ANALISIS KINERJA *LIGHTNING ARRESTER* PADA GARDU INDUK AMPENAN 150 *kV* MENGGUNAKAN *SOFTWARE PSCAD*

ANALYSIS OF LIGHTNING ARRESTER PERFORMANCE OF THE AMPENAN 150 kV SUBSTATION USING PSCAD SOFTWARE

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ABSTRAK

Gangguan listrik pada gardu induk sering terjadi ketika terjadi sambaran petir. Proteksi pada gardu induk khususnya *lightning arrester (LA)* digunakan untuk melindungi *transformator*. *LA* mampu melindungi *transformator* dengan cara memotong arus saat terjadi sambaran petir, apabila *tranformator* dengan *LA* ditempatkan pada jarak optimum. Penelitian ini bertujuan untuk menegtahui jarak optimum *LA* dengan *transformator,* kemampuan *LA* ketika memotong arus petir dan memantau suhu serta arus bocor *LA.* Metode yang digunakan adalah membandingkan hasil perhitungan kemampuan *LA* dengan *spesifikasinya.* Perhitungan menggunakan simulasi arus puncak petir 5 – 35 *kA* dan diolah menggunakan *software PSCAD*. Arus hasil simulasi yang mengalir dan arus yang dipotong *LA* masing-masing 4,45 - 31,12 *kA*, dan 4,39 - 30,77 *kA* tidak melebihi 10 *kA* ketika terjadi sambaran petir. Tegangan maksimum hasil simulasi pada *transformator* 223,25 - 304,57 *kV* tidak melebihi *basic insulation level* (*BIL*) *transformator* yaitu 650 *kV.* Arus bocor *LA* terpantau dibawah 1,5 *mA* yaitu dalam kondisi baik. Selisih suhu terpantau pada kawat *ground LA* 1 ^{O}C dimungkinkan adanya ketidaknormalan antar *phase* dan perlu pengukuran 1 minggu lagi. Jarak antara *LA* dengan *transformator* yang terpasang pada gardu induk Ampenan 150 *kV* adalah 5 *meter*, sehingga tidak melebihi jarak maksimum.

Kata Kunci: *Lightning Arrester*, Arus Petir, *Sofware PSCAD*

ABSTRACT

Electrical disturbances at substations often occur when lightning strikes occur. Protection at substations, especially lightning arresters (LA), is used to protect transformers. LA is able to protect the transformer by cutting the current during a lightning strike, if the transformer with LA is placed at the optimum distance. This study aims to determine the optimum distance between LA and transformers, the ability of LA when cutting lightning currents and monitor the temperature and leakage current of LA. The method used is to compare the results of the calculation of the ability of LA with its specifications. The calculation uses a simulation of lightning peak current of 5 – 35 kA and is processed using PSCAD software. The simulated current flowing and the current cut by LA are 4.45 - 31.12 kA, and 4.39 - 30.77 kA respectively not exceeding 10 kA when a lightning strike occurs. The maximum voltage simulated on transformers 223.25 - 304.57 kV does not exceed the basic insulation level (BIL) of the transformer, which is 650 kV. LA leakage current was observed below 1.5 mA which is in good condition. The temperature difference monitored on the LA 1 ^{OC} ground wire is possible for abnormalities between phases and needs another 1 week of measurement. The distance between LA and the transformer installed at the 150 kV Ampenan substation is 5 meters, so it does not exceed the maximum distance.

Keywords: Lightning Arrester, Lightning Current, PSCAD Software

I. INTRODUCTION

Electrical energy is channeled from substations to consumers, often there are disturbances. Electrical disturbances in substations are caused by two factors, namely internal factors such as substation equipment experiencing damage and external factors *such as human error and* can also be natural disturbances such as lightning, earthquakes, floods, wind and others.

There are three power transformers at the Ampenan substation of 60 MVA each for transformers *I and 30* MVA *for* transformers II and III which must be protected from interference. The three *transformers* are installed arresters with a distance of 5 *meters* and have a *Basic Insulation Level (BIL)* of 650 *kV*. *Transformer I* is the highest load, so it is more focused on discussing *transformer* I.

