Research on X Ray Live Work of UHV Transmission Line by Helicopter

Jun Wang, Nan Wang, Shuai Li, Guangkai Yu, Yong Peng, Songyuan Cao, and Yuli Wang

Abstract In this paper, an X ray device used in UHV helicopter live work is developed, and its electrical performance, mechanical performance and X ray detection function are tested. The results show that the feature of the device meet requirements of live operation on site. In addition, the suspension method are used for field work, which solves the problems of inconvenient of X ray live test of UHV transmission lines.

Keywords Ultra-high voltage · Connecting hardware · Helicopter · X ray · Live working

1 Introduction

The events of disconnection at the self-voltage nozzle of transmission lines have occurred from time to time. Now, X ray test technology has a large number of applications in transmission line for high-resolution penetrating detection of line and fittings, so as to detect hidden defects in real time and quickly and prevent dis-connection accidents, which has very important practical significance [1–5]. However, on the one hand, the application of existing X ray detection technology mainly depends on power outage detection. If large-scale detection is carried out, the power outage time of the line will be greatly prolonged, and the economy is low. Live detection

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J. Wang · N. Wang · S. Li
State Grid Electric Power Space Technology Company Limited, Beijing 100000, China

G. Yu · Y. Peng · Y. Wang (✉)
China Electric Power Research Institute, Wuhan 430074, China
e-mail: 1910654759@qq.com

S. Cao
State Grid Anhui Electric Power Co. Ltd, Hefei 230041, China

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has only been applied in a small range on 110/220 kV lines, and some units have carried out live detection pilots on 750 kV lines [6–8]. On the other hand, when X ray inspection of connecting fittings is carried out on EHV transmission lines, due to the large tower height and many operating points, the traditional tower climbing inspection method has the problems of high labor intensity, low efficiency and high risk, which is difficult to meet the actual operation and maintenance requirements of EHV trans-mission lines. Using helicopter to carry out X ray live detection can not only complete the operation in the live environment of the line, but also greatly improve the detection efficiency and reduce the operation risk, which has strong practical significance [9–13].

In order to make it safe and feasible for helicopters to carry out X ray detection, in this paper, a set of X ray detection system based on live working of helicopters was successfully developed, and passed the electrical performance, mechanical performance and communication performance tests. Combined with the operation flow of X ray inspection and the operation characteristics of helicopter suspension method, the flight test schemes of helicopter suspension method are analyzed and formed, and the practical demonstration is completed in flight training, forming a complete and detailed operation flow. The project results are planned to be demonstrated and applied in ultra-high voltage transmission lines, and can be further popularized in power systems after the technology application is mature.

2 Design of X Ray Live Detection Device for 1 Helicopter

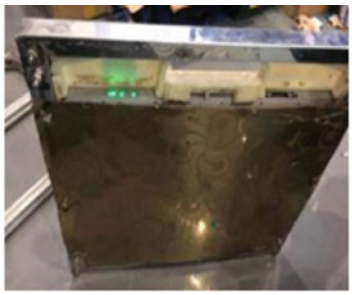
2.1 Overall Structure of the Device

In this paper, a helicopter live X ray test system is proposed based on XRS-3 X ray machine, which is mainly composed of (1) X ray machine, (2) X ray receiver, (3) equipotential supporter, (4) operation PAD, (5) wireless router, as shown in Figs. 1 and 2. In this paper, the tablet computer is used as the control terminal, as shown in the following figure.

2.2 Equipotential Detection Tooling

During the live working, to maintain the electric potential of the online testing device all the time, avoid spark dis-charge with small gap, and consider the convenience of installing and adjusting the position after on-line, an equipotential supporter is proposed, and it contains: X ray receiver shield, pulley, lightweight conductive rod and X ray machine shield. Its structural diagram is as follows (Fig. 2).

