

A Mechanical Model of Single Transmission Line Tower

Zhihong Jin

School of Zhihong Jin

, North China Electric Power University, Bao Ding 071000, China

zijinzh@163.com

Keywords: single transmission line tower, static analysis

Abstract: The purpose of this paper is to analyze the force status of a single transmission line tower suitable for DC UHF transmission in the vertical direction of the main line. Using the method of theoretical mechanics and material mechanics, the top hamper and the main column are regarded as rigid body, and the static model of single transmission line tower is established by neglecting the influence of friction. Considering the impact of pre-tensioning cable to solve all the tension of the main column at the bottom of the force when the tower occurs a small angle tilt. Finally, we get F_z is a function of T . When the pre-tension in the stay increases, F_z increases rapidly. And the pressure on the base increases dramatically.

1. Introduction

UHV line corridor has a large part of the terrain through the flat, wide and scattered Gobi Desert and grassland areas. These areas are flat terrain, the basis of the lower cost of land, pulling the tower of the economic advantages of obvious. Pulling line tower generally consists of the top hamper, the main column and stay composition. Top hamper and the main column is generally composed of angle steel truss structure, which has a good overall stability, and which can withstand greater axial pressure. The cable is made of high strength steel strand and can withstand a lot of tension. These two structures give full part to their strength characteristics, making the amount of cable tower material to reduce. In addition, the base of the cable tower is smaller, reducing the basic investment in engineering, and protecting the environment. Experiments and operational experience also show that the cable tower is highly stable, strong wind resistance, even strong anti-ice ability, good seismic performance [1].

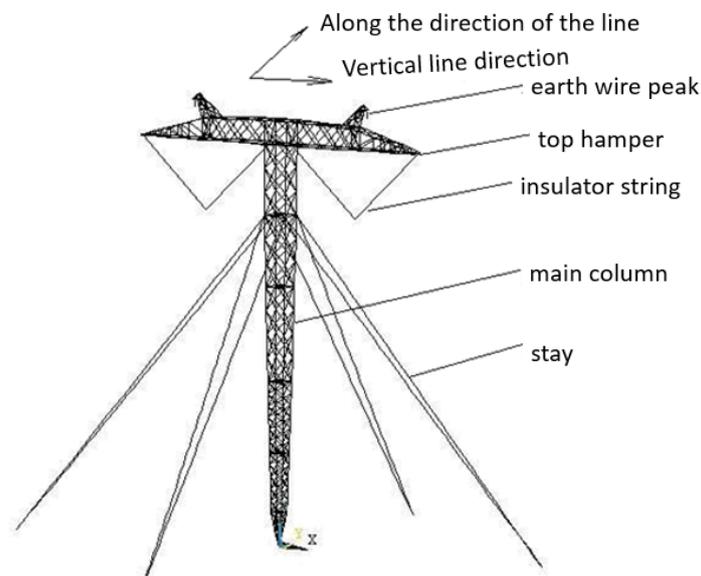


Fig. 1 Design of Special High Pressure Single Transmission Line Tower

Single transmission line tower is suitable for DC UHV transmission tower type, as shown in Fig1. Compared with other UHV DC cable tower type, single transmission line tower has a relatively small footprint, simple structure, clear force and so on [2].

2. Static Analysis of Single Transmission Line Tower

2.1 The situation

This paper chooses to analyze the wind direction in the vertical direction, as shown in Fig.2.

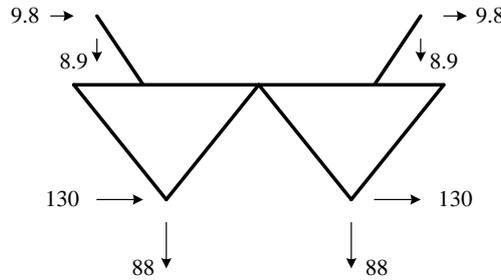


Fig. 2 Force diagram

2.2 Model Assumptions

1. The tower head and the main column are the spatial truss structure which is composed of angle steel. In this study, the deformation of the main column is neglected. The tower head and the main column are regarded as rigid body, ignoring the influence of the shape of the main column, and simplifying it as shown in Fig. 5.

2. Under the action of gravitational load on the cable tower, the bottom of the main column is compacted with the spherical structure, and the main column can only produce the rotation around the center of the sphere. Therefore, the connection between the bottom of the main column and the ground is the ball hinge as shown in Fig. 3.