Lightning Arrester is equipment to protect substations from high voltage. *Lightning Arrester* at the substation must be installed at the very front of the *transformer, in order to* protect the *Transformer* optimally (Hidayatulloh, et al: 2016).

Arresters placed for high voltage substations can be determined by some evaluation and process of designing substations. Failure of the *arrester* during *over voltage* can put the substation at risk of damage. Electric power systems need to be protected from lightning surges, to prevent damage to the electric power system, with good and correct design (Kurniawan: 2018).

The working principle of *the arrester is that under normal circumstances* the arrester acts as an insulator, and when a surge voltage arises, this tool turns into a conductor with relatively low resistance, so that it can channel high current to the ground, after the surge is gone, *the* arrester *must quickly return to isolation. Arresters* are generally installed at each end of the high-voltage overhead line entering the substation. Optimizing the location of the *arrester in* the distribution network can improve the performance of the distribution network in protecting equipment against lightning induction (Wiwin, et al: 2018).

The Ampenan substation in the Lombok electricity system is the highest load substation located in the city of Mataram. Mataram City is an area that has the highest load when compared to other regions in the Lombok electricity system. Overvoltage needs to be analyzed due to lightning strikes on transmission lines for equipment protection at the Ampenan substation, to find out how much the *arrester*'s ability to protect *the transformer*. The reliability and safety of the substation can be maintained, so that the distribution of the electric power system in the city of Mataram and its surroundings is not disrupted.

1. Lightning Arrester

Lightning Arrester is equipment designed to protect other equipment from surge voltage (both circuit surge and lightning surge) and the influence of *follow current*. *The arrester* must be able to act as an insulator, deliver several milliamperes of leakage current to the ground at system voltage and turn into an excellent conductor, conduct thousands of amperes of surge current to the ground, have a voltage lower than the withstand voltage of the equipment when overvoltage occurs, and dissipate aftermath current flowing from the system through the arrester (*power follow current*) after the lightning surge or circuit surge has been dissipated. (Sapari: 2016).

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

The purpose of lightning protection in lightning is to secure equipment and installations from direct strikes by lightning surges. Network voltage under normal circumstances, the protective nominal voltage acts as insulation or ideally does not drain current from the ground network. The impulse overvoltage arrives at the terminal of the protective device, then the protective device immediately turns into a conductor and flows the impulse current to the ground so that the amplitude of the overvoltage propagating to the protected equipment is reduced to below the impulse voltage resistance of the protected equipment. Here are the parts of an Arrester:

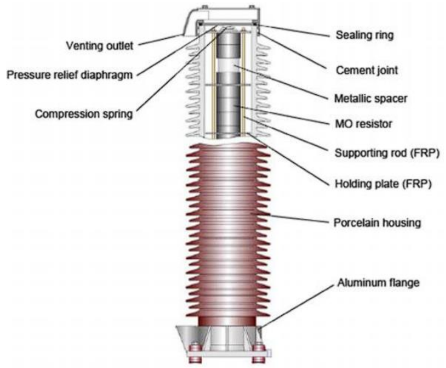


Figure 1. Lightning Arrester (PT PLN (Persero): 2009)

a. Connecting to Sender

There are two electrodes on the arrester, namely the top electrode connected to the voltage part and the bottom electrode connected to the ground.

b. Watertight Connection and Cover

The watertight connection serves to drain electricity that is grounded and block water from entering. While the cover or protector functions so that dust cannot enter the tool so that the performance of the Lightning Arrester can work properly.

c. Spark Gap

Spark Gap in the form of air gaps that function when there is an overvoltage by lightning surges or sparks on the installed arrester, then in the spark gap or between sparks there will be an arc.

d. Valve prisoner

The resistance used in this arrester is a type of material whose resistance properties can change when it gets a change in voltage.

e. Grounding Point

The grounding point is a part connected by a conducting wire to the ground that serves to drain excess voltage to the ground. (Tasbir, M: 2020).

