Sag and Tension of 275 kV Transmission Line using Catenary

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Sag and Tension of 275 kV Transmission Line using Catenary

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ABSTRACT

This research will develop a catenary method to determine the sag and tension analysis on the 275 kV transmission line conductors. The catenary method is dependent on the equation of the weight of the conductor, the maximum tensile stress of the conducting wire, the length of the span, and the maximum sag of the conductor. The method will be used in determining the value of sag and tension with the design of the model using software AutoCAD. The results of research for the same tower sag height of 6.86 m, with a tension of 4610.83 kg and a conductor length of 401.06 m, while sag for the tower is not the same height of 8.14 m, with a tension of 4012.84 kg, and changes in conductor length 401.06 m. The increase in current causes the sag value to increase, when the minimum current sag value is 6.9828 m, and the maximum current sag value increases to 8.44 m. While the tension will decrease along so that temperature is increased. The current minimum pressure of 4531.27kg, and at the time of maximum tension of 3749.728kg. Sag and tension are also affected by ambient temperature when the minimum temperature is 20 ℃ sags are 6.8621 m and when the maximum temperature is 40 ℃ sag increases to 7.793492 m. Tension will decrease with each increase in temperature when the minimum temperature is 20 ℃ tension 4610.538 kg when the maximum temperature is 40 ℃ the tension is reduced to 4062.345 kg.

KATA KUNCI: *ACSR, Catenary, Sag, Tension, Transmission Line.*

NOMENCLATURE

D	sag
S	span
W	Conductor weight per unit length
H	Tensile strength
H_t	The tensile strength at t℃
L	Conductor length
T	Tension
X_{min}	The lowest point of the catenary curve horizontally
Y_{min}	The lowest point of the catenary curve vertically
h_1	Elevation of suspense at the lowest point
h_2	Elevation of suspense at the highest point
D_{max}	The maximum sag
I	Current
R	Resistance
α	Temperature coefficient
E	The intensity of solar radiation
dc	Diameter conductor
W_s	The heat generated by solar energy
W_c	Power loss
τ	Constant Stefan Boltzmann
e	Relative emissivity of the surface conductor
T_c	Conductor temperature
T_a	Ambient temperature
p	Air pressure
V_m	Wind velocity

1.0 INTRODUCTION

Along with the increasing need of electric energy and capacity centers of generation, especially on the island of Sumatra caused additional necessary transmission line capacity. Efforts distribution capacity enhancement is achieved by optimizing the transmission line following the current-carrying capability strong. The transmission line must be provided with economical electricity reliably and with sufficient voltage well.

A framework for an electric power system is vast and complex, its components include power systems, distribution systems, and distribution systems that are the foundation of industrial exploitation of electrical power. Therefore, it has to know how the system implementation work high voltage lines, ranging from the action, preparation, assembly, and installation of the transmission line. Judging from the importance of the implementation of the installation work very influential channel transmissions on electricity supply, the effect of sag and tension is two essential things to be considered in the transmission line.

According to Stokes Law, the burden of this tensile stress will result in increased length of wire by the modulus of elasticity. Another thing that will lead to the period of expansion because of the high temperatures that occur in the conductor. This elevated temperature can be caused by many things, one of which is due to the onset of copper losses due to load current through the

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conductor. The higher the load current through the form of heat will cause higher losses, which in turn will be added to the burden of excitement in the conductor wire. Sag increases when there is a continuation of the conductor caused by rising when there is an extensive heat and also mechanical loads by wind [6].

This research will develop a method for determining catenary sag and tension analysis on 275 kV transmission line conductors. The catenary method is a function of the weight equation conductors, wire maximum tensile stress, long-span, and the maximum sags of the conductor. Processing methods will be used to identify the value of sag and tension with the design of the mo using statistical software is AutoCAD and assess the value of sag and tension of the conductor temperature influence due to line current and ambient temperature.

1.1 Sag Transmission Wire For Same High Towers

The region has a flat surface topography that would have the same transmission tower wire strung high that the tower will be the same height. Figure 1 is a curve shape catenary to the tower as high as the long span (S), sagging maximum (D), the length of the conductor (L), Tensile wires (H), heavy conductor (w), and specific voltage wire (a).

