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Design and Installation of Lightning Arrester System at Karitas Yogyakarta Junior High School

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Abstract
The Karitas Yogyakarta junior high school building is located in Yogyakarta, standing on an area of 4,750 m² with two buildings of two floors each. This building is located near swamps and settlements between people's houses, and is surrounded by plantations and rice fields at the back. This building is not equipped with a lightning distribution system, even though tall buildings need this system to protect against the danger of lightning strikes. This research designs a lightning distribution system according to applicable standards, and the results show that the density of lightning strikes per year is 20.28 km²/year with the largest equivalent coverage area of 8,297.045466 m². The highest probability of a lightning strike to a building is 0.086 with protection level I for all buildings. To protect the entire building, 9 lightning rods are needed and the grounding system requires 3 electrode rods.
Keywords: *Grounding; Lightning Arrester; Protection*

Abstrak
Gedung SMP Karitas Yogyakarta terletak di Yogyakarta, berdiri di atas lahan seluas 4.750 m² dengan dua bangunan masing-masing dua lantai. Bangunan ini berlokasi di dekat rawa dan permukiman di antara rumah penduduk, serta dikelilingi oleh perkebunan dan sawah di bagian belakang. Gedung ini tidak dilengkapi dengan sistem penyalur petir, padahal bangunan yang tinggi memerlukan sistem ini untuk melindungi dari bahaya sambaran petir. Penelitian ini merancang sistem penyalur petir sesuai standar yang berlaku, dan hasilnya menunjukkan kerapatan sambaran petir per tahun sebesar 20,28 km²/tahun dengan area cakupan ekuivalen terbesar 8.297,045466 m². Probabilitas sambaran petir ke bangunan paling besar adalah 0,086 dengan tingkat proteksi I untuk seluruh gedung SMP. Untuk melindungi seluruh gedung diperlukan 9 batang penangkal petir dan sistem pentanahan memerlukan 3 batang elektroda.
Kata Kunci: Penyalur Petir; Pentanahan; Proteksi

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INTRODUCTION

Lightning is a natural event that occurs when it rains. Lightning occurs due to the attractive force between positive and negative charges (Sulistiawati *et al.* 2023),. The cause of lightning is due to the negative charge in the clouds which causes a positive charge to be induced on the ground, thus forming an electric field between the cloud and the ground (Dali *et al.*, 2022). The greater the positive and negative that is stored in the cloud, the more the charge will be released in the form of light or lightning. Every occurrence of lightning or lightning will produce a sound called rumbling. Indonesia is located on the equator and has a tropical climate. The tropical climate causes one of the seasons, namely the rainy season (Andriani, 2024).

The rainy season generally has a high intensity of rain, as a result, Indonesia has a high intensity of lightning. The high intensity of lightning is described in units of thunder days. The high intensity of lightning causes a high number of thunder days. Indonesia has tall buildings, so there is a risk of damage due to lightning strikes. The effects resulting from lightning strikes result in damage and fires to electrical equipment (Biantoro *et al.*, 2020). One example of a location that will be studied is the Karitas Yogyakarta Junior High School building. The Karitas Yogyakarta Junior High School building is under the auspices of the Karitas college foundation. This building stands on a land area of 14,750 m^2 with six buildings, each consisting of 2 floors. The building stands in a residential area on flat land between residential buildings. Apart from that, there are still large expanses of field land (Ramadhan *et al.*, 2020).

Figure 1. Karitas Yogyakarta Junior High School Building

Every building has electrical installations and electronic equipment, these two components really need a lightning conductor if a lightning strike occurs. This is because buildings that are multi-storey and located on open ground are more susceptible to lightning strikes (Yusuf and Saprudin, 2021). Both mechanical disturbances and disturbances that occur due to nature. Lightning strikes can harm electrical equipment in the building, resulting in damage and can endanger living creatures in the building (Nawir *et al.*, 2018). To reduce the impact and protect damage caused by direct lightning strikes. So the building needs to be installed with an external lightning distributor (Duanaputri *et al.*, 2021). This research carried out case sampling at the Karitas Yogyakarta Junior High School Building. The building does not have a lightning distributor installed, so this research was conducted to find out the need for a lightning protection system in the building (Noviana and Karim, 2022). This was done because of the school management's lack of awareness of the potential for lightning strikes in the area (Mulyadi *et al.*, 2023). After conducting a survey, the arrester in the building has not been found and plans are still in progress to create a lightning arrester system in the Karitas Yogyakarta Junior High School building.

