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Insulation Coordination System 150kV Substation and Transmission Line against Lightning Surge Interference in Nickel Smelting Plant

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Abstract

Related with the increasing demand for electrical energy at nickel smelting plant, a highly reliable electric power system is needed to be able to supply important loads such as electric furnaces and auxiliary equipment. The electric power system delivers electrical power to consumers through substations and transmission lines. The distribution of electrical power through high voltage overhead lines sometimes goes through areas with a high enough lightning strike potential that it can cause sudden blackouts due to direct strikes and back flashovers. Therefore, it is necessary to insulation coordination of the substation and transmission line to avoid damage to electrical equipment. This research aims to determine the magnitude of the voltage due to lightning strikes on GSW and Conductor by varying the location of the lightning protection system on 150 kV overhead line which is useful for obtaining isolation coordination systems on transmission lines and substations in the nickel smelting plant. This research using the specific methodology and approach with a survey to collect data transmission tower specifications, tower grounding resistance, arrester and other supporting data and then create the data that has been collected into the model that has been developed in ATPdraw Software. Next, a simulation of lightning stroke on GSW and conductors without lightning protection such as Transmission line Arrester (TLA) and direct grounding that connected on GSW. This research was carried out by selecting lightning strikes in the current strike of 40 kA, 80 kA and 100 kA on transmission line and GSW with varying grounding resistance of 5 Ω, 10 Ω and 16 Ω which are simulated using ATPdraw software. This research showed that the installation of lightning protection equipment on high-voltage overhead lines and transmission towers resulted in a significant voltage drop due to lightning strikes and not exceed BIL of the existing insulators.

Keywords: Lightning strike, transmission line, ATP draw, Basic Insulation Level (BIL), Ground Static wire (GSW)

1. Introduction

The 21st century is a very modern era, where technology is developing very rapidly, and electrical energy has become a basic and very important need. Transmission lines are one of the main technological parts in the process of providing electrical energy. If there is interference on the transmission line, it will also cause interference and affect equipment connected to the electric power system [1].

One of the large users of electrical energy is industry, in this case will be discussed as the research object is the nickel smelting industry. The location of the nickel smelting industry is PT Vale Indonesia (PTVI) Sorowako, South Sulawesi which is surrounded by forests, three lakes and mountains that are prone to lightning strikes. The PTVI transmission line is in that location and is often hit by lightning strikes, that the transmission line is a very important asset in distributing electrical energy for the nickel smelting process [2]. Based on the Sorowako lightning density map [3] and PT Vale Indonesia's electric power system disturbance data 2009 - 2024, 14% is caused by lightning strikes on the transmission line and substation, the Sorowako area has a high lightning density. This is reinforced by several insulators damaged on the 150 kV transmission line due to the over voltage value caused by lightning strikes exceeding the Basic Insulation Level (BIL) of the existing insulator, causing Flash over on the isolator.

Lightning arises due to potential differences between clouds and the earth. Separation of charges in clouds is a process because clouds move continuously and regularly, and during their movement the clouds rub against other clouds, causing negative charges to gather on one side of the cloud (top or bottom), as well as positive charges to gather on the opposite side [4]. If the potential magnitude is different enough between the cloud and the earth to a large value, there

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will be a discharge of negative charges from the cloud to the earth or vice versa, which is intended to reach equilibrium between the charges. Air is the medium that electrons will pass through in this charge discharge process.

Over voltage occurs on High Voltage transmission line can detained deep time limited. Based on the source, IEC created classification over voltage become over voltage sourced from lightning, over voltage sourced of switching and temporary over voltage. Over voltage sourced from lightning that occurs in the system power electricity due to two types of strike, that is direct strike and indirect strike. On the transmission line, direct strike can occur on the transmission tower parts such as wire phase, ground wire and tower. Meanwhile Indirect is strike to the ground near tower transmission line. For High voltage transmission line 150 kV, interference due to indirect strike can ignored. When a lightning strike occurs on a high voltage transmission line, the voltage will rise in the line and the surge over voltage will propagate to the end of the line [5].

If the over voltage value exceeds the BIL value of the insulator it will cause Back Flashover. Regarding the threat of traveling waves coming from overhead lines so as not to damage the insulators and equipment in the substation, protection devices such as direct grounding connected to GSW, and surge arresters are needed to cut the traveling waves entering the substation, towers, and transmission line. Correlation between the insulation strength of electrical equipment, electrical circuits, and protective devices so that the insulation of the equipment is protected from the dangers of overvoltage technically and economically. This is referred to as Isolation Coordination in the electric power system [6]. Good isolation coordination will be able to guarantee that: the equipment insulation will be able to withstand normal system working voltages and abnormal voltages that may arise in the system, the equipment insulation will fail only if an external overvoltage occurs and if failure occurs, it will only be in places that have been calculated and cause minimum damage.

