Installation of Electrostatic Lightning Protection System at Mranggen Village Office, Srumbung District, Magelang, Central Java

I Gusti Agung Made Sunaya[1], I Gde Nyoman Sangka[2], I Made Purbhawa[3], I Gede Ketut Sri Budarsa[4], and I Ketut Parti[5]

[1,2,3,4,5] Electrical Engineering Department, Politeknik Negeri Bali, Bali, Indonesia
a_sunaya@pnb.ac.id

Abstract. Buildings with a high risk of lightning strikes due to factors such as height, geographical location, and strategic function must be equipped with a lightning protection system. The primary purpose of installing a lightning rod is to protect the building structure, electronic equipment and ensure the safety of occupants or users of the building. Mranggen Village Office, located in Srumbung District, Magelang Regency, is situated in a mountainous area near Mount Merapi. The building has two floors with a total height of 18 meters, classifying it as a high-risk structure for lightning strikes. As a mitigation measure, an electrostatic lightning protection system based on the Early Streamer Emission (ESE) method was installed. This specialized protection system is designed to intercept lightning discharges before they strike the protected structure. It functions by generating an upward streamer earlier than conventional lightning rods, thereby increasing the likelihood that the lightning discharge will follow the ESE path to the ground. This proactive approach offers a wider protection radius compared to traditional systems. The implementation of the KURN R150 electrostatic lightning rod, mounted at a height of 3 meters above the highest point of the building, is based on its specifications. The system is capable of providing a protection radius of up to 133 meters, covering a total protected area of approximately 55,543 m². This coverage includes not only the Village Office itself but also a nearby temple structure located approximately 50 meters from the site. Lightning currents are safely channeled to the ground through a grounding system consisting of two rod electrodes. The measured ground resistance value is 0.63 Ohms, which complies with the requirements of SNI 03-7015-2004, which sets a maximum allowable resistance of 5 Ohms. With a protection system that meets national standards, the safety of the building, its electronic systems, and the surrounding community is expected to be effectively safeguarded from lightning hazards.

Keywords: Early Streamer Emission, Grounding, Lightning Rod, Resistance

1 Introduction

The Mranggen Village Office, located in Srumbung Subdistrict, Magelang Regency, Central Java Province, serves as the administrative center supporting local governance at the village level. Due to its location in a highland area, the building is particularly vulnerable to lightning strikes, especially during the rainy season. In accordance with

A. A. N. G. Sapteka et al. (eds.), *Proceedings of the International Conference on Sustainable Green Tourism Applied Science - Engineering Applied Science 2025 (ICOSTAS-EAS 2025)*, Advances in Engineering Research 280,
https://doi.org/10.2991/978-94-6463-878-3_46

the Regulation of the Minister of Manpower of the Republic of Indonesia *No. PER.02/MEN/1989 (Menteri Tenaga Kerja Republik Indonesia, 1989)* and *No. 31 Tahun 2015 (Menteri Tenaga Kerja Republik Indonesia, 2015)*, Lightning protection systems are required to be installed in workplaces that fall into specific categories to ensure safety from lightning strikes. These include isolated or tall buildings and structures that rise above their surroundings, such as towers, chimneys, silos, transmission antennas, and monuments. They are also necessary in buildings where explosive or flammable materials are stored, processed, or used, including ammunition factories and warehouses for explosives. Public buildings such as places of worship, hospitals, schools, theaters, hotels, markets, stations, and temples must also have lightning protection systems. Additionally, buildings housing irreplaceable items, such as museums, libraries, and archival storage facilities, require protection, as do open areas like plantations, golf courses, sports stadiums, and locations where explosive or flammable materials are present. According to SNI 03-7015-2004 and the NF C 17-102 standard, lightning protection systems are classified into four levels based on the level of risk and required protection (Association Française de Normalisation [AFNOR], 2012; *Badan Standardisasi Nasional* [BSN], 2004). Level I represents the highest classification, intended for buildings with very high lightning strike risk and severe potential damage. Level II is applied to buildings with moderate lightning risk and moderate risk to occupants or electronic equipment. Level III is the most commonly used protection level in Indonesia, particularly for residential and smaller buildings that are not very tall. Finally, Level IV is suitable for buildings or structures with very low lightning strike risk and minimal damage potential, such as guard posts, field huts, temporary storage buildings, and buildings in areas with very low lightning intensity. To mitigate such risks, it is crucial to implement a lightning protection system that complies with established safety standards. A lightning protection system operates by safely channeling the electrical energy from a lightning strike into the ground, thereby minimizing the risk of damage to the building and its contents. This study aims to evaluate the effectiveness of a modern electrostatic lightning protection system in comparison to a conventional system. The electrostatic system, which is based on the Early Streamer Emission (ESE) principle, is engineered to offer enhanced protection by initiating the upward leader (streamer) earlier than conventional lightning rods. It functions by detecting variations in atmospheric electric fields and releasing electrical charges to form a conductive path that attracts lightning strikes and safely diverts them to the grounding system (Arfianto et al., 2018; Triyanto et al., 2022).