METHODS

The first step before starting this service program is to conduct a literature study. Where the goal is to search for and find reference sources that are relevant to the design and installation process being carried out. This source comes from journals, books, papers, and other sources of information related to the topic of installing lightning rods.

A. Lightning Parameter

Lightning voltage, measured in megavolts (MV), indicates the difference in electrical potential between the cloud and the ground or between different parts of the cloud. Lightning duration refers to how long the flash lasts, usually on a scale of microseconds to milliseconds. Lightning polarity indicates whether the current flowing is positive or negative (Saragih *et al.*, 2020) Flash frequency describes how often lightning occurs in a particular location over a period of time. Apart from that, other parameters that are also important include the spatial and temporal distribution of lightning, which provides information about the distribution pattern and timing of lightning occurrence in a region (Seniari *et al.*, 2021). Understanding these parameters is critical in risk mitigation and infrastructure planning, especially in the fields of electrical and building engineering. Lightning parameters state the characteristics or description of lightning itself. There are quite a lot of lightning parameters, especially those related to lightning protection efforts. Apart from that, these lightning parameters are also useful in studying the effects of damage due to lightning strikes and their possible uses (Putra *et al.*, 2024). These parameters include: lightning wave shape, strike density (Ng), peak current (Imax), average wave steepness (di/dt). The following are lightning parameters according to SNI standards.

Table 1. Index of Lightning Parameter

Lightning Parameter		**Protection Level**		
		I	II	III-IV
Peak Current	I (kA)	200	150	100
Total Charge	Q_{Total}	300	225	150
Impulse Charge	Q_{Impuls}	100	75	50
Energy	W/R (kJ/Ω)	10000	5600	2500
Average Stepness	di/dt 30/90% (kA/µs)	200	150	100

B. Types of Lightning Protection

There are several types that can be used in the design of lightning conductors, and these types can be used according to the location and structure of the building. The following are the types that can be used in the design of lightning conductors:

a. Catenary Wire Lightning Conductor
This type of lightning conductor uses the principle of the Faraday cage, consisting of conductors that are spaced sufficiently apart to avoid direct contact of lightning currents with the building.

b. Faraday Cage Lightning Conductor
This type of conductor has a cage-like structure consisting of conductors that cover the roof and walls of the building to be protected.

c. Franklin Lightning Conductor
This type of conductor was invented in 1752 by a scientist named Benjamin Franklin. It consists of a conductor made of a metal rod, which is 2-8 meters tall, placed at the top of the building structure.

d. Natural Component Lightning Conductor
This type of conductor uses the building's structure itself as the lightning conductor. The building's structure can be used entirely or partially for the external installation.

C. Lightning Protection Standards

This system is one of the external lightning protection parts which functions as a channel for lightning current from the air termination to the terminal. earth electrode. According to SNI 03-7015-2004, conductors need to be designed so that they cannot cause induction on electrical equipment located inside or outside the building and also distribution conductors must be installed as short as possible. There are two types of conductors, namely insulated and non-insulated conductors. If the conductor cable is not insulated, give a distance of around 0.1 m or 10 cm. For the distribution conductor material, there are several provisions or factors that need to be known for selecting the distribution conductor, namely that it is strong against heat, does not corrode easily, has high conductivity and is economical. In installing the Down Conductor there is a procedure for placing it by looking at the condition of the building. Where, if the wall is made of non-flammable material, the distribution conductor can be placed inside the wall or on the surface of the wall. Then, if the wall is made of flammable material, the distribution conductor can be placed on the surface of the wall or wall. As long as the lightning temperature increase is not dangerous. Then if the wall is made of flammable material and the temperature is very dangerous, the conductors must be spaced at a distance of about 0.1 m and brackets made of metal attached to the wall. The minimum size used for distribution systems is according to SNI 03-7015-2004

