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Analysis of the Effect of wind Loads on the dynamic response of the Suspended Crossing-Tower Auxiliary System

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Abstract. The operational impact analysis of Crossing-tower Auxiliary Fittings System is a performance impact analysis of the operational stability and performance indicators of the line and auxiliary towers under a variety of environmental conditions for the long-term operation of the auxiliary crossing-tower system. In this paper, the suspension type auxiliary tower fitting system is divided into two types: the hard rod connection and the soft line connection. The influence of the arrangement of the wind pendulum, ice coating and anti-vibration hammer on the mechanical performance is considered. At the same time, the influences of the length of the bridge, the span and sag of the ground wire on the displacement and stress-strain of the bridge over the tower are analyzed. On this basis, it lays a certain theoretical basis for the structural optimization of the suspended tower auxiliary system.

1.introduction

The overhead transmission line inspection robot based on ground wire walking[1] is a kind of intelligent inspection equipment for high voltage overhead transmission line. The manual inspection work can be completely replaced by the robot, which runs on the ground wire of high voltage line with obstacles such as anti-vibration hammer concave[2], suspension clamp and tension bridge. The robot can continuously walk in the overhead transmission line, identify and record the line defect information. Above all, there is high practical value and broad market space about the inspection robot. When the inspection robot is walking on the line, the bracket and strain insulator-string on ground wire of the strain tower are the main obstacles to the robot. If you want to smoothly pass these obstacles to realize the full-range inspection of the inspection robot[3], these obstacles must be accurately identified and the distance from the obstacle to the robot[4] must be measured, so that the robot can overcome obstacles stably and reliably. However, it puts forward too high requirements for the function of inspection robot, which increases the technical difficulty of its structure and function design, and greatly limits the practicability of the inspection robot. Therefore, this paper proposes a suspension bridge crossing system[5] for strain tower on overhead ground wire to solve this problem, as shown in Figure 1.

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Fig 1. Suspension Bridge Crossing System

2.Finite element model

The model of two transmission lines with a span of 300m and a height of 100m was established. The tower in the middle of two transmission lines was not taken as the main analysis object, and the simplified bracket was used instead of it in the model. The components of the model are shown in Figure 2, and the parameters of each part are shown in Table 1. All steel types of the components are Q235. Figure 2(b) is an enlarged view of the red circled part in Figure 2(a).



(a) Overall layout of line

(b) Components of the model Fig 2. The components of the model

Table 1.Basic parameters of the model

Components	Parameters	Density	Elastic Modulus
Ground wire	Area: 152.81×10 ⁻⁶ m ² ; Initial stress: 180MPa	3458kg/m ³	1.05e11
Ground wire bracket	Width b1: 50mm; Thickness t1: 4mm; Length L _{zj} : 0.5m	7850kg/m ³	2.06e11
Angle steel	Width b2: 50mm; Thickness t2: 4mm; Length L _{jg} : 0.4m	7850kg/m ³	2.06e11
Connecting rod	Width b3: 50mm; Thickness t3: 4mm	7850kg/m ³	2.06e11
crossing rod	The hard rod: Diameter d1: 20mm; Length Lgqg: 2m	7850kg/m ³	2.06e11
	The soft line: Diameter d1: 20mm; Length Lgqg: 2m	3458kg/m ³	1.05e11

According to the above model parameters, the finite element model of the line and its crossing-tower fitting system is established. Simulate the ground wire with the tension-only LINK10 unit, and use the form-finding analysis method to find the shape according to the initial stress. The refined model of the connection part is established by solid185 unit. Considering the contact problem between angle steel, connector, bolt and crossing rod, three contact pairs are established, as shown in Fig 3. In order to save calculation costs, the above two parts are simulated by BEAM188 units. The finite element model is shown in Figure 4.



Fig 4. Finite Element Model

3.the Effect of wind Loads on the dynamic response of the Suspended Crossing-Tower Auxiliary System

3.1 Numerical Simulation Calculation of Transmission Line

Traditional overhead transmission lines are mostly spirally hinged around a central core with one or more layers of single wires to form concentric hinged wires, which are called "round wires" in engineering (as shown in Figure 5). The cross section of the round wire is not an ideal smooth circular section. Since the outermost surface of the conducting wire is hinged by a plurality of small single wires, the outer surface has certain roughness, which may eventually affect the coupling effect of the fluid on the transmission line. It can be seen from Fig. 6 (a) and (b) that with the increase of reduced wind speed.



Fig 5. Concentric hinge wire model

Fig. 6 (c) is the main frequency diagram of the aerodynamic coefficient of circular conductor. After calculation, it is found that in the real section, the dominant frequency of the drag coefficient is about twice that of the lift coefficient.

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Fig 6. Comparison of coefficient of fixed wind around cross section and smooth cross section Figure 6 (d) shows the variations of the Strouhal numbers of the real section and the smooth cylinder section with the reduced wind speed. It can be seen from the figure that considering the roughness of the wire surface, the St number shows a decreasing trend with the increase of the reduced wind speed, and it is also smaller than that of smooth cylinder under the same conditions.

3.2 wind-induced vibration analysis

There is the largest area of windward when the wind is along the line, so it is the most unfavorable load condition to the wire[6]. This paper mainly analyzes the wind-induced vibration response under this wind direction angle. The vertical position difference of the whole model is small (the height of the line is 100m), so the wind speed difference at different vertical heights is not considered. Taking the average wind speed as 20m/s, the wind speed time series under class B landform at 100m height is simulated by weighted amplitude wave superposition(WAWS) method [7], as shown in Fig. 7. According to the windward area of each element, the force is uniformly applied to each node in the form of concentrated force. Perform transient analysis, and the analysis results are shown in Figure 8-9.



