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Lightning Arrester Installation to Reduce Blackout in Lahat District

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ABSTRACT: The distribution system in Gemini feeders frequently got trips due to lightning strikes. Lightning strikes can generate transient overvoltage, which could damage components and equipment in the distribution system. Additionally, it will cause a blackout to the customers around Lahat District. Lightning Arresters are necessary to install to reduce transient overvoltage. In the Gemini feeder, the optimization of Lightning Arresters installation locations was not carried out yet. Therefore, it is critical to simulate the overvoltage that could appear in the Gemini feeder distribution system and optimize the LA installation locations so that the number of trips can be significantly reduced. Simulation work was carried out by using ATP / EMPT software. Optimization of arrester installation could be observed from the response of the peak average overvoltage value that appeared in the transformer. Before installing the arrester, the appeared voltage on Phase a, Phase b, and Phase c were 197 kV, 91.5 kV, 101 kV, respectively. After optimizing the arrester installation location, the appeared voltage on Phase a, Phase b, and Phase c were 34.6 kV, 24.33 kV, and 10.83 kV, respectively. The overvoltage dropped after the arresters were installed in proper locations.

Keywords: distribution lines, lightning arresters, optimization

ABSTRAK: Sistem distribusi di pejulang Gemini sering mengalami pemadaman karena sambaran petir. Sambaran petir dapat menghasilkan tegangan lebih transien, yang dapat merusak komponen dan peralatan dalam sistem distribusi. Selain itu, akan menyebabkan pemadaman listrik bagi pelanggan di sekitar Kabupaten Lahat. *Lightning Arrester*(*LA*)perlu dipasang untuk mengurangi tegangan lebih transien. Di penyulang Gemini, optimasi lokasi pemasangan *LA* belum dilakukan. Oleh karena itu, sangat penting untuk mensimulasikan tegangan lebih yang dapat muncul di sistem distribusi feeder Gemini dan mengoptimalkan lokasi pemasangan *LA* sehingga jumlah pemadaman dapat dikurangi secara signifikan. Pekerjaan simulasi dilakukan dengan menggunakan software *ATP* / *EMPT*. Optimalisasi instalasi *arrester* dapat diamati dari respon nilai tegangan lebih rata-rata puncak yang muncul pada transformator. Sebelum memasang *arrester*, tegangan yang muncul pada Fasa a, Fasa b dan Fasa c masing-masing adalah 197 kV, 91,5 kV, 101 kV. Setelah optimalisasi lokasi pemasangan *arrester*, tegangan yang muncul pada Fasa a, Fasa b, dan Fasa c masing-masing adalah 34,6 kV, 24,33 kV, dan 10,83 kV. Tegangan lebih turun setelah *arrester* dipasang di lokasi-lokasi yang sesuai.

Kata Kunci: salurandistribusi, arresterpetir, optimisasi

INTRODUCTION

In some areas, electrical energy needs continue to increase every year, requires electrical energy distribution planning so that the electrical energy demands can be sufficed(Batih and Sorapipatana, 2016). Power plants utilize several resources, i.e., coal, water, gas, and geothermal are generally located far from the demand centres. Therefore, the electrical energy should be transmitted through transmission lines, substations, and distribution lines.

Generally, in Indonesia, the transmission and distribution lines are overhead line types. And large parts of the power system network are interconnected outdoor. High voltage cables are installed only in heavily populated regions interconnected to Gas Insulated Substation (GIS) buildings(Bolland and Saether, 1992;

Ardizzon, Cavazzini and Pavesi, 2014; Zarrouk and Moon, 2014; Jinsong *et al.*, 2015; Perrin *et al.*, 2015).

Overhead lines are potentially hit by lightning, even more in a tropical country like Indonesia. Especially in the rainy season when the lightning occurrence intensity in Indonesia is very high(Zoro, 2019). Lightning overvoltage could penetrate to power system network by the following: (a) lightning strikes in the vicinity; (b) direct lightning strikes to the lines conductors generating a travelling wave on the lines; and (c) lightning strikes to earthing wires or towers.

