Understanding Earthing and Lightning system and how to design with the international standards

A project from my 14 years of experience of electrical engineering projects…

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1- Effects of electrical current on the human body:

The International Electrotechnical Commission (IEC) provides guidelines and standards for electrical safety, including the effects of electrical currents on the human body. These guidelines are used to assess and mitigate risks associated with electrical exposure. The IEC standard that addresses this is IEC 60479, "Effects of current on human beings and livestock."

Here's a simplified chart summarizing the effects of electric current on the human body according to IEC 60479:

Current (AC or DC)	**Duration of Exposure**	**Effects**
1 mA	Brief	Generally imperceptible; may cause a slight tingling sensation.
5 mA	Brief	Tingling sensation; may cause minor discomfort but is usually not harmful.
10-20 mA	Brief	Muscle contractions; can be painful; and may cause difficulty in releasing the source of current.
20-50 mA	Brief to Moderate	Painful muscle contractions; possible respiratory difficulty; risk of severe injury
50-100 mA	Brief to Moderate	Risk of severe injury; possible heart arrhythmia; muscle damage
100-200 mA	Brief to Moderate	High risk of heart fibrillation; severe muscle contractions; and possible burns.
Above 200 mA	Brief to Prolonged	Risk of cardiac arrest; severe burns; potentially fatal.

Key Considerations:

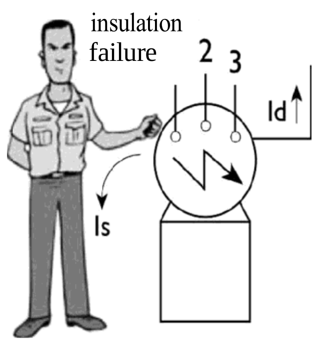
- **Duration of Exposure:** The longer the exposure, the more severe the effects. The impact of current on the body increases with prolonged contact.
- **Path of Current:** The path through the body affects severity. For instance, current passing through the chest is more dangerous than current passing through an arm or leg.
- **Voltage Levels:** Higher voltages increase the risk of severe injury or death, especially if combined with high current levels.

Important Safety Note: Always adhere to safety standards and guidelines and ensure proper safety measures are in place to prevent electrical hazards.

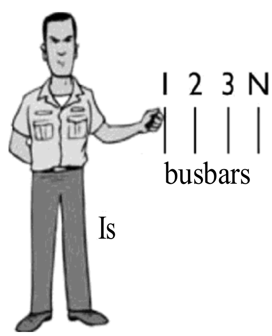
2- Why we use Earthing system?

In the implementation of an electrical project, it is essential to consider the design of an earthing system due to several important factors, which will be outlined succinctly below.

PE conductor



INDIRECT CONTACT



DIRECT CONTACT

2.1 Safety of Personnel

- **Prevent Electric Shock:** Earthing provides a path for electrical current to dissipate safely into the ground in the event of a fault, such as a short circuit or insulation failure. This reduces the risk of electric shock to individuals who might meet exposed conductive parts.

2.2. Protection of Equipment

- **Prevent Damage:** Electrical faults can cause dangerously high voltages to build up, damaging equipment. An earthing system helps to stabilize the voltage levels within the electrical system, protecting equipment from damage due to overvoltage.

2.3. Overvoltage Protection

- **Lightning Protection:** Earthing systems help to protect buildings and equipment from lightning strikes. When lightning strikes, the high voltage can safely dissipate into the ground through the earthing system, preventing damage to the structure and connected electrical systems.

2.4. Stabilization of Voltage

- **Reference Point for Circuits:** An earthing system provides a common reference point for the electrical system's voltage, ensuring that all system parts are at the same potential. This helps in maintaining the correct functioning of the electrical system and prevents overvoltage conditions.

2.5. Fault Current Pathway

- **Safe Discharge of Fault Current:** In the event of a fault, such as a live wire meeting a metal casing, the earthing system provides a low-resistance path for the fault current to flow to the ground. This causes protective devices, like circuit breakers or fuses, to trip, disconnecting the power and preventing further hazards.

2.6. Compliance with Regulations

- **Legal and Code Requirements:** Many electrical codes and standards, such as the National Electrical Code (NEC) in the United States, mandate the use of earthing systems to ensure the safety of electrical installations. Compliance with these regulations is not only a legal requirement but also ensures the safety and reliability of the electrical system.

2.7. Reducing Electromagnetic Interference (EMI)

- **Minimizing Noise:** In complex electrical systems, especially in industrial settings, earthing helps reduce electromagnetic interference (EMI) and electrical noise, ensuring the proper functioning of sensitive equipment.

2.8. Dissipation of Static Electricity

- **Static Discharge:** In some cases, the earthing system also helps dissipate static electricity that may accumulate on conductive surfaces, preventing sudden discharges that could harm sensitive equipment or cause a fire.

Conclusion

An earthing system is essential for the safety of individuals, the protection of equipment, and the overall reliability and stability of electrical systems. By providing a safe pathway for fault currents and stabilizing the voltage in the system, earthing minimizes the risk of electric shock, equipment damage, and fire hazards.

3- Idea Of working

An earthing system works by providing a low-resistance path for electrical currents to flow safely into the ground. It acts as a protective measure, ensuring that any fault current, such as from a short circuit or lightning strike, is safely discharged, reducing the risk of electric shock, fire, or equipment damage. The system also stabilizes voltage levels within the electrical system, ensuring safe and reliable operation.

4- Types of Earthing Systems:

Here's a brief overview of the main earthing systems:

1. TT (Terra-Terra):

- Description: In this system, the supply system's neutral is connected to earth at the supply source, while the installation's earth (or earthing system) is independent of the supply system.

- Characteristics: The earthing of the installation is done using its own earth electrode, separate from the supply system. This can be beneficial in cases where the supply system's earthing is unreliable or the installation's earthing can be more easily maintained. In TT we surely need (to use (RCB) because the the fault current is too small and doesn't disconnect the circuit.

- Usage: Common in domestic and smaller commercial installations, particularly where supply-neutral earthing may be problematic.

2. IT (Isolated Terra) :

- Description : The supply system's neutral is isolated from earth, and the installation has its own earth connection.

- Characteristics : This system is characterized by its high resistance to earth faults, as the neutral is not directly connected to earth. It often includes a monitoring system to detect insulation faults.

- Usage : Often used in critical or sensitive installations like hospitals or industrial environments where continuity of supply is crucial.

3. TNC (Terra-Neutral-Conductor) :

- Description : In this system, the neutral and the earth are combined into a single conductor (PEN) throughout the distribution network.

- Characteristics : The combined neutral and earth conductor is used throughout the distribution network, and the system can be less complex in terms of wiring. However, it might pose a higher risk of potential faults affecting both the neutral and earth.