Table 2. Minimum Cross-sectional Area for Some Types of Materials

Level Protection	Material	Cross-Sectional Area (mm^2)
I - IV	Copper (Cu)	16
	Aluminum (AI)	25
	Ferrum (Fe)	50

The material used has its own specific resistance value depending on the type used, following is a table 3 of the specific resistance of the conductor material.

Table 3. Types of Resistance in Conductor Materials

Electrical Conducting Materials (Conductor)	Resistance Type (Ohm.Meter)
Gold	$2{,}44 \times 10^{-8}$
Silver	$1{,}59 \times 10^{-8}$
Copper	$1{,}68 \times 10^{-8}$
Aluminum	$2{,}65 \times 10^{-8}$
Steel	$9{,}71 \times 10^{-8}$
Platinum	$10{,}6 \times 10^{-8}$
Nichrome	100×10^{-8}
Carbon	$(3\text{-}60) \times 10^{-5}$

D. Earth Termination

The earth termination system is one part of the external lightning protection system which functions to spread or neutralize lightning currents towards the ground. By planting one or more electrodes in the ground, electrodes that can be used in earth termination systems can be in the form of rod, ribbon, or plate electrodes. In earthing systems, the recommended value of grounding resistance is below 5 ohms. To obtain the grounding value according to the applicable standards, there are several methods that are used to calculate the grounding value if the measurement results are above 5 ohms. This method can use the single rod method or in parallel by adding a rod electrode connected using a BC cable. single wheel and multiple rod electrode circuits. The following is a table of multiplication factors using 2 rods with 1 line.

To ensure the effectiveness of the earth termination system, it is crucial to periodically check and maintain the grounding resistance. Environmental factors such as soil moisture, temperature, and the presence of corrosive elements can affect the performance of the grounding system over time. Regular inspections and maintenance, including the addition of moisture or chemical enhancers to the soil around the electrodes, can help maintain the grounding resistance within the recommended range. This proactive approach not only ensures compliance with safety standards but also enhances the overall reliability of the lightning protection system, safeguarding both people and property from the dangers of lightning strikes.

Table 4. Multiplication Factors Using 2 Rods with 1 Line

Total Rod	Resistivity Types (Ωm)
2	1.16
3	1.29
4	1.36
8	1.68
12	1.80
16	1.92

RESULT AND ANALYSIS

A. Initial Parameters for Determining Lightning Protection

Before embarking on the design phase, this research requires the collection of comprehensive data. This data will afterward be processed to determine whether the building requires the installation of a lightning conductor. The initial step involves carrying out meticulous measurements and thorough observation. These activities are pivotal in gathering accurate and relevant data pertaining to the building's current state and its susceptibility to lightning strikes. Once these measurements and observations are completed, the collected data is carefully analyzed. This analysis is crucial as it provides insight into various factors, such as the building's height, location, structural materials, and the frequency of lightning occurrences in the area.

Table 5. Building Data Observation Results

No	Location	Height (m)	Length (m)	Wide (m)	Roof Material
1	Building A	14	48	10	Clay Roof Tiles
2	Building B	14	40	10	Clay Roof Tiles

Table 6. Lightning Day Data

Location	Number of Days of Strikes
Yogyakarta	148

C. Risk Estimate Calculation

In the calculations according to PUIPP based on the indices listed, the results were obtained for the Karitas Yogyakarta Junior High School building.

