An Auxiliary Device for Realizing the Rapid Replacement of UHV Composite Insulators

Guo Hao\(^1\), Long Yang\(^1\), Li Peng\(^1\), Zhen Zhaohui\(^1\), Mao Dun\(^1\), Zeng Wenyuan\(^1\)

\(^1\) State Grid Hunan Transmission & Maintenance Company, Hengyang, China, 421000; 
\(^2\) Intelligent Live Working Technology and Equipment Key Laboratory of Hunan Province (2016TP1025) Changsha, China, 410000; 
\(^3\) Live Inspection and Intelligent Operation Technology State Grid Corporation Laboratory

Abstract: In view of the problem that it is difficult to replace the UHV composite insulator quickly due to the large stress of the composite insulator in hot-line work, an auxiliary device for realizing the rapid replacement of UHV composite insulator is developed in this paper. By designing the mounting and connecting parts suitable for the installation of UHV insulator and yoke plate, the stress at the joint part of insulator is transferred so that the insulator and connecting part of yoke plate can be broken away without stress. The device is light and flexible, which can effectively improve the working efficiency of hot-line working operators.

1. Introduction

Hot-line work is an important means to ensure the safe and stable operation of UHV power grid and live replacement of composite insulators is an important defect elimination project for live work[1]. The structure height of the composite insulator of the straight line pole of the UHV line is about 9 meters, and the weight is about 100 kilograms, which is 50% to 60% larger than the size of the insulator of the UHV line[2]. In the implementation of composite insulator live replacement work, the load of roadway is usually transferred to the load-bearing tool so that the insulator can be loosened to pull away the joint part. However, because the UHV composite insulator is affected by its own gravity, the shape after relaxation is "bow-shaped", and there is still a larger stress at the junction between the u-shaped ring of the insulator on the side of the conductor and the yoke plate, leading to the insulator to be hard to disengage. It requires repeated adjustment of the length of strength bearing tools, which consumes a lot of time and physical power, bringing great safety risks[3,4].

To solve this problem, a "quick insulator replacement device for UHV transmission line" is developed. By adopting the principle of transfer connecting stress, the two ends are firmly installed on the insulator and yoke plate respectively. Through the transfer stress relaxation joint part, the work of replacing the straight insulator chain of UHV dc transmission line with live electricity can be efficiently completed.

2. General idea and requirement of design

According to the functional requirements, each functional module of the rapid replacement device is designed in this paper, divided into transmission mechanism design, insulator denser design and overall design. Finally, the tool is tested to verify whether it meets the requirements. If it does, field trial is carried out, and the specific design idea is shown in figure 1:
Quick release device function requirement analysis
Transmission mechanism design
Insulator densener design
Overall design of quick release device
Force analysis
Field trial

Figure 1 Design Idea of Auxiliary Device for Rapid Replacement

The details are as follows:

(1) The structure of the tower body and the use of insulators are analyzed, as well as the mechanical characteristics of the transmission tower;

(2) The functional requirements of the transmission mechanism and compactor of the quick change device are analyzed, and corresponding components are designed in accordance with the requirements;

(3) The entire modeling force analysis of the whole set of rapid replacement device is carried out, and its mechanical strength is checked, the unqualified will be redesigned;

(4) Use the complete set of auxiliary disconnecting device made by processing to assist in the replacement of composite insulator of ± 800kV UHV dc line. The complete set of tools designed including transmission mechanism, densener, insulated rope and end fixture must meet the requirements of "Live Work and Tools" and "Electrical Safety Working Rule" (circuit part).

3. Device configuration design and processing

3.1 Transmission mechanism design

In order to meet the needs of rapid replacement of insulators, it is necessary to design a convenient and effective transmission device, which requires that the transmission cord can be conveniently driven adjusted when working high above the ground. After communication with the person in charge of the front-line operation, the transmission device is designed in combination with the daily work, as shown in Figure 2.

According to the analysis of figure 2, the transmission device is mainly divided into five parts: yoke plate fiche, support rod, fixed pulley, turbine rod drive mechanism and hand crank. The yoke plate fiche is located on the top of the transmission device and plays a main supporting role, which fixes the transmission device on the side connecting plate of the crossarm. The support rod is located on both sides of the transmission device and acts as a force on the supporting device. The fixed pulley is located at the top of the support rod and is distributed symmetrically on the left and right, which is connected by the rope and the insulator string compressor. The turbine rod drive mechanism and the hand crank are the power source of the drive device, which is used to tighten and fix the rope and realize the quick replacement of the UHV composite insulator.
3.2 Design of insulator compactor
On the basis of the design of the transmission device in Figure 2, it is necessary to design a matching insulator string compactor to ensure that the transmission device can be firmly pressed on the composite insulator in the process of line tightening. The specific design of insulator compactor is shown in Figure 3.

The analysis of Figure 3 shows that the insulator compactor is connected with the transmission device through the ropes at both ends, and is closely connected with the composite insulator in the process of tightening the line by utilizing the tensile force of the transmission device. In addition, the insulator compactor is adopted the sheet metal integrated cutting and forming process, and in order to reduce the burden on the operator, the lightweight design is made on the basis of guaranteeing intensity.

3.3 Quick replacement auxiliary device processing list
In addition to the two main parts of the aforementioned transmission mechanism and insulator compactor, the quick replacement device also contains a small number of processing ancillary components, and the main processing materials and quantities are attached to the processing list of the device, as shown in Table 1.

Table 1 Processing List of Main Device

| Number | Name                      | Quantity | Material            |
|--------|---------------------------|----------|---------------------|
| 1      | Main body of the handle   | 1        | 45# steel           |
| 3      | Turbine                   | 1        | Brass               |
| 4      | Worm end cover            | 1        | Aluminum 6061       |
| 5      | Clamping plate            | 1        | Aluminum 6061       |
| 6      | Worm                      | 1        | 35CrMo              |
| 7      | Main axis                 | 1        | Aluminum 6061       |
| 8      | Turbine end cover         | 2        | Aluminum 6061       |
| 9      | Wire rope pulley          | 2        | Nylon net           |
| 10     | M8 bolt                   | 2        | 35CrMo              |
| 11     | Turbine box               | 1        | Aluminum 6061       |
| 12     | Zinc bar card             | 2        | Aluminum 6061       |
| 13     | Zinc bar fixing bolt      | 2        | 35CrMo              |
| 14     | Zinc bar card fixed plate | 1        | Aluminum 6061       |

4. Assembly test and application

4.1 Integral assembly for quick replacement of auxiliary device
Figure 4 is the assembly diagram of the quick replacement device, which is divided into two parts: (a) transmission mechanism of the replacement device and (b) compactor of the replacement device. The UHV rapid replacement device is mainly composed of a revolving gear and a compacting device, which are connected by an insulating rope.
4.2 Force analysis of quick replacement auxiliary device

In order to verify the stress performance of the designed auxiliary tool for rapid replacement device, mechanical simulation software is used to analyze the mechanical force of the device. Under the condition that the guide pulley of the unilateral stay line bears 500kg weight, the schematic diagram of the force analysis of the device is shown in Figure 5.

As can be seen from Figure 5, the minimum safety factor reaches 1.96 under the action of 500kg weight, which is much larger than the original design requirement of 200kg. Therefore, the auxiliary device is designed reasonably and meets the structural strength.

4.3 Field application

To verify the actual result of the device, the State Grid Hunan Transmission Maintenance Company Hot-line Work Center is entrusted to carry out the simulation of live replacement of high-voltage composite insulator on the training site. The following operation procedure is hereby formulated:

(1) First, this paper place the main body of the device on the end of the yoke plate and lock the bolts on the card slot of the yoke plate to fix the main body of the device;

(2) Jam the compactor on the zinc bar at the end of the insulator string, and lead out two insulation ropes from the guide pulley of the upper stay wire of the main body to the fixed hole position of the two wings of the compactor, and fix them with the anti-loosening lock;

(3) Turn the handle at the main end and tension the insulation rope after decelerating through the turbine worm, thereby tensioning the two wings of the compressor. Since the compactor has tightened the insulated zinc rod, the function of lifting the zinc rod of insulator string is achieved in the subsequent continuous tensioning of the insulation rope, thus shortening the distance between the insulator string and the yoke plate and achieving the purpose of operation.

**Fund Project:**
National Network Hunan Electric Power Co., Ltd.. Science and Technology Project(5216A3190005)

**References**
[1] Yan X, Yan Y, Zhu M.(2019) Operation, Maintenance and Live Working of UHV AC Transmission Lines .Communication Power Supply Technology, 36 : 229-230.
[2] Zhang Y, Xie Q, He C, Zhuo R. (2017) Experimental Study on Mechanical Property of UHV Composite Post Insulator. Southern Power System Technology, 11: 27-33+67.
[3] Yang L, Zeng P.(2019) Current Situation of Safe Operation Technology of UHV Transmission Lines. Electronic Technology and Software Engineering, 02: 230-231.
[4] State Grid Corporation of China(2013).Power Safety Working Regulation (power line part).China Electric Power Press, Beijing.