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Design and Research of a Miniature Live Coating Robot for Overhead Bare Conductors

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Abstract. To solve the problem of insufficient crossing distance of overhead lines, the current power grid mainly adopts coating insulation layer on the outer surface of bare wires to achieve the purpose of line protection. However, the existing coating robots have large volume and weight, and there are problems such as insufficient climbing and braking capabilities. This article will improve the existing insulation coating robot technology, develop a compact and lightweight bare wire live insulation coating robot, reduce the volume and weight of the robot, achieve lightweight, and enable it to adapt to scenes where the distance between wires is relatively small, the distance below trees is close, the wire diameter is small, and the span is large. It will increase the climbing and braking capabilities of the robot, so that it can adapt to shuttle between mountains and forests with sloping lines, Increase the robot's span crossing ability, further improve work efficiency by increasing its battery life and operating mileage, and achieve the goal of expanding application scenarios.

Keywords. Component, overhead bare conductors, live coating, micro type

1. Introduction

The height of overhead distribution line poles and towers is relatively low, and there is often a problem of insufficient crossing distance in actual operation. For example, when exposed overhead lines pass through densely populated areas, forests, fish ponds, and other areas, there are some super high trees that are difficult to cut down under the line. Illegal construction, building houses, fishing, and other situations within the line protection area are prone to accidents such as electric shock, short circuit, tripping, and causing personal injury and property damage, serious threat to the safe operation of the line. To solve the problem of insufficient crossing distance of overhead lines, the current power grid mainly adopts coating insulation layer on the outer surface of bare wires [1] to achieve the purpose of line protection.

With the continuous increase in the scale of the power grid and the improvement of intelligence, the operation management and control of the power grid are gradually developing towards intensive control and intelligence. At present, the use of insulation coating robots for on-site coating of insulation materials on overhead bare wires has

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been widely promoted within the power grid, greatly improving the coating efficiency. However, due to the large volume and weight of the existing coating robots [2-7], their climbing ability, braking ability, and span crossing ability are insufficient, resulting in high requirements for construction wires. For example, the distance between the three-phase wires is too close, the slope of the wires is too large, the distance between the wires and the trees below is too small, the wires are too thin, and the span is too large, all of which cannot meet the usage conditions of the coating robots. Therefore, there are still many overhead lines that cannot use coating robots for on-site insulation construction.

In response to the above situation, this article will improve the existing insulation coating robot technology, develop a compact and lightweight bare wire live insulation coating robot, reduce the volume and weight of the robot, achieve lightweight, and adapt to scenes where the distance between wires is relatively small, the distance below trees is close, the wire diameter is fine, and the span is large, and increase the robot's climbing and braking capabilities, Enable it to adapt to shuttle sloping routes between mountains and forests, increase the robot's span crossing ability, and further improve work efficiency by improving endurance time and operating mileage, achieving the goal of expanding application scenarios.

2. The Scheme of Whole Machine

(1) Design a main and driven wheel type line walking mechanism, driven by a walking motor through belt transmission, to achieve synchronous movement of the front and rear walking wheels;

(2) Install a locking device on the line walking mechanism. After the robot is suspended on the distribution wire, it can hold the distribution wire through the locking device ring, giving the robot a certain ability to prevent the line from falling off. Even if the front and rear walking wheels detach from the distribution wire due to unexpected circumstances, the robot will not directly fall;

(3) Install an elastic tongue pressing device on the line walking mechanism, and maintain continuous contact between the tongue pressing and the distribution wire after hanging the wire, achieving a reliable equipotential state between the robot and the bare distribution wire;

(4) Install an elastic meter wheel device on the line walking mechanism, and maintain continuous contact between the meter wheel and the distribution wire after hanging the wire, used to record the walking distance of the robot; Design a compact dual material tank and screw type extrusion mechanism to evenly squeeze liquid insulation material into the nozzle. The extrusion speed matches the line walking speed, evenly covering the bare transmission wire to meet the long-distance coating requirements;

(5) Design an adaptive coating mechanism, where the nozzle can automatically maintain real-time coaxial status with the wire under the action of spring force, ensuring uniform thickness of the insulation material coating layer;

(6) Design the main control system of the equipment, which is used to directly control robot line walking, extrusion, spraying and other operations;

(7) Design a multi-functional ground end remote control that integrates parameter modification, screen display, and remote control. It communicates with the main control system of the equipment through wireless network for bidirectional data

communication. Construction personnel can remotely operate the robot on the ground by operating the remote control;

(8) Provide electromagnetic protection to the control system to ensure that the robot's operation is not affected by electric fields;

(9) Develop a remote control robot control and human-machine interaction software system that can adjust the insulation coating thickness ability of the live insulation coating robot.

3. Detailed Design of a Miniature Live Coating Robot

3.1. Overall Structural Design

The micro live coating robot is mainly composed of several parts, including the line walking mechanism, extrusion mechanism, coating mechanism, and control system, as shown in the following figure 1:

