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AIR TERMINATION OF LIGHTNING PROTECTION FOR THE BUILDINGS WHICH CONTAINING SOLID FLAMMABLE MATERIALS

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ABSTRACT:
Damage inflicted upon facilities and equipment within a building primarily results from lightning strikes. Consequently, the installation of lightning rods emerges as a vital necessity to augment the overall protection of a structure. This not only serves the collective welfare but also aligns with governmental interests. The imperative nature of this measure lies in its role in safeguarding a myriad of equipment and production activities that involve the use of flammable materials. These materials come in various forms, encompassing solids, liquids, and gases, both within the building and its surrounding areas.Within the realm of lightning protection systems (LPS), this research specifically adopts the conventional Franklin rod as the preferred choice for factory buildings. The study accentuates the essential need for a Level IV protection rating within the LPS framework. Furthermore, it strongly advocates for the multiplication of lightning protection rods to fortify the defense mechanism. A minimum recommendation of four rods per building roof is proposed, highlighting the critical significance of proactive measures. These measures are indispensable to ensure comprehensive protection against potential damages caused by lightning strikes in industrial settings. The proactive installation and adherence to these protective measures underscore the commitment to maintaining a secure and resilient environment for both equipment and personnel.

Keywords: Lightning Protection, lightning strikes, lightning protection rods, flammable materials, factory

INTRODUCTION

Lightning discharges to earth can be hazardous for building structures, individuals as well as to service power supplies, telephone cables, computer cable networks, gas and water metal piping, industrial activities, processes involving oil and other types of fuels, etc.

The hazard of a lightning strike to a building structure can result in damage to the structure and contents of the building, failure of electronic systems and damage either inside or near the building structure. The effects of structural damage and failure can extend to the area close to the building structure or affect the environment around the building structure (Abuseif et al., 2023; Freddi et al., 2021; Voulpiotis et al., 2021). Hazards to electric power services can result in damage to the electric power system itself and failure of electronic equipment connected to the electric power system (Li et al., 2024). If lightning strikes a flammable material, either directly or indirectly, it can result in an explosion and fire which can cause losses that are difficult to repair, both for the structure of the building and environmental problems such as the risk of living things around it discussed in the Sueta (Bibri et al., 2024; Liang et al., 2024; Mardanimajd et al., 2024; Sueta et al., 2015).

There are examples of cases of the strikes from lightning on flammable wood materials, namely the case of a lightning strike at the "Gubug Makan Mang Engking" Restaurant, in the Tangerang Regency area, Banten, Indonesia, where a lightning strike occurred at noon, September 2, 2022, on the restaurant's building structure made of wood which is a flammable material. Lightning that strikes directly causes fire in buildings quickly resulting in considerable losses both to the building structure and the environment around the building.

The details from the design and the installation of modern lightning protection systems for the protection on buildings and other structures against fire and structural damage which caused by lightning in the current standards are well described where discussed in the Sueta. (Sueta et al., 2015). This research only discuss the number of needs for adequate lightning protection rods and basic considerations in the installation and design of adequate grounding facilities for protection from lightning in systems provided for building types that contain flammable materials in the Lubis discussion (Lubis et al., 2019). The research refers to the design of lightning rods in the Wood Chips processing factory building in Lumajang, East Java, Indonesia.

The standard has defined the electromagnetic scope by means of lightning strike protection zones. LPZ (Lightning Protection Zones) are areas with the same level of threat then regarding direct or indirect lightning strikes and associated electrostatic and electromagnetic fields. LPZs don't always require real physical boundaries. LPZ 0 (Zero) is treated as the most dangerous, while LPZ 1, 2, 3 are less critical. The design and placement of the lightning protection system is responsible for the safety of the structure and associated contents located within the LPZ 0B area.

For better protection, utilities should be placed in higher zones. As illustrated in Figure 2, for equipment housed at LPZ 1 (or higher), a surge protection device (SPD) is recommended. This is necessary to limit the transfer of energy from the area visible to strike electromagnetic fields, lightning, or surge currents. For water and gas utilities, this requirement is met using the limiting procedure described in Kuan (Kuan et al., 2019).

