Grounding System With Top Grounding Method on Overhead Transmission Lines of Langsa - Lhokseumawe

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Abstract

Continuity of electricity distribution is the most important thing in the industrial sector. A momentary disruption in distribution can cause significant losses. This is certainly a challenge so that the electricity supply is always available in any condition. One way that can be done to overcome the increase in excess current in the channel due to lightning strikes is by installing grounding with the Top Grounding method. It is known that the overhead transmission lines of Langsa - Lhokseumawe is one of the radial backbone lines of the Aceh system. Based on the disturbance in the first semester of 2024, there have been 4 lightning strikes on this line. This is certainly a small number, but every year there are always lightning strikes that cause equipment trips. The consequences are very significant because they can disrupt the optimization of the Arun PLTMG and Nagan Raya PLTU. Furthermore, if these two power plants are not ready when the Langsa - Lhokseumawe SUTT trip occurs, the Aceh system could enter a Black Out condition or total blackout. The factors that influence the determination of the location point for placing Top Grounding are based on the tower that is most often struck by lightning and including the resistance of the soil around the tower. Before being implemented, this system was simulated using the ATP Draw application.

Keywords: ***Top Grounding, ATP Draw***

Introduction

As the manager of Transmission and Main Substation, UPT Banda Aceh is obliged to maintain the reliability of Transmission and Main Substation in the Aceh Subsystem. The working area of UPT Banda Aceh with 22 Substation and 2,970 towers spread along the east and west coasts of Aceh Province with a circuit length of 1,965.65 kms. With the length of the circuit, the vulnerability to disturbances due to lightning strikes is quite large, especially for segments with a fairly high level of lightning strikes. This is in line with the number of lightning strikes that occurred throughout 2019 - 2022 on transmission towers as many as 99,928 lightning strikes with an average number of strikes of 2,081 per month, of which 112 resulted in disturbances.

If there is a disturbance in the Aceh system which is still radial, it is very susceptible to widespread disturbances or even to System Blackout. For this reason, it is necessary to install reliable lightning protection on the Tower which is able to channel lightning strikes to the ground properly. In the Langsa-Lhokseumawe segment, several lightning protection methods have been installed, but the results have not been optimal. Therefore, for a more reliable lightning protection installation, a simulation must be carried out first on the ATP Draw application to obtain a better method