The research on insulation coordination systems for a 150kV substation and transmission line in a nickel smelting plant offers significant benefits to the field of data science. Firstly, the study involves the collection, processing, and analysis of extensive electrical and environmental data. By leveraging data science techniques, such as statistical analysis and machine learning, researchers can identify patterns and correlations in lightning strike incidents, grounding resistance, and voltage surges. This allows for more accurate prediction models and improved decision-making processes in designing and implementing effective lightning protection systems. Additionally, the use of simulation software like ATPdraw in this research provides a rich dataset that can be used for further data-driven insights. By analyzing the simulation outputs, data scientists can develop optimization algorithms to enhance the performance of insulation coordination systems. This can lead to the creation of predictive maintenance schedules, minimizing downtime and maximizing the reliability of the power system. The integration of data science in this research not only advances the field of electrical engineering but also contributes to the development of smart, data-driven solutions in industrial power systems.

This research aims to determine the magnitude of the voltage on the 150 kV transmission tower which arises due to lightning strikes on GSW and conductors as well as varying the locations of the arresters on 150 kV overhead line which is useful for obtaining isolation coordination systems on transmission lines and substations in PT Vale Indonesia. This research was carried out by selecting lightning strikes in the current strike between 40 kA and 100kA on ground wire and conductor with varying grounding resistance between 5 Ω and 16 Ω with simulation use device Alternative Transient Program draw software [7]. from the results of Previous studies showed that the installation of lightning protection equipment on high-voltage overhead lines and transmission towers resulted in a significant voltage drop due to lightning strikes lowering under basic insulation level of existing insulators 9 disc.

2. Literature Review

The 150 kV high voltage transmission line will be represented in the form of surge impedance or inductance. The overvoltage that occurs in the tower as surge impedance is directly proportional to the peak current, while in the tower as inductance the overvoltage is directly proportional to the steepness of the current. The surge impedance of the tower is derived from the geometric shape of the tower [8]. In transmission lines there are three types of towers, namely (a) Square, (b) Gantry, and (c) Corset as shown in figure 1.

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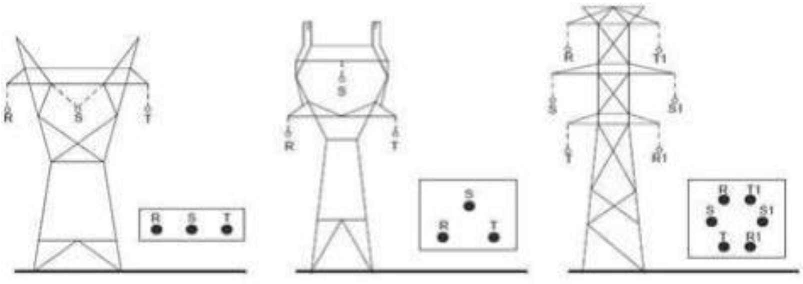

(a) (b) (c)

Figure 1. Transmission tower type

The tower used in the research is type A. Based on figure 2, the transmission tower surge impedance modeling is divided into several parts, namely, modeling the tower legs, and modeling the tower arms and according to [9]. The formula used to determine the value of each item in the tower:

$$\mathrm{Ri} = \frac{-2\mathrm{Zt1}\ \ln\sqrt{\gamma}}{\mathrm{h1+h2+h3}}\ \mathrm{hi} \quad (\mathrm{i} = 1,2,3) \tag{1}$$

$$\mathrm{R4} = -\mathrm{Zt2}\ \ln\sqrt{\gamma} \tag{2}$$

$$\mathrm{Li} = \propto\ \mathrm{Ri}\ \frac{2\mathrm{H}}{\mathrm{Vt}} \tag{3}$$

$$\mathrm{H} = \mathrm{h1} + \mathrm{h2} + \mathrm{h3} + \mathrm{h4} \tag{4}$$

Note: Zti = Tower surge Impedance; Vt =Surge propagation velocity ($300\frac{m}{\mu s}$); γ=Attenuation coefficient (0.7); α=Damping coefficient (1); R: Damping resistance; L= Damping inductance.

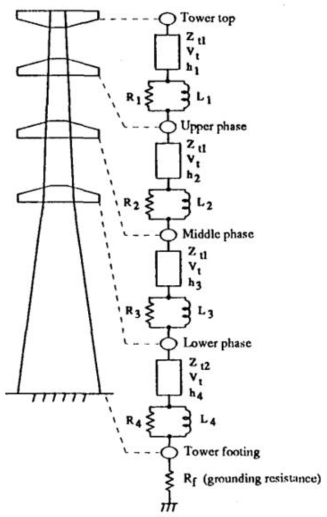

Figure 2. Transmission Tower Model

A transmission tower as a cylinder and considering that the depth of true ground below earth's surface can be disregarded and h>>r [9], its surge impedance is simplified and given by:

$$\mathrm{Z_t} = 60\left[\ln\left(\frac{\mathrm{H}}{\mathrm{R'}}\right) - 1\right] \tag{5}$$

Note: Zt = Tower Impedance (Ω); R'= equivalent radius of the tower (m); and H = Tower Height (m)

Activities to minimize the occurrence of internal and external disturbances to prevent damage to equipment caused by lightning strikes is to install arresters. An arrester is installation safety device resulting from overvoltage disturbances caused by lightning strikes or electrical surges. The arrester is tasked with protecting the insulation or securing the installation from overvoltage disturbances caused by lightning strikes or high transient voltages from electrical equipment [10], [11].