- Usage : Common in some older or less complex systems, but can be less safe compared to TNS or TN-C-S systems due to potential neutral faults.

4. TNS (Terra-Neutral-Separate) :

- Description : In this system, the neutral and earth conductors are kept separate from the supply transformer through to the installation.

- Characteristics : The neutral is connected to earth at the supply transformer, and a separate earth conductor is used throughout the installation. This system provides good fault protection and is generally considered safer than TNC.

- Usage : Common in new installations and in countries with advanced electrical standards, offering better safety and reliability.

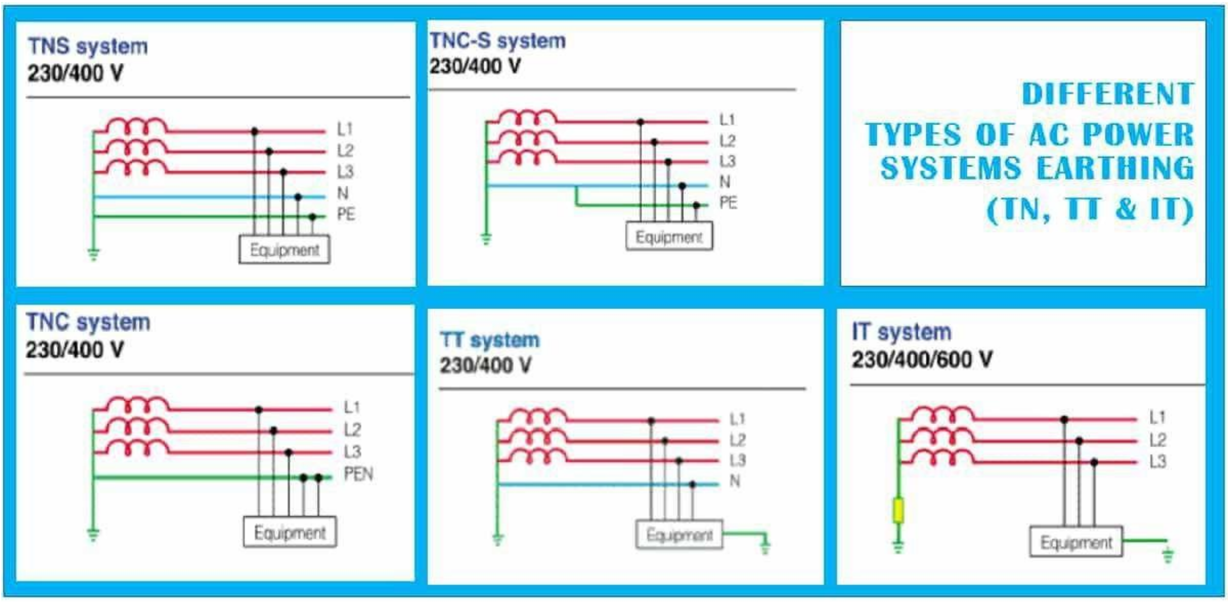
5. TNC-S (Terra-Neutral-Conductor-Separated) :

- Description: This system combines TNC and TNS principles. The neutral and earth are combined in the supply network up to a certain point, and then separated into individual conductors at a certain point in the installation.

- Characteristics: It starts with a combined neutral and earth conductor (PEN) from the supply and splits into separate neutral (N) and earth (PE) conductors within the installation. This setup aims to balance the safety and practicality of TNC and TNS systems.

- Usage: Widely used in modern installations as it provides a good balance of safety, cost, and reliability.

Each earthing system has its own advantages and is chosen based on safety requirements, installation conditions, and local regulations.



5- Human body resistance

The electrical resistance of a human body can vary widely depending on several factors, including skin condition, moisture level, point of contact, and the voltage applied. However, some general ranges are often cited:

1. Dry Skin

- Resistance: 100,000 to 1,000,000 ohms (100 kΩ to 1 MΩ)

- Dry skin significantly increases the resistance, making it harder for current to pass through the body.

2. Wet Skin

- Resistance: 1,000 to 10,000 ohms (1 kΩ to 10 kΩ)

- When the skin is wet or sweaty, the resistance drops considerably, making it easier for current to flow through the body.

3. Internal Body Resistance

- Resistance: 300 to 1,000 ohms (0.3 kΩ to 1 kΩ)

- Once the current penetrates the skin and reaches the internal tissues, the resistance decreases significantly, as internal body tissues and fluids are more conductive.

Factors Affecting Human Body Resistance

- Skin Condition: Dry, intact skin provides higher resistance. Abrasions, cuts, or wet skin lower the resistance.

- Moisture: Sweaty or wet skin drastically reduces resistance.

- Point of Contact: Resistance varies depending on whether the current enters through the hands, feet, or other parts of the body.

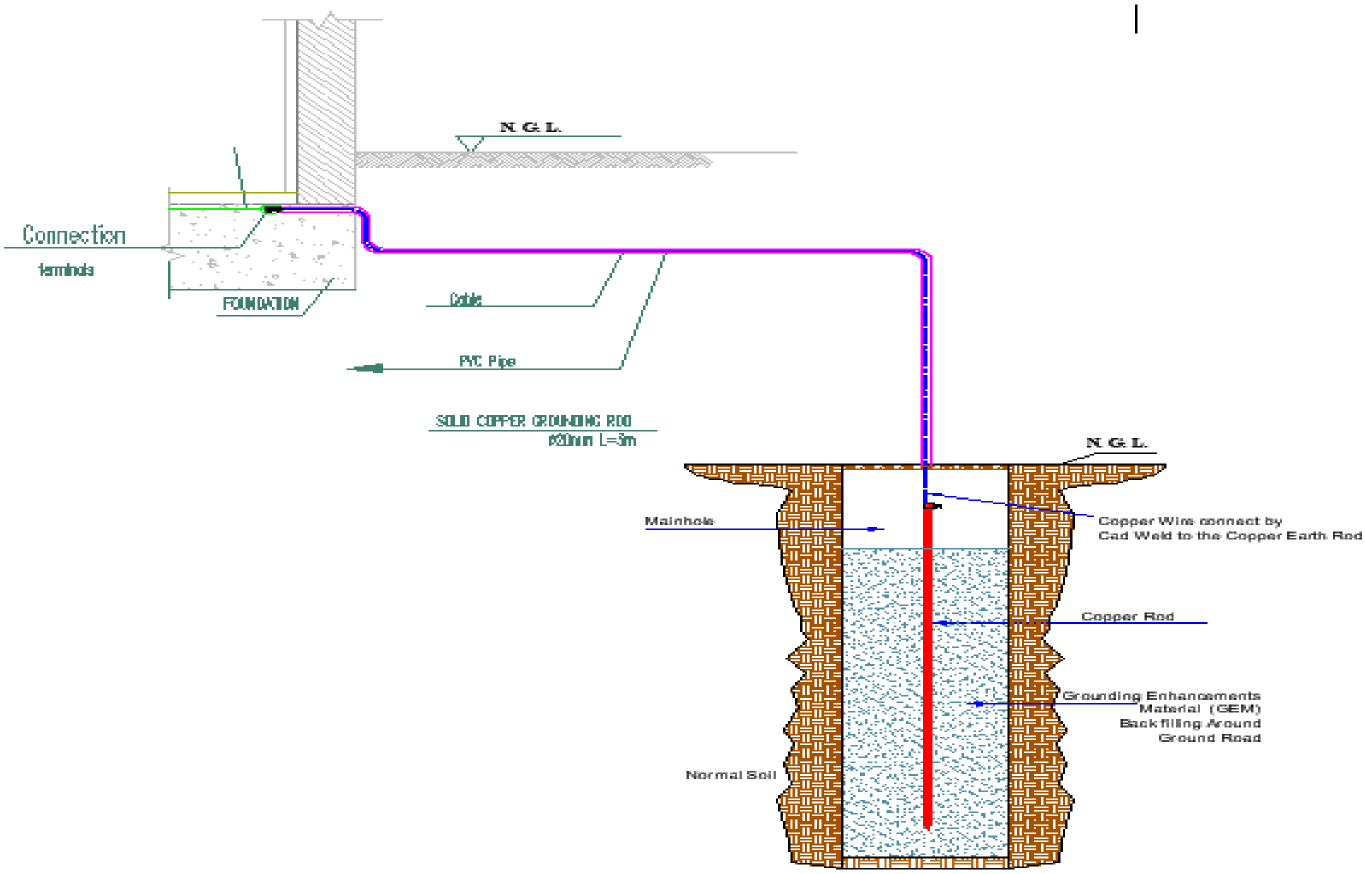
- Voltage: At higher voltages, the body's resistance decreases as more current passes through the skin.