Lightning hit to distribution lines causes the lines voltage to increase significantly, which could trigger a blackout in the distribution network(Tossani *et al.*, 2017). The tripping commonly occurs in a substation. Distribution lines are usually equipped with lightning protection components such as Lightning Arrester (LA) to reduce the overvoltage. In fact, in several locations, the distribution lines are provided with ground wires.

South Sumatra province consists of 17 districts with diverse land contours, i.e., swamp, flat, height, and mountain lands. Relating to the lighting occurrences, based on the PLN UP2D S2JB Rayon Ampera outages data 2017 – 2019, most of the outages occurred during a thunderstorm. A case of damage of a power transformer at PLN Gunung Megang South Sumatra has shown the importance of optimum arrester installation on the 20 kV distribution lines.

Lahat is a district in South Sumatra with a high outage rate due to natural disaster compared with other districts in South Sumatra. In this paper, a study on optimizing LA installation for distribution lines network, namely Gemini distribution feeder at Lahat District, is presented. The objectives are to calculate the amplitude of overvoltage when lightning current is injected into the distribution lines network and reduce the outage durations by optimizing LA installation locations.

METHODOLOGY

This study utilized ATP/EMTP Software to simulate the lightning strike to the Gemini distribution feeder(Mata *et al.*, 2000). ATP Draw is a software used to digitally simulate electromagnetic and electromechanical transient phenomena in electric power systems. The time function of the disturbance occurrence is the calculation variable of ATP Draw.

Referred to the existing Gemini distribution feeder network – 3 phases; 20 kV – the simulation diagram was constructed. The Gemini feeder consists of two tracks Melur and Seruni, with lines length of 26.5 km and 9.5 km. The AAAC cables with a diameter of 150 mm^2 are installed on the tower with a span of about 50 m. A 30 MVA power transformer supports this distribution network at the distribution substation and 100 step-down mounted transformers on distribution towers. Figure 1 shows the distribution network of Gemini feeders.

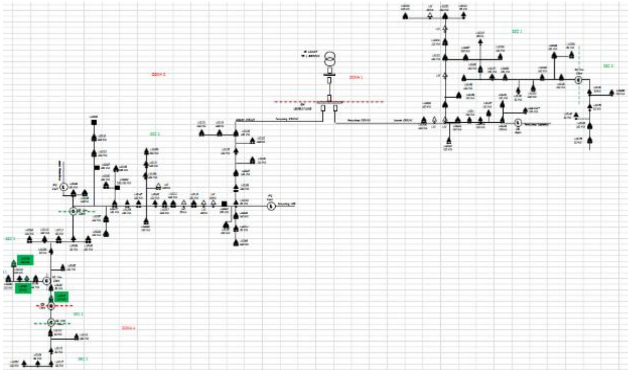


Figure 1. Single line diagram of Gemini distribution.

Before and after LA installation, the simulation was carried out to analyze the amplitudes and the waveform characteristics. Before LA installation, a simulation was carried out to examine the distribution lines without LA. Afterwards, a simulation was carried out after installing the arresters at several locations on distribution lines. Arrester installation and lightning strike locations were varied to obtain the optimum arrester locations.The constructed simulation circuit is shown in Figure 2.

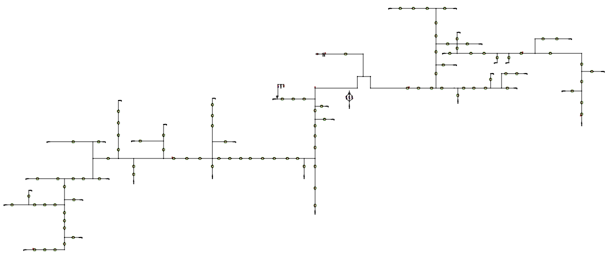


Figure 2. Constructed simulation circuit using ATP Draw.

Lightning waveforms were generated by using Heidler component with a current magnitude of 10 kA. Meanwhile, MOV type arrester with a breakdown voltage of 24 kV and discharge current of 10 kA was used.Figure 3 shows the Heidler and arrester components.