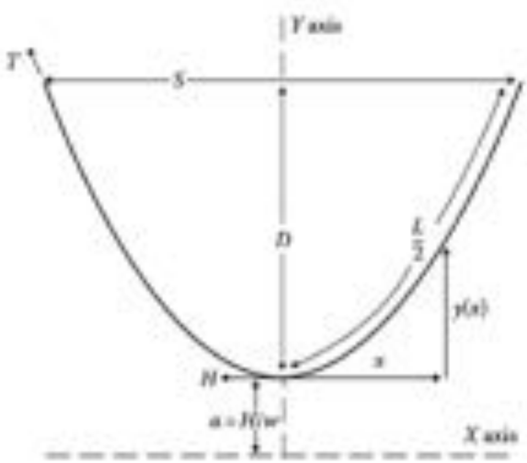

Figure 1: Catenary curve to the same tower height [8]

Catenary equation proper use hyperbolic function. Relative to the low point of the catenary curve shown in Figure 1, the height of the conductor, y (x), above the low point of this is given by the following equation [8].

$$y(x) = \frac{H}{w}\cosh\left(\left(\frac{w}{H}x\right) - 1\right) \quad (1)$$

Substitution x = S / 2, so that it's obtained the equation (2) [8].

$$D = \frac{H}{w}\cosh\left(\left(\frac{wS}{2H}\right) - 1\right) \quad (2)$$

The equation for calculating high tension on the same tower can be using equation (3) [8].

$$T = H + wD \quad (3)$$

To calculate the change in length due to sagging wires can using equation (4) [8].

$$L(S) = \frac{H}{w} \times \sinh\left(\frac{w \times S}{H}\right) \quad (4)$$

1.2 Sag Transmission Wire For Not Equal High Towers

The region has the same surface topography is not high will have the same transmission towers are not high, so the wire strung on the tower will not be as high. Two (2) pieces of the towers of unequal height can be illustrated as in Figure 2, which shows a wire that is created on two fulcra, which is not as high.

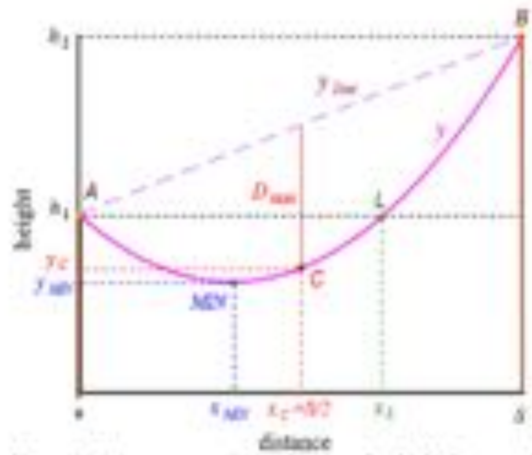

Figure 2: Catenary curve is not the same for the high towers [3]

X_{min} and Y_{min} is the value of the lowest point of the catenary curve, to calculate X_{min} using equation (5) [3].

$$X_{min} = \frac{S}{2} - \left\{\frac{H}{w} \times Sinh^{-1}\left(\frac{h_2 - h_1}{2 \times \frac{H}{w} \times \sinh\left(\frac{S}{2 \times \frac{H}{w}}\right)}\right)\right\} \quad (5)$$

To calculate Y_{min} using equation (6) [3].

$$Y_{min} = h_1 - 2 \times c \times \sinh^2\left\{\frac{1}{2}\left[\frac{S}{2 \times c} - \sinh^{-1}\left(\frac{h2 - h1}{2 \times c \times \sinh\left(\frac{S}{2 \times c}\right)}\right)\right]\right\} \quad (6)$$

Substitution of X_{min} Y_{min} to the equation (7) [3].

