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# Research on the Wind-induced Vibration Coefficient of Transmission Tower-line System

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**Abstract**

The six different non-linear finite element model of the transmission tower-line system which have different spans and different height difference was established by the finite element analysis software, and wind velocity time series with resorting to weighted amplitude wave superposition (WAWS) was simulated. Based on the established models and the simulated wind velocity time series, the wind-induced response of transmission tower-line system in time history was calculated to achieve wind-induced vibration coefficient of transmission towers of various models. By comparative analyzing, span and height difference on the impact of wind-induced vibration coefficient of transmission towers was studied. The results show that the span and height difference have a certain impact on wind-induced vibration coefficient of transmission towers, and the effects on tower top are more obvious than tower bottom. With the increase of span, wind-induced vibration coefficient reduces gradually, but with the increase of height difference, wind-induced vibration coefficient increases gradually.



Keywords:transmission tower-line system; weighted amplitude wave superposition; dynamic analysis in time historye; Wind-induced response; Wind-induced vibration coefficient.

## 1. Introduction

Transmission tower-line system is an important lifeline project as high voltage electric power's carrier. High transmission tower structure is sensitive to the wind; the dynamic effects are very obvious under the effect of wind loads. At present, in the design of transmission tower-line system architecture design, wire and transmission tower is usually carried out separately. When calculating the wind load of transmission tower, effects of the fluctuating wind to the structure are taken into account by the wind-induced vibration coefficient. Further, the strength of transmission tower is calculated.

Fore the transmission tower, when tower height is less than 60m, the wind-induced vibration coefficient of the whole tower is the same values. Otherwise the value of the wind-induced vibration

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coefficient is determined in accordance with the structures load standard (GB5009-2001) [1]. However, due to the special transmission tower shape, it does not meet Simplified conditions of the existing norms for calculating the wind-induced vibration coefficient [2-3]. In this regard, some domestic scholars conduct some research. Literature [9] analyzed the changes of local quality and area on the impact of the wind-induced vibration coefficient of towers. Literature [7] established the finite element model of the transmission tower-line system, comparatively analyzed the differences of the wind-induced vibration coefficient between the single transmission tower and the transmission tower-line system, but did not consider span and height difference on the impact of the wind-induced vibration coefficient. In this paper, the finite element models of the transmission tower-line system which have different spans and different height difference were established, and span and height difference on the impact of wind-induced vibration coefficient of transmission towers were comparatively analyzed.

## 2. Mechanical calculation models

This model is a spatial analysis two line tower model for spatial analysis containing a tower and two lines. Shown in Fig.1, force bars of transmission tower were simulated with beam-rod element. Insulator was simulated by link8 element. Conductor and ground wire were simulated by link10 element. Because the link10 element can simulate the geometrical deformation, it is commonly used to simulate the cable of the relaxation. To simplify the model, four bundle conductors will be simplified into a wire; the wire is four times the size and quality of the sub-conductor. Conductor is LGJ-400/35; cross section area is 425.24mm$^2$; the wire weight is 13.49N/m. Ground wire is JLB40-150. Suspension insulator string is composed of 28 XP-7 porcelain insulators. The height of every insulator is 0.15m, and the wind area of every insulator is 0.03m$^2$ and the volume is $3.015\times10^{-5}$kg/m$^3$. Assuming that the diameter is 0.02m, and then the length and the equivalent density is 0.15m, $1.55\times10^5$ kg/m$^3$ respectively.

When conductor and ground wire are discredited into finite element, find the form of cable first by adjusting the initial tension to determine the location of the initial state. The initial tension of conductor and ground wire is usually small, ratio of rise to span is relatively large, and therefore the appropriate curved cable element should be used. On the boundary, the four nodes of tower legs are constrained with fixed end. Transmission tower and ground wire are restrained with consolidation coupling, so are conductor and insulator. The other end of conductor and ground wire is considered fixed end [6]. In order to consider span and height difference factors, calculation was divided into six kinds of conditions that were listed in Table I.

