Evaluation of Parameters in the Development of a Building Protection System

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Abstract – *This research aims to determine the external lightning protection system that has been installed as well as determine the effectiveness of the lightning protection system. The method is carried out by observation, measurement of building protection needs from lightning strikes, protection radius, conductor distribution, and ground termination. Based on the evaluation results, there is a radius of 150 m that has been previously designed to protect buildings that are scattered with high termination air of 30 m from the ground. The measurement results of 1.55 Ω of earth resistance was obtained after adding 3 copper conductors with a diameter of ¾ inch with a length of 2 m.*

Keywords: *lightning rod, protection needs, strike radius*

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I. Introduction

Lightning occurs because there is a negative charge at the bottom of the cloud that causes a positive charge induced above the surface of the land to form an electric field between the cloud and the ground. The potential difference generated between the load on the cloud and the surface of the earth results in the release of lightning-shaped charges [1]-[3].

The losses generated are very large, so we need a lightning protection system that can protect all parts of a building, including humans and equipment in it against the dangers and damage due to lightning strikes [1], [3], [4]. To protect tall buildings from the lightning, the way to go is with the installation of the lightning rods that are reliable and meet the applicable requirements so that in case of a lightning strike the means is what will deliver the lightning current into the ground [5]-[7].

Buildings which are scattered with different elevations require security and comfort from lightning strikes and therefore an external lightning rod system has been installed with a lightning rod installation method, the Franklin type of lightning rod. From the analysis of data calculations, evaluation on the maximum current that can cause protection failure, the risk of protection failure per year, and the annual strike can be made. From the data obtained, it can be determined whether a building is well protected. Protection against lightning strikes consists of several levels according to the needs. The more important and the height of the building, the higher the level of protection is needed [8].

At the Indorama Engineering Polytechnique campus, lightning rods are installed to protect the buildings in the area. To find out whether the lightning protection system is reliable and meets the applicable requirements, the evaluation and development of the protection system are carried out. This is due to the fact that the security of a building or object against lightning strikes is essential in the provision of a well-planned system implementation. Then in case of a strike, the facility will channel the lightning current into the ground safely without causing danger to humans or other dangerous objects inside, outside, or around the buildings. Based on the identification of the problems that have been carried out, this research was implemented for the external lightning rod installation by determining the level of protection, area of the lightning rod, the critical location due to lightning strikes, and the grounding system.

This study aims to evaluate the erosion and analyse using the Franklin's method of interference with external lightning protection to protect buildings from direct lightning strikes. It is implemented by first taking the measurement data and image dimensions of buildings, level of protection, lightning strike density, determining the lightning current to the resistance of the buildings, distribution of conductors, and the grounding that will determine the location of its permitted corresponding resistance.

Through the analysis of these methods, an efficient and reliable lightning protection system for the future development of the buildings in the area of Indorama Engineering Polytechnic campus can be realised. Based on surveys and observations that have been made, it turns out that there is a lack of ground resistance on the external lightning protection system which is very important for the lightning rod installation.

A. Lightning

Lightning is a natural event which is the process of releasing electric charges that occurs in the atmosphere. This charge release event occurs due to the formation of concentrations of positive and negative charges in the cloud or even the difference in charge with the surface of the earth. Lightning is more common between one charge and another charge in the cloud compared to what happens between the charge center in the cloud and the surface of the earth. Both types of charge release can cause disruption or loss [1]-[2], [9].

