International Journal of Engineering Research
Volume No.4, Issue No.4, pp : 192-196
ISSN:2319-6890)(online),2347-5013(print)
01 April 2015

Practical Approach on Lightning and Grounding Protection System

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Abstract: Lightning Protection and Grounding of Electrical and Mechanical equipment's for the Protection of the Human Beings, Structure of the building and equipment protection, safe working of the Worker at Industry as per my latest practical knowledge in the site environment in extreme climatic condition of low lying areas of the Gulf Region in the challenging projects. All the conductor calculation, Lightning Risk Factor calculations, all the system information regarding the level of protection required for site are mentioned in this paper. Lightning, Electrical and Mechanical Equipment surge protection is the one of the major complicated protection in the World as it is unpredictable. As both can cause major causality and damage the building and equipment's in the path way surroundings. As per the world status there are more number of causalities as occurred due to Lighting and short circuit errors. Grounding of the electrical and mechanical equipment can have low potential difference hence will not cause much damage as the surge current has easy path to the ground. Complete information regarding the Lightning and Surge arrestor system is illustrated as per my findings while working as the Design Electrical Engineer.

Keywords—Risk Factor, Earthing, Grounding, Air terminal, Conducor loop, Surge arrestor, Earth pit, Earth rod, Down conductor, rebar(steel reinforcing bar).

I. Introduction

Design of electrical grounding with lightning protection systems is one of the most important aspects of any electrical distribution system, yet it is often misunderstood and subsequently installed improperly. There are several important reasons why a grounding and lightning protection system should be installed. But the important reason is to protect people! Other reasons includes protection of structures and equipment from unintentional contact with energized electrical lines. The grounding system must ensure maximum safety from electrical system faults and lightning. Equipment and building protection is provided by low impedance grounding and bonding between electrical services, protective devices, equipment and other conductive objects so that faults or lightning currents do not result in hazardous voltages within the building. Also, the proper operation of overcurrent protective devices is frequently dependent upon low impedance fault current paths.

Many factors determine the overall impedance of the grounding system. Building components, such as structural steel and interior piping systems, can be used to create an effective grounding system. The manner in which these components are installed and interconnected can have a dramatic effect on the overall effectiveness of the grounding system. One of the primary factors that can increase the impedance of the grounding system is the type and manner in which the electrical connections to the grounding system are made. Contractors and others install these systems cannot underestimate the importance of ensuring that each grounding connection is made in an effective manner.

Lightning, Electrical and Mechanical Equipment surge protection is the one of the major complicated protection in the World. As both can cause major causality and damages in the building and the path way surroundings. As per the world status there are more number of causalities as occurred by the Lighting and short circuit errors. Grounding of the electrical and mechanical equipment will have low potential difference and hence can cause less effect on the human and building structure. Complete information regarding the Lightning and Surge arrestor system is illustrated as per my finding while working as the Design Electrical Engineer.

II. Lightning System and Methodology

A. Risk Factor

The Risk factor is calculated using the lightning history from the purposed geographical location. The Lighting protection depends on the Ground materials and the soil resistivity of the proposed site location. Also the type of purpose of the building also matters for the Lightning protection system installed.

The risk is calculated by the probable average annual loss in the structure and in the service due to the Lightning Flashes, divided into:

1. Annual number of lightning flashes influencing the structure and the service
2. Probability of damage by one of the influencing lightning classes.
3. The mean amount of consequential losses.

Lightning flashes influencing the structure may be divided into, 1. Flashes terminating on the structure,

2. Flashes terminating near the structure, direct to connected services (power, telecommunication lines, other services) or near the services.

Lightning flashes influencing the service may be divided into,

1. Flashes terminating on the service,
2. Flashes terminating near the service or direct to a structure connected to the service.

The types of damage are classified in to
D1: Injury to living beings
D2: Physical Damage
D3: Failure of Electrical and Electronic Systems.
The types of Losses are classified into

International Journal of Engineering Research
Volume No.4, Issue No.4, pp : 192-196
ISSN:2319-6890)(online),2347-5013(print)
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L1: Loss to Human
L2: Loss of service to Public
L3: Loss of Cultural Heritage
L4: Loss of Economic Value

As per the information we have received from the above classifications the Design Engineer will assign the risk Factor for the Building to be protected.

R1: risk of loss of human life
R2: risk of loss of service to the public
R3: risk of loss of cultural heritage
R4: risk of loss of economic value

For calculating the Risk assessment we have application software which provides us the Class of Lightning protection required for the particular Project. According to the risk calculation the Lightning Protection System type will be applied for the building premise.

B. Class of Lightning Protection System

According to the Risk factor of the Building system Class of Lightning Protection system is determined by the Characteristic of the Structure of Building to be protected.

