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Implementation of a Conventional Lightning Protection System in a Village Government Building in Bogor: A Community Engagement Approach

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ABSTRACT

Background: This article presents the implementation of a lightning protection system at the Cibanon Village Hall in Bogor as part of a technology-based community service program.
Contribution: The initiative to install a conventional lightning rod in the Cibanon Village Hall building to protect electronic equipment.
Method: The methodology includes site assessment, risk analysis, system design, and installation following international standards.
Results: The results obtained from this study are the area that has the potential for lightning strikes, so it is recommended to install a conventional lightning rod installation with 4 (four) lightning rods on top of the building and 1 (one) rod in the ground with a depth of 7.5 m with a grounding resistance value of 2.02 Ohm.
Conclusion: Shows the level of security requirements for the Cibanon Village Hall building against lightning strikes. The initiative also fostered community awareness and participation, highlighting its replicability in other rural areas with similar environmental threats.

1. Introduction

Lightning is a natural atmospheric phenomenon that occurs as a result of electrostatic discharge, typically initiated by the accumulation of negative charges at the base of thunderclouds. This charge imbalance induces a corresponding positive charge on the Earth's surface, creating a strong electric field between the cloud and the ground. When the electric potential difference becomes sufficiently large, a discharge occurs in the form of a lightning strike [1]–[3]. While visually striking, lightning is extremely dangerous. It carries immense electrical energy that can cause severe physical damage to buildings, ignite fires, harm or even kill humans and animals, and destroy sensitive electronic equipment. Given these risks, implementing a robust lightning protection system is not only necessary but also essential for safeguarding infrastructure and human life [4]. A well-designed system should ensure the safe interception and grounding of lightning currents to prevent harm. This is especially critical in areas with high lightning strike frequency, where the potential for damage increases proportionally. Modern protection systems must meet standardized criteria to ensure consistent and effective performance, particularly in high-risk zones [5].

One such area at risk is Cibanon Village in Bogor, Indonesia, a region known for its frequent thunderstorms. The Village Hall building in Cibanon is a critical public facility, serving various community functions. As such, ensuring its safety and operational integrity is of paramount importance. In response to the threat of lightning, a conventional lightning protection system has been installed at the site, employing the standard Franklin rod installation method [6], [7]. This system consists of rod-type air terminals strategically placed to intercept lightning strikes and direct them safely to the ground via conductors and grounding electrodes. Calculations were conducted on an annual basis to evaluate the adequacy of this installation to estimate the maximum lightning current that could potentially overwhelm the system and the probability of system failure. These figures allow stakeholders to assess whether the level of protection is sufficient or whether additional measures are required. Notably, lightning protection is not a one-size-fits-all solution it must be customized according to the structure’s size, function, and vulnerability. Buildings that are taller or serve essential public purposes, like the Village Hall, require higher levels of protection, as even a single failure can have far-reaching consequences [8], [9].

To understand why such precautions are necessary, it is important to delve deeper into the science of lightning. Lightning occurs when there is a significant electrical charge separation in the atmosphere, typically within cumulonimbus clouds. Inside these clouds, intense updrafts and downdrafts cause collisions between water droplets, ice crystals, and hailstones, leading to the segregation of charges, Negative charges settle at the bottom of the cloud, while positive charges rise to the top. This separation creates the conditions needed for electrical discharge. Most commonly, lightning occurs within the cloud itself, between areas of opposite charge. However, cloud-to-ground strikes, although less frequent, are far more dangerous and destructive. In both cases, the electrical energy released during a strike can reach temperatures hotter than the surface of the sun and generate shockwaves that cause thunder. These immense forces can damage buildings, disrupt electrical systems, and pose a direct threat to human life. Understanding these dynamics is crucial in the design and implementation of effective lightning protection systems [10].