In electric power systems, arresters are one of the main equipment for insulation coordination. When a surge arrives at substation, the arrester will release abnormal electrical charges and voltages that will affect the substation and its equipment so that interference can be reduced [12]. Arrester equipment has thermal resistance, which is able to withstand energy from current continuation, and must be able to break it [13].

For modeling the lighting arrester in ATP draw, the IEEE standard model [14] is used as shown in figure 3 below:

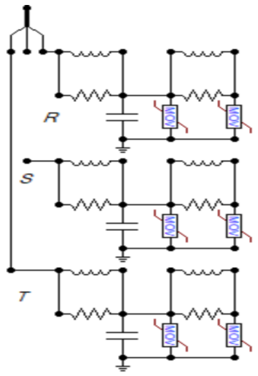

Figure 3. Model of Arrester IEEE

Figure 3 shows IEEE arrester model [15]. There are two non-linear resistance which were separated by resistor and inductor connected parallel. In this model, capacitor represents the height of arrester. The IEEE arrester parameter could be calculated by 6 until 10:

$$\mathrm{Lo} = 0.2 \times \frac{d}{n} \quad (6)$$

$$\mathrm{Ro} = 100 \times \frac{d}{n} \quad (7)$$

$$\mathrm{L1} = 15 \times \frac{d}{n} \quad (8)$$

$$\mathrm{R1} = 65 \times \frac{d}{n} \quad (9)$$

$$\mathrm{C} = 100 \times \frac{n}{d} \quad (10)$$

Note: Arrested height in meter; n= amount of parallel column from metal oxide.

In this research, the Arrester model was used according to IEEE standards with arrester height =2.099 meter. The values of these parameters are Ro = 209.9Ω; R1 = 136.435 Ω; Lo= 0.4198 µH; L1 = 31.485 µH; and C = 47.64 µF.

For Modelling the source of lightning strikes in the ATPdraw 7.2 application using the Heilder component and connected to a resistor. The lightning source used in this research is IEC, with a magnitude of 40 kA, 80kA and 100 kA. The lightning source in the application is modeled as in the figure 4 below.

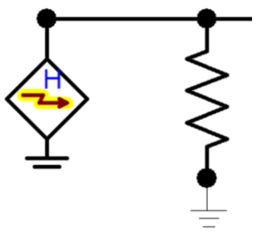

Figure 4. Source of Lightning Strike in ATPdraw

This research began with a survey to collect data such as transmission tower specifications, BIL of several electrical equipment in substation (average 750kV) and other supporting data. Then model the transmission line parameters into the ATP software and enter the data that has been collected into the model that has been developed [16], [17], [18]. Next, create simulation with lightning stroke 40 kA, 80 kA and 100kA on GSW near tower 1 with grounding resistance is 5 Ω, 10 Ω, and 16 Ω with and without installing direct grounding connected to the GSW and then create simulation with lightning stroke 40 kA, 80 kA and 100kA with grounding resistance is 5 Ω, 10 Ω and 16 Ω on phase conductors with and without TLA. Then view and analyze the over voltage readings in each simulation that has been carried out.

Figure 5 illustrates the modeling of a 150 kV transmission line from tower 1 to tower 6 with a lightning strike model connected to the GSW near tower 1 using ATP draw software without installing a TLA on the tower and direct grounding connected to ground wire.

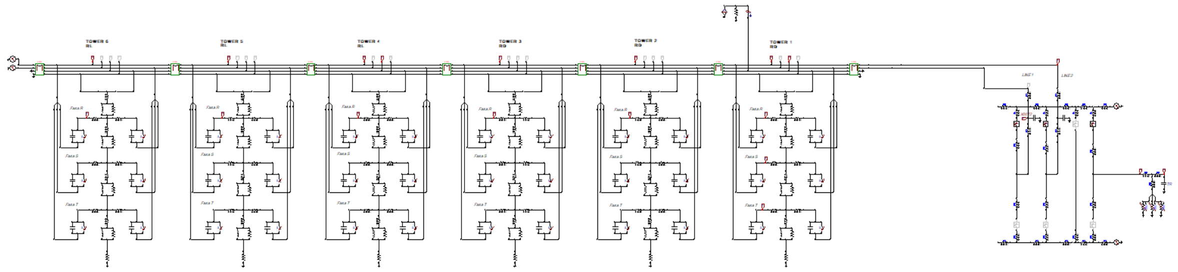

Figure 5. Transmission line and lightning strike modeling using ATP draw without TLA and direct grounding

Figure 6 illustrates the modeling of a 150 kV transmission line from tower 1 to tower 6 with a lightning strike model connected to the ground wire near tower 1 using ATP draw software with direct grounding connected to the ground wire on tower 1 and substation.

