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Research Article

The Effect of Resistive Leakage Current on The Reliability of Lighting Arrester in PLN UPT Bogor Area

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Abstract: The biggest cause of transmission disruptions in the Bogor Technical Implementation Unit (UPT) working area is natural disturbances caused by lightning. Lightning arresters (LA) are substation equipment that function as safety devices for installations from overvoltage disturbances caused by lightning strikes (lightning surges) and switching surges. LA are installed to cut off surge voltages by diverting surge currents to the ground. Given the critical role of LA, corrective maintenance is necessary to ensure their reliability. The test commonly performed is the measurement of resistive leakage current in the LA. The purpose is to determine the condition of the LA, whether it is still in good condition or not. Factors that affect the results of leakage current measurements are the position of the field probe, fluctuations in the arrester voltage level, and the influence of ambient temperature and humidity. The LA in the UPT Bogor system currently uses arresters with technology that utilises gapless Metal Oxide blocks, better known as MOSA (Metal Oxide Surge Arrester) type. This thesis discusses the impact of damage based on the analysis of Resistive Leakage Current Measurements of MOSA Type Lightning Arrester.

Keywords: Lighting; Lightning Arrester; MOSA; Leakage Current.

1. Introduction

A substation is part of the power system, where the substation is part of the transmission system. Components - Substation equipment components must be properly maintained to ensure the reliability of the substation equipment. Lightning arresters (LA) are one of the substation equipment components that play a very important role in protecting substation equipment from overvoltage disturbances caused by lightning surges and connection surges, as well as conducting surge currents to the ground. Overhead transmission lines are highly susceptible to disturbances caused by lightning strikes, which generate travelling waves (voltage surges) that can ultimately enter power generation centres and substations. Therefore, power generation centres and substations must be equipped with LA (Lightning Arresters) (K/DIR/2010). To ensure the reliability of the LA (Lightning Arrester) in protecting against lightning surges, maintenance must be performed on the arrester. One type of LA (Lightning Arrester) maintenance is the inspection of resistive leakage current, where we observe the condition of the Metal Oxide Surge Arrester (MOSA). This maintenance is carried out under voltage conditions because to measure the resistive leakage current of the LA (Lightning Arrester), it must be in operation with voltage support from the transmission line. To measure the resistive leakage current, an LCM (Leak Current Monitor) test device is used. Leakage current disturbances in the LA greatly affect the work process when there is excess voltage due to lightning surges. The impact of LA failure can affect GI equipment (LA Exploration, 2017). PT PLN (Persero) UPT Bogor, as the manager of high and extra-high voltage transmission system operations and maintenance, is responsible for maintaining the reliability of the electricity supply from the power plant to the distribution unit. Therefore, the reliability of substation equipment must be maintained and well-maintained. In substation maintenance, particularly the maintenance of LA (Lightning Arrester) equipment, UPT Bogor has a tool for measuring resistive leakage current in MOSA (Metal) type LA (Lightning Arrester). Oxide Surge Arrester) using an LCM testing device. The LCM can measure leakage current in Metal-Oxide Arresters caused by current from the line. [2]

2. Methods

The research method used in this study was a literature study, which involved reading theories related to the topic of the final project, consisting of data on PT PLN (Persero) transmission system equipment, reference books owned by the author, journals, articles, the internet, and others. In addition, this study also involved an Analytical Study, which involved obtaining specifications and types of related equipment, such as calculating resistive leakage current and corrective leakage current. The characteristic data of the MOSA (Metal Oxide Surge Arrester) type LA (Lightning Arrester) during research at PT PLN (Persero) UPT Bogor was Zinc Oxide Arresters Valve Elements, made of Zinc Oxide with a number of additive components to meet the desired characteristics. The basic material composing the MOSA block chip is ZnO (~90% by weight), while other additives consist of: MnO, B_2O_3, NiO, Sb_2O_3, Cr_2O_3 (~10% by weight). The ZnO compound has excellent conductivity when a discharge current of 1-100 kA passes through it, but acts as a capacitor or high resistance when a current below that value passes through it. This is related to the Voltage-Current Characteristics (V-I Characteristics) of Metal Oxide Compounds. For ZnO elements with a diameter of 3 inches, the current that can be conducted from normal conditions to surge conditions ranges from 0.1 Amperes to 10,000 Amperes. The energy dissipation capability of ZnO is also much better than that of Silicon Carbide. A metal oxide disc with a diameter of 3 inches and a height of 2.1 inches has the same dissipation capacity as a silicon carbide disc plus a gap with a diameter of 3 inches and a height of 2.2 inches. This gapless design allows for a shorter metal oxide arrester design with a pressure relief rating of up to 65,000 Ampere RMS Symmetrical.[1]