2 Methodology

Conventional lightning rods known as Franklin Rods have a limited radius or range of protection because they protect an area within a certain distance from the air terminal rod, according to the geometric formula shown in Equation 1 (International Electrotechnical Commission [IEC], 2020).

$$Rp = h.\tan\alpha \tag{1}$$

Where Rp is the protection radius, h is the height of the air terminal from the protected area, and α= the protection angle (30° - 60°).

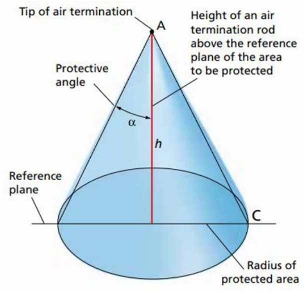

Figure 1. Franklin Rod Protection Radius (International Electrotechnical Commission [IEC], 2020)

In general, the protection radius based on Early Streamer Emission (ESE) is determined using the standard equation from NF C 17-102, and according to Rohani (2017) as follows:

$$Rp = \sqrt{2.r.h - h^2 + \Delta t(2r + \Delta t)} \quad (2)$$

Where Rp is the lightning rod protection radius, h is the distance between the lightning rod point and the area to be protected. ΔT: 60µs, r = 20 for level 1, r = 30 for level 2, r = 45 for level 3 and r = 60 for level 4.

The down conductor is a component of a lightning protection system, either conventional or based on Early Streamer Emission (ESE), that functions to channel lightning current from the air terminal to the grounding system. The lightning current, once safely discharged into the ground, no longer poses a threat to humans or causes damage to protected structures or equipment. When selecting a conductor, both the type and size must comply with applicable standards to ensure effective and safe operation.

$$A_0 = I_0.(\sqrt{\frac{(8.5\times10^{-6}\times s}{log_{10}(\frac{T}{274}+1)}}) \quad mm^2 \quad (3)$$

Where A_0 =Cable cross-sectional size and I_0 (lightning current)=200.000A

The earthing termination system is a component of the external lightning protection system designed to conduct and neutralize lightning current into the ground without posing a hazard to individuals or causing damage to installations within the protected structure. According to the General Requirements for Electrical Installations (PUIL) 2020 and SNI 03-7015-2004, the maximum allowable grounding resistance value is 5 Ohms (DirJen Ketenagalistrikan, 2011). If the measured resistance exceeds this standard, an evaluation must be conducted, and appropriate corrective measures must be implemented to ensure compliance with applicable regulations.

3 Result and Discussion

3.1 Result

The Mranggen Village Office is a two-story building with a total height of 18 meters, including the roof. Located more than 50 meters away from the office is a temple building. Among all the surrounding structures, the village office is the tallest. The installation of a lightning protection system at the Mranggen Village Office addresses two primary concerns: the protection radius provided and the extent of the area that can be effectively covered by the lightning rod. A lightning rod based on the Early Streamer Emission (ESE) principle was selected to provide Level I to Level IV protection, in accordance with the calculation method specified in Equation 2.

For level I $Rp = \sqrt{2.20.3 - 3^2 + 60(2.20 + 60)} = 78.555\, m$

For level II $Rp = \sqrt{2.30.3 - 3^2 + 60(2.30 + 60)} = 85.854\, m$

For level III $Rp = \sqrt{2.45.3 - 3^2 + 60(2.45 + 60)} = 96.234\, m$

For level IV $Rp = \sqrt{2.60.3 - 3^2 + 60(2.60 + 60)} = 105.151\, m$

The KURN R150 air terminal is an ESE-based electrostatic lightning rod, based on factory specifications, which provides estimated protection radius results as shown in Table 1. When the air terminal is installed 3 meters from the protected area, a protection radius of 133 m is obtained.