In the case of the Cibanon Village Hall, a detailed lightning risk assessment was conducted to determine the appropriate level of protection. Based on the calculation, the danger index was measured at 13, indicating a relatively high risk. According to meteorological data, the lightning strike density in the Bogor region is approximately 16 strikes per square kilometer per year. With a strike exposure area of 134,934 square meters, or approximately 0.135 km^2, the expected strike frequency for the building area is about 0.17566 strikes per day per square kilometer. From this information, it becomes evident that the Village Hall is exposed to a significant level of lightning activity throughout the year. Furthermore, the protection requirement analysis, which considered potential damage factors, reinforced the need for a comprehensive system. Consequently, the recommended solution included the installation of four air terminals on the roof and one grounding electrode with a depth of 7.5 meters, achieving a grounding resistance of 2.02 Ohms. This setup is in line with standard safety requirements and ensures that any lightning strike is safely discharged into the earth, thereby minimizing risk to the building and its occupants.

The implementation of lightning protection systems such as the one at the Cibanon Village Hall underscores the importance of proactive infrastructure planning, especially in lightning-prone regions. As climate patterns continue to evolve and extreme weather events become more frequent, buildings, particularly public facilities, must be equipped with adequate safety systems to withstand natural hazards. The Franklin rod method, though developed centuries ago, remains a reliable and cost-effective solution for many types of structures, including those with dome-shaped or conical roofs. It is crucial, however, that these systems are installed following proper engineering standards and are periodically inspected to ensure ongoing effectiveness. Community awareness also plays a vital role; educating residents and facility managers about the purpose and function of lightning protection can lead to better maintenance and support for such systems. Ultimately, protecting a building from lightning is not merely a matter of compliance but a commitment to the safety, resilience, and functionality of essential community infrastructure. Through thoughtful planning and scientifically informed implementation, the risks posed by lightning can be significantly reduced.

Given the high frequency of lightning strikes in the Bogor region and the critical public function of the Cibanon Village Hall, this study addresses an urgent need to implement a reliable lightning protection system to safeguard public infrastructure from physical damage, operational disruptions, and potential economic losses. Furthermore, community awareness regarding the importance of lightning protection remains limited, emphasizing the necessity of a technical approach that simultaneously incorporates community empowerment.

The primary contribution of this study lies in the implementation of a conventional Franklin rod-based lightning protection system tailored to the specific characteristics of the building and its surrounding environment. Additionally, this research contributes to community engagement by involving local stakeholders in the planning, installation, and maintenance processes, thereby enhancing sustainability and promoting grassroots understanding of lightning risk mitigation.

Accordingly, the objective of this study is to design and implement an effective lightning

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protection system for the Cibanon Village Hall by conducting a comprehensive lightning risk assessment using local meteorological data and national safety standards. The study also aims to evaluate the performance of the installed system through grounding resistance measurements and to develop a collaborative model involving academia, local government, and the community for technology-based disaster risk reduction.

2. Method

The method used for the installation of conventional lightning rods is carried out in stages. The process of taking data and images of building dimension measurements. Information about the Cibanon Village Hall building. The location of the Cibanon Village Hall is located at 106.8034473 East Longitude and 6.6286485 South Latitude in the design of each protection radius. These coordinates were used to determine environmental conditions and support the protection system's design. The protection radius for each lightning rod is calculated based on the rolling sphere method and cone of protection theory, which considers the height of the air terminal and the structure to be protected [11].

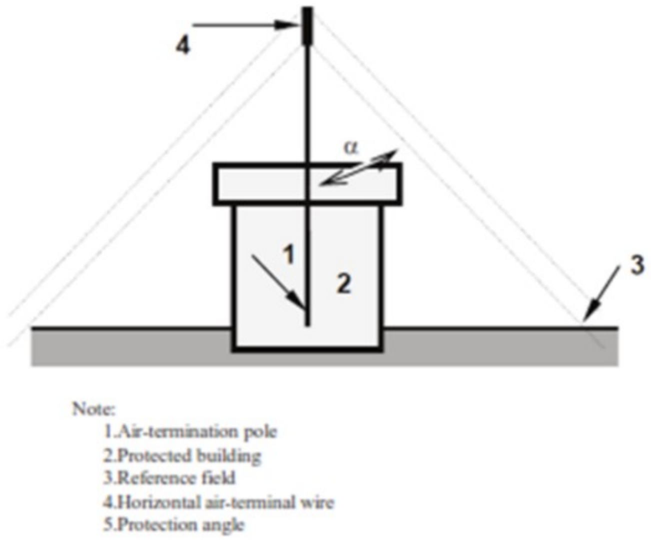

Figure 1. Franklin's method of lightning protection system [12].