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$$y(x) = 2 \times c \times \sinh^2\left(\frac{x - X_{min}}{2 \times c}\right) + Y_{min} \qquad (7)$$

To calculate the maximum sag using the equation (8) [3].

$$D_{max} = 2 \times c\left(\frac{h2 - h1}{2 \times S}\left[\frac{S}{2 \times c} - \sinh^{-1}\left(\frac{h2 - h1}{2 \times c \times \sinh\left(\frac{S}{2 \times c}\right)}\right) + \sinh^{-1}\left(\frac{h2 - h1}{S}\right)\right] - \sinh^2\left(\frac{1}{2} \times \sinh^{-1}\left(\frac{h2 - h1}{S}\right) + \sinh^2\left\{\frac{1}{2} \times \left[\frac{S}{2 \times c} - \sinh^{-1}\left(\frac{h1 - h2}{2 \times c \times \sinh\left(\frac{S}{2 \times c}\right)}\right)\right]\right\}\right)\right) \qquad (8)$$

To calculate the change in length of the wire using the equation (9) [8].

$$L(S) = \frac{H}{w} \times \sinh\left(\frac{w \times S}{H}\right) \qquad (9)$$

To calculate the tower is not the same tension to high, given the equations (10) [8].

$$T = H + wD \qquad (10)$$

1.3 Steady-State heat balance

Heat conductor size depends on the size of the current and resistance at conductor temperatures prevailing. Considerable channel resistance due to temperature change can be calculated using equation (11) [4].

$$R_2 = R_1(1 + \alpha_0(t_1 - t_0)) \qquad (11)$$

So that the heat generated by the conductor as the heat generated by the electrical losses are calculated using equation (12) and the resistance is calculated using equation (13) [1].

$$W_c = i^2 \times R \qquad (12)$$

$$R_m = \frac{1 + \alpha t}{1 + 20\alpha} \times R_{20} \qquad (13)$$

Besides the heat is also generated by the absorption of heat from the sun to the conductor calculated using equation (14) [1].

$$W_s = \alpha . E . dc \qquad (14)$$

The heat spread radiation according to Stefan Bolzman law that is the amount of heat dispersed by radiation versus the fourth power of the absolute temperature of the conductor to be calculated using equation (15) [1] [5].

$$W_r = 17.9 \times 10^{-8} . e . ((273 + T_c)^4 - (273 + T_a)^4) . dc \qquad (15)$$

The convection heat loss rate (Wk) is the major heat loss from an overhead conductor [7], so the heat caused by convection given equation. (16) [1].

$$Wk = 5.73 \sqrt{p . V_m / dc} . \Delta t \qquad (16)$$

If the length of a wire conductor has an area π.dc, the equation (16) can be simplified into equation (17) [1].

$$Wk = 18 . \Delta t \sqrt{p . V_m dc} \qquad (17)$$

Heat balance equation states that any amount of heat generated inside the conductor that is equal to the amount of heat that spread, therefore the heat balance equation can be expressed in the form of equation (18) [1] [5].

$$W_c + W_s = W_k + W_r \qquad (18)$$

$$I^2 R + \alpha . E . dc = 18 . \Delta t \sqrt{p V_m dc} + 17.9 \times 10^{-8} . e . ((273 + T_c)^4 - (273 + T_a)^4) . dc \qquad (19)$$

1.4 Effect of temperature to changes in the sag and tension

Sag and length of wires hanging from changes in temperature, so that the excellent increase sag and conductor length will increase with increasing temperature that occurs while the value of the tension generated will be reduced [2], when the temperature increases, the elongation of the conductors will be increased, as well as the wire tension due to the temperature that is given by equation (20) to the equation (25) [4].

$$\sigma_t^3 + A\sigma_t^2 = B \qquad (20)$$

$$A = \frac{L^2 \gamma^2}{24\sigma^2} E + \alpha E(t_2 - t_1) - \sigma \qquad (21)$$

$$B = \frac{L^2 \gamma^2 E}{24} \qquad (22)$$

The tensile stress values obtained the wire can be calculated using equation (23) [4].

$$H_t = \sigma_t q \qquad (23)$$

So that the value of the sag and tension due to temperature change can be calculated using equation (24) and (25) [4].

$$d = \frac{S^2 w}{8H_t} \qquad (24)$$

$$T_{AB} = H_t\left[1 + \frac{1}{8}\left(\frac{Sw}{H_t}\right)\right] \qquad (25)$$

2.0 Results

In this section will explain the results of the design sag and tension to the tower as high on the transmission line of 275 kV, the results of the design sag and tension to the tower is not equally high for transmission lines of 275 kV, the result of the effect of temperature due to the imposition of the flow channel to changes in the value of sag and in addition, the result of the influence of ambient temperature to changes in the value of sag and tension, and the result of the influence of temperature due to the merger between channel currents and ambient temperature to changes in value of sag and tension.