- Pressure: The pressure with which a person contacts a live conductor can also affect resistance; more pressure generally reduces resistance

 # Conclusion

In general, the electrical resistance of the human body ranges from about 1,000 ohms to 1,000,000 ohms, depending on various conditions. Safety precautions should always be taken to avoid contact with electrical sources, as the human body's resistance can decrease under certain conditions, increasing the risk of electric shock. But for our calculations we always use the worst case (**1000 ohms**).

6- Earthing System components



Earth trench

An earthing (or grounding) system is composed of several key components that work together to ensure the safe dissipation of electrical fault currents into the ground. These components are crucial for maintaining the safety and stability of electrical systems. Here's a breakdown of the primary components of an earthing system:

1. Grounding Electrode
2. Earthing Conductor (Grounding Conductor)
3. Earth Busbar (Ground Busbar)
4. Bonding Conductors
5. Grounding Rod Clamp (or Ground Clamp)
6. Earthing enhancement material

Earthing Enhancement Material (EEM) is used to improve the efficiency and effectiveness of the earth electrode system, especially in areas where the soil resistivity is high or unstable. These materials are applied around the grounding electrode to lower the overall resistance and ensure a reliable path for fault currents.

Common Types of Earthing Enhancement Materials:

1. Bentonite Clay
2. Graphite Powder
3. Carbon-Based Compounds
4. Chemical Compounds (e.g., GEM - Ground Enhancement Material)
5. Marconite

7. How to reduce the earth resistance?

Reducing earth resistance is important in electrical systems to ensure effective grounding and safety. Earth resistance refers to the resistance of the ground or earth to the flow of electrical current. Here are several methods to reduce earth resistance:

7-1 Increase the Grounding Electrode System Size:

- Use larger or additional ground rods, plates, or other grounding electrodes. Increasing the surface area in contact with the soil lowers resistance.

7-2 Improve Grounding Electrode Material:

- Use materials with better conductivity for grounding electrodes, such as copper or galvanized steel, instead of less conductive materials.

7-3 Enhance Soil Conductivity:

- Increase soil conductivity using the methods we mentioned before

7-4 Use Multiple Ground Rods or Electrodes:

- Install multiple ground rods or electrodes connected in parallel to distribute the current more effectively and reduce overall resistance.

7-5 Maintain Moisture in the Soil:

- Keeping the soil around grounding electrodes moist improves conductivity. Regular watering or installing a moisture retention system can help, especially in arid regions.

7-6 Install Grounding Rods at Proper Depth:

- Drive grounding rods deeper into the earth to reach more conductive soil layers. Ensure they are placed below the frost line in colder climates.

7-7 Regular Maintenance:

- Periodically check the grounding system for corrosion or deterioration and perform maintenance as needed to ensure continued effectiveness.

7-8 Improve Grounding System Design:

- Ensure that the design of the grounding system follows best practices and standards, such as those provided by the National Electrical Code (NEC) or equivalent local standards.

7-9 Use a Grounding Grid:

- For larger installations, consider using a grounding grid, which consists of a network of interconnected ground conductors buried in the soil to provide a low-resistance path.

Each of these methods can help reduce earth resistance, and often a combination of several methods is employed to achieve the best results. By changing these factors, we can reduce the earth resistance to the required rate which is normally between 2 to 5 ohms.

8. soil resistivity

Table (1) is an approximate table of **soil resistivity** for different types of soils and materials:

Soil Type	Resistivity (Ω.m)	We choose for our calculations
Sea Water	0.1 - 1 Ω.m	0.3 Ω.m
Clay (Wet)	1 - 30 Ω.m	15 Ω.m
Clay-Sand Mixture	10 - 150 Ω.m	75 Ω.m
Sand and Gravel (Dry)	100 - 3,000 Ω.m	300 Ω.m
Sandstone	500 - 5,000 Ω.m	2,500 Ω.m
Crystalline Rock	10,000 - 1,000,000 Ω.m	250,0000 Ω.m

9. Effects of corrosion on the earth conductors

- Corrosion is a natural chemical or electrochemical process where materials, typically metals, deteriorate due to reactions with their environment. In earthing systems, **corrosion** primarily affects metal components like grounding rods, conductors, and connections, leading to the degradation of their conductive properties over time.

How Corrosion Affects Earthing Systems:

1. **Increased Resistance:** Corrosion forms oxides or other compounds on the surface of grounding materials, reducing their conductivity. This increases the earth resistance, which can impair the effectiveness of the earthing system.

2. **Weakening of Grounding Rods:** Corroded rods or electrodes lose their structural integrity, which may lead to breakage or reduction in contact with the surrounding soil, further compromising system performance.

3. **Reduced Safety:** A corroded earthing system may not effectively dissipate fault currents or lightning strikes, posing a safety risk. This can lead to increased touch and step voltages, which can be dangerous for people and equipment.

4. **Poor Longevity:** Corrosion shortens the lifespan of earthing systems, leading to frequent maintenance or replacement, increasing costs over time.

