Analysis of Leakage Current Measurement on Lightning Arrester Gi Cibinong PT. PLN (Persero) Bogor Transmission Implementation Unit

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ABSTRACT
This study aims to analyze the measurement of leakage current on Lightning Arrester at Cibinong Substation of PT PLN (Persero) Bogor Transmission Implementation Unit in order to evaluate the performance of the protection system against lightning and overvoltage disturbances. Leakage current measurements were carried out using a Leakage Current Measurement tool on several bays and transformers in the substation. The measurement results showed that most of the Lightning Arrester operated in good condition with leakage current values that did not exceed the maximum limit set at 150 μA. However, there was one Lightning Arrester unit that showed leakage current exceeding the set limit, especially in Bay Bojonegoro 2, which reached 518 μA in phase R. This condition indicates the need for routine maintenance and further evaluation to avoid potential failure in transmission system protection. Overall, the test results show that the performance of the Lightning Arrester at Cibinong Substation is generally good, but regular monitoring and maintenance are essential to maintain the reliability of the protection system.

Keywords: Lightning Arrester, leakage current, protection, Substation, leakage current measurement.

Introduction
PT PLN (Persero) is a company engaged in the field of electrical services, including the distribution of electric power, operation of generating units, and management of electric transmission networks. One of the strategic units in the transmission system is the Main Substation (GI), which plays an important role in the process of distributing electric power from the transmission network to the end consumer. In the Main Substation, the electric voltage is lowered from the transmission voltage to the low distribution voltage before being distributed to the load through the distribution network. In addition, the Main Substation is also the center for monitoring operations, measurements, and safety settings to ensure the reliability of the electric power system.

In the Substation, there are various electrical equipment that support operations and security, such as High Voltage Air Ducts (SUTT), busbars, isolators, power transformers, circuit breakers (PMT), disconnecting switches, and protection systems. One of the important components in the protection system is the lightning arrester, which functions to protect electrical equipment from voltage surges due to lightning or other phenomena. To ensure the reliability of this equipment, monitoring and measurement of leakage current is required, which is the main indicator of the condition of the lightning arrester.

Leakage currents that exceed the threshold can be a sign of damage or decreased performance of the lightning arrester, which has the potential to cause electrical system disruption or further damage to other equipment in the substation. Therefore, measurement and analysis of leakage currents are very necessary to maintain the reliability of substation operations, especially in the Cibinong GI, which is under the responsibility of PT PLN (Persero) Bogor Transmission Implementation Unit.

In this study, the measurement of leakage current in lightning arresters is the main focus because leakage current can provide an overview of the insulation condition of the equipment. If the leakage current is too large, this can indicate insulation degradation caused by various factors such as pollution, humidity, or material aging. This condition, if left unchecked, can affect the performance of the lightning arrester and even result in failure of the protection system.

Cibinong Substation was chosen as the research location because it is one of the strategic substations that serves electricity distribution in the Bogor area and its surroundings. As part of the PT PLN (Persero) transmission system, Cibinong Substation plays an important role in maintaining the reliability of electricity supply in the region. Therefore, maintenance of equipment in this substation, including lightning arresters, must be carried out in a planned and comprehensive manner to minimize the risk of disruption. This study will involve direct measurement of leakage current on lightning arresters using devices that comply with applicable standards. The measurement data is then analyzed to determine whether the leakage current value is still within safe limits. In addition, factors that influence the increase in leakage current, such as environmental conditions and operating loads, will also be considered in the analysis. Through this study, it is hoped that a better understanding can be obtained regarding the condition of lightning arresters in Cibinong Substation, so that it can provide a real contribution in supporting PT PLN (Persero)'s efforts to improve the reliability of the electric power system. The results of this study are also expected to be a reference for the maintenance and management of similar equipment in other substations.

The importance of the role of lightning arresters in the substation protection system and the need for periodic monitoring of equipment conditions, this study was conducted with the title "Analysis of Leakage Current Measurements on Lightning Arrester GI Cibinong PT PLN (Persero) Bogor Transmission Implementation Unit." This study aims to analyze the condition of lightning arresters based on leakage current measurements and provide recommendations for repair or replacement of equipment if necessary, in order to improve the reliability of the electrical system at the substation.

