

Temperature and wind impacts on sag and tension of AAAC overhead transmission line



Babar Noor *, M. Zulqarnain Abbasi, Shahryar Shafique Qureshi, Sanaullah Ahmed

Department of Electrical Engineering, IQRA National University, Peshawar, Pakistan

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ABSTRACT

The transportation of electricity from the point of generation to the consumer premises is termed as a power system. Power system comprises of three entities, power generation, transmission and distribution. Among these entities, the inefficiency in transmission part contributed to most of the losses. These losses depend on the resistance, inductance and capacitance, which are termed as the constants of a transmission line. The performance of transmission lines mostly depends on these constants i.e., if the height of transmission line from ground is less, then its capacitance effect will be more and its performance will be degraded. On the contrary, if the height of line is high, its capacitance will be low but its tension will be high. Therefore, a transmission lines are connect in a curve like shape or catenary and is termed as sag. Sag must be providing in transmission line to minimize tension. Sag and tension should be adjusted within the safe limits. This research work presents a simulation setup to calculate sag and tension of AAAC (All Aluminum Alloy Conductor) overhead transmission line for multiple spans with impact of different weather conditions. Four different cases of temperature and wind are used and explained in detail for equal level spans. The simulations were carried out in ETAP software and the results showed that with the rise of temperature the weight of conductor increases, which increases the sag. Secondly, with the increase in sag, the tension of the conductor decreases in the AAAC.

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1. Introduction

The system that transports electricity from the point of generation to the end user is termed as a transmission system. Transmission lines and sub-stations play a central role in the transmission system (Quintana et al., 2016). Lines transporting the electricity embody the biggest part of the power system network. Therefore, appropriate modeling of these lines is one of the binding issues needs to be take care while designing and erecting transmission system. The subsequent performance of the transmission system depends on type of transmission modeling used in the system (Taleb et al., 2006).

Transmission lines are never connect in straight lines between supportive towers but are as a curve shape named a catenary as shown in Fig. 1. The sag is providing in the transmission line to minimize

tension in the transmission system (Oluwajobi et al., 2012). However, there is an inverse relationship between sag and tension. In case of high tension in a transmission line, the sag will be little but there is a chance of breaking the transmission line. Contrary if sag is too much, the extent of conductor will be use and as a result, there will be increase in cost. The intensity of sag also depends on the distance between two towers. Greater the distance between connecting towers greater will be the sag (Seppa, 1993).

The sag-tension calculations in the transmission system are aim at fixing appropriate limits between sag and tension to continue uninterrupted power supply to the consumers. The sag-tension calculation allows calculating the conductor temperature as well as ice and wind load simultaneously (Mehta and Mehta, 2005). The tension is keep within limits by the tension limit of the towers and conductor. While clearance distance of sag depends on ground and line crossings. In case the crossing distance is less than the clearance distance, there will be chances of occurring line faults (Oluwajobi et al., 2012). The quantity of insulator strings and there installation techniques in that "V" or "I" configuration can be set

* Corresponding Author.

Email Address: babarnoor@inu.edu.pk (B. Noor)

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are also important for calculation of sag-tension. The insulator string by its nature possesses the characteristics of an element therefore being element contributes in adding up further sag caused by conductor itself (Quintana et al., 2016).

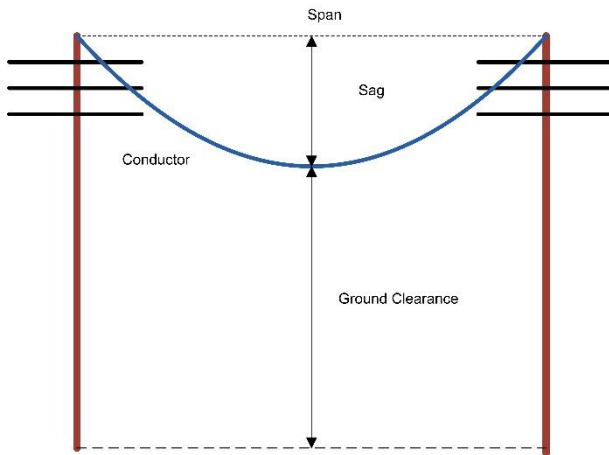


Fig. 1: Conductor, sag and ground clearance level

To consider bundle conductors are also important in various cases, for per phase more than one conductor is used. For extra high voltage system, two bundle conductors per phase is used and sometimes substation that is collect power from generating stations may use three conductors per phase. Thus, all the fundamentals concerning the sag-tension estimation process is necessary to consider for ensuring that the outcome match the actual conditions (Quintana et al., 2016; CIGRE, 2007).

2. Calculation of sag

While designing overhead lines, care needs to be taken so that the sag is adjusted in such a way, that tension running in the conductors is within safe range. In fact, tension is administered by conductor weight, temperature variation, ice load on wires and effect of wind. According to normal practice, conductor tension is keep below 50% of its eventual tensile power. It means least factor of safety of a conductor tension needs to be two. Now calculation of sag as well as tension of a conductor will be carry out keeping level of support at equal (Mehta and Mehta, 2005).

2.1. When supports are at equal levels

A conductor is considering between two supports A and B of equi-level with O as the lowest point such as reflected in Fig. 2. We can prove that lowest point prevails at the mid-span.

Consider a point P on the conductor. Taking the lowest point O as the origin and let the co-ordinates of point P be x and y. Assuming that the curvature is so small that curved length is equal to its horizontal projection (i.e., OP = x), the two forces acting on the portion OP of the conductor are (Kamboj and Dahiya, 2014):

- The weight $w x$ of conductor acting at a distance $x/2$ from O.
- The tension T acting at O.

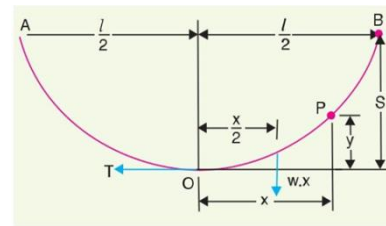


Fig. 2: When supports are at equal levels; Let: L: Length of span; w: Weight per unit length of conductor; t: Tension in the conductor

Equating the moments of above two forces about point O, we get,

$$T y = w x * \frac{x}{2} \quad (1)$$

$$y = \frac{w x^2}{2T} \quad (2)$$

The maximum sag is show by the value of y at either of the supports A and B in Fig. 2. At Support P

$$x = \frac{l}{2} \text{ and } y = s$$

putting equations from (1) and (2)

$$s = w \left(\frac{l}{2}\right)^2 \frac{1}{2T} \quad (3)$$

is the sag up to the point P.

For a whole transmission line between supports i.e., from point A to B in Fig. 2.

$$s = \frac{w l^2}{8T} \quad (4)$$

Practically the sag is measure by Eq. 4 between two level supports, which includes the weight, length and tension between every two supports. That is between every two supports these terms should be find mechanically and mathematically. The need of low cost simulation setup to find sag and Tension is necessary.

3. Methodology

For the result-oriented sag-tension, sag-tension of AAAC transmission line considering different equal span lengths of different operating conditions are analyze in this research. The tool used for the calculation is ETAP. The ETAP's module containing an analytical strength for Transmission and Distribution Line Sag and Tension calculation. It is easily available low cost simulation software to calculate the appropriate sag and tension in order to ensure appropriate operating conditions on the overhead transmission lines. Four cases i.e., 1, 2, 3 and 4 are shown in tables. In 1 sag-tension of AAAC under minimum operating condition with no wind effect is analyze because in winters the temperature is minimum.

In case 2 temperature is increase from minimum to normal temperature and calculate sag and tension of AAAC. In case 3 the temperature is maximum because in summers the temperature reaches to its peak value and then calculated sag and tension under maximum temperature. In case 4 a worst condition i.e. Maximum temperature with maximum wind effect and checked its effect on sag and tension.