10. Calculations

When we are talking about designing an earthing system we should know about short circuit current, because the earth conductor should carry the short circuit current.

We can calculate the short circuit current depend on this formula:

$I_{sc} = MV_{sc} / \sqrt{3}\, VL$

$MVA_{sc} = MVA_{base} / X_{cu}$

Where:

MVA_{sc} = Short Circuit Mega Volt Ampere

MVA_{base} = Source Mega Volt Ampere

X_{cu} = Transformer or source Impedance.

First - Design and choose the Earthing conductor size

The below equations and calculations are the ways I always use for designing an earth system depending on (BS 7430) standard I have made an Excel sheet to simplify all my calculations and I will try to simplify it step by step.

at the beginning, I’m trying to calculate the size of the main cable of the earthing.

The cross-sectional area of the earthing conductors shall be equal or bigger than the value determined by the following formula:

According to BS 7430

$$A = \frac{I\sqrt{t}}{K}$$

where :-

A = The cross-section area of the main earthing conductor (mm2)
I = fault current (ampere) (**We found it earlier)**
T = duration of fault current (seconds) (**0.5 or 1 sec)**
K = material coefficient of the main earth conductor (A.sqrt(sec.)/mm2)
We can find K on this formula

K = α * SQRT { LOGe ((T2+β) / (T1+β)) }

where:-
T2 = The maximum permitted final temperature of the conductor (c) =(240)
T1 = ambient temperature of the conductor (c) = (50)

Metal	(α) A/mm2 (r.m.s)	β C◦
Copper	226	254
Aluminum	148	228
Steel	78	202

SELECTED CROSS SECTION AREA FOR THE MAIN COPPER CONDUCTOR (mm2) =

Example: if we have a 1.5MVA transformer, how to calculate main earth cable?

1- **MVAsc = MVAbase / Xcu**
Xcu can be find from the transformer characteristics
1.5/0.05 = 30MVA
ISC = MVsc /$\sqrt{3}$ VL
= 30MVA/$\sqrt{3}$ x0. 38
= 45KA.

2- $$A = \frac{I\sqrt{t}}{K}$$

A= 45000* $\sqrt{0.5}$ /K

$$k = K\sqrt{\log_e\left(\frac{T_2+\beta}{T_1+\beta}\right)}$$

= 226 * $\sqrt{(loge(240+254)/(50+254)}$ =167.88

3 – from above equation A= 189.54

We assume an extra %10 for corrosion factor the size will be (208.49)mm2 and the nearest size from this size will be (240)mm2

Second - Design and earth rods to get the minimum earth resistance:

In designing the earth system, we must pass the following calculations to get the minimum required resistance with a minimum rod:

First step we assume one rod and we can find the resistance depends on the following formula

Note: all the calculations should be done with the help of excel sheet)

1 - CALCULATION OF SINGLE EARTHING ROD RESISTANCE

According to BS 7430:2011 + A1:2015 Equation 9.5.3

$$R_r = \frac{\rho}{2\pi L}\left[\ln\left(\frac{8L}{d}\right) - 1\right]$$

Where :-

ρ Rho : Specific Resistivity of the Soil (ohm.m) (From Table 1)

L : length of the earth rod (m) (1,5 or 3 m)

D : diameter of the earth rod (m) (0.016 or 0.02)

If the result doesn't meet our required resistance we must go to the next step which is adding low resistivity material with the earthing Rod..

2 - RESISTANCE OF EARTH ELECTROL IN LOW RESISTIVITY MATERIAL.

According to BS 7430:2011+A1:2015 Equation 9.5.7

The Resistance of a backfilled electrode Rb in Ohms calculated from:

$$R_b = \frac{1}{2\pi L}\left[(\rho - \rho_c)\left(Ln\left[\frac{8L}{D}\right] - 1\right) + \rho_c\left(Ln\left[\frac{8L}{d}\right] - 1\right)\right]$$

Where : -

P : Resistivity of the soil (ohm. m) (From Table 1)
ρ_c : Resistivity of the conductive material used for backfill (Assume 1)
d : diameter of the earth rod (m) (0.016 or 0.02)

L : Length of the Rod in meters (m) (1,5 or 3)
D : Diameter of Infill in meters (m) (0.3 or 0.5)

If the result doesn't meet our required resistance, we must go to the next step which is adding more Rods connected together all around the building with an equal space between one and the next and the calculation will be as below...

3 - CALCULATION OF EARTH RESISTANCE MULTIPLE RODS IN A HOLLOW SQUARE

According to BS 7430:2011 + A1:2015 Equation 9.5.8.5

$$R_{TOT} = R_r\left(\frac{1+\lambda\alpha}{N}\right)$$

where: -

$$\alpha = \frac{\rho}{2\pi RS}$$

ρ	:	Specific Resistivity of the Soil (ohm. m)	(From table 1)
R_r	:	Resistance of Single Rod	(Result of step 2)
N	:	Number of Rods around the square	(N rods)
S	:	Space of Rods in Meters (m)	(S meters)
λ	:	Appropriate factor	(from Table 2)
N	:	Number of Rods side of the square +1	(N= (n/4) + 1)

And we also calculate the resistance of the conductor which we use to connecting between rods by the below equation:

4- CALCULATION OF EARTH RESISTANCE FOR STRIP OR ROUND CONDUCTOR

According to BS 7430:2011 +A1:2015 Equation 9.5.5

$$R_{ta} = \frac{\rho}{2\pi L}\log_e\left(\frac{L^2}{\kappa hd}\right)$$

where :-

ρ (Rho) : specific resistivity of the soil (ohm. m) (From Table 1)

L : the total length of conductor (m)

h : the depth of burial in meters (m) (3)

d : Diameter of the round conductor or cross-sectional area of the strip (m)

k : has a value of 1.36 for the strip or 1.83 for the round conductor.

