*Naveen Devkaran. International Journal of Engineering Research and Applications*
*www.ijera.com*
*ISSN: 2248-9622, Vol. 12, Issue 6, (Series-I) June 2022, pp. 36-40*

RESEARCH ARTICLE OPEN ACCESS

# Risks and Challenges of implementing Lightning Protection System in Existing Oil & Gas Facilities

Naveen Devkaran
*Electrical Engineering, DAVIET Jalandhar*
*Punjab Technical University, India*

---
Date of Submission: 28-05-2022 Date of Acceptance: 10-06-2022
---

## I. INTRODUCTION

Oil and gas plants built in early sixties and seventies were experiencing fire situations near fuel gas, lube oil and other process vents during thunderstorm days. A large number of these facilities were not provided with lightning protection system at that time. This study has been carried out with the objective of reviewing the existing Lightning Protection System (LPS) and recommend the improvements in order to eliminate fire due to lightning strikes for the identified areas of Process, associated utilities area and tankage areas.

The study for lightning protection system has to consider the facilities in a running Plant, carry out risk assessment to determine which facilities are at risk, provide an adequate protection in line with international standards (IEC 62305), evaluate available options for installing lightning protection equipment including ease of installation and with minimum risk to the running facilities.

## II. LPS THEORY & DEFINITIONS

*A. Need for Lightning Protection System*

Lightning is a natural phenomenon considered as “Atmospheric Electricity” which develops as a result of natural build-up of electrical charge separation in the storm clouds. Lightning strikes cause enormous loss of life and property all over the world. Lightning flashes to earth may be hazardous to structures and services.

The hazard to a structure can result in

- Injury to living beings in or close to the structure
- Damage to the structure and its contents
- Failure of associated electrical and electronic systems.

Consequential effects of the damage and failures may be extended to the surroundings of the structure or may involve its environment.

The hazard to services can result in

- Damage to the service itself
- Failure of associated electrical and electronic equipment.

To reduce the loss due to lightning, protection measures are required. The necessity of providinglightning protection and to what extent is determined by risk assessment as per IEC 62305-2.

The calculated risk factors (R: R1, R2, R4) for each structure/ facility is compared withthe tolerable risk value ($R_T$). In case, this value of R is more than $R_T$ then protection measures need to be provided, else lightning protection measures are not required.

The tolerable risk value ($R_T$) shall be taken in line with IEC as:

- $1 \times 10^{-5}$ for R1 considering loss of human life or permanent injuries as the type of loss
- $1 \times 10^{-3}$ for R2 considering loss of essential services as the type of loss
- $1 \times 10^{-3}$ for R4 considering economic loss as the type of loss

The risk assessment calculations determine the class of lightning protection system (LPS) andother means to be provided for a structure in order to bring the risk value within the tolerable limit.

*B. Risk Assessment*

In order to evaluate whether or not lightning protection for an object is needed, a risk assessment was carried out in accordance with the procedures defined in IEC. The risk to be evaluated included:

- Risk of loss of human life
- Risk of loss of service to the public
- Risk of loss of cultural heritage
- Risk of loss of economic value

For a particular structure/ facility each of the relevant risk factors were calculated and compared withthe tolerable risk values.

The risk components for a structure included:

- Risks due to flashes to the structure
- Risks due to flashes near the structure
- Risks due to flashes to a service connected to the structure
- Risks due to flashes near a service connected to the structure

The risk components for a service included:

- Risks due to flashes to the service
- Risks due to flashes near the service
- Risks due to flashes to the structure to which the service is connected

The risk components in a structure is defined by following general equation:

- $R_X = N_X \times P_X \times L_X$

Where

- $N_X$ is the number of dangerous events per annum
- $P_X$ is the probability of damage to a structure
- $L_X$ is the consequent loss in a structure

Based on the above general equation, the values of each of the risk components in a structurenamely $R_A$, $R_B$, $R_C$, $R_M$, $R_U$, $R_V$, $R_W$ and $R_Z$ are calculated to arrive at the total risk value for eachcategory of loss.

Values of risk components $R'_B$, $R'_C$, $R'_V$, $R'_W$, and $R'_Z$were not calculated as the plantdoes not provide any direct services to the public in terms of power, gas, water, telecomservices.

### C. *Basis of LPS Design*

The Lightning Protection System (LPS) was designed

- To convey the lightning energy to earth via a defined route.
- To ensure low impedance connection to the earth mass.
- To eliminate the secondary effects of potentially dangerous over voltages arising from the dissipation of either lightning or induced currents.