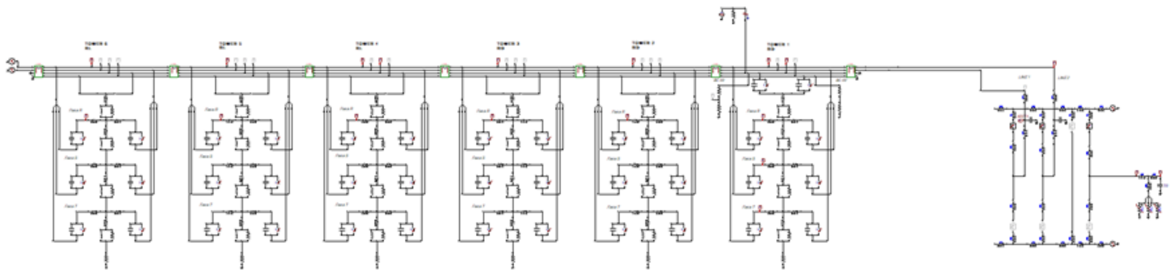

Figure 6. Transmission line and lightning strike modeling using ATP draw with direct grounding.

Figure 7 illustrates the modeling of 150 kV transmission line from tower 1 to tower 6 with a lightning strike model connected to the phase conductor near tower 1 using ATP draw software without installing Transmission line arrester.

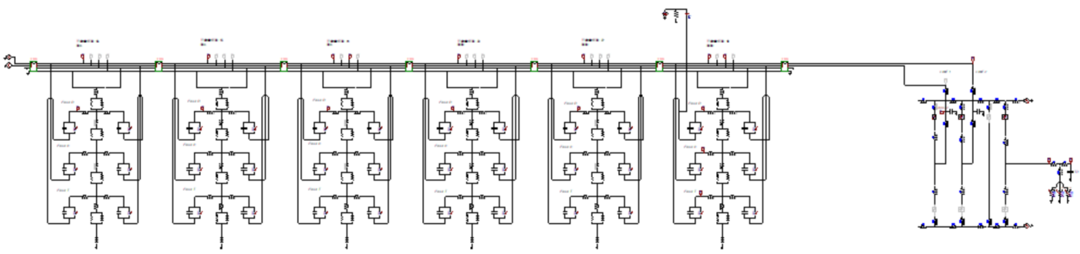

Figure 6. Transmission line and lightning strike at Conductor modeling using ATP draw without installing TLA

Figure 8 illustrates the modeling of 150 kV transmission line from tower 1 to tower 6 with a lightning strike model connected to the conductor near tower 1 using ATP draw software with installing Transmission line Arrester on tower 1 and substation.

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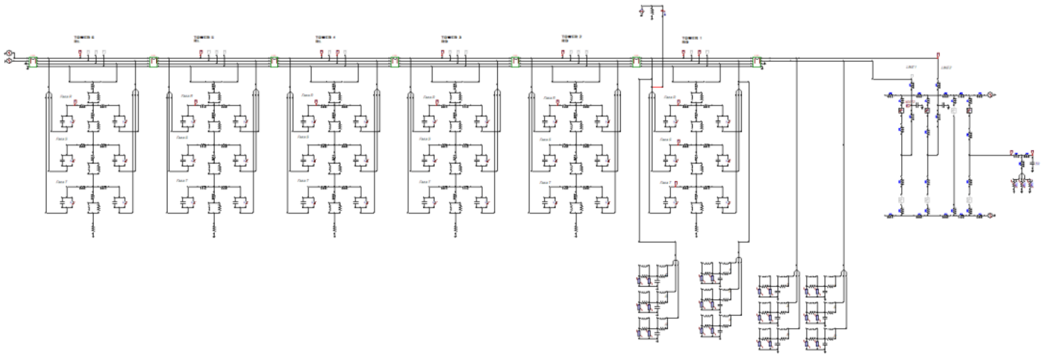

Figure 7. Transmission line and lightning strike at Conductor modeling using ATP draw with installing TLA in Tower 1 and Substation

For compare results chart from for circuits that use arresters and do not use arresters, a comparison formula is used:

$$\% \text{ reduce } = \frac{V1 - V2}{V1} \text{ x } 100\% \tag{11}$$

Note: V1 = peak voltage value before installing the arrester; and V2 = peak voltage value after installing the arrester.

3. Results and Discussion

In this study, a direct strike was carried out on the tower because a direct strike on the tower can cause greater damage than an indirect strike. A direct lightning strike is where a lightning strikes directly at the tower, the strike at the tower can hit the ground wire and the phase wire. The simulation is carried out with the condition of lightning striking a ground wire which is assumed to be in 2 scenarios, namely the scenario before using protection and the scenario after using protection (TLA and direct ground) with the face time and tail time of the lightning current according to IEC standards is 8/20 µs. The analysis is carried out by looking at the voltage characteristics when lightning strikes the ground wire and conductor before and after installing the lightning protection system.

