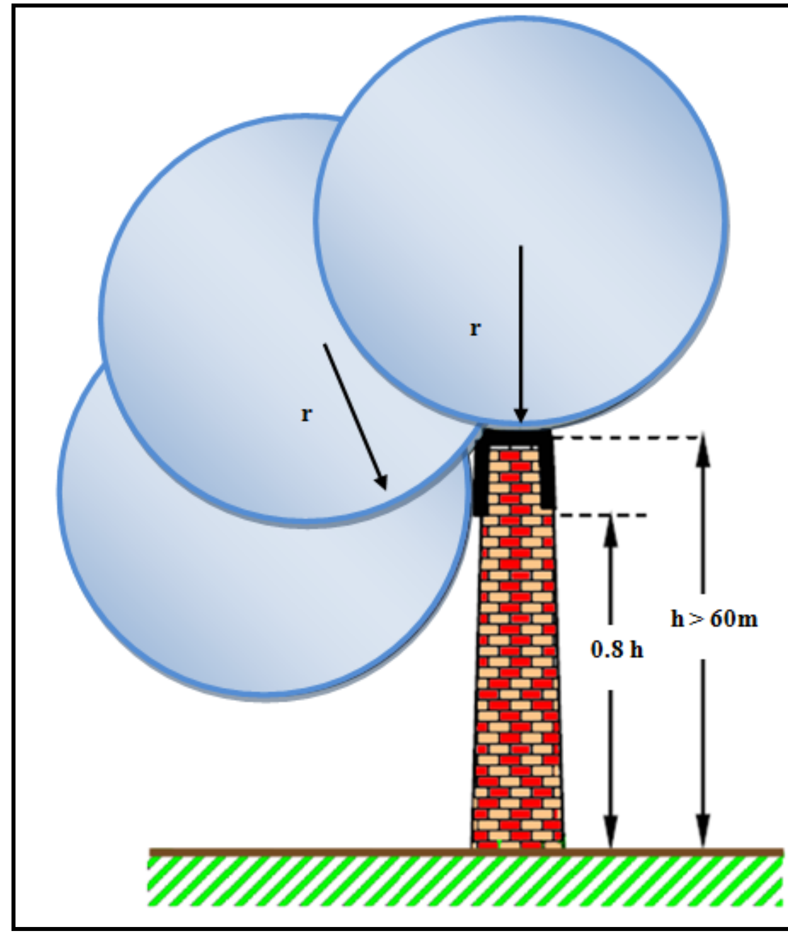
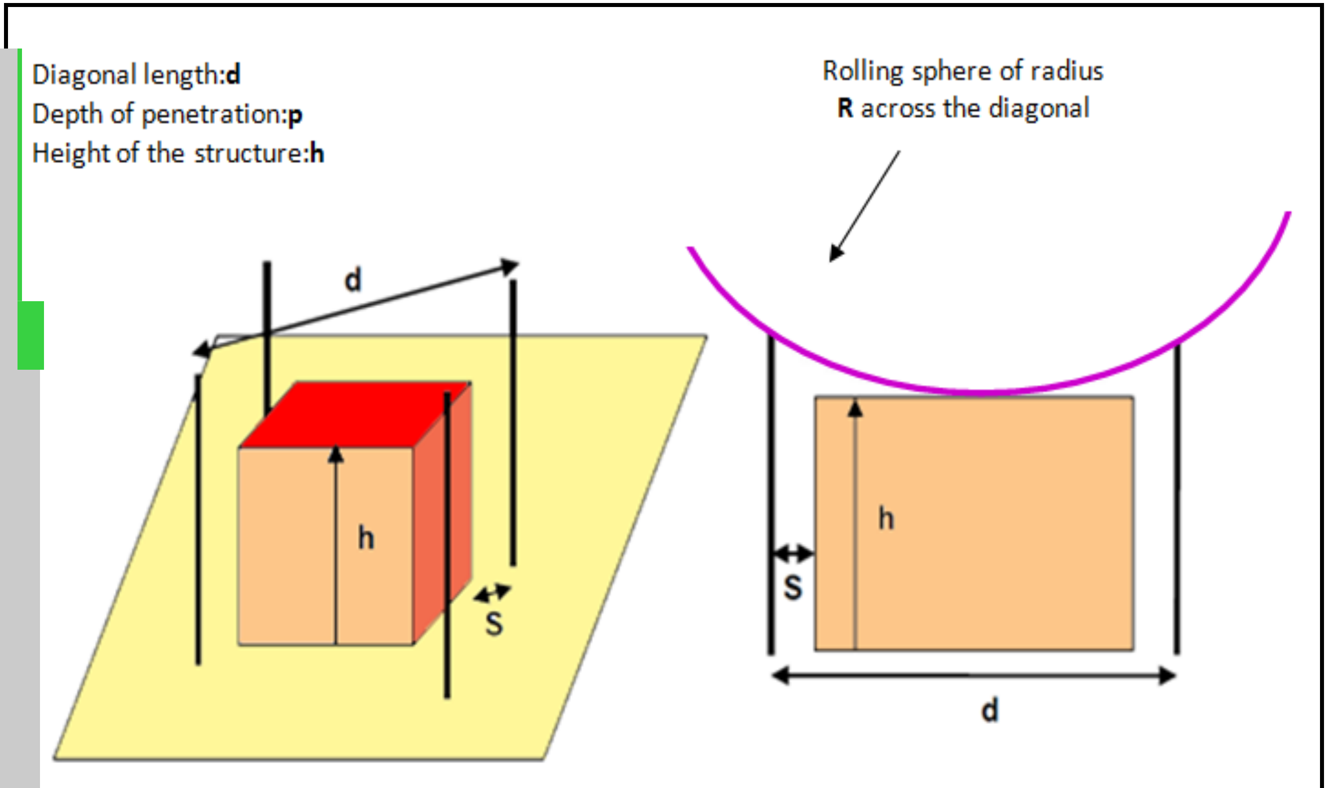
h<60m