Formulation of the problem:

1) How lightning arresters are designed to handle surge currents, leakage currents on lightning arresters regularly.
2) How to perform leakage current measurement analysis on lightning arresters at the Bogor Main Substation in order to provide a deep understanding of the performance and condition of this protection equipment.

LITERATURE REVIEW

1. Lightning arrester

Lightning arrester is an important device in the electrical system that functions to protect equipment from voltage surges caused by lightning strikes. One of the important parameters used to assess the condition of the lightning arrester is leakage current. Leakage current can provide an early indication of insulation degradation in lightning arresters, which is often caused by aging of the material, environmental contamination, or physical damage.

2. Leakage Current Concept in Lightning Arrester

Leakage current is the electric current that flows through the insulation or surface of the lightning arrester when it is in normal operating conditions. Leakage current measurements are carried out to:

1) Knowing the health condition of the lightning arrester.
2) Detects degradation due to internal or external damage.
3) Prevent operational failures that can cause major damage to the electrical system.

Leakage current can be divided into two components:

1) Capacitive current: Caused by the inherent capacitance of the lightning arrester.
2) Resistive current: Directly related to the condition of the insulation and is often used as an indicator of damage.

3. Leakage Current Measurement Method

Leakage current measurements can be carried out using several techniques, including:

a). On-line Method

This method allows measurements to be made without disconnecting the system from operation. Commonly used instruments are:

1) Clamp meter specifically for leakage current.
2) Residual Current Transformer (RCT). The on-line method has the advantages of real-time measurement and minimal interference to system operation.

b) Off-line Method

Performed when the lightning arrester is removed from the system. Typically used for in-depth measurements, such as laboratory tests using special voltage sources.

4. Factors Affecting Leakage Current

Some factors that affect leakage current measurement results include:

1) Environmental contamination: Dust, humidity and pollution can increase surface leakage current.
2) Material aging: Degraded insulating material will cause an increase in resistive leakage current.
3) Working voltage: Higher voltage tends to increase leakage current.

5. Case Studies and Related Research

Several studies and case studies have discussed leakage current measurements in lightning arresters, including:

1) Leakage Current Analysis for Damage Prediction. This study shows a linear relationship between the increase in resistive leakage current and the level of damage to the lightning arrester insulation. An algorithm-based approach can help detect potential failures earlier.
2) Use of Current Sensors for Real-time Monitoring. The development of IoT technology-based sensors allows continuous monitoring of lightning arrester conditions, reducing the risk of sudden damage.

6. New Technology for Leakage Current Measurement

The latest technologies include:

1) Digital Leakage Current Monitors: Devices that can accurately measure resistive current components.
2) Waveform Analysis Technique: Used to analyze leakage current waveforms and identify fault patterns.
3) IoT-based sensors: Enable remote monitoring and cloud-based data processing.

Leakage current measurement is a critical step in ensuring optimal performance of lightning arresters. On-line and off-line methods have their own advantages depending on operational needs. The use of modern technologies, such as IoT and digital-based analysis, can improve measurement accuracy as well as maintenance efficiency.

Research Method

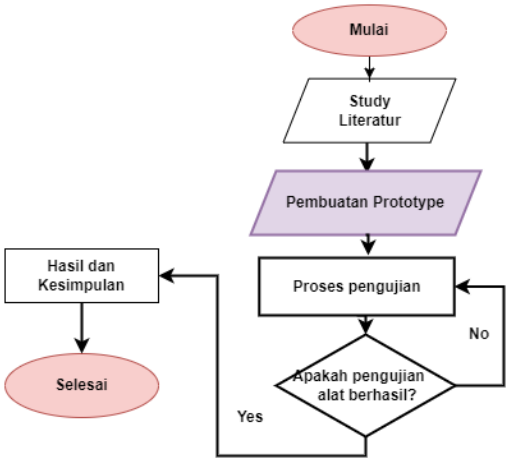

Figure 1. Flowchart

The following is a flowchart description:

1) Data collection

At this stage, relevant data is collected, including: Single Line Diagram of 150 kV Cibinong Substation, to determine the layout of the electrical system and the position of the lightning arrester. Leakage Current Measurement Data Using Thermovisi, to see the heat distribution that indicates possible damage to the arrester. Leakage Current Measurement Data Using Leakage Current Measurement, to obtain quantitative data of leakage current that can be compared with operational standards.