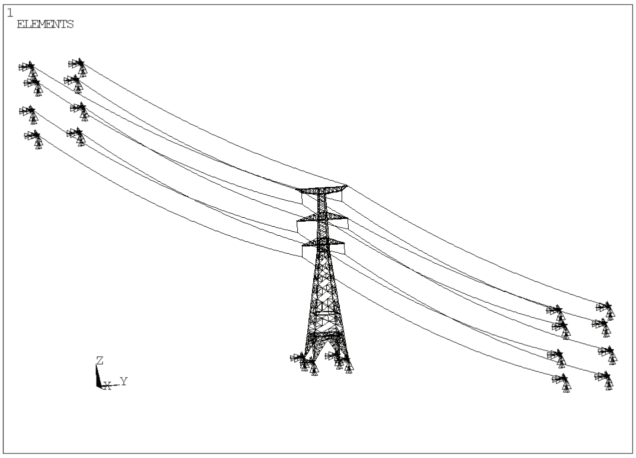


Fig. 1. Finite element model of transmission tower-line system

TABLE I. THE MODELS OF IN DIFFERENT CALCULATION CONDITIONS

| Condition NO. | Span (m) | | Height difference (m) | |
|---|---|---|---|---|
| | *Left* | *Right* | *Left* | *Right* |
| 1 | 400 | 400 | 0 | 0 |
| 2 | 600 | 600 | 0 | 0 |
| 3 | 800 | 800 | 0 | 0 |
| 4 | 600 | 600 | 10 | -20 |
| 5 | 600 | 600 | 30 | -40 |
| 6 | 600 | 600 | 50 | -60 |

## 3. the dynamic analysis of transmission tower-line system in time history

In this paper, fluctuating wind speeds based on Kaimal spectrum which reflects the change of wind speed with height above ground and Davenport coherence function, were numerically simulated by means of WAWS, and the wind-induced response of each model was calculated in time history. Firstly, the wind speed simulation program of spatial correlation is developed by using MATLAB [5]. Selecting sampling sites of wind speed time series are uniformly distributed in the windward side. Take a sample point every 10.0m on the transmission line. Transmission tower is divided into 12 regions, the position of simulated wind speed time history at the middle of each region [10]. The average wind speed is 10m/s at the 10m height. Time step$\triangle$t is 0.2s, and the total length of time of the total of 3000 steps is 600. Secondly, according to the fluctuating wind speed and the average wind speed of the nodes, tower sections and load distribution nodes, further obtain the wind load time-history of the nodes. And finally, the simulated wind load time-history is exerted on the corresponding nodes of the calculation models so as to calculate the wind-induced response in time history. Due to limited space, here the simulated wind load time-history is only given about the top of the tower in the condition 1 (Fig.2). And the displacement time history curve, the velocity time history curve and the acceleration time history curve are also given about the nodes in the department (Fig.3-5).

