Evaluation of The Performance of The Hy10w2-24 Lightning Arrester as a Lightning Protection System for a 100 Kva Distribution Transformer at PT. Razza Prima Trafo

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Abstract

This research aims to evaluate the performance of the HY10W2-24 lightning arrester (LA) as a lightning protection system for a 100 kVA distribution transformer at PT. Razza Prima Trafo. The LA is a protection device designed to divert transient over voltages to the ground, thereby safeguarding equipment from damage. The evaluation was conducted descriptively through field observation, interviews, document analysis, and technical analysis based on residual voltage, Basic Insulation Level (BIL), and grounding system conditions. The results show that the HY10W2-24 lightning arrester still performs effectively with a residual voltage of approximately 67 kV, which is significantly lower than the transformer's BIL of 125 kV, resulting in a protective margin of 46.4%. Furthermore, the distance between the arrester and the transformer is 2.5m, in accordance with SPLN standards. Therefore, the HY10W2-24 LA is considered reliable for use as a lightning protection system in electrical distribution installations

***Keywords**:* Lightning Arrester, Lightning Protection, Residual Voltage, Distribution Transformer, Protective Margin, Grounding.

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Introduction

The electrical power system is a primary necessity, both for daily life and for industrial needs [1]. In electrical power systems, there are distribution transformers that convert voltage from medium voltage (20 kV) to low voltage between phases (380V - 400V) and neutral phase (220V), which are then used for small industrial, office, and household needs [2]. In general, consumers expect a continuous and adequate quality electricity service system [3]. However, the electricity system in transmission and distribution lines is not immune to disturbances that can disrupt the electricity distribution process, both internally and externally. One external disturbance that causes equipment failure is lightning strikes [4]. As the name implies, lightning is a flash of light emitted as a result of the release of electrical charges that occur throughout the world. Theoretically, lightning occurs due to an imbalance of charge between thunderclouds and the ground or the clouds themselves [5]. The number of direct and indirect lightning strikes has increased dramatically [6]. The voltage of a lightning strike can range from hundreds of millions of volts between the clouds and the earth. Although these values do not reach the ground, millions of volts can be channeled into buildings, trees, or distribution lines that are struck [7]. The propagation of lightning surges can cause overvoltage in power lines and even damage electrical equipment, especially transformers. Therefore, to protect electrical equipment, a lightning arrester is needed to cut off or limit the voltage surge from lightning entering the electrical equipment installation by directly diverting or releasing the excess voltage surge to the ground [8].

Research on the performance of lightning protection systems using lightning arresters has been conducted by Akbar Wirayuda, Zuraidah Tharo, and Parlin Siagian (2025) with the title "Analysis of Lightning Arrester Performance on Radio Transmitters at the RRI Building in Medan." The study focused on evaluating the effectiveness of arresters in protecting radio transmitter systems from voltage surges caused by lightning strikes. The methods used included soil resistance measurements, field observations, and interviews with technicians. The results of the study showed that a grounding system with a resistance below 5 Ω was able to reduce voltage surges to a protection level of 99%. In addition, the installation distance of the arrester and periodic maintenance were important factors that affected the reliability of the protection system.

Compared to that study, this study has a different focus. While the previous study focused on the protection of radio transmitting equipment, this study specifically evaluates the performance of the HY10W2-24 Lightning Arrester on a 100 kVA distribution transformer at PT. Razza Prima Trafo. The analysis was conducted by calculating the residual voltage, protection margin, and maximum protection distance based on the arrester specifications and actual field conditions. Thus, this study is expected to provide a new contribution in the form of a technical evaluation of arrester performance in electrical power distribution systems, particularly distribution transformers.

PT. Razza Prima Trafo, as a company engaged in the distribution and maintenance of transformers, uses HY10W2-24 type lightning arresters on 100 kVA capacity distribution transformers. However, the extent to which these devices can perform their functions effectively still needs to be evaluated. This is important to ensure that the installed protection system works properly according to standards and is capable of preventing damage caused by lightning strikes. Based on this background, this study was conducted to evaluate the performance of the HY10W2-24 lightning arrester on a 100 kVA distribution transformer at PT. Razza Prima Trafo. This evaluation is expected to provide a realistic picture of the effectiveness of the lightning protection system used, as well as provide technical input for improving the reliability of the power distribution system.