Figure 3. Simulation components (a) Heidler, and (b) Lightning Arrester

Based on the empirical experiences of the lightning strike occurrences in the Melur and Seruni tracks, the locations of the lightning strikes could be projected. For these two tracks, the lightning strike nodes were predicted as in Table 1. The zero nodes of reference were the substation power transformer.

Table 1. Lightning strike nodes

Observation locations	Lightning strike nodes		
Melur track	AM= 8.20 km	BM = 10.55 km	CM = 15.30 km
Seruni track	AS = 7.80 km	BS = 10.35 km	CS = 11.80 km

Overvoltages in the simulated system were observed by placing several voltage probes at nodes that need to be analyzed. The prove nodes are as shown in Table 2.

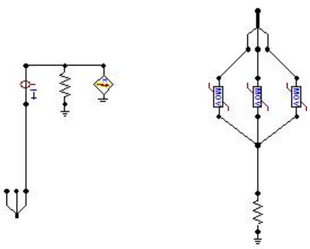
Table 2. Probe nodes locations

Observation locations	Probe nodes		
Substation	Power transformer secondary side		
Melur track	TM = 7.40 km	MM = 18.35 km	UM = 24.90 km
Seruni track	TS = 7.65 km	MS = 10.20 km	US = 11.90 km

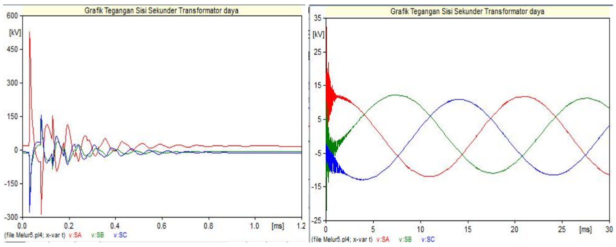
At the same location with the voltage probes, lightning arrester components would be placed in the simulation circuit.

RESULTS AND DISCUSSION

The simulation obtained some results, as shown in Figure 4 – Figure 9.

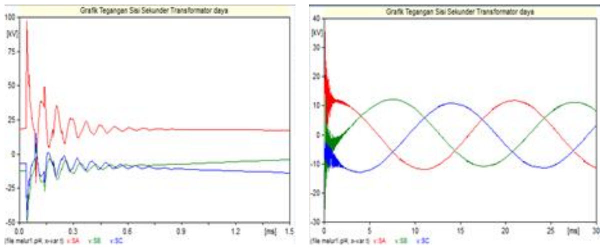


(a) (b)



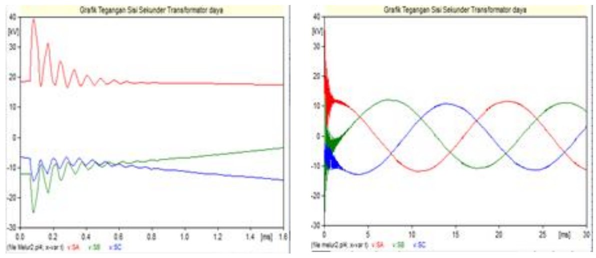
(a) (b)

Figure 4. Voltage magnitude at transformer secondary side, lighting strike to AM node (a) arrester uninstalled, and (b) arrester installed



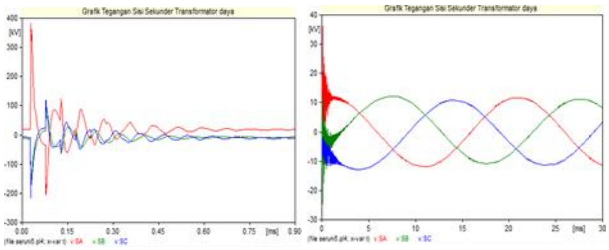
(a) (b)

Figure 5. Voltage magnitude at transformer secondary side, lighting strike to BM node (a) arrester uninstalled, and (b) arrester installed



(a) (b)

Figure 6. Voltage magnitude at transformer secondary side, lighting strike to CM node (a) arrester uninstalled, and (b) arrester installed



(a) (b)

