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Experimental Investigation of Insulator Dielectric Strength of Transmission Tower in Rocky Areas

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Abstrac

Lightning is a natural phenomenon that destroys a power line. According to the Sumatra load supplier and handling Center (Sumatera P3B), the intensity the number of lightning strikes on a 150 kV transmission line was very high in Indonesia, reaching 66%. As a result, the isokeraunik level on the 150 kV transmission line in that area is at 174 days/year, and the flashover occurrence rate in its ceramic insulators is 82% in the hilly area, 16 % in the rice fields, and 2% in the desserts/pastures. The investigation results showed correlations between the occurrence of back-flashover and contaminants of insulators. Furthermore, the results of the experiment show that the insulator contaminated with moss has a lower dielectric strength as the rate of breakdown voltage in the test voltage 78.728 kV is 20.54 kV in the test with a single plate, 30.511 kV with two plates, 56.328 kV with three plates, and at 196.85 kV for its 11 plates.

Keywords: Back-flashover, Insulator contaminant, Rocky Areas.

Introduction

Indonesia's electric power transmission system is predominantly utilise overhead lines rather from the system of underground cables. Due to overwork, overhead power lines are highly susceptible to lightning strikes. As a matter of fact, the upper line, fixated on bumpy regions, is extremely near mists, so it are more incessant to lightning strikes. West Sumatra, Indonesia, is in a region with a lot of lightning. In West Sumatra, a 150 kV transmission line connects Payakumbuh to Koto Panjang, and the annual diversity of common thunderstorm days (IKL: This region has an isokeaunic level of up to 165, indicating that lightning strikes directly into lightning. The maximum chance of dropping is 165. Transmission is high thanks to the running pylons that make up the transmission lines. West Sumatra Submachine (Padang UPT) and Riau Submachine (Riau UPT) are connected by this trunk line. As a result, there needs to be a lot of resistance to lightning strikes.

Based on records from the Sumatran Load Distribution and Control Center (P3B Sumatra), the depth of lightning disturbance on a 150 kV transmission line can be very excessive, which is 66% (Warmi and Michishita, 2017) (Warmi and Michishita, 2018). Lightning overvoltage surges can damage the insulation of transmission lines (flashover) in addition to causing blackouts. In fact, circuit breakers were disabled at Payakumbu Substation and Koto Panjang Substation by a number of broken insulators. Therefore, in order to ascertain the 150 kV Payakumbuh - Koto Panjang transmission line's overall lightning performance in West Sumatra, an evaluation is required. In this article, author conducted an experiment to investigate the dielectric strength of the 150 kV Payakumbuh – Koto Panjang transmission line insulator in a rocky location.

Data Invetigation

1.1 Thunderstrom Activity in West Sumatera

Figure 1 suggests Western Sumatera's isokelaunic level map. Between Payakumbuh and Koto Panjang, there is a certified pink overhead line of 150 kV. 51 (20.5%) of the 248 pagodas are in rice fields, 41 (16.5%) are in deserts or grasslands, and 156 (63%) are on hills. There have been 165 days with thunderstorms, with high temperatures ranging from 33°C to 36°C. consistent with 12 months within the place in which towers No. 1 to 140 stand (Warmi and Michishita, 2017) (Warmi and Michishita, 2018) (Warmi and Viyoldi, 2019) (Warmi and Michishita, 2017). Every year, Indonesia's level of entertainment generally rises rapidly due to the country's tropical climate. The topography of the path also has a significant impact on the variety of lightning strikes.

Figure 1. *Map of Isokeraunic level*

1.2 Transmission Line Under Study

The explored channel is a fair protected transmission line with a limit of 150 kV. 1.5% times the pinnacle length, the common level of the floor link is 32.2m. ACRS (Aluminum Channel Metal Built up) is applied to each piece of the street, the stage screw width is 25.5 mm, the distance between stage links is 4.7 m, and the leeway distance is 2% of the pinnacle length. Ranges range from 147 m to 434 m with a typical length of 332.5 m. The protection has a BIL (Essential Protection Level) of 110 kV as per the board displayed in Table 1. The quantity of boards utilized for protection is 11 boards relying upon the cross area. Aside from floor wires, the Payakumbuh-Koto Panjang transmission tower has other wellbeing frameworks like curve horns, TLAs (transmission line arresters), down conveyors and establishing frameworks. Every turret has a bended horn toward the finish of the cover (the bended horn opening is 1.13 to 1.6 meters long). The quantity of TLAs is 45 (every one of the 10 introduced towers has 1 he TLA). There are 36 down guides (mounted on high strength lightning towers) and each pinnacle has an establishing framework. (Warmi and Michishita, 2017) (Warmi and Michishita, 2018) (Warmi and Viyoldi, 2019).

Figure 2. *Transmission line under study*

Table I. *The Insulator Specifications.*

Insulators Code Material	11 Porcelain Suspension Insulators
BIL	1,21 MV
Diameter (D) in centimeter	25,4
Total of length in meter	1,6 – 1,87

Research Methodology

The research method used in this study is the experimental one which aims to to find the effect of contaminants such as moss and dust in the breakdown voltage on the insulator (Salem *et al.*, 2020) (Zhang *et al.*, 2015) (Warmi and Viyoldi, 2019)..

1.3 Research Design

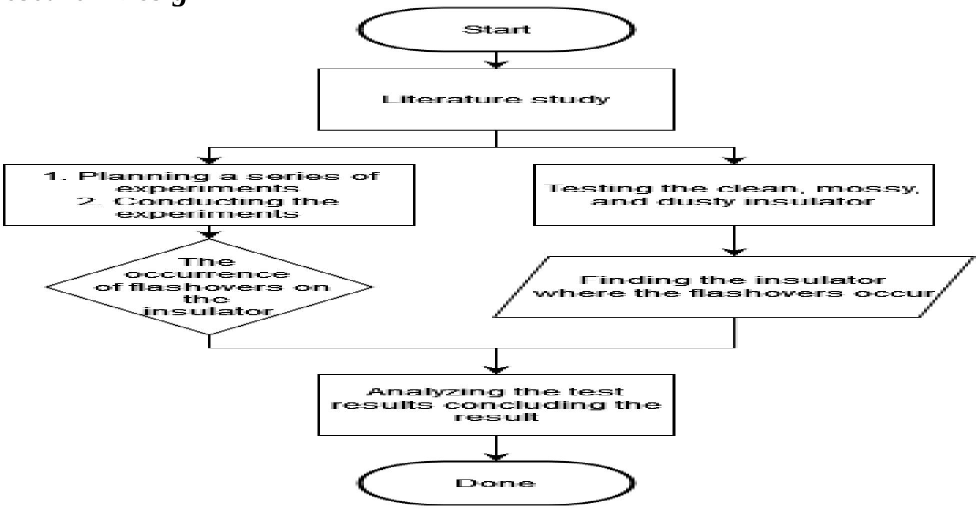

Figure 3. *Circuit of Experiment*

1.4 *Circuit of Exsperiment*

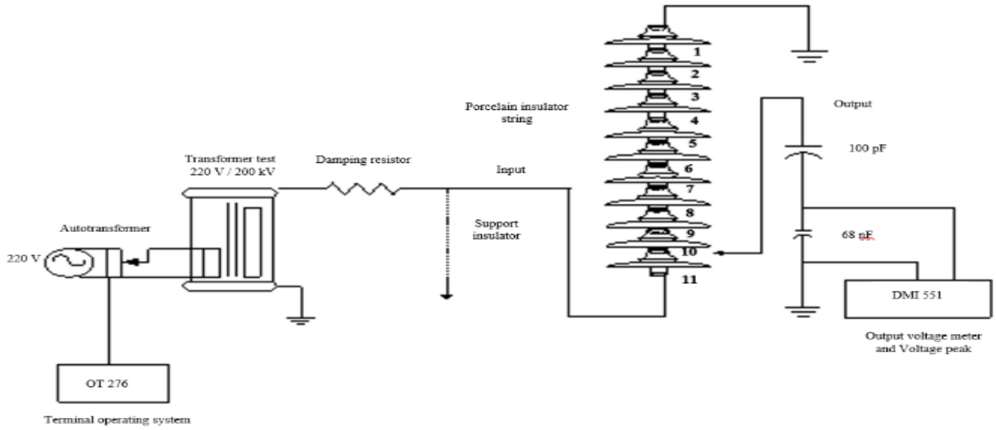

Figure 4. *Circuit of Experiment*

1.5 *Exsperimental Procedures*

1. Preparing tools or equipments as follows:
a) Test transformer with a winding ratio of 220 V/100 kV. Power 5 kVA
b) Auto Transformer
c) Damping resistor
d) AC voltage measurement capacitor, 100pF
e) AC voltage measuring device (multimeter)
f) Oscilloscope
g) Input wire, output wire and ground wire
h) 150 kV high voltage insulator to be tested
i) MCB
2. Selecting the mossy-contaminated insulator for the breakdown voltage test as the variable of the research
3. Conducting these following stages in the experiment
a) Arrange the equipment as shown above
b) Check the grounding circuit and transformer.
c) Ensure that the discharge rod is removed from the circuit and that the door of the Faraday cage is locked.
d) Attach the clothespin at the seventh point
e) Turn on the multimeter by pressing the power button.
f) Setting the oscilloscope:
i. Set Channel 1 at its Maximum number
ii. Set measurement Math 1 at its maximum capacity
iii. Set Math at ch1*1466,88
g) Press the Run button
h) Move the MCB position to the ON position
i) Adjust the voltage on the regulator until the input on a multimeter appears at a value of 10 V
j) Record the maximum voltage value that appears on the oscilloscope
k) Move the MCB to the OFF position and lower the voltage on the regulator
l) Repeat the experiment for the clamping point of six to one.
m) Before moving the clamp point, chech the ground circuit first

2. Analysis and Results

2.1 Experiment Breakdown Voltage

The insulator used for testing the breakdown voltage was the insulator with moss contaminant has covered its surface. This mossy-contaminated insulator has been used for about 2-5 years. In addition, when testing the insulators the number did not match to the experimental circuit in Figure (a). This happened because of the equipment capacity to perform was insuffient; for instances, the transformer was not able to increase the voltage of 150 kV for one string of insulators, the cables were not cofficient with the intended use, and limitation of the oscilloscope in testing the voltage value. As a results, the tests was carried out only by using three insulating plates equipped by five insulator chains as shown in Figure 4 below (Warmi and Viyoldi, 2019) (Ouyang *et al.*, 2019) (Warmi and Febrian, 2021)..

Figure 5. *Testing the Breakdown Voltage of the Mossy Insulator*

The test shown in Figure 5 is an insulator test which is carried out in stages from the first plate to the third plate using the same voltage test on each plate of 78.82 kV. Meanwhile, theresults of the next insulator plates are done by analyzing the trend values of the three plates that have been tested. The results can be seen in Table II below.

Table II. *The Breakdown Voltage Test on the Mossy Insulator*

BIL (kV)	The Number of Insulator Plates	The rate of theVoltage Translucent Prediction (kV)	The decrease rate of Dielectric Strength Decrease	BIL 1%	The decrease rate of Dielectric Strength Decrease
110	1	20,54	89,5	1.1	81.33
110	2	15,25	102,4	2.2	86.13
110	3	18,76	103,7	3.3	82.93
110	4	16,40	105,9	4.4	83.73
110	5	15,51	106,9	5.5	83.73
110	6	14,62	107,6	6.6	83.73
110	7	13,73	108,0	7.7	83.73
110	8	12,84	108,4	8.8	83.73
110	9	11,95	108,7	9.9	83.73
110	10	11,06	108,9	11	83.73
110	11	10,17	109,1	12.1	83.73

Based on table II above, a graph of the comparison of the value of the breakdown voltage measurement with a decrease in the dielectric strength of the insulator can be drawn as in figure (c). The breakdown voltage test can only be carried out using 3 insulator plates, while the next insulator plate test is shown in Figure 5 below.

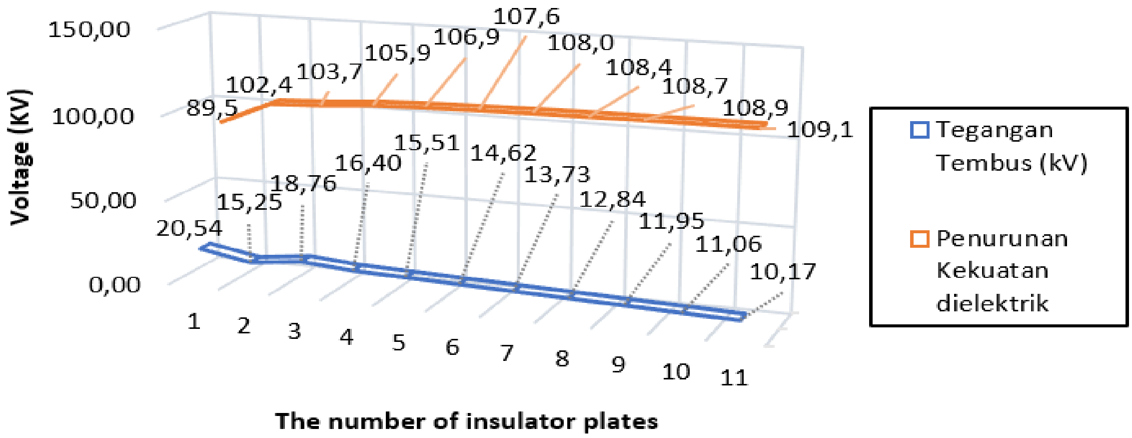

Figure 6. *The Breakdown Voltage Test of the Mossy Insulator.*

Figure (f) shown the number of insulator plates tested affects the breakdown voltage value and the dielectric strength value of the insulator. The more mossy insulator the tested, the higher the breakdown voltage value that occurs. Similarly, the low electric strength is caused by the BIL value of a insulator of 110 kV. The decrease in the value of dielectric strength that occurs is 25.03% per insulator.

2.2 XRD Measurement Result

XRD testing is done by testing three test samples,which are the clean, mossy and dusty insulator. The testings were done by testing each sample one after another. The testing duration was approximately 30 minutes for the three samples. After that the test results will be processed directly by a computer connected to the X-Ray Diffractometer (XRD) tool. The test results can be seen in table III below.

Table III. *The XRD Test of the Mossy Insulator*

Chemical Formula	Compound Name	Flashover rate		
		Clean Insulator (peak)	Mossy Insulator (peak)	Dusty Insulator (peak)
Ca0.2 Sr0.8	Calcium Strontium	0	3	2
Si O2	Silicon Oxide	0	26	6
Al2 Si2 O5 (O H)4	Aluminum Silicate	1	3	1
Al2 O3	Aluminum Oxide	0	1	1

From table III it can be seen that the results of the total flashover rate show the best compound material for insulator which reduce the occurrence of flashover on the insulator surface. The best compound is the Aluminum Oxide where there is zero flashover occurrence in the clean insulator, one in the mossy insulator, and one in the dusty flashover, the second one is Aluminum Silicate of one flashover occurrence in the clean insulator, three in the mossy insulator and one in the dusty insulator,the third one is Calcium Strontium of 0 flashover occurrence in the clean insulator, three in the mossy insulator and two in the dusty insulator, and the least rate is Silicon Oxide of 0 flashover occurrence in the clean insulator, 26 in the mossy insulator and six in the dusty insulator.

So it can be concluded that the Silicon Oxide compound is dominantly caused the occurrence of flash on the insulator with the moss contaminant as its the rate is the highest of 26 peaks.

Conclusion

The moss is a contaminant that greatly affects the breakdown voltage on the insulator as the value is highly decreased in the dielectric strength of the insulator of 83.73% per insulator. In addition, XRD testing also proves that moss has an effect on the occurrence of breakdown voltages in the insulator because it contains a high Silicon Oxide compound of 26 peak.

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