Study on safety management of guy wires in the construction of UHV (EHV) transmission lines

Fang Jianjun1, *, Hou Jiyong2, and Dai Chenghao3

1State Grid of China Technical College, 250002 Jinan Shandong, China
2State Grid of AC Construction Company, 100052 Xicheng Beijing, China
3Shanghai Transmission & Transformation Engineering Co. Ltd. Shanghai, China

* Corresponding author: 137339750@qq.com

Abstract. The guy wires play an important and key role in the erection of the tower. Temporary guy wires are also used extensively in the stringing engineer. This study summarizes the causes of many serious accidents caused by temporary guy wires that do not meet the requirements of use and operation. It focuses on the high-risk links in the guy wire operation, from the calculation and verification before the use of the guy wire, the construction technical plan, the control of key links, and the construction process. The implementation of management and control is analyzed and summarized, and the key monitoring links of safety management and control of guy wires are summarized. The study provides reference for the construction of other similar HUV (EHV) high voltage transmission lines.

1. Introduction

"Guy wires" is one of the key words in the "State Grid Corporation Electric Power Safety Work Regulations (Part of Power Grid Construction)". In the construction of UHV and UHV transmission lines, a large number of temporary construction guy wires will be used. The guy wires play an important and key role in the erection of the tower. Temporary guy wires are also used extensively in the construction of ground wire racks. Temporary guy wires are also used in the reconstruction of old ground wires and tower dismantling. When using a suspended pole tower, it is necessary to set up external or internal guy wires, drop guy wires (support rope), control guy wires (control rope), and during wire construction, there are tightening tower reverse guy wires, wheel crossing guy wires and crossover guy wires, etc. In addition to the above main application scenarios, guy wires are often used in electric poles, rope way masts, etc [1-3].

After combing and analyzing the construction safety accidents of power transmission and transformation projects that have occurred since 2005, it was found that nearly 80% of the accidents occurred repeatedly, and the temporary pull wire (wire rope) did not meet the requirements of use and operation and caused many serious accidents. In the process of transmission line construction, vertical and unstable structures usually need to be balanced to prevent tipping. The main function of the guy wires is to balance the forces in the opposite direction. When the forces in the opposite direction are not balanced, unbalance of forces will occur, and accidents will occur. Therefore, in the process of guy wires construction, it is particularly important to carry out all-round management and control of the construction process of the guy wires. [4-5]

In order to learn lessons from accidents and prevent the recurrence of safety accidents caused by guy wires pulling, this study analyzes and summarizes the implementation of high-risk links in the guy wires.
operation from the calculation and verification before the use of the guy wires, the construction technical plan, the control of key links, and the control of the construction process. The study can provide a reference for the construction of other similar special (ultra) high voltage transmission lines.

2. Calculation and verification of the guy wires

Taking the internal suspension and external guy wires holding pole to disassemble the tower as an example, the hoisting operation is carried out under the premise of ensuring the safety of the guy wires. Before the construction of the tower, it is necessary to arrange the construction site in detail, including the relative position of the guy wires and the center of the foundation, the angle with the horizontal plane and the stability requirements. According to the measurement data, calculate the allowable ground anchor buried position in the guy wires direction. The specific calculation model is shown in the figure.

Fig.1 Diagram of the force calculation model for each part of the inner suspension and outer guys wires

As shown in Figure 1, point A and B is the position of the apex and bottom of the pole, point O is the center of the pole, T1 and T2 are the supporting ropes. F is the control rope, P is the hoisting wire rope, G is the hoisted component, and S is the hoisting the two external guy wires on the opposite side of the force, the angle between the external guy wires and the ground is B, take 45°, the angle between the control rope and the ground is y, take 30°, a is the angle between the hoisting wire rope and the plumb line, take 15°, The inclination angle θ of the pole is generally controlled between 5°~10°. Then: the allowable breaking force of the steel wire rope used for the holding rod is [T], the basic safety factor k takes a value of 3, the dynamic load factor k1 takes a value of 1.3, the unbalance coefficient k2 takes a value of 1.2, and Tpl is the comprehensive breaking force of the wire rope.

The calculation and specification selection methods of other guy wires are as above. The tension tower reverse temporary guy wires is calculated according to the balanced tension provided by the design, taking into account the angle to the ground and the angle with the cross arm. The temporary guy wires of the crossing frame (false cross arm) is subjected to the bearing guy wires under the accident state. The force and the angle between the guy wires and the ground are calculated. The selection of the guy wires specification should be based on the calculation of the force plus the safety factor of the steel wire rope under the different working conditions required by the safety regulations, the dynamic load factor, Make a selection after the unbalance factor. Steel wire ropes shall be used for temporary pulling wires used for tower assembly or erection. The safety factor K, dynamic load factorK1 and unbalance factor K2 of the steel wire rope are shown in Table 1~Table 3.