Literature Review

2.1 Electric Power Distribution System

The distribution system is part of the electrical power system. This distribution system is useful for distributing electrical power from large power sources to consumers. So, the main function of the distribution system is to distribute electrical power from the distribution substation to electricity customers with adequate service quality. The main challenge in operating the distribution network is addressing disruptions quickly, as the majority of disruptions in the power system occur within the distribution network [9]. There are several causes of disturbances that can be grouped into internal disturbances and external disturbances. Internal disturbances are disturbances caused by the system itself, such as short circuits, damage to switching devices, insulation failure, damage to generators, and so on. External disturbances are disturbances caused by nature or outside the system, such as broken lines or cables due to wind, storms, lightning, and so on [10].

Distribution Transformer

Distribution transformers are a very important component in the distribution of electrical power from substations to consumers because they are crucial in the distribution of low-voltage electrical power. Distribution transformers function to convert alternating current electricity from a medium voltage of 20 kV to a low voltage of 380/220V with a fixed frequency of [11]. Transformers are highly sensitive to overvoltage disturbances because the insulation system and windings inside the transformer have a maximum operating voltage limit. When lightning strikes, momentary overvoltage can cause flashover, insulation damage, and even fires in the transformer. The specifications of the transformer used in this study are as follows:

a. Nominal Power : 100 Kva

b. Nominal Voltage : 20 kV/400 kV

c. BIL : 125 kV

2.2 Lightning Strikes and Overvoltage

Overvoltage is voltage that exceeds the basic rating of equipment or the BIL of equipment and can only be withstood by the system for a limited time. Overvoltage caused by lightning is referred to as natural overvoltage because lightning is a natural phenomenon that cannot be controlled by humans [12]. Overvoltage caused by direct lightning strikes can occur due to direct strikes to phase wires or ground wires, and strikes around overhead lines (indirect strikes) that can cause induced overvoltage. In the case of a direct strike, all of the lightning energy is released into the overhead line, while in the case of an indirect strike, only part of the lightning energy is released into the overhead line. Thus, the largest and most dangerous overvoltage is caused by a direct strike. Meanwhile, according to Rusck, the maximum induced overvoltage is 400 kV [13]. When lightning strikes the distribution network directly or through electromagnetic induction, a transient overvoltage will occur. This voltage can travel through conductors and cause damage to electrical equipment if it is not immediately diverted to the ground.

2.3 Lightning Protection System

A protection system is a system that functions to prevent or limit damage to equipment due to disturbances [14]. Based on the purpose or nature of the protection itself, lightning protection is divided into two types, namely: lightning strike protection and lightning overvoltage protection. Lightning strike protection is more preventive in nature, while lightning surge protection no longer prevents but reduces the effects caused by lightning strikes, in this case if the first type of protection fails to perform its function [15]. The main components of protection include a lightning arrester, which is the main device that withstands overvoltage and diverts it to the ground, and a grounding system that functions to divert lightning currents to the earth with low resistance.

2.4 Lightning Arrester

A Lightning Arrester is a safety device that protects electrical networks and their equipment from abnormal overvoltages caused by lightning strikes (flash over) and switching surges in a network. This Lightning Arrester provides a greater opportunity for abnormal overvoltage to be diverted to ground before the safety device damages network equipment such as transformers and insulators. Therefore, the Lightning Arrester is a voltage-sensitive device, so its use must be adjusted to the system voltage [16].

2.5 Grounding System

The grounding system is a system for protecting electrical devices from disturbances, especially power surges caused by lightning. The grounding system is described as the connection between a piece of equipment or electrical circuit and the earth [17]. If proper safety measures are implemented, there must be a well-designed and properly constructed grounding system. Impedance selection must be done analytically. If Zn = large, If = small, and Δ = large, then the grounding system to correct the overvoltage that occurs in the undisturbed phase is not too large so that the equipment insulation limit can be maintained or reduced [18].