h>60m



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An object with isolated vertical rods;

min height of the vertical rod = h+ p

$$p = R - \sqrt{R^2 - \left(\frac{d}{2}\right)^2}$$

Where,
R is radius of the rolling sphere relevant to the level of protection.

d is the separation between the two rods.

Air Termination: Materials and Dimension

- There are several available materials that can be used in the construction of air termination system, as long as they fulfill some criteria such as;
  - Non-corrosive (materials to be combined)
  - Compliance with min cross-sectional dimensions
  - Compliance with min thickness

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Suitability of materials for inter connection

Material	Hot-dip GI	Aluminum	Copper	SS	Mild Steel
Hot-dip GI	✔	Possible	✖	Possible	Possible
Aluminum	Possible	✔	✖	Possible	✖
Copper	✖	✖	✔	Possible	✖
SS	Possible	Possible	Possible	✔	Possible
Mild steel	Possible	✖	✖	Possible	✔

Minimum thickness of building components that can be used as a part of the air termination system. Note that these specifications are independent of the Level of Protection

Material	Thickness (mm) If puncturing should be avoided	Thickness (mm) If puncturing is acceptable
GI and Stainless Steel	4	0.5
Aluminum	7	0.7
Copper	5	0.5
Zink	Not recommended	0.7
Titanium	4	0.5

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Down Conductor

- **Should consider:**
  - Min no of down conductor (i.e. 2)
  - Position
  - Separation
  - Bending
  - Safety clearence (mandatory to cover the first 1.5 m length above the ground with an insulation material to avoid touch potential)
  - Accessibility for inspection
  - Natural components (Section 3.5, MS IEC 62305-3:2007)

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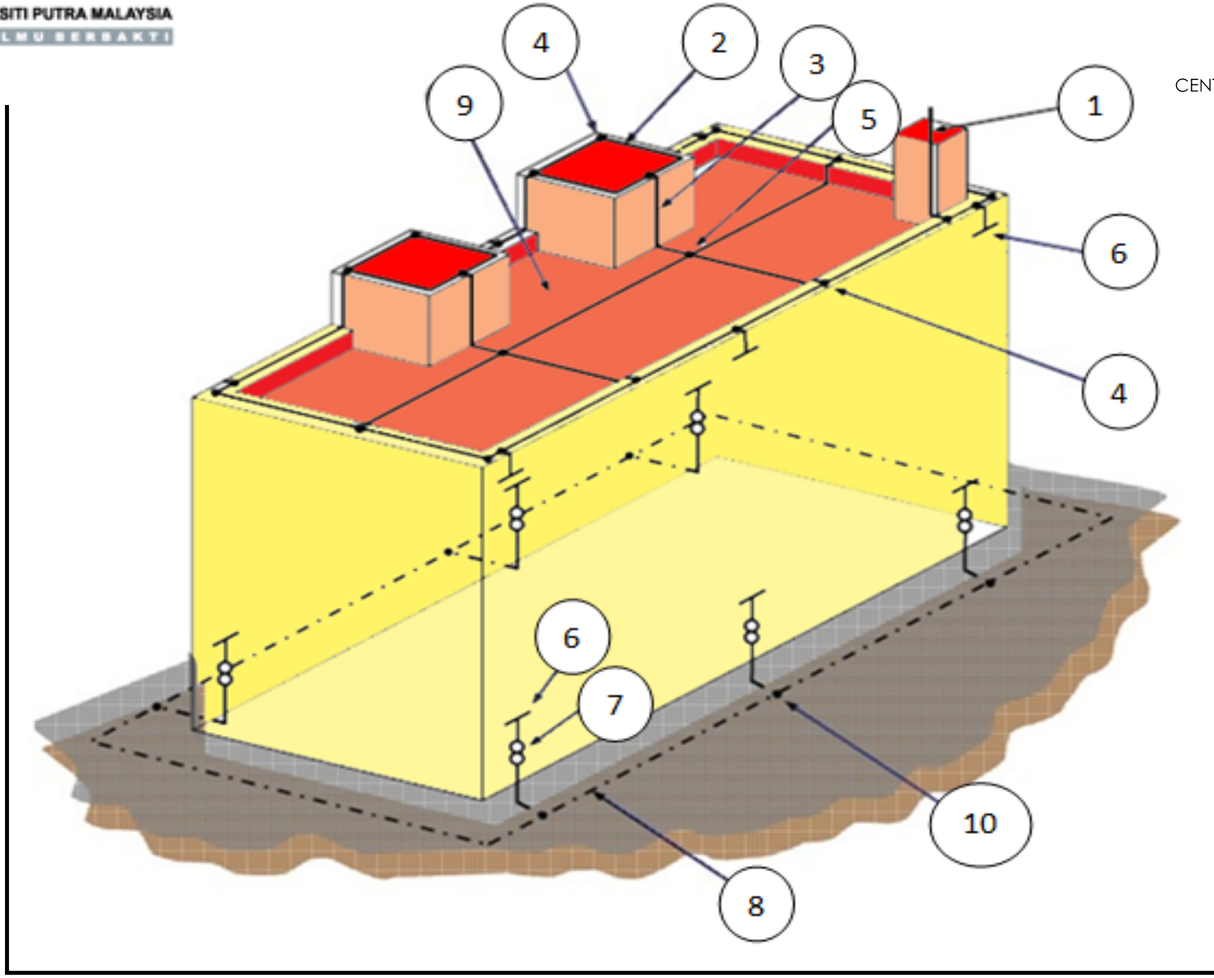