2. Calculating the Rating of *a Lighting Arrester*

a. Calculates maximum system voltage (Vmax) and Rated Voltage (Ea)

Vmax = Vnom + 10% Vnom (1)

Ea = Vmax Koef Earthing (2)×

b. Determining the impedance of the conducting channel

$$Z = 60\, ln \frac{2h}{d} \quad (3)$$

Information:

Z = Conducting channel impedance (Ohms)

h = Height of transmission wire from above ground level (m)

d = Transmission wire diameter (m)

The breakdown voltage equation of an insulator can be determined by the following data and equations:

K1 = 0.4 ×*W*

K2 = 0.7 ×*W*

$$Ud = \left(K_1 + \frac{K_2}{t^{0.75}}\right) \times 10^3 \quad (4)$$

Information:

K1 = First electrical energy constant

K2 = Second electrical energy constant

W = The length of the 150 kV voltage insulator stretch is 1.5 *meters*

t = voltage calculated based on wavefront time (1.2 *µsec*)

c. Determining the Discharge Current / Working Current *of the Arrester*

The discharge current/work of the *Arrester* can be determined by the following equation:

$$He = \frac{2(U_d - U_A)}{Z} \quad (5)$$

Information:

It = Discharge Current (*kA*)

Ud = Air Insulation Breakdown Voltage (*kV*)

UA = Working Voltage/Arrester Discharge (*kV*)

z = represents the impedance of the conducting channel (Ω)

d. Calculating *LA Distance*

$$Ep = Ea + \frac{2A \times S}{V} \quad (6)$$

- Rated Transformer Impulse *Spark Voltage* (*Ea*)
- Determining *the Base Insulation Level* (BIL*) Transformer* (*Ep*) on the *nameplate* LA *Substation Power Transformer*
- The steepness of the coming wave (*A*) is 1000 *dv/s*
- Constant wave propagation speed (*v*) 300 *m µ/s*

e. Calculating the LA temperature difference

The Temperature Difference at Max Load can be done by the following formula:

$$\Delta T = (7)\left(\frac{I_{Max}}{I}\right)^2 \times (C - K)$$

Where:

ΔT = Temperature Difference at Maximum Load

IMax = Maximum Current ever achieved

I = Current at *Thermovision*

C = Clamp *Thermovision Results*

K = *Conductor Thermovision* Results

II. METHODOLOGY

This study uses a method of comparing the results of LA capability calculations with *specifications.* The calculation uses a simulation of lightning peak current of 5 – 35 *kA* and is processed using *PSCAD software*. The theories studied are directly related to this Final Project research, as well as examining theories that support problem solving in this Final Project research. The theory is obtained from reading sources such as scientific journals, printed books, ebooks and some previous research. The purpose of this study *is to determine whether the lightning arrester equipment installed at the substation is in accordance with the needs of the system*, and to determine the optimum distance of placement of the arrester to the protected equipment, as well as to determine the temperature and leakage current *of the lightning arrester* equipment at the 150 kV Ampenan substation . The data used are:

a. Single line diagram of Ampenan Substation 150 *kV*
b. Lightning Arrester (Nameplate) Specification Data
c. Transformer Specification Data (Nameplate)
d. Transmission Wire Specification Data
e. Ground level transmission wire height
f. Daily *Checklist* Data Current Leaking *Lightning Arrester*
g. Thermovision Data *of Lightning Arrester* and *Transformer*