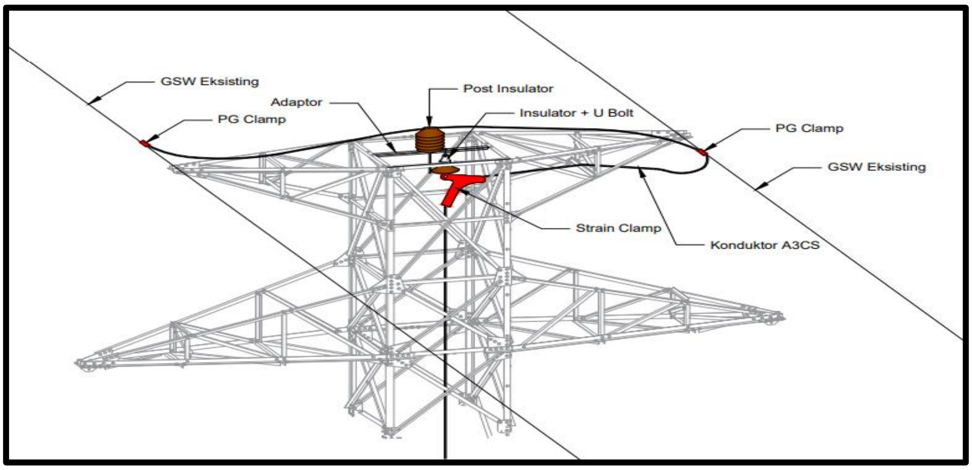
Research Methodology

The research method used in this study is a numerical simulation approach based on software modeling, aimed at analyzing the performance of lightning protection systems on transmission lines using the ATPDraw (Alternative Transients Program Draw) application. The study begins with the collection of technical data, including tower geometry, conductor specifications, insulator characteristics, grounding resistance, and lightning current parameters based on IEC standards. A detailed transmission line model is then developed in ATPDraw, representing the tower as a multi-segment variable-impedance transmission line, along with ground wires, phase conductors, and grounding systems. Lightning is simulated using a current source with standard impulse waveforms such as 8/20 µs or 10/350 µs to assess the system's response to direct strikes. The simulation results, which include transient voltages and current distribution, are analyzed to determine the occurrence of backflashover or overvoltages exceeding insulation withstand levels. Through this approach, the study provides insights into the effectiveness of lightning protection and the influence of various technical parameters on system performance

The following is the design and calculations required:

1. Top Grounding Metode

Here is the design used:



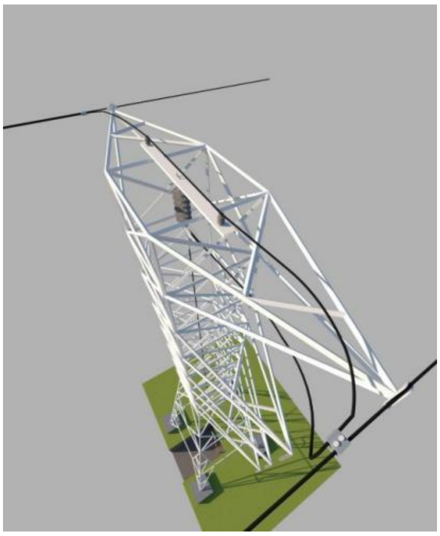


Figure 1. Top Grounding Design

Meanwhile, the grounding design with coupling electrodes is as follows:

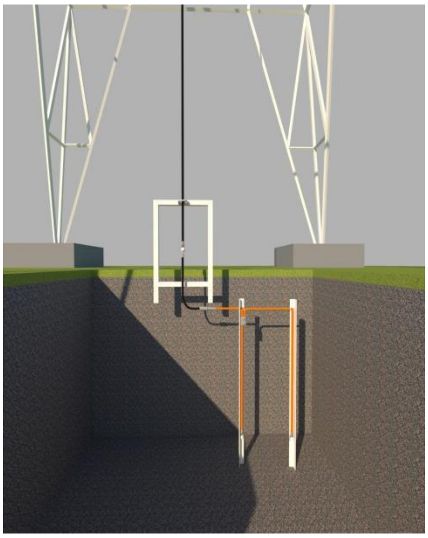


Figure 2. Coupling Electrode Design

2. Calculation of Grounding System Parameters

2.1 Grounding system with electrode length 5.35 m, diameter 3 cm and distance between electrodes 11.7 m

a. Resistansi Value

Using formula $R = \frac{\rho}{2\pi n L} . \ln\left(\frac{2L}{\sqrt[4]{2^{0,5} \cdot s^3 \cdot r}}\right)$

Information

Table 1. Parameter Resistance Value

Symbol	Description	Value
R	Total resistance to ground (Ohm)	
ρ	Soil resistivity (Ohm·meters)	30
L	Soil resistivity (meters)	5.35
n	Number of ground rods	2
r	Electrode radius (meters)	0.03
s	Distance between ground rods (meters)	11.7
ln	Natural logarithm (basis e)	

Step 1: Calculate the inside of the logarithm

$$\sqrt[4]{2^{0,5} \cdot s^3} = \sqrt[4]{1,4142 \cdot (11,7^3)} = \sqrt[4]{1,4142 \cdot (1602,2)} = \sqrt[4]{2265,9} \approx 6,72$$

$$\frac{2L}{6,72 \cdot r} = \frac{2 \cdot 5,35}{6,72 \cdot 0,03} = \frac{10,7}{0,2016} \approx 53,07$$

$$\ln(53.07) \approx 3.970$$

Step 2: Calculate the outside factors of the log

$$\frac{\rho}{2\pi nL} = \frac{30}{2 \cdot \pi \cdot 2 \cdot 5,35} = \frac{30}{67,23} \approx 0,446$$