KEY: (1) Air termination rod; (2) Horizontal air termination conductor; (3) Down-conductor; (4) T-type joint; (5) Cross type joint; (6) Connection to steel reinforcement rods; (7) Test joints; (8) Type B earthing arrangement, ring earth electrode; (9) Flat roof with roof fixtures; (10) T-type joint- Corrosion resistant

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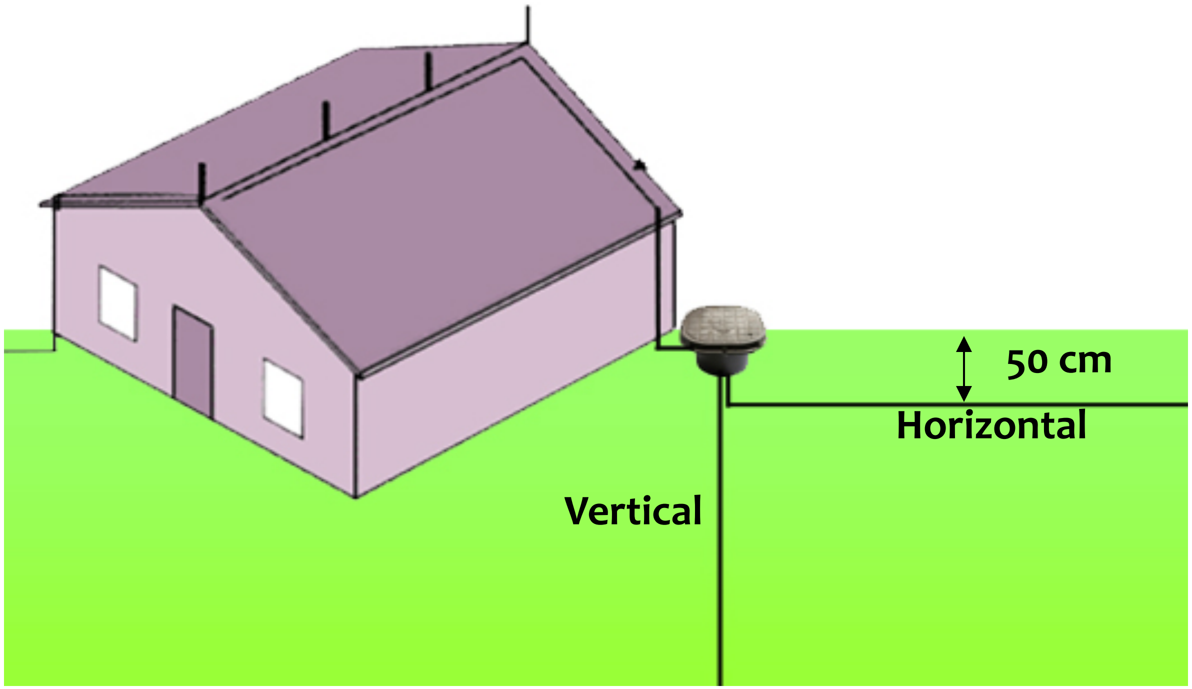
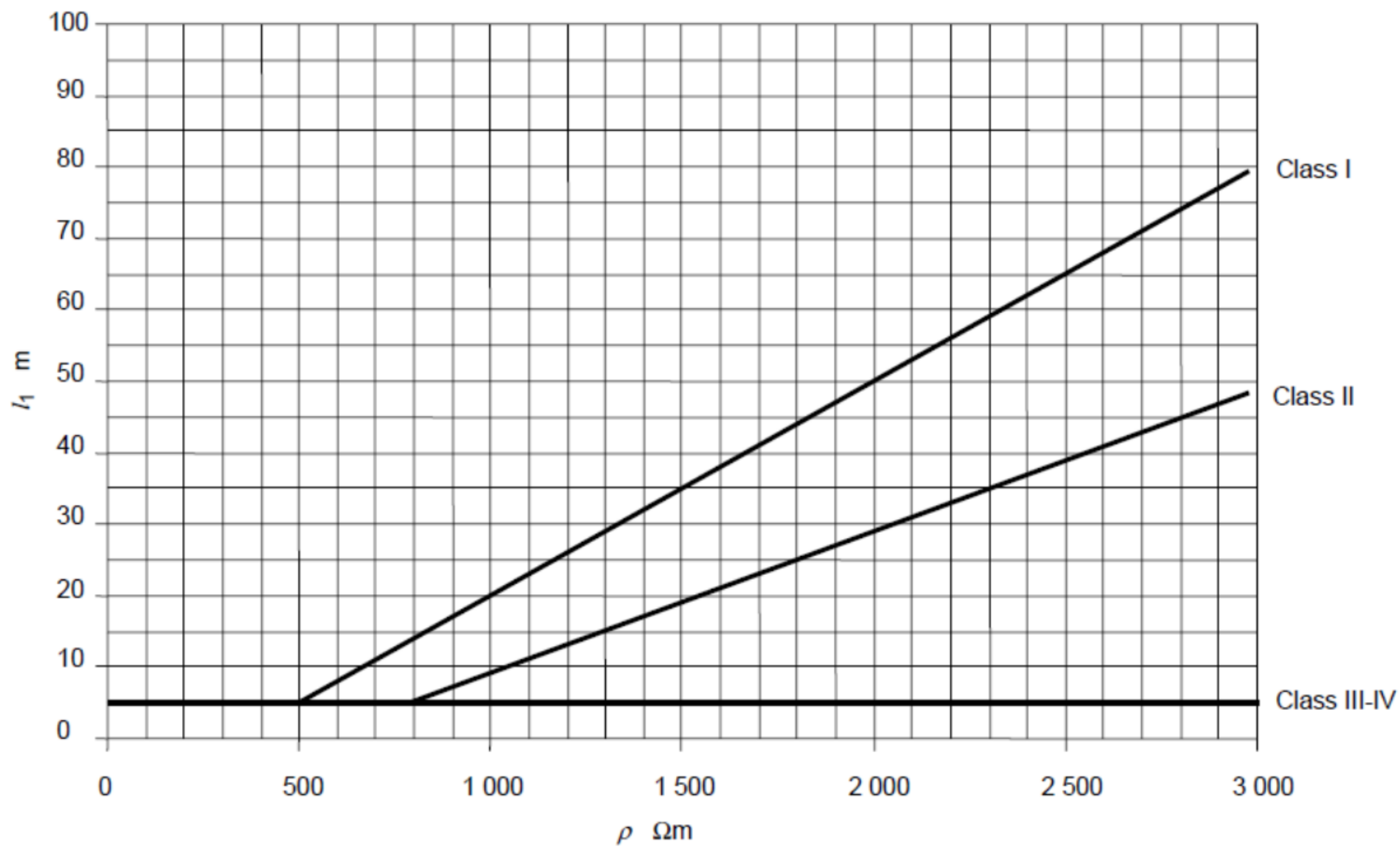
Earth Termination System