The average number of lightning strikes per year *Nd* can be calculated by multiplying the annual flash density to earth *Ng* and the effective protection area of the building *Ae* [10], as in equation (1).

$$Nd = Ng.\ Ae \qquad (1)$$

The density of lightning strikes to the ground is influenced by the average thunder day per year in the area. This is indicated by the relationship in equation (2).

$$Ng = 4.\ 10^{-2}.T^{1.26} \qquad (2)$$

While the magnitude of *Ae* can be calculated using equation (3).

$$Ae = ab + 6h\ (a + b) + 9\pi h^{2} \qquad (3)$$

So from the substitution of Equations (2) and (3) to equation (1), the value of *Nd* can be searched using equation (4).

$$Nd = 4.10^{-2}\,T^{1.26}\,[\,ab + 6\,h\,(\,a + b\,) + 9\pi h^{2}\,] \qquad (4)$$

where *a* is the length of the building roof (m), *b* is the width of the building roof (m), *h* is the height of the building roof (m), *T* is the annual thunder day, *Nd* is the lightning strike density to the ground (strike/km^2/year) and *Ae* is the area that still has a lightning strike number of *Nd* (km^2).

The average annual frequency of lightning that hits the ground near the building *Nn* can be calculated by multiplying lightning density to land annually *Ng* with the coverage of the area around the building struck *Ag*, as shown in equation (5).

$$Nn = Ng.\ Ag \qquad (5)$$

The area around the lightning strike *Ag*, is the area around the building where a strike to the ground causes an additional potential land location that can affect the building. Lightning strikes can cause some damage, namely death, mechanical damage, thermal damage, and electrical damage.

The building's safety system is designed to protect the building from various types of disturbances. One of the building safety systems is the lightning protection system along with its earthing. Building installations according to location, shape and usage susceptible to lightning strikes and require installation of lightning rods are as follows; tall buildings, buildings that store flammable materials, building for public facilities, and building with special functions necessity.

The type of lightning rod is also affected by the state of the roof of the building to be secured. For buildings with flat roofs, which are buildings which have a high difference between roofing and under roof less than 1 meter, the appropriate system is the Faraday system, which suitable for lightning protection system around the flat roof. Whereas for sharp roofs or differences in height of lumbar and displacing more than 1 meter, the appropriate system is the Fanklin's method, namely the lightning rod system with rod electrodes.

B. Protection Room

At the beginning of the discovery of lightning rods and a few years after that, the protective chamber of a conical lightning rod with a cone peak angle ranging from 30° to 45° is shown in Fig. 1(a). The choice of the magnitude of the protection angle indicates the desired level of protection. The smaller the protection angle, the higher the level of protection obtained, but the more expensive the construction costs. For analytical calculations, the three-dimensional protection space can be described in two dimensions and because of its symmetrical shape, the analysis can be carried out only on half as shown in Fig. 1(b).

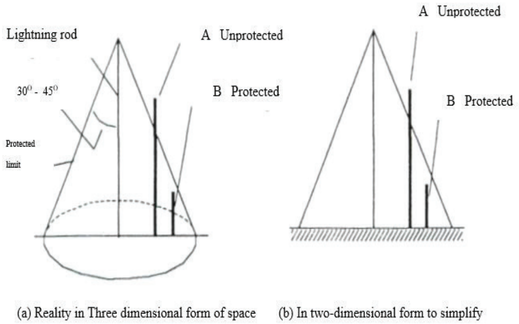


Fig.1. Conventional protection room [11].

All objects inside the protective cone chamber (or protective triangle field) will be protected from the lightning strikes. While objects that are outside the protective cone space (or outside the protective triangle field) are not protected. The protection room according to the electrometric model is almost the same as the protection room based on the old concept, which is also a conical space with only the inclined plane of the cone is curved with a certain radius, as shown in Fig. 2.

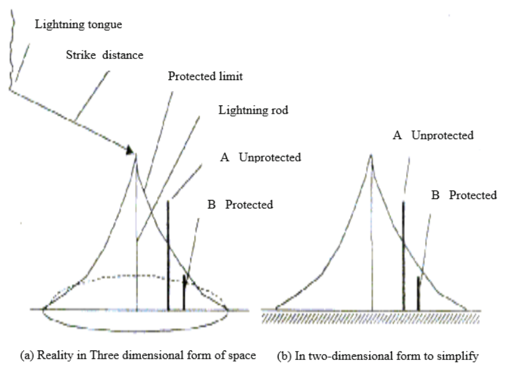


Fig. 2. The concept of protection chamber for electrometric [11].

