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Lightning Arrester Analysis at Pandu 150 Kv Substation

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Abstract. The process of distributing electricity from the substation to the consumers often occurs interference, electrical interference at the station caused by two factors that are internal factors and external factors. Internal factors such as lack of good equipment, while external factors such as human error and natural disturbances such as lightning, earthquakes, flood, wind and others. Safety protection system on electrical equipment of Pandu substation. Surge arresters play an important role in Pandu substations to limit switching overvoltages and lightning strikes, followed by overvoltages from lightning current to earth. the efficiency of the arrester is a function of the distance from its location to the protected equipment, the maximum system voltage achieved is 165 kilo vot, the arrester`s rated voltage is 132 kilo volt line impedance /conductor 475,764 ohms, air insulation breakdown voltage 1515.8 kilo voltv, arrester discharge current 4.27 kilo ampers and an optimal distance between arrester and transformer 10.96 meters.

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1 Indroduction

Electrical energy is needed for everyday life. Electrical energy that reaches customers or consumers requires reliability so that there is no disturbance in the distribution of electrical energy. Disturbances caused by overcurrent in the transmission system cause interruptions in the supply of electricity to the load and cause losses to the transmission system as well as losses to consumers. A short circuit is the occurrence of a live or non-voltage conductor connection directly or indirectly through a medium (resistor or load), causing an abnormal current flow [1].

The protection system has an important role when the operation of the electric power system is disrupted. With the existence of a protection system, it is hoped that it can minimize the area of interference and as a safety for electrical equipment so that it meets the feasibility and economical criteria to provide reliable and quality electric power. But all of these goals will not be achieved if there is an operation error in the protection system. Operation errors are caused by a protection system that is working improperly due to incorrect settings or system operating errors. Therefore, it is necessary to be careful in setting up and testing periodically and operating the system according to procedures [2]

In the process of distributing electrical energy from substations to consumers, disturbances often occur. Electrical disturbances at substations are caused by two factors, namely internal and external factors. Internal factors such as the lack of good equipment itself while external factors such as human error and natural disturbances such as lightning, earthquakes, floods, wind and others. Therefore the substation protection system has a very important role as a safeguard for the electrical equipment found at the substation [3]. One of the protection systems at the substation is Lightning Arrester.

Lightning Arrester is the most important equipment to protect substations from high voltage, arresters have an important role in substations to limit switching and lightning surges and then lightning surges flow to the ground. In the electric power system, the arrester is the key to isolation when the surge arrives at the substation, then the arrester will release an electric charge and an abnormal voltage that will affect the substation and its equipment will decrease [4].

The placement of arresters for high-voltage substations can be determined by several evaluations and the process of designing substations [5]. Therefore arrester failure during overvoltage can cause the substation to be at risk of damage [6]. Every electric power system needs to be protected from lightning surges, to prevent damage to the electric power system, with good and correct design it is very important as a consideration for electric power system protection.

Determining the optimum position of the arrester is very influential in protecting the power system and minimizing the risk of failure, thus enabling the maintenance of the right protection scheme in each network, as a result the cost of protection is reduced according to the cost of the elements being protected [7].

The working principle of the arrester is that under normal circumstances the arrester acts as an insulator, and when a surge voltage arises this device turns into a conductor with a relatively low resistance, so that it can channel high currents to the ground [8]. To ensure that there is no interference with the system, there is a substation lightning arrester abbreviated as Arrester as a protector for electrical installations and electrical equipment against overvoltage caused by lightning surges or circuit surges [9]. This lightning arrester acts as bypass around the insulation by forming a path to facilitate current through lightning strikes so that high overvoltage does not arise in the equipment [10].

Furthermore, once the surge is gone, the arrester must quickly return to isolation. Generally arresters are installed at each end of high-voltage overhead lines entering the substation. Optimizing the location of arresters in the distribution network can improve the performance of the distribution network in protecting equipment against lightning induction. Then, arresters have different functions according to the state of the voltage. It will function as insulation on the voltage normal, but when there is a lightning surge which results in overvoltage, the arrester will serves as a conductor by passing a high current to the ground [11]. That's what lightning arrester used to reduce the surge voltage by flowing the surge current to the ground in the order which is very small, so that the influence of the follow current does not participate in being grounded [12].

