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The Analysis of the Sag distance for supplying the High Voltage of the Stranded Aluminium

Nattapong Phanthuna
Dept. of Electrical Engineering, Faculty of engineering, Rajamangala University of technology Phra-Nakron (RMUTP)
Bangkok, Thailand
nattapong.p@rmutp.ac.th

Chanon Tewsikares
Power System Engineering Authority, Provincial Electricity Authority (PEA)
Bangkok, Thailand
big.tew.bt@gmail.com

Panisra Phrmmanok
Dept. of Electrical Engineering, Faculty of engineering, Rajamangala University of technology Phra-Nakron (RMUTP)
Bangkok, Thailand
panisra.php2707 @gmail.com

Akaradage Khongkaphan
Dept. of Electrical Engineering, Faculty of engineering, Rajamangala University of technology Phra-Nakron (RMUTP))
Bangkok, Thailand
akaradage07@gmail.com

Piyatida Phanthuna
Dept. of Science and Technology Rajamangala University of technology Phra-Nakron (RMUTP)
Bangkok, Thailand
piyatida.r@rmutp.ac.th

Boonserm Ainsuk
Power System Engineering Authority, Provincial Electricity Authority (PEA)
Bangkok, Thailand
b.ainsuk02@gmail.com

Abstract— Most of the wires used in high voltage systems, above ground use 400 square millimeters of all-aluminum conductor (AAC) cable. Which has excellent corrosion resistance properties, but if there is power in the system and the temperature rises over a period of time. It can adversely affect the strength of the electric cable and the higher the tension inside the cable. This is a direct consequence of the looseness of the electric wire. This causes a reduced electrical safety distance and a shorter cable life. Therefore, it is important to know the overcurrent rating, IEC1597 and IEEE738 Standards are applied. Come for comparison to consider in the analysis of rated current that can cause fatigue and loss of strength, elevated temperature and suitable sag for the distribution system.

Keywords—sag distance, cable, standard aluminium

I. Introduction

In the power system installation, most of the system had used the aluminum electric wire that was stranded, size 400 sq. mm. by having the overload current position should not exceed 855 Amp, because that wire can resist the corrosion as excellent properties which the wire was designed to apply in the high voltage distribution [1-4]. Nevertheless, that cable may reduce the strength of itself, if the cable has received the heat temperature from the current [5] by the fatigue or creep value must not be over than 75˚C and the strength loss of the conductor should not exceed 93˚C as the mechanical stress will cause the reducing lifetime of the cable, moreover, the both cases can increase the sag distance [6]. Therefore, it is necessary to consider the overload current position and the sag distance that has appropriate of the conductor in accordance with the IEEE 738 and IEC 1597 standards to search the effect of higher temperatures on aluminum wires for extending the lifetime of the electric wire.

II. The Electrical Cable Specifications and Characteristics

The capability in supporting electrical current of the cable has depended on the heat of the conductor received from the electric current which be the cause of the strength loss within the electric wire due to the expanding tension and strain. Therefore, it is necessary to know the parameters that will be used as shown in table 1

TABLE I. Electrical cable characteristics

The actual cross-sectional area.	389.14 mm^2
Diameter of the cable.	2.85 mm
Diameter of the stranded conductor.	25.65 mm
Cable weight	1.075 kg/m
Ultimate tensile	6025 kg
Maximum Ampacity	855 A
Elasticity coordinates	5500 kg/mm^2
Coefficient of the expansion based on the length	23×10^{6}
DC resistance value at a temperature of 20 ˚C	0.0742 Ω/kg

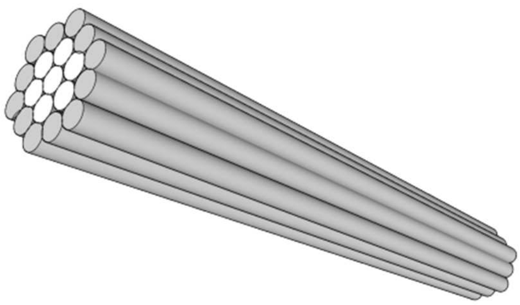

Fig. 1. 3D model of the Aluminum Conductor (*AAC*)

III. The Factors of the Strength loss within the Cable

The thermal effect of the cable can reduce its strength and increase the tension of the wires. Therefore, the IEC1597&IEEE738 standard has been used for determining the heat rating constant in order to analyze the cable current rating. From the analysis, it was found that the current ratings of the two standards had a slightly different value of 8% as shown in the figure. And the factors of power loss are follows: [7] [8]

- Convective heat transfer, often referred to simply as convection, is the transfer of heat from one place to another by the movement of fluids.
- Heat loss from radiation that depends on the diameter and ambient temperatures.