The kind or lightning protection system employed depended on whether the structure/ building/ facility is constructed of non-conducting (insulating) medium such as concrete and bricks or is made of conducting materials such as steel structures, steel roofs, etc. In case of former construction separate air terminal system components and down conductors were provided. In the latter case the framework of the structure itself was used as an air termination system and down conductors.

Electrical and electronic equipment located with the structures/ facilities are subject to damages caused by the lightning electromagnetic impulse (LEMP). This equipment are to be provided with LEMP protection measures (LPMS) to avoid failure of internal systems and to meet this requirement it was ensured that:

- Cables shall be shielded type with shields of adequate cross section; shields shall bebonded to earthing system at either end.
- Use of TNS system
- Laying of all internal system cables inside cable ducts.

The total plant shall be connected by an earthing system which is incorporated into all buildings and interconnected across the site. The earthing network shall be maintained throughout the electrical installation to control the hazards to personnel due to voltage gradients under abnormal conditions. The earthing network consists of main earth conductor (grid conductor) forming a closed ring network with required number of earth electrodes connected to it to provide a common earth for electrical devices and metallic structures. Earthing networks shall be constructed from copper material. From each earth electrode two distinct connections shall be made to the main earth conductor. Each building or area earth network shall be interconnected in at least two points with one or several other earthing networks. These interconnection points shall be provided with connecting boxes and have disconnecting links so that separate earth systems can be tested. The earth plates shall be used for taking multiple earth connections to two or more equipment. The maximum permissible earth resistance values of the earthing system in the plant were ensured as following:

- For electrical equipment **-** 1 ohm
- For static discharge **-** 1 Mega-ohm
- For lightning discharge – 10ohms

### *D. Major Components of Lightning Protection System*

#### *1) Air Termination*

The air terminal shall be capable of drawing the lightning discharge to it in preference to vulnerableparts of the protected structure. The air terminations can be of vertical or horizontal type. Thismetallic element can be as rods, mesh conductor or catenary wires.

The air-termination system shall be positioned in such a way that the structure is fully situated withinthe protected zone. No metal installation shall protrude outside the volume protected by airterminationsystems.

The minimum separation distance between external LPS and structural parts, the metal installations and internal systems shall be provided as per clause 6.3, IEC 62305-3 to avoid sparking.

Vertical air terminations shall be used for very high structures with small base areas e.g. non conducting chimneys etc. Vertical terminations shall be provided for the chimneys. Vertical air terminations shall project at least 300 mm above the protected structure. All the vertical air terminations provided on the same structure shall be interconnected.

Material, configuration and minimum cross-sectional area of air-termination conductors and air termination rods shall be as per Table 6 in IEC 62305-3.

*2) Down Conductor*

This air termination system shall be connected to the earth through the down conductors.The down conductors shall be installed so that, as far as practicable, they form a direct continuationof the air-termination conductors.

Down conductors shall be installed straight and vertical such that they provide the shortest and mostdirect path to earth. The formation of loop shall be avoided as much as possible. Down conductorsshall not be installed in gutters or down-spouts.

If the air-termination consists of catenary wires (or one wire), at least one down-conductor is neededat each supporting structure.

If the air-termination forms a network of conductors, one down-conductor is needed at least at eachsupporting wire end.The number of down-conductors shall not be less than two and should be distributed around theperimeter of the structure to be protected, if the LPS is installed on the structure itself.

The separationdistance between down-conductors shall be as per Table 4 in IEC 62305-3.Material, configuration and minimum cross-sectional area of down-conductors shall be as per Table 6in IEC 62305-3.

*3) Earth Termination*

This metallic element is intended to conduct and disperse the lightning current into the earth, whilstminimizing any potentially dangerous over voltages arising from the dissipation of either lightning orinduced currents or power frequency fault currents.

Each down conductor shall be provided with an earth electrode and all earth electrodes shall beinterconnected. The earth electrodes shall be interconnected by mesh conductors. The earthtermination network shall be common for both lightning protection system and electrical equipment earthing system.

The whole of lightning protective system including any earth ring shall have a combined resistance toearth not exceeding 10 ohms without taking account of any bonding.

Steel reinforcement of foundations can be used as earth electrodes and supplemented to external earth electrodes.