To prevent this from happening, every substation installation must be equipped with an arrester. lighting arresters are used to reduce surge voltage by means of flowing current surge to the ground in a very small order, so that the influence of going with the flow does not follow as well as grounded [13]. In order to get the best results from arresters, optimum placement of arresters is needed which greatly affects the function and performance of these arresters in protecting equipment from overvoltage. One way to overcome problems that occur due to natural disturbances such as lightning which causes overvoltage which will damage equipment is by using arresters. This arrester must be able to channel the lightning surge fault current that occurs as soon as possible to the ground. Thus, at a substation it is necessary to protect against lightning surge disturbances. Placement of arresters as close as possible to the equipment can protect the equipment from transient overvoltage disturbances.

When a traveling wave occurs which causes overvoltage to equipment that is located a little far from the arrester. An arrester must be able to act as an insulator, carry several milliamperes of leakage current to ground at system voltage and turn out to be an excellent conductor, carrying thousands of amperes of surge current to ground, having a voltage lower than the withstand voltage of the equipment in the event of an overvoltage, and eliminating the aftershock current flowing from the system through the arrester (power follow current) after the lightning surge or circuit surge has been successfully dissipated.

Lightning Arrester has an important role in coordinating equipment isolation at substations. The main function of the Lightning Arrester is to limit the voltage value of the substation equipment it protects. The length of the lead connecting the arrester also needs to be taken into account, because the inductive voltage on this lead when a surge occurs will affect the value of the total parallel voltage to the protected equipment.

The purpose of lightning protection in Sendang is to protect equipment and installations from direct lightning strikes. Under normal network voltage conditions, the nominal protective voltage acts as an isolation or ideally does not drain current from the ground network. But if an impulse overvoltage arrives at the terminal of the protective device, the protective device immediately turns into a conductor and conducts the impulse current to ground so that the amplitude of the overvoltage that propagates to the protected equipment decreases to below the resistance of the impulse voltage of the protected equipment.

2 Research Method

the research method used by the author in this study, including literature study which examines several theories that are directly related to this research, as well as examines theories that support problem solving in this thesis research. Some of these theories are obtained from reading sources such as scientific journals, printed books, ebooks and some previous research. Furthermore, observations where data collection for this thesis research were directly obtained from the research object, by asking directly employees of PT PLN (Persero) Pandu 150 Kv Substation and discussing directly with the supervisor. There are also some data needed such as a single line diagram of the substation, transformer data, lightning arrester protection data used and the implementation of lightning arrester maintenance

3 Result and Discussion

3.1 Lightning Arrester Performance Analysis

Analysis of the performance of lightning arresters based on their placement distance from the protected equipment. This analysis aims to determine the optimum distance between the arrester and the power transformer installed at the Pandu 150 Kv Substation. The arrester specifications installed in the R, S, T phase are in table 1 below

Table 1 Specifications for light arresters at the Pandu substation

Technical Data	Voltage : 150/20 KV
Merek : ABB	Frekuensi : 50 Hz
Type EXLIM Q132-XV170	Discharge Current : 10 kA
Rated Power : 36/60 MVA	Phase Current : 3 Phase
Short Circuit Impedance : 12.141%	BIL : 650 KV

(source from substation template)

Then to find out the performance distance of the lightning arrester to the load, in this case the 60 kvA power transformer, then a standard isolation distance is needed that is installed at the substation. The following is a table of standard isolation distances in Figure 1 below