2) Leakage Current Calculation and Measurement: Based on the available data, leakage current calculations and measurements are carried out to identify potential damage to the lightning arrester.
3) Analysis of Results with Leakage Current Measurement: The results of leakage current measurements are analyzed using the Leakage Current Measurement tool, to determine the level of degradation of the insulating material on the arrester.
4) Analysis of Results with Thermovisi: Data from Thermovisi is used to analyze the heat distribution in the arrester, which may indicate damage to internal elements.
5) Comparison of Measurement and Calculation Results: The measurement and calculation results of both methods are compared to validate the results and see the correlation between leakage current and heat distribution.
6) Determination of Operational Feasibility of Lightning Arrester: Based on data analysis, the operational feasibility of lightning arrester is determined. If the leakage current exceeds the threshold, the arrester is considered unfit and needs to be repaired or replaced.

7) Conclusion Drawing: Conclusions are made based on the results of measurements and analysis, including the operational condition of the arrester and recommendations for further action.

Results and Discussion

Analysis of leakage current measurement on Lightning Arrester at Cibinong Substation PT PLN (Persero) Bogor Transmission Implementation Unit. In calculating the percentage of leakage current using the *Leakage Current Measurement method* at Cibinong Substation PT PLN (Persero) Bogor Transmission Implementation Unit, the results obtained show significant variations at various locations (BAY) and phases (R, S, T). The percentage of leakage current is calculated using the formula:

$$\%\text{Arus Bocor} = \left(\frac{I_{\text{leak}}}{I_{\text{max}}}\right) \times 100\%$$

where *I* leak is the measured leakage current value in microamperes (μA), and *I* max is the maximum leakage current limit determined by the standard. For example, in BAY Cibinong 1 R, the measured leakage current is 7 μA, while the maximum limit allowed is 150 μA. Using this formula, the percentage of leakage current in phase R is 4%, which indicates a condition that is still within reasonable tolerance limits.

Based on the results of measurements carried out at the Cibinong Main Substation, there are several important observations on the leakage current conditions in each BAY that are monitored:

1. BAY Cibinong 1 (Phase R, S, T):
   - The R phase shows a leakage current of 4%, which is within safe limits, indicating good insulator condition.
   - Phase S has a higher percentage of leakage current, which is 13%. This indicates a decrease in the quality of the insulator in this phase, although it has not reached a critical value.
   - Phase T at BAY Cibinong 1 recorded a leakage current of 5%, which is still considered good, although further monitoring is needed to ensure that the isolator performance remains optimal.
2. BAY Cibinong 2 (Phase R, S, T):
   - At BAY Cibinong 2, the R phase recorded a leakage current of 16%, which is quite high and indicates possible degradation of the insulator.
   - In phase S, the percentage of leakage current reaches 28%, indicating a fairly severe insulation condition. Therefore, inspection and maintenance of insulators in this phase are very necessary to avoid further system failure.
   - The T phase in BAY Cibinong 2 shows a leakage current of 7%, which is still within reasonable limits, but still needs to be monitored further.
3. BAY Cibinong 3 (Phase R, S, T):
   - At BAY Cibinong 3, the R phase showed 8%, which is still acceptable. However, the S phase reached 19%, which is higher than the tolerance limit, indicating a possible problem with the insulator of this phase.
   - Phase T at BAY Cibinong 3 recorded a leakage current of 3%, which is lower and indicates better conditions compared to other phases.
4. BAY Transformer 1 (20 MVA) and Transformer 2 (30 MVA):

- In Transformer 1, the leakage current was recorded quite high with a value of 47% in the R phase, 54% in the S phase, and 52% in the T phase. This indicates a significant decrease in the quality of the insulation which needs to be repaired immediately.
- In Transformer 2, the leakage current value is also quite high, namely 50% in the R phase, 42% in the S phase, and 45% in the T phase. Although slightly lower compared to Transformer 1, this high leakage current still indicates insulation degradation that requires more attention.