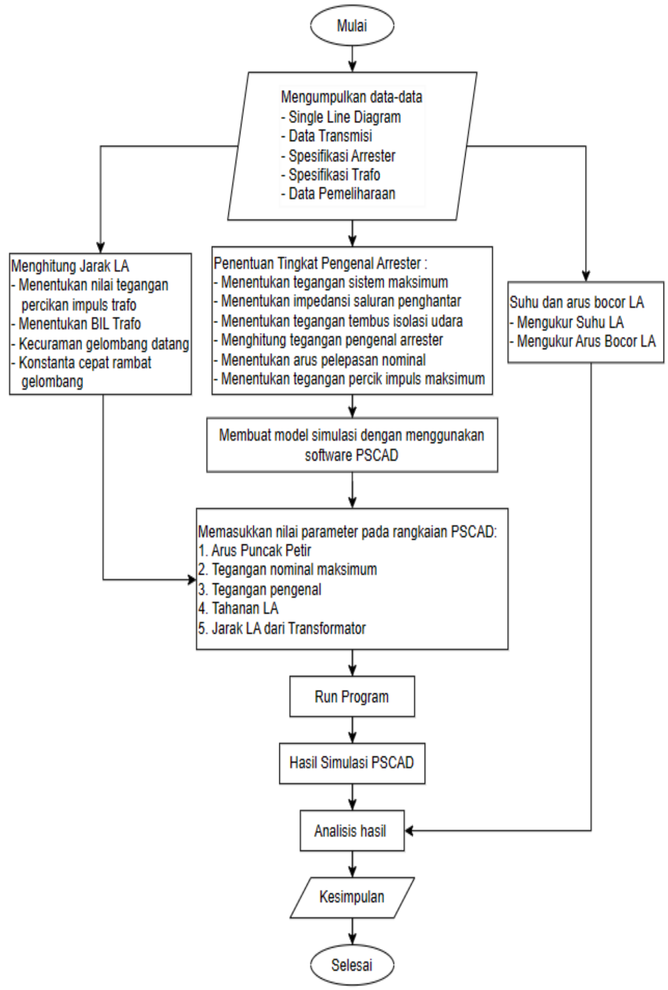


Figure 2. Research Flow Chart.

III. RESULTS AND DISCUSSION

1. Transformer and *LA* Specifications at Ampenan Substation 150 *kV*

Table 1. Technical Data of Ampenan Substation transformer 150 *kV*

Technical Data	
Brand	: UNINDO
Type	: VVIII 400Y / 76 *kV*
No. *Transformer*	: P060LEC857 – 13
Rated Power	: 36/60 *MVA*
Phase	: 3
HV/LV Voltage	: 150/20 *kV*
Frequency	: 50 *Hz*
HV/LV *Current*	: 40/25 *kA*
BIL	: 650 *kV*
Cooling	: *ONAN/ONAF*

Table 2. Technical Data *LA* Ampenan Substation 150 *kV*

Technical Data	
Brand	:ABB
Type	: PEXLIM Q132-YV170
Serial number	: Phase : R 75267794
	: S 75267795
	:T 75267796
Rated voltage: 132 *kV*	
Frequency : 50 *Hz*	
Discharge current: 10 *kA*	
Short Circuit : 65 *kA*	
LA Height : 1.7 *m*	

2. Determine the rating of the lightning arrester attached to the conducting channel

The Maximum Voltage of the system can be determined by the equation:

Vm = Vnominal + (Vnominal × 10%)
= 150 + (150 × 0.1)
= 150 + 15
= 165 *kV*

The maximum voltage of the system is 165 *kV while on* the Arrester nameplate *with the PEXLIM serial number Q132-YV170*, the number 170 is the maximum voltage value of the Lightning Arrester which is 170 *kV*, so that the *installed* Lightning Arrester *is able to work above the maximum voltage standard.*

Determining the rated voltage LA can be done with the equation:

Ea = Vm × Earthing Coefficient
= 165 × 0.8
=132 kV

The rated voltage of the Lightning Arrester is 132 kV, *on* the nameplate *Arrester with the serial number PEXLIM Q132-YV170*, the number 132 is the rated voltage value of the Lightning Arrester which is 132 *kV, so that the installed* Lightning Arrester *is able to work at the rated voltage standard.*

150 *kV* transmission wire on the Ampenan Substation transmission line using *ACSR HAWK* type conductor with 240 mm^2 interview results with *PT. PLN (Persero)* NTB Ampenan Regional Main Unit that the average height of the conductor from the ground is 20 m, obtained tilapia radius (*r*) is:

$L_{lingkaran} = \pi r^2$

$r = \sqrt{\frac{L_{lingkaran}}{\pi}}$

$r = \sqrt{\frac{240}{\pi}}$

r = 8.74 *Mm* = 0.00874 *m*

Then the *channel impedance* is:

$Z = 60 \ln \frac{2h}{r}$

$Z = 60 \ln \frac{2\times 20}{0{,}00874}$

$Z = 505.723\ \Omega$

The breakdown voltage equation of an insulator can be determined by data and equation (4)

W = The span length of a 150 *kV* voltage insulator is 1.5 *meters*

K1 = 0.4 *W* = 0.4 x 1.5 = 0.6

K2 = 0.7 *W* = 0.7 x 1.5 = 1.05

t = voltage calculated based on wavefront time, 1.2 *μsec*

$Ud = \left(K1 + \frac{K2}{t^{0,75}}\right) \times 10^3$

$Ud = \left(0{,}6 + \frac{1{,}05}{1{,}2^{0,75}}\right) \times 10^3$

Ud = 1515.8 *kV*

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 = Represents the impedance of the conducting channel (Ω)

Then the arrester's discharge current/work is calculated by equation (5)

$He = \frac{2(Ud-UA)}{Z}$

$He = \frac{2(1515{,}8-500)}{505{,}723}$

He = 4.02 *kA*

The discharge current (*Ia*) after being calculated is 4.02 *kA below the value listed on the* Arrester nameplate, *which is 10 kA*, so that the selection of *Class* 10 kA *is in accordance with his needs.*

The optimum distance between *the lightning arrester* and the *transformer* requires the following data:

- Rated Transformer Impulse *Spark Voltage* (*Ea*)
  Using Table 2.2, a maximum impulse spark voltage of 577 *kV is obtained*.
- Determining *the Basic Insulation Level* (BIL) *of a Transformer* (*Ep*)
  On *the nameplate LA Transformer* Power Substation Ampenan known *Ep* = 650 *kV*.
- The steepness of the coming wave (*A*) is 1000 *dv/s*
- Wave propagation speed constant (*V*) 300 *m μ/s*

The optimum distance is calculated between *the lightning arrester* and *the transformer* then we can use equation (6):

$$Ep = Ea + \frac{2A \times S}{V}$$

$$S = (Ep - Ea) \times \frac{V}{2A}$$

$$S = (650 - 577) \times \frac{300}{2 \times 1000}$$

$$S = 10.95 \text{ meter}$$

The maximum distance between the lightning arrester and the transformer is obtained 10.95 meters, *while the distance* (S) *between the lightning arrester and* the transformer installed at the Ampenan substation is 150 *kV* 10.95 meters, thus the placement *of the lightning arrester* against the transformer or other protected equipment is below the maximum value, because the installed distance is less than the calculated distance.

3. Substation Maintenance

a) Level I Lightning Arrester Inspection

Table 1. Result *Level Inspection* I *Lightning Arrester* GI Ampenan

Phase	**Rated Leakage Current *LA* (*mA*)**	**Condition**
R	0,6	Good
S	0,5	Good
T	0,6	Good

Level 1 inspection *of the 150 kV* Ampenan Substation *Lightning Arrester*, it can be concluded that the leakage current condition is in good condition. A good leakage current value is below 1.5 *mA* (Source: Indra M.R, 2020). So that the *Lightning Arrester* at the Ampenan Substation works well. If the leakage current in LA *exceeds 1.5* mA, *then there is an indication* that the LA *performance is declining, over time it will cause a short circuit (*Short Circuit*).*

b) Lightning Arrester Level II Inspection

The results of the *Thermovision Measurement of Clamp* and Conductor of Lightning Arrester Transformer 1 at the 150 kV Ampenan Substation show that *the clamp* and conductor in the *Lightning Arrester Transformer* 1 of the *150 kV Ampenan Substation* are in good condition because the temperature difference at the maximum load in the range *of* .0 OC - 10 OC is in good condition.