Nominal Voltage (kV)			11	22	33	66	77	110	154	187	220	275
No Fire Bow Horn	Number of Isolators		2	(3) 2	3	(5) 4	5	7	(10) 9	(11) 10	(13) 12	(16) 15
	50% Skip Voltage for Isolator Coupling (kV)		220	(306) 220	306	(455) 380	455	610	(843) 764	(920) 843	(1075) 997	(1312) 1232
	Standard Insulation Distance (m)		0.40	(0.55) 0.40	0.55	(0.80) 0.70	0.80	1.10	(1.50) 1.35	(1.65) 1.35	(1.90) 1.75	(2.30) 2.20
With Fire Bow Horn	ZIZO 80%	Number of Isolators				(5) 4	(6) 5	(8) 7	10	(11) 10	(13) 12	(17) 16
		Butt of Fire Horn (m)				(0.59) 0.47	(0.71) 0.59	(0.94) 0.82	1.17	(1.29) 1.17	(1.52) 1.40	(1.98) 1.87
		Standard Insulation Distance (m				(0.70) 0.55	(0.80) 0.70	(1.10) 0.95	1.35	(1.45) 1.35	(1.75) 1.60	(2.25) 2.10
	ZIZO 80%	Number of Isolators				(5) 4	(6) 5	(8) 7	10	(11) 10	(13) 12	(17) 16
		Butt of Fire Horn (m)				0.55	(0.06) 0.55	(0.88) 0.77	1.09	1.21	1.43	1.86
		Standard Insulation Distance (m				0.65	(0.75) 0.65	(1.00) 0.90	1.25	1.40	1.60	2.10
Standard Insulation Distance (m)			0.10	0.15	0.25	0.40	0.45	0.70	1.00	1.05	1.25	1.60

Note: Note: Prices in parentheses are what is commonly used

Figure 1 Standard Isolation Distance and Minimum Isolation Distance

3.2 Determination of the capacitance of the lightning arrester on the installed conductor line

3.2.1 Determine the maximum stress side

To find out the quality of distribution in a substation, of course, a safety device is needed that is able to control leakage currents from lightning strikes. The following is the maximum stress based on the equation:

$$\begin{aligned} Vm &= V\ Nominal \times 110\%\ (tolerance\ factor) \\ &= 150\ kV \times 1{,}1 \\ &= 165 kV \end{aligned}$$

It should be noted that based on the equation above, the tamplate body arrester (EXLIM Q132-XV170) installed has a voltage capacity of 170 kV. This means that this voltage capacity is the maximum voltage value in the lightning arrester. Of course this indicates that an arrester installed can be able to work above the maximum standard voltage. therefore of course this Lightning Arrester (LA) acts as a shortcut (By Pass) around isolation by forming a path to facilitate current through a lightning strike so it doesn't higher overvoltage occurs equipment > 170 KV [10]

3.2.2 Determine the main voltage on the lighting arrester

At the main voltage of the lightning arrester, the following equation is obtained in the calculation:

$$\begin{aligned} Ea &= V\ Nominal \times Earthing\ Coefficient \times 110\% \\ &= 150\ kV \times 0.8 \times 1.1 \\ &= 132\ kV \end{aligned}$$

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It should be noted that based on the equation above, the tamplate body arrester ((EXLIM Q132-XV170) installed has a voltage capacity of 132 as rated voltage. The equation and template body in the arrester indicates that the lightning arrester works according to the rated voltage standard.

3.2.3 Determine the line/conductor impedance

At the Pandu substation, it has a distribution of 150 kV with an average height from the ground of 20 meters. The conductors at the substation use ASCR type conductors of size 435/55. According to the KBMI or SPLN Manufacturing data sheet 41-7: 1981. Cable size 435/55 has a Diameter = 28.80 mm. so the value of R is:

R = Diameter/2
= 28.80/2
= 14.40 mm
= 0.0144 m

then the line impedance is:

Z = 60 nominal current x 2h/r
= 60 nominal current 40 x 0.0144
= 60 nominal current x 2.777
= 475.764 ohm

3.2.4 Determining the Air Insulation Voltage

The breakdown voltage equation for the insulator can be determined using the data and the equation below:

W = Length of Voltage Isolator Range 150kV Is 1.5m
K1 = 0,4 W
= 0,4 x 1.5 meter
= 0.6
K2 = 0,7 W
= 0,7 x 1.5 meter
= 1.05

then if the calculated voltage is based on the wavefront time, 1.2 μs then the equation is

