Research and Application of Light Combined Composite Material Holding Pole

Zhaojun Ge¹, Zhaohui Su¹, Ning Jia²∗, Fawei Zheng³, Dayan Zhou³ and Qiang Liu³

¹State Grid Corporation of China, Beijing 100000, China
²China Electric Power Research Institute, Beijing 100055, China
³State Grid XuZhou Power Supply Company, Xuzhou 221000, China
∗Email: 286488316@qq.com

Abstract. Suspension spanning frame is widely used in the construction of newly constructed overhead transmission lines, and plays an important role in protecting the safety of the objects being crossed. The temporary beam of the suspension cable-type span is installed on the transmission tower, and the impact load in the event of an accident will be transmitted to the transmission tower through the temporary beam. Therefore, the installation of temporary beams will have an important impact on the safety of transmission towers. This paper analyzes the typical installation method of the suspension cable spanning frame on the transmission tower, discusses the dynamic simulation method of the suspension cable spanning frame and the transmission tower under the impact of the conductor, selects a 500kV transmission line crossing project to carry out the wire breakage Analysis of the impact of the lower impact load on the transmission tower. The results show that the wrong installation method will have a significant adverse effect on the safety of the transmission tower. Based on the analysis results, suggestions for the installation of temporary beams were proposed, which provided a reference for the suspension construction of the suspension bridge.

1. Introduction

With the improvement of railway, highway, power line and other infrastructure in China, the number of new overhead transmission lines crossing the above-mentioned infrastructure is increasing due to the restriction of transmission corridor. Tension stringing across construction involves many factors and high risk level, so safety construction is particularly important, especially when crossing high-speed railway, expressway and ultra-high voltage power line. In order to protect the safety of the object to be crossed, the method of erecting crossing frame is widely used, among which the suspension type crossing structure is widely used because of its large span distance, no terrain influence, simple structure and convenient erection.

The suspension type crossing frame (as shown in Fig. 1) does not need to set up ground crossing frame body. Its temporary beam is directly installed on the transmission tower on both sides of the span span. The bearing cable is installed on the temporary beam and the capping net is laid. In the case of tension stringing accident, the falling conductor first impacts the capping net, and then transfers the impact load to the transmission tower through the bearing cable and temporary beam, so as to protect the crossed objects from the impact of the falling conductor.
Previous studies only focused on the impact resistance and safety of suspension and lattice spans under tension stringing accident, while the safety research of transmission tower under the impact load of temporary beam is often ignored. This paper analyzes the typical installation mode of temporary beam of suspension type crossing structure on transmission tower, discusses the nonlinear dynamic simulation method of conductor impact suspension bridge in case of accident, calculates the impact load, and then analyzes the rationality of different installation methods, and gives relevant suggestions to ensure the safety of transmission tower in crossing construction, which is of great significance to the installation of temporary beam in crossing construction Guiding significance.

2. Typical Installation Method of Suspension Crossing Structure
There are three main ways to install the temporary beam of suspension type crossing frame on the transmission tower, as shown in Figure 2.

![Figure 2. Installation method of temporary beam of suspension crossing structure](image-url)
(1) The first installation method of temporary crossbeam is as follows: four stay wires are used to hang the temporary beam on the square tower under the lower cross arm of the transmission tower, and two outer stay wires are driven at the end of the lower cross arm of the tower.

(2) The second installation method of temporary crossbeam is: use 6 stay wires to hang the temporary beam on the square tower under the lower cross arm of the transmission tower, and 4 middle stay wires are hit on the main material of the tower body.

(3) The third installation method of temporary beam is: install the temporary beam on the tower body of transmission tower with 2 external cables.

3. Impact Simulation Analysis under Accident

By using the finite element numerical simulation method, the dynamic response analysis of suspension bridge and transmission tower system under accident can be realized, and the load response of temporary beam of suspension bridge to transmission tower under conductor impact can be obtained, which can provide support for the rationality of temporary beam installation. Taking Tianwan Nuclear Power Station Phase III Aitang double circuit 500kV Line Crossing Qingyan railway as an example, this paper takes the first installation method of temporary beam as the research object, carries out modeling and simulation analysis.

The transmission line project is a 500kV Double Circuit Transmission line crossing the main tower. The span of the crossing span is 291M, and the included angle between the line direction and the railway is 72° 50 ′3″. JL / lb20a-630 / 45 conductor is used. The distance between the outer edge of the transmission tower foundation on both sides of the crossing span and the edge of the railway guardrail is 148.2m and 97.4m respectively.