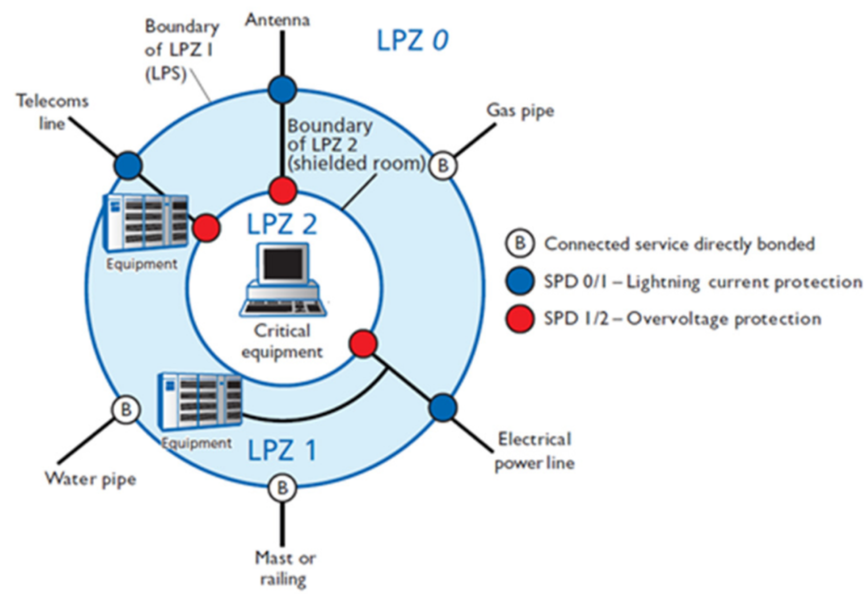

Figure 1. Concept of Lightning Protection Zones (LPZ)

Table 1. Damage and Loss in a Structure

Point of strike	Source of damage	Type of damage	Type of loss
Structure	S1	D1 D2 D3	L1, L4[b] L1, L2, L3, L4
Near a structure	S2	D3	L1[a], L2, L4
Service connected to the structure	S3	D1 D2 D3	L1, L4[b] L1, L2, L3, L4 L1[a], L2, L4
Near a service	S4	D3	L1[a], L2, L4

Only for buildings for structures with an explosion risk and hospitals or other buildings where failure of internal systems could immediately endanger human life.
Only for places where animals can die.

Table 2. Minimum and Maximum Flow Levels for Structures

LPL	I	II	III	IV
Maximum current (kA)	200	150	100	100
Minimum current (kA)	3	5	10	16

Starting from the lowest possible lightning current and the highest the first part of the standard has defined four levels of lightning protection (LPL). In turn, Lightning Protection System (LPS) is classified based on LPL.

Each LPS level has o LPL correspondent level. Direct correspondence, e.g. LPL I = LPS I. A high LPL requires the same or a higher LPS. Explosive and thermal effects at the point of impact, together with reflections on the structure being analyzed should be reflected in the design process. The designer can choose between two types of external LPS based on the consequences discussed in IEC 62305-3 Part 3 (Commission, 2010)are: Isolated, Non Isolated.

Isolated LPS is usually selected for structures made of flammable materials or with a risk of explosion. If there is no such hazard, a non-isolated system can be installed. The external LPS described in Kuan (Kuan et al., 2019) includes the following parts: Air Termination System, Down Conductor System, Ground Termination System.

An LPS must be implemented by connecting together individual elements using appropriate lighting protection components according to EN / IEC 62561. To minimize the potential damage produced by lightning strikes to structures, proper design and selection of appropriate parts is required which is discussed in IEC 62305-3 Part 4 .

The main purpose of the air termination system is to arrest the lightning discharge current and discharge it safely to earth via the down conductor and earth termination system. This is why the design and implementation of air termination systems is so important. For air termination design EN/IEC 62305-3 proposes the following structure, and a combination of these [6]: Aerial rods (or finials) in the form of freestanding poles or connected by conductors in a net on the roof. Catenary conductors (or hanging), on freestanding poles or connected to conductors in a net on the roof. Conductor grid meshed, in direct contact with the roof or suspended above.