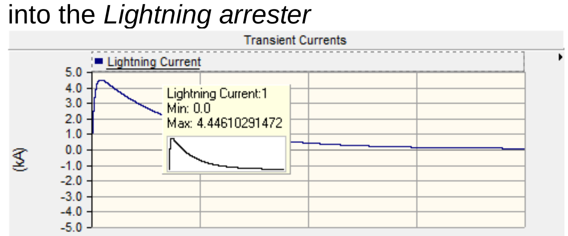
The results of *MTU (Main Material)* Thermovision Measurement of *Transformer Lightning Arrester* 1 at the 150 kV Ampenan Substation showed that the temperature in the upper LA Insulator, middle LA Insulator and lower LA *Insulator in phases* R, S and T was normal. Furthermore, in the *LA ground wire, the difference between phase S and T* is under normal circumstances, while *in phase R with S* and phase *T* with R in condition *I*, where there may be abnormalities and need further investigation.

4. Large Simulation of Current Cut by Lightning Arrester When Lightning Peak Current Is Varied

This simulation was carried out between a lightning arrester and a transformer with lightning currents varying by 5 *kA, 10 kA, 15* kA, 20 kA, 25 kA, 30 *kA* and *35* kA.

a) Peak Lightning Current 5 *kA*

Simulated current results that lightning flows into the *Lightning arrester*



Picture 1. Simulated current results that lightning flows into the Lightning arrester

Figure 3 shows that the maximum value of peak current flowing is 4.45 *kA*. The regulated peak current of lightning is 5 *kA*, so the current flows down before reaching the *lightning arrester.*

Simulated results of lightning currents cut by *Lightning arrester*

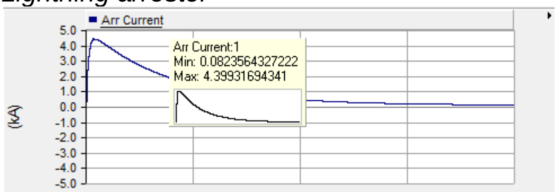


Figure 4. Simulated results of lightning currents cut by Lightning arrester

Figure 4 shows that the maximum value of current cut by a *lightning arrester* is 4.39 *kA*. The current cut by the lightning arrester *leaves the current passing through the* transformer that does not exceed 10 *kA*, so it does not exceed the specifications of the *lightning arrester*.

Voltage simulation results on *Transformer*

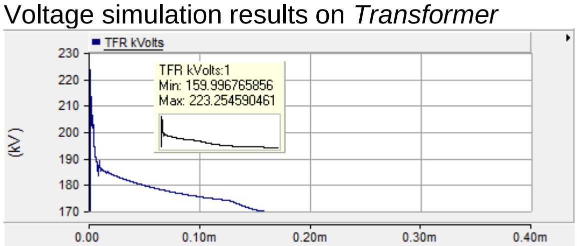
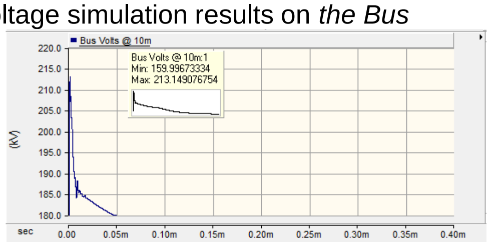


Figure 5. Voltage simulation results on Transformer

Figure 5 shows that the minimum value of Voltage in the *Transformer* is 159.99 kV while the maximum voltage in the system is 165 *kV so that the voltage returns to normal after lightning*. The maximum value of the voltage on the transformer is *223.25* kV while the BIL *of the transformer* is 650 *kV* so it *does* not exceed the specifications from *Transformer*.