3.1. Simulation of lightning strikes on GSW

The simulation results of a lightning strike 100 kA with grounding resistance 10 Ω on a ground wire without direct grounding connected to the GSW can be seen in Figure 9, and with direct grounding installed, it can be seen in Figure 10.

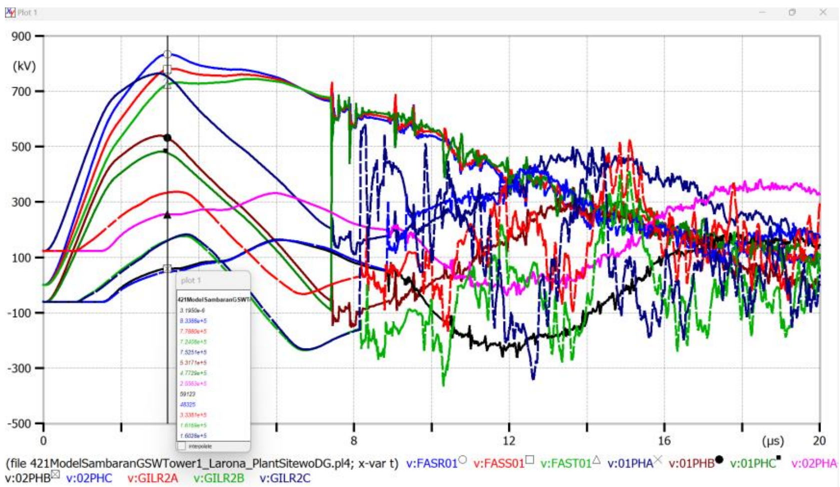

Figure 8. Voltage wave due to lightning strikes on GSW without direct grounding

From the graph in figure 9, it is obtained: near tower 1 phase A :833 kV, phase B=778 kV and phase C 724 kV. This value comes from the voltmeter reading on the ATP draw modeling which is installed near the insulator of each phase.

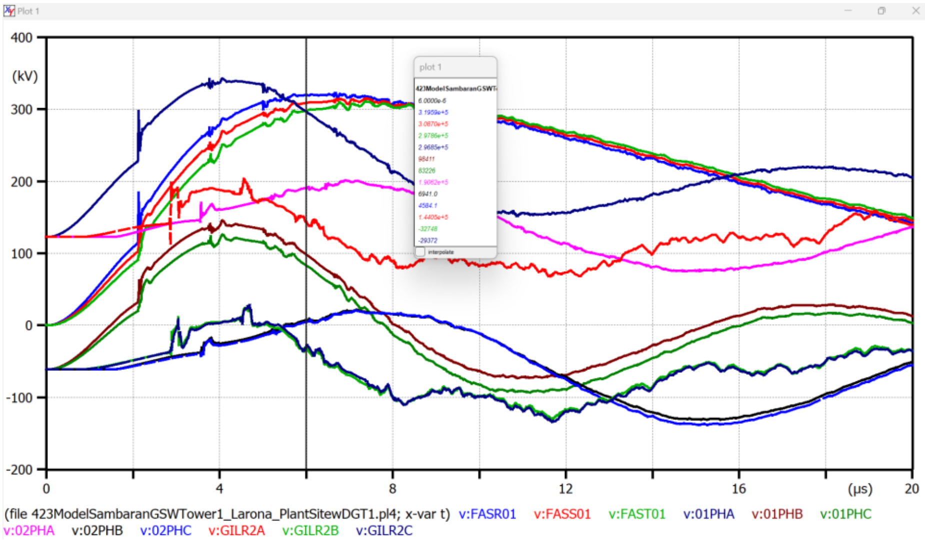

Figure 9. Voltage wave due to lightning strikes on GSW with installing direct grounding

From the graph in figure 10, it is obtained: near tower 1 phase A :319 kV, phase B=308 kV and phase C 287 kV

Figure 9 shows the increase in voltage on the phase A tower arm of 833 kV due to lightning strike 100 kA on the GSW without any additional protection on the tower, and the voltage value on the phase A will cause a back flashover [19], [20]. The voltage value measured on the phase A exceeds the BIL of the 9 insulator pieces is BIL 730 kV that installed on the transmission tower so that it can cause short circuit disturbances in the electrical system. Meanwhile, figure 10 shows the voltage drop on tower 1 is 62% with value 319 kV by installing direct grounding connected to the GSW, so that it does not cause back flashover in the electrical system.

