Development of foreign matter removal robot for overhead transmission lines

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Abstract. In recent years, the limitations of artificial live working have become increasingly prominent. Researching robot technology that replaces manual work has become an important branch of intelligent research on power maintenance. In this paper, the objects and tasks of foreign matter removal in overhead transmission lines are analyzed. The structure of the robot is introduced, and the control method and software design of the robot system are described. The test and field application show that the robot is reliable, stable and easy to control. It can remove floating foreign matters on the overhead line, meet the requirements of live working of the transmission line, and can replace the manual removal of foreign objects.

1. Introduction

During the operation of high-voltage transmission lines, there is a long-term threat of drifting foreign matters such as plastic greenhouses and kite lines [1-2]. In severe cases, single-phase grounding, phase-to-phase short-circuit and other power grid accidents may occur. According to statistics, in recent years, there are 118 hidden dangers of foreign matters in the transmission lines of 110kV and above in Hubei Province, China, causing over 10 trips of faults. Faced with a large number of defects and hidden dangers, it is difficult to complete the vacancy work quickly and safely in the traditional manual way. At the same time, with the large-area application of compact and multi-circuit lines on the same tower, the traditional transmission line maintenance mode has not adapted to the live working under the small window electrical distance [3-5].

The live maintenance robot has the advantages of safe operation, high efficiency and strong standardization, and is increasingly favored by power companies. A large number of researches on foreign matter removal robots for overhead transmission lines have been carried out at home and abroad, and many achievements have been made [6-7]. However, the existing robots have obvious shortcomings: 1) Mainly for the ground line to complete the line inspection task, but insufficient research on the wire robot; 2) The general weight is large, the battery life is short, and the light weight principle that cannot meet the requirements of modern robots cannot be met.

2. Overall design of the robot

The robot can be used when the transmission line is live. The robot walks on various specifications of steel strands, aluminum stranded wires, aluminum-clad steel strands, OPGW cables through self-
clamping walking mechanism, climbing obstacles. After encountering a foreign matter, the robot clamps it, and the double cutter head rotates to cut and remove it off. The whole process uses wireless electronic remote control and video monitoring, it does not damage the guide and the ground wire itself during the process of cleaning.

The design process is shown in Figure 1.

![Design flow chart](image1)

**Figure 1.** Design flow chart.

3. **Robot hardware design**

3.1. **Walking system**

The principle of the walking system is: Frictional force of the rubber wheel and the wire provides the driving power of the traveling vehicle, the kinetic energy is provided by the worm wheel screw reduction motor. The motor drives the rubber wheel to rotate under the chain connection, and the rubber wheel and the bracket clamp the wire to advance and retreat. The design is shown in Figure 2.

![Walking system design](image2)

**Figure 2.** Walking system design.

3.2. **Remove system**

The cleaning system includes a cutting mechanism and a foreign matter holding positioning mechanism. The traveling mechanism carrying device reaches the front of the foreign matter, so that the matter is within the range of the robot's open finger. At this time, the mechanical finger motor is activated, and the mechanical finger is tightened to clamp the foreign matter.

After the foreign matter is positioned, the motor drives the two blades to rotate at the same time, and the motor is controlled to move the cutter head along the running path to the foreign object direction to achieve the purpose of foreign matter removal. The design is shown in Figure 3.
3.3. On-line and off-line system

The Operation personnel does not need to go up the tower to place the robot on the line. The robot has a winch mechanism and is wound with an insulated rope. The insulated rope is discharged, and one end of the insulated rope is thrown through the wire by a rope thrower or a drone, and then fixed on the ground. After fixing, the control winch rotates and the robot will rise independently along the insulated rope. After the robot reaches, the upper cover rotates above the wire, and the traveling mechanism sheave fixes it. After that, loosen the insulated rope at the fixed end of the ground, and wind the hanging insulated rope into the winch. The robot successfully goes online.

When the robot needs to go offline, first fix one end of the insulated rope lowered by the robot, the upper cover of the robot is opened and released to the ground, and then the fixed end of the insulated rope is cancelled. The robot automatically recovers the insulated rope, the offline operation ends. The design is shown in Figure 4-5.

![Figure 3. Remove system design.](image)

![Figure 4. On-line schematic.](image)
3.4. Motor drive system

The motor drive uses the IR2104 core driver chip to drive the H-bridge with low on-resistance IRF3205, the design is shown in Figure 6. The control part and the MOS tube drive current are optically isolated by a high speed optocoupler. To reduce the sudden change of current when the motor starts, the motor starts with a soft start. At the same time, the motor on each loop is monitored for current. When the motor is abnormal, the software system will automatically control to stop the motor from rotating.
The robot is equipped with a wireless WIFI video transmission system, which can monitor the whole operation process in real time, avoiding the risk of line injury caused by high-altitude blind operation. The video transmission system can also be used separately for the inspection line equipment to realize multi-purpose.

4. Robot field application
Implementing robot foreign matter removal operation on a 110kV overhead line, line tower type is SDN31-18, wire type is LGJ-400/35, live working site is shown in Figure 7-8.

![Figure 7. Online operation.](image1)

![Figure 8. Clearing operation.](image2)

During the application process, the robot goes up and down normally, the joint motors work well, the mechanical fingers smoothly clamp the foreign matter, and then the cleaning operation is carried out correctly. The robot movements are continuous and smooth throughout the operation, the ground control commands are real-time and accurate, and the ground receiving robot feedback information is real-time and accurate, and the operation time is about 60 min.

5. Conclusions
The new overhead transmission line maintenance robot is safe, reliable, easy to carry, easy to operate, stable, time-saving and labor-saving. It will become more and more important in line maintenance work. The robots prototyped in this paper have the following advantages:
1) The robot is used for the point-and-click operation, and the worker does not need to go up and down the tower. Compared with the conventional equipotential charging operation, the work efficiency is significantly improved.
2) The entire foreign body cleaner weighs only 12.2Kgs and requires only two operators to complete the job. At the same time, due to the use of the way of throwing the rope up and down, the line can be placed at the place where the foreign object is located, and the operation is more flexible.

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