- to dispersed the lightning current into the mass of the earth.
- to reduce any potentially dangerous over voltages.
- In general, an earthing resistance below 10 Ω, measured at low frequency, is recommended.
- From the view point of lightning protection, a single integrated earth-termination system is preferable and is suitable for all purposes, such as lightning protection, power system and telecommunication systems.
- Earth termination system shall be bonded to achieve a lightning equipotential bonding to minimize the affect of lightning side flashing and step potential hazard.

Type A



Electrodes that are connected directly at the end of the down conductor



The minimum length of Type A electrode (Adopted from MS IEC 62305-3:2007).

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Type B

- Type B arrangement comprises either a ring conductor installed external to the structure to be protected, in contact with the soil for at least 80% of its total length, or a foundation earth electrode. Such earth electrodes may also be meshed.

- Refer to MS IEC 62305-3:2007, Section 5.4.2.2 for determining the specifications of Type B arrangement.

General guidance for the selection of material for earthing system *(Adopted from MS IEC 62305-3:2007)*

Material	Form	Corrosion Resistance	Corrosion increased by	Galvanic destruction
Copper	Solid Stranded Coated	Suitable for many environments	Sulphur Compounds & some organic materials	Not by other usual soil contents or usual metals
Hot-dipped galvanized steel	Solid	Suitable for benign soil	High chloride content	By copper
Stainless steel	Solid Stranded	Suitable for many environments	High chloride and tin content	Not by other usual soil contents or usual metals
Lead	Solid Coated	Suitable for Sulphur rich environments	Acidic soil	By copper and stainless steel