Figure 7. Voltage magnitude at transformer secondary side, lighting strike to AS node (a) arrester uninstalled, and (b) arrester installed

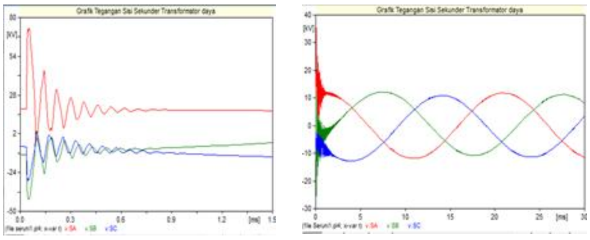

(a) (b)

Figure 8. Voltage magnitude at transformer secondary side, lighting strike to BS node (a) arrester uninstalled, and (b) arrester installed

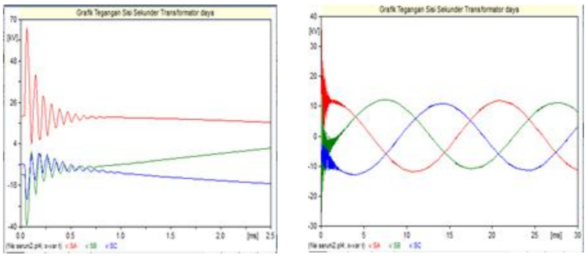

(a) (b)

Figure 9. Voltage magnitude at transformer secondary side, lighting strike to CS node (a) arrester uninstalled, and (b) arrester installed

Peak voltage Vp is a factor that should be anticipated from an overvoltage waveform. The Vp of the simulated circuit are shown in Table 1 shows the detail of the data, and Figure 10 shows theVpbefore and after arrester installation.

Strike Nodes	Phase	Vp before Arrester Installation(kV)	Vp after Arrester Installation (kV)
Melur 8.2 km	A	527	32
	B	239	22
	C	276	10
Melur 10.55 km	A	97	35
	B	49	25
	C	46	11
Melur 15.3 km	A	39	35
	B	24	24
	C	14	11
Seruni 7.8 km	A	382	36
	B	156	24
	C	216	11
Seruni 10.35 km	A	72	35
	B	42	25
	C	29	11
Seruni 11.8 km	A	65	35
	B	39	25
	C	25	11

Table2. Comparison of peak overvoltage values on the secondary side of the transformer due to lightning strikes before and after arrester installation.

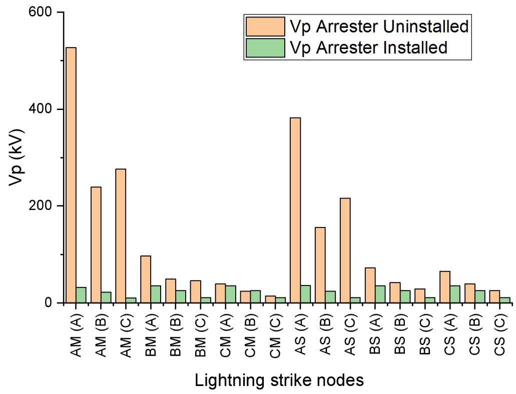


Figure 10. Vp before and after installing.

Figure 10shows that at phase AM (A), AM (B), AM (C), AS (A), AS (B), and AS (C) the drop voltage is very significant after arrester installation.At Melur track when the arrester was installedat 8.2 kmthe voltage dropto 6.1%.The Vprange is about 10 kV - 35 kV after arrester installation. This voltageis low enough to avoid a breakdown inthe power transformer and alsoreduce the load on the arrester that generally installed at the substation.Thissimulation result could be used as guidance for reducing blackout in Lahat District.

CONCLUSION

Distributionlines at PLN Lahat District undergonehigher blackoutincidentdue to lightning compared to other districts.In order to solve this problem,proper arresterinstallation locations should be determined. By using ATP/EMTP Software,a simulation study has been carried out to determine the optimum arrester locations. The results show that lightning arrester with the determined installation locations has dropped the Vp. This result could be used as guidance to reduce blackout at PLN Lahat District.

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