The standard highlights that air termination sections must be installed at corners, open points and edges of structures (Cheema et al., 2023; Elkins et al., 2023; Santhanam et al., 2023). To determine the position of the air termination system, there are three basic methods recommended in SNI 03-7015-2004 as follows: “Ptotective Corner Method”.“Mesh Method”,“Rolling Sphere Method”. In the Rolling Sphere Method, an imaginary ball is rolled over the surface of the structure (Fig. 2) discussed in Stefanescu (Stefanescu & Botezan, 2016).

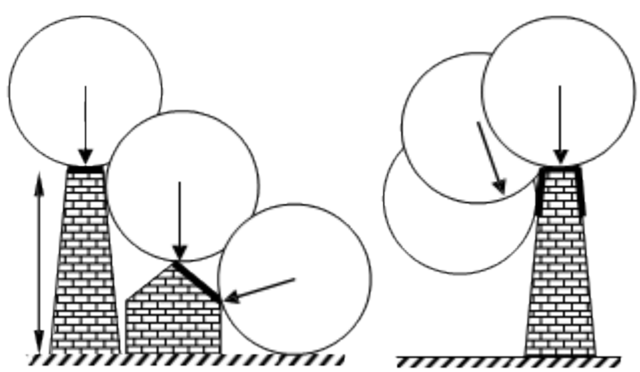

Figure 2. Example of Rolling Sphere Method [3]

The points that are vulnerable to lightning flashes are the points where the ball hits the structure. Therefore, the air termination must be located so that the ball can reach the air termination, but not the structure. As the risk of lightning to the sides of buildings is low, vertical flank protection below protected areas is only required for buildings above 60 m (at least 20 % of the top vertical sides).

Table 3. Maximum Rolling Sphere Radius according to LPS Class [3]

Class of LPS	Rolling sphere radius
I	20
II	30
III	45
IV	60

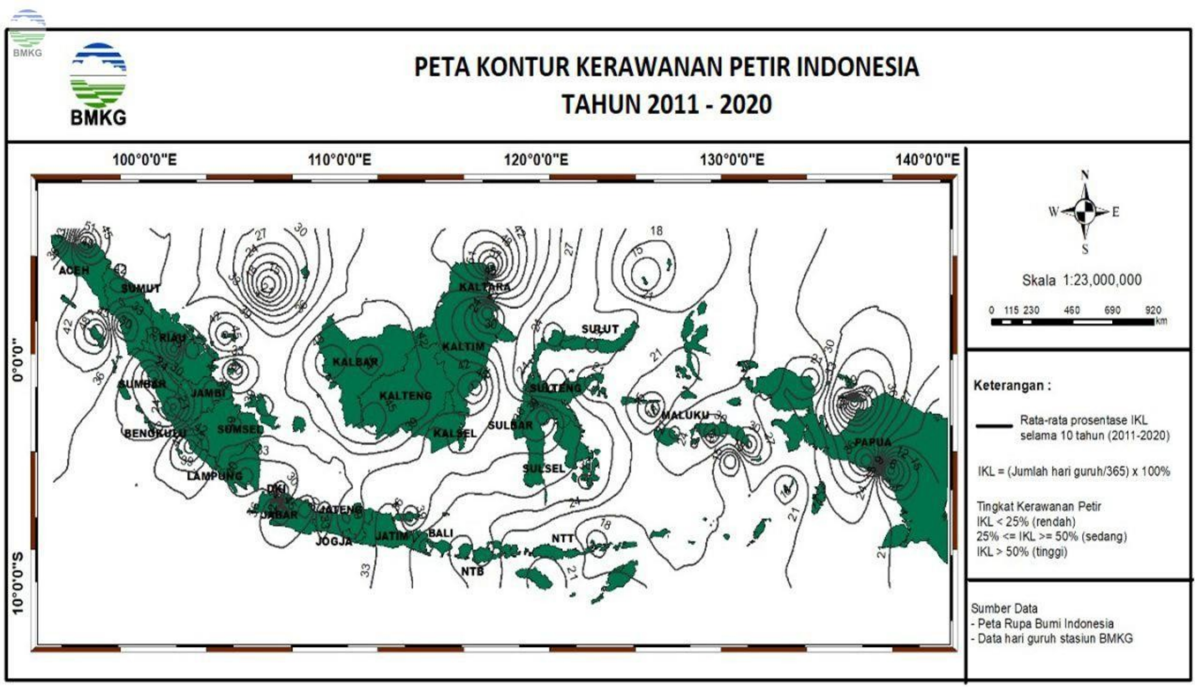

Figure 3. Indonesia Lightning Vulnerability Contour Map 2011 - 2022 [8]