These calculations are for level spans only when both the towers are on same height. The height of tower is 16m and spacing between conductors is 1.5m. The conductors used in the research are AAAC (All Aluminum Alloy Conductor) because:

1. These conductors are of high strength made of Aluminum-Magnesium-Silicon alloy and are having better ratio of strength to weight enabling the conductors to exhibit more efficient electrical characteristic. They have excellent sag-tension characteristics and superior corrosion resistance when compared with other conductors.
2. Comparing with traditional ACSR, AAAC are lighter in weight, are having lower electrical losses and comparable strength and current carrying capacity.

4. Results and discussion

4.1. Case 1

In the first case, sag-tension under minimum operating temperature i.e. 5°C is analyzed because in winters the line contracts as a result there will be low sag. In Table 1, four different span lengths for equal level supports in minimum operating temperature i.e., 5°C are analyzed using AAAC.

Table 1: Minimum operating temperature 5 °C

Type of Conductor	Span(m)	Wind Speed (N/m ²)
AAAC	50	0
AAAC	100	0
AAAC	150	0
AAAC	200	0

When the span length is 50m, the sag is 0.17 and tension is 1747. As the span increases from 50m to 100m, the sag is 0.66 and tension is 1653. Similarly, for 150m and 200m the sag and tension is 1.49,1504, 2.65 and 1259 respectively. So from the Fig. 3 it can be seen that when the span length increases the sag also increases this is because sag is directly proportional to span length and inversely proportional to tension.

4.2. Case 2

In the second stage, normal operating temperature to calculate sag and tension of a transmission line is considered. In Table 2, four different span lengths for normal operating condition using AAAC are considered.

When the span length is 50m the sag and tension is 0.22 and 1336. For 100m, the sag is 0.87 and tension is 1183. Similarly, for 150 and 200m span

the sag is 1.95, 3.47 while tension is 989 and 747 respectively. In this case shown in Fig. 4, there is rise in temperature due to which sag is more than minimum temperature while tension is less.

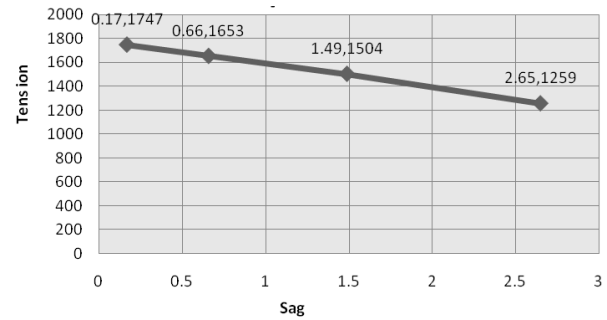


Fig. 3: Sag-Tension results for minimum temperature

Table 2: Normal operating temperature 30 °C

Type of Conductor	Span(m)	Wind Speed (N/m ²)
AAAC	50	0
AAAC	100	0
AAAC	150	0
AAAC	200	0

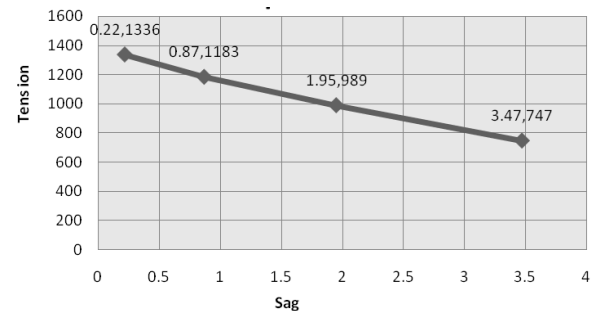


Fig. 4: Sag-tension results for normal temperature

4.3. Case 3

In third stage, sag and tension under maximum operating temperature is considered. Because due to increase in temperature, the weight of metallic bodies of conductor also increases as a result further increase in sag.

From Table 3, it is noticed that four different span lengths are consider for maximum operating condition because temperature does not remain constant, it varies with time and every temperature has its own effect on sag.

Table 3: Maximum operating temperature 50 °C

Type of Conductor	Span(m)	Wind Speed (N/m ²)
AAAC	50	0
AAAC	100	0
AAAC	150	0
AAAC	200	0

In this case, the temperature is maximum so when the span length is 50m the sag and tension is 0.27 and 1074. As the span Length increases to 100m, 150m and 200m the sag is 1.08, 2.44 and 4.33 while tension is 922,747 and 548. From the Fig. 5, it is clear that due to maximum temperature the sag is also larger than normal temperature. This is because due to rise in temperature, the metallic body of conductor expands and as a result, the weight of

conductor increases that is directly proportional to sag.