Lightning Protection Level	Lightning Protection System
I	I
II	II
III	III
IV	IV

Table (i) Class of Lightning Protection System

There are four Different Class for the Lightning protection system based on the Risk Factor of the Building Structure. The relation between the lightning protection level and lightning protection level is shown in Table (i) .

An external Lightning Protection System has three major systems combined they are,

1. Air termination system
2. Down conductor system
3. Earth termination system

1. Air Termination System

Air termination system can be composed combination of the following elements such as intercepting terminal rod, Catenary wire for wire air termination type of protection and Mesh Conductors.

(a) Positioning of the Air terminal

Air termination system interception rod has to be placed at the corner, exposed points and edges in the open air located at high level of the building structure.

There are some of the acceptable methods to determine the position of the air termination system,

(a) Protection Angle Method
(b) Rolling Sphere Method
(c) Mesh Method

(a) Protection Angle Method

In protective angle method the Lightning system is assigned as per the figure (i) shown which shows the height of the terminal rod for the lightning protection,

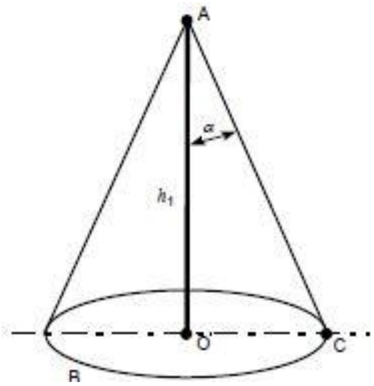

Figure (i) Representation of Protection Angle Method

A- Edge of the air terminal system
R - Reference plane
O-C - Radius of the protected area
h - Height of the air termination rod.
α – protection angle.

The oval shaped reference plane is the area where the systems will be protected. The Protection angle of the Lightning protection system Determined by the class of lightning Protection system.

(b) Rolling Sphere Method:

Rolling Sphere method is the calculating the area of protection for the Building to be protected in this the length of the air terminal above the surface reference plane will be the radius of the Rolling sphere calculation.

Area covered by the rolling sphere is the area will be protected by the air terminal. The figure (ii) shows the details of the rolling sphere calculation details.

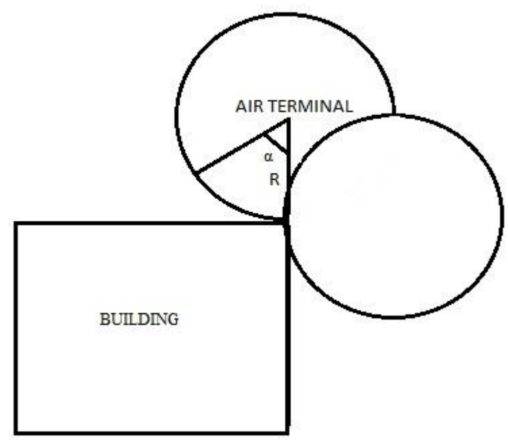

Figure (ii) Representation protection of Rolling Sphere

Where,R – Radius of the rolling Sphere for the lightning protection or height of the air termination system

α – protection angle

The height of the air terminal rod can be found out by the formula:

R = 10. I ^0.65------------- (i)

ISSN:2319-6890)(online),2347-5013(print)
01 April 2015

Where, I – Surge Current in kA.

R – Radius of the Rolling Sphere protection.

(c) Mesh Method:

The mesh method is the interconnection of the all the air terminal at the roof edge of building to be protected. This mesh line conductor travels through the roof edge line, roof overhangs and roof ridge lines.

The mesh method network of air termination system is accomplished in such a way that the lightning conductor will always have at least two metallic routes to the earth, hence lightning current getting easy route to the earth.

In the Table (ii), Class I is the high Protection to Class IV is the Low protection level. The mesh size is the mesh interconnection between the loop in the roof of the building.

Class of LPS	Rolling Sphere size, R m	Mesh size, w m
I	20	5x5
II	30	10x10
III	45	15x15
IV	60	20x20

Table (ii)Rolling Sphere Size and Air Terminal Mesh Size.

For the any of lightning protection system the roof conductor shall be of wire conductor or the square rod type conductor.

The preferred earth rod loop conductor shall be the thin wired earth cables as per the short circuit voltage rating of the electrical system.

2. Down Conductor

In order to reduce the probability of damage caused due to the Lightning current flow in the Lightning protection system, the down conductor has to be arranged, accordingly to have an easy path for the surge current.