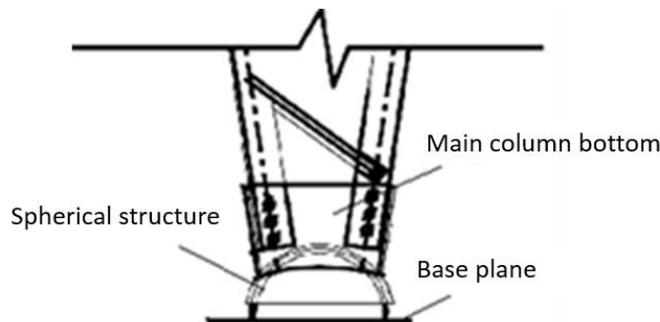


Fig. 3 Hinged structure at the bottom of the main column

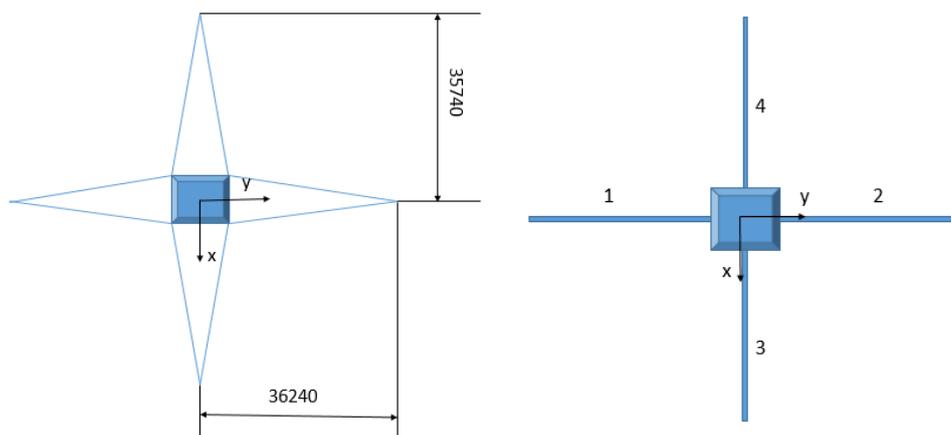


Fig. 4 A plan view of the stay system

3. Extra high-pressure single transmission line tower made of high-strength stay, can only withstand tension. The single transmission line tower has a total of eight stay, its top view shown in Figure 3, three-dimensional structure shown in Figure 4. As described in i, the two bars are reduced to a tie bar, and the angle between the tie bar and the vertical direction is 41.18° . In the absence of wind conditions, the i -th tension of tie bar is T_i .

4. Insulator string and the head of the tower, the wire can be connected to the relative rotation, and the insulator string longer (10.6m), so the insulator string can only withstand tension and compression load. We can regard that the insulator string is only by the role of two forces.

2.3 Load description

As the high-voltage lines of the larger range, so the ground wire by the gravity, wind load is much larger than the tower load. This research work is a simplified calculation, so consider neglecting the load acting directly on the tower, considering only the load on the ground wire. When the tower is analyzed and calculated, the load static force of the ground wire is equivalent to the point force of the ground wire on the tower. The load units in the following figure are kN .

2.4 Static Analysis

Fig. 5 shows the stress analysis of the simplified model of the single-column puller tower (due to the proportional reason, some structural simplification).