Based on the modeling in figure 5 and 6, the simulation then continues by injecting lightning currents of 40 kA, 80kA and 100 kA on GSW with varying grounding values of 5 Ω, 10 Ω and 16 Ω. The simulation is carried out with 2 conditions, namely when there is no direct grounding installed which is connected to the ground wire at transmission tower No. 1 and the substation, see table 1 and when direct grounding is installed, see table 2 the results of this simulation can be seen in the following tables:

Table 1. Voltage peak due to lightning strikes on GSW near tower 1 without direct grounding

Surge current (kA)	Phase	Peak Voltage (kV) with grounding resistance16 Ω				Peak Voltage (kV) with grounding resistance 10 Ω				Peak Voltage (kV) grounding resistance 5 Ω			
		Arm Tower 1	Phase Cond. Tower 1	Phase Cond. Tower 2	Substation Larona	Arm Tower 1	Phase Cond. Tower 1	Phase Cond. Tower 2	Substation Larona	Arm Tower 1	Phase Cond. Tower 1	Phase Cond. Tower 2	Substation Larona
100	A	1047	917	302	384	833	752	255	338	649	612	221	292
	B	999	697	231	224	778	531	161	160	585	388	98	108
	C	953	637	96	106	724	477	48	59	521	335	13	24
80	A	833	763	264	328	665	632	228	289	519	511	201	258
	B	793	549	165	160	619	416	112	110	469	296	79	75
	C	754	500	70	62	573	373	34	24	418	255	-11	68
40	A	412	444	191	223	259	317	162	190	295	207	161	189

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	B	391	245	2.8	45	234	118	-26	7	259	310	-26	5.7
	C	370	220	-1.8	47	209	97	-31	3.1	233	119	-31	1.6

Note: < Basic Insulation Level of Existing insulator 9 disc (730 kV); >Basic Insulation Level of existing insulator 9 disc(730kV)

The table above shows that a lightning strike on a ground wire of 100 kA with a ground resistance value of 10 Ω and 16 Ω and a lightning strike of 80 kA with a ground resistance of 16 Ω causes BFO. Meanwhile, lightning currents of 40 kA with a grounding resistance of 5 Ω,10 Ω,16 Ω and 80 kA lightning strikes with a grounding resistance of 10 Ω and 16 Ω, as well as 100 kA lightning strikes with a grounding resistance of 5 Ω do not cause BFO in the electrical system.

The grounding resistance has the effect of reducing the peak lightning voltage with surge current 100kA from 1047 kV (16 Ohm) to 649 kV (5 ohm) to prevent BFO on the existing insulator.

Table 2. Voltage peak due to lightning strikes on GSW near tower 1 with installing direct grounding

Surge current (kA)	Phase	Peak Voltage (kV) with grounding resistance16 Ω				Peak Voltage (kV) with grounding resistance 10 Ω				Peak Voltage (kV) grounding resistance 5 Ω			
		Arm Tower 1	Phase Cond. Tower 1	Phase Cond. Tower 2	Substation Larona	Arm Tower 1	Phase Cond. Tower 1	Phase Cond. Tower 2	Substation Larona	Arm Tower 1	Phase Cond. Tower 1	Phase Cond. Tower 2	Substation Larona
100	A	350	319	203	151	319	297	190	144	273	317	157	185
	B	343	119	20	-27	308	99	68	-33	248	115	-30	-51
	C	336	100	19	-25	297	83	43	-31	223	94	-33	-27
80	A	281	284	186	139	255	263	176	135	223	239	166	125
	B	277	88	30	-28	248	69	-70	-39	210	46	-18	-48
	C	272	74	21	-25	239	57	-85	-35	196	36	-21	-40

Note: < Basic Insulation Level of Existing insulator 9 disc (730 kV); >Basic Insulation Level of existing insulator 9 disc(730kV)

The table above shows that after installing direct grounding connected to the GSW on tower 1 and the substation close to the power transformer, there are no lightning strikes on the ground wire of 80 kA and 100 kA with grounding resistance values of 5 Ω, 10 Ω and 16 Ωs causing BFO insulators on the transmission line.

3.2. Simulation of Lightning Strikes on Phase Conductors

The simulation results of lightning strike 100 kA with grounding resistance 10 Ω on phase wires or conductors phase A without TLA installation can be seen in figure 11, and also the effect of TLA performance installed on transmission towers 1 and substation is shown in figures 12.

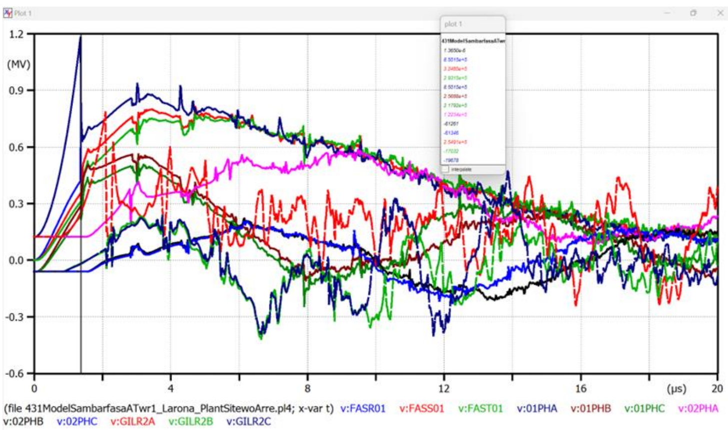

Figure 10. Voltage wave due to lightning strikes on Conductor without TLA

From the graph in figure 11, it is obtained: near tower 1 phase A :855 kV, phase B=324 kV and phase C 293 kV.