The size of the radius is the same as the distance from the lightning tongue. Strike distance (ability to grab or reach an object) from the lightning tongue is determined by the amount of lightning current that occurs. Thus, the degree of curvature of the inclined plane of the cone is influenced by the magnitude of the lightning current that occurs.

C. Field of Strains and Strike Lines

The protection range of a lightning rod can be explained by the strike plane or striker line. The field of the strain is the position of the strike points, namely the points where the lightning tongue has reached a distance to an object equal to the distance of strike. Field strains are three-dimensional shapes in real conditions. To simplify the analysis, a two-dimensional shapes can be used, namely the lines as shown in Fig. 3.

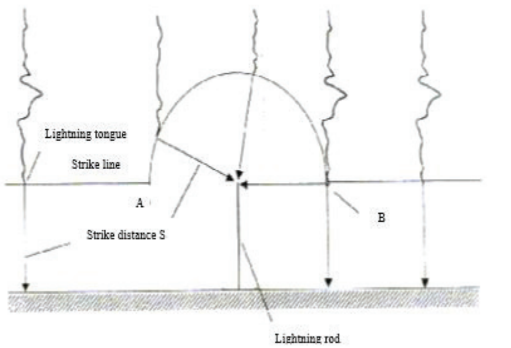


Fig. 3. Lines of a lightning tongue for a particular lightning current [11].

Points A and B are critical points, meaning that all lightning with a current I passing through these points will strike the lightning rod or head towards the ground with a 50% probability. Fig. 4 shows the graphics area at a distance of 30 m protection coverage strike.

The magnitude of the lightning discharge peak current can be found by equation (6).

$$I = 10.6\, Q^{0.7} \tag{6}$$

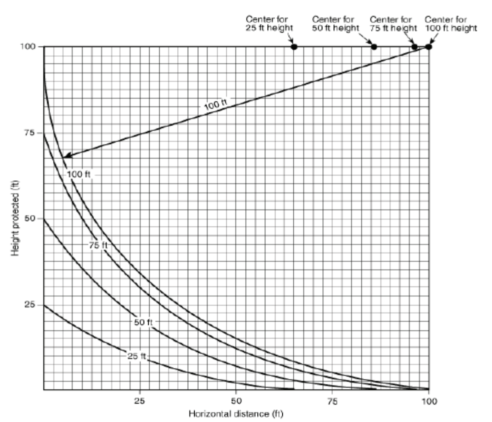


Fig. 4. Graph of 30 m protection coverage area at strike distance [12].

where I is the lightning peak current (kA) and Q is the lightning tongue load (Coulombs). A medium great relationship with the current bolt spacing is shown in equation (7).

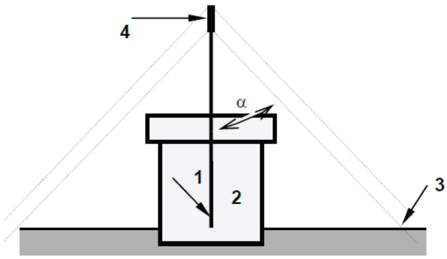
$$S = 8\, I^{0.65} \tag{7}$$

Strike distance is the distance of the radius used in the non-conventional protection room. The equation that is often used to determine the strike distance is the Whitehead equation, which until now is an equation that is widely recognized truth.

D.Lightning Protection System for Conical Roof

The lightning protection system for cone-roofed buildings is more suitable using the Franklin's method. This method is the oldest but still reliable enough to protect buildings from lightning strikes and still widely used, especially for cone / dome-roofed buildings. In Fig. 5, the Franklin's method of a lightning rod is shown.

The rod electrodes in the Franklin's method have a conical protection area with the rod electrode as the axis. Half of the peak angle is called the protection angle which is usually 56° at taken corner and specifically 45° at taken refuge angle for a combustible building.