Step 3: Calculate the outside factors of the log

$$R = 0,446 \cdot 3,970 \approx 1,77\Omega$$

b. Inductance value

Using formula $L=2l\left(\ln\left(\frac{4l}{\sqrt[4]{2^{1/2} \cdot s^3 \cdot r}}\right)10^{-7}\right.$

Information

Table 2. Parameter Inductance Value

Symbol	Description	Value
L	Inductance (Henry)	
l	Length of rod/conductor (meters)	5.35
s	Distance between bars or structural elements (meters)	11.7
r	Radius of the rod/conductor (meters)	0.03
in	Natural logarithm	
×10−7	Conversion factors from physical units	

Step 1: Calculate the inside of the logarithm

$$\sqrt[4]{2^{1/2} \cdot s^3} = \sqrt[4]{1{,}4142 \cdot (11{,}7)^3} = \sqrt[4]{1{,}4142 \cdot 1602{,}2} = \sqrt[4]{2265{,}9} \approx 6.72$$

Penyebut dalam log $= 6{,}72 \cdot 0{,}03 = 0{,}2016$

$$\frac{4l}{0{,}2016} = \frac{4 \cdot 5{,}35}{0{,}2016} = \frac{21{,}4}{0{,}2016} \approx 106{,}15$$

$\ln(106{,}15) \approx 4{,}666$

Step 2: Calculate the inductance L

$$L = 2 \cdot 5{,}35 \cdot 4{,}666 \cdot 10^{-7} = 10.7 \cdot 4{,}666 \cdot 10^{-7}$$

$$\approx 49{,}93 \cdot 10^{-7}$$

$L \approx 4.99 \times 10^{-6} H = 4{,}99\ \mu H$

$L \approx 4{,}99\ \mu H$

c. Capacitance value

Using formula $C = \frac{\varepsilon r \cdot l}{18 \cdot In\left(\frac{4l}{r}\right)}$

Information

Table 3. Parameter Capasitive Value

Symbol	Description	Value
C	Capacitance (Farad)	
εr	Relative permittivity of the medium (soil or air)	10
l	Length of conductor (meters)	11.7
r	Radius of conductors (meters)	0.03
in	natural Logarithm (basis e)	

Step 1: Calculate the inside of the logarithm

$$\left(\frac{4l}{r}\right) = \frac{4 \cdot 5{,}35}{0{,}03} = \frac{21.4}{0{,}03} \approx 713{,}33$$

$\ln(713{,}33) \approx 6{,}570$

Step 2: Calculate the Capacitance

$$C = \frac{30 \cdot 5{,}35}{18 \cdot 6{,}570} \cdot 10^{-9} = \frac{160{,}5}{118{,}26} \cdot 10^{-9} \approx 1{,}357 \cdot 10^{-9}$$

$C = 1{,}36$ nF

2.2 Calculating Tower Body Parameters

Based on Chapter 5.3.5 – Tower as a variable-impedance transmission line of Procedures for Estimating the Lightning Performance of Transmission Lines – New Aspects from Cigre describes as follows:

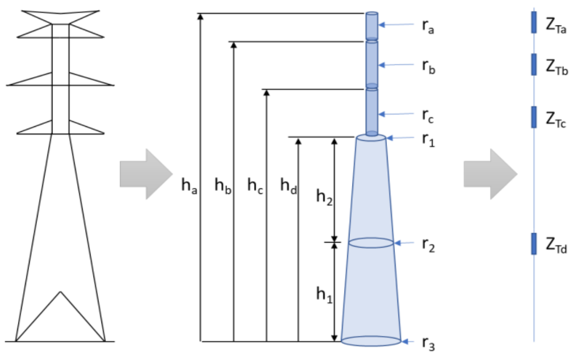


Figure 3. Tower Impedance Modeling

So a simulation model can be created in the ATP Draw application as follows
The design creation steps are as follows:
1. Create a new project
2. Select the 3-phase system template
3. Right-click on the canvas, select the desired components to create a tower design
4. Add Voltage Probe and Current Probe to monitor voltage and current strikes
5. Fill in the data according to table 4
6. Save