At the end we will calculate all the resistances in parallel and we will get the required value

$$1/R = 1/R_{TOT} + 1/Rta$$

R = Combined system earth resistance (ohm)

Table (2)

Electrodes in a Hollow Square (BS 7430)

No of Rods Side of Square (n)	Factor (λ)
2	2.71
3	4.51
4	5.46
5	6.14
6	6.63
7	7.03
8	7.30
9	7.65
10	7.90
12	8.32
14	8.67
16	8.95
18	9.22
20	9.40
Table 2 BS 7430:2011+A1:2015	

Table3	
Conductor Size in mm^2	Coefficient Resistance
25	0.00642
35	0.00765
50	0.0089
70	0.0107
95	0.0126
120	0.01421
150	0.01575
185	0.01764
240	0.02025
300	0.02268
400	0.02565
25 x 3mm Tape	0.025

If the above values are not acceptable, we are obliged to go to the next and final step of design:

5- RESISTANCE OF THREE RODS OF EQUILATERAL TRIANGLE

According to BS 7430:2011+A1:2015

Equation 9.5.8.1

The Resistance of a backfilled electrod Rb in Ohms calculated from:

$$Re = \frac{1}{3} \cdot \frac{\rho}{2\pi L}\left[\left(Ln\left[\frac{8L}{d}\right] - 1 + \frac{2L}{S}\right)\right]$$

R_e =

ρ	Resistivity of the soil (ohm. m)	**From Table 1**
L	Length of the Rod in metres (m)	**1,5 or 3**
d	diameter of the earth rod (m)	**0.020**
S	Length of One side of the Equilateral triangle	**3.00**
n	No of Earth Rods	**3.00**

And Then:-

-Repeat Step 2

-Repeat Step 4

THE COMBINED EARTH RESISTANCE OF THE RODS & CONDUCTOR (LOOP) AS FOLLOWS

1/R = 1/Re + 1/Rb + 1/Rta

RT = Combined system earth resistance (ohm)

1/RT = 1/Step5 + 1/Step2 + 1/step4

RT = ohm

Note : If the desired value of less than 0.5 ohm is not achieved by using Equilateral Triangle electrode. Hence it is recommended to make more than one triangle with same characteristics and connect all Low Current Triangulars together to achieve what we are looking for

FOR EXAMPLE IF WE HAVE 5 DIFFERENT TRIANGLE WITH (8.11 OHMS) AND WE CONNECTR THEM TOGETHER THE COMBINED EARTH RESISTANCE OF THE RODS & CONDUCTOR (LOOP) AS FOLLOWS

Rt1	Triangular Earthing Resistance	Rt1 =	8.11
Rt2	Triangular Earthing Resistance	Rt2 =	8.11
Rt3	Triangular Earthing Resistance	Rt3 =	8.11
Rt4	Triangular Earthing Resistance	Rt4 =	8.11
Rt5	Triangular Earthing Resistance	Rt5 =	8.11

1/R = 1/Rt1 + 1/Rt2+1/Rt2+1/Rt4+1/Rt5

R = Combined system earth resistance (ohm)

1/RT	=	0.123	+	0.123	0.123	0.123	0.123

RT = **1.62** ohm

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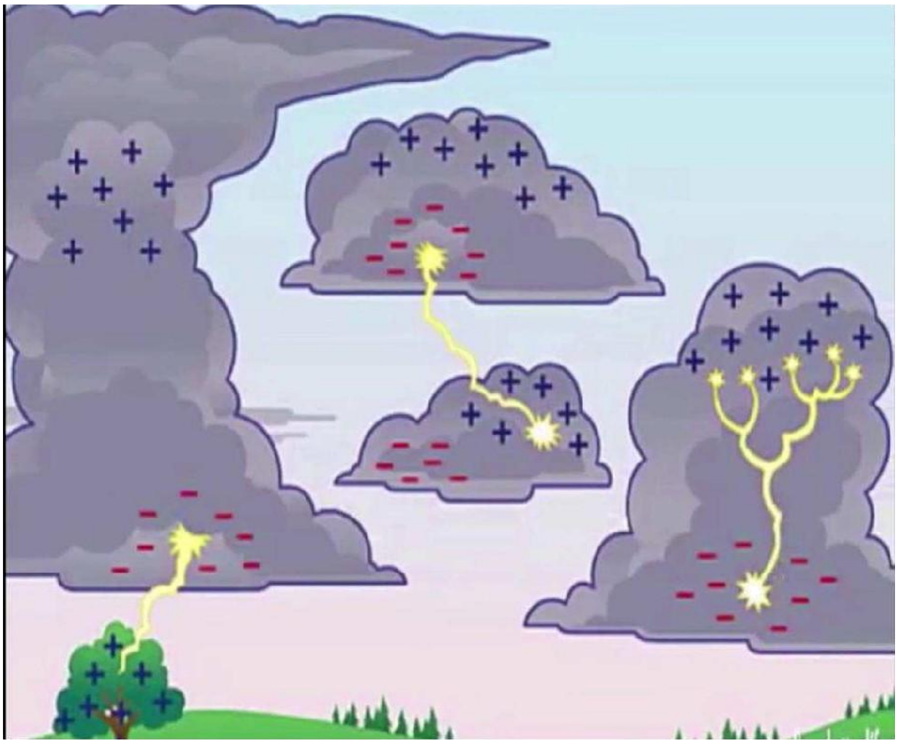
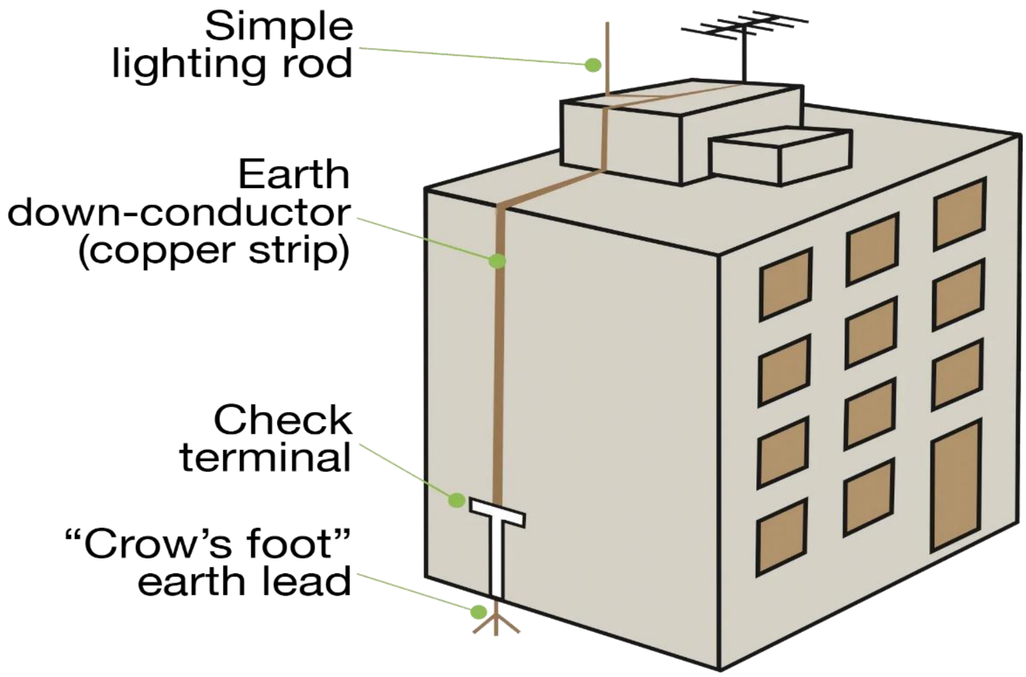
Lightening Protection System





First: What is Lightning?