Building A

$R = A + B + C + D + E$

$R = 14$

Building B

$R = A + B + C + D + E$

$R = 12$

Table 7. Index of Protection Installation

No	Building	Index						Danger Level	Protection Recommendations
		A	B	C	D	E	R		
1.	A	3	3	2	0	6	14	High	Highly Recommended
2.	B	3	3	0	0	6	12	Medium	Recommended

D. Index of NFPA (National Fire Protection Association)

After carrying out calculations to find out whether the building needs protection or not, then calculate the efficiency according to NFPA (National Fire Protection Association).

$N_g = 0{,}04 \times Td^{1.25}$ strikes per km^2 per year

$N_g = 20{,}64$ strikes per km^2 per year

E. Equivalent Coverage Area

Calculation of the equivalent coverage area (Ae), where this calculation is used to determine the surface area at risk of being hit by lightning strikes

Building A

$A_e = ab + 6h\,(a + b) + 9\pi h^2$

$A_e = 11279{,}88\ m^2$

Building B

$A_e = ab + 6h\,(a + b) + 9\pi h^2$

$A_e = 10474{,}96\ m^2$

F. Calculation of Lightning Strike Frequency

Calculating the frequency of lightning strikes is an important step in assessing the risk of a particular building or installation. The method often used to estimate the frequency of lightning strikes is based on international standards such as IEC 62305 (Suharto *et al.,* 2021).

Building A

$N_d = N_g \times A_e \times C_1 \times 10^{-6}/year$

$N_d = 0{,}116$ / year

Building B

$N_d = N_g \times A_e \times C_1 \times 10^{-6}/year$

$N_d = 0{,}116$ / year

G. Risk of Damage

Values from calculating the frequency of lightning strikes to the Karitas Yogyakarta Junior High School building. Then to get the level of protection for the building. The following is a calculation of the risk of damage obtained (Pratiwi, 2023).

$$N_C = \frac{1{,}5\times10^{-3}}{C} = 0{,}0001$$

H. Frequency Analysis

Frequency calculation (Ec) is used to determine the level of protection in the Karitas Yogyakarta Junior High School building

Building A and Building B

$$E = 1 - \frac{0{,}0001}{0{,}116}$$

$$E = 0{,}99$$

I. Air Termination

Calculating the protection radius value obtained from the splitzer for the Karitas Yogyakarta Middle School building aims to find out whether the radius provided by the splitzer can protect the entire building or not (Karta *et al.*, 2020).

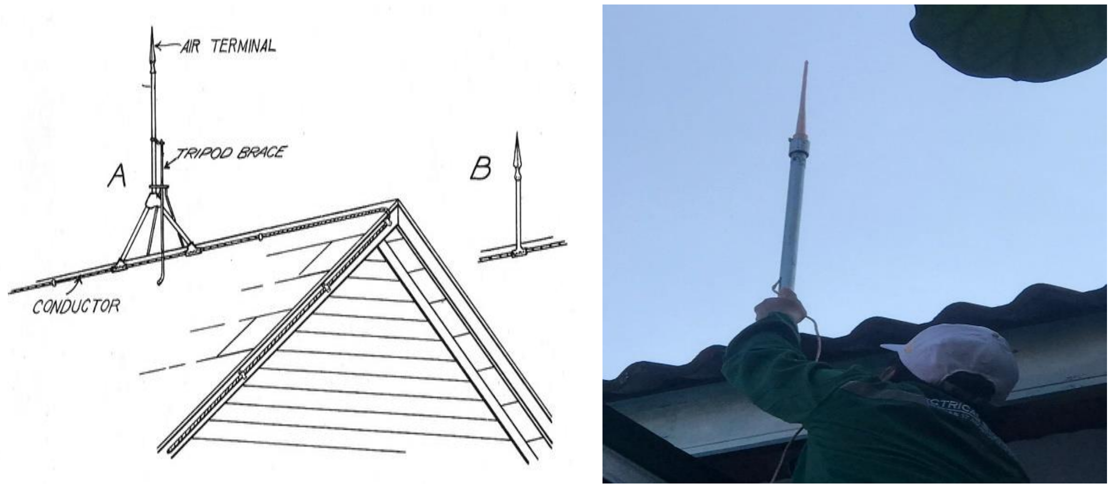

Figure 1. Air Termination Design and Installation Process

The following are the calculations for each Building A and Building B. Before knowing the protection radius, first find out the distance between the lightning strikes on the building.