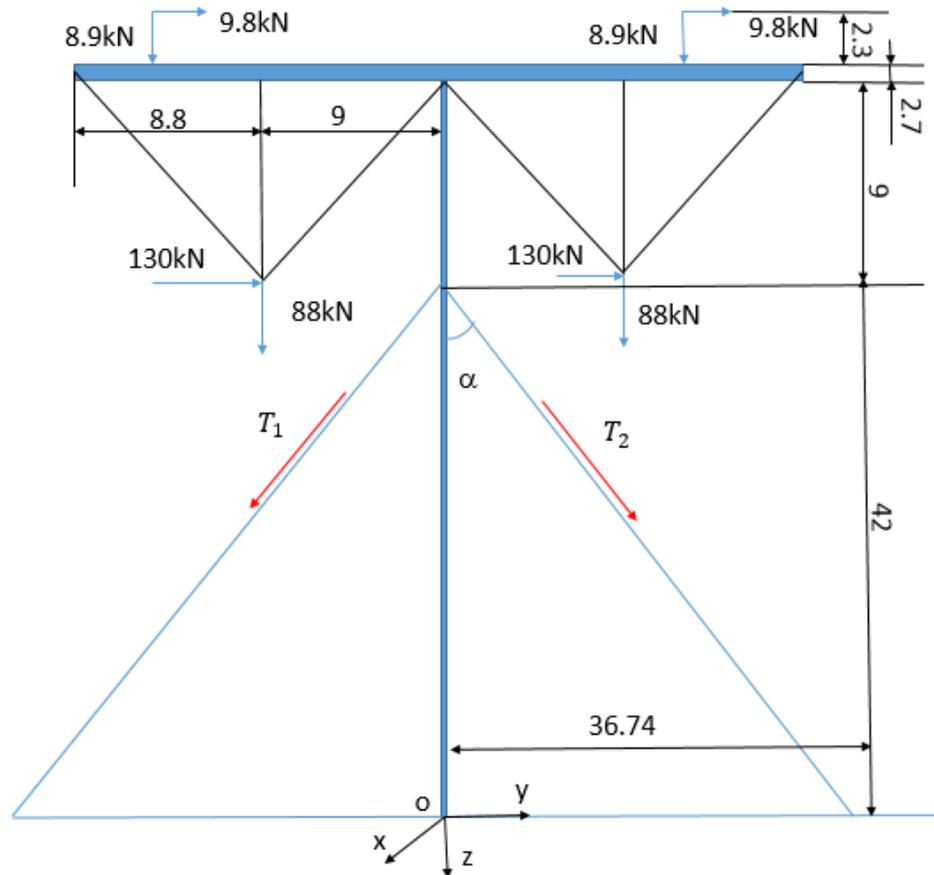


Fig. 5 Free-body diagram of pull line tower simplified model

According to the theoretical mechanics knowledge, the equilibrium equation can be listed by the equilibrium condition [3]

$$\begin{cases} \sum F_x = 0, F_x + T_3 - T_4 = 0 \\ \sum F_y = 0, F_y + 130 \times 2 + 9.8 \times 2 - T_1 \sin \alpha + T_2 \sin \alpha = 0 \\ \sum F_z = 0, F_z - 88 \times 2 - 8.9 \times 2 - T_1 \cos \alpha - T_2 \cos \alpha - T_3 \cos \alpha - T_4 \cos \alpha = 0 \\ \sum M_o = 0, 9.8 \times 56 \times 2 + 130 \times 42 \times 2 - T_1 \times 42 \times \sin \alpha + T_2 \times 42 \times \sin \alpha = 0 \end{cases}$$

In addition, when the wind is applied, the tension in the tie rod 1 and rod 2 which are shown in Fig 5 becomes [4]

$$T_1 = \frac{(\Delta l + \Delta l_1) E_1 A_1}{l_1}$$

$$T_2 = \frac{(\Delta l - \Delta l_2) E_2 A_2}{l_2}$$

In this case, the forces of the stay 3 and the stay 4 are the same

$$T_3 = T_4$$

According to assumption 2

$$E_1 = E_2, A_1 = A_2, l_1 = l_2$$

According to the direction of the stay force, the force in stay 1 increases, and the force in stay 2 decreases. The inclination of the cable tower is very small, where Δl_1 、 Δl_2 are small changes in the amount. And we could believe

$$\Delta l_1 \approx \Delta l_2$$

According to the above formulas, we can get

$$T_1 = T + \Delta T$$

$$T_2 = T - \Delta T$$

where:

$$\Delta T = \frac{\Delta l_1 E_1 A_1}{l_1} = \frac{\Delta l_2 E_2 A_2}{l_2}$$

4. Conclusions

Solve the above equations

$$\left\{ \begin{array}{l} F_x = 0 \\ F_y = 6.53kN \\ F_z = (3.02T + 193.8)kN \\ \Delta T = 217.29kN \end{array} \right.$$

When the pre-tension in the cable increases, F_z increases rapidly. And the pressure on the base increases dramatically. Therefore, on the one hand, the increasing in the stay in the pre-tensile stress can make the tower more stable. On the other hand, this will be a sharp increase in the base force, affecting the use of the base time. In practical engineering, we need to consider two factors to get a comprehensive consideration of the economic and security about the T value.

References

- [1] WANG Zhangqi, YANG Wengang, ZHANG Kai, et al. The Influence of Initial Guy Cable Prestress on UHV Transmission Line Single Mast Guyed Tower's Mechanical Properties. Proceedings of the CSEE[J]. 2014. 34 (9) 1498-1505(in Chinese).
- [2] Kong Wei, Dang Jian, Shan Liang, et al. Study on initial pre-stresses distribution of guyed transmission tower [J]. Jilin Electric Power, 2010, 38(5) 19-21(in Chinese).
- [3] Junfeng Li, & Xiong Zhang (2010), Theoretical Mechanics, Beijing, Tsinghua University press.
- [4] Qinshan Fan, & Yajun Yin (2008), Mechanics of Materials, Beijing, Tsinghua University press.