The distance between down conductor as per the Class of Lightning Protection System is shown in the Table (iii);

Class of LPS	Typical Distance m
I	10
II	10
III	15
IV	20

Table (iii) Distance between down conductor

Conductors connect the air terminals to each other and to the metal structure of the building, to miscellaneous metal parts of the building and down to the counterpoise and/or earth electrodes. In some cases, Grounding connections are made to the steel columns or to the rebars (steel reinforcing bars) used in concrete construction. In most large buildings, the heavy steel structure provides a much lower impedance path to earth than separate down conductors installed as part of the lightning protection system. These steel columns can be used as the down conductors. Since the lightning current is not effected by the structure, multiple down conductor paths in parallel will result in lower voltage differences between the top of the building and the foundation. This voltage differential can be important in buildings with electronic equipment interconnected between floors, in antenna towers and similar instances.

Test joints shall be installed in each of the Down conductor connection to the Earth Rod except in the case of natural down conductor through rebar. For the measuring purpose the joints shall be capable of being opened with the help of a tool.

3. Earth Termination System

Earth is the looping of the down conductor to the Earth rod at the Earth pit for the easy transfer of high current due to surge current from Lightning Strike.

There are two type of Earth termination system;

Type (A):- In this, the Air Termination is done at one or two of the building roof, this air terminals will not be meshed. There will be down conductor which connect all the Earth Termination. This type is mostly used in the low structure especially houses.

Type (B):-In this Earth Termination System is preferred for the meshed air termination system and Lightning protection system with several down conductors. This type of arrangement comprises either a ring electrode external to the structure in contact with the soil. This type of Earthing is recommended for the bare solid rock.

The distance between the earth rods should be two times the height of the earth rod. Every Earth pit should be minimum 1.5meter away from the any building structure. If the Earth pit location is near to the water pipe so the soil resistivity will be reduced to get better discharge of surge current.

III. Electrical Busbar Grounding

The Earth bar to the earth pit is connected according to the type of Power Equipment to be protected. As per the maximum fault which will be following through the system is considered as the fault current for the Earth system.

The table below shows the fault current detail of the different system in power system.

Type of the System	Fault current (kA)	Fault Clearing time(Tc)
LV System	44	0.5
HV System	1.5	0.3

As per the type of the system and their Fault current details provide us the Size of the conductor to be used in the Grounding system. Each electrode at the Earth pit shall be Minimum 2metre depth such that it penetrates summer water table.

IV. Mechanical Equipment & Structure Grounding

Equipment grounding pertains to the system of electric conductors (grounding conductor and ground busbar) by which all noncurrent carrying metallic structures within an industrial plant are interconnected and grounded. The main purposes of equipment grounding are as follows:

(1) To maintain low potential difference between metallic structures, ensuring freedom from electric shocks to personnel in the area
(2) To contribute to superior protective performance of the electric system.
(3) To avoid fires from volatile materials and the ignition of gases in combustible atmospheres by providing an effective electric conductor system for the flow of ground-fault currents and lightning and static discharges to essentially eliminate arcing and other thermal distress in electrical equipment.

All electric conductor housings (for example, metallic conduits, cable trays, junction boxes, etc.), equipment enclosures, and motor frames should be interconnected by an equipment grounding conductor system that will satisfy the protection requirements.

The Equipment Grounding Conductor sizing is done using the Voltage drop calculation and according to the size of the power cable the Earthing Cable is laid. In voltage drop calculation the load of the Equipment is considered and accordingly the size of the cable determined.

Cable sheath at the cable gland at the both ends are also connected to the grounding loop for the protection. All Cable trays and trunkings are also looped with the grounding busbar. Also all the structures such as metal stairs of the access to the roof used in the building shall be looped with the Grounding Busbar. All the Mechanical Pipes are looped with the Grounding busbar for the Protection from surge current which occurred outside the site or inside the site.

V. Results and Tables

Conductor calculation is done for both Lightning and also for the Grounding of the Equipment inside the Building.

(a)Lightning Protection Conductor:

The minimum thickness of the meshed lightning conductor at the roof top of the building shall be,

Material	Minimum Thickness
Galvanized Steel	0.5
Stainless Steel	0.4
Copper	0.3
Aluminium and Zinc	0.7
Lead	2.0

Table (iv) Minimum Thickness Lightning Conductor

The conductor size is done by calculating the Class of the Lightning protection required for the Structure.

Soil Resistivity can be calculated using Wenner four-pin probe. As per this Site, Soil Resistivity Calculation, the soil resistivity at a depth 1.5meter below the Ground level is

Soil resistivity (ρ) soil = 53 Ω-m

An additional layer of gravel or Asphalt will be placed around open area that does not contain reinforced concrete layer, to ensure high surface layer resistivity:

Surface layer resistivity (ρs) = 10000 Ω.m

Four lightning protection levels (LPL) are defined, the highest level being LPL I and the lowest level LPL IV.