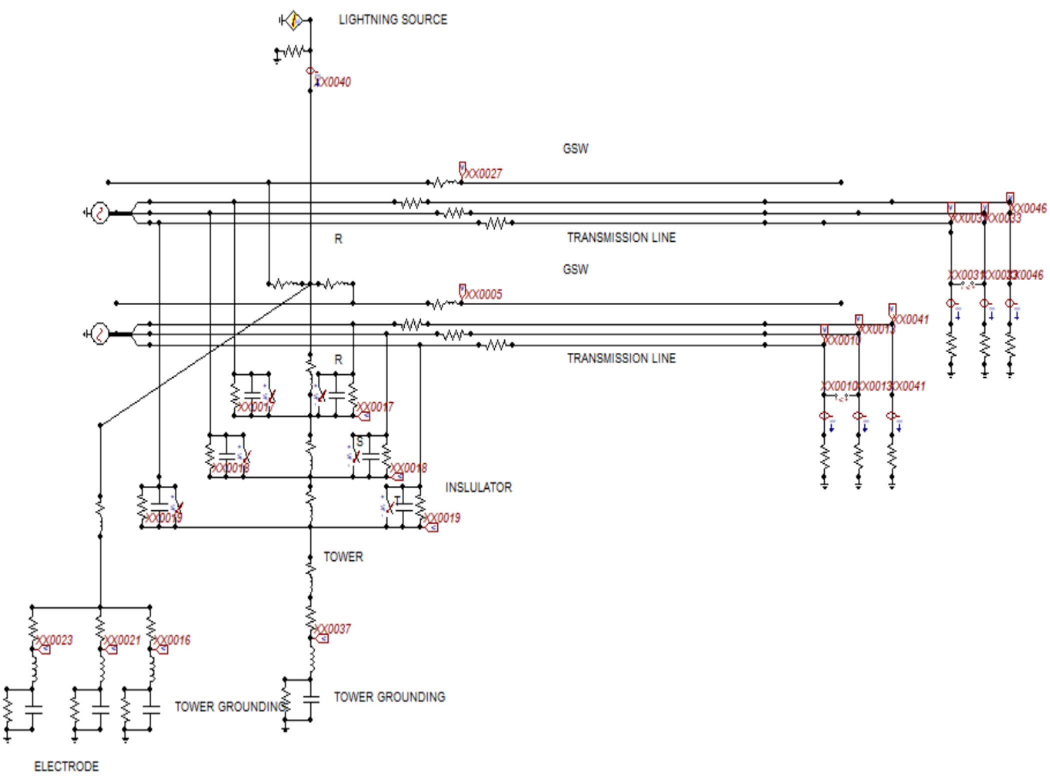


Figure 4. Simulation Model

From this model, the following parameters can be determined:

Table 4. Parameters

No.	Parameters	Value	Unit	information
1	BIL Isolator	750.000	kV	Impulse Voltage Limit of Isolator 120 kN 150 kV
2	Isolator Resistance	20	kΩ	Low value
3	Isolator Capacitance	100	pF	Low value
4	Isolator Capacitance	0.1	Ω	Low value
5	Isolator Capacitance	0.1	Ω	Low value
6	A3CS Down Conductor Resistance	0.3	Ω	Low value
7	Bottom Tower Impedance	82	Ω	
8	Middle Tower Impedance	110	Ω	
9	Middle Tower Impedance	150	Ω	

Results

Running the ATP Draw Application

Simulation of transient disturbances due to lightning using atpDraw software. With the strike parameters ranging from 50kA to 190kA, the following results were obtained.

