Research on Anti-galloping Method for 6×1520 mm^2 Large Cross Section Conductors

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***Abstract*—The anti-galloping method was proposed for the 6×1520 mm2 large cross section conductor. The galloping model was established by using nonlinear finite element method and considering geometric nonlinear, aerodynamic nonlinear and initial deformation. The galloping characteristics and the critical conditions to excite galloping were obtained for the large cross section conductor. And the anti-galloping effect was also evaluated by using the rotary clamp spacers. The results show that the multi-bundled conductors are more vulnerable to the galloping phenomenon than the single conductors under the same ice and wind conditions. And the galloping characteristics obtained by 1520 mm2 large cross section conductor are basically the same with other cross section conductors. The anti-galloping effect can meet the requirement by using rotary clamp spacer for the 6×1520 mm2 large cross section conductor in the easy galloping areas. And even in the harshest ice and wind conditions, the galloping amplitude can be reduced in the largest extent and the time to excite galloping can be greatly extended.**

Keywords-large cross section conductor; anti-galloping method; rotary clamp spacer; UHV DC transmission line; nonlinear finite element method

I. INTRODUCTION

The galloping of iced conductors has became one serious disaster which endanger safe operation of the transmission line, which causes great threats on safe and stable operation of the line every year[1,2]. A large quantity of research works have been developed on galloping mechanism and prevention method of iced conductor in the transmission line in domestic and foreign country from beginning of 1930s in last century[3]. The corresponding research works on anti-galloping technology of the ultra-high voltage DC transmission line applying the conductor with the multiple split large section area are lack in the domestic and foreign countries.

For the conductor with the 6×1520 mm^2 large cross section conductor, it's characteristics of the high overhead line, many split number etc are favorable conditions to excite galloping, research on the effective anti-galloping measures shall be carried out on the line which passes through the galloping area, and capability of the line against icing galloping shall be improved.

Iced conductor galloping is one of typical structural self-excitation vibration phenomenon, including strong non-linearity, and galloping influence factors are complicated [4-9]. The concrete pertinent research works shall be developed according to the concrete line engineering conditions, meteorological and geographic conditions, and effective anti-galloping measures shall be developed to ensure safe and stable operation of the line. This paper establishes the icing galloping analysis model of the conductor with 6×1520 mm^2 large cross section conductor, analyzes galloping characteristics of the conductor with 6×1520 mm^2 large cross section conductor and evaluates anti-galloping effect of the rotary clamp spacer applied in the ultra-high voltage DC transmission line. Research achievement of this paper has been directly applied in anti-galloping design of the engineering construction.

II. ANALYSIS MODEL

Calculation of the galloping characteristics of the conductor with finite element method is an effective analysis technology [10,11]. This paper realizes analysis on galloping characteristic of the conductor with 6×1520 mm^2 large cross section conductor with the non-linear finite element instantaneous dynamic method. In which, pneumatic load takes advantage of the actual measured data of the air channel, the quasi-stable assumption is applied to carry out simplification treatment of pneumatic load.

Because the tower structure has great relative rigidity compared to the fittings of the conductors, deformation influence of the transmission tower structure can be neglected when the galloping conditions are considered. Rigidity influence of the transmission tower in the line shall not be considered during modeling process. The transmission tower in the model shall apply the fixed boundary to substitute. The conductor is simulated by the non-linear curve beam and the connection fitting is simulated by the plate or the beam unit. Typical finite element model for galloping of continuous five spans conductor in Figure 1.

In order to simplify calculation and improve operation convergence speed. Because of complicity of the coupling structure, the secondary factors shall be neglected as possible when the value model is established. Compared to the actual model, the main assumption conditions applied by value calculation models are shown as following:

(1) Neglect influence of elastic deformation of the transmission tower structure on calculation result, the corresponding transmission tower is substituted by the fixed boundary;

(2) In order to consider the geometrical non-linear conductor fitting insulator system, the following assumptions are generally made:

① Characteristics of material: the conductor fitting is in according with Hooke law, and plastic deformation isn't considered;

② Geometric non-linear mode: large displacement and small strain, section area change of the conductor isn't considered.

