Development and Application of Foreign objects Removal Device for High Voltage Transmission Line

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Abstract. This paper presents a device for removing foreign objects on high-voltage transmission lines in the power system. The device aims to solve current difficulties including high labor density and low success rate. Firstly, the main functional components of the foreign object removal device are analyzed, then the design innovation points and the key technology of the device are proposed. Besides, the device has been applied to the actual work site of power transmission line maintenance for the field test and data analysis. Experimental result demonstrates that it has lower labor intensity, remarkable social benefit and economic effect.

1. Introduction

Influenced by strong wind, man-made and other conditions, transmission lines often hang foreign objects such as kites (wires), kongming lantern, plastic bags, advertising banner, etc. If the foreign objects suspended on the transmission line can not be removed in time, it will affect the security and stability of power grid operation, and even cause fault of the transmission line [1]. Through the investigation and study, there is no mature industrialized special tool for foreign objects removal in domestic power industry currently.

At present, the method of insulating rope entanglement is commonly used in foreign objects removal and maintenance of power lines. It can realize no power interruption of power supply. However, due to the lack of cutting tools, it is difficult to deal with foreign objects. The disadvantage is low efficiency and technical problems such as damage to the lines in the process by winding and pulling the insulating rope [2]. In electric power company, the inventions of foreign objects removal tools are based on personnel assisted climbing, insulating pole suspension methods mostly in staff innovation and QC activity. Due to the limit of tower height, terrains, live work conditions, it is impossible to realize foreign objects removal without power interruption for high-span lines with large distance to the ground.

With the development of science and technology, foreign objects can be removed by using unmanned aerial vehicle (UAV) fire spraying and laser gun, but it cannot be implemented in forest farms and crops where fire is easily induced. Besides, unmanned aerial vehicle and laser gun are expensive, enough heavy to carry, and both tools have not been widely used in daily maintenance work.

Aiming at the disadvantages of destructiveness, limitation and low efficiency of traditional foreign objects removal methods, a novel foreign objects removal device for high-voltage transmission lines has been designed and invented in this paper. The advantages of this novel device are convenient to
carry, reliable in machinery, simple in operation and low in operation risk. Furthermore, it can realize live removal and industrial assembly production.

2. Overview of the proposed device
At present, the method of “insulated rope twisting” is widely utilized in the removal of foreign objects in power lines. This method uses an insulating rope with a middle bolt spring-like wire hook to throw the wire, and the grounding worker pulls the insulating rope to the foreign object, and the twisting of the spring-shaped wire hook causes the foreign objects to be twisted with the rope. Then the foreign objects can be removed by pulling on the rope.

The method of “insulated rope twisting” has the following drawbacks. Firstly, in the case of solid foreign objects, this method often causes foreign objects and insulated rope hooks to entangle the wires, which make it difficult to remove foreign objects. Secondly, the wire hooks directly contact the lines. If the force is too vigorous, then the insulation performance of the insulated rope is decreased. Thirdly, for this method, it is difficult to control the force. Therefore, the use of this method may cause line oscillation and phase-to-phase short circuit, and also jeopardizes the safety of operator [3].

In this paper, a new foreign objects removal device used in high-voltage transmission line is proposed, which overcomes the shortcomings of traditional devices. The proposed foreign objects removal device is introduced in the next sections.

3. The characteristics and innovation analysis of the proposed device

3.1 Structure and Function
The device consists of four functional parts: suspension, transmission, cutting and detachment. The four parts are innovative by insulating hook head, half-moon guide plate, five-axis linkage, blade and fixing frame, insulated power rope and strip-shaped pull-off plate.

Fig 1. Overall design drawing of foreign objects removal device for high-voltage transmission line
The suspension part is divided into two parts: insulated hook and half-moon guide plate. The insulating hook is made of epoxy resin and made by 3D printing, which is convenient for factory processing. The front end of the insulated hook is equipped with a semi-moon-shaped suspension
auxiliary guide plate. The guide plate is about 6cm long and has a crescent shape. One of the end regions is slightly larger. All of the end regions are drilled. One side of the small hole is embedded in the slot of the head of the insulated hook at one end, and is bolted through the fixing hole, and the guiding plate can be rotated by 180 degrees. The other side is connected by an insulated rope. When the tool is suspended, the insulated rope is thrown over the line to pull the tool to the line. Through the transition of the guiding plate, the insulated hook can be hung on the line, and the inside of the insulated hook head is inlaid with a small-sized bearing. By pulling implemented by operators on the ground, the device can be moved smoothly to the foreign objects.

Fig 2. The schematic of suspension part

The transmission part adopts five-axis linkage, including two power shafts and three transmission shafts. The outer surface of the power shaft is polished to increase the external friction. The insulated rope is deployed according to the fig 3. The operator drives the blade on the power shaft to rotate by pulling the insulating rope.