$U_{50\%} = (K1+K2/t^{0.75}) \times 10^3$
$U_{50\%} = (0.6+1.05/1.2^{0.75}) \times 10^3$
$U_{50\%} = 1515.8$ Kilo Volt

Furthermore, to analyze the lighting arrester in terms of loading, of course it is necessary to carry out measurements which aim to determine the condition of the lighting arrester grounding system. A high grounding value indicates an anomaly in the lighting arrester grounding system. Grounding measurements are carried out in a no-voltage condition [14]. The important things that need to be considered during the process of measuring the value of grounding are as follows:

a. Make sure the test equipment has a good power supply.
b. Disconnect the ground wire from the lighting arrester circuit. Measurements are made only on the grounding circuit.
c. Clean the ground wire, so that the measuring tool is well connected to the ground wire.
d. Use earth as a measurement reference, not grounding other equipment that is already connected to the substation mesh system.
e. After measurement, make sure the grounding system connection is reconnected properly.

Evaluation and recommendations for each measurement are described in table 2 below.

Table 2. Evaluation and Recommendations for Measurement Results of lighting arrester Insulation Resistance Values

Ground Resistance Value	Evaluation	Recommendation
< 1 Ω	Good condition	
> 1 Ω	there is a degradation of the lighting arrester grounding function	a. clean the ground wire, including on the side of the nut and bolt connecting the ground wire to the arrester body. b. repeat measurement c. if the measurement results are still > 1 Ω, then plan improvements to the grounding system

(source from substation)

Next, if possible, carry out grounding system improvement activities including the following activities:

a. Repair ground wire connection with grounding rod.
b. Replacement of ground wire and rod.
c. Checking the grounding rod connection with the mesh system.

3.2.5 Determining the Discharge Current/Working Current of the Arrester

Known:
Ud = 1515.8 kv (Air Insulation Breakdown Voltage)
UA = 500 kV (Working Voltage/Arrester Discharge)
Z = 475.764 (Ω) (Represents the Impedance of the Conducting Line)

Then the arrester discharge/work current can be known by the following equation:

Ia = 2ud-UA/z
= 2 (1515.8 – 500)/475.764
= 4.27 KA

In accordance with the calculation results above, the discharge current value is 4.27 kA below the value stated on the Arrester nameplate ((EXLIM Q132-XV170) which is 10 kA. So that the choice of Class 10 kA is in accordance with their needs.

3.3 Maintenance of Lightning Arrester at the 150 KV Pandu substation

3.3.1 Measurement of Insulation Resistance Value (Megger test)

Measurement of the insulation resistance value aims to determine the ability of Lightning Arrester insulation at operational voltage. Measurements are carried out in an off-voltage condition (turns off). The test points are as follows:

a. Lightning Arrester insulation resistance from top terminal to ground.
b. Insulation resistance on each Lightning Arrester stack.
c. Insulator insulation resistance seat / post insulator

Important things that need to be considered during the measurement process are as follows:

a. Make sure Lightning Arrester is clean.
b. Disconnect the Lightning Arrester conductor wire and grounding wire.
c. Make sure the test equipment has a good power supply.
d. Use a test kit with a measuring capability of > 1GΩ.
e. After the measurement, make sure the connection between the conductor wire and the Lightning Arrester grounding wire is properly reconnected [15]

The scheme for implementing insulation resistance measurements is shown in Figure 2 below

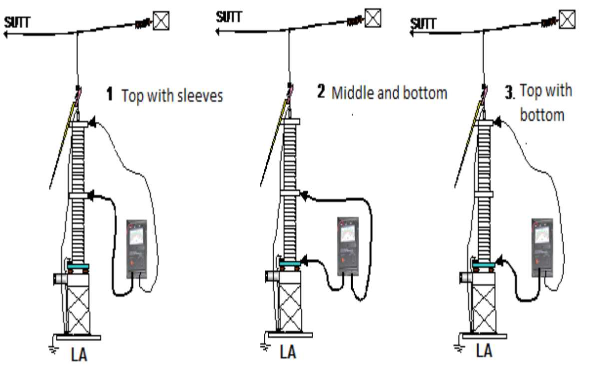

Figure 2. Compartment Insulation Resistance Rating (Megger) Measurement Scheme in Lightning Arrester