Lightning is a natural, powerful electrical discharge that occurs during thunderstorms. It is caused by the buildup of electrical charges in the atmosphere, typically within clouds, resulting in a sudden release of energy as a flash of light and sound (thunder).

Second: How Does Lightning Happen?

1. Charge Separation: In a thundercloud, updrafts and downdrafts cause particles to collide, leading to a separation of electric charges. Typically, positive charges accumulate at the top of the cloud, while negative charges collect at the bottom.

2. Electric Field Creation: The buildup of charges creates a strong electric field between the cloud and the ground or within different parts of the cloud.

3. Discharge: When the electric field becomes strong enough, it ionizes the air, creating a conductive path. A stepped leader descends from the cloud, and when it gets close to the ground, a return stroke travels upward from the earth, completing the discharge, resulting in a flash of lightning.

Third: How to Protect Yourself from Lightning?

1. Indoors:

- **Stay inside during a thunderstorm.**
- **Avoid using wired electronics, plumbing, or touching metal surfaces.**

2. Outdoors:

- **Avoid open areas, tall objects (like trees), and water bodies.**
- **Crouch down with feet together if no shelter is available, but avoid lying flat on the ground.**

3. Lightning Rods:

- **Buildings and structures can be protected using lightning rods, which direct lightning safely to the ground, preventing damage.**

Fourth: Steps of design

- how we know that a building needs Surge protection?

Determining whether a building needs surge protection depends on various factors related to the building's electrical system, equipment, location, and exposure to potential electrical surges. Here's a step-by-step approach to assess if surge protection is necessary:

1. Assess the Risk of Lightning Strikes

- Geographic Location: Buildings in regions prone to thunderstorms or with high lightning density (e.g., coastal or mountainous areas) are at higher risk of lightning strikes.

- Building Height: Tall buildings, towers, or those on hilltops are more vulnerable to direct lightning strikes.

- Nearby Structures: If there are taller structures or trees nearby, these may attract lightning, reducing direct risk to the building, but induced surges can still occur.

2. Evaluate the Electrical Equipment in the Building:

- Sensitive Electronics: Buildings with sensitive or expensive equipment (e.g., computers, servers, medical devices, industrial control systems) are more prone to damage from surges. Surge protection is critical in such cases.

- High-Value Equipment: If a building contains high-value electrical equipment (e.g., data centers, factories, or offices), surge protection should be considered to prevent financial loss or downtime.

- Appliances and HVAC Systems: Large appliances like HVAC systems, elevators, or refrigeration units can be damaged by electrical surges. Surge protection may be recommended if these systems are essential to building operations.

3. Check for Frequent Power Disturbances

- Frequent Power Outages: Areas with unstable power supply or frequent power outages may experience voltage fluctuations and surges, increasing the need for surge protection.

- Switching Surges: Surges can also be caused by switching operations within the building (e.g., large motors, compressors, or transformers) or from the utility grid.

4. Identify the Type of Power Supply

- Direct Utility Supply: Buildings directly connected to a utility power grid without intermediary surge protection from the utility are more exposed to transient surges from the power grid.

- Solar Panels or Wind Turbines: Buildings with renewable energy systems, such as solar or wind power, can introduce surge risks, requiring specialized surge protection for inverters and electrical interfaces.

5. Review the Building's Electrical System Design

- Earthing and Grounding System: A well-designed grounding system helps mitigate surges, but if the grounding system is inadequate or non-compliant, surge protection becomes more critical.

- Old Electrical Wiring: Buildings with outdated electrical systems (e.g., without modern circuit breakers or proper grounding) are more susceptible to surges and may benefit from added protection.

6. Compliance with Standards and Codes

- Local Building Codes: Check local electrical codes or standards e.g. (IEC, NEC) which may require surge protection for certain types of buildings or systems e.g. (hospitals, schools, public buildings).

- Business or Insurance Requirements: Some industries, insurers, or regulatory bodies may mandate surge protection to safeguard critical operations or meet safety standards.

7. Consider the Cost of Potential Damage

- Cost of Downtime: In commercial or industrial buildings, even a short downtime caused by equipment failure from a surge can result in significant financial loss. In such cases, surge protection is essential.

- Repair or Replacement Costs: Calculate the potential cost of repairing or replacing equipment damaged by a surge versus the cost of installing surge protection.

8. History of Surges or Lightning Strikes

- Previous Incidents: If the building or nearby structures have experienced damage from surges or lightning in the past, it is a strong indicator that surge protection is needed.

- Utility Surge Records: Check with the local utility provider to understand the frequency of surges or transient voltage issues in the area.

Keys of thinking before Design:

Designing a lightning arrester involves several key steps to ensure the effective protection of electrical systems from lightning-induced surges. Here's a brief overview of the steps involved:

1. Determine System Requirements

- Voltage Rating: Identify the system voltage (e.g., medium or high voltage) that the lightning arrester will protect. The arrester must withstand normal system voltages without failing.

- Current Capacity: Estimate the maximum surge current that the arrester must handle during a lightning strike. This is critical for selecting the arrester's energy dissipation capabilities.

- Location and Application: Determine where the arrester will be installed (e.g., on transmission lines, substations, or industrial facilities) and whether it will protect overhead lines, transformers, or sensitive equipment.

2. Select the Arrester Type

Choose from various types, such as:

- Gapless Metal Oxide (MOV): The most common, using zinc oxide varistors.

- Expulsion Type: Uses a spark gap for lower voltage systems.

- Metal oxide arresters are preferred for their reliability, fast response, and low residual voltage after a discharge.

3. Establish Lightning Arrester Ratings

- Nominal Discharge Current: Select the discharge current rating based on expected lightning strikes in the area and protection needs.

- Maximum Continuous Operating Voltage (MCOV): The arrester must operate continuously at the system's operating voltage without breaking down.

- Impulse Withstand Voltage: Choose an arrester that can handle high impulse voltages from lightning strikes without damage.

4. Define Energy Absorption Capacity

- Calculate the energy absorption capacity of the arrester based on the energy from expected surge events. This will ensure the arrester can dissipate the surge without failure or thermal breakdown.

5. Choose the Material and Design

- Metal Oxide Varistors (MOV): Design or select arresters with MOV blocks that provide non-linear resistance, allowing them to conduct during surges and block current during normal conditions.

- Insulation: Choose materials like porcelain or polymer for housing the arrester, ensuring it can withstand environmental conditions (e.g., UV radiation, pollution).

- Sealing: Ensure the arrester is properly sealed to prevent moisture ingress, which could lead to failure.

6. Ensure Proper Coordination with the System

- Coordination with Insulation Levels: Ensure that the arrester's clamping voltage (the voltage it limits surges to) is below the insulation withstand level of the equipment it is protecting. This prevents insulation damage during surges.

- Grounding: Properly design and size the grounding system for the arrester to ensure that it can safely discharge surge currents into the earth.