Research Methodology

The method used in this study is a descriptive research method with an evaluative case study approach. Descriptive research is used to provide a systematic description or explanation of the actual condition of the HY10W2-24 type lightning arrester used in 100 kVA distribution transformers. The case study approach was chosen because this study focused only on one distribution substation unit, allowing researchers to conduct a more in-depth and comprehensive study of the object being observed. The evaluative nature of this study can be seen in its efforts to assess the extent to which the lightning protection device is still functioning properly and in accordance with standards, as well as to identify technical factors that can affect the effectiveness of the device. The data collection techniques used in this study can be seen in the flowchart below:

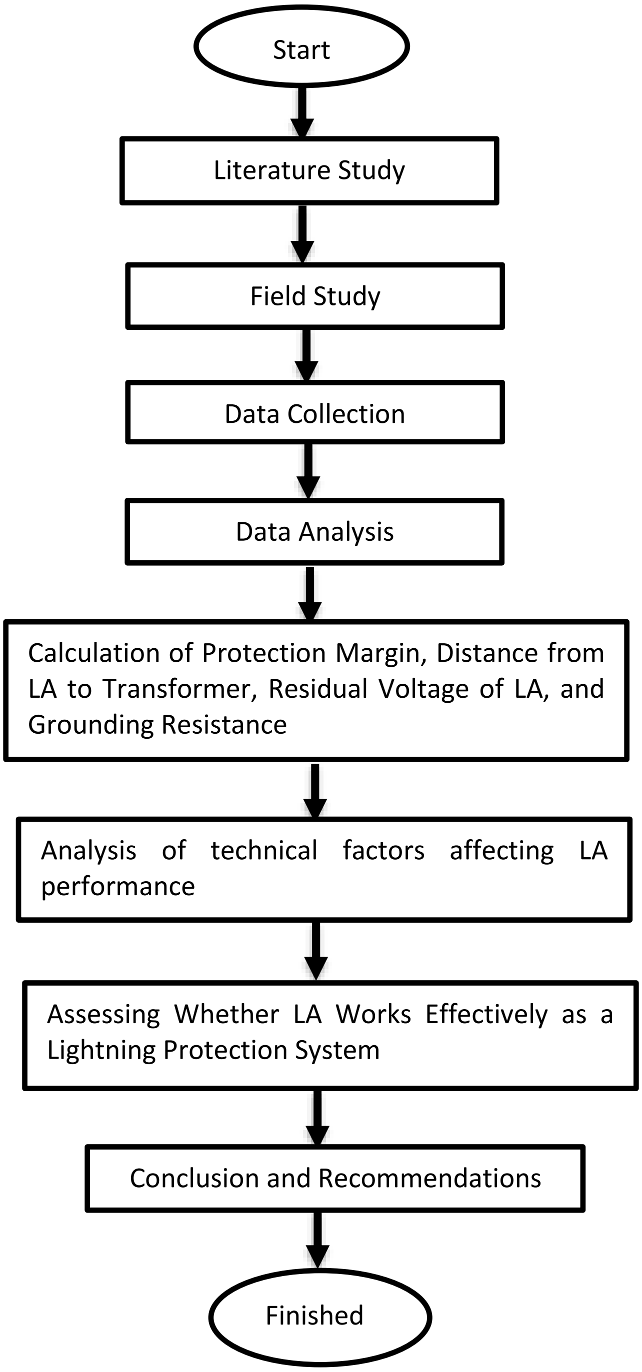

Figure 1. Research Flowchart

The data used in this study consists of:

a. Primary data, which is data obtained directly through field observations and interviews with officers or technicians at PT. Razza Prima Trafo.
b. Secondary data, which is data obtained from technical documents, equipment specifications, fault history records, inspection reports, and relevant literature.

This study refers to the following technical standards and references:

a. IEC 60099-4: Metal-oxide surge arresters without gaps for a.c. systems.
b. SPLN 61-1: General Provisions for Lightning Protection Installation in Medium Voltage Electrical Power Systems.
c. Relevant previous research results.