Table 5. lightning strike

No.	lightning strike (kA)
1	50
2	80
3	100
4	120
5	140
6	160
7	180
8	190

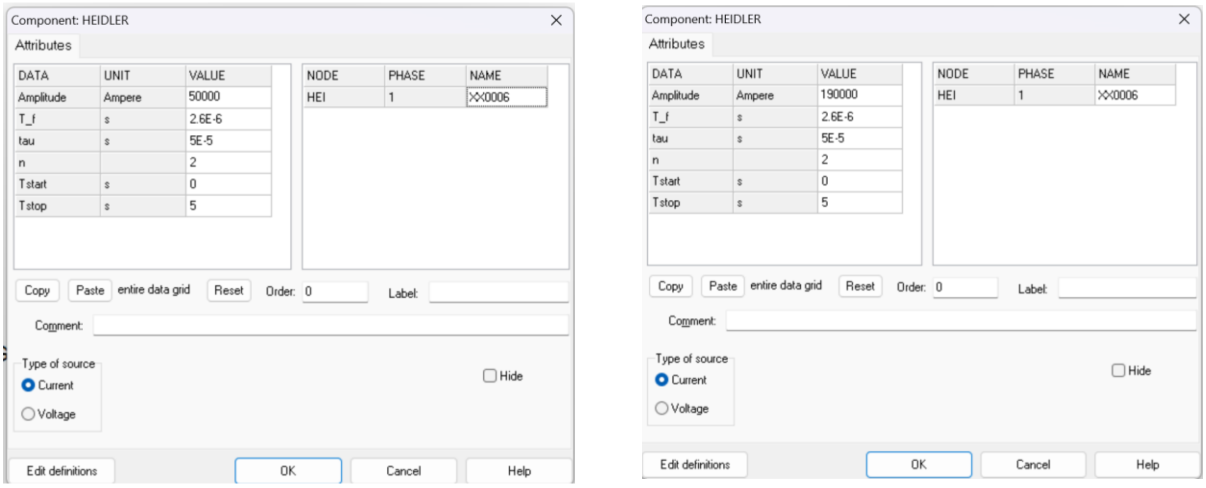
The steps to input lightning strikes are as follows:

1. Double Click on the lightning source/current source, on the following logo:

Figure 5. lightning source/current source logo

2. Input the desired lightning strike value according to the previous table

Figure 6. Lightning Strike Input on Application

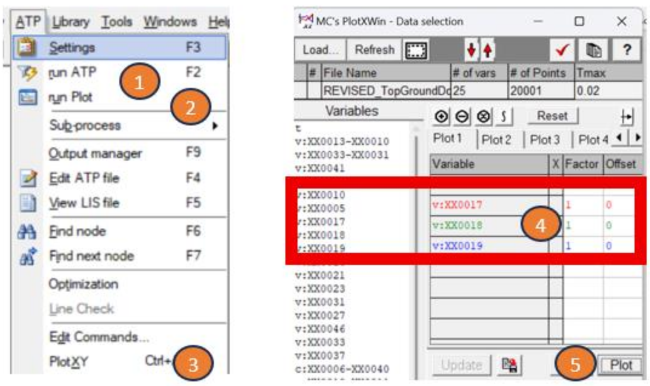


Simulation Results

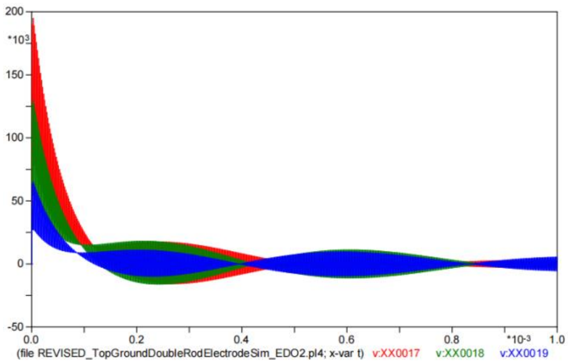
Steps to run the application are as follows:

1. On the ATP Tab - Click Run ATP, a command prompt appears, click enter
2. Click RUN Plot – PLOTXY
3. Select the insulator whose lightning current you want to display
4. Click Plot
5. A current graph appears on the insulator

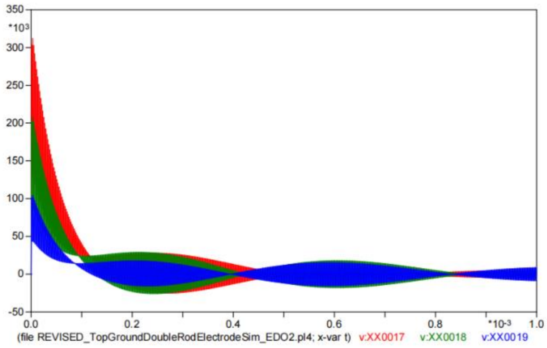
Figure 7. Steps to run the application



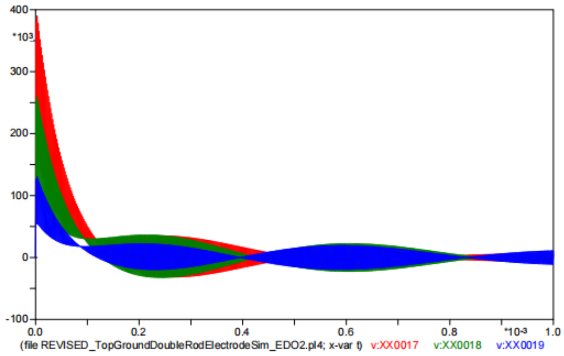
The following is a graph of the results of running the application according to the desired lightning strikes.



