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Failure Analysis of the Guyed-V Tower Link Plate Deformation of a 500 kV Transmission Line

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Abstract. Component analysis, mechanical property test, field survey and finite element mechanical calculation were used to analyse and evaluate the deformation failure of the Guyed-V Tower link plate of a 500 kV transmission line. The results show that the main cause of the failure is the relaxation of the guy after right front guy or wire is subjected to a large impact towards the large side. The weak design of the link plate structure and the misfitting of angle steel are the indirect causes of the failure. The construction angle of anchor cable is larger than the design value, and the tension of anchor cable is low, which has a certain impact.

1 Introduction

The guyed-V tower has the advantages of simple structure, low costs, convenient construction and so on, and has once become the first choice to reduce the cost of the line body. However, with the continuous progress of power grid construction, in order to meet the change of actual demand for infrastructure and operation and maintenance as well as the improvement of reliability requirements for equipment, the design of power transmission and transformation projects is also constantly changing to meet various complex environments and operating conditions. In the 2005 edition of *Typical Design of Transmission and Transformation Project of State Grid Corporation of China: 500kV Transmission Line Classification*, the cable tower such as the guyed-V tower and the ramen tower are no longer included[1], because the cable tower has some problems such as poor design consideration, too large or too small tension of the cable and weak link plate design[2-4].

In this paper, the deformation failure of a 500kV transmission line draw-V towing plate is investigated from the aspects of the plate quality, size, appearance, tensile test, installation of the plate, field survey and measurement, mechanical simulation calculation and so on.

2 Analysis background

On September 23, 2019, during the maintenance of a 500kV transmission line power failure, it was found that link plates between the right cross arm and the right side of the vertical column were deformed and bent on #94 tower. The right cross arm was shifted to the large-number-side by about 300mm and to lower position. Cross arm and link plate of left side were not damaged, as shown in figure 1-2.

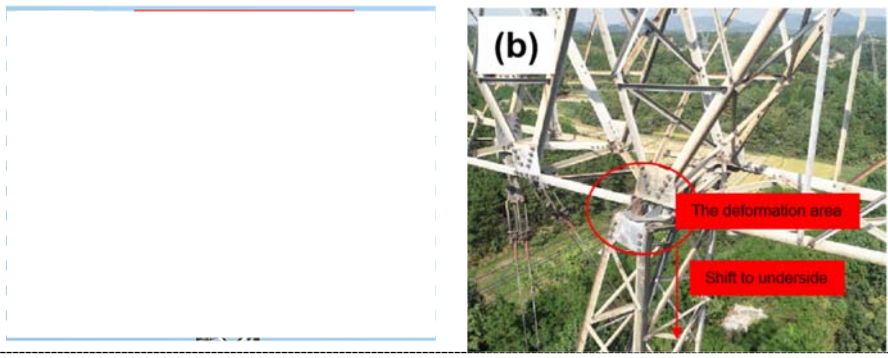

Figure 1. (a) Cross arm and vertical column of right side; (b) Link plates of right side.

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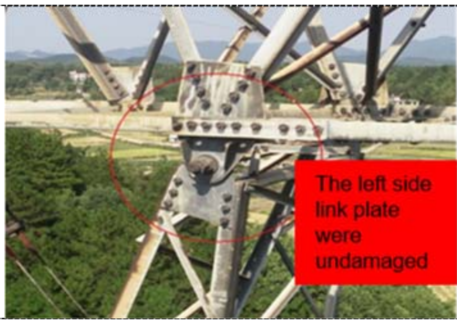

Figure 2. Link plates of left side.

3 Test

3.1 Link plate material

3.1.1 Appearance

The appearances of #94 tower link plates are inspected. As we can see from figure 3-4, the damaged right side link plates are bent to nearly 90°, and there are fresh marks on the outside. No corrosion marks were found on the left and right side coupling plates, and no corrosion marks were found on the cracks. It is speculated that the bending time is relatively short and there is no serious corrosion on the surface of the coupling plate. Refer to Guidelines for Corrosion Safety Assessment of Steel Structures of Transmission Lines for light corrosion (grade C).

Figure 3. Deformed link plates of right cross arm of # 94 Tower.

Figure 4. Undeformed link plates of the left cross arm of # 94 Tower.

3.1.2 Component testing

The composition of the upper and lower link plates on the small-number side of #94 tower were tested, and the composition of the upper link plates were Q235A, which met the requirements of GB/T 700-2006 Carbon Structural Steels. The composition of the lower plates were Q345B, which met the requirements of *GB/T 1591-1994 High Strength and Low Alloy Structural Steels*.

3.1.3 Tensile tests

Tensile tests were carried out on the upper and lower plates on small-number side of #94 tower. The tensile properties of the upper plates met the requirements of Q235A in GB/T 700-2006 Carbon Structural Steels. The tensile properties of the lower plates met the requirements of Q345B in *GB/T 1591-1994 High Strength and Low Alloy Structural Steels*.

3.2 Field investigation

Field investigation found the angle steel installation error of right side link plates. On the small-number side of #94 tower, No.213 angle steel should be installed on right side link plates, but the actual installation was No.212 angle steel. When those link plates were slightly deformed, the lower part of the angle steel could not support them, as shown in figure 5, and the correct installation of angle steel is shown in figure 2.

In addition, it was found that the left trailing cable of #94 tower was seriously slack, and the ground anchor on the right side of the small tower was pulled out 2 cm, and the ground cracked near the anchor, indicating that the cable was greatly impacted, as shown in figure 6.