3.1. Modeling Process

Mature finite element analysis software is used to simulate the impact dynamics of suspension crossing structure. The modeling content includes suspension type crossing structure (including temporary beam, bearing cable, capping net, stay wire), transmission tower and spreading conductor system. The process of establishing numerical model is to establish the part parts of the above modules, and then assemble each part according to the relative position in the assembly. The finished model is shown in Figure 3.

![Figure 3. Numerical simulation model](image)

3.2. Unit Selection

When choosing the element type, the linear truss element t3d2 is used for the load-bearing cable, capping net and conductor. The element type allows the truss element to bear the lateral impact load, and takes into account the finite axial strain, which is suitable for simulating the tensile mechanical behavior of the slender rope and simulating the lateral impact behavior of the slender rope. The linear beam element B31 is adopted for temporary beam and transmission tower, which allows shear deformation of beam, which is suitable for simulating slender beam and short thick beam.

3.3. Material Properties

The materials used in the model include UHMWPE fiber rope, steel wire rope, Q345 steel and JL / lb20a-630 / 45 conductor. The material parameters used are shown in Table 1 ~ Table 3 respectively.
Table 1. Material parameter table of tower material and wire rope

| Name  | Material | E (GPa) | U  | Yield Strength (MPa) |
|-------|----------|---------|----|----------------------|
| Tower | Q345     | 206     | 0.3| 345                  |
| Rope  | /        | 90      | 0.3| 1500                 |

Table 2. Conductor material parameter table

| Conductor Type | E (GPa) | U  | Breaking Force (kN) |
|----------------|---------|----|---------------------|
| JL/LB20A-630/45| 63      | 0.3| 151.5               |

Table 3. Material parameter table of bearing cable and sealing rope

| Name                | Material                        | Linear Density (Ktex) | Elongation (%) | Breaking Force (kN) |
|---------------------|---------------------------------|-----------------------|----------------|---------------------|
| Bearing cable       | UHMWPE fiber rope               | 317.80                | 6.00           | 355.50              |
| Sealing rope        | UHMWPE fiber rope               | 157.50                | 2.30           | 177.70              |

3.4. Boundary Condition

The gravity acceleration value of 9.8m/s² is applied to the conductor to realize the gravity field loading. The contact between the conductor and the capping network is set according to the general contact, and the tower bottom is fully constrained.

The binding position of the temporary beam and the transmission tower body is fully coupled with each translational degree of freedom of the node, and the connection between the stay wire and the temporary beam and the transmission tower also adopts the full coupling connection of each translational degree of freedom of the node. The finite element model connection of the first typical installation method of temporary beam is shown in Fig. 4.

Figure 4. Connection location

4. Impact Load Analysis of Temporary Beam on Transmission Tower

4.1. Result Analysis

The distance between the conductor and the network is 30m. When one traction and four stringing are adopted, the traction plate (180 meters away from the left tower) under the disconnection accident will impact the suspension type crossing frame.

The maximum tension of 630 conductor is 190.2kN when it falls at the height of 30m away from the blocking network and impacts the main bearing cable with diameter of 20mm.
Table 4. Load peak table of temporary beam to transmission tower

| Right tower connection point | ① | ② | ③ | ④ | ⑤ | ⑥ |
|-----------------------------|----|----|----|----|----|----|
| Peak load(kN)               | 116.2 | 111.3 | 141.5 | 148.6 | 592.0 | 645.2 |

It can be seen from table 4 that when the conductor is broken, each connection point of the transmission tower is subjected to a large impact load. Figure 5 shows the utilization overrun bar (marked with red bar), among which the lower cross arm member of the tower.

![Figure 5. Cloud chart of utilization rate of cross arm under tower](image)

4.2. Improvement Analysis of Temporary Beam Installation Method

The second typical installation method of temporary beam was used to improve the model. The suspension rope between the temporary beam and the transmission tower is added, and the rope is mainly suspended on the main material of the tower, so that the main material is stressed. Temporary beam and lower cross arm of transmission tower.

![Figure 6. Improve the installation method of rear Temporary Beam](image)

After the improvement of temporary beam installation method, the load of temporary beam on transmission tower under the same accident condition is shown in Table 5. The cloud chart of the utilization rate of the cross arm under the tower after improvement is shown in FIG. 7.