From the results of these measurements, several conclusions can be drawn:

- At BAY Cibinong 1, the insulator condition is still quite good in most phases, although the S phase requires more attention. The T phase also needs to be monitored regularly.
- At BAY Cibinong 2, especially at phase S which shows high leakage current (28%), intensive inspection and insulator repair measures are needed to prevent system failure.
- BAY Cibinong 3 shows quite good conditions in the R and T phases, but the S phase also shows quite high leakage current, which needs further attention.
- Transformer 1 and Transformer 2 showed significant insulation degradation, with quite high leakage currents, which required replacement or maintenance to maintain the stability of the electrical system.

As a follow-up, it is recommended to conduct regular monitoring of leakage currents on all BAYs and transformers, and implement an online monitoring system to provide real-time information on leakage current conditions.

Table 1. Results of Lightning Arrester Leakage Current Measurements at the Cibinong Substation, PT PLN (Persero) Bogor Transmission Implementation Unit

No	BAY	Phase	Calculation Results (%)
1	Cibinong 1	R	4%
2	Cibinong 1	S	13%
3	Cibinong 1	T	5%
4	Cibinong 2	R	16%
5	Cibinong 2	S	28%
6	Cibinong 2	T	7%
7	Cibinong 3	R	8%
8	Cibinong 3	S	19%
9	Cibinong 3	T	3%
10	Cibinong 4	R	18%
11	Cibinong 4	S	60%
12	Cibinong 4	T	30%
13	Cibinong 5 (Transformer 1 - 20 MVA)	R	47%
14	Cibinong 5 (Transformer 1 - 20 MVA)	S	54%
15	Cibinong 5 (Transformer 1 - 20 MVA)	T	52%
16	Cibinong 6 (Transformer 2 - 30 MVA)	R	50%
17	Cibinong 6 (Transformer 2 - 30 MVA)	S	42%
18	Cibinong 6 (Transformer 2 - 30 MVA)	T	45%

Analysis of Leakage Current Measurement Results:

Based on the results of leakage current measurements on the Lightning Arrester at the Cibinong Main Substation of PT PLN (Persero) Bogor Transmission Implementation Unit, the following analysis can be carried out:

1) Leakage Current Value at Each BAY:

- In general, the leakage current measurement results for several BAYs show significant variations. For example, in BAY Cibinong 4, there is a very high result in the R phase, which is 518%, which is far beyond the normal limit and indicates a major problem in the condition of the Lightning Arrester at that point.
- On the other hand, BAYs such as Cibinong 1 and Cibinong 3 showed more stable results with lower leakage current percentage (below 20%).

2) Comparison Between Phases:

- In most BAYs, there is a significant difference between the leakage currents in the R, S, and T phases. For example, in BAY Cibinong 4, the S and T phases show higher results compared to the R phase. This could indicate an imbalance in the load distribution or specific problems in certain phases.

3) Leakage Current Limit:

- The measurement results of the percentage of leakage current can be compared with the accepted leakage current limits for each phase and BAY. Usually, leakage currents exceeding 150 μA can be considered dangerous and require maintenance or replacement. However, at some points such as Cibinong 4 R and Cibinong 4 S, the percentage of leakage current is very high (above 50% and 60%), indicating that the Lightning Arrester in the area requires immediate attention to prevent a larger system failure.

4) Performance Evaluation and Maintenance:

- The calculation result of leakage current percentage that is higher than normal value indicates that the Lightning Arrester may be worn out or contaminated, so that its performance decreases. Further monitoring is needed, especially in BAY with very high output, to avoid potential more severe damage.

