Modeling and Safety Performance Analysis of Transmission Tower Influenced by Sandstorm

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Introduction

Strong winds and sandstorms are two important forms of wind-sand hazards, and as natural disasters with high risk, they will seriously affect the safety of transmission lines.

A few scholars [1] have studied the mechanical responses of transmission towers under wind-sand loads. In this paper, based on the conservation law of momentum and the theory of sand weather rating, mechanical simulation will be carried out to analyse the mechanical responses of a cuptypetower under strong winds and sandstorms from statics and dynamics. A wind-sand load calculation model is established, and the influence of strong sandstorms on transmission tower is solved by analysing the mechanical performances of the cuptypetower.

Theory of simulation

Stages of the setup preparation:

1. The 220kV single-circuit cuptypetower is selected as the research object, and the ANSYS APDL finite element software is used to model. BEAM188 unit is used for poles, with a total of 1174. the full height of the tower is 32.2m. The main material of the tower is Q345 steel, and the auxiliary material is Q235 steel.

According to the law that the average wind speed varies along the height, the transmission tower is divided into 7 sections [2-3] to improve the efficiency of calculation (Fig.1).

2. According to the regulation [4], the formula of calculating the standard value of static wind loads can be obtained. Then use the log-law wind profile to fit the average wind speed [5] and use the Kaimal fluctuating wind power spectrum [6] to fit the fluctuating wind velocity in Matlab to calculate some ten-second fluctuating wind loads [7].

According to the classification [8] and the reference [9], the calculation parameters of sand weather can be obtained. To simplify the calculation, it is assumed that the collision between sand particles and the tower is an elastic collision with the same velocity before and after the collision. And then the formula of calculating sand loads can be obtained.

Finally, the static wind-sand load calculation model and the dynamic wind-sand load calculation model can be also obtained.

3. The loads of each section are calculated separately at the height of the midpoint of each section of the tower, and then applied equally to each node of that section at the wind speed of 20m/s and at three wind angles of 0°, 45° and 90°, where 0° is the direction perpendicular to the tower line and 90° is the front side of the tower.

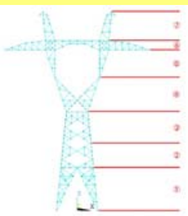
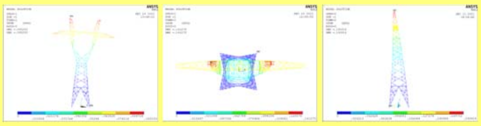


Fig. 1. Finite element model and section of the cuptypetower.

Simulation

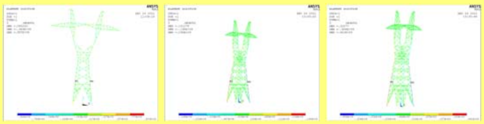
STATIC WIND LOAD SIMULATION

Fig. 2 shows the total displacement cloud maps of the tower at different wind angles. Fig. 3 shows the stress cloud maps of the tower at different wind angles. At 90° wind angles, the total displacement and the maximum stress are both the largest under the static wind loads.



(a) Wind load at 0° (b) Wind load at 45° (c) Wind load at 90°

Fig. 2 Total displacement cloud maps, 20m/s wind speed.

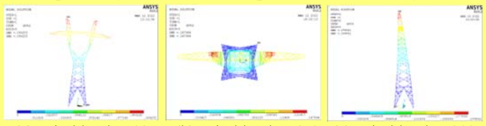


(a) Wind load at 0° (b) Wind load at 45° (c) Wind load at 90°

Fig. 3 Maximum stress cloud maps, 20m/s wind speed.

STATIC WIND-SAND LOAD SIMULATION

The total displacement cloud maps of the tower under the static wind-sand loads are shown in Fig. 4 and the corresponding stress cloud maps are shown in Fig. 5.



(a) Wind load at 0° (b) Wind load at 45° (c) Wind load at 90°

Fig. 4 Total displacement cloud maps, 20m/s wind-sand speed.

(a) Wind load at 0° (b) Wind load at 45° (c) Wind load at 90°

Fig. 5 Maximum stress cloud maps, 20m/s wind-sand speed.

DYNAMIC WIND LOAD SIMULATION

This paper focuses on the analysis of the dynamic loads at the wind speed of 20m/s and 90° wind angle. The fluctuating wind velocity time series curve at the highest point of the first section of the tower in Matlab is shown in Fig. 6. The wind speed power spectrum is compared with the target power spectrum in Fig. 7. The mechanical responses under dynamic wind loads are shown in Fig. 8.

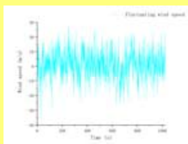


Fig. 6 Dynamic wind velocity time series curve at the height of 7m.

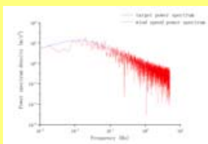


Fig. 7 Comparison of simulated fluctuating power spectrum with target power spectrum at the height of 3.5m.

(a) Time series curves of each simulated point (b) displacement time curve at the top point

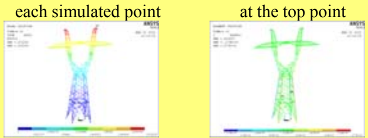
(c) Maximum displacement cloud map at the top point (d) the maximum stress cloud map at the top point

Fig. 8 Mechanical responses under the dynamic wind loads

DYNAMIC WIND-SAND LOAD SIMULATION

The mechanical responses under dynamic wind-sand loads are shown in Fig. 9.

(a) Time series curves of each simulated point (b) displacement time curve at the top point



(c) Maximum displacement cloud map at the top point (d) the maximum stress cloud map at the top point

Fig. 9 Mechanical responses under the dynamic wind-sand loads

Results

Under the static loads at 20m/s wind speed and different wind angles, the largest displacement of the tower under static wind loads is 190.914mm and the greatest stress is 214MPa, both occurring at 90° wind angle. Comparatively, the largest displacement at the top of the tower under static wind-sand loads is 199.841mm and the greatest stress is 225MPa, both also occurring at 90° wind angle. By comparison, the largest displacement increased by 4.47% and the greatest stress increased by 4.89%.

The downwind displacement and mechanical responses at the top point of the tower under strong sandstorm conditions both increase with the increasing load values. When the average downwind wind speed is 20 m/s, the largest displacement at the top of the tower under wind loads is 237 mm, and the largest displacement at the top point under wind-sand loads is 253.229 mm, an increase of 6.28%. Accordingly, the greatest stress of the tower under wind loads is 259 MPa, and the greatest stress of the tower under wind-sand loads is 277 MPa, increasing by 6.50%.

Conclusions

The main conclusions drawn from all these work are:

- The wind-sand loads have a greater impact on the mechanical responses of the whole tower than the pure wind loads in the static simulation;
- Dynamic loads are more dangerous for transmission towers than static loads;
- Because the wind-sand loads increase with the rise of sandstorm level, more attention should be paid to studying the transmission tower systems in windy and sandy areas.

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