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2.1 Results sag and tension Design For High Same Tower

For the same design for the tower height sag using equation (2), the calculation results can be seen in Figure 3.

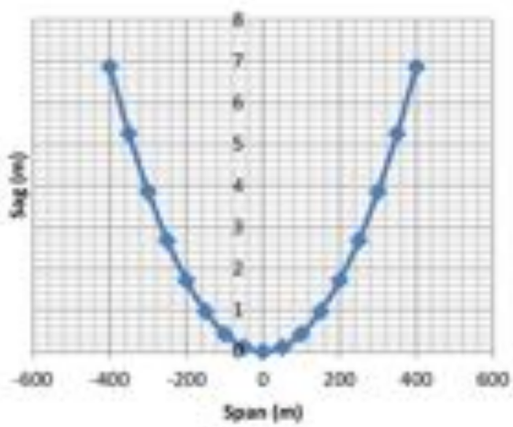

Figure 3. The curve sag to the same tower height

Figure 3 is a sag curve shape for the tower as high as in the x-axis as long as the y-axis span and large sag, resulting from the calculation in getting the sagging value of 6.86 m, to sag design results in the equally high tower can be seen in Figure 4.

Figure 4. Design sagging to the same tower height using software AutoCAD

From the calculation of the value of high tension on the same tower obtained at 4610.83 kg, where the value of tension gained an increase of 10.83 kg and for changing the conductor length of 401.06 m is obtained which undergo elongation of 1.06 m.

2.2 Results sag and tension Design For The Tower is Not The Same High

For the unequal design for the height of the tower to sag using equation (7), with the results of the calculation can be seen in Figure 5

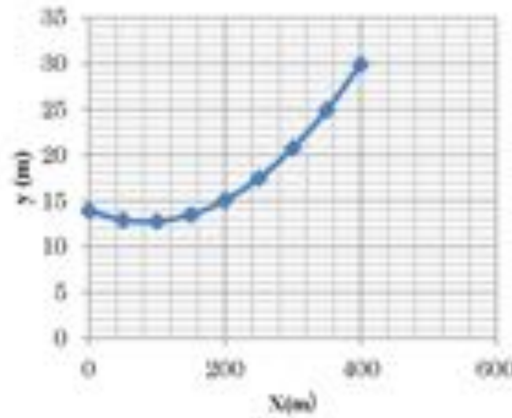

Figure 5 Curve sag of the conductor to the tower is not the same height using the catenary

Figure 5 is a conductor sag curve shape is not the same for the tower height to the x-axis is the y-axis span length whereas the sag of the conductor that is an excellent value it brings, and the value of the lowest point of the curve using the catenary sag conductor located at coordinates 83.41 m 12.7 m x-axis and the y-axis.

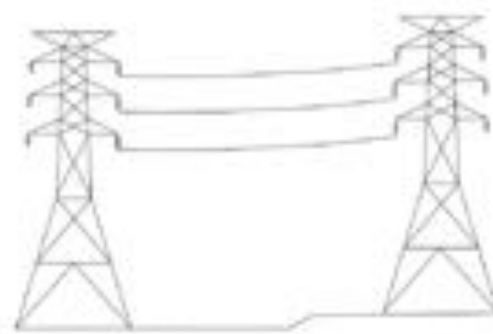

Figure 6 Design for the tower is not the same sag height using software AutoCAD

From the calculation results, the obtained value for the tower is not the same tension high of 4612.84 kg where the value of the tension generated an increase of 12.84 kg and also for the conductor length of 401.06 m and undergo elongation of 1.06 m.

2.3 Effect of Temperature Due to Current on Changes in Sag and Tension

Any increase in line current will cause the rise of temperature

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on the conductor so that the conductor will undergo expansion and elongation. As a result, the value of sag will increase along with the rise in temperature caused by the increase in the flow channel. However the value of the tension on the conductor is inversely proportional to the rise in the flow channel, each rated the current rise in tension obtained value will be reduced, and vice versa when the current value decreases, the value received tension will increase.