Note:
1.Air-termination pole
2.Protected building
3.Reference field
4.Horizontal air-terminal wire
5.Protection angle

Fig. 5. Franklin method of lightning protection system [11].

II. Methodology of Research

The Franklin's method used for this external lightning rod installation is carried out in stages. The first is the process of collecting a data and image measurement of the dimensions of the buildings.

Information about buildings inside the Indorama Engineering Polytechnic campus consists of the Vocational DTY building, Administration Building, Lecture Building, Workshop Building, UKM Building, and Mushola Building. The information on campus location at position 107° 25' 06.0 " east longitude and 6° 33'12.1" south latitude is used in the design of each building protection radius [3].

III. Results and Discussion

A. Results of Building Situation Measurements

Table I to VI shows the data related to the physical and non-physical characteristic for the vocational DTY building, administration building, lecturer residence, workshops buildings, the building of SMEs mosque building respectively.

TABLE I
VOCATIONAL BUILDING DTY

Characteristics	Size
Building Height	15 m
Building Length	31 m
Building Width	30 m
Building Roof Length	35 m
Building Roof Height	3 m
Building Roof Width	34 m
Land Resistance	2.32 Ω
Number of people	12 people
Time of attendance	56 hours/week
IKL	50
Frame Material	Metal

TABLE II
ADMINISTRATION BUILDING

Characteristics	Size
Building Height	11 m
Building Length	80 m
Building Width	14.1 m
Building Roof Length	84 m
Building Roof Height	3 m
Building Roof Width	18 m
Land Resistance	2.56 Ω
Number of people	50 people
Time of attendance	40 hours/week
IKL	50
Frame Material	Metal

TABLE III
LECTURE BUILDING

Characteristics	Size
Building Height	11 m
Building Length	90 m
Building Width	7.2 m
Building Roof Length	94 m
Building Roof Height	3 m
Building Roof Width	12 m
Land Resistance	2. 64 Ω

Number of people	280 people
Time of attendance	40 hours/week
IKL	50
Frame Material	Metal

TABLE IV
WORKSHOP BUILDING

Characteristics	Size
Building Height	15 m
Building Length	96 m
Building Width	30 m
Building Roof Length	100 m
Building Roof Height	3 m
Building Roof Width	34 m
Land Resistance	1. 8 2 Ω
Number of people	120 people
Time of attendance	40 hours/week
IKL	50
Frame Material	Metal

TABLE V
SMEs BUILDING

Characteristics	Size
Building Height	8 m
Building Length	24 m
Building Width	12 m
Building Roof Length	26 m
Building Roof Height	3 m
Building Roof Width	14 m
Land Resistance	2. 92 Ω
Number of people	20 people
Time of attendance	12 hours/week
IKL	50
Frame Material	Metal

TABLE VI
MOSQUE BUILDING

Characteristics	Size
Building Height	6 m
Building Length	6 m
Building Width	6 m
Building Roof Length	8 m
Building Roof Height	2 m
Building Roof Width	8 m
Land Resistance	3.23 Ω
Number of people	20 people
Time of attendance	15 hours/week
IKL	50
Frame Material	Metal

B. Determination of Protection Level

Strike lightning density value is obtained by inserting the number of a thunder days T in equation (8).

$$Fg = 0.25\ T \qquad (8)$$

The value of days of thunder is T=64, to obtain 16 strikes / km ^{2} / year.

