

Effect of Tower Construction Analysis Against Reliability Level of SUTET 500kV to Lightning Strike

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Abstract — The Extra High Voltage Air Line (SUTET) is a transmission line conductor with a voltage of 500kV which aims to deliver electrical energy from the plant to the load center, so that electrical energy can be efficiently discharged. The gap between the distant towers and the different tower construction causes the transmission channel's insignificance. Unreliable tower lines can cause channel outages and damage to existing equipment in the tower. It is necessary to construct effective and efficient transmission line tower types because of the expensive cost of repair and maintenance. So that, the transmission line performance can work reliably. Furthermore, software is needed to analyze the effect of tower construction on the reliability level of SUTET 500kV to the lightning strike using the waves running method. The software existence can be used to calculate the lightning disturbance that occurs in the tower with various types of construction in Indonesia. Also, this research results contribute to the continuity of electricity system services in Indonesia.

Keywords— electrical system; lightning strike; Extra High Voltage Air Line component;

I. INTRODUCTION

Transmission towers have the very important role in the process of distributing electrical energy from one place to another. This is due to the increasingly modern and sophisticated era so that the need for increased electrical energy in the industrial sector or the needs of society at this time. The increasing need for electrical energy must be followed by a high quality electrical energy system and has a high reliability, the principle in the transmission of electrical energy is both safe and economical. With the transmission tower, it is necessary to construct a specific transmission tower so that the need to distribute electrical energy is not hampered due to the damage of the transmission tower[1].

Disturbances that occur in the transmission tower construction one of them caused by lightning strikes. The occurrence of such damage can lead to the main components work is not in accordance with their needs resulting in failure of protection or damage to electrical construction networks that affect the transmission line. That means the reliability of a power system is determined by the ability of the system to supply

sufficient electrical energy to the consumer. So, this system must be reliable and meet the requirements to be able to reduce the sudden disruption caused by lightning strikes [2].

Transmission networks in Indonesia are more dominant using airways when compared to underground channels, because the transmission network in the manufacture more economical, easy to reach and cheap operational costs. In addition, the current electric power system is an interconnection system between one power plant and another with a purpose if either one of the power plant or transmission line is interrupted, the supply of electricity can still run. Another problem with the airways is the frequent interference with the main components. Indonesia conditions that have a tropical climate often happens lightning strikes and it is enough to make the transmission system is potentially struck by lightning. In addition, the use of airways that have different tower construction and different tower height coordinates has become one of the factors affected by lightning strikes [3-7].

Video surveillance for transmission lines, which can record the man-made destroying, foreign objects attaching to the lines, swing of the lines, conductor icing, etc. [8]

Therefore, to obtain reliable and sustainable power distribution, it is necessary to analyze the effect of tower construction on the reliability level of 500kV SUTET to the lightning strike to produce the modeling result and the software that can be applied to facilitate the design automatically.

The remainder of this paper is organized as follows: an analysis calculation of the flash interference in the tower on transmission system is presented in Section 2. In Section 3 software trial is addressed. Finally, some conclusions are shed.

II. RESEARCH METHODOLOGY

To perform this analysis calculation using the current wave method to obtain a negative reflection wave so that almost all of the flashback / backflashover occurs at the top of the phase wire so as to calculate the flash interference in the tower[3]

With case studies on Krian Substation in 2018, the main part of this method will be discussed as follows:

1. Disturbance at construction height of different tower.

To obtain the angle of ground wire protection in the construction of AA type Tower and CC type, so it can be calculated:

$$x = \sqrt{(L)^2 + (H)^2} \quad (1)$$

$$\sin \theta = \frac{L}{x} \quad (2)$$

$$\theta = \sin^{-1} \Xi \quad (3)$$

Lightning failure on phase wire

$$D = 8,875 \cdot 10^{-8} \xi I K \Lambda \quad (4)$$

Where the value of D is to obtain lightning density per square meter per year by entering IsoKeraunik Level (IKL)

$$A = (2 \pi + 1) H t^2 + 4 H g (S - H t) \quad (5)$$

Where the value of A is the area of protected area ground wire with meter² unit.

$$L = 100 \cdot \frac{1000}{s} \cdot A \cdot \Delta \quad (6)$$

The L value represents the lightest amount of lightning that may occur in the transmission tower.

$$\text{Log } P\theta = \frac{\theta \sqrt{Ht}}{90} - 4 \quad (7)$$

Pθ represents the probability of failure of ground wire protection.

$$\Sigma \Phi O = P\theta \cdot L \quad (8)$$

The value of SFO is the amount of lightning disturbance on the phase wire per 100 km of introduction per year due to the failure of ground wire protection in each tower construction [3].

2. To get the value of interference on the construction line of Tower of Krian - Gresik, it is necessary picture of transmission tower and its shadow wire [3][6] :

$$\alpha_1 = \sqrt{h_{tp}^2 + \left(\frac{1}{2}c - \frac{1}{2}a_{12}\right)^2} \quad (9)$$

$$\alpha_2 = \sqrt{h_{tp}^2 + \left[a_{12} + \left(\frac{1}{2}c - \frac{1}{2}a_{12}\right)\right]^2} \quad (10)$$

$$\alpha_{1\Box} = \sqrt{(2 h_t - h_{tp})^2 + \left(\frac{1}{2}c - \frac{1}{2}a_{12}\right)^2} \quad (11)$$

$$\alpha_2 = \sqrt{(2 h_t - h_{tp})^2 + \left[a_{12} \left(\frac{1}{2}c - \frac{1}{2}a_{12}\right)\right]^2} \quad (12)$$

Where the value of

a₁ : the distance between ground wire 1 and phase 1 wire

a₂ : the distance between the ground wire 2 and the phase wire 1

a₁' : the distance between the ground wire 1 and the phase shadow wire 1

a₂' : the distance between the ground wire 2 and the shadow phase wire.

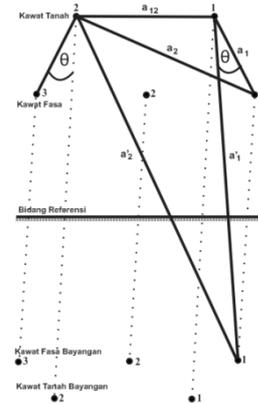


Fig. 1. The transmission structure and the shadow wire

$$K = \frac{\ln \sqrt{\frac{a_1' \cdot a_2'}{a_1 \cdot a_2}}}{\ln \left(\frac{2hg}{\sqrt{a_{12} r}} \right)} \quad (13)$$

The value of K is the Clutch factor by entering the values obtained in the previous formula

$$Z_g = 60 \ln \left(\frac{2hg}{a_{12} r} \right) \quad (14)$$

The Z_g value is the result of a ground wire impedance

$$\ln R_t = \frac{h_o}{h_t(x_b - x_u)} [x_b (\ln x_b - 0,87) - x_u (\ln x_u - 0,87)] + \frac{h_t - h_o}{h_t} \ln (1,14 x_u) \quad (15)$$

The R_t value is the equivalent radius of the Tower by changing the value of the meter unit to the leg unit and the final result is converted back into meters.

$$Z_t = 60 \ln \left(\sqrt{2} \frac{2h_t}{r_t} \right) - 60 \quad (16)$$

The value of Z_t is the impedance value of the Transmission Tower.

$$\alpha = \frac{2 \cdot Z_g}{Z_g + 2 \cdot Z_t} \quad (17)$$

$$\beta = \alpha \square 1 \tag{18}$$

Calculates the transmission coefficient (a) at the top of the tower for the waves coming from the bottom of the tower. Which is used to find the reflection coefficient (b) at the top of the tower for the waves coming from the base of the tower.

$$\varepsilon = \frac{2 \cdot Z_g}{Z_g + Z_t} I \sigma \tag{19}$$

e is the peak voltage of the tower with the peak current value (Is) = 60.

$$\delta = \frac{R_f - R_t}{R_f + R_t} \tag{20}$$

The value of the reflection coefficient (d) at the base of the tower is used to calculate the waves coming from the top of the tower

$$\langle = \frac{2 \cdot Z_g}{Z_g + 2 \cdot Z_t} \tag{21}$$

The value of α is used to find the transmission coefficient at the top of the Tower for the incoming wave.

$$V = K_1 \cdot W \frac{K_2 \cdot W}{t^{0.75}} \tag{22}$$

$$V_{50\%} = \left(1 + e^{\frac{t}{\tau}}\right) + V \tag{23}$$

The value of $V_{50\%}$ is the impulse voltage of the tower voltage (V) with the lightning advance time (t) = 0.5 μ s.

$$\tau_\chi = \tau + \frac{X_1}{c} \tag{24}$$

Tc is the time when the peak voltage drops suddenly due to the reflection wave (critical time) with the value of the cross-sectional area of the conductor (c) = 300.

$$E_0 = \left(\frac{Z_g \cdot Z_t}{Z_g + 2 \cdot Z_t} I_0\right) / \tau \tag{25}$$

The value of e_0 is the initial stress of the top of the Tower

$$\begin{aligned} Vi &= e_0(1 - k) \cdot \left(t_c - \frac{X_1}{C}\right) + d \cdot e_0 \left(t_c - \frac{2h_t - X_1}{C}\right) \\ &+ d \cdot e_0 (b - K) \left(t_c - \frac{2h_t - X_1}{C}\right) + d^2 \cdot b \cdot e_0 \\ &\left(t_c - \frac{4h_t - X_1}{C}\right) + d^2 \cdot b \cdot e_0 (b - Ka) \\ &\left(t_c - \frac{4h_t - X_1}{C}\right) + d^3 \cdot b^2 \cdot e_0 \left(t_c - \frac{6h_t - X_1}{C}\right) \end{aligned}$$

$$+ d^3 \cdot b^2 \cdot (b - Ka) \left(t_c - \frac{6h_t - X_1}{C}\right) \tag{26}$$

Vi is the isolator voltage by inputting the input value in the previous result.

$$\Pi_0 = E_0 \cdot V_i \tag{27}$$

The value of P_0 is the peak value of a certain lightning current.

$$(Pi\%) = \sum P \times \sum \frac{\text{flicker failure}}{\text{flicker's quantity}} \tag{28}$$

$$(Qi\%) = \sum Qj \times \sum \frac{\text{pounced time}}{\text{amount of time}} \tag{29}$$

The P value is the number of possible flashes. By entering the value of percentage Pi and the percentage of the possibility of a certain lightning current wave advance time (Qj).

$$0_t = 60\% \times L \times P \tag{30}$$

0_t is the number of lightning disturbances in the transmission tower channel.

III. RESULT AND DISCUSSION

Software testing is divided into two outputs, the first is to analyze the height difference of tower construction on the lightning strike and the second to analyze the tower line Krian – Gresik. Fig. 1 below shows AA Suspension Tower and Fig. 2 describes Tower of Tention CC.

A. Interference at height construction of different tower.

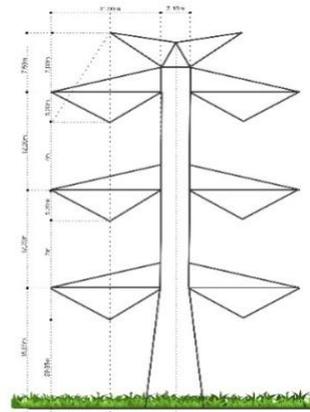


Fig. 2. AA Suspension Tower

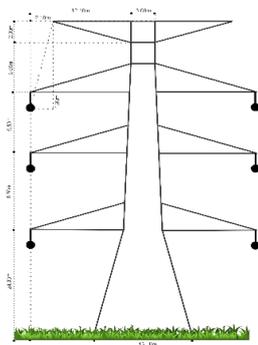


Fig. 3. Tower of Tention CC

TABLE I. THE ANGLE OF SHIELDING BASED ON THE HEIGHT OF THE GROUND WIRE AGAINST THE PHASE WIRE

Pilar	Type	Height Top	L	X	Sin θ	θ
T.15	CC+3	14,4	2,10	15,641	0.1342	7,71°
T.16	AA+3	15.8	5.95	16.883	0.3524	20,63°
T.17	AA+0	12.8	5.95	14.115	0.4215	24,93°
T.18	AA-3	12.8	5.95	14.115	0.4215	24,93°
T.19	AA+0	12.8	5.95	14.115	0.4215	24,93°

In Table 1. Tower Pillar no. 15-19 have different shooting angles due to variations in the high phase wire addition. By obtaining a varying angle it can calculate the flash interruption in each Tower construction [5].



Fig. 4. Results of the program on the AA tower

B. AA Suspension Tower

Fig.4 above shows that a protection angle of 24.93 °. On the angle of shield A suspension tower is considered not good because according to Provoost theory in 1960 it suggested a good shielding state of the transmission tower if it is less than 18° angle [5].

After obtaining the angle of protection it can calculate the value of lightning disturbance in the tower by using formula (8) and obtain the result of 74027 interruption [3].

C. CC Tension Tower



Fig. 5. Program Results on CC Type Tower

Fig. 5 above obtain a protection angle of 9.61°. at the angle of the CC suspension tower shell is considered good because according to the Provoost theory in 1960 it suggests a good shielding state of the transmission tower if it is less than 18° angle. By performing the calculation of the formula (6) then obtaining a lightning distortion value of 0.1751 disorder [3].

D. Disturbance on the line of transmission tower Krian-Gresik.

Average disturbance in the queue - gresik line using the AA tower type suspension. With +0 (AA+0) tower height. In the formula (24) with the critical time (t) 0.5 and the critical current (I_o) 60 then obtained:

TABLE II. TIME OF CRITICAL VOLTAGE

Time t (μ second)	Critical voltage (tc) time
0.5	0.5366
1	1.0366
1.5	1.5366
2	2.0366
2.5	2.5366

In table II, inserting different input (t) will produce different critical voltage (tc) time.

TABLE III. TOWER PEAK VOLTAGE

t (μ second)	I _o (kA)	E ₀ (kV)
0,5	60	12265.7297
0,5	120	24534.6023
0,5	180	36801.9035
0,5	220	44980.1042
1	60	6133.6505
1	120	12267.3011
1	180	18400.9517
1	220	22490.0521
1,5	60	4089.1003
1,5	120	8178.200
1,5	180	12267.3011
1,5	220	14993.3680
2	60	3066.8252
2	120	6133.6505
2	180	9200.4758
2	220	11245.0260

In Table III. Represents the formula (24) by producing the initial peak voltage value of Tower (E_0).

In Table IV. It is a calculation step to the end. The table above is used to compare all E_0 values with V_i , if the value of $E_0 < V_i$, then *backflashover* or flashover occurs. In $T = 1.5$, when $P_0 = 0,702$ to downwards has *backflashover*.

TABLE IV. VOLTAGE COMPARATOR WHEN HIT BY A STRIKE

T	t_c	I_0	E_0 (kV)	V_i (kV)	$\frac{E_0}{V_i}$ (P_0)
0,5	0,536	60	12265.729	4552.158	2.695
0,5	0,536	120	24534.602	9101.496	2.695
0,5	0,536	180	36801.903	13652.244	2.695
0,5	0,536	220	44980.104	16686.076	2.695
1	1,036	60	6133.650	5505.214	1.114
1	1,036	120	12267.301	11010.429	1.114
1	1,036	180	18400.951	16515.644	1.114
1	1,036	220	22490.052	20185.787	1.114
1,5	1,536	60	4089.100	5823.370	0.702
1,5	1,536	120	8178.20	11646.740	0.702
1,5	1,536	180	12267.301	17470.110	0.702
1,5	1,536	220	14993.368	21352.357	0.702
2	2,036	60	3066.825	5982.447	0.512
2	2,036	120	6133.650	1196.8954	0.512
2	2,036	180	9200.475	17947.343	0.512
2	2,036	220	11245.026	21935.642	0.512

tention tower obtains 9.6121° angle protection with 0,175 lightning disturbance. So, this is more effective using CC tension tower.

- The calculation of lightning disturbance in the Krian - Gresik line is 3,990 flash / 237011 km, per year is in accordance with existing data from PLN.
- In lightning disturbance of transmission towers apart from being influenced by different tower constructions are also influenced by the number of days of thunder (IKL)

The results of research on the development of lightning outage application software to detect the Reliability of 500 kV Extra High Voltage Air Channels to lightning strikes can contribute directly to the public because it concerns the continuity of electrical system services in Indonesia. Our further research will be development of lightning outage application software to detect the reliability of 1 MV Extra High Voltage Air Channels.

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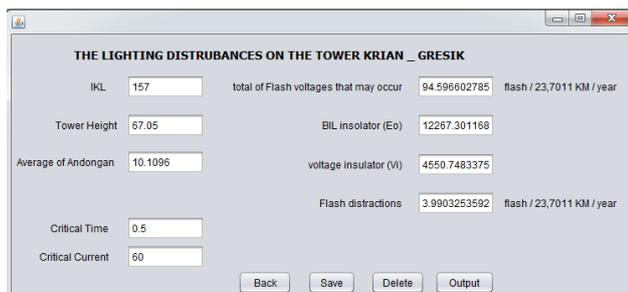


Fig. 6. Calculation results of channel interference.

Fig. 6 above points out the final result of the disturbance calculation with a disturbance value of 3.9903 flash / 23.7011 km per year.

IV. CONCLUSION AND FURTHER RESEARCH

From the result of this result analysis can be concluded that:

- On Suspension AA transmission towers get 24.93° angle protection with 74027 flash disturbance and CC