Fig 3. The schematic of five-axis linkage

The cutting blade adopts the design of the drum blade. The longitudinal length of the blade is 120mm. The blade mounting hole distance can meet the requirements of ordinary utility knife size and is easy to be replaced. The tool cross-section rotation radius is 55mm, which can avoid the disadvantages of the flat blade design, which is easy to be entangled.
The detachment part adopts a strip-shaped detaching plate with a length of about 6cm and a width of about 2cm. As showed in fig 4.

The operating procedures of the proposed device are: Firstly, a thin insulated rope is thrown over the line that suspends the foreign objects, and the other end of the thin insulated rope is pulled to lift the device to the vicinity of the line. The device is reliably suspended on the line by the guiding action of the half-moon guiding plate. Under the action of the bearing, the device can be easily slid onto the foreign objects, and then the insulated power rope is pulled back and forth by the ground operator. The foreign object is cut by blade with high-speed rotating. After the foreign object is cleaned up, gently pulling the detachment rope to complete the detachment of the tool.

Fig 5. The physical map of the foreign objects removal device for high-voltage transmission line
A. The Innovation of the Proposed Device

The innovations of the proposed device are mainly in the following three aspects.

Firstly, the use of the proposed device does not need high-altitude operation, and the device can be suspended and disengaged by ground operation. The device changes the design of the conventional hook, using a half-moon guide plate, the guide plate is adjustable in direction, and its shape is semi-streamlined and is not limited by the line size model. The hook can smoothly complete various types of line-overs, thereby achieving high-altitude suspension through ground traction. The device hook is designed with a strip-shaped pull-out plate. When the work is done, the ground operator can easily remove the device by simply pulling the rope.

Secondly, the proposed device adopts five-axis linkage and rope power transmission, which is an ingenious design. The device shape, blade size and wire position are matched. Innovatively, the blade is used to cut foreign objects through five-axis linkage. The device is based on actual needs and has a wide range of applications.

The proposed device can realize the replacement of the pulley and the line foreign objects removing device. After replacing the pulley, the device can be utilized to lifting the line working items and the insulating flexible ladder. The applicability is strong.

B. The Application of the Proposed Device

The proposed device has been tested by tension mechanical strength test and other technologies, and has been successfully used in live operation of transmission line of Huaibei Power Supply Company for many times. The application benefits of the device are mainly the following two aspects:

Firstly, economic benefits. After investigation, municipal power supply company need to carry out foreign objects removal operations in the maintenance of transmission lines, about 25 times a year [4]. The number of people required for traditional work is 5, and by using the proposed device, the number of workers is only 2, which saves staff salary costs. The traditional working insulation rope has a large degree of wear, and the damage rate per operation is 33%. By using the proposed device, the abrasion degree of the insulation rope can be reduced, thereby reducing the equipment cost. In addition, by using this device, it is possible to realize live-operation, and the single operation reduces the power cut time by about 1.5 hours, thereby reducing a large amount of pecuniary loss [5]. In summary, the economic benefits of the device are very significant.

Secondly, social benefits. Under the current situation that the power load tends to be tight, the device can quickly remove the foreign objects in transmission line without power cut, eliminate the hidden dangers of the safe operation of the line in time and ensure the reliable supply of social power. The device is simple, reliable and easy to operate. Therefore, this device greatly reduces the labor intensity of the operators and the risk of live working, which brings good social benefits.

4. Conclusions

This paper proposes a novel foreign objects removal device for high-voltage transmission line. Compared with the domestic foreign objects devices, the proposed high-voltage transmission line foreign objects removal device realizes that it does not need to climb up, and does not need auxiliary tools such as insulated rods and insulated ladders to achieve foreign objects removal.

This device is lightweight, flexible, safe, and easy to operate. The device has won the “First Prize” of the 2019 Shanghai University Student Extracurricular Academic Science and Technology Work “Challenge Cup” competition, and obtained the national invention patent and the national utility model patent.

However, the specific use of the device still requires manual operation. In the follow-up study, we will cooperate with the power equipment such as the robot arm and the drone to make the operation more advanced.

Acknowledgments

This work was supported by the science and technology project of State Grid.
REFERENCES

[1] Yuanlin Zhao, Yongjun Zhi, Zhaoyang Qi(2017), “Development of Portable Foreign objects Processing Device for Transmission Line,” Electric Power Safety Technology, vol. 19 no. 7, pp. 44-47.

[2] State Grid Henan Electric Power Company Maintenance Company, “Rotary cutting power transmission line hanging material clearing device,” China, CN201410560135.3.

[3] Weitong Chen, Xiang Yan, “New report on the special equipment for the removal of foreign materials in suspended transmission lines,” 201936000G20096, pp. 1-10.

[4] Zhenbo Wang, Qiang Chen(2018), “Annual operation analysis report of transmission line of State Grid Huaibei Power Supply Company,” State Grid Huaibei Power Supply Company, pp. 1-3.

[5] Haoran Zhang, Yuhe Liang, “Special tools for removing foreign objects from overhead transmission lines,” China, CN105743020 B:1-2.