Voltage simulation results on *the Bus*

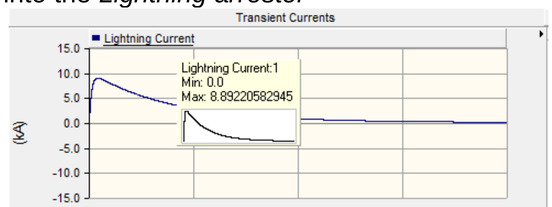


Picture 2. Voltage simulation results on the Bus

Figure 6 shows that the minimum value of Voltage *on the Bus is 159.99* kV while the maximum voltage on the system is 165 *kV* so that the voltage returns to normal after lightning. The *maximum* rated voltage on the *bus* is 213.15 *kV*.

b) Peak Lightning Current 10 *kA*

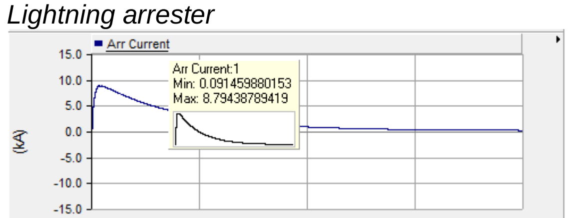
Simulated current results that lightning flows into the *Lightning arrester*



Picture 3*.* Simulated results of lightning currents flowing into the Lightning arrester

Figure 7 shows that the maximum value of peak current flowing is 8.89 *kA*. The peak current of the regulated lightning is 10 *kA*, so the current flowing down before reaching the *lightning arrester.*

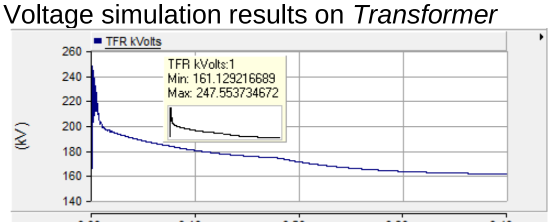
Simulated results of lightning currents cut by *Lightning arrester*



Picture 4*.* Simulated results of lightning currents cut by Lightning arrester

Figure 8 shows that the maximum value of current cut by a *lightning arrester* is 8.79 *kA*. The current cut by the lightning arrester *leaves the current passing through the* transformer that does not exceed 10 *kA*, so it does not exceed the specifications of the *lightning arrester*.

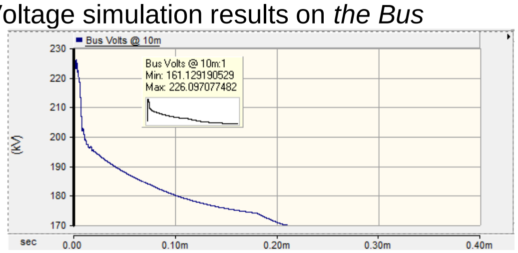
Voltage simulation results on *Transformer*



Picture 5*.* Voltage simulation results on Transformer

Figure 9 shows that the minimum value of Voltage in the Transformer is *161.13* kV while the maximum voltage in the system is 165 *kV so that the voltage returns to normal after lightning*. Maximum value *The voltage on* the Transformer is 247.55 kV *while* the BIL of the Transformer *is 650* kV so it does not exceed the specifications from *Transformer*.

Voltage simulation results on *the Bus*



Picture 6. Voltage simulation results on the Bus

Figure 10 shows that the minimum value of Voltage on the *Bus* is 161.13 kV while the maximum voltage on the system is 165 *kV* so that the voltage returns to normal after lightning. The *maximum* value of the Bus Voltage is 226.1 *kV*.

Table 4. Results of Simulated Lightning Peak Current Cut by Lightning *Arrester*

Lightning peak current (kA)	Flowing current (kA)	Cut Current (kA)	Max voltage . on *Transformer* (*kV*)	Max. Voltage *on Bus* (*kV*)
5	4,45	4,39	223,54	213,15
10	8,89	8,79	247,55	226,1
15	13,34	13,21	262,65	236,21
20	17,78	17,61	274,38	245,48
25	22,23	22	285,65	255,01
30	26,67	26,39	295,56	263,52
35	31,12	30,77	304,57	272,02

Table 4 shows that the peak current of lightning is set to increase by 5 – 35 *kA* then produces the value of current flowing, current cut, voltage on the transformer and voltage on the bus increasing so that the value of the peak current of lightning is directly proportional to the value of current flowing, current cut, *voltage on the transformer and voltage on the* bus.