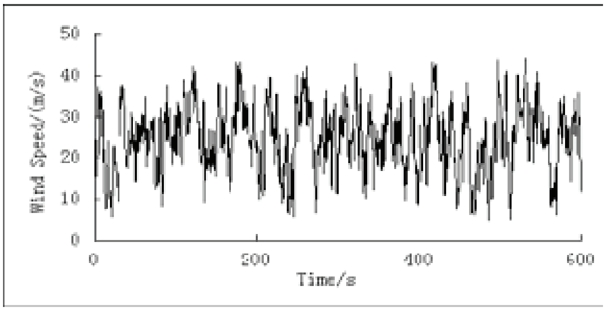


Fig. 2. The wind speed time series of the top of the tower in the condition

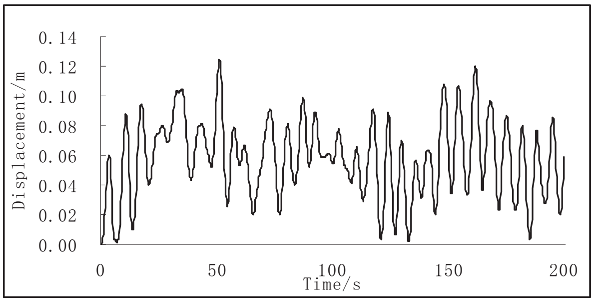


Fig. 3. The displacement time history curve of the node in the top of the tower

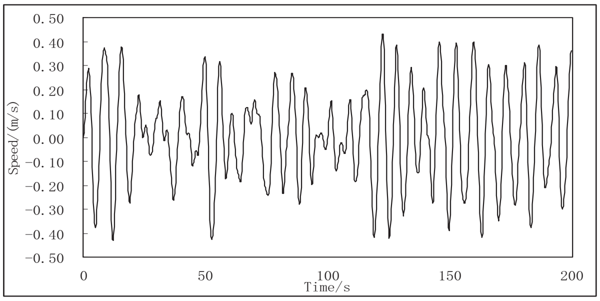


Fig. 4. The velocity time history curve of the node in the top of the tower

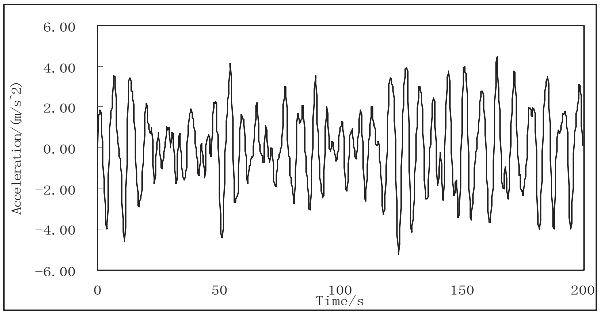


Fig. 5. The acceleration time history curve of the node in the top of the tower

## 4. Calculating the wind-induced vibration coefficient of transmission towers

In this paper, according to the results of the wind-induced response of transmission tower-line system, the wind-induced vibration coefficient of transmission towers is calculated using the following formula [4]:

$$\beta(z) = 1 + \frac{gm(z)\sigma_a(z)}{\mu_s \mu_z \omega_0 A(z)} \tag{1}$$

Where: $m(z)$ is concentrated mass at the height $z$; $A(z)$ is wind area at the height $z$; $\sigma_a(z)$ is acceleration variance at the height $z$; $g$ is ensuring coefficient; $\mu_s$ is the shape coefficient of structures; $\mu_z$ is wind pressure coefficient of height changes; $\omega_0$ is basic wind pressure.

Firstly, the wind-induced response of each established model was calculated in time history by using the finite element analysis software, to obtain acceleration time history data of the wind-induced response. Secondly, the wind-induced vibration coefficient of transmission towers in the different height is calculated by statistical processing and analysis of acceleration time history data. And finally, the wind-induced vibration coefficient calculated under the different conditions were compared, at the same time compared with load standard results, to analyze span and height difference on the impact of wind-induced vibration coefficient of transmission towers. Table II shows the value of wind-induced vibration coefficient of transmission towers calculated under the different conditions and according to load standard.