Material	Configuration	Minimum Dimensions			Comments
		Earth rod (Ø mm)	Earth conductor	Earth plate (mm)	
Copper	Stranded[3]		50 mm²		1.7 mm min diameter of each strand
	Solid round[3]		50 mm²		8 mm diameter
	Solid tape[3]		50 mm²		2mm min thickness
	Solid round	15			
	Pipe	20			2 mm min wall thickness
	Solid plate			500 x 500	2 mm min thickness
	Lattice plate			600 x 600	25 mm x 2 mm section min length of lattice configuration : 4.8 m
Steel	Galvanized solid round[1) 2)]	16[9)]	10 mm diameter		
	Galvanized pipe[1) 2)]	25			2 mm min wall thickness
	Galvanized solid tape[1)]		90 mm²		3 mm wall thickness
	Galvanized solid plate[1)]			500 x 500	3 mm wall thickness
	Galvanized lattice plate[1)]			600 x 600	30 mm x 3 mm section
	Copper coated solid round[4)]	14			250 µm min radial copper coating 99.9% copper content
	Bare solid round[5)]		10 mm diameter		
	Bare or galvanized solid		75 mm²		3 mm min wall thickness
	Tape[5) 6)]				
	Galvanized stranded[5) 6)]		70 mm²		1.7 mm min diameter of each strand
	Galvanized cross profile[1)]	50 x 50 x 3			
Stainless steel	Solid round	15	10 mm diameter		
	Solid tape		100 mm²		2 mm min thick

Configuration and minimum dimensions of earth electrodes (MS IEC 62305-3:2007 page 55)

Backfill Material

- Common practice to reduce the earth resistance.
- Few such materials are bentonite and bentonite-based compounds, coke breeze, graphite and lime.
- For details of the selection and usage of performance enhancement materials of earthing systems, refer IEC 62561-7 (2011): Lightning protection system components (LPSC) - Part 7: Requirements for earthing enhancing compounds.

Lightning Protection Measures (LPM)

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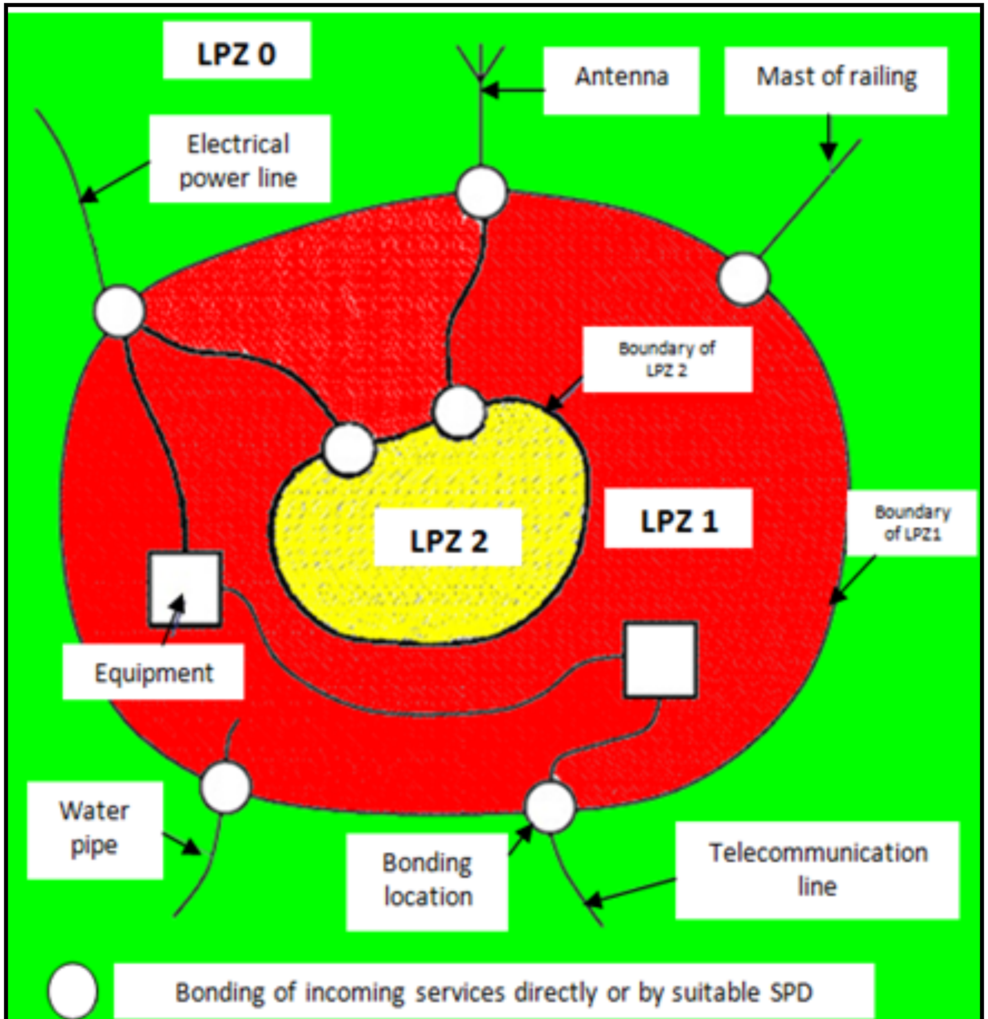