Franklin's method is considered more appropriate for buildings with cone-shaped roofs. Although it is the oldest method, it remains reliable for safeguarding structures against lightning strikes and continues to be widely applied, particularly for buildings with dome or conical roofs. Figure 1 illustrates the application of a lightning rod using Franklin's method. In Franklin's method, the rod electrodes provide a conical zone of protection with the rod acting as the central axis. The angle from the tip to the edge of this cone is known as the protection angle, which is typically 56° at standard corners and specifically reduced to 45° at critical points for buildings with combustible materials.

The following steps were carried out in the implementation: (1) Survey and Measurement, field surveys were conducted to measure the dimensions of the Cibanon Village Hall, including building height, roof type, and surrounding features that might affect lightning risk. (2) Risk Assessment, a lightning risk assessment was conducted by international [12], [13] to determine the level of protection required and the number of lightning rods needed. (3) System Design, based on the data collected, a design layout was prepared using drawing tools. The layout included the placement of the air terminals, down conductors, and grounding system. The radius of protection was determined to ensure full coverage of the building. (4) Installation Process, the installation included, mounting of the air terminal at the highest point of the building, installation of down conductors along the walls, construction of the grounding system using copper rods and grounding wires buried at a safe distance. (5) Testing and Verification, after installation, the system was tested using earth resistance meters to ensure grounding resistance met safety requirements (generally < 5 ohms). A visual inspection and continuity test of all connections were also performed. (6) Training and Handover, the local officials and staff were given training on the function, maintenance, and periodic inspection of the lightning protection system. The flowchart for implementing community service activities is shown in Figure 2.

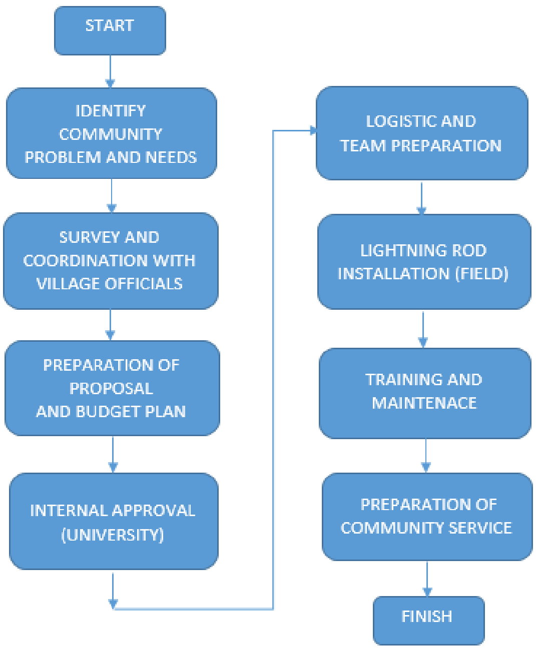

Figure 2. Implementation flowchart lightning rod installation at Cobanon village

Prediction of the installed radius for building protection. Then, the process is carried out to determine the level of protection, the density of lightning strikes, determining the amount of lightning current against the resistance of buildings [14]. After that, the determination of the distribution conductor, the grounding will be determined according to the permitted resistance

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value according to SNI 03-7015-2004 [10] concerning the Lightning Protection System in Buildings.

3. Results and Discussion

This The installation was successfully completed within the planned timeframe and budget. The protection radius effectively covered the entire building area, reducing the risk of direct lightning strikes [15]–[17]. The grounding resistance achieved was 0.6 ohms, well within the standard range [18]–[20]. The Community response was positive, with increased awareness of lightning-related hazards and enthusiasm for further technological empowerment projects [21], [22]. The success of this community service indicates that rural communities can adopt basic lightning protection technologies when accompanied by proper education and stakeholder involvement [22]–[25]. The collaborative model between academia, local government, and community members proved effective and replicable in other villages facing similar hazards [26]–[30]. Challenges encountered included weather delays and initial resistance due to lack of awareness, which were mitigated through consistent communication and participatory approaches [31]–[33].