Fig 7. Wind speed

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Fig 8. Contact displacement between crossing rod and connector

Fig 9. Contact displacement between bolt and screw hole on connector

As can be seen from figure 10-11, compared with the whole span line, the model geometric size of crossing-tower fittings system is very small. At the same time, the stiffness of the hard crossing rod is greater than that of the ground wire. And the displacement of the hard crossing rod in the whole time course is very small, which is only about 1 / 100 of that of the ground wire. In the whole calculation process, the maximum stress value in the middle of the crossing rod fluctuates in the range of only $20 \sim 220$ MPa. The maximum stress value is less than the yield strength, so the model is always in the elastic range.



Fig 10. Time history of displacement change of the ground line



the crossing rod

3.3 ice coating analysis

When the icing thickness of the overhead line is b, the icing volume on the 1-meter overhead line is:

$$V = \frac{\pi}{4} \left[(d+2b)^2 - d^2 \right] = \pi b (d+b)$$
 (1)

If the density of ice $\rho = 0.9 \times 10^{-3} kg/cm^3$, Acceleration of gravity $g = 9.80665m/s^2$. The specific load of ice weight is:

$$\gamma = \frac{\rho V g}{A} = \frac{\rho \pi b (d+b) g}{A} = 27.728 \frac{b (d+b)}{A} \times 10^{-3} (M P a / m)$$
(2)

Inside, b is the icing thickness, b is the outer diameter of overhead line, A is the sectional area of overhead line. In the case of icing, the specific load of the overhead line is the sum of the specific load of dead weight and the specific load of ice weight.

Figures 12 to 13 show the distribution of deformation, stress and strain under the load of wind and icing simultaneously. In this case, the results are similar to those under wind load only, but the stress is slightly larger, and the displacement of ground wire and crossing rod is larger. Figure 14-15 shows the

comparison of the time history of the displacement of ground wire and the displacement of the crossing rod in the two cases (both the effect of wind and icing, only the effect of icing).



4. Parameter analysis

On the basis of the finite element model of suspended crossing-tower fittings, the influence of the length of the crossing rod, the span and sag of ground wire on the crossing-tower fittings is analysed, and the change trend of the displacement, stress and strain of the crossing rod is discussed, as shown in Figure 16. Considering that the results of icing load case and non-icing load case are similar, parameter analysis is only carried out for non-icing load case.



(a) The influence of the length of the crossing rod on the time history of the displacement of crossing rod



(b) The influence of the span of ground wire on the time history of the displacement of crossing rod



(c) The influence of the sag of ground wire on the time history of the displacement of crossing rod Fig 16. Time-history analysis of parameters on displacement of crossing rod

5. Conclusion

(1) Through the finite element analysis of suspension type crossing-tower fitting system and side type crossing-tower fitting system, it is found that under the wind load, the main deformations of the two kinds of fitting systems are swing with the ground wire. However, due to the constraint of the connecting angle steel in the middle of the crossing bar, the displacement is close to zero.

(2) Considering the simultaneous action of icing load and wind load, the displacements of ground wire and crossing rod are slightly larger than those under wind load only. And the distributions of deformation, stress and strain are the same under the two working conditions.

(3)Through the analysis of the influence of the length of the crossing rod, the span and sag of the ground wire on the time history of the displacement change of the crossing rod, the displacement of ground wire is almost the same under all the conditions of the length of the crossing rod changed, so it is found that the change of the crossing rod has little influence on the ground wire.

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Reference

- [1] XU, D.1.,(2017) Obstacle Recognition and Location of Inspection Robot for High-Voltage Transmission Lines [J], Internet Application, (5):102-103.
- [2] Dong, J., (2010) Electric power fittings manual [M]. China Electric Power Press, Beijing.
- [3] Zhou, F.Y., Wu, A.G., LI,Y.B., (2008) An inspection robot running on 110kV power transmission line[J]. Electric Power, 41(3):32-35.
- [4] Zhang, F., Guo R., LU, S., et al. (2019) Obstacle Recognition and Location of Inspection Robot for High-Voltage Transmission Lines[J]. Electric Power, 52(4):111-118.
- [5] Xue, D.L., H, G.F., Wu, Y.Z., et al. Suspension bridge system used to cross overhead ground wire tension tower: China,201811201176.8[P].2019.01.08.
- [6] Zhang, B., Ma, J., Li, M.L., et al. (2016) . The Stress Distribution Characteristics of Transmission Tower under the Action of Wind Load[J]. Journal of Henan Science and Technology, 19: 135-137.
- [7] Xiao, Z.Z.,(2009)Wind-induced response analysis and equivalent wind loads of UHV transmission tower[D]. Doctoral dissertation of Chongqing University.
- [8] Zeng, J.T., (2019) Analysis of fatigue S-N curve of metal materials [J].Metallurgy and Materials, 39(1):184-185.
- [9] Yan, Y., Selection of S-N curves and fatigue safety factors and their impacts on calculation[J].China offshore Platform,1993,8(1):14-18.

- [10] Li, X.H., Li B.Y., XU N.G., (1997) The Response of Overhead with Dampers Transmission Wire to the Gentle Breeze[J].Proceedings of the CSEE, 05:352-355.
- [11] Xu, H.B., (2009) Function of the Dissipation Power of Vibrating Dampers in Transmission Line[J].Journal of Anhui Institute of Architecture(Natural Science),03:17-22