Results

4.1 Actual Conditions and Operating System of the HY10W2-24 Lightning Arrester

The HY10W2-24 type Lightning Arrester (LA) is a gapless ZnO (zinc oxide) nonlinear arrester that works by withstanding transient overvoltages caused by lightning strikes so that they do not damage electrical equipment. Under normal conditions, the LA has a very high impedance so that no current flows through it. However, when a voltage surge exceeds the nominal voltage, the nonlinear characteristics of the ZnO varistor drastically reduce the impedance, allowing the surge current to be diverted to ground. After the surge ends, the arrester returns to its insulating state. Based on field observations at PT. Razza Prima Trafo, the following actual conditions were obtained:

a. Lightning Arrester Type : HY10W2-24, non-linear ZnO varistor type
b. Nominal Voltage : 24 Kv
c. Continuous Operating Voltage : ±19.5 kV
d. Breaking current : 10 kA
e. Installation Distance : 2.5 m
f. Grounding resistance : 3.5 Ω

This arrester is installed in parallel with the transformer, so that whenever a lightning surge occurs, excess energy will be discharged to the ground through the grounding electrode. The ground resistance value of 3.5 Ω is still within the standard (≤ 5 Ω), so the protection system can work properly. With an installation distance of 2.5 m, the Lightning Arrester is still within the permissible protection limit, although ideally the arrester should be installed as close as possible to the transformer terminal (< 2 m) so that the voltage drop effect on the connecting conductor is minimized.

4.2 Residual Voltage

The residual voltage value on the arrester can be obtained from the data sheet. There are three types of residual voltage tests, namely lightning impulse residual voltage, step current impulse residual voltage, and switching impulse residual voltage. In this study, a lightning impulse residual voltage value of 67 kV was used, as per IEC 60099-4 standards, this parameter is the most representative for assessing the arrester's performance against overvoltage in distribution systems. The residual voltage on the arrester is smaller than the BIL on the transformer, namely 67kV < 125kV. This indicates that the transformer's insulation capacity is still sufficient to withstand overvoltage caused by lightning strikes. Thus, the HY10W2-24 arrester can be categorized as effective in protecting transformers.

Table 1. Residual Voltage Value of HY10W2-24 Arrester

No.	Residual Voltage	kV
1	Steep current impulse residual voltage ≤ kVp	76.0
2	Lightning impulse residual voltage ≤ kVp	67.0
3	Switching impulse residual voltage ≤ kVp	60.0

4.3 Protection Margin Calculation

The protection margin indicates the level of safety of the transformer insulation against the residual voltage from the Lightning Arrester. It is calculated using the formula:

$$\mathbf{MP} = \frac{\boldsymbol{BIL - Vsisa}}{\boldsymbol{BIL}} \ \mathbf{x\ 100\%}$$

Therefore,

$$\text{MP} = \frac{125kV - 67kV}{125kV} \text{ x } 100\%$$

MP = 46.4%

The protection margin value of 46.4% means that this arrester is capable of reducing the voltage by almost half of the transformer's insulation capacity. According to IEEE standards, a good protection margin is >20%, so a value of 46.4% can be categorized as very effective.

4.4 Calculation of Maximum Protection Distance

The maximum installation distance of the Lightning Arrester from the transformer is calculated using the formula:

$$\boldsymbol{L_{maks}} = \frac{\boldsymbol{BIL - Vsisa}}{\boldsymbol{S}}$$

Where: S (Electric Field Gradient) = 20 kV/m

Therefore,

$$L_{maks} = \frac{125kV - 67kV}{20kV/m}$$

L_{maks} = 2.9 m

The calculation results indicate that the maximum installation distance for the arrester to remain effective is 2.9 m. Since the actual distance in the field is 2.5 m, the arrester installation is still within the protection limit.