Zonal Concept

MS IEC 62305-3:2007, pp. 25

Basic LPM

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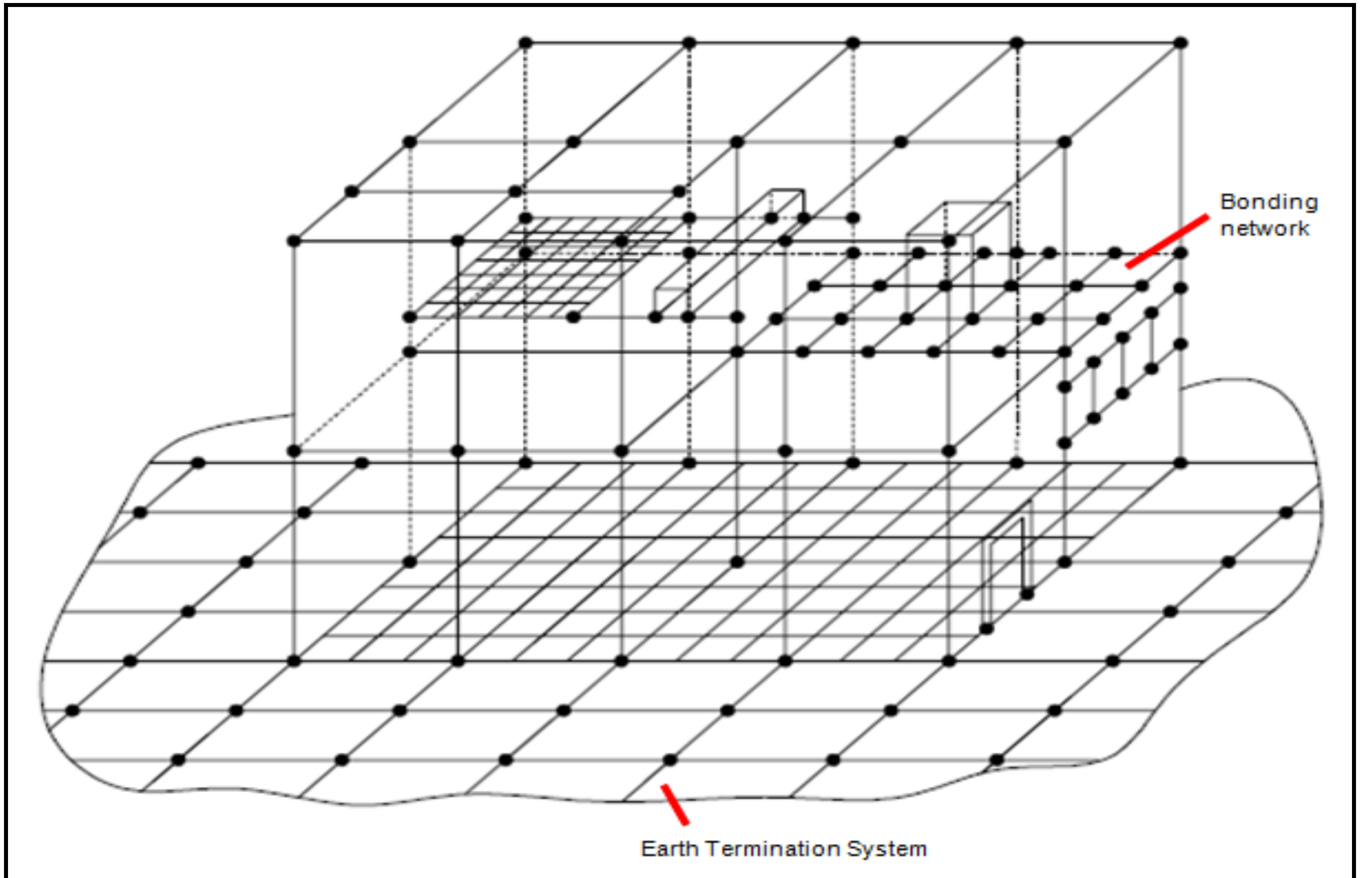
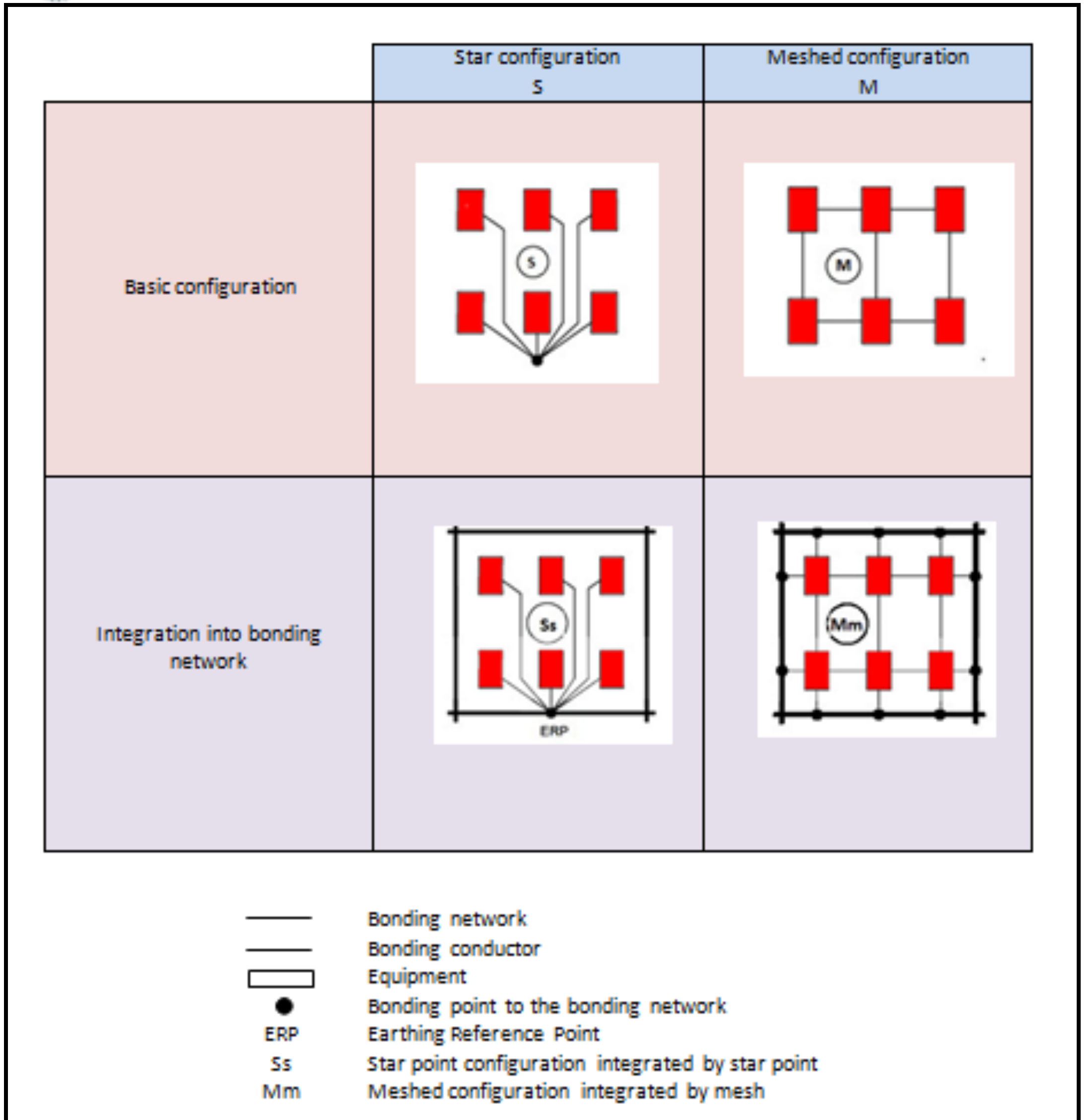
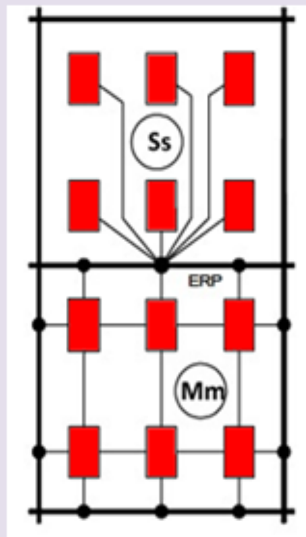
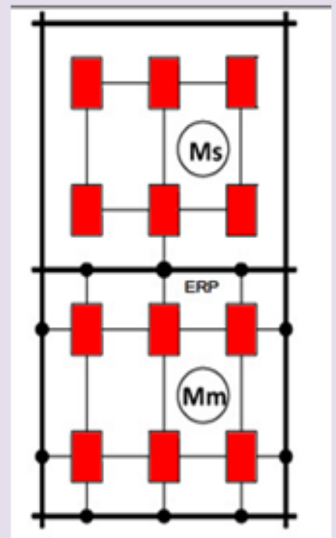
a. Earthing and bonding