Based on above conditions, the basic movement equation solved by instantaneous dynamic analysis is,

$$[M]\{\ddot{u}\}+[C]\{\dot{u}\}+[K]\{u\}=\{F(t)\} \quad (1)$$

[M]means quality matrix; [C] means damping matrix; [K] means rigidity matrix; $\{\ddot{u}\}$ means acceleration vector of the node; $\{\dot{u}\}$ means speed vector of the node; {u} means displacement vector of the node; {F(t)} means load vector at t moment.

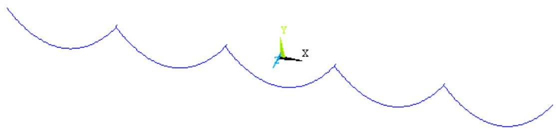

FIGURE I. FINITE ELEMENT CALCULATION MODEL OF CONTINUOUS FIVE SPANS.

The movement balance equation (1) is a two order non-linear differential equation set, it can't apply the standard solution to solve the ordinary differential equation set in theory. Two types of value solutions are generally applied during actual finite element dynamic analysis, i.e., vibration mode superimposition method and direct integration method. The integrated solver provided by the commercial finite element software is applied to solve in this paper.

III. Analysis of Galloping Characteristic and Anti-Galloping Effect

A. *Influence of Different Conductor Type On Galloping*

Type of the conductor is JL1X1/G2A-1520/125-481, take advantage of the common 10mm U shaped icing as calculation conditions, schematic figure of the icing section of the conductor is shown as figure 2, refer to results of the air channel test for pneumatic parameters. Firstly analyze the galloping excitation wind speed of the conductor with different section area. It is learnt from calculation results listed in figure 3, galloping wind speed of the iced conductor rises up following increasing of the conductor section area. Main reason is galloping of the conductor with great section area needs great energy under equivalent conditions. The galloping amplitude of the conductor with different section area is calculated at same time under 12m/s wind speed conditions. It is learnt from the results shown in figure 4, galloping amplitude of the conductor drops down under same icing and wind excitation conditions following increasing of the conductor section area. And the total reduction amplitude is very small. Therefore for the conductor with large section area of 1520 mm^2, galloping phenomenon will also occur under suitable ice and wind conditions, its galloping characteristics are basically same as these of the conductor with other section area.

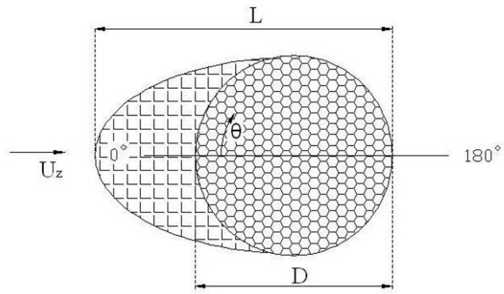

FIGURE II. SCHEMATIC FIGURE OF U SHAPED ICING SECTION.

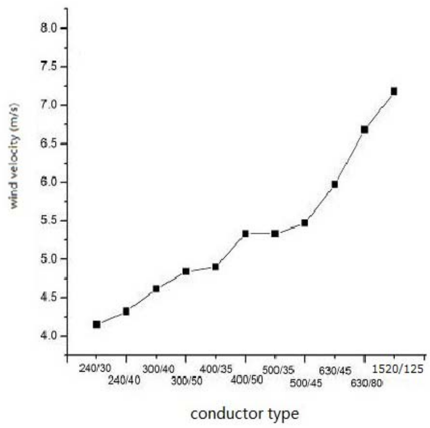

FIGURE III. GALLOPING WIND SPEED OF DIFFERENT TYPE CONDUCTOR UNDER 10MM ICE.