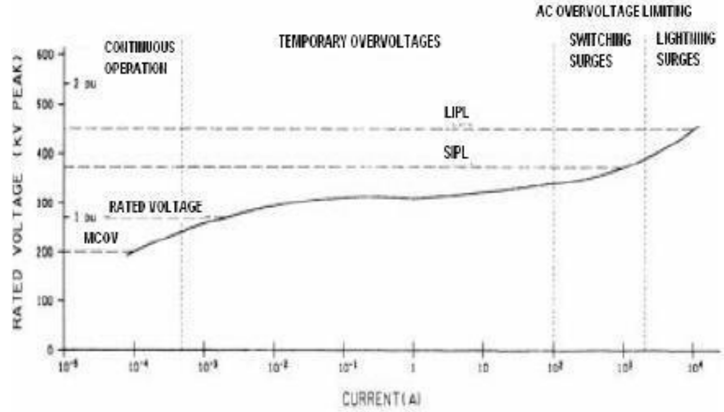

Figure 1. V-I Characteristic Curve of Metal Oxide Block Disc Source: [1].

International standards for calculating leakage current values use several standards that refer to European (IEC) and American (IEEE/ANSI) standards, as well as several limitations obtained specifically from manufacturers (for example, the permissible resistive leakage current limit on arresters). Several standards that are used as references are as follows:
IEC 60099-1, 1999: Non-linear resistor typegapped surge arresters for a.c systems.
IEC 60099-3, 1990: Artificial Pollution Testing of Arresters.
IEC 60099-4, 2001: Metal Oxide Surge Arresters without Gaps for AC Systems.
IEC 60099-5, 2000: Selection and Application Recommendations
IEC 60507, 1991: Artificial Pollution Test on High-Voltage Insulators to be used in AC systems.
ANSI/IEEE Std C62.2-1987: Guide for the Application of Gapped Silicon Carbide Surge Arresters for Alternating Current Systems.
IEEE C62.1-1989: Standard for Gapped Silicon Carbide Surge Arresters for AC Power Circuits.
IEEE Std C62.22-1997: Guide for the Application of Metal-Oxide Surge Arresters for Alternating-Current Systems.
IEEE Std C62.11™-2005: Standard for Metal-Oxide Surge Arresters for AC Power Circuits (>1 kV)

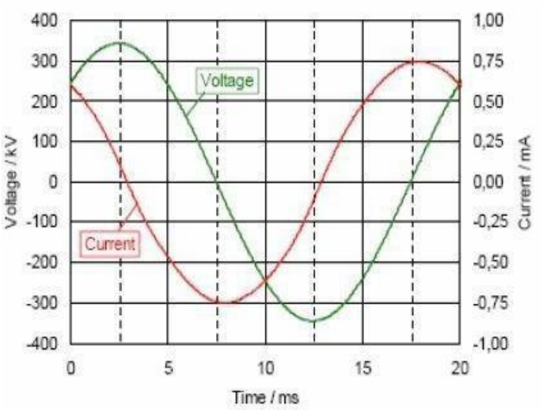

Figure 2. Oscilloscope graph of leakage current in the arrester Source: [1].