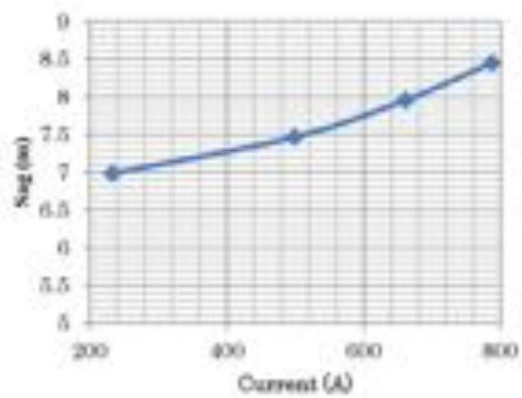

Figure 7 Current effect curve for sag

Figure 7 is the result of the calculation circuit to sag; it can be seen that when the minimum current is 232.72 A sag value generated of 6.98 m and then at the time of the maximum current is 786.86 A sag of the resulting value increased to 8.44 m.

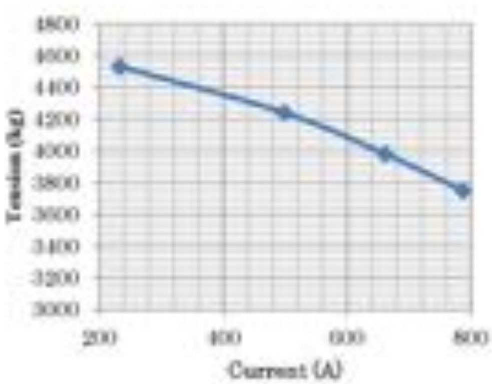

Figure 7 Current effect curve for tension

Figure 8 is a curve shape of the current relationship of tension can be seen that the effect of channel flow inversely to changes in the value of the tension, any increased value of the line current tension value obtained will wane, it can be seen that when the minimum current value is 232.72 A the tension generated is 4610.538 kg, then when the maximum current is 786.86 A The resulting tension value is reduced to 3749.728 kg.

2.4 Effect of Ambient Temperature on Changes in Sag and Tension

An increase in ambient temperature will cause expansion and elongation of the conductors, where development and elongation of conductors will lead to increasing the value of sag, the more significant the increase in temperature will cause the value of sag produced will increase. However, the value of the tension on the conductor is inversely proportional to the rise in ambient temperature, each value of the rise in ambient temperature then the value of tension obtained will be reduced and vice versa when the value of the ambient temperature reduced the value received tension will increase. Figure 9 is the result of the calculation of the influence of ambient temperature to changes in value of sag and tension which can be seen that when the minimum temperature is sag generated a value of 6.8621 m then when the maximum temperature The resulting sag value increased to 7.793492 m.

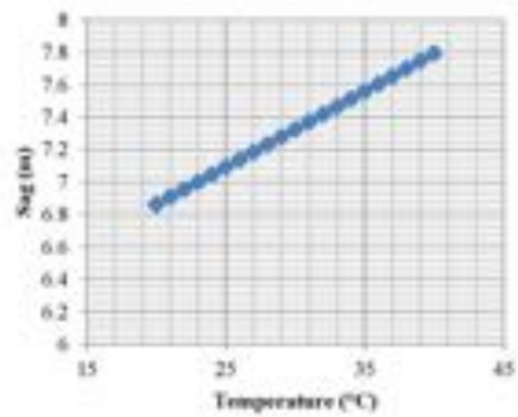

Figure 9 Effect of ambient temperature on changes in sag

Figure 10 shows the results of the ambient temperature rise in relation to the value of tension, each value of the increase in ambient temperature then the value of tension obtained will be reduced and vice versa when the value of the ambient temperature reduced the value obtained tension will increase. It can be seen that when the minimum temperature is the value of tension generated by 4610.538kg, then when the maximum temperature is the resulting tension is reduced to 4062.345kg.