The results of measuring the value of insulation resistance (megger test) respectively in 2022 at the substation the following data is obtained :

Table 3. Measurement Results Lightning Arrester Insulated Prisoner in 2022

Line	Pandu 150 KV		Standar
Phase Section	A-G	D-G	
Phase R	601	0.0003	> 1 GΩ
Phase S	1010	0.0105	
Phase T	525	0.0008	

(source from substation)

Information :
Down – Ground
Above - Ground

Based on the results table 3 of resistance measurements lightning arrester isolation for the last 1 year (measurements were carried out 1 year once), it can be said that prisoners insulation ligthning arrester conductor Pandu is in good condition because > 1 GOhm. Based on the results of resistance measurements lightning arrester isolation for the last 1 year (measurements were carried out 1 year once), it can be said that prisoners insulation lighting arrester conductor Pandu is in good condition because > 1 GOhm.

3.3.2 Measurement with Thermovisi and Surge Counter Lightning Measurement arrester

3.3.2.1 Measurement with Thermovisi

The following is a measurement of lighting arresters using thermovision. The data from the thermovision measurement results were taken as a sample of the lightning arrester with the brand Pandu substation type EMP 150 kV with using a thermovision camera device in table 4 below:

Table 3. Measurement results with the Thermovisi device

bay observation object	Current clamp temperature Shooting (°C)	Temperature current conductor Shooting (°C)	Change the clamp temperature to Conductor (0 s/d 10 (°C)
terminal LA Phasa R	22	22	0
terminal LA Phasa S	22	22	0
terminal LA Phasa T	22	22	0
Body LA Phase R	22	22	0
Body LA Phase S	22	22	0
Body LA Phase T	22	22	0

(source from substation)

Based on table 3 above, the measurement results above can be seen that the condition of the clamps and the conductor at the terminal and body of the lightning arrester is still good at 22 °C, because the measurement temperature is less than 39 °C based on the PLN SK DIR 520 2014 recommendation standard where it is obtained and the temperature difference between the phases and between clamps and conductors have not exceeded 10 °C. The recommendations above are based on PLN SK DIR 520 2014.

3.3.2.2 Surge Counter Lightning Measurement arrester

The lightning arrester surge counter test aims to determine whether the device is capable of working when a surge occurs. If in good condition, the counter will increase when given a DC voltage impulse. The DC voltage impulse used in the test is generated from a

400-500 µF capacitor, 220-300 VAC. The implementation is carried out in a non-voltage condition [16].

The important things that need to be considered during the process of measuring the value of grounding are as follows:

a. Disconnect the ground wires on both sides of the lightning arrester surge counter.
b. Clean the lightning arrester surge counter insulator before testing
c. Execution of the test:
    1) Charge the capacitor with a 220 V AC supply voltage for 30 – 60 seconds.
    2) Connect the two poles of the capacitor immediately to the two ends of the surge counter, so that an impulse DC current is experienced by the surge counter.

4 Conclusion

the results of the study it can be concluded that the specifications of the equipment lightning arrester installed at the Pandu 150 Kv substation has according to system requirements. the calculation is done the optimum distance between the lightning arresters and transformers obtained S = 10.96 meters, while the distance (S) between the lightning arrester and the transformer attached to the substation main Pandu 150 kV is S = 5 meters, thus the placement lightning arrester against transformers or other equipment that protected is below the optimum value, because S installed < S count. Insulation resistance test that has been carried out at the Pandu substation then it can be said that the insulation resistance the Pandu conductor's lightning arrester is in good condition. This can seen from much lower than the standard standardinsulation resistance is > 1 GOhm.

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