Study on Type Selection and Head Layout of Zhangzhou Long Crossing Tower

Ye Xin 1*, Guo Jingfeng 1, Wang Chengwu 1, Lin Yinhe 1, Xie Ming 1, Song Xinxin 2
Fujian Yongfu Electric Power Design Co., Ltd. 1
Wuhan University of Technology 2
*Corresponding author’s e-mail: yexin@fjyongfu.com

Abstract: By comparing the schemes of combined angle steel and steel tube tower, the tower type of Zhangzhou long crossing tower was optimized, and through different tower head layout, the tower head types of long crossing tower and anchor tower were compared from the technical and economic aspects, in order to provide a certain practical significance for the design and application of long crossing tower.

1. Introduction
The Zhangjiang River crossing section of Zhangzhou nuclear power transmission project is located on the east side of Xiaqi village, Shaxi Town, Zhangpu County and the northwest side of Huqiu village, Dongxia Town, Yunxiao County. The length of the whole crossing section is about 2.5 km (Zhangzhou nuclear power plant Donglin line) and 2.4 km (Zhangzhou nuclear power plant Wufeng line). The span of the crossing section is more than 1000 m and the height of the crossing tower is more than 100 m. According to the technical regulations for long span design of 110kv ~ 750kv overhead transmission lines (DL/T 5485-2013) [1], Zhangjiang River crossing section is designed as a long span, and the design wind speed reaches 45 m/s. How to optimize the tower type scheme and tower head layout is the top priority of tower optimization design.

2. Comparison of Tower Type Schemes
At present, there are three main types of long span tower at home and abroad: reinforced concrete chimney tower, combined angle steel tower and steel tube tower. Because the construction of reinforced concrete chimney tower is difficult and the bearing capacity of earthquake is poor, this type of tower is not used in this crossing section. Through the comprehensive comparison of the combined steel tower and steel tube tower, the steel tube tower is recommended in this project.

2.1. Reasonable Stress of Structure
The mechanical performance of steel tube is better than that of steel pipe. The radius of gyration of steel pipe is larger, and the radius of gyration of steel pipe is about twice of that of single angle steel under the condition that the cross-sectional area and calculation length are basically the same. In addition, the wind resistance coefficient of steel pipe components is relatively small, which can greatly reduce the wind load of the tower [2].

2.2. Lighter Consumption of Tower Material
Due to the characteristics of structural stress, the single base weight of steel tube tower is lighter than that of angle steel tower. Although the cost of steel tube tower is about 20% - 25% higher than that of angle steel tower, the foundation force of steel tube
tower is obviously less than that of angle steel tower, and the foundation engineering quantity can be greatly reduced. Therefore, when the height of steel tube tower is higher, its economy will be better than that of angle steel tower [3,4].

③ The actual situation of the project. The crossing section is 4×JLHA1/G4A-640/290 conductor has large cross section and many splits. The load of iron tower is far more than that of general 500kv Line. According to the calculation, supposing that Q420 high-strength angle steel is used, the main materials of the tower body need to use more than four pieces of combined angle steel. The lower part of the tower body and the tower leg, even using the Q420 high strength angle steel with four pieces of L300×35, cannot meet the stress requirements. Thus, the steel pipe type must be used.

In recent years, a certain proportion of angle steel has been used in the design of steel tube tower built in China, which has the following advantages:

(1) Reduce the type and quantity of steel pipe components. In a certain range, the use of angle steel, especially small angle steel, can reduce the number and types of steel pipe components.

(2) Reduce the difficulty of tower processing. For steel pipe components, whether it is intersecting connection, flange connection or plug plate connection, there is a lot of welding work. Some angle steel is used, and bolt connection is used to replace a lot of welding work, and angle steel can be processed in large quantities, which improves the processing efficiency.

(3) Reduce the difficulty of tower construction. Due to the complex structure of tower head, cross arm and partition, the angle steel and bolt connection are adopted, which greatly reduces the difficulty of tower head processing and assembly.