Table 1. Steel wire rope safety factor K

| No. | Nature and conditions of work                                      | K  |
|-----|-------------------------------------------------------------------|----|
| 1   | Ropes using manpower winch to lift tower or tighten the conductors and ground wires | 4.0 |
| 2   | Ropes Using motorized winch, hoisting unit to erect pole tower or stringing | 4.0 |
### Table 2. Steel wire rope dynamic load coefficient $K_1$

| No. | How the starting or braking system works | $K_1$ |
|-----|----------------------------------------|-------|
| 1   | Towed by manual winch or winch through the block | 1.1   |
| 2   | Towing directly with manual winch or winch | 1.2   |
| 3   | Towed by a motorized winch, tractor or car through a block | 1.2   |
| 4   | Directly towed by motor winch, tractor or car | 1.3   |
| 5   | Braking system when controlled by brake for block | 1.2   |
| 6   | Braking system when directly controlled by brake | 1.3   |

### Table 3. Steel wire rope unbalance factor $K_2$

| No. | Withstand uneven lifting rigging | $K_2$ |
|-----|----------------------------------|-------|
| 1   | Each branch holding pole when lifting with a herringbone of double holding pole | 1.1   |
| 2   | Bounding slings for each branch when lifting gate type or large pole tower | 1.2   |
| 3   | When tow sets of traction devices connected by a balance pulley block and two independent sets of braking devices work in parallel, the lifting tools of each device | 1.2   |

### 3. Technical measures for guy wires construction

#### 3.1 Preparation of construction materials and tools

The specific requirements for the guy wires setting should be specified in the operation instruction, construction technical measures, and three measures & one plan. Generally, it includes the main tool materials and setting requirements, which can be calculated and determined according to the actual construction needs of the construction site, the strength of the guy wires, the site topography, geology, and soil quality. All materials are ready, and the foundation of the pole and tower should be checked before assembling the tower. The inspection and inspection work of the used wire ropes, ground anchors and fixings has been completed and complies with the construction regulations.
3.2 Preparation of construction workers
Take the pole-holding towers of the super (ultra) high voltage transmission lines as an example, the construction workers need to be assigned a job leader. The job responsibility is to be fully responsible for the on-site work, and the workers have a clear division of labor to ensure the quality of the work: Responsible Check whether the safety measures on site are in place correctly and whether the construction personnel are working in violation of regulations: inform the team members of the dangerous points before work, explain the safety measures and technical measures, and confirm that every team member is aware of it. Equipped with a safety supervisor, the job responsibility is to be responsible for the depth measurement of the ground anchor pit; responsible for the daily inspection of the on-site construction tools and equipment: responsible for the on-site safety supervision of the assembly. There are 6 high-altitude construction workers who are responsible for the erection, lifting and dismantling of the pole. 4 technicians and 8 assistant workers are required for the control of the pole-holding wire and lifting parts. They are responsible for the four directions of the tower hoisting process and the process of lifting, lifting and dismantling the pole.

3.3 Control of the construction process of the guy wires
When working on site, the construction personnel must be trained in professional safety technology, pass the examination, and hold a certificate to work. During the installation process, the construction personnel must carefully understand the contents of the implementation of the construction organization design (construction plan) and safety technical measures, and the construction must be carried out in accordance with the regulations of the construction drawings.

Before operation, carefully check the types of wire ropes and accessories required by the construction plan. They should meet the current technical standards promulgated by the State Grid and have qualified certificates. It is strictly prohibited to use pull wire ropes and accessories that do not meet the safety technical requirements. Do not replace small ones with large ones. It is strictly forbidden to use steel wire ropes that have already appeared dead knots, dead bends, loose strands, severe corrosion, broken strands and broken wires; check carefully before operation Whether the thread of the ingot clip (U-shaped ring) is worn out, Whether there is a slip buckle, etc. It is strictly forbidden to use the ingot clip with loosening and loosening of the nut slide; after the tail rope of the pull wire rope is fixed with the ingot clip (U-shaped ring), there must be an observation bend for observing the looseness of the pull wire, and check whether there is any change in the observation bend during the construction. ; Strictly follow the requirements of the construction plan, arrange the anchor position of the fixed guy wires, and set up the ground anchor pit and horse track according to the force direction of the guy wires; when backfilling, it should be necessary to prevent rainwater soaking.

When connecting the pull wire rope, use lifting shackles in accordance with the regulations. It is strictly forbidden to use material loops to connect. It is strictly forbidden to connect two wire ropes directly to the rope socket. It is strictly forbidden to fix the pull wire on a tree stump or other non-firmly stressed plants or objects; use theodolite When correcting the pole, the two co-axially opposite pull wires should be tightened at the same time to adjust the pole vertically. It is strictly forbidden to force or overload the guy wires at one end.

After the pole is assembled and the vertical adjustment is completed, the chain of the lever hoist should be clamped with a clamp.

4. Construction process control of pull wire

4.1 Arrangement of pole-pull guy wires and ground anchors
The wire rope and ground anchor should be selected after calculation, and the wire should be reliably fixed before hoisting. According to the topography of the site, determine the external guy wires method (cross guy wires or diagonal guy wires) and then make on-site layout. The guyed ground anchors should be located in the direction of the extension line with an angle of 45° to the center line of the foundation,
and the distance from the center of the foundation should not be less than 1.2 times the height of the tower.