$$r_S = 10 \times Imax^{0.65}$$

$$r_S = 313.09 \text{ meter}$$

Building A

a. Angle of Protection

$$\theta = sin^{-1}\left(1 - \frac{h}{rs}\right)$$

$\theta = 71{,}90°$

b. Radius of Protection

$$r = \frac{h}{\sin(90° - \theta)} \sin(\theta)$$

$r = 47{,}42$ m

c. Distance Between Splitzer

$$r = \frac{h}{\sin(90° - \theta)} \sin(\theta)$$

$r = 4{,}58$ m

d. Total Splitzer

$$Total\ Splitzer\ = \frac{Roof\ Length}{Distance\ of\ Splitzer}$$

$Total\ Splitzer\ = 5$ rods

The calculations carried out for Building A include several main aspects of lightning protection. First, the protection angle is calculated using the inverse sine formula, where the protection angle (θ) is $71{,}90^0$. This angle determines the area that will be protected by the lightning protection system. Next, the radius of protection is calculated based on the building height (h) and the known protection angle. Using trigonometry formulas, it is found that the radius of protection is 47,42 m. This is the distance from the lightning rod at which the protection area is still effective. The distance between lightning rods is calculated using a similar formula involving building height and protection angle. The result is a distance between lightning rods of 4,58 m. This ensures that the lightning rods are placed at the correct distance to provide maximum protection. Finally, the total number of lightning rods required is calculated based on the length of the building roof and the distance between the lightning rods. It was found that a total of 5 lightning rods were needed to protect the entire roof. All of these calculations ensure that Building A is effectively protected from potential lightning strikes, with optimal lightning rod placement to safely cover a large area.

Building B

a. Angle of Protection

$$\theta = sin^{-1}\left(1 - \frac{h}{rs}\right)$$

$\theta = 71{,}90°$

b. Radius of Protection

$$r = \frac{h}{\sin(90° - \theta)} \sin(\theta)$$

$r = 47{,}42$ m

c. Distance Between Splitzers

$$r = \frac{h}{\sin(90° - \theta)} \sin(\theta)$$

$r = 4{,}58$ m

d. Total Splitzer

$$Total\ Splitzer\ = \frac{Roof\ Length}{Distance\ of\ Splitzer}$$

$Total\ Splitzer\ = 4$ rods

The calculations carried out for Building B cover several main aspects of protection. First, the protection angle is calculated using the inverse sine formula, with a protection angle value (θ) of $71{,}90^0$. This angle determines the area that will be protected by the lightning protection system. Next, the protection radius is calculated based on the building height (h) and the known protection angle. Using trigonometric formulas, it was found that the protection radius was 47,42 m, which is the distance from the lightning rod where the protection area is still effective. The distance between rods is calculated using the same formula, resulting in a distance between lightning rods of 4,58 m, which ensures placement of lightning rods at the correct distance for maximum protection. Finally, the total number of lightning rods required is calculated based on the length of the building roof and the distance between the lightning rods. It is known that 4 lightning rods are needed to protect the entire roof. All these calculations ensure that Building B is effectively protected from lightning strikes, with optimal lightning rod placement to protect a large area.

J. Down Conductor

The distribution system requires a cross-sectional area that is able to withstand the heat resulting from lightning strikes.

