Design verification of stress and sag for 500 kV transmission line

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Abstract. Transmission line stress directly affects the tower sag force structure and a safe distance from the safe operation of the transmission lines play a crucial role. Calculation method for the preparation of the design process were complied, simply enter transmission liner parameters can be automatically obtained stress and sag. According to a 500 kV transmission line tests carried out stress sag design verification, checking ground found stress design errors and were corrected to ensure the safety of the project. Calculation program can be developed for different voltage levels for line stress on cables sag design verification.

Keywords: 500 kV transmission line, stress and sag, calculation program, design verification of stress.

1. Pay-off stress sag calculation code requirements

In the design of wire pay-off stress sag, we should first select meteorological conditions and safety coefficient calculation. Under normal circumstances, analyzing from the Angle of engineering design, there are four kinds of meteorological conditions as control [5], (1) Lowest ambient temperature, no wind, no ice. (2) Has the largest wind speed and air temperature, no ice. (3) Ice coating, air temperature is –5 Celsius degree, corresponding wind speed. (4) According to the annual mean temperature in the local, thinking vibration may occur. Under the condition of no ice and no wind, wire stress calculated at 25 % of wire breaking stress.

In DL/T5092 rules [6], the maximum stress of wire is in the sag lows, Based on safety factor K divide the destruction stress of the wire, maximum use stress can have to get. Use the formula is expressed as:

$$\sigma_{max} = \frac{\sigma_p}{K}, \tag{1}$$

where σ_{max} – wire's stress in the sag, low maximum; σ_p – conductor or ground wire of the instantaneous failure stress; K – safety factor of guide wire and ground wire.

Meanwhile, DL/T5092 regulations, Conductor design safety coefficient should not be less than 2.5, Ground safety factor should be greater than the wire. When a vibration control measures be carry out, average running stress of ground should not exceed 25 % of the failure stress.

2. Pay-off stress sag calculation

From a certain state of wire stress to ascertain wire stress under an unknown one, fundamental principles is based on which the relationship of Two states between the length of wire under the stress of the corresponding relationship. When the distance between the wire suspension point is fixed, we can get the conductor stress of another state by the principle of same lines if calculate the two geometric line length under different meteorological conditions. The equation of the state of the wire is presented by:

$$\sigma_{c2} - \frac{Er_2^2 l^2}{24\sigma_{c2}^2} = \sigma_{c1} - \frac{Er_2^2 l^2}{24\sigma_{c1}^2} - aE(t_2 - t_1), \tag{2}$$

when 1, 2, ..., N stress limit conditions are known, the corresponding parameters are γ_{mx}, t_{mx}, σ_{mx}. Put them into state equation respectively, equation (2) can be written to:

$$\sigma_x^2\left\{\sigma_x+\left[\left(\frac{Er_{mx}^2l^2}{24\sigma_{mx}^2}-\sigma_{mx}-aEt_{mx}\right)+aEt\right]\right\}=\frac{Er^2l^2}{24}. \tag{3}$$

We can know from the second equation, wire pay-off stress calculation under different span first need to obtain the known conditions, the known conditions known as the "control condition".

If the coefficient in the third equation:

$$F_{mx}=\frac{Er_{mx}^2l^2}{24\sigma_{mx}^2}-\sigma_{mx}-aEt_{mx}. \tag{4}$$

The biggest of the F_m is the control stress condition. So just put the span of the equation as the variable, by comparing the F_m value to select the control conditions of the qualification and the critical span effectively, according to second equation, controlling load, temperature and weather conditions allowable stress as the known data. With meteorological condition of wire stress than load, temperature data as another kind of meteorological conditions into state equation, can be various and stress state of wire.