When the site cannot meet the requirements, the forces of each department shall be checked and special safety measures shall be taken. Ground auger and ground anchor are a tool that closely cooperates with the guy wires to transfer the force of the guy wires to the earth and anchor it to the ground. The use of ground auger requires that the straight rod part is fully drilled into the ground below, the block wood is added in front of the force. Ground anchors are usually required to be purchased 2 meters below the ground and at the same time digging a certain slope in the direction of force inclined ditch and so on. The pull line basically uses a 15.5mm steel wire rope with a 18.5mm steel wire rope sheath and a 5t ground anchor. Pull line The depth of ground anchors shall not be less than 2.5m.

The traction system should be placed on the side of the main hoisting surface, and the distance between the traction device and the ground anchor and the center of the tower should not be less than the entire height of the tower 0.5 times the height, and not less than 40m.

4.2 Conventional layout of pole-pull guy wires and ground anchors

4.2.1 Arrangement of cross guy wires
Four external pull wires is need to set up. When the local anchor type uses multiple ground drills, the ground drills are separated by 1~1.5m, and they are connected by 3t double hooks. The load bearing side of the ground should be padded with railroad wood, and the position of the pull wire ground auger should be on the cross arm. The center line and the vertical line of the cross arm. If it is close to the power line, when the distance cannot be satisfied, the position of the guy wires and the method of hoisting can be determined by the technician according to the specific situation. The hoisting work surface is generally selected on both sides of the line direction.

4.2.2 Arrangement of diagonal guy wires
The four outer guy wires are arranged on the extension line of the diagonal line of the iron tower, and the others are the same (arrangement of cross guy wires); Anchors should be buried separately, choose to be on both sides of the center line or vertical line of the cross arm, one ground auger and one railroad wood on each side, the distance should be 1.2 times the tower height.

5. Safety control of guy wires construction
It is forbidden to correct the inclination or bending of the tower by adjusting the temporary guy wires when there are people on the tower. The assembled poles and towers shall not be fixed overnight with temporary guy wires. When it is necessary to stay overnight, take safety measures to temporarily pull the cord. The temporary guy wires of the pole tower should be removed after all the permanent guy wires are installed, and the on-site commander shall conduct unified command when removing. It is forbidden to install a permanent guy wires and then remove a temporary guy wires.

During the lifting and lowering of the holding pole, the temporary guy wires on the four sides should be adjusted by the guy wires controller in a timely manner according to the command of the commander. During the lifting and positioning of the components, no adjustment of the holding rod guy wires is allowed. The lower end of the inner guy wires of the holding pole should be tied under the main material node near the upper end of the tower. The middle position of the rocker arm or the non-hanging trolley position shall not be suspended from the hoisting trolley or other temporary guy wires.

When the pole adopts a single-sided rocker arm lifting component, the opposite rocker arm and the lifting block shall be tightened as a balance guy wires. It is not advisable to lift components on both sides at the same time without a rocker arm holding pole. If the lifting components on both sides should be equipped with temporary holding rods. During the lifting process of the pole, the waistband and the pole should be monitored not to be jammed, and the guy wires should be loose when the pole is lifted.
After the holding pole is in place, the four-side pull wires should be tightened and fixed, and a dedicated person should be on duty during the tower assembly process. The wire reel should be stable, flexible in rotation, and reliable in braking. If necessary, put on a temporary guy wires to fix it.

The preparations for the temporary guy wires and reinforcing measures of the wire-tightening tower and the temporary anchoring for the conductors and ground wires should be completed. For the structural support being assembled and hoisted, it should be ensured that the ground anchor is buried and the guy wires is fixed firmly, and the independent frame combination should be fixed with four-sided guy wires.

6. Conclusion
The guy wires cannot be understood as a single wire rope, but a small system that includes lashing points, steel ropes, ground anchors, and wire rope clamps, U-rings and other fastening and connecting tools. As a structural system that balances certain forces, if any link fails, the guy wires system will collapse and accidents will occur. Accidents is caused by link fails, Such as loose lashing points, insufficient steel wire rope strength, improper setting of ground anchors, improper use of U-shaped rings. The static guy wires described above. Sometimes the guy wires need to be released synchronously and dynamically during operations such as pole lifting. This is a method that usually uses a thread release and manual control. There is no standard tool and equipment for the thread release device, and each unit generally processes it by itself according to their own construction habits. This kind of dynamic control guy wires is generally not stressed. If the force is too large, it is easy to lose control and accidents occur. No matter what kind of guy wires is out of control, it will often lead to more serious consequences. Such as upside-down holding poles, upside-down towers, incidents such as the ground line running away, and even personal injuries occurred. The actual accident cases show that the accidents caused by the pulling wire are not carried out in accordance with the correct method and plan.

The safety management and control of guy wires construction must strengthen on-site monitoring, especially when there are many uncertain factors in the geographical and terrain conditions or the surrounding environment. New technical means can also be used to assist in monitoring the guy wires, such as setting observation bends, installing tension sensor monitors or Means such as sensor chip.

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