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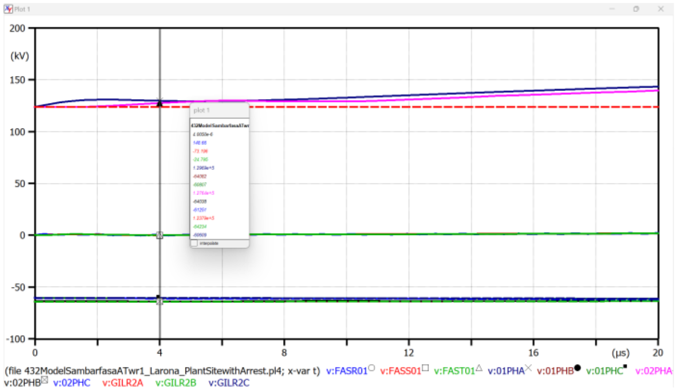

Figure 11. Voltage wave due to lightning strikes on Conductor Phase A with installing TLA tower 1 and Substation Larona

From the graph in figure 12, it is obtained: near tower 1 phase A :129 kV, phase B: -64 kV and phase C: -60 kV.

Figure 11 shows the increase in voltage on the phase A tower arm of 855 kV due to lightning strike 100 kA on the conductor phase A without any additional protection on the tower, and the voltage value on the phase A will cause a back flashover. The voltage value measured on the phase A exceeds the BIL of the 9 insulator pieces is BIL 730 kV that installed on the transmission tower so that it can cause short circuit disturbances in the electrical system. Meanwhile, figure 12 shows the voltage drop on tower 1 is 85% with value 129 kV phase A by installing TLA on tower 1 and substation, so that it does not cause back flashover in the electrical system [19], [20].

Based on the modeling in figure 7 and 8 [21], the simulation then continues by injecting lightning currents of 40 kA, 80 kA and 100 kA into the conductor phase A on the transmission line with varying grounding values of 5 Ω, 10 Ω and 16 Ω. The simulation is carried out with 2 conditions, namely when there is no TLA installed which is connected to the conductor at transmission tower No. 1 and the substation, see table 3 and when TLA is installed, see table 4. The results of this simulation can be seen in the following tables:

Table 3. Voltage peak due to lightning strikes on Conductor Phase A near tower 1 without TLA

Surge current (kA)	Phase	Peak Voltage (kV) with grounding resistance16 Ω				Peak Voltage (kV) with grounding resistance 10 Ω				Peak Voltage (kV) grounding resistance 5 Ω			
		Arm Tower 1	Phase Cond. Tower 1	Phase Cond. Tower 2	Substation Larona	Arm Tower 1	Phase Cond. Tower 1	Phase Cond. Tower 2	Substation Larona	Arm Tower 1	Phase Cond. Tower 1	Phase Cond. Tower 2	Substation Larona
100	A	888	888	122	256	855	855	122	254	824	824	122	253
	B	362	292	-61	-15	324	256	-61	-17	290	224	-61	-18
	C	332	254	-61	-17	293	217	-61	-19	256	184	-61	-21
80	A	826	826	122	274	794	794	122	272	764	764	122	271
	B	313	245	-61	-14	276	211	-61	-16	242	179	-61	-18
	C	290	213	-61	-15	252	178	-61	-18	216	146	-61	-21
40	A	826	826	122	274	794	794	122	272	764	764	122	271
	B	313	245	-61	-14	276	211	-61	-16	242	179	-61	-18
	C	290	213	-61	-15	252	178	-61	-18	216	146	-61	-21

Note: < Basic Insulation Level of Existing insulator 9 disc (730 kV); >Basic Insulation Level of existing insulator 9 disc(730kV)

The table above shows that a lightning strike on a conductor phase A of 40 kA, 80 kA, 100 kA with a ground resistance value of 5 Ω, 10 Ω and 16 Ω causes BFO on the transmission line with a value exceed of the BIL existing insulator 9 disc.

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The grounding resistance has the effect of reducing the peak lightning voltage with surge current 100kA from 888kV (16 Ohm) to 824 kV (5 ohm), but still affect to BFO on the existing insulator.

Table 4 . Voltage peak due to lightning strikes on Conductor Phase A near tower 1 with TLA in Tower 1 and arrester in Substation Larona

Surge current (kA)	**Phase**	**Peak Voltage (kV) with grounding resistance16 Ω**				**Peak Voltage (kV) with grounding resistance 10 Ω**				**Peak Voltage (kV) grounding resistance 5 Ω**			
		Arm Tower 1	**Phase Cond. Tower 1**	**Phase Cond. Tower 2**	**Substation Larona**	**Arm Tower 1**	**Phase Cond. Tower 1**	**Phase Cond. Tower 2**	**Substation Larona**	**Arm Tower 1**	**Phase Cond. Tower 1**	**Phase Cond. Tower 2**	**Substation Larona**
100	A	0.3	154	146	124	0.2	129	127	123	-0.2	129	127	123
	B	0.3	-62	-62	-63	-0.08	-64	-64	-64	-0.4	-64	-64	-64
	C	0.3	-61	-61	-61	-0.03	-60	-61	-60	-0.3	-60	-61	-60

Note: < Basic Insulation Level of Existing insulator 9 disc (730 kV); >Basic Insulation Level of existing insulator 9 disc(730kV)

The table above shows that after installing TLA on tower 1 and arrester in the substation Larona, there are no lightning strikes on the ground wire of 100 kA with grounding resistance values of 5 Ω, 10 Ω and 16 Ωs causing BFO insulator on the transmission line.