RESEARCH METHODS

The research method used to evaluate the system of lightning protection in the wood chips factory building is as follows: The data consists of two types of data, namely technical data and non-technical data, which are obtained by carrying out measurements in the field and are the basic data used as material for evaluation, analysis and recommendations to determine the coordination of lightning protection conductor protection. Recapitulate existing literature by analyzing for factory buildings, Checking the data directly obtained from the relevant agencies on the object of research, Recap the data that needed to be able to maximize the use of lightning protection in the factory area.

The lightning strike effects mainly depends on the conductivity of the material by way of discharge (Kumar et al., 2018; Yousefpour et al., 2020; Zhang et al., 2019). Lightning strikes can directly or indirectly affect building structures, so the effects can occur indirectly or directly. The effects of the main lightning strike on Stefanescu [3] are described as follows: Electricity – step and contact voltage as a result of the electric field created by the electric discharge lost in the ground of the lightning strike site. It is very dangerous for humans and animals. Thermal – burst and fires caused by critical heat release result in consistent injury and damage . Electrodynamics – electrodynamic forces determine the cause from forces and stresses of mechanical in parallel conductors carrying current at the same sense. Physiological – deafness and blindness , nervous, shock, fainting, coma etc.

The effects of lightning can be cumulative, so to protect building equipment, structures, and living things from lightning discharges, effective protection measures must be considered and implemented. The first step towards protection to be optimal should be a site audit to uncover the risk of lightning strike and decide on implemented the appropriate protective measures (Chahar et al., 2023). Lightning is an unpredictable natural phenomenon so to exclude electromagnetic influences and the penetration of lightning currents into the building structure and grounded metal shield (iron cage) would be the ideal solution. But in real use it is impossible or impractical to implement that design.

RESULTS AND DISCUSSION

The term "hazardous structure" covers a wide range of objects from agricultural storage to explosives and ammunition, from sawmills to the largest petrochemical plants. Heat from lightning lines, sparks or conductor overheating can cause explosions in sawdust or dust-air mixtures described in Baatz (Protection & Guide, 1977). On the other hand, the aftermath of an explosion in a small workshop is very different from a similar incident in a large industrial complex. The necessary precautions are in principle the same: lightning ducts must be kept away from the immediate environment of flammable and explosive materials; no sparks on the joints and clamps; no excessive heating of the conductors; no flashover or splashing on nearby components; no flashover or sparking due to induced voltage or raised potential to earth system. The essential measures are: network air terminals at a safe distance from roofs with flammable materials; protection of hazard areas by catenaries, eg for open shops; cover nets for air termination to intercept any lightning strike; and increased number of down conductors for greater current sharing; if possible, there should be no descending conductors in the building; sufficient conductor cross-section; reliable and durable connection; avoid, as far as possible, adjacent components; mesh earthing system under the structure; and securing potential equalization by screening electrical installations and binding all metal services, equipment, components and installations covered in NFPA 780 (Fardhuansa, 2023).

Lightning strikes can cause disturbances in the electric power system. In multi-storey buildings or buildings, the disturbance effect due to lightning strikes is getting bigger according to the height and area of the building or buildings. The cause of the damage caused by lightning strikes, in particular, is the large amplitude of the lightning current and the steepness of the lightning current, where the amplitude of the lightning current ranges from 5kA to 200 kA which is discussed in Suryadi (Suryadi & Sudjono, 2020). The damage to the building that was struck could be in the form of thermal damage, for example, the part that was struck by fire and could also be in the form of mechanical damage to the roof of the building or the walls of the building which resulted in cracks or collapse. In the category of flammable buildings, even though the frames and foundations are made of iron, the materials inside are flammable or factory-produced materials are wood chips which are flammable materials as described in the US EPA .