3.1. Program Result

Before the community service program in Cibanon Village was implemented, the lightning problem that often occurred around the Village Hall greatly disturbed the safety of people, and the equipment in the Cibanon Village Hall was sometimes disrupted after lightning occurred. As has happened, the electrical connectivity in the Village Hall was cut off by the trip of the electric meter switch, including the disruption of an internet device that has a function to connect one computer to another in one network scope.

3.2. Determination of Protection Level

The density of lightning strikes is obtained by entering the value of thunder day (T) in Eq. (1).

$$Fg = 0.25\ T \tag{1}$$

With the number of thunderstorm days T = 64, then Fg is 16 strikes/km^2/year. In determining the level of protection, the area that attracts lightning strikes and the level of need for lightning rods are first calculated, which is the level of danger of buildings to lightning strikes. The condition of the coverage area for lightning strikes can be used, then: Ae = 2686.34m^2, Determining the number of lightning strikes per day per km2 as in Eq. (2), then:

$$Ne = (0.1 + 0.35 \sin \lambda)\ (0.4 \pm 0.2) \tag{2}$$

The value of λ is the geographical line of the location of Cibanon Village of 33.12^{O} which is in the Bogor area. Ne = 0.17466 lightning strikes/day/km^2. C1 is a damage factor index based on the building situation with a value of 1 (one), and an IKL of 50 in the city of Bogor, in Eq. (3) it is possible for the Cibanon Village building to be struck by lightning as follows:

$$Ps = Ae\ NeIKL\ 10^{-6} \quad (3)$$

By entering the values of Ae, Ne and IKL in equation (3), we get:

Ps = 0.02345 lightning strikes/year.

The level of danger of the Cibanon Hall building can be determined by the following equation:

$$Pr = Ps\ C2\ C3\ C4\ C5 \quad (4)$$

By entering the values of Ps, C2, C3, C4, and C5 in Eq. (4), we get Pr = 0.7035

Table 1, shows the lightning installation requirement index based on the damage factor for the entire area coverage.

Table 1. Lightning Installation Needs Index Based on Damage Factors in Coverage

No.	Lightning Installation	Index
1	**Damage Factors Based on Building Use**	**A**
	Buildings and their contents are quite important,	
	such as water towers, factories, government buildings	2
2	**Damage Factors Based on Building Construction**	**B**
	Buildings with reinforced concrete or steel frame with or without metal	2
3	**Damage Factors Based on Building Height (in meters)**	**C**
	> 12 to 17	3
4	**Damage Factors Based on Building Situation**	**D**
	At the foot of the hill up to three-quarters of the hill height or	1
	in the mountains up to 1000 meters	
5	**Damage Factors Based on Thunder Days per Year**	**E**
	64	5
6	**Lightning Installation Requirements Based on Damage Factors**	**R**
	Estimated hazard (rather large) and Lightning Installation (recommended)	13

3.3. Implementation of Activities

The installation of lightning rods at the Cibanon Village Hall has been successfully carried out according to plan, as seen in Figure 3 and Figure 4. The installed lightning protection system functions well and has been tested to ensure its effectiveness in preventing lightning strikes. The local community has responded positively to the installation. Awareness of the importance of lightning protection has increased, and some residents are also interested in installing similar systems in their homes. Although the implementation went smoothly, there were several challenges, such as less-than-supportive soil conditions. In the future, regular monitoring and increased socialization are needed so that the community better understands how to maintain this system independently.

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Figure 3. Photo session with the electrical engineering team with the head of Cibanon village

(a) (b)

Figure 4. Shows the lightning rod installation being installed (a); Completed installation results (b).

3.3. Output Achieved

After the implementation of the installation of lightning rods at the Cibanon Village Hall, there was an increase in public awareness of the importance of protection against lightning strikes. Residents began to understand the risks of lightning strikes and the benefits of installing a lightning protection system. The main output of this activity was the installation of a conventional lightning rod system that functioned well. This system has been tested and confirmed to be able to channel lightning currents to the ground safely, thereby protecting the Village Hall building and its surroundings. As part of the output of the activity, technical documentation has been prepared regarding the installation and maintenance of the lightning rod system.