- Solar heat that increase from absorption radiation of area or structure material

For the selection of the steady-state thermal rating from standards can consider or calculate as below which the first equation is the Ampacity of IEEE STD 738 and the second equation is the Ampacity of IEC 1597

$$I = \sqrt{\frac{q_c + q_r - q_s}{R(A)}} \quad (1)$$

The calculation of the steady-state thermal rating (ampacity) beads on IEEE STD 738 can calculate from the equation (1) which q_c is the forced convection heat loss, q_r is Radiated heat loss and q_s is solar heat gain. By the resistance at temperature is called R(A)

$$I_{max} = \sqrt{\frac{P_{rad} + P_{conv} - P_{sol}}{R(T)}} \quad (2)$$

According to IEC 1597 standard, the steady-state thermal rating (Ampacity) can be calculated as equation (2). Where P_{rad} is the heat loss from the radiation, P_{conv} is the convection of heat loss and P_{sol} is the solar heat on the conductor surface. By the electrical resistance of a conductor at a temperature T (Ω/m) is the R(T)

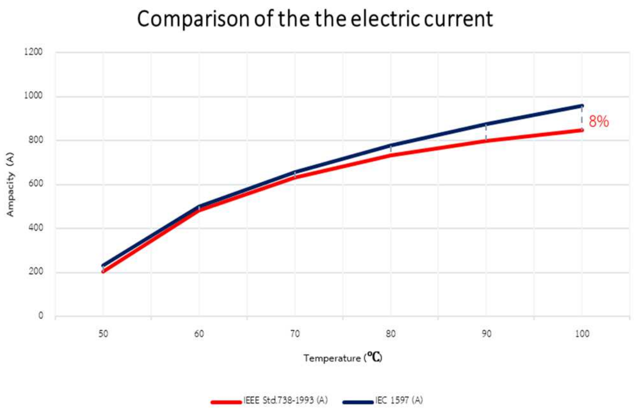

Fig. 2. The comparison graph of electricity current

IV. The Effect of the High Temperature in Operating Aluminum Cables

The aluminum conductor standard has specified the temperature above 75 ˚C will cause the loss of elasticity. And in case of over than 93 ˚C, it will cause a loss of the conductor's mechanical strength. Therefore, the temperature of the conductor wire is prohibited to exceed the specified standards value which have been shown in Figure 3. The loss of the conductor used at high temperatures can be divided into the equations as shown below.

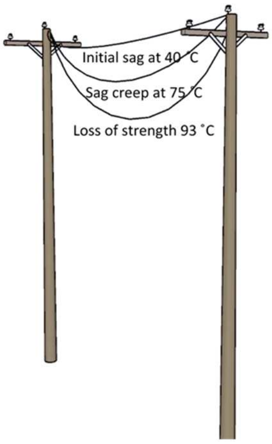

Fig. 3. The heat temperature of the aluminum cable distance

A. *The fatigue of electric wires (Creep)*

When the cable is used for the higher temperatures of more than 75 ˚C, the cable will increase the flexible ability and is not going to be returned to the original state. Hence, the tensile strength and initial fatigue temperature values have to be considered in order to reduce the magnitude of the cable which can be calculated from equations (5) and (6). Moreover, the temperature change value is often used in various calculation processes to model the effects of creep on conductor sag and tensions by having the equation as (8) which ε_c is Primary creep strain)kN/mm^2(, [9]

$$\varepsilon_c = K\sigma^{1.3}t^{0.16} \quad (3)$$

$$\varepsilon_c = MT^{1.4}K\sigma^{1.3}t^{0.16} \quad (4)$$

$$\Delta T = \frac{\varepsilon_{high} - \varepsilon_{ambient}}{\alpha} \quad (5)$$