(a) X ray Machine



(b) X ray receiver

(c) Equipotential supporter

(d) Operation PAD

(e) Wireless router

Fig. 1 Helicopter live X ray detection system

2.3 Equipotential Control Terminal

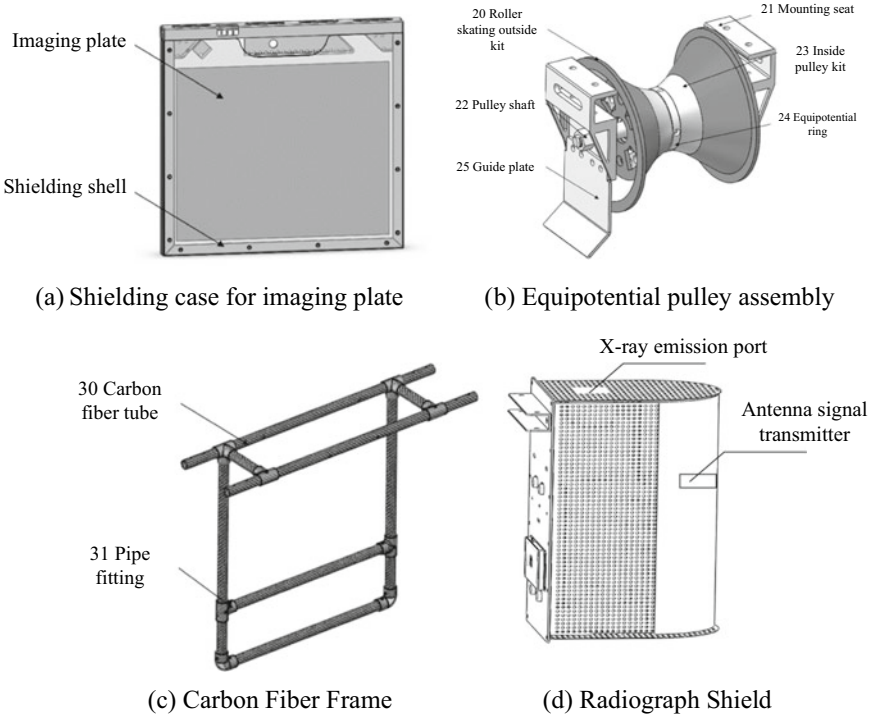
The portable control terminal mainly realizes the functions of ray emission and image acquisition, and adopts wireless control. It is proposed to use tablet computers instead of notebook computers, and fix it with metal brackets, to prevent the EMI during live work (Fig. 3).

3 Performance Test of X Ray Live Detection Device for 2 Helicopter

3.1 Electrical Performance Test

Equipotential function test and arc discharge immunity test of X ray live work system proposed above were conducted in the environmental climate hall of UHV AC test base. the test layout is as follows (Fig. 4).

Place all equipment on the remote operating insulation testing device. Boosting the voltage to a specified voltage which is equal to the UHV rated phase voltage. Adjust



(a) Shielding case for imaging plate (b) Equipotential pulley assembly

(c) Carbon Fiber Frame (d) Radiograph Shield

Fig. 2 Schematic diagram of equipotential detection tooling structure

Fig. 3 Flat panel control terminal and protective housing

the height of the insulating platform to cause arc discharge between the measured object and the wire, and observe the effect of arc discharge on the X-ray device.

The AC voltage test results are shown in Table 1.

The discharge arc in the test is shown in Fig. 5:

From the experiment, X ray imaging can be carried out on the test hardware samples to observe the crimping of clamps, and the imaging quality is clear. It is obvious that the X ray live work system is able to suffer the EMI in live working environment of 1000 kV AC and below, mainly due to high-frequency conduction

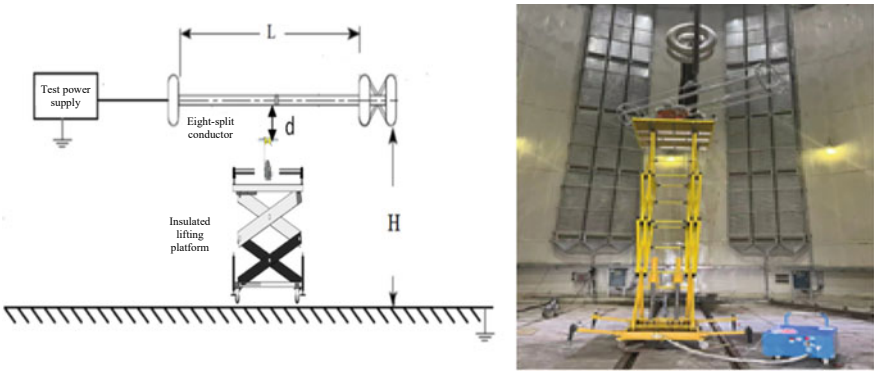


Fig. 4 Test layout

Table 1 AC voltage live test results

Test voltage (kV)	Discharge distance cm	Test result
400	0	Work normally in the test
	18	
	25	
	33 (critical discharge distance)	
500	0 (equipotential)	Work normally in the test
	10	
	22	
	38 (critical discharge distance)	
635	0 (equipotential)	Work normally in the test
	48	
	77	
	89 (critical discharge distance)	

current and electromagnetic radiation interference generated by arc discharge in the process of entering and leaving equipotential.

3.2 Mechanical Property Test

The total weight of the whole on-line device is 22 kg. In order to verify the bearing capacity of equipotential tooling support, 50 kg standard counter-weight is used for 5 min static load test. The results show that the support can bear 500N tension without deformation or damage (Fig. 6).