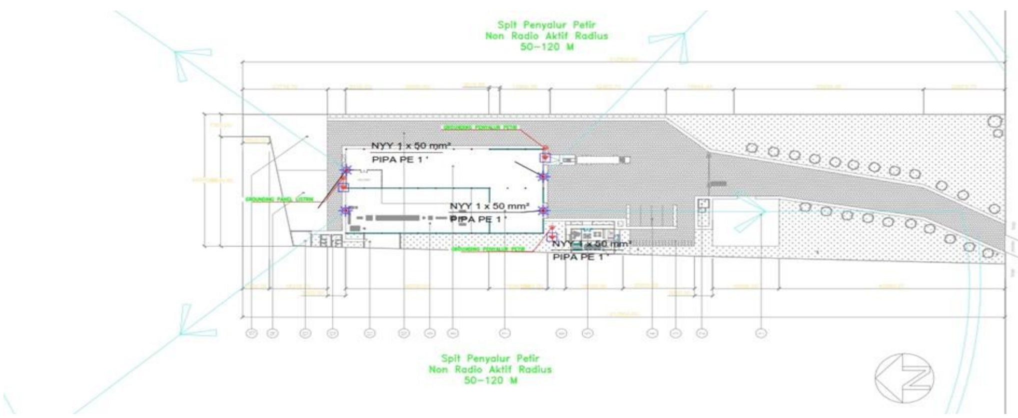

Figure 4. The Wood Chips Factory Building

The Wood Chips Factory Building is a wood chip factory building located on Jl. Raya Krajan, Besuk, District Tempeh, District. Lumajang, East Java. The number of people in the Figure 4. Lightning Protection Laying Location Detailsbuilding ranges from ± 100 to 200 people every day, and the building is a processing center so that there are many electrical and electronic equipment to support administration such as computers, internet networks, telephone networks (PABX), etc. Therefore, in accordance with the provisions of IEC IEC 62305-3 part 3, the lightning protection system that must be used in the Wood Chips Factory Building is an External Protection System (Martín-Gutiérrez et al., 2023).

Tip of The Lightning Protection (Non-Radioactive

The tip of the lightning protection (non-radioactive) is mounted on the end of a 1 ½ mm galvanized iron pipe which is provided with a hole for the conducting electrode and is also provided with a locking bolt made of copper material, which aims to facilitate control. lightning catcher, because of the nature of lightning which always strikes the high and pointed surface. The iron pipe junctions are insulated so that the iron pipe and the pointed electrode are not connected by electricity, which aims to prevent lightning from being directly connected to the iron pipe.

Table 4. Table of Lightning Intensity – Isokreunik in Indonesia

City	Island	Lightning Flash	IKL	Level
Alor	NTT	39	10,56	Rendah
Amahai	Maluku	109	29,95	Sedang
Ambon	Maluku	82	22,36	Rendah
Bogor	Jawa	201	55,15	Tinggi
Banyuwangi	Jawa	101	27,56	Sedang

Ng is the annual average density of lightning strikes to ground and can be calculated based on the formula from SNI 03-7015-2004 with Td is the number of thunder days per year obtained from the Isokeraunik table as follows:

Ng = 0,04 x Td1,25 /km2 year (1)

Ng = 0,04 x 1011,25

Ng = 12,8074 /km2/year

Calculating the equivalent coverage area of the Wood Chips Factory Building, Lamongan, East Java with Ae which is the equivalent coverage area of a building (m2) on the basis of where a is the length of the building; b is the width of the building and h is the height of the building. The equivalent coverage area for a Factory Building has a length of (a) 55m; width (b) 28 m and maximum height (h) 9.65 m can be calculated based on the formula from SNI 03-7015-2004, as follows :

Ae = ab + 6h (a + b) + 9Πh2 (2)

Ae = (55 x 28) + {(6 x9,65) x (55+ 28)}+ 9 x Π x (9,65)2

Ae = 1540 +(57,9 x 83) + 2633 Ae = 8978,7 m2

Calculating the estimated frequency of direct lightning strikes (Nd) on the Lamongan Wood Chips Factory building. The estimated frequency of direct lightning strikes (Nd) to the protected structure is obtained based on the formula from SNI 03-7015-2004 [7], which is:

Nd = Ng x Ae x 10-6 /year (3)
Nd = 12,8074 x 8978,7 x 10-6
Nd = 0,115/year

Determine the efficiency of the LPS (Lightning Protection System) and then determine the level of protection. From the local BMKG station, the value of the local annual lightning strike frequency is obtained, namely Nc is the value of the local annual lightning strike frequency, and E is the efficiency of the SPP (Lightning Protection System), which is allowed is 10-1/ year. The value of Nd > Nc requires a lightning protection system and SPP efficiency can be calculated based on the SNI 03-7015-2004 [7] formula, namely:

E = 1 – Nc / Nd 4)
E = 1 – 0,1 / 0,115
E = 0,869

So based on the table it is found that the Factory building has a class IV level of LPS protection. Using the generally accepted relationship for the strike distance (r) in the Rolling Sphere table for LPS, the following is obtained:

$r=10 \cdot I^{0,65}$ (5)

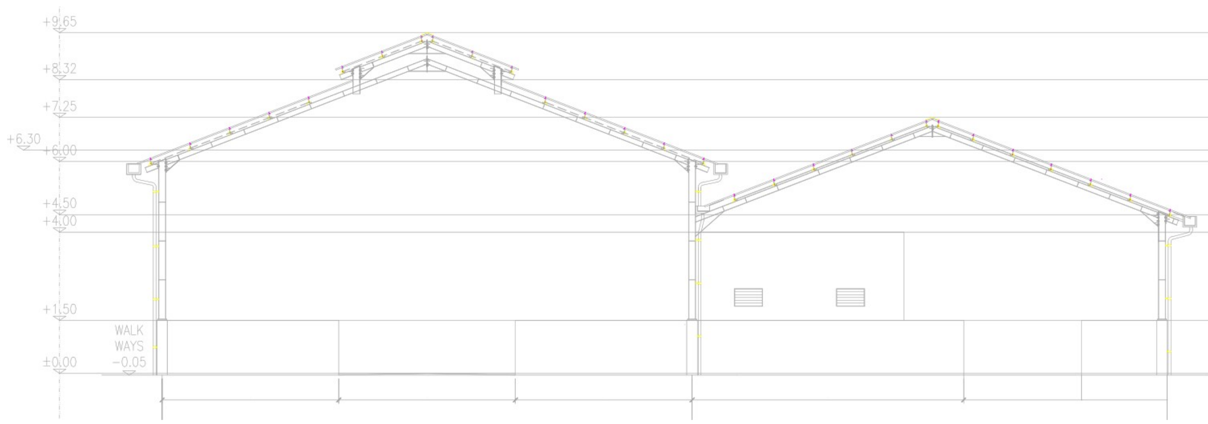

Figure 5. Factory Architectural Side View Detail

Where I is the peak current from the strike resulting from the previous calculation, resulting in a rolling ball radius value for LPS class IV (LPL IV), r = 60 m. The proposed LPS consists of two air terminations placed at the diagonal corners of the upper roof of the building. The distance between two air terminals is d, the height of the air terminal is h1 and the height of the roof mounted equipment is he. By applying the Rolling Sphere method we get:

h1 – he > p, (6)

where,

p = r – (r2 - (d / 2)2)1/2 (7)

By substituting calculations (6) into account (7) and using project-specific data the following conditions for air terminal heights are obtained:

h1 > 3.05 m, (8)

Suggested proposal for air terminal height is h1 = 4 m.

CONCLUSION

A case study for structural protection for a Wood CHips Factory is also presented, the solution obtained is to apply a class IV system of lightning protection which is illustrated and analyzed in detail by both methods, namely rolling ball and protection angle which illustrates very well the application of the EN / IEC 62305 and SNI – 03 – 7015 - 2004. Analysis of the rolling ball method shows which a protection radius of 60 m is fully capable of protecting the building structure with a total of 4 Air Terminations. The rolling sphere method shows that rolling spheres reveal a wider area of protection with the resulting LPS being simple, reliable, and easy to implement and also being able to secure buildings and the contents of buildings where flammable materials are present. The External Lightning Protection System for the Lumajang Wood Chips Factory Building has been well planned, but the protection system for building units must use an overall protection system that is safe and in accordance with SNI. The External Lightning Protection System in the Wood Chips Factory Building requires periodic and adequate maintenance and checking due to the presence of flammable materials in the building.

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