Integration of electronic systems into the bonding network



	Combination 1	Combination 2
Integration into bonding network		

	Bonding network
	Bonding conductor
	Equipment
	Bonding point to the bonding network
ERP	Earthing Reference Point
Ss	Star point configuration integrated by star point
Mm	Meshed configuration integrated by mesh

Combination of integration method

- For complex system

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Minimum cross–sectional area for bonding components

<table>
<tr><th colspan="2">Bonding component</th><th>Material</th><th>Cross-section (mm²)</th></tr>
<tr><td colspan="2">Bonding bars (copper or galvanized steel)</td><td>Cu, Fe</td><td>50</td></tr>
<tr><td colspan="2" rowspan="3">Connecting conductors from bonding bars to the earthing system or to other bonding bars</td><td>Cu</td><td>14</td></tr>
<tr><td>Al</td><td>22</td></tr>
<tr><td>Fe</td><td>50</td></tr>
<tr><td colspan="2" rowspan="3">Connecting conductors from internal metal insulation to bonding bars</td><td>Cu</td><td>5</td></tr>
<tr><td>Al</td><td>8</td></tr>
<tr><td>Fe</td><td>16</td></tr>
<tr><td rowspan="3">Connecting conductors for SPD</td><td>Class I</td><td rowspan="3">Cu</td><td>5</td></tr>
<tr><td>Class II</td><td>3</td></tr>
<tr><td>Class III</td><td>1</td></tr>
<tr><td colspan="4">*NOTE: Other material used should have cross section ensuring equivalent resistance</td></tr>
</table>