TABLE II. THE VALUE OF WIND-INDUCED VIBRATION COEFFICIENT CALCULATED UNDER THE DIFFERENT CONTIONS

| Height (m) | Wind-induced vibration coefficient calculated under the different conditions | | | | | | |
|---|---|---|---|---|---|---|---|
| | *Load standard results* | *1* | *2* | *3* | *4* | *5* | *6* |
| 5 | 1.10 | 1.07 | 1.07 | 1.07 | 1.070 | 1.070 | 1.070 |
| 15 | 1.27 | 1.24 | 1.24 | 1.24 | 1.240 | 1.240 | 1.240 |
| 22.5 | 1.35 | 1.37 | 1.37 | 1.36 | 1.370 | 1.370 | 1.370 |
| 28.5 | 1.40 | 1.39 | 1.38 | 1.37 | 1.380 | 1.380 | 1.380 |
| 33.5 | 1.42 | 1.43 | 1.42 | 1.41 | 1.419 | 1.419 | 1.419 |
| 40 | 1.48 | 1.45 | 1.43 | 1.41 | 1.427 | 1.427 | 1.428 |
| 46.5 | 1.53 | 1.49 | 1.46 | 1.43 | 1.456 | 1.456 | 1.457 |
| 49 | 1.54 | 1.65 | 1.60 | 1.58 | 1.683 | 1.684 | 1.686 |
| 55 | 1.57 | 1.80 | 1.74 | 1.71 | 1.732 | 1.733 | 1.735 |
| 60.2 | 1.60 | 2.05 | 1.96 | 1.90 | 1.947 | 1.948 | 1.951 |
| 65.5 | 1.59 | 1.97 | 1.88 | 1.82 | 1.868 | 1.869 | 1.872 |
| 71 | 1.61 | 2.29 | 2.17 | 2.06 | 2.153 | 2.154 | 2.158 |

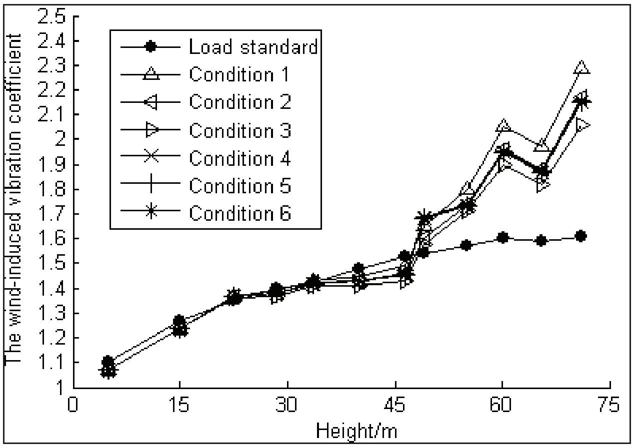


Fig. 6. The comparison chart of the wind-induced vibration coefficient

Table II and Fig.6 were comprehensively analyzed; and results can be obtained as follows:

The wind-induced vibration coefficient of transmission towers calculated according to load standard changes evenly along the height of transmission towers. The wind-induced vibration coefficient of transmission towers calculated according to dynamic analysis in time history changes evenly below cross arm of transmission tower, but the wind-induced vibration coefficient in the cross arm position exist some mutations. The above conclusions are similar with the literature [7], [8]. For the models established in this paper, the wind-induced vibration coefficient in the cross arm position is more 11% than computing nodes near the tower body.

The results calculated under the different span show: the wind-induced vibration coefficient near the tower legs almost have no changes. With the span enlargement, the wind-induced vibration coefficient decrease of about 0.7%-2% on the tower body part, and decrease of about 3%-5% on the tower head part. The results calculated under the different height difference show: the wind-induced vibration coefficient near the tower legs almost have no changes. With the height difference enlargement, the wind-induced vibration coefficient increase of about 0.06%-0.07% on the tower body part, and increase of about 0.1%-0.2% on the tower head part

## 5. Conclusion

a) The results calculated in time history show: The wind-induced vibration coefficient of transmission towers changes evenly below the cross arm of transmission tower, but the wind-induced vibration coefficient in the cross arm position exists surge. This is coursed by concentrated mass and wind area in the position of the cross arm.

b) By comparing the calculating results in the different conditions, some conclusions are drawn: the variation of span and height mainly affect the wind-induced vibration coefficient of transmission tower head, and have a weak effect on the transmission tower body. The span's change on the impact of the wind-induced vibration coefficient is more obvious, but the height's alteration on the impact of it is less. With the increasing span, wind-induced vibration coefficient reduces gradually, and with the increasing height, wind-induced vibration coefficient increases gradually.

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