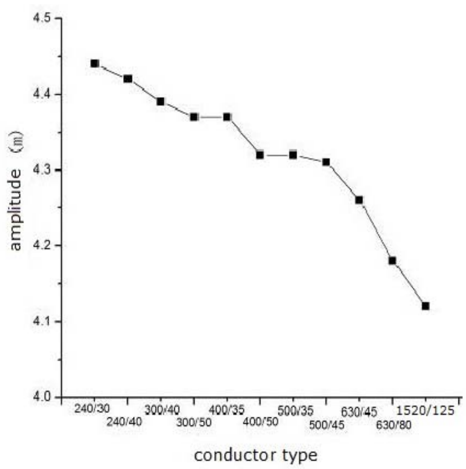

FIGURE IV. AMPLITUDE OF DIFFERENT TYPE CONDUCTOR UNDER 10MM ICE AND 12M/S WIND SPEED.

B. Equations

Take advantage of finite element method to analyze galloping conditions of the conductor in the transmission line. Take the 1520 large cross section conductor with the span of 400mm, 15mm U shaped eccentric icing and wind speed of 10m/s as sample, time stepping curve at the centre position is given in figure 5. It is learnt from calculation results that maximum galloping amplitude can reach about 9m under severe U shaped icing conditions. Change of horizontal tension after galloping of the conductor is given is figure 6, maximum dynamic tension can reach 1.5 times initial tension. Because galloping characteristic of the conductor is basically same, it is learnt from calculation results, galloping characteristic of the conductor in the transmission line is basically same at the conductor in other line.

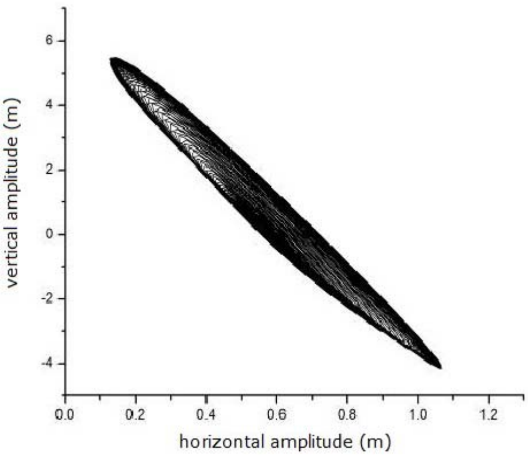

FIGURE V. AMPLITUDE IN 500M SPAN AT WIND SPEED OF 10M/S AND 10MM D SHAPE ICE.

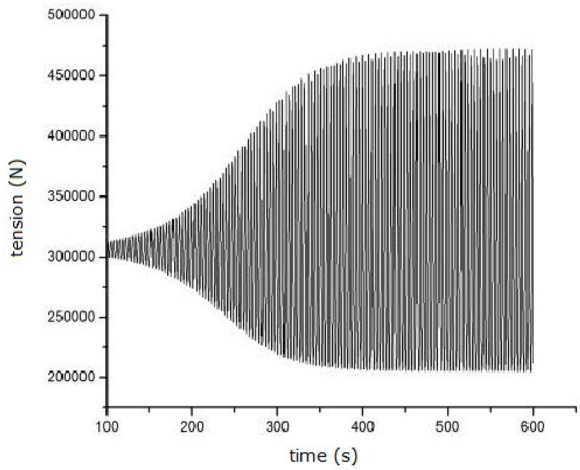

FIGURE VI. TENSION OF CONDUCTOR IN 500M SPAN AT WIND SPEED OF 10M/S AND 10MM D SHAPE ICE.

C. Anti-Galloping Effect Evaluation of Rotary Clamp Spacer

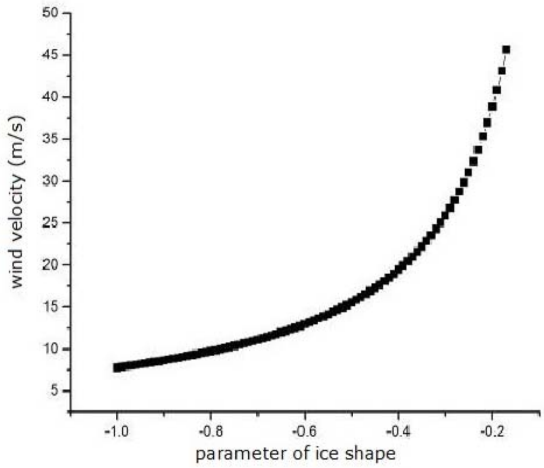

FIGURE VII. WIND SPEED OF CONDUCTOR UNDER DIFFERENT PARAMETER OF ICE SHAPE.