4.5 Technical Factors Affecting the Performance of the HY10W2-24 Lightning Arrester

Based on observations and calculations, there are several technical factors that affect the performance of the HY10W2-24 Lightning Arrester, namely:

a. Distance Between the Arrester and the Transformer

The closer the arrester is installed to the transformer terminal, the smaller the voltage drop on the connecting conductor. In this case, a distance of 2.5 m is still safe (below 2.9 m).

b. Grounding System

The grounding resistance value of 3.5 Ω is still within the standard (≤5Ω). However, the lower the grounding resistance value, the more effective the lightning current discharge to the ground.

c. Residual Voltage Characteristics

The Lightning Arrester was tested under three test wave conditions (lightning, step, and switching). In a 20 kV distribution system, the main parameter is the lightning impulse residual voltage. The residual voltage value of 67 kV indicates that the arrester is still capable of protecting the transformer with a sufficiently high protection margin.

d. Physical Condition and Service Life

Lightning arresters that have been in operation for a long time may experience degradation of the ZnO varistor material, leading to an increase in leakage current and a decrease in protective capability.

4.6 Lightning Strike Data in the Study Area

In addition to technical factors, the performance of lightning arresters is also greatly influenced by the level of lightning activity at the research location. Based on PT. Razza Prima Trafo's internal records in August 2025, there were 8 lightning strikes with a duration of 2-3.5 seconds, a voltage surge of 19-24 kV, and a current surge of 5-10 kA. All strikes occurred under normal conditions, which means that the arrester successfully conducted the surge energy to the ground without causing any disturbance to the transformer.

Table 2. Lightning Strike Data at PT. Razza Prima Trafo (Aug 2025)

Time	Duration of strike (s)	Voltage Surge (kV)	Current Surge (kA)	Status
Aug (2025)	3	22	8	Normal
Aug (2025)	2.5	21	7	Normal
Aug (2025)	2	19	5	Normal
Aug (2025)	3	22	8	Normal
Aug (2025)	2	20	6	Normal
Aug (2025)	3	23	9	Normal
Aug (2025)	3.5	24	10	Normal
Aug (2025)	2.5	21	7	Normal

4.7 Summary of Lightning Arrester Technical Data and Lightning Strike Data

To clarify the analysis results, the following is a summary of the overall technical data of the HY10W2-24 lightning arrester and the lightning strike data recorded at PT. Razza Prima Trafo. This summary combines information from manufacturer specifications, field measurements, and lightning strike event data. The presentation in table form is intended to provide a more comprehensive overview of the actual condition of the lightning protection system and to facilitate drawing conclusions.

Table 3. Summary of Technical Data on Lightning Arresters and Lightning Strike Data

Category	Parameter	Value	Description
Technical Data of LA	Lightning Arrester Type	HY10W2-24	Zno Gapless Arrester
	Nominal Voltage	24 kV	Suitable for 20 kV Distribution Systems
	Residual Voltage	67 kV	*Residual Voltage* @10kA (8/20μs), from *datasheet*
	BIL Transformer	125 kV	*Basic Insulation* level of 100 kVA transformer
	Protection Margin	46.4	(BIL-Vsisa)/BIL x 100%
	Maximum Distance	2.9 m	Calculation Result (BIL-Vsisa)/S, where S = 20kV/m
	Actual Distance	2.5 m	Field measurement result
	Grounding Resistance (Ω)	3.5 Ω	Grounding Resistance Measurement Results
Lightning strike data	Number of Strikes (Aug 2025)	8 times	Internal Notes of PT Razza Prima Trafo
	Duration of Strike	2–3.5 seconds	Based on field records
	Voltage Surge	19–24 kV	Measurement results at the time of strike
	Current surge	5 – 10 kA	Recorded peak current value
	LA Operation Status	Normal	All events are discharged to ground, without transformer interference

Conclusion

The research results indicate that the HY10W2-24 lightning arrester installed on the 100 kVA distribution transformer at PT. Razza Prima Trafo works well and meets standards. With an installation distance of 2.5 meters, grounding resistance of 3.5 Ω, and a residual voltage of 67 kV, which is still well below the transformer's BIL of 125 kV, the arrester has a protection margin of 46.4%, ensuring safe protection of the equipment. Lightning strike data reaching currents of 5–10 kA also remains within the arrester's capacity, and all incidents were recorded as normal without causing any disruptions. This proves that the HY10W2-24 lightning arrester is effective in protecting distribution transformers from overvoltage caused by lightning strikes.

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