According to the classification, the current peak (50 kA) is highest for LPL I and reduced to 37.5 kA for LPL II and to 25 kA for LPL III and LPL IV.

Corresponding to the four lightning protection levels, four classes of LPS (I, II, III, IV) are defined.

The Fault current created due to the lightning stroke is shown in the table (iv);

Class of LPL/LPS	Fault Current **I**f (kA)
I	50kA
II	37.5kA
III & IV	25kA

Table (v) Class of Lightning Protection System and the Fault Current Range

The Lighting and grounding conductor as per the type of lightning protection is calculated using the Conductor sizing formula,

$$A = \frac{I_f}{\sqrt{\left(\frac{TCAP \times 10^{-4}}{T_c \cdot a_r \cdot \rho_r}\right) \times \ln\left(\frac{K_o + T_m}{K_o + T_a}\right)}} \text{ ------------- (ii)}$$

Where,

A - Conductor Cross section; mm2
I_f - Maximum Earth Fault Current (kA)
T_m – Maximum allowable temperature (°C)
T_a – Ambient temperature (°C)
K_o – Material constant for Copper at 0 °C.
TCAP – Thermal capacity factor Copper- 3.42j/cm3-°C.
a_r – Thermal Co-efficient of resistivity for copper 1/°C.
ρ_r – Specific Resistivity for copper at 20°C.
T_c – Maximum fault Duration Sec.

From ASTM Standards,

K_o – 234 °C
TCAP –3.42j/cm3-°C
a_r – 0.00393 1/°C
ρ_r – 1.72µ.ohm.cm of copper at 20°C.
T_m – 250 °C

Calculation are done based on the ASTM Material data sheet and the Class of Lightning Protection System. Design Margin of 30% is taken into consideration in the final conductor sizing. In further simplification of the Conductor sizing Equation (ii); we have Equation (iii);

$A_{kcmil} = I . K_f . \sqrt{t_c}$ -------------(iii)

Where,

A_{kcmil} - area of conductor in kcmil
I - rms fault current in kA
tc - current duration in s
K_f - constant from ASTM for the material at various values of T_m(fusing temperature or limited conductor

ISSN:2319-6890)(online),2347-5013(print)
01 April 2015

temperature based on 11.3.3) and using ambient temperature (*Ta*) of 40 C

As the Lightning protection system is Meshed, so consider the path 50:50 ratio for mesh effect i.e. the meshed loop at roof and the down conductor in the lightning protection system.

IV. Conclusion

After the installation check for the resistivity of the earthing and grounding to have resistance valve less than 1 Ω. As per finding it is noted that the potential difference of the equipment is reduced so as to safe guard human and the building structures from the damage caused by the lightning surge or short circuit current.

It is observed that the Lightning protection System I & II should have a yearly check and the Lightning Protection System III & IV requires two year check-up for the resistivity and looping for the error less protection. It is observed that the Earthing done on rebar should have more number of down conductor as the Rebar is Steel and hence the conductor do not have more conductivity as compared to copper.

The Conductor sizing varies according to the rating of current through the conductor. All the power cable should have earth cable which will be the have size of the power cable (for example-240mm2 power cable requires 120mm2 earth cable).

References

i. *ANSI/IEEE 141-1986 "Recommended Practice Electrical Power Distribution for Industrial Plants"; Approved by IEEE Board (Dec12, 1985) and American National Standards Institute (Jun 04, 1986).*

ii. *IEEE-80-2000 "IEEE Guide for Safety in AC Substation Grounding"; By sub Station Committee of Power Engineering Society-Approved on 30 January 2000, By IEEE-SA Standards Board.*

iii. *BS-EN 62305-3:2006 –Part 1: Protection Against Lightning – General Principles.*

iv. *BS-EN 62305-3:2006 –Part 2: Protection Against Lightning – Risk Management.*

v. *BS-EN 62305-3:2006 –Part 3: Protection Against Lightning – Physical Damage to Structures and Life Hazards.*

vi. *BS-EN 62305-3:2006 –Part 4: Protection Against Lightning – Electrical and Electrical Equipment's within Structures.*

vii. *BS-EN 6651-1999 –Code of Practice for Protection of Structures Against Lightning.*

viii. *Risk Assessment Application "aplicaciones tecnologicas" is used and the details which is based on the IEC EN 62305.*

ix. *Kahramma Standards: - "Regulations for the Installation of Electrical Wiring Electrical Equipment and Air conditioning Equipment" Dec 2010.*

x. *NFPA 70 – 2011 Edition – National Electrical code.*