b. Magnetic shielding and line routing

- Arise from lightning flashes direct to or nearby the structure.
- Spatial shields may be grid-like, or continuous metal shields, or comprise the natural components of the structure itself.
- Shielding of internal lines: using metallic shielded cables, metallic cable duct and metallic enclosure of equipment will minimized internal induced surges.
- Routing internal lines: to minimize induction loops and reduce the creation of internal surges to the structure. The loop area can be minimized by routing the cables close to natural components of the structure, which have been earthed and by routing electrical and signal lines together.
- Shielding of external lines: to reduce surges from being conducted onto the internal systems. ·
- Materials and dimensions of magnetic shields shall comply with the requirements of MS IEC 62305-3:2007

c. Coordinated SPD protection

- **To limits the effect of internal and external surges for both power and signal lines.**

- **To share the energy between them according to their energy absorbing capability.**

- **The characteristics of the individual SPDs as published by the manufacturer need to be considered.**

- **The primary lightning threat is given by the three lightning components:**
  - **The first short stroke**
  - **The subsequent short strokes**
  - **The long stroke**

- **The energy coordination is needed to avoid SPDs within a system from being overstressed.**

SURGE PROTECTION

For optimum performance of SPDs;

- ✓ Wiring system, starting from the main panel, is according to the national codes of practice.

- ✓ Electrical safety devices such as earth fault tripping devices (RCDs, RCCBs or ELCBs), over current tripping devices (MCBs, MCCBs or thermal fuses) and voltage stabilizing devices are properly installed and are in good condition

- ✓ Electrical system has a single earthing point (close to the main panel) with low earth resistance when measured at low frequency at the earth pit,

- ✓ Power feeds to outdoor systems are confined into dedicated distribution boards,

For a productive and cost effective surge protection scheme the following steps should be taken:

- **System analysis and risk assessment**
- **Strategic location selection for protective devices**
- **Selection of appropriately coordinated protective devices**
- **Proper installation and commissioning**
- **Regular maintenance and replacement of faulty devices**

For installation, a building is divided into several zones of protection (refer MS IEC 62305-4:2007 Section 4)

Selection of SPDs for power systems

- Where to install: main panel, sub panels, plug etc.
- Impulse Current handing Capacity, I_{imp}
- Let through voltage (Voltage protection level), U_p
- Response time
- Maximum Continuous Operating Voltage (MCOV)

Selection of SPDs on communication and data lines

- System operating current and voltage
- Bandwidth and insertion losses
- No of pins (lines) & cable type
- Plug type

INSPECTION AND MAINTENANCE OF LPS

Objectives

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To ascertain that;

- The LPS conforms to the design based on this standard
- All components of the LPS are in good condition and capable of performing their designed functions, and that there is no corrosion
- Any recently added services or constructions are incorporated into the LPS.

Inspections should be made as follows:

- During the construction of the structure, in order to check the embedded electrodes
- After the installation of the LPS
- Periodically at such intervals as determined with regard to the nature of the structure to be protected, i.e. corrosion problems and the class of LPS
- After alterations or repairs, or when it is known that the structure has been struck by lightning.

Complete guidelines of inspection and maintenance of LPS is given in MS IEC 62305-3:2007 Section 7 and Section E7

Maintenance

Regular Inspection is among the fundamental conditions for reliable maintenance of an LPS. The property owner shall be informed of all observed faults and they shall be repaired without delay.

For further details of maintenance, refer Sec 7 in MS IEC 62305-3.

UPDATES FROM WG/ RESEARCH INST.

- **LPS WG: Newly approved TC 81 (National Mirror Committee) by ISC E Committee in June 2015**

- **Lightning Safety: Recent Strategic Meeting in Lusaka, Zambia, organized by NAM S&T. From this meeting;**
  - A Resolution for Declaration of the International Lightning Safety Day on 28th June every year, which was unanimously adopted by the participants of the International Symposium and Strategic Meeting on Lightning Protection, has been submitted to UNESCO.
- **Technical Brochure: TB 549-2013: Lightning Parameters for Engineering Applications, by WG C4.407**

- **Seminar: School's Environmental Safety, organized by Ministry of Education and attended by 120 teachers in Besut, Terengganu.**

CONCLUDING REMARKS

- MS IEC 62305 series provide comprehensive guidelines on the design and installation of LPS for buildings.

- The developed book is NOT a replacement to the existing standards MS IEC 62305 but it is an easy guide to those documents.

- It is also NOT just a summary of those standards, but provide easy access and quick reference to the detailed documents, with some clear and useful illustrations.

- Updates from WG/ Research Inst. are useful and crucial for knowledge sharing, activity planning and research progress in lightning-related areas.

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On Guidebook

CENTRE for ELECTROMAGNETIC and LIGHTNING PROTECTION RESEARCH (CELP)

General Public: To understand the basic principles of lightning protection

Engineers: To make sure that they design, select, install, supervise and enforce LPS where the quality and safety is inline with MS IEC 62305 (2007)

LP Providers: To understand the acceptability and quality of their systems are inline with MS IEC 62305 (2007)

LP Seekers: To understand whether they get the correct system

Management: To understand whether they approved the correct system


Thank You
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