Table 1. KURN Protection Radius Data Sheet

Height (m)	KURN R85 (m)	KURN R 150 (m)
3	60	133
10	76	140
20	86	150
30	96	160

When using a conventional lightning rod, the protection radius is obtained using Equation 1.

$$R_P = 3\ tan\ 60^{\circ} = 5.19\ m$$

The lightning conductor is very important to consider when selecting the conductor cross-sectional area and cable type. The assumption is based on a lightning strike of 0.01s, a maximum conductor temperature of 1000°C (Bar Cooper), and a lightning current of 200,000 A.

$$A_0 = 200000(\sqrt{\frac{(8.5\times10^{-6}\times0.01}{log_{10}(\frac{1000}{274}+1)}}) = 27.04\ mm^2$$

The calculation determined that the minimum required conductor cross-sectional area is 27.04 mm². However, since this size is not commercially available, a BC 50 mm² conductor was selected.

In the lightning protection system installation, the grounding system consists of an electrode rod embedded in the soil and connected to the down conductor from the air terminal (Srinivasan et al., 2020; Sugirinta et al., 2023). The electrode material is copper or copper-coated steel, both of which have high electrical conductivity. For the lightning protection system at the Mranggen Village Office, a 1-inch diameter rod electrode with a length of 3 meters was used. To achieve a low grounding resistance value, two rod electrodes were installed in parallel at a distance of 2 meters apart in water-containing (wet) soil conditions. The grounding resistance was then measured using a Kyoritsu 4102A Earth Tester, yielding a result of 0.63 Ω, as presented in Figure 2.

Figure 2. Results of Ground Resistance Measurement Using the Kyoritsu 4102A Earth Tester

3.2 Discussion

Before the development of lightning protection systems based on the Early Streamer Emission (ESE) technology, buildings relied on conventional lightning rods, which are passive systems wherein the air terminal receives lightning strikes and conducts the current to the ground. The protection radius provided by such systems is limited. For example, the Mranggen Village Office, which measures approximately 30 meters in length and 15 meters in width, would achieve a protection radius of only 5.19 meters when using a conventional lightning rod installed 3 meters above the highest point of the roof. To ensure a wider coverage area, more than one air terminal must be installed, as illustrated in Figure 3.

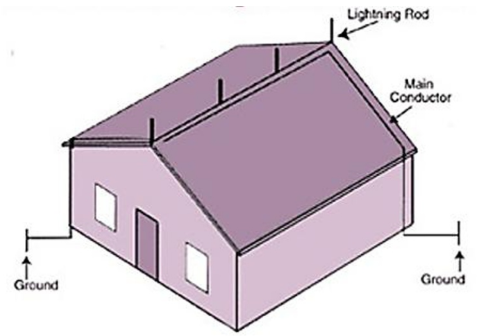

Figure 3. Illustration of Conventional Lightning Rod Installation

In general, the protection radius is based on the NFC 17-102 standard, which is based on Early Steamer Emission (ESE). For level 1, the protection radius is 78.555 m, for level 2, the protection radius is 85.854 m, and for level III, the protection radius is 96.234 m, and for level IV, the protection radius is 105.151 m.

Figure 4. Illustration of the Installation of an Electrostatic Lightning Rod

Figure 4 shows an illustration of the installation of an electrostatic lightning rod with 1 air terminal, obtaining a protection radius of more than 100 m. The higher the installation of the electrostatic lightning rod air terminal, the wider the protection radius will be (Sukamdi et al., 2023; Suryadi, 2017).