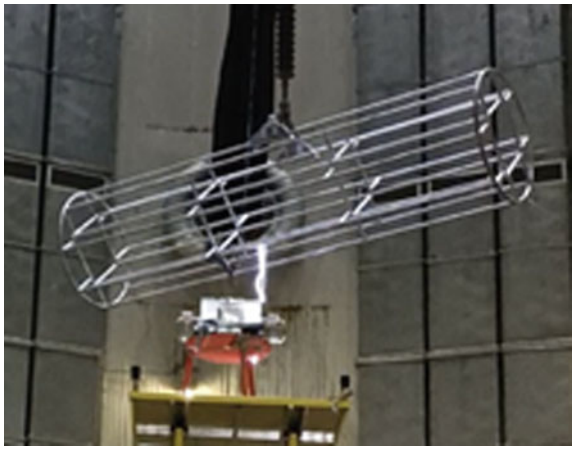


Fig. 5 Arc discharge test of 635 kV AC

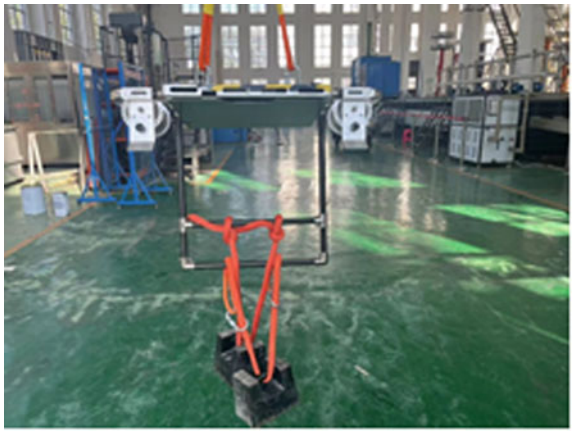


Fig. 6 Mechanical static load test of equipotential tooling support

3.3 X Ray Shooting Test of Ultra-High Voltage Clamp

In this paper, XRS-3 pulse ray machine is selected. In order to ensure the penetrating effect of X ray test system, the sample of tension clamp (NY-1250/100) of 1250 mm^2 large wire diameter wire on 1100 kV line was selected, and the photographing experiment was carried out (20/30/40/60 pulses) respectively. The photographing effect met the requirements of field use. Between 2–20 pulses, the image definition was slightly different with the in-crease of pulse number, and when the pulse number reached 20, the image quality was basically not affected (Fig. 7).

Fig. 7 Test layout and imaging diagram of NY-1250/100 tension clamp sample

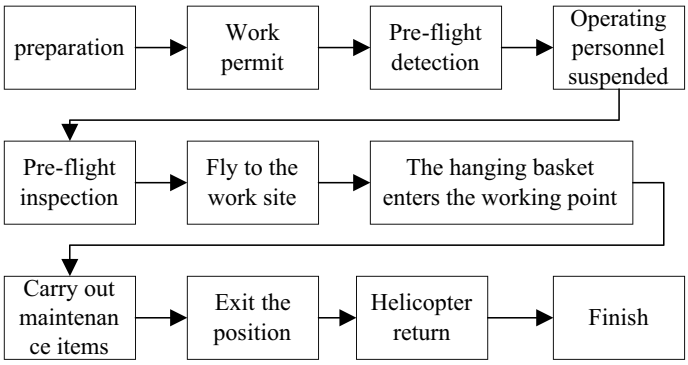


Fig. 8 Operation flow chart of helicopter hanging basket method

4 Field Application

4.1 Helicopter Suspension Operation

The suspension method is mainly applicable to UHV lines, 6-split and 8-split conductor lines, mainly 1000, 800 and 1100 kV. 750 kV lines can be selected for EHV lines. The helicopter trans-ports two operators and tools to the operation position at the same time through a special hanging basket, and all of them are installed and operated by online personnel to carry out inspection operations, without the need for the helicopter to hover for a long time.

The operation flow are shown in Figs. 8 and 9.

4.2 Operation Efficiency Analysis

We set up a training unit to carry out X ray on-line special training in Xiantao Training Base. A total of 4 qualified opera-tors carried out the whole-process hanging basket method and sling method on-line operation for 5 days, 15 sorties and 9 h, and took

Fig. 9 Field application picture

dozens of photos of tension clamps. The main difference between sling method and hanging basket method lies in the different ways of going on and going out, which has been introduced in detail above, and the working flow on the conductor is the same.

During this training, the operator recorded in detail the time nodes such as personnel and equipment on-line, equipment installation and photo shooting. After many flight test analysis, the total time for completing the operation of one-phase 8 split conductors is about 70 min. See the following table for the time distribution of each step in the whole on-line operation process. It can be seen from the data in the table that the measurement time of 8 sub-conductors accounts for about 47.8% of the total operation time, and the proportion of 3-phase conductors in the total operation time is about 60%. With the improvement of the proficiency of operators, the efficiency of disassembling and installing equipment among each sub-conductors will gradually improve. However, due to the influence of site and line distance in actual line operation, there is great uncertainty in the time of take-off and take-off, and the proportion of online operation time to total operation time may be greatly reduced, so the impact of simply improving online operation efficiency on overall operation efficiency will be very limited. Therefore, to improve the efficiency of helicopter X ray inspection operation, it is necessary to comprehensively consider various aspects and continuously optimize the operation process from all aspects.

5 Conclusion

- A helicopter live X ray test system is proposed based on XRS-3 X ray machine, which is mainly composed of X ray machine, X ray receiver, equipotential supporter, operation PAD, wireless router;

- The electrical performance, mechanical performance, communication performance and X ray detection function of the helicopter X ray live work system are tested, and the results show that the feature of the device meet the requirements of live operation on site;
- The suspension method are used for field operation, which solves the problems of inconvenient of X ray live test of UHV transmission lines.

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