(4) The quality of iron tower is easy to control. The connection of steel pipe needs a lot of welding work, and the quality of welding directly affects the safety and reliability of the tower structure. The use of angle steel connection minimizes the quality problems caused by welding [5].

According to the analysis of the height, root opening, cross arm length and stress of the tower, it is recommended that the main materials and inclined materials of all tower types should be steel pipe members, and the horizontal diaphragm and auxiliary materials of the tower can be angle steel members. Considering the purpose of reducing tower weight, the main material and inclined material of straight tower and tension tower body are steel pipes. Angle steel can be used for cross arm members.

3. Tower Head Layout

3.1 Layout of Crossing Tower Head

For double circuit linear tower, according to the different conductor arrangement, it can be divided into vertical arrangement and triangular arrangement; According to the string type tower head, it can be divided into V-string and I-string. Since the basic wind speed of this crossing section is 45 m/s, the angle between V-strings should be about 105 degrees. When the tower head adopts V-string triangle arrangement, the length of one side cross arm should be about 40m, the wind load of the tower increases greatly, which also has a negative impact on the torsion and bending bearing capacity of the tower, and the economic type is poor. Therefore, the V-string triangle arrangement is not considered for the linear tower in this crossing section.

The following is the schematic diagram of three layout schemes, I-string triangle, vertical and V-string vertical arrangements.

Scheme (a): I-string two-layer cross arm triangular arrangement is adopted.
Scheme (b): I-string three-layer cross arms are vertically arranged.
Scheme (c): V-string three-layer cross arms are vertically arranged.
Figure 1. Scheme (a) I-string two-layer cross arm (triangular arrangement)

Figure 2. Scheme (b) I-string three-layer cross arms (vertical arrangement)
The following table takes the cross tower 5SZK-93 as an example to compare the relevant indexes of the above three schemes. The main material is Q420 and the height of the crossing tower is 93m.

Table 1. Index comparison of different tower head schemes of crossing tower

| Scheme     | Calculated Weight (t) | Tower Head Type       |
|------------|------------------------|-----------------------|
| Scheme (a) | 411.6                  | Triangular I-String   |
| Scheme (b) | 355.2                  | Vertical I-String     |
| Scheme (c) | 367.5                  | Vertical V-String     |

Through comparison, scheme (b) has the lowest index, and the tower material consumption is 15.8% lower than scheme (a) and 3.5% lower than scheme (c). Scheme (b) has the best economy.

The main reasons for this result are as follows:

1. The load of long span tower is mainly wind load. For the tower head with three-layer cross arm arrangement, because the cross-arm arrangement adopts the method of divide and rule, the total area of front wind resistance of the cross arm at the head is much smaller than that of the tower head with two-layer cross arm arrangement. The total area of wind resistance of the former is 542 m², while that of the latter is 1342 m². The small area of wind resistance is very beneficial to the stress of the whole tower. The basic wind speed of the long span section of the project is as high as 45 m/s. The favorable factor that the bending moment of the tower is reduced due to the reduction of the height of the tower is not enough to make up for the adverse effect of the large wind area on the cross arm.

2. Due to the high tension of wire breaking of long span tower, the cross arm of conductor and ground wire and inclined material of tower body are mostly controlled by wire breaking condition. In triangle arrangement scheme, because two-phase conductors need to be arranged on each side of the
lower cross arm, the length of the cross arm reaches 32.5m, the ratio of the length of the cross arm to
the width of the tower body at the cross arm is 32.5/6.7 = 4.9, while the ratio of the vertical arrangement
scheme is only 15.5/6.3 = 2.5, It will make the main material of the tower body and the cross arm suffer
great torque and bending moment respectively, which will lead to the jump increase of the specifications
of the cross arm and the skew material of the tower body.