For calculations from the above equations, the constants of the room temperature creep equations for EC Grade aluminum formed by rolling rod (K) is usually considered as 1.16 and the constants of elevated temperature creep equations for EC grade aluminum formed by rolling rod (M) should be applied at 0.0129 by σ is the stress of the conductor (kN/mm^2)

B. *The mechanical strength loss of cables*

In case of the temperature is higher than 93 ˚C for a long period, the electric cable will be lost the mechanical strength of itself. However, the comparison of that time for transmitting the current in emergency times while the strength of constant cables can be calculated from the equation (5), by T is conductor temperature (C˚), t is elapsed time (h) and d is Stand diameter)mm.[10]

$$RS = (-0.24T + 134)t^{-(0.001T - 0.095)(\frac{2.54}{d})} \quad (6)$$

V. The Sag Didtance of the Aluminum Conductor

When the power system has transferred the electricity, the temperature within the cable will be increased in accordance with the relationship of fatigue and loss of strength, resulting the elongation and looseness increased. Therefore, the tensile force and sag distance can be calculated by using these equations below which the optimal electric pole distance is 80 meters. For determining the fatigue and loss strength on the sag distance at the various temperature, we are able to consider as shown in Table 2 and Figure 4. [11]

$$T_1^3 + \left[\left(\frac{C_1 W_0 L}{T_0}\right)^2 - T_0 + C_2\left(t_1 - t_0 - \frac{C^o}{100\alpha}\right)\right] T_1^2 - (C_1 W_1 L)^2 = 0 \quad (7)$$

$$Y = \frac{WL^2}{8T_0} \quad (8)$$

T_o = Tensile strength in the first condition (kg)
T_1 = Tensile strength in the second condition (kg)
W_0 = Weight of cable at the first condition (kg/m)
W_1 = Weight of cable at a second condition (kg/m)
t_0 = Temperature values of the first condition (˚C)
t_1 = Temperature values of the second condition (˚C)
L = Space of an electric pole (m)
A = Cross-sectional area of a cable (sq.mm.)
E = Modulus of cable elasticity (kg/sq.mm.)
α= Linear expansion coefficient of a cable based on temperature (˚C)
C^o = Creep of a cable (%)
C_1, C_2 = Constant values

TABLE II. The Sag are Temperature Increase.

Span (m)	Erection Temperature							
	40˚c	50˚c	60˚c	70˚c	80˚c	90˚c	100˚c	125˚c
80	0.743	0.92	1.108	1.288	1.457	1.616	1.764	2.098

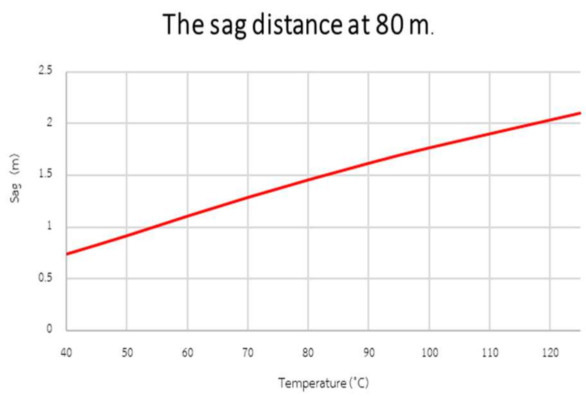

Fig. 4. The comparison graph of electricity current

VI. he Consideration of the Strength Loss and Creep Value Within the Cable

The power distribution should be considered for the main problem with the relation of the fatigue and strength loss within the cable, because of the long-distance power transmission increased the heat temperature within the line. Therefore, we are able to analyze these parameters by following the topics below.

A. The Considering Strength Loss of Cables in the Emergency State.

According to tables 3 and 4, we have described the effect of a loss of strength and considered a pole spacing of 80 meter and the surrounding temperature (40 ˚C approximately). It was found that the result was 95.976% because of the capacity loss at 100 ˚C within 10,000 hours utilized. However, the electric wire cannot be used at 125 ˚C because the line efficiency was 80% within a period of 4,000 hours. Consequently, these states have affected directly on the line slack, for example it is able to cause the problems with electrical safety distance and service life of the cable.

TABLE III. The Loss of Strength in the Emergency Temperature at 100˚ C, for the Active Time in 10000hour and RS = 95.979%.