4. Impact and Implementation on Data Science Knowledge

The findings of this research have profound implications for the application of data science in the optimization and management of high-voltage transmission lines and substations. The significant voltage drop observed after installing lightning protection equipment, as demonstrated in the simulations, provides a valuable dataset for data scientists to develop predictive models. These models can forecast potential overvoltage scenarios and suggest proactive measures to mitigate the impact of lightning strikes. By continuously monitoring and analyzing data from these systems, data scientists can create real-time alerts and automated response systems to enhance the resilience of the power infrastructure.

Furthermore, the study highlights the importance of grounding resistance in reducing the peak voltage during lightning strikes. This insight can be utilized to develop machine learning algorithms that optimize the placement and specifications of grounding systems based on historical data and environmental conditions. Such data-driven approaches can lead to more efficient and cost-effective designs, ensuring the safety and reliability of electrical equipment in harsh conditions like those in a nickel smelting plant.

The research also opens avenues for advanced data analytics in the context of environmental factors affecting electrical systems. By incorporating data on weather patterns, geographical features, and lightning density maps, data scientists can enhance the accuracy of risk assessments and develop more robust insulation coordination strategies. This holistic approach ensures that the power system is well-equipped to handle varying environmental challenges, thereby reducing the likelihood of power outages and equipment failures.

Lastly, the integration of data science in this research promotes a deeper understanding of the interactions between different components of the electrical system. By analyzing the data from various simulations and real-world scenarios, data scientists can uncover hidden patterns and dependencies that may not be apparent through traditional analysis methods. This comprehensive understanding enables the development of more effective and innovative solutions for lightning protection and insulation coordination, ultimately contributing to the advancement of both electrical engineering and data science fields.

5. Conclusion

Modeling transmission line systems, transmission towers and lightning strikes using ATP draw version 7.2 is very useful to determine the value of overvoltage due to lightning strikes on high-voltage overhead lines and substations by entering data on 150kV equipment such as, phase wire, GSW, insulator, tower, tower arm, grounding tower, arrester, transformer.

Lightning strikes that occur on the ground wire before direct grounding connected to GSW produce voltage on the phase wire near tower 1 phase A, phase B and phase C respectively 833 kV, 778 kV, 724 kV and after installation direct grounding 319 kV, 308 kV, 287 kV. Where the voltage drops of 62% resulted in no disruption of the electrical system to continue producing nickel at PTVI

Lightning strikes that occur on phase A conducting wires before installing the arrester produce voltage on phase wires near tower 1 phase A, phase B and phase C respectively 855 kV, 324 kV, 293 kV and after installation arrester become 129 kV, -64 kV, -60 kV. Where the voltage drop is 85% which results in uninterrupted electrical systems to continue producing nickel at PTVI

The increase in overvoltage due to lightning strikes can cause damage to insulators on electrical equipment on transmission line 150kV and substation. The use of direct ground and Transmission Line Arresters in transmission line is very effective to reducing over voltage caused it. The value of the voltage drops on the transmission line after applying direct grounding on the GSW and TLA on the conductor does not exceed the rating of the BIL of 9 disc of existing insulator (730kV) and several electrical equipment in substation average BIL 750kV so that the equipment used is safe and continues to work normally.

The grounding resistance below 5 Ω on the tower has an effect on the peak voltage drop of 649 kV when there is a 100kA lightning strike on the GSW or tower without direct grounding, so that BFO does not occur on the existing insulator.

For further research, it would be better to be attention to the influence of the level of contamination of insulators on dust exposure in nickel mining areas, so that we can see the level of reduction in BIL of the insulator as well as looking at the differences in overvoltage characteristics resulting from lightning strikes on the GSW and conductor.

6. Declarations

5.1. Author Contributions

Conceptualization: B.S., S.M., I.K., D.U., and A.A.; Methodology: S.M.; Software: B.S.; Validation: B.S., S.M., I.K., D.U., and A.A.; Formal Analysis: B.S., S.M., I.K., D.U., and A.A.; Investigation: B.S.; Resources: S.M.; Data Curation: S.M.; Writing Original Draft Preparation: B.S. and I.K.; Writing Review and Editing: S.M. and B.S.; Visualization: B.S.; All authors have read and agreed to the published version of the manuscript.

5.2. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

5.3. Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

5.4. Institutional Review Board Statement

Not applicable.

5.5. Informed Consent Statement

Not applicable.

5.6. Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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