Lightning current impulses vary from 1.5 kA to 20 kA (IEC 60099-4). For HV arresters (Us ≥ 123 kV), there are generally only 10 kA and 20 kA classes. Recommendations for test results take into account the percentage difference between the measured resistive leakage current and the resistive leakage current recommended by the manufacturer as follows:

- GOOD: 0%–50% of recommended Ir. Re-measurement after 2 years.
- WEAKENED: 50%–80% of recommended Ir. Re-measurement required after 1 year.
- MONITOR: 80% - 100% Ir recommendation Re-measurement 1 month later
- DAMAGE: > 100% Ir recommendation Re-measurement / replace LA immediately

3. Results and discussion

This Results of Resistive Leakage Current and Corrective Leakage Current Calculations The effect of temperature and operating voltage on resistive leakage current can be seen in Table 4.1. In this study, the author took samples of LA transformers from 5 GI Cibinong. The correction table is based on a reference of 20°C and U = 0.7 Ur.

Table 1. Effect of Ambient Temperature and System Voltage on Resistive Leakage Current.
Source: [2].

Temperature [°C]	0	0	0	20	20	20	40	40	40	50	50	50
System voltage [kV]	380	400	420	380	400	420	380	400	420	380	400	420
Measured value [μA], uncorrected	31	39	47	47	48	70	67	82	99	75	92	112
Measured value [μA], corrected	46	46	46	46	46	46	46	46	46	46	46	46

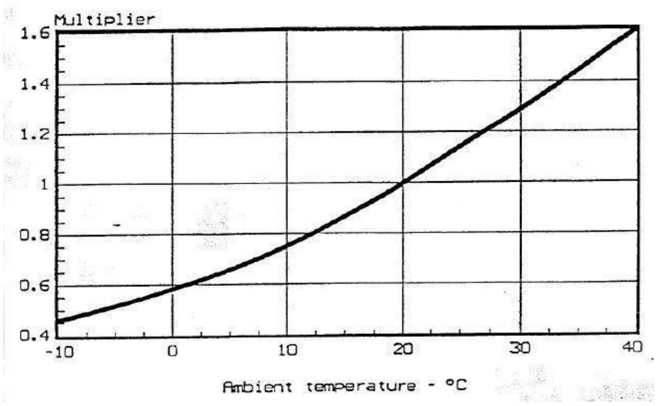

Figure 3. Maximum recommended resistive current at 20°C. Reference level Ir = 50 μA (D 1) Source: [2].

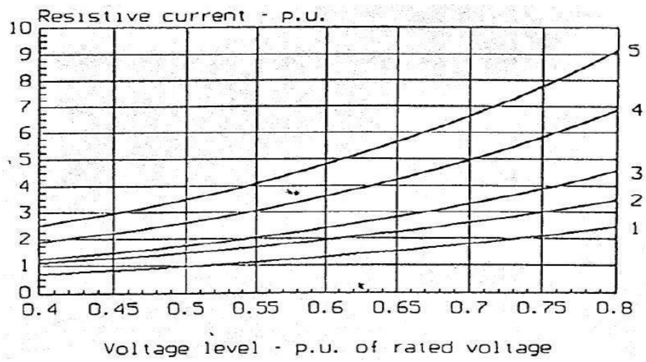

Figure 4. Correction for Temperature (D2) Source: [2].

Based on the results of the resistive leakage current calculation for Bay Transformer 5 GI Cibinong, the following results were obtained: LA bay Transformer 5 specifications:

- Brand: ABB type Exlim R162 AH 170
- Bay: Transformer 5 150/20 kV
- Ambient Temperature: 32°C

Phase Voltage: 150 / √3 = 86.60 kV
Voltage Ratio: Uc = 187 / √3
= 107,946 kV
Rated Voltage: Ur = Uc / 162 kV
= 107,946 / 162
= 0,666

Based on Figure 3, the maximum recommended Ir at a voltage rating of 0.666 is 1.1.pu (D1), so the resistive leakage current value at 20°C is:
1.1 × 50 = 55 μA

Based on Figure 4, for an ambient temperature of 32°C, the value is 1.3.pu. Therefore, the maximum Ir at 32°C (D2) is: 1.1 × 1.3 = 1.43 pu

The resistive leakage current at 32°C is: 1,43 × 50 = 71,5 μA

Corrective leakage current: Ir corr = Ir × (D1) × (D2)
= 71.5 × 1.1 × 1.43
= 111,840 μA