Earth electrodes shall be installed in such a way as to allow inspection during construction. However concrete pits shall be provided for some of the electrodes to enable testing during the life of the plant. The embedded depth and the type of earth electrode shall be such as to minimize the effects of corrosion, soil drying and freezing and thereby stabilize the conventional earth resistance. Earthing rods shall be proprietary made of solid copper and be 3.6metre minimum in length or as long as necessary to achieve at least the maximum permissible total resistance to earth.

Material, configuration and minimum dimensions of earth electrodes shall be as per Table 7 in IEC62305-3.

Precautions shall be taken care at joints of dissimilar metals.

*4) Natural Components of LPS*

Natural components made of conductive materials, which will always remain in/on the structure andwill not be modified (e.g. interconnected reinforced steel, metal framework of the structure, etc.) maybe used as parts of an LPS.

In case of buildings/ structures of conducting material, the framework itself provides an efficient natural network of many paths to earth. The structural steel columns shall be connected to the plant earth grid and as such down conductors are not required. Lightning protection shall be limited to the bonding of steel structures to the main earthing system.

The following parts of a structure should be considered as natural air-termination components andpart of an LPS.

a. Metal sheets covering the structure to be protected provided that:
   - The electrical continuity between the various parts is made durable (e.g. by means ofbrazing, welding, crimping, seaming, screwing or bolting).
   - The thickness of the metal sheet is not less than the value t' given in Table 3 in IEC 62305-3.
   - They are not clad with insulating material.

Metal components of roof construction (trusses, interconnected reinforcing steel, etc.), underneath non-metallic roofing, provided that this latter part can be excluded from the structure to be protected.

Metal parts such as ornamentation, railings, pipes, coverings of parapets, etc., with cross sections not less than that specified for standard air-termination components.

Metal pipes and tanks on the roof, provided that they

are constructed of material with thicknesses and cross-sections in accordance with Table 6 in IEC 62305-3.
Metal pipes and tanks carrying readily-combustible or explosive mixtures, provided that they are constructed of material with thickness not less than the appropriate value of t' given in Table 3 in IEC 62305-3 and that the temperature rise of the inner surface at the point of strike does not constitute a danger. If the conditions for thickness are not fulfilled, the pipes and tanks shall be integrated to earthing network by bonding.

*5) Methods for Positioning Air-Termination System*
The following methods can be used to position and design the air-termination system:
- The rolling sphere method
- The protection angle method
- The mesh method

The rolling sphere method is suitable in all cases.
The protection angle method is suitable for simple-shaped buildings, but it is subject to limits of airterminationheight depending upon the class of LPS. This method shall be restricted to the maximumheight of air-termination above reference plane of the area to be protected as indicated in Table 2, IEC 62305-3. The protection angle varies with height of air-termination with respect to the referenceplane (top of the structure/ facility to be protected) and shall be taken from IEC.
The mesh method shall be used for designing the horizontal conductor spacing for the air terminationsystem on plane surfaces of buildings/ structures/ facilities to be protected.

## III. PROPOSED SOLUTION FOR IMPLEMENTATION

A. *Floating Roof Storage Tanks*
The risk assessment calculation for Floating Roof Storage Tanks was carried out in line with IEC 62305 and without LPS the calculated risk value for loss of human life ($R_1$) and economic loss ($R_4$) is more than thetolerable risk $R_T$.

**Table-1:** Calculated Overall Risk without LPS

| | **Loss of Human Life ($R_1$)** | **Loss of Essential Service ($R_2$)** | **Economic Loss ($R_4$)** |
|---|---|---|---|
| **Calculated Risk (R)** | 1.200E-04 | 7.244E-05 | 1.261E-03 |
| Tolerable Risk ($R_T$) | 1.000E-05 | 1.000E-03 | 1.000E-03 |
| Direct Strike Risk ($R_D$) | 1.182E-04 | 7.091E-05 | 1.241E-03 |
| Indirect Strike Risk ($R_I$) | 1.846E-06 | 1.537E-06 | 1.981E-05 |

Risk assessment calculation for the area with air termination system and tank body being used asdown conductor results in the value for loss of human life ($R_1$) and economic loss ($R_4$) within thetolerable risk $R_T$.

