Parameter analysis of wind-induced vibration of electrical transmission line models

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Abstract. there are distinct growing tendencies in the span and height of electrical transmissions lines. However, little attention was paid on parameter analysis of wind-induced vibration of electrical transmission lines, especially on the gradient height. By means of a finite element software, electrical transmission line models were established to study the influence of 4 parameters to the response of electrical conductors and the gust response factor through a simulated wind field. The influence of some parameter was nonlinear and irregular.

Introduction

Due to the disequilibrium in the resource distribution, electrical transmission lines, which have traits of ultra-high-voltage, long span and large density, will play an important role in the economic advancement.

Ozono et al^[1] have studied the vibration properties of an electrical transmission tower-line system in plane. Yasui^[2] has established electrical transmission line models and calculated their dynamic characteristics and wind-induced vibration properties by means of link elements. Momomura^[3] has measured wind-induced vibration of a full-scale electrical transmission line system in a mountainous area. Loredou-Souza and Davenport^[4,5] has come up with design plans of electrical transmission line models in two different scale and studied aerodynamic damping and the interaction of lines between them. Observed in wind tunnel tests of a full aeroelastic model^[6,7], the wind-induced responses of the electrical transmission tower-line system in short span are very complicated. The vibration of an electrical transmission tower occurs not only in the along-wind direction, but also the across-wind direction and the torsional direction. Observed in wind tunnel tests of a aeroelastic model^[8-14], the wind-induced responses of the electrical transmission tower-line system in long span are more complicated in the effects of coupling between transmission tower and line.

There are distinct growing tendencies in the span and height of electrical transmissions lines. Wind loads is the number one cause for power line damage. Nevertheless, little literature refers to the parameter analysis of wind-induced vibration properties of electrical transmission lines. In default of these analyses, engineering designers cannot search any codes about electrical transmissions lines whose height exceed gradient height hitherto. Under the current conditions, the influence of gradient height only can be studied by numerical simulation. Finally, based on elaborate models and analyses from ANSYS software, the influence trend of different parameter and a corresponding gust response factor^[15] can be derived, which benefit engineering requirements in the future.

Wind field simulation

Through harmonic synthesis method^[16,17], the target stochastic wind field can be simulated accurately and effectively. The spectral density associated with stochastic wind velocity and its coherence have the forms suggested by Davenport (1961)^[18]. The target wind filed is terrain exposure

category B from China code^[19]. Due to limited space, some equations can not be listed here. Figs. 1 and 2 respectively show different characteristics of target wind field and simulation wind field.

Fig. 1 Target profile VS simulatoin profile Fig. 2 Target spectrum VS simulatoin spectrum

Figs. 1 and 2 both show the reliability of simulatoin wind filed.

Parameter analysis

Utilising the ANSYS software, electrical transmission line models with 3 spans was established and it is without any bunched conductor. As for boundary Conditions, one side of every insulator connects an electrical conductor and another side link a fixed hinge support. In the light of past study, the influence of coupling between transmission tower and line is negligible to the transmission line. Hence, this electrical transmission line model is valid. Fig. 3 shows the ANSYS model of the electrical conductor mentioned above.

Fig. 3 Model of the electrical conductor

As shown in Fig. 3, obviously, the whole model was symmetric in plan. The middle span was 2500m with the ratio of sag to span equalling to 9.458% and the rest of span were 1200m with the ratio of sag to span equalling to 4.268%. The length of insulator was 19m and the height of the middle insulator top was 350m. The default of average wind speeds was 40 m/s in the 10m height. Through ANSYS models , the effects that 4 mutual independent parametres (wind speed , span , height and mass) lead to diffenent wind-induced vibration properties of electrical transmission lines can be studied. Attention is put on the tension induced only by wind loads, in the end of the middle span, and displacement in the along-wind direction, in the midst of the middle span, of electical transmission lines. The Gust response factor is derived by dividing the max of tension by its average.

Fig. 4 ,6,8 and 10 respectively show the influence of mean wind speed, span, height of the middle insulator top and multiple of mass of electrical conductors to displacement in the along-wind direction. Fig. 5,7,9 and 11 respectively show the influence of the 4 parameters mentioned above to tension of a middle electrical conductor in the end of the middle span.

Table 1-4 respectively show the influence of the 4 parameters mentioned above to the gust response factor.

(1) Wind velocity

The variable of average wind speeds in the 10m height ranged from 20m/s to 40 m/s and the increment was 5m/s.

Fig. 4 The influence of mean wind speed to displacement Fig. 5 The influence of mean wind speed to tension

Table 1 The influence of mean wind speed to the gust response factor

Mean wind speed (m/s)	20	25	30	35	40
Gust response factor	1.265	1.195	1.208	1.23	1.145

(2) Span

The variable of span ranged from 500m to 2500m with the constant of the ratio of sag to span and the increment was 500m.

Fig. 6 The influence of span to displacement

Fig. 7 The influence of span to tension

Table 2 The influence of span to the gust response factor

Span (m)	500	1000	1500	2000	2500
Gust response factor	1.346	1.276	1.171	1.153	1.145

(3) Height

The variable of height of insulator top ranged from 350m to 500m. Besides, gradient height (350m) was considered.

Fig. 8 The influence of height to displacement

Fig. 9 The influence of height to tension

Table 3 The influence of height to the gust response factor

Height (m)	350	400	450	500
Gust response factor	1.145	1.163	1.128	1.124

(4) Mass

The variable of the multiple of the original electrical conductor mass ranged from 1 to 5 and the increment was 1.

Fig. 10 The influence of multiple of mass to displacement Fig. 11 The influence of multiple of mass to tension

Table 4 The influence of multiple of mass to the gust response factor

Multiple of mass	1	2	3	4	5
Gust response factor	1.145	1.219	1.328	1.393	1.503

Conclusions

(1) The RMS values of the response of the measured electrical conductor were negligible for the corresponding mean value. The response of the measured electrical conductor was quasi static.

(2) With the multiple of mass increasing, the response of the measured electrical conductor decreased. However, it was converse to the rest of variables.

(3) The influence of distance parameters to the response of the measured electrical conductor approximated linear change. However, it was nonlinear to the rest of variables.

(4) The influence of mean wind velocity to the gust response factor was irregular. With span increasing, the gust response factor decreased. However, it was converse to multiple of mass. In addition, below gradient height, With height increasing, the gust response factor increased, but, upon gradient height, it was converse.

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