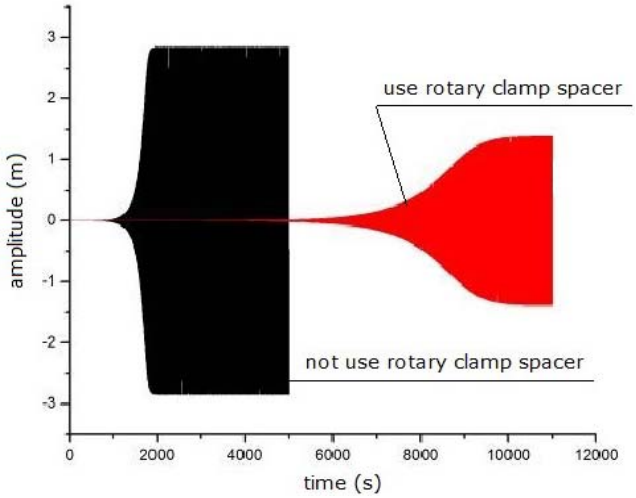

FIGURE VIII. COMPARISON OF GALLOPING AMPLITUDE BEFORE AND AFTER USE ROTARY CLAMP SPACER.

For the area in the transmission line which is liable for galloping, anti-galloping of the conductor mainly applies the rotary clamp spacer according to anti-galloping design requirements. Take advantage of finite element value method to analyze anti-galloping effect after installation of the rotary clamp spacer in the conductor. Take advantage of absolute value of average pneumatic lift force coefficient as shape coefficient to measure icing eccentricity degree of the conductor.

Calculation results of galloping wind speed of the conductor under different conductor icing shape parameter conditions are given in figure 7. Learnt from results in the figure, galloping wind speed rises up following reduction of absolute valve of the shape parameter of the conductor icing, it means galloping wind speed of the conductor rises up obviously following reduction of eccentric icing degree. After the rotary clamp spacer is installed, galloping wind speed can be improved effectively through changing eccentric icing characteristic, so as to reach galloping inhabitation effect. Figure 8 shows time stepping curve for galloping of the conductor under D shaped icing conditions of the conductor and 15m/s wind speed conditions after eccentric icing shape parameter is reduced to 0.5 from 0.98. Learnt from analysis result, galloping occurs in the conductor even after the rotary clamp spacer is installed in the conductor. But galloping amplitude is inhibited and galloping amplitude is reduced about 2/3, time for galloping excitation is prolonged greatly.

IV. Conclusion

Establish icing galloping analysis model of the conductor with 6×1520 mm^2 large cross section conductor, analyze galloping characteristic of the conductor with 6×1520 mm^2 large cross section conductor, carry out anti-galloping effect evaluation on the rotary clamp spacer applied in the anti-galloping area of the transmission line, and the following conclusions are obtained based on research achievements of this paper.

(1) For the conductor with large section area of 1520 mm^2, galloping phenomenon will also occur under suitable ice and wind conditions, its galloping characteristics are basically same as these of the conductor with other section area.

(2) Compared to the single conductor, the multiple split conductor is more liable to be affected by galloping under same ice and wind conditions, necessary anti-galloping design shall be considered in the liable galloping area for the conductor with 6×1520 mm^2 large cross section conductor.

(3) Good anti-galloping effect is obtained in the line engineering be liable to excite galloping when the rotary clamp spacer is applied. Galloping amplitude is effectively inhibited even under severe galloping wind and ice conditions, and time for galloping excitation is prolonged greatly.

(4) The finite element analysis flow for the multiple split conductor mentioned in this paper is also applicable to anti-galloping deign analysis of the split conductor in other structure type.

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