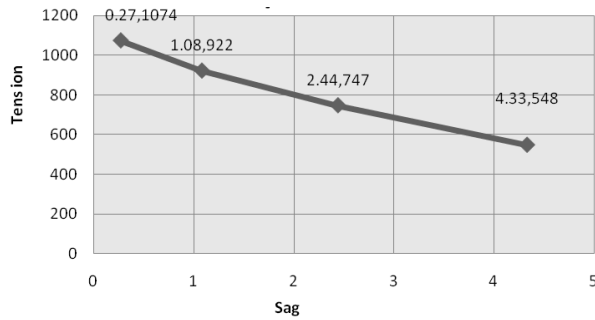


Fig. 5: Sag-tension results for maximum temperature

4.4. Case 4

In the last case, sag and tension under worst condition is analyzed because the temperature is maximum and at the same time, there is maximum wind effect.

In Table 4 high wind speed with maximum temperature is consider because the wind load on the conductor will increase the apparent weight of the conductor resulting in an increase in tension.

Table 4: Maximum operating temperature 50 °C with maximum wind speed 50 N/m²

Type of Conductor	Span(m)	Wind Speed (N/m ²)
AAAC	50	50
AAAC	100	50
AAAC	150	50
AAAC	200	50

In this case, the temperature is maximum with maximum wind effect. The temperature is same as in previous case but wind is added. Due to wind load on the conductor will increase the apparent weight of the conductor resulting in an increase in tension. Therefore, from the Fig. 6 it is shown that sag is same as previous case due to same temperature but tension is high due to wind effect.

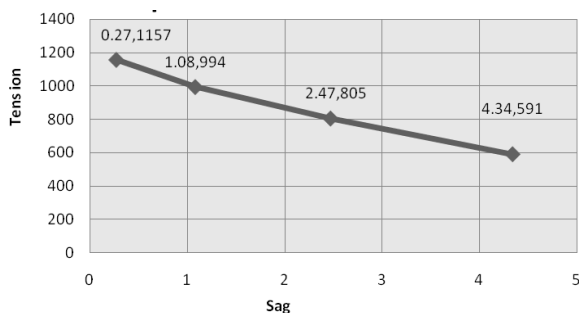


Fig. 6: Sag-tension results for maximum temperature with wind effect

5. Conclusion and future work

In this paper, four different cases were considered for sag-tension estimation of AAAC overhead conductor in transmission lines. The various span lengths considered under different operating conditions. For these conditions, the height of tower was same but operating conditions

of temperature are different. From the results the following conclusions are drawn:

1. In winters, the temperature is minimum so due to low temperature the AAAC line contracts as a result there will be low sag that will indicate a high tension, so it is clear from our result of case 1 when the temperature is low there is low sag and that indicates high tension.
2. In spring, the temperature is normal so the sag of AAAC line will be high than winters and there will be less tension than previous case. In summers, the temperature is maximum so due to increase in temperature the metallic body of conductor expands as a result the weight of conductor increases so sag is also increased. Therefore, it is clear from our results that in this case there is maximum sag and minimum tension.
3. In case 4 worst condition i.e., both maximum temperature and maximum wind effect at a same time is consider. Because wind will increase apparent weight of the conductor, as a result increase in tension and due to maximum temperature there will be maximum sag. From the result, it is clear that due to wind effect there is increase in tension occur.

Therefore, for the sag estimation of overhead conductor ETAP software is very helpful to predict sag-tension behavior of overhead conductor in transmission line more efficiently, moreover it is easily available software as compared to high cost commercial software to calculate sag-tension.

From this paper, one can easily find the sag-tension values of AAAC conductor for the different cases of temperature without calculating it mathematically.

In future, the sag-tension estimation of other conductors will also be considered in ETAP.

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