Table-2: Calculated Overall Risk with LPS

| | **Loss of Human Life ($R_1$)** | **Loss of Essential Service ($R_2$)** | **Economic Loss ($R_4$)** |
|---|---|---|---|
| **Calculated Risk (R)** | 1.970E-06 | 6.064E-05 | 8.008E-05 |
| Tolerable Risk ($R_T$) | 1.000E-05 | 1.000E-03 | 1.000E-03 |
| Direct Strike Risk ($R_D$) | 1.241E-07 | 5.910E-05 | 6.027E-05 |
| Indirect Strike Risk ($R_I$) | 1.846E-06 | 1.537E-06 | 1.981E-05 |

The traditional method for providing air termination systems on floating roof tanks involves providing catenary wires/bare copper conductors. The catenary wires with small steel supports need to be connected to the existing steel platformstructures on the top of tank. Additionally for rolling ladder flexible bonding conductor of 35mm width to be applied across rolling hinges,between ladder and top of the tank & between ladder and floating roof.For the Floating Roof multiple shunt connections need to be provided between floating roof and the tankshelf at about 1.5mts interval around the roof periphery.

The shell typically discharges its electrical charge more rapidly than the floating roof. This difference in electrical potential increases the risk of sustained arcing, which can cause a shower of sparks at the roof shell interface. The traditional method to overcome the risk of these sparks is providing shunt connections between the roof and the tank shell at multiple locations. The electrical bond these shunts establish are unreliable as they have gaps with respect to the tank wall when the roof moves up and down because drift of the floating from its center and deformity in tank shell during construction or over a period of time. The LPS so provided is hence prone to greater risk of sustained arcs which can lead to fire situations in case of hydrocarbon vapor release from the rim seal.

Substantially reducing the risk of sustained arcsrequires a reliable, full-time, low impedance, and low resistance connection between the tank shell and roof. Additionally, the connection mustoperate regardless of the tank wall's condition. API Recommended Practice 545 recommends use of bypass conductors for conduction of the intermediate and long duration component of lightning-strokecurrent.

It states that the tank floating roof shall be bonded to the tank shell by direct electrical connection through an appropriate number of bypass conductors. Each conductor, including connections, shall have a maximum end-to-end electrical resistance of 0.03 ohm. The bypass conductors shall be of the minimum length necessary to permit full movement of the floating roof. Bypass conductors should be evenly spaced not more than every 30 m (100 ft) around the tank circumference with a minimum of two.

The Retractable Grounding Assembly (RGA) is a solution that is effective in meeting therisk-reduction requirements.

The retractable, braided grounding cable consists of wide tinned coper braided cable maximizes surface area and adjusts itslength (extracts and retracts) with the height of the floating roof thereby keeping a constant tension,guaranteeing the lowest possible impedance/resistance.

The RGA is not affected by the conditionof the tank because the RGA and cable arebolted and sealed to optimal locations on thetank shell and floating roof.

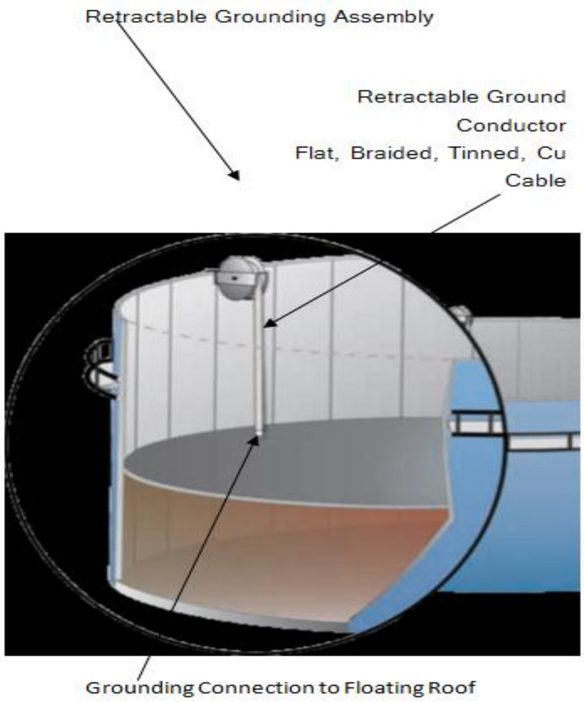


Figure-1: LPS for Floating Roof Tanks

Figure-2: RGA Assembly

REFERENCES

[1]. The IEEE Website (online)
[2]. IEC Standard 62305 (Part 1 to 4)
[3]. Eduard M. Bazelyan, Yuri P. Raizer,*Lightning Physics and Lightning Protection, CRC Press*
[4]. Tibor Horvath, *Understanding Lightning and Lightning Protection, Wiley Publications*