Building A

$$R = \frac{\rho \times l}{A}$$

$R = 6{,}66x10^{-5}$ Ohm

Cross-Sectional Area

$$A = Io\sqrt{\frac{R.s}{log10\left(\frac{T}{274}+1\right)}}$$

$A = 61{,}91$ mm

Building B

$$R = \frac{\rho \times l}{A}$$

$R = 5{,}52x10^{-5}$Ohm

Cross-Sectional Area

$$A = Io\sqrt{\frac{R.s}{log10\left(\frac{T}{274}+1\right)}}$$

$A = 57{,}88$ mm

K. Earth Resistance Measurement

In the lightning protection installation process, it is necessary to measure the value of the ground resistance, which is located around the Karitas Yogyakarta Junior High School building. Where the value of ground resistance using 1 rod electrode with a length of 1,5 meters and the type of ground resistance is 6,15 Ohm. Therefore, two additional rods were added so that there were 3 rods with the resistance value decreasing by 2,23 Ohm.

Figure 2. Measuring Soil Resistance Values with an Earth Tester

Building A and Building B

a. Calculation of Single Rod

$$R = \frac{\rho}{2.\pi.L}\left[ln\frac{8.L}{d} - 1\right]$$

$$R = 28{,}67 \text{ Ohm}$$

b. Calculation of Earth Resistance

$$a = \left(\frac{\rho}{2.\pi.\text{R.s}}\right)$$

$$a = 0{,}055$$

c. Parallel grounding value with 3 Rods

$$Rn = R\left(\frac{1+(\lambda.a)}{n}\right)$$

$$Rn = 2{,}30 \text{ Ohm}$$

Karitas Yogyakarta Junior High School, as an educational institution located in an area prone to lightning, requires an effective protection system to avoid damage due to lightning strikes. This community service focuses on designing and installing lightning protection systems which aim to protect school infrastructure and ensure the safety of students and staff. The community service carried out at Karitas Yogyakarta Junior High School succeeded in achieving its main goal by designing and installing an effective lightning protection system. Apart from that, the education provided to schools also adds more value to this project, by increasing understanding of the importance of protection against lightning.

This project can be used as a model for similar services in other schools that are at risk of lightning strikes. For the sustainability and improvement of the system that has been installed, several recommendations that can be given include: (a) The school must carry out routine maintenance to ensure the lightning protection system continues to function properly. (b) If there are new technological developments in the lightning protection system, it is recommended to upgrade the existing system. (c) Hold regular training for new staff or as a refresher for existing staff regarding lightning protection systems.

Figure 3. The Final Result of Installing a Lightning Rod

With an effective lightning protection system in place, it is hoped that Karitas Yogyakarta Junior High School can operate more safely, significantly reducing the risk of damage to its infrastructure. This includes safeguarding the school's buildings, electrical systems, and technological equipment, all of which are crucial for the daily operations and educational activities of the school. Moreover, the safety of all school residents—students, teachers, and staff—will be better ensured, protecting them from the potentially deadly dangers of lightning strikes. Implementing such a system goes beyond just providing a technical solution. It also plays a vital role in fostering a culture of safety and preparedness within the school community. By integrating lightning protection measures, the school can educate its residents about the importance of safety protocols and the proper responses to lightning-related emergencies. This heightened awareness and understanding can lead to more responsible and cautious behavior during storms, further mitigating risks. Additionally, this service underscores the commitment of the school to prioritize the well-being of its community. It highlights the proactive steps taken to create a safer learning environment, which can also positively influence the overall perception of the school's dedication to excellence and care. The implementation of a lightning protection system is, therefore, a comprehensive approach that not only addresses immediate physical threats but also promotes a long-term, sustainable culture of safety and vigilance within Karitas Yogyakarta Junior High School.

CONCLUSION

Based on community service conducted on the Karitas Yogyakarta junior high school building, the following conclusions were obtained: The Karitas Yogyakarta junior high school building requires the installation of a lightning protection system according to the General Regulations for Lightning Protection Installation (PUIPP). Furthermore, according to NFPA standards, the entire building needs a lightning protection system with a protection level value of I, in accordance with the Indonesian National Standard (SNI) 03-0715-2004. The building requires 9 splitzer to protect the entire building. Each building uses cables with a cross-sectional area of 50 mm^2, and 3 electrode rods are needed to achieve maximum resistance.

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