7. Test and Validate Design

- Conduct high-voltage testing to validate the performance of the arrester under controlled conditions, simulating lightning strikes and surges.

- Perform thermal, mechanical, and environmental tests to ensure durability and reliability.

8. Installation and Placement

- Place the arrester as close as possible to the equipment it is protecting, minimizing the lead length to reduce voltage drop.

- Ensure proper installation per the manufacturer's guidelines, including mounting, grounding, and alignment with the overall protection scheme.

9. Maintenance and Monitoring

- Design or select arresters that allow for easy inspection and maintenance, especially in high-risk environments.

- Use diagnostic tools (e.g., thermal cameras or leakage current monitors) to track the arrester's health over time and ensure timely replacement if needed.

❖Calculations

LIGHTNING PROTECTION SYSTEM
RISK ASSESSMENT SHEET AS PER (NFPA 780)

Project Details:

Project Name:

First of all we should be familiar with the below

N_d	Yearly expected lightning strike frequency to the structure
N_c	Tolerable lightning strike frequency to the structure
N_g	Yearly average flash density in the region (fl/km^2/year)
A_e	Equivalent collective area of the structure (km^2)
C_1	Environmental coefficient
C_2	Structure Coefficient
C_3	Structure Contents Coefficient
C_4	Structure Occupancy Coefficient
C_5	Lightning Consequence Coefficient

We should find each of (N_d & N_c) to decide the building needs to install Lightening arrestor or not.

IF $N_d \leq N_c$ Hence, LPS May Be Optional

IF $N_d > N_c$ Hence, LPS Should Be Installed

Calculation Of N_d

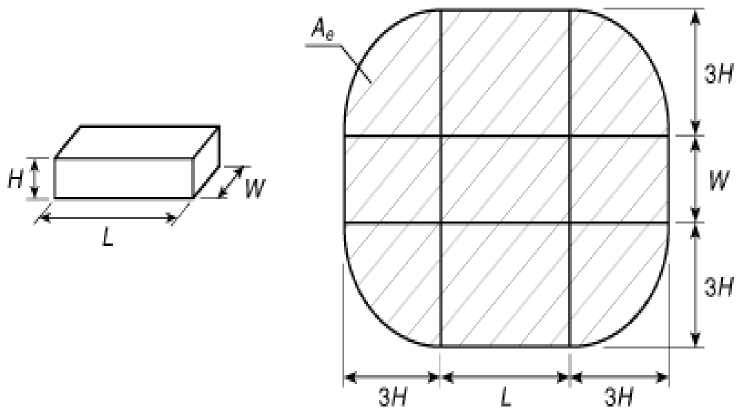
$N_d = (N_g) \times (A_e) \times (C1) \times 10$ -6

Building Dimensions:

Length(L) (m): Width(W) (m): Height(H) (m):

Collective Area Calculation (Ae):

Rectangular structure



For a rectangular structure, $A_e = LW + 6H(L + W) + \pi 9H^2$.

Ae = ( ) m2

Determination of Location Factor (C1): How to Choose among constants

C1	Relative Structure Location
0.25	Structure surrounded by taller structures or trees within a distance of 3H.
0.5	Structure surrounded by structures of equal or lesser height within a distance of 3H.
1.0	Isolated structure, with no other structures located within a distance of 3H.
2.0	Isolated structure on hilltop.

Determination of (N_g): Choosing N_g would be depending on International Lightning data from 2016 to 2023 collected by Vaisala's NLDN and GLD360 detection networks, which monitor in-cloud and cloud-to-ground lightning 24/7 worldwide.

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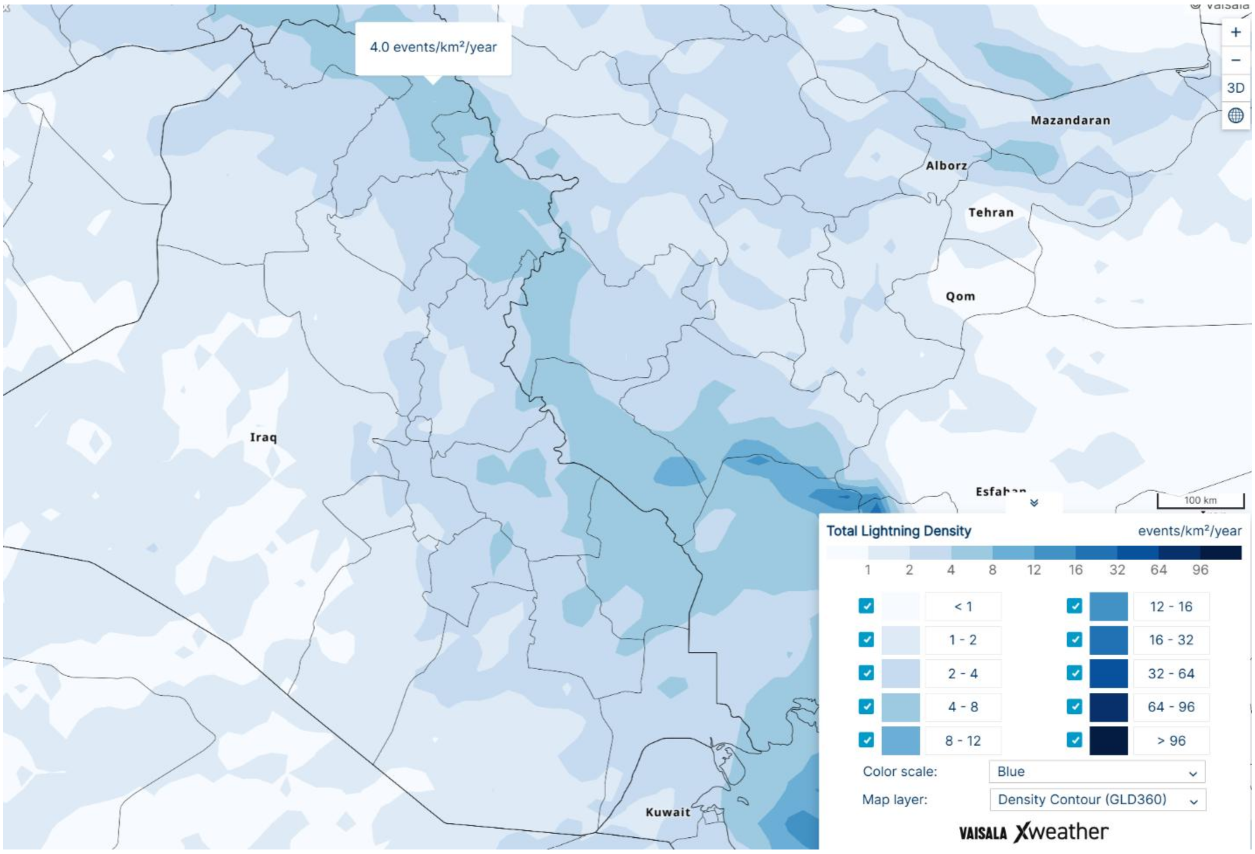

According to the above map this value is (4-8) at its highest value and we use it.