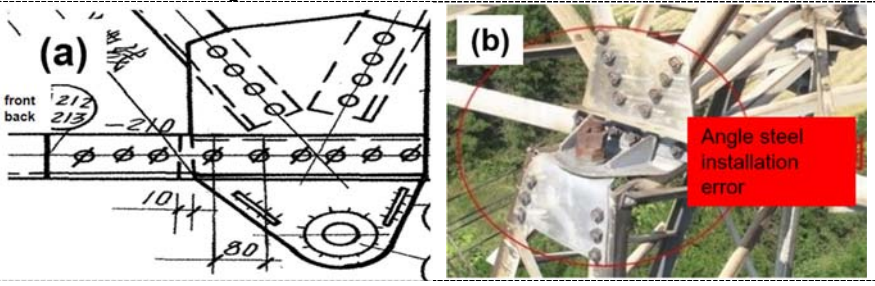

Figure 5. (a) Angle steel installation on design drawing; (b) Angle steel incorrectly installed, unable to support reinforcement.

Figure 6. Cracks occur on the ground near the ground anchor on the right side of the small-number-side of #94 tower, and the degree between ground anchor and ground is larger than that of cable and ground.

The total station instrument was used to measure the cable Angle, and the result was shown in table 1. The maximum cable Angle was 61.91°, slightly larger than the 60° given in the design value. After the on-site recovery, the single tension of #94 and #95 rods and towers was measured as 8.8-14.1kN, part of which was less than the design requirement of 12.88-17.17kN, as shown in table 2. To sum up, the horizontal component of tension that the cable can provide to resist the unbalanced tension decreases, and the impact resistance decreases. At the same time, the vertical component which is harmful to the strength and stability of the structure is larger, which means that the ground anchor has a larger force.

According to the meteorological data observed by the municipal meteorological station during the fault period, from September 17 to 23, the maximum wind speed in this section was 12.8m/s, which did not exceed the maximum designed wind speed of 30m/s.

Table 1. #94 tower cable angle.

Cable position	Designed Angle (degree)	Allowable deviation (degree)	Measuring Angle (degree)	Angular deviation (degree)
Left small-number side	60	±1	60.71	0.71
Left big-number side	60	±1	61.91	1.91
Right small-number side	60	±1	61.48	1.40
Right big-number side	60	±1	61.45	1.45

Table 2. #94 , #95 tower single cable tension.

Cable position	#94 tower		#95 tower		Standard
	Single cable 1 (kN)	Single cable 2 (kN)	Single cable 1 (kN)	Single cable 2 (kN)	
Left small-number side	12.70	11.80	12.70	11.80	Single cable: 12.88-17.17kN
Left big-number side	11.50	12.10	11.50	12.10	
Right small-number side	14.05	11.50	14.05	11.50	
Right big-number side	8.80	11.05	8.80	11.05	

3.3 Finite element mechanical calculation

Based on the measured data and assuming that the initial tension of the cable is only half of the measured tension, the finite element structural analysis software MIDAS2017 was used to simulate the mechanical performance of the Guyed-V tower under the condition of cable relaxation. The main column is equivalent to a cylindrical section and a beam element. Only oblique wind load and ground conductor load of 10m/s are considered. The maximum displacement of the structure is up to 98mm, and the deformation mode of the structure is consistent with the failure.

4 Analyse and discussion

The Guyed-V tower is a typical design, but there are some accident cases. Through the analysis of the domestic cases of cable tower accidents, it is found that most of the accidents are caused by the poor design of the tower, the tension of cable is too large or too small and the design of the link plate is weak. Such as LH23.7 linear sliding door tower of 220kv Xubao Transmission Line suffered three same nature pour tower accidents in 1979-1983 consecutively. And Chen Yousong thought LH23.7 type linear sliding door design to be thoughtless, suggested that with the introduction of new tower, calculation and design must be carefully, and should adapt to specific geographical conditions and the change of weather conditions; It was proposed that the 214 link plates did not meet the design requirements [2]. According to the analysis of the falling tower accident of Chifeng 220kV Wuda Transmission Line in 2013, the Guyed-V tower line has a weak ability to withstand strong winds during operation. In addition, it is suggested to conduct a key inspection of the cable towers in the line under its control, check the stability of the foundation and cable, and conduct a comprehensive tightening of all the cable towers [3].Wang Guofan[4] pointed out that under special meteorological conditions, such as strong wind, or when the cable becomes loose at ordinary times, the cable tower is likely to lose stability and fall.

Although the tower has been in operation for many years, the test results show that the performance of the link plates are still in line with the standards at that time. The outlet Angle of cable anchor construction is 2° larger than the design, and the cable tension in operation is only 80% of the minimum designed value, which can provide a smaller horizontal component of tension to resist unbalanced tension, and a larger vertical component of weak structural strength and stability, which is less favorable than the design condition. Those link plates, which is mainly subjected to the stress of the cross arm and the wire itself, suddenly lost local stability and bent, which should be caused by the impact from the right side of the cross arm and pointing to the front. The design material strength and thickness of the link plates are too low, especially the right side angle steel is misinstalled, which lead to the link plates did not play the due supporting role to the instability bending after the impact. The modeling and analysis results based on the condition that the tension of the cable is reduced by half after impact, the Angle of the cable, the thickness of the sheet metal, and the wind speed are consistent with those in the field.

5 Conclusion

Failure of the Guyed-V tower link plate deformation of a 500 kV transmission line was mainly caused by the relaxation of the right front cable which caused by impact on this cable or large impact towards the large–number side on wire. In the mean time, the weak design of the link plates structure and the misfitting of angle steel are the indirect causes of the coupling bending failure. The construction angle of anchor cable is larger than the design value, and the tension of anchor cable is low, which has a certain impact.

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