② Due to the square layout of the second layer cross arm, the front support material becomes the
stress material, and the bar size will be enlarged to a certain extent, and the weight will be increased.

The main advantages of the three-layer cross arm crossing tower are as follows:
① The length of cross arm is shortened a lot, so it is very easy to realize that the ground wire has a
negative protection angle to the conductor, which greatly strengthens the lightning protection effect of
the line;
② Suppose the crossing tower adopts the design of double circuit vertical arrangement, the
arrangement of three-layer cross arms is consistent with that of anchor tower, which avoids the similar
line spacing when the crossing tower with two-layer cross arms is transiting to the anchor tower with
vertical arrangement of conductor;
③ The crossing tower with three-layer cross arms can greatly reduce the width of the line corridor,
which is beneficial to the local economic construction in the future;
④ The weight of ground wire frame and conductor cross arm is relatively light, which brings great
convenience for construction and installation.

Through the above analysis, the vertical arrangement scheme of I-string three-layer cross arms is
adopted for the crossing tower of the project, which has advantages in technical and economic indicators.
Considering all factors, the vertical arrangement scheme of I-string three-layer cross arms is
recommended for the tower head of long span linear tower.

3.2 Arrangement of Anchor Tower Head

The following are two layout schemes: vertical arrangement and triangle arrangement of anchor tower.

Scheme (d): triangular arrangement of two-layer cross arms. Scheme (e): three-layer cross arms are
arranged vertically.

Figure 4. Scheme (d) Two-layer cross arms (triangular arrangement)
The following table takes the anchor tower 5SJM-30 as an example to compare the relevant indexes of vertical arrangement and triangular arrangement.

| Scheme       | Calculated Weight (t) | Tower Head Type          |
|--------------|-----------------------|--------------------------|
| Scheme (d)   | 226                   | Trigonometric Arrangement|
| Scheme (e)   | 219                   | Vertical Arrangement     |

Through comparison, the tower material consumption of scheme (e) is about 3% lower than that of scheme (d), and the overall economy of scheme (e) is better.

For the vertical arrangement of double circuit tension tower, due to clear circuit, simple structure, clear force transmission, convenient construction and maintenance, it has been widely used at home and abroad and accumulated rich operation experience. And because of the vertical arrangement of the crossing tower, in order to match with the type of the tower, the line spacing of the crossing tower is close to that of the crossing tower; Therefore, the vertical arrangement scheme is recommended for the anchor tower head.

4. Conclusion
In this paper, Zhangzhou long-span linear tower and anchor tower are taken as the research objects. By comparing the cross-section types of main materials, the tower type is optimized. It is suggested that the long-span linear tower adopt the mixed scheme of steel pipe and angle steel. Through the technical and economic comparison of different tower head layout, it is recommended that the vertical arrangement scheme of i-string three-layer cross arms be adopted for the tower head of the long span linear tower of the project, and the mature vertical arrangement scheme be adopted for the anchor tower. This scheme is reasonable in structure layout, safe and reliable in technology, and has good economic and social benefits, which provides reference for the planning, design and application of the crossing tower.
References

[1] Technical Specification for Long span Design of 110kv ~ 750kv Overhead Transmission Lines (DL/T 5485-2013).

[2] Sun zhusen, Cheng Yongfeng, Zhang Qiang, et al. Promotion and Application of Transmission Line Steel Tube Tower [J], power grid technology, 2010, 34 (6).

[3] Li Feng, Tian Lu, Chen Haibo, et al. Development and Application of UHV Steel Tube Tower [J]. Electric power construction, 2012, 33 (11).

[4] Technical Code for Design of Steel Tube Tower of Overhead Transmission Line (DL / T 5254-2010).

[5] Zhang Zifu, Zhu Binrong, Yang Jingbo, et al. Design and Research Of 1000kv UHV New Steel Pipe and Angle Steel Hybrid Tower, China electric power, 2016, Vol.49, No.2.