This guide was provided to the village government so that they can carry out routine maintenance independently. Through the technical training provided in this program, several villagers have gained skills in installing and maintaining lightning rods. This opens up opportunities for them to be involved in similar projects in the future, both in their own villages and in other areas. The successful installation of lightning rods at the Cibanon Village Hall can be used as a model for implementation for other villages that have a high risk of lightning strikes. With the documentation that has been prepared, this method can be replicated by adjusting to local geographical conditions and needs. The results of this activity have also been documented in the form of reports and articles that can be used as references by academics, government, and the general public who are interested in the field of lightning risk mitigation.

3.5. Next Stage Plan

The next stage after installing conventional lightning rods at the Cibanon Village Hall, Bogor is to carry out periodic maintenance and monitoring to ensure that the system continues to function optimally. The village government and community will be involved in this monitoring with a predetermined schedule. As a follow-up step, additional training will be provided to the local community so that they have more in-depth skills in maintaining and repairing lightning rod systems. This aims to increase village independence in maintaining lightning protection systems.

The success of installing lightning rods at the Cibanon Village Hall can be a model for other areas facing high lightning risks. Therefore, the next stage is to propose similar projects in other locations that require lightning protection systems. After the system has been running for some time, a comprehensive evaluation will be carried out to assess its effectiveness. If deficiencies are found, improvements will be made both in technical aspects and in the approach to socialization with the community. To support the sustainability of the program, the village can collaborate with external parties such as universities, research institutions, and local governments to obtain support in the form of funding, advanced training, and lightning rod technology innovation. Grounding Resistance Measurement, the measuring instrument used in measuring grounding resistance is the Earth Tester Digital Model 4105A and the condition of the measuring instrument is checked first before use. After measuring 3 (three) locations, the average final grounding resistance value is 2.02 Ohm.

4. Conclusion

Based on the calculations and risk analysis, the risk assessment index of 13 indicates a high level of hazard, necessitating the implementation of a reliable and effective lightning protection system. The annual lightning strike density in the Bogor area, recorded at 16 strikes per square kilometer, along with a lightning exposure area of 134,934 m^2 and an average strike frequency of 0.17566 per day per km^2, reinforces the considerable potential for damage caused by lightning in the area. The building damage index, also calculated at 13, further emphasizes the significance of this risk. Reflectively, these findings highlight the urgency of adopting a risk mitigation strategy grounded in localized data and technically sound approaches. The proposed installation of a conventional lightning protection system, consisting of four air terminals on the roof and one grounding rod driven to a depth of 7.5 meters, achieving a grounding resistance of 2.02 Ohms, represents a feasible and standard-compliant solution. Critical evaluation of this design should be conducted periodically, as changes in the surrounding environment, soil

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conditions, and the potential increase in lightning activity due to climate change may affect the system's effectiveness.

Despite the successful implementation of the conventional lightning protection system at the Cibanon Village Hall, this study is not without its limitations. The current assessment primarily focuses on quantitative parameters such as strike density, risk index, and grounding resistance, yet it lacks a comprehensive analysis of long-term system reliability under varying environmental conditions. Additionally, the study does not explore alternative lightning protection technologies or consider cost-benefit comparisons with advanced systems such as early streamer emission (ESE) or charge transfer systems. Furthermore, community engagement, while a notable strength of this project, was limited to the installation and basic training phases. There remains an opportunity to evaluate the depth of knowledge transfer and the sustainability of community-led maintenance practices over time. Including qualitative assessments, such as stakeholder interviews or behavioral surveys, would enrich future studies by uncovering socio-cultural factors that influence system adoption and upkeep. Future research should aim to monitor the system's performance over a multi-year period, particularly during extreme weather events, and investigate how changing climate conditions affect lightning frequency and strike intensity in the region. Comparative studies involving different protection methods, material durability analyses, and integration with smart monitoring systems could also enhance both technical and social outcomes. Expanding the model to multiple village locations with varied topography and infrastructure types would further validate the replicability and scalability of this intervention. By addressing these areas, future work can build on the foundation established in this study, contributing to the broader body of knowledge on lightning risk mitigation in rural and resource-constrained environments.

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