Table 5. Load peak table of improved temporary beam to transmission tower

| Right tower connection point | ① | ② | ③ | ④ | ⑤ | ⑥ | ⑦ | ⑧ |
|-----------------------------|----|----|----|----|----|----|----|----|
| Peak load(kN)               | 0.55 | 81.0 | 71.9 | 21.3 | 13.0 | 110.5 | 86.9 | 60.7 |
Figure 7. Cloud chart of utilization rate of cross arm under tower after improvement

After the improvement of the temporary beam installation method, the peak load of each connection point of the tower is significantly reduced, and the utilization rate of the lower cross arm member is not exceeded. By adding the suspension point of temporary beam and replacing the cross arm of the tower with the main material of the tower as the main bearing point, the hidden danger of safety is eliminated and the safety of the transmission tower is ensured.

5. Suggestion on Installation of Temporary Beam of Suspension Type Crossing Structure

Through the above analysis, the rationality of the three temporary beam installation methods is summarized as follows:

(1) Installation method 1: all the stay wires are fixed on the cross arm of the transmission tower. Insulator strings and conductors need to be installed at the end of the cross arm of the transmission tower, which has high design strength and can be used as the temporary beam suspension point; however, the middle part of the cross arm does not consider bearing direct load, so the temporary beam is suspended. Hanging in this position will exceed the design load of the cross arm, and there is a greater safety risk. If it is necessary to put it in this position, necessary reinforcement measures should be taken to avoid the risk of cross arm failure.

(2) In the second installation mode, the guy wire is punched on the end of the transmission tower and the main node of the tower body. The bearing capacity of the above position is large, and there are 6 stay wires on the temporary beam, which can well share the impact load transferred from the temporary beam to the transmission tower, and the installation method is reasonable.

(3) In the third installation method, the temporary beam is only suspended on the cross arm of the transmission tower through one stay wire at each end, and the position of the stay wire deviates from the installation position of the insulator string on the cross arm, which is easy to cause excessive local stress of the cross arm of the tower, which is unreasonable.

6. Conclusion

In this paper, three common installation methods of suspension crossing structure on transmission tower are analyzed, and the dynamic simulation method of suspension bridge and transmission tower under conductor impact is discussed. Taking a 500kV transmission line crossing project as an example, the impact of impact load on transmission tower under broken conductor is analyzed.

(1) The connection position between the temporary beam stay wire and the transmission tower should select the point with large bearing capacity such as the end of the tower cross arm and the main node of the tower body.

(2) It is not easy to install more than 6 guyed members near the tower due to too many stay wires.

(3) Before the crossing construction, the dynamic analysis of the transmission tower shall be carried out to accurately grasp the stress condition of each part of the transmission tower in case of conductor falling accident, and the installation mode of Temporary Beam shall be adjusted in time. When the tower members exceed the design value due to construction conditions, necessary reinforcement measures should be taken.
7. Acknowledgments
State Grid Corporation Science and Technology Project Funding(Project Name: Dynamic Impact Load Effect on Suspension Crossing Frame at Transmission Tower, Project No.: GCB11201900108).

8. References
[1] A. K. Banejee, Deployment control of a cable connecting a ship to an underwater vehicle [J]. Journal of Guidance, Control, and Dyn., 1994, 17(6):803-805.
[2] S. Djerassi, H. Bamberger. Simultaneous deployment of a cable from two moving platforms [J]. Journal of Guidance, Control, and Dyn., 1998,21(2):41-47.
[3] Lepidi M, Gattulli V. Non-linear interactions in the flexible multi-body dynamics of cable-supported bridge cross-sections[J]. International Journal of Non-Linear Mechanics, 2016, 80: 14-28.
[4] F. Geoffrey, Improved deployment characteristics of tether-connected munition systems [J]. Journal of Guidance, Control, and Dyn., 2001,24(3):151-157.
[5] Shabana A.A. An absolute nodal coordinate formulation for the large rotation and deformation analysis of flexible bodies. Department of Mechanical and Industrial Engineering, University of Illinois at Chicago, 1996.
[6] Hsieh AJ, Chantawansri TL, Hu W, et al. New insight into the influence of molecular dynamics of matrix elastomers on ballistic impact deformation in UHMWPE composites [J]. Polymer, 2016, 95:52-61.
[7] F.X. Kromm, T. Lorriot, B. Coutand, et al. Quenisset. Tensile and creep properties of ultra-high molecular weight PE fibres[J]. Polym. Test. 22 (2003) 463-470.
[8] L. Chen, K. Zheng, Q. Fang. Effect of strain rate on the dynamic tensile behaviour of UHMWPE fibre laminates [J]. Polymer Testing, 2017, 63: 54-64.
[9] Ning Jia,Yong Junxia, Research on the method of wire impact suspension type spanning frame [J]. Materials Science and Engineering, 562(2019)012041.