The current flowing to LA is 4.45 – 31.12 *kA while the current cut by LA is 4.39 – 30.77* kA, so that *the current cut by* LA is *98% or the current flowing to the* transformer is *still below 10* kA.

The voltage on the transformer *is 223.25 - 304.57 kV and the voltage on the bus* is 213.15 - 272.02 *kV, so it does not exceed* the basic insulation level *(*BIL) *on the transformer*, which is 650 kV*.*

Table 5. Results of Minimum Voltage Simulation on Transformer and Minimum Voltage on Bus

Lightning peak current (*kA*)	Min voltage. on *Transformer* (*kV*)	Min. Voltage on *Bus* (*kV*)
5	159,99	159,99
10	161,13	161,13
15	161,51	161,51
20	161,9	161,9
25	162,29	162,29
30	162,68	162,68
35	163,06	163,06

Table 5 shows that the minimum stand on the *transformer* and the minimum voltage on *the bus* are the same, which is 159.99 - 163.06 *kV*. The maximum working voltage on the Substation is 165 *kV*, so the voltage on the *transformer* and the voltage on the *bus* do not exceed the maximum working voltage after being struck by lightning.

5. Comparison of Simulation and Analysis Results with *Lightning Arrester* Specifications and *Transformer Specifications*

Table 6. Comparison of simulation and analysis results with *lightning arrester specifications*

	Simulation and Analysis Results	**LA Specifications**
Maximum working voltage analysis	165 *kV*	170 *kV*
Rated voltage	132 *kV*	132 *kV*
Maximum working voltage simulation	159.99 - 163.06 *kV*	165 *kV*
Discharge current	4.02 kA	10 kA
Leakage current	0.5 - 0.6 mA	1.5 mA

Table 6 shows that the results of the lightning arrester working voltage analysis are 165 kV, so it does not exceed the specification of the lightning arrester, which is 170 kV. The rated voltage of the lightning arrester analysis results is 132 kV so that it does not exceed the system requirement of 132 kV. The simulated working voltage after lightning current is 159.99 – 163.06 kV so that it does not exceed the needs of the lightning arrester system, which is 165 kV. The discharge current of the lightning arrester analysis results is 4.02 kA, so it does not exceed the specification of 10 kA. The leakage current of the lightning arrester is 0.5 -0.6 mA, so it does not exceed 1.5 mA.

Table 7. Comparison of analysis results with *transformer specifications*

	Analysis Results	***Transformer Specifications***
Maximum voltage of transformer when struck by lightning	223.25 - 304.57 *kV*	650 *kV*

Table 7 can be analyzed that the maximum voltage when struck by lightning is 223.25 - 304.57 kV so that it does not exceed the BIL of the transformer, which is 650 kV.

IV. CONCLUSION

1. The peak lightning current that LA is able to cut is above 98%. The peak current of lightning in the *PSCAD* simulation is *set at 5* - 35 kA, resulting in the value of the current flowing to the lightning arrester is 4.45 - 31.12 *kA, the current cut by* the lightning arrester is *4.39 - 30.77* kA, so that the current flowing to the *trabsformator* does not exceed 10 kA. *The voltage on the* transformer is 223.25 - 304.57 kV and the voltage on the *bus is* 213.15 - 272.02 *kV, so it does not exceed* the basic insulation level *(*BIL) *on the transformer*, which is 650 kV*.*
2. The maximum distance between the lightning arrester and the transformer is *10.95* meters, *while the distance between* the lightning arrester and *the* transformer installed at the Ampenan substation *is 50* kV*, thus the placement* of the *lightning arrester* against the *transformer* The protected one is below the maximum value, because the installed distance is less than the calculated distance.
3. The lightning arrester *leakage current* is in good condition, which is 0.5 – 0.6 *mA, so it is still below 1.5* mA*, while the temperature difference on the* LA *ground* wire is 1 ^{OC} so that it is possible that there are abnormalities between *phases* and need further investigation in *phase R* with S *and* phase T *with R* in condition *I*.

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