Table 2. LCM Test Results for 5 GI Cibinong Transformators

Bay Transformators 5 GI Cibinong 150 KV				
Fasa	**Standart (μA)**	**15 Maret 2019**		
		Leakage Current (μA)	**Recommendations**	**Next Testing**
R	91	72.11	WEAKENED	1 year
S	91	71.19	WEAKENED	1 year
T	91	70.98	WEAKENED	1 year

As seen from the average results between phases, in the Bay Transformer measurement for 2019. In 2019, phases R, S, and T were in the WEAKENED percentage range (50%–80% of the recommended Ir). The results of the resistive leakage current calculation within the WEAKENED recommendation, resistive leakage current, and corrective current on the 5-phase GI Cibinong transformer at an ambient temperature of 32°C may not necessarily be reliable as a benchmark for diagnosing deterioration in the LA.

A. Results of LA Insulation Resistance Testing.

Seeing the results of the resistive leakage current measurement, which is quite large, to determine the measurement error, it can be compared with the results of the LA insulation resistance test/measurement.

Table 3. LA insulation resistance test results for 5 GI transformer bays

Fasa	**R**	**S**	**T**
Top – Bottom	68.6 GΩ	64.5 GΩ	46.7 GΩ
Top - Ground	61 GΩ	42.5 GΩ	54.3 GΩ
Bottom - Ground	2.9 MΩ	3.1 MΩ	8.6 MΩ

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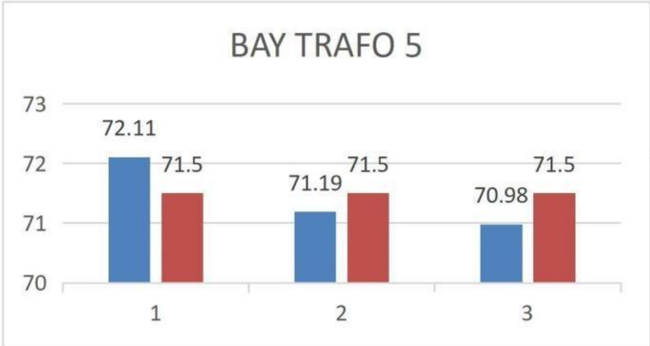

Figure 5. Comparison graph of LCM test results with theoretical calculations

Description: Test Results Ir (Ir (μA) Cibinong in 2019
Theoretical Calculation (Ir (μA)

Table 4. Comparison of LCM Test Results with Theoretical Calculation Results and Insulation Resistance Results

Type	Substation	Bay	Phasa	Test Result LCM		Theoretical Calculation Results				Insulation Resistance Test Results	
				Ir corr (μA)	Ir (μA)	k voltage D1	k Temperature D2	Ir corr (μA)	Ir (μA)	Awal	Akhir
ABB type Exlim R162 – AH170	Cibinong	Trafo 5	R	112,3	72.11	1,1	1,43	111.840	71,5	53,5 GΩ	68,6 GΩ
			S	113,6	71.19	1,1	1,43	111.840	71,5	76,5 GΩ	64,5 GΩ
			T	111,7	70.98	1,1	1,43	111.840	71,5	50,7 GΩ	46,7 GΩ

From Table 4, it can be seen that the comparison between the LCM test results and the calculation results is not significantly different. There are differences in the insulation resistance tests on each transformer bay. From the results of the insulation resistance test, the deterioration is seen in the upper and lower parts of the LA compartment.

4. Recomedations

In further development, it is expected that field measurement data and measurement results using simulators will be added. In future developments, it is hoped that an analysis of the effects of widespread leakage currents will be added. The results of the analysis and measurements can be followed up immediately in order to maintain the reliability of the substation. A comparative study of leakage currents in LA with the LA manufacturer is needed.

5. Conclusion

The results of the LCM test with the theoretical calculation results are not significantly different. On the LCM test equipment, the test error is 5% of the results obtained when conducting the LA leakage current test. In the theoretical calculation of the resistive leakage current of LA bay transformer 5 at an ambient temperature of 32℃, the results still indicate a WEAKENED level, which means that the LA cannot yet be categorised as being in poor condition. With the analysis of resistive leakage current measurements, the reliability of the LA can be monitored to determine the possibility of utilising the LA's service life and, on the other hand, to replace faulty or worn-out LAs before they fail. Factors that affect leakage current in LAs are temperature and service life.

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