C. Coverage Conditions

In determining the level of protection, the area of interest that is struck by lightning and the level of need for lightning rods shall first be calculated, which is the level of building hazard against lightning strikes. As for the condition of the area of coverage against lightning strikes, from equation (3),

$$Ae = 134{,}934\ m^2$$

Determine the number of lightning strikes per day per km ^{2} as in equation (9), then

$$Ne = (0.1 + 0.35 \sin \lambda)\ (0.4 \pm 0.2) \qquad (9)$$

A value is the geographical line location of the Indorama Engineering Polytechnic campus of 33.12° in the Purwakarta Regency.

$$Ne = 0.17466 \text{ lightning strikes/day/km}^2$$

$C1$ is the damage factor index based on the situation of buildings with a value of 1, and IKL of 50 in the city of Purwakarta. The possibility that buildings in the coverage area of the Indorama Engineering Polytechnic campus are struck by lightning is as follow,

$$Ps = Ae\ Ne\ \text{IKL}\ 10^{-6} \qquad (10)$$

By inserting the values Ae, Ne, and IKL in equation (10), the following value is obtained.

$$Ps = 0.0235\ 6 \quad \text{lightning strikes/year}$$

The hazard level of the building in the coverage area in the Indorama Engineering Polytechnic campus can be determined by the following equation.

$$Pr = Ps \cdot C2 \cdot C3 \cdot C4 \cdot C5 \qquad (11)$$

By inserting the values Ps, $C2$, $C3$, $C4$, and $C5$ in equation (11) the following value is obtained.

$$Pr = 0.7035$$

Table VII shows the lightning installation needs index by a factor of damage to the coverage.

TABLE VII
LIGHTNING INSTALLATION REQUIREMENT INDEX BASED ON DAMAGE FACTOR FOR COVERAGE

1	**Damage Factor based on Building Usage** The building and its contents are quite important for example water towers, factories, government buildings	A 2
2	**Damage Factors based on Building Construction.** Buildings with reinforced concrete construction or iron frames with or not metal	B 2
3	**Damage Factor based on Building Height (in meters)** > 12 to 17	C 3
4	**Damage Factor based on Building Situation.** At the foot of the Hill up to three-quarters of the height of the Hill or in the Mountains up to 1000 meters.	D 1
5	**Damage Factor based on Thunder Day per Year** 64	E 5
6	**The level of lightning installation needs to be based on damage factors.** Hazard estimate (somewhat large) and Lightning Installation (recommended)	R 13

IV. Results and Discussion

From the results of research and discussion of lightning rod installation planning for Indorama Engineering Polytechnic campus buildings, it can be concluded as follows. First, the calculations, the magnitude of hazard assessment index 13 is relatively large degree of danger and in need of a good and reliable lightning rod installation. In one year, the density of lightning strikes in the city of Purwakarta is 16 strikes/km/year. Then attractive area for coverage of lightning strike is 134,934 m^2, with the number of lightning strikes of 0.17466/day/km^2.

Also, from the results of the analysis of calculations for the value of the level of lightning installation needs based on the damage factor of each coverage, the total building damage index of 13 is obtained, illustrates that the estimated hazard is rather large and recommended for installation.

Finally, it can be said that the grounding system used in the planning of a lightning rod installation is the vertical grounding electrodes in the ground and the horizontal planting of plates with a depth of 2 m of 5 points of electrodes and 1 plate for each terminal water reference point. After installing 3 electrode points with a depth of 2 m by connecting them parallel to the system, getting a resistance value that is even better than before is expected. The more electrodes that are paired parallel to the system, the better the grounding resistance value in the protection system.

Nomenclature

a	*long roof of the building*
Ae	*wide effective protection area on the building*
Ag	*coverage area around the building is struck*
b	*building roof width*
C1	*damage factor based on the building situation*
C2	*damage factor based on construction*
C3	*damage factor based on height*
C4	*damage factor is based on thunder days*
C5	*damage factor based on usage*
d	*lightning distance*
Fg	*lightning strike density*
h	*high roof of the building*
I	*peak lightning current*
Nd	*frequency of direct lightning strikes annually*
Ne	*number of lightning strikes per day per km2*
Ng	*lightning density to earth per year*
Nn	*average frequency of the flash*
Pr	*danger level of the building*
Ps	*the possibility of a lightning strike*
Q	*charge of lightning tongue*
S	*radius of the lightning strike*
T	*day thunder per year*

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