If we mark $a=\left[\left(\frac{Er_{mx}^2l^2}{24\sigma_{mx}^2}-\sigma_{mx}-aEt_{mx}\right)+aEt\right]$ and $b=\frac{Er^2l^2}{24}$, the third equation can be written as the following three degree univariate polynomial equation.

$$\sigma_x^2(\sigma_x+a)=b. \tag{5}$$

Equation (5) can be solved by numerical method and satisfactory results can be obtained. After the pay-off stress is calculated, we can acquire sag by the following equation:

$$f=\frac{gl^2}{8\sigma_0\cos\varphi}, \tag{6}$$

where φ in the sixth equation is the angle of elevation difference of suspension point.

3. Developing the check calculation program

Through related standard procedures [6-7], we can check it for calculating the physical properties parameters of wire.

By entering the largest ice thickness, wind speed design program can automatically acquire the uneven shape coefficient and wind pressure coefficients of the wire. According the conventional wire stress value to Input horizontal stress initial value of the wire, program can be calculate the pay-off stress and sag of the wire. On the basis of getting optic fiber fly strain, we can calculate pay-off stress value range by safety factor, then discriminating the right and wrong of results. Check calculation program output pay-off stress and sag automatically with a picture. The specific processes as shown in Fig. 1.

4. Design check calculation of engineering cases

4.1. Project Summary

In accordance with the relevant standards and the reference information, A 500 kV test circuit design wind for 27 m/s, designing ice thickness is 50 mm, guide and ground wire parameters shown in the following table. Transmission line tension segment show in Fig. 2.

Table 1. Wire parameters

Name	Mark	OD (mm)	Section (mm^2)	Unit weight (kg/km)	Ex (MPa)	Coefficient of linear expansion (10^{-6}/°C)	Failure stress (N)	Safety factor
Guide line	JLHA1/G1A-460/60	29.8	525	1754.9	69000	19.3	393.2	3
Ground wire	XGJ-180	17.5	182.8	1521.7	185000	11.5	1230.9	3.85

4.2. Checking calculation results

Design check value and error value of ground wire (XGJ-180) compare as Table 2. Due to space limitations, this article only gives five typical span and the corresponding four pay-off stress temperature value. Correct pay-off stress at different temperature, different representative shift away from the stress value at about 45 MPa. The temperature of 5 degrees Celsius represent that when span is 350 m, stress value of pay-off is 45.03 MPa and corresponding sag is 4.286 m. Design institute of the given ground wire pay-off stress in the table corresponding to pay-off stress value under the condition is only 5.22 MPa and The corresponding sag value is 36.975 m. Contrastive analysis them, we can conclude that design pay-off stress sag is error. Pay-off stress of guide line (JLHA1/G1A-460/60) at different temperature, different representative shift away from the stress value at about 18 MPa. The temperature of -5 degrees Celsius represent that when span is 350 m, stress value of pay-off is 18.22 MPa. Wire pay-off stress design value and checking calculation results are unanimous.

Table 2. Ground wire pay-off stress design check value and error value contrast

T(°C)	Stress	Span				
		300	325	350	375	400
15°C	Check calculation values	45.49	45.14	44.88	44.66	44.49
	Error design value	5.31	5.25	5.20	5.16	5.13
10°C	Check calculation values	45.59	45.23	44.95	44.73	44.55
	Error design value	5.33	5.26	5.21	5.17	5.14
5°C	Check calculation values	45.70	45.32	45.03	44.79	44.61
	Error design value	5.35	5.28	5.22	5.18	5.15
0°C	Check calculation values	45.81	45.41	45.10	44.86	44.66
	Error design value	5.37	5.29	5.24	5.19	5.16

5. Conclusion

Developed transmission line pay-off stress sag design checking program, and to conduct a 500 kV test circuit guide ground wire pay-off stress sag design checking.

Ground wire type XGJ-180 pay-off table data for calculating is error. Given the pay-off stress value only have 5.22 MPa under the condition of 350 m span in temperature 5°C, and the corresponding correct value should be 45.03 MPa. Comparison and analysis to determine that it will eventually lead to pay-off sag of construction is error, if use error pay-off stress value. To ensure the engineering safety and complete successfully, the designer are required to redesign drawing.

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