Temperature	Sag	Sag (RS = 95.979%)
40	0.743	0.784
100	1.764	1.825

TABLE IV. The Loss of Strength in the Emergency Temperature at 125 ˚ C, for the Active Time in 4000 hour and RS = 80%

Temperature	Sag	Sag (RS = 80%)
40	0.743	0.987
100	1.764	1.825
125	2.098	2.133

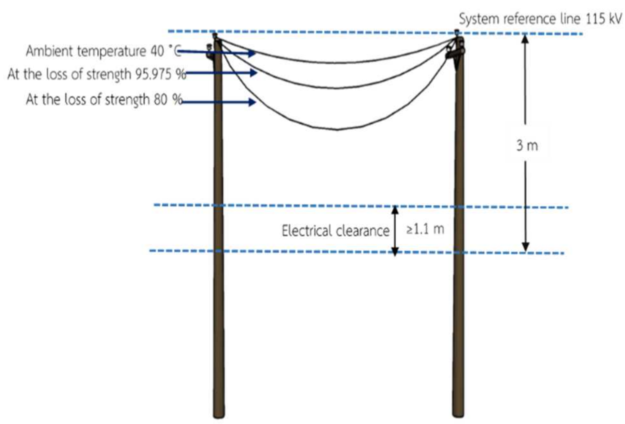

Fig. 5. The Sag Distance from Effects of The Strength Loss

B. The Considering Creep Value of The Electrical Wires

The heat temperature and the hours of the used cable are important factors for increasing and decreasing the temperature within the wire. However, the power distribution at the emergent time would increase higher the temperature. Therefore, we could summarize the sag distances as the table 5 by using the distances obtained from tables 3 and 4 for comparing the sags as shown in figure 7. And the safety distance should be not more over than 1.1 meters as figure 6 which we are able to determine from the distances between the 115 KV transmission system, 22 and 33 KV system.

TABLE V. THE SAG OF WIRE AT THE CONDITION EMERGENCY.

Normal temperature (˚C)	The sag of wire at the condition normal	The sag of wire at condition emergency 100 ℃ 10,000 hour compare 125 ℃ 4,000 hour Temperature rise 18 ˚C
40	0.743	1.1
50	0.922	1.3
60	1.108	1.45
70	1.288	1.65
80	1.457	1.75
90	1.616	1.9
100	1.764	2.05

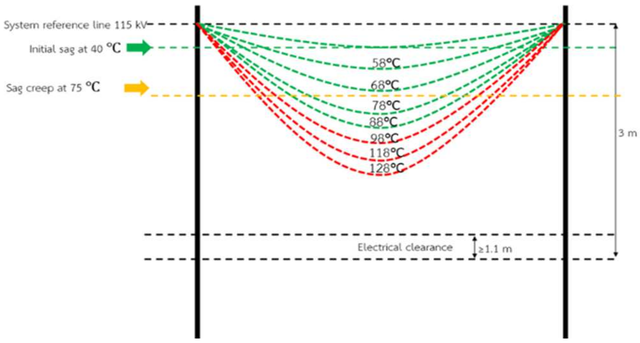

Fig. 6. The Sag Distance from Effects of The Strength Loss

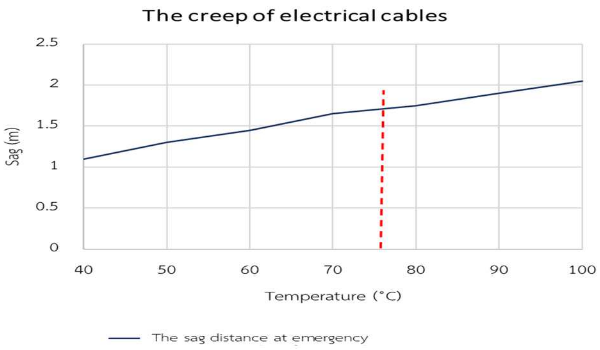

Fig. 7. The graph of the qualified safety criterion

VII. CONCLUSION

In conclusion, it was found that the normal states at 100 ˚C for 10,000 hours and at 125 ˚C for 4,000 hours would increase the temperature (18 ˚C approximately). Therefore, the maximum temperature of the cable should not exceed 75 ˚C because it is able to cause the fatigue and strength loss of electric wire. Nevertheless, the temperature of the power distribution at the emergent time is prohibited to exceed 93 ˚C for extending the service life of the electric cable

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