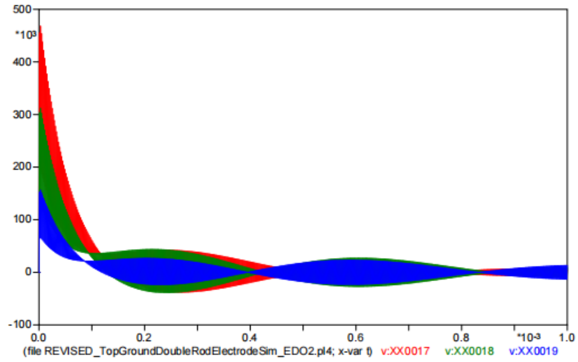
Lightning Strike 50 kA



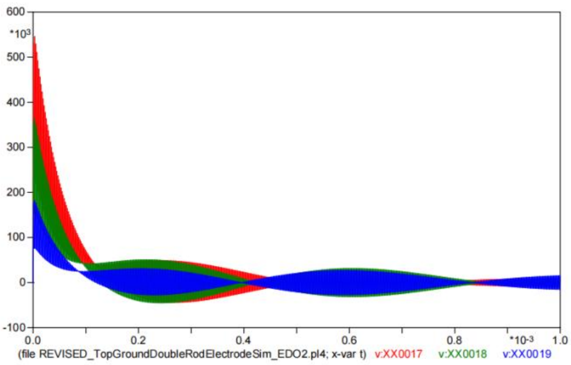
Lightning Strike 80 kA



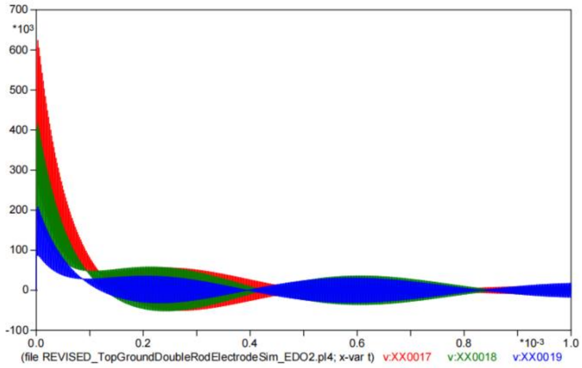
Lightning Strike 100 kA



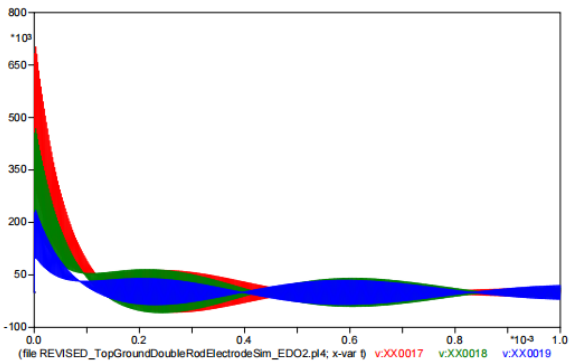
Lightning Strike 120 kA



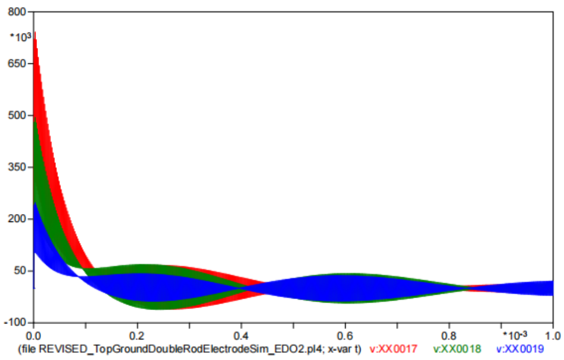
Lightning Strike 140 kA



Lightning Strike 160 kA



Lightning Strike 180 kA



Lightning Strike 190 kA

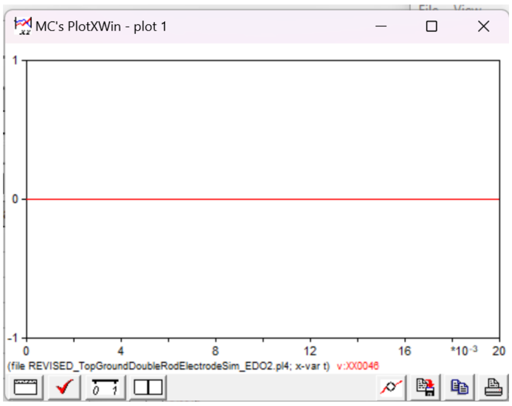


Figure 8. Lightning impulse does not penetrate the insulator plate

From the simulation results in the graph above, the lightning impulse voltage can be obtained as follows:

Table 6. lightning strike results

No.	lightning strike (kA)	Tegangan Impuls (kV)
1	50	190
2	80	310
3	100	390
4	120	470
5	140	550
6	160	620
7	180	690
8	190	750

Because the magnitude of the voltage induction on the tower body can be reduced to 750 kV at a maximum lightning strike of 190 kA, the insulator is still able to withstand lightning impulses so that it can increase the reliability of isolation from lightning impulse disturbances.

Influencing Factors
1. Making a Simulation design by considering the connection of all equipment
2. Grounding Design and its parameter values
3. The type of soil moisture used determines the length of the electrode used

Conclusion

Based on the results of the top grounding installation simulation overhead transmission lines of Langsa - Lhokseumawe, the following conclusions were obtained:

This simulation uses a moist medium (soil) resistivity with a value of 10 ohms, capable of withstanding lightning impulses of up to 190 kA with an impulse voltage generated of 750 kV which is still in accordance with the Isolator BIL. So the insulator is still able to withstand lightning impulses so that it can increase the reliability of isolation from lightning impulse disturbances.

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