5) Impact On System:

- High leakage current can indicate serious problems in the performance of the Lightning Arrester which can potentially cause failure of protection to the electrical system in the substation. Therefore, leakage current measurements must be carried out routinely to ensure all devices are in optimal condition and prevent damage to the transmission system.

The results of leakage current measurements on the Lightning Arrester at the Cibinong Substation show significant variations between BAY and phase. Some BAYs, such as Cibinong 4, show a very high percentage of leakage current, which requires immediate attention for maintenance or replacement of equipment. Periodic monitoring and measurement must continue to be carried out to ensure the reliability of the protection system and prevent greater damage to the electrical infrastructure.

Leakage Current Measurement on Lightning Arrester at Cibinong Substation

Leakage current measurement on Lightning Arrester is done to ensure that the protection system is functioning properly, especially to protect the system from lightning and overvoltage. The leakage current limit permitted by PT PLN (Persero) is 150 μA. If the leakage current

measurement exceeds this value, the Lightning Arrester is considered not functioning optimally and requires maintenance or replacement.

The following table shows the results of leakage current measurements at various bays and phases at the Cibinong Main Substation of PT PLN (Persero) Bogor Transmission Implementation Unit:

Table 2. Results of Leakage Current Measurements on Lightning Arrester at Cibinong Substation

Bay/Region	Phase	Leakage Current Limit (μA)	Resistive Current (μA)	Corrective Value (μA)
Cibinong 1	R	150 μA	4 μA	6 μA
	S	150 μA	12 μA	18 μA
	T	150 μA	5 μA	8 μA
Cibinong 2	R	150 μA	10 μA	15 μA
	S	150 μA	20 μA	30 μA
	T	150 μA	7 μA	11 μA
Cibinong 3	R	150 μA	8 μA	12 μA
	S	150 μA	18 μA	27 μA
	T	150 μA	3 μA	4 μA
Cibinong 4	R	150 μA	7 μA	10 μA
	S	150 μA	16 μA	24 μA
	T	150 μA	4 μA	6 μA
Transformer 1 – 20 MVA	R	150 μA	45 μA	68 μA
	S	150 μA	52 μA	78 μA
	T	150 μA	47 μA	71 μA
Transformer 2 – 30 MVA	R	150 μA	50 μA	75 μA
	S	150 μA	38 μA	57 μA
	T	150 μA	43 μA	65 μA

Analysis:

1. Cibinong 1, Cibinong 2, Cibinong 3, Cibinong 4: Leakage current in each bay in phase R, S, and T shows a value lower than the specified limit, which is 150 μA. Thus, the performance of Lightning Arrester in all these bays can be considered good and feasible to operate.

2. Transformer 1 – 20 MVA and Transformer 2 – 30 MVA: In both transformers, although the leakage current value is within the specified limit, the measured corrective value (such as in phase R, S, and T) shows that the protection system is still under control with a slight increase compared to the resistive current measurement. This shows that the Lightning Arrester on the transformer can function properly, but regular monitoring is needed to ensure that there is no decrease in performance in the future.

Overall, Cibinong Substation shows leakage current measurement results that are still within safe limits for all bays and transformers. For Transformers 1 and 2, although the leakage current values do not exceed the limits, routine monitoring and maintenance are very important to ensure that the Lightning Arrester continues to function optimally in the face of lightning or overvoltage disturbances.

Conclusion

The results of the study conducted at the Cibinong Main Substation of PT PLN (Persero) Bogor Transmission Implementation Unit, it can be concluded that the performance of the Lightning Arrester at this main substation is still in good condition. The results of the leakage current measurements in each bay and transformer show a value that does not exceed the maximum limit set, which is 150 μA, which indicates that the protection system against lightning and overvoltage disturbances is functioning optimally. However, there is a slight increase in leakage current in transformers 1 and 2 which needs to be watched out for and get further attention, so that routine maintenance and periodic monitoring are very important to maintain system performance. Overall, the results of this test indicate that the Lightning Arrester at the Cibinong Main Substation can be relied on to protect electrical equipment from external disturbances. However, it is advisable to continue to monitor and test periodically so that there is no decrease in performance that can affect the stability of the transmission system as a whole.

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