Calculation of Tolerable Lightning Strike Frequency (N_c):

N_c Can be found according the following equation.

$$N_c = (1.5 \times 10^{-3}) / ((C2)(C3)(C4)(C5))$$

Now We have to find all of (C2,C3,C4,C5)

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Determination of Construction Coefficient (C2):

C2	Roof Material		
Structure Material	Metal	Nonmetallic	Combustible
Metal	0.5	1.0	2.0
Nonmetallic	1.0	1.0	2.5
Combustible	2.0	2.5	3.0

C_2 =

Determination of Structure Contents Coefficient (C_3):

C_3	Structure Contents
0.5	Low value and noncombustible.
1.0	Standard value and noncombustible.
2.0	High value, moderate combustibility.
3.0	Exceptional value, flammable liquids, computer or electronics.
4.0	Exceptional value, irreplaceable cultural items.

C_3 =

Determination of Structure Occupancy Coefficient (C_4):

C_4	Structure Occupancy
0.5	Unoccupied.
1.0	Normally Occupied.
3.0	Difficult to evacuate or risk of panic.

C_4 =

Determination of Lightning Consequence Coefficient (C5):

C_5	Lightning Consequence
1.0	Continuity of facility services not required, no environmental impact.
5.0	Continuity of facility services required, no environmental impact.
10.0	Consequences to the environment.

C_5 =

How to Choose the class of protection Level:

Protection level	Lightning protection efficiency
I	98 %
II	95 %
III	90 %
IV	80 %

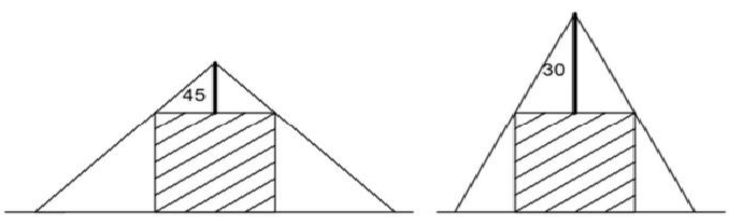
The table above clarifies the classes and the range of each which can be find from this equation:

- **E >= 1- (Nc/ Nd)**

Design of Air termination (Mesh or Rod)

Designing an air termination system is critical for providing protection against direct lightning strikes in buildings and structures. There are two common types of air terminations: **mesh (grid) systems** and **rod (finial) systems**. The choice between the two depends on the building's structure, location, and protection needs. Here’s how to design both types:

In designing ROD type we should take into account the angle between the top of the rod and the building roof border have to be between (30-45) degree and its preferable to be less than 30 but if it is more than 45 degree we obliged to use mesh type for designing, and also the second provision is that the height of the rod should be equal or more than the building diagonal as shown in the below photo..



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The below table contains the LSP height and dimensions of the according to classes

Height of air termination (m)	Distance d(m) and protection angle (Rounded down to nearest degree)							
	LPL 1		LPL2		LPL 3		LPL 4	
	Distance	Angle	Distance	Angle	Distance	Angle	Distance	Angle
1	2.75	70	3.27	73	4.01	76	4.7	78
2	5.49	70	6.54	73	8.02	76	9.41	78
3	7.07	67	8.71	71	10.45	74	12.99	77
4	7.52	62	9.42	67	12.31	72	13.95	74
5	8.32	59	10.25	64	14.52	71	16.35	73
6	8.57	55	10.82	61	14.14	67	17.43	71
7	9.29	53	11.65	59	15.72	66	18.24	69
8	9.53	50	12.32	57	16.4	64	18.85	67
9	9.65	47	12.85	55	16.93	62	20.21	66
10	9.9	45	13.27	53	17.32	60	20.5	64
11	10	42	14.08	52	19.05	60	19.84	61
12	10.07	40	14.3	50	19.2	58	20.78	60
13	10.16	38	14.44	48	19.27	56	21.64	59
14	9.8	35	14.5	46	19.27	54	22.4	58
15	9.74	33	15	45	19.91	53	23.1	57
16	9.61	31	14.92	43	20.48	52	22.85	55
17	9.04	28	15.31	42	20.99	51	23.4	54
18	8.78	26	15.65	41	21.45	50	23.89	53
19	8.86	25	15.94	40	21.86	49	25.21	53
20	7.68	21	15.07	37	21.45	47	25.6	52

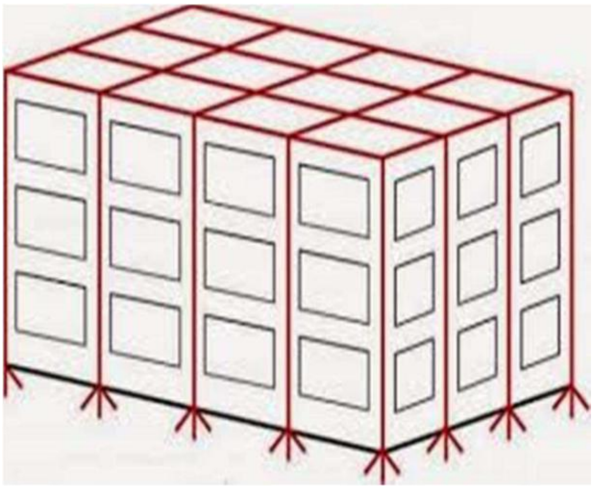
If the above two conditions are not possible, we should go to the second type of lightening system which is (Mesh type)

The mesh (or grid) system involves a network of interconnected conductors spread across the roof or surface of the structure to provide protection. The key design considerations are based on guidelines provided by standards like **IEC 62305**.

In Mesh type we have to make a network of a metal (Use corrosion-resistant materials (e.g., copper, aluminum, or steel) in a square shape of (5x5m ,10x10m, 15x15m , 20x20m) according to classes as below:

Note: for conductors. Ensure the conductor has sufficient cross-sectional area (typically ≥ 50 mm²) for copper).

LPL	Mesh Size
I	5 m x 5 m
II	10 m x 10 m
III	15 m x 15 m
IV	20 m x 20 m



Design of down conductor:

About the down conductor we can use the below table to know how many down conductors we need for our project.

Class of LPS	Typical distances (m)
I	10
II	10
III	15
IV	20

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The table below contains the required value of earth resistance for different applications:

Recommended values of earth resistance

system	Recommended earth resistance(ohm)
Light current	0.5-1
Low voltage	5
Medium voltage	2.5
High voltage	0.5
Lightning Protection	10

Many Thanks for

My God

My parents

All readers

Who is looking for science...

15-Jan-2024