Table 2. Comparison of Conventional and Electrostatic Lightning Rods

Aspect	Convesional	Electrostatic
Work principle	Passively captures lightning strikes through the arrestor rod	Ejecting the streamer earlier to attract faster and wider lightning strikes
Protection Radius	Limited, depending on the height of the pole and the angle of protection (45°)	Wider coverage, can reach >100 meters, depending on the model and installation height
Effectiveness Level	Effective in limited areas, requiring multiple units for large areas	Effective for large areas with fewer units
Aesthetics/Visual	Simpler and more common	More modern design

The KURN R150 electrostatic lightning rod that has been installed in the Mranggen 1 village office, air terminal 3 m high from the highest roof, as an illustration shown in Figure 5 and Figure 6, the protection radius from the highest point of the air terminal installation in the village office obtained a protection radius of 133 m as shown in Table 1, obtained a protected area of 55,543.46 m2. The KURN R150 electrostatic lightning rod has been installed in the Mranggen 1 village office, air terminal, 3 m high from the highest roof. Figure 5 shows the protection radius from the highest point of the air terminal installation in the village office, which obtained a protection radius of 133 m, as shown in Table 1, resulting in a protected area of 55.543,46 m².

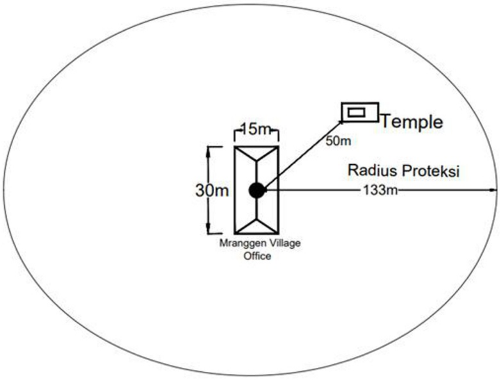

Figure 5. Illustration of the KURN R150 Protection Radius for the Mranggen Village Office and the *Candi* Area

The lightning current down conductor is installed using BC 50 mm² cable, which is connected to the grounding termination at the control terminal panel. The grounding electrodes used are 1-inch diameter, 3-meter-long rods, with two rods installed in parallel to achieve a low grounding resistance of less than 5 ohms. Several soil factors that influence grounding resistance (Arifin, 2021) include:

Moisture Content. Wet soil tends to have lower resistance because water enhances electrical conductivity.

Soil Type. Clay and cultivated soil generally have lower resistance compared to sandy soil.

Grounding Electrode Depth. The deeper the electrode is buried, the better, as deeper soil layers are typically more moist.

Ground resistance was measured using a Kyoritsu KEW 4105A digital Earth Tester. With two 1-inch-diameter, 3-meter-long grounding rods installed in parallel and connected with a BC 50 mm² conductor, the measurement result was 0.63 ohms**,** which meets the standard requirements in SNI 03-7015-2004**.** The KURN R150 electrostatic lightning rod for the Mranggen village office was installed on February 6, 2025. The main building of the village office and the temple have been included in the protection area at a protection radius of 133 meters. After installation, its effectiveness needs to be evaluated through monitoring of extreme weather and lightning events based on BMKG data in Table 3, and Figure 6 shows a lightning strike map in June 2025. Cloud-to-ground lightning strikes are lightning that occurs from clouds to the ground, which is dangerous because it can cause damage to buildings, fires, and death. Lightning strikes that occurred from January 2025 to June 2025 in the Magelang area and other Central Java, the Mranggen village office and other buildings did not experience damage. This is an indicator that the KURN R150 provides effective protection (KURN Engineering, 2023).

Table 3. Lightning Strike Information for 2025 for Parts of Java and Central Java

Month	Number of strikes
February 2025	> 60,000
March 2025	> 60,000
April 2025	> 60,000
May 2025	> 60,000
June 2025	> 60,000

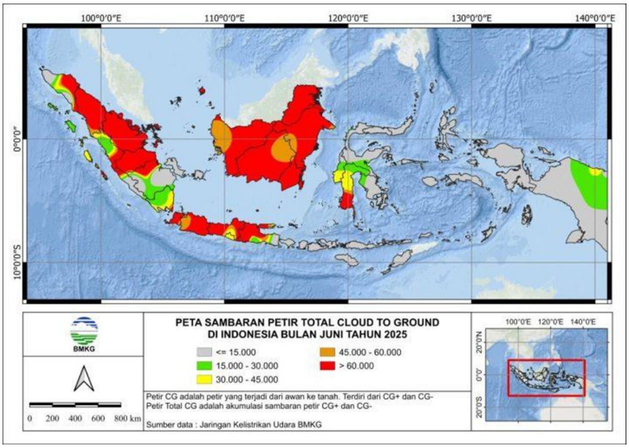

Figure 6. Cloud-to-Ground Lightning Strike Map for June 2025 (in Indonesian)

4 Conclusion

The KURN 150 electrostatic lightning rod installed to protect the Mranggen village office, 3 meters above the roof, has a protection radius of 133 meters or a protected area of 55,543 m2. Meanwhile, for the grounding system, the grounding resistance measurement results were 0.63 Ohms. This value meets the maximum standard of 5 Ohms.

References

Arfianto, T., Anwari, S., & Pratama, R. O. F. (2018). Simulasi sistem proteksi petir eksternal dengan metode pembalik muatan menggunakan Matlab. *Jurnal Rekayasa Hijau*, *2*(1). https://doi.org/10.26760/jrh.v2i1.2044.

Arifin, J. (2021). Pengukuran nilai grounding terbaik pada kondisi tanah berbeda. *Jurnal ELTIKOM*, *5*(1). https://doi.org/10.31961/eltikom.v5i1.251

Association Française de Normalisation [AFNOR]. (2012). *F C 17-102 (2011): Early Streamer Emission Lightning Protection Systems*, 33.

Badan Standardisasi Nasional [BSN]. (2004). SNI 03-7015-2004: Sistem proteksi petir pada bangunan gedung. *Sni 03 - 6572 - 2001*, 112.

DirJen Ketenagalistrikan. (2011). *Persyaratan umum instalasi listrik 2011 (PUIL 2011)*. DirJen Ketenagalistrikan. https://gatrik.esdm.go.id/assets/uploads/download_index/files/ d8197-buku-puil-2011.pdf.

International Electrotechnical Commission [IEC]. (2020). *IEC 62305 & IEC 62561 (2020): International standard for lightning protection system design and product testing*. EC/BS EN 62305-1 - General principles (Issue August).

KURN Engineering. (2023). *KURN R-150: Sistem Proteksi Petir Electrostatic*.

Menteri Tenaga Kerja Republik Indonesia. (1989). *Peraturan Menteri Tenaga Kerja Republik Indonesia No. PER.02/MEN/1989 tentang pengawasan instalasi penyalur petir*. Instalasi Alarm Kebakaran Automatik.

Menteri Tenaga Kerja Republik Indonesia. (2015). *Peraturan Menteri Ketenagakerjaan Nomor 31 Tahun 2015 tentang perubahan atas peraturan Menteri Tenaga Kerja Nomor PER.02/MEN/1989 tentang pengawasan instalasi penyalur petir*.

Rohani, R. (2017). Evaluasi sistem penangkal petir eksternal di gedung rektorat Universitas Negeri Yogyakarta. *Jurnal Edukasi Elektro*, *1*(2). https://doi.org/10.21831/ jee.v1i2.17423.

Srinivasan, V., Fernando, M., Kumara, S., Selvaraj, T., & Cooray, V. (2020). Modeling and assessment of lightning hazards to humans in heritage monuments in India and Sri Lanka. *IEEE Access*, *8*. https://doi.org/10.1109/ACCESS.2020.3046100.

Sugirinta, I., Saputra, I. G. N. A., Mudiana, I., & Ta, K. (2023). *Study of the Effectiveness of Lightning Protection System on 1 MWp Bangli Solar Power Plant*. https://doi.org/10.5220/ 0010950500003260.

Sukamdi, Dali, S.W., Wiharya, C. & Asror, A. A. (2023). Perencanaan instalasi penangkal petir pada bangunan industri furniture. *Elposys: Jurnal Sistem Kelistrikan*, *9*(2). https://doi.org/10.33795/elposys.v9i2.616.

Suryadi, A. (2017). Perancangan instalasi penangkal petir eksternal Politeknik Enjinering

Indorama. *SINERGI*, *21*(3). https://doi.org/10.22441/sinergi.2017.3.009.

Triyanto, R., Nisworo, S., & Setiawan, H. T. (2022). Perencanaan sistem proteksi petir pada kawasan Candi Borobudur. *ULIL ALBAB : Jurnal Ilmiah Multidisiplin*, *1*(9), 2847–2859. ttps://ulilalbabinstitute.id/index.php/JIM/article/view/659.