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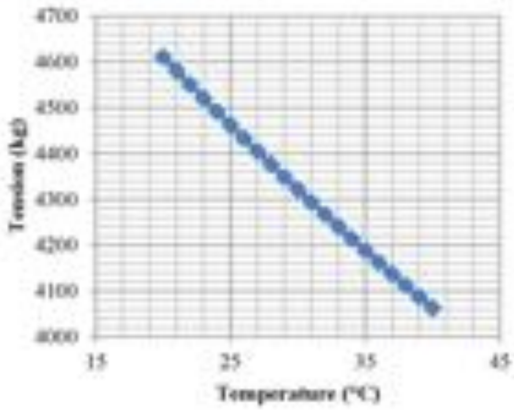

Figure 10 Effect of ambient temperature on changes in tension

2.5 Effect of Temperature Due to Current and Ambient Temperature to Change in Sag and Tension

If the temperature of the flow channel due to be merged with the ambient temperature, it will get the temperature difference between the two, the difference between the temperatures used in calculating the value of sag and tension, so that the obtained value changes sag and tension values shown in Figure 11.

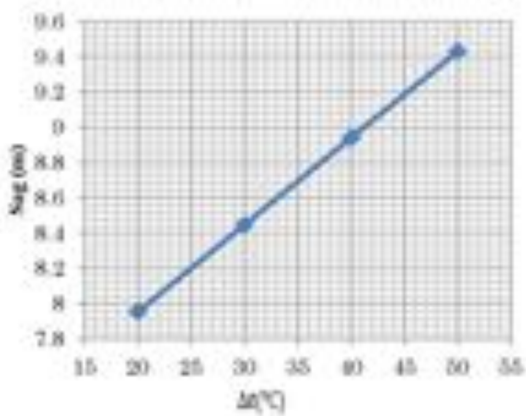

Figure 11 The influence curve of temperature on sag

Figure 11 is the shape of the yield curve sag value changes due to the influence of temperature due to the merger between channel flow and temperature environment in which the most substantial sag results obtained are 9.43 m with the difference between the temperature at 50°C.

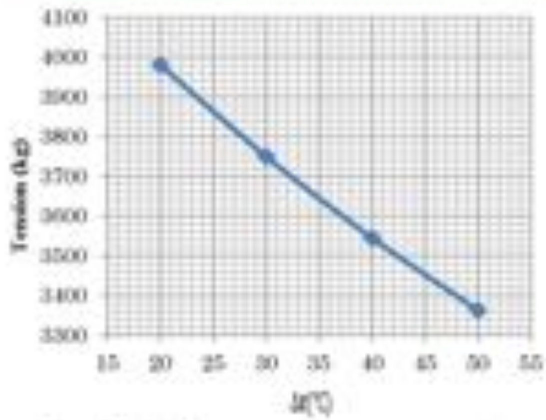

Figure 12 The influence curve of temperature on tension

Figure 12 is the result of changes in the value of the tension due to the influence of temperature due to the merger between channel flow and ambient temperature in which the tension value generated 3362.057 kg with the difference between the temperature of which is 50°C.

3.0 Conclusions

Based on the results of the design have been made to the same high tower obtained sag value of 6.86 m, with a value of 4610.83 kg tension and conductor length 401.06 m. While the tower is not the same for the high obtained sag value of 8.14 m, with a value of 4612.84 kg tension, and changing the conductor length of 401.6 m, changes in the value of sag and tension strongly influenced by changes in temperature, based on calculations that have been done that any increase in the flow channel and ambient temperature will result in increased value sagging while for the tension will decrease, it can be seen that when the minimum flow generated sag value of 6.98 m, with the value of the tension of 4531.27 kg, then at the time of maximum current sag value generated 8.44 m, With the value of the tension of 3749.72 kg, for the ambient temperature at the time of the minimum conditions resulting sag value of 6.8621 m, with a value of tension 4610.538 kg. Then when the ambient temperature conditions of maximum value The resulting sag of 7.793492 m, with value tension, amounted to 4062.345 kg. The merger between the temperature due to the flow channel and ambient temperature sag value that produced will be larger, it can be seen that the time difference between the maximum temperature is 50°C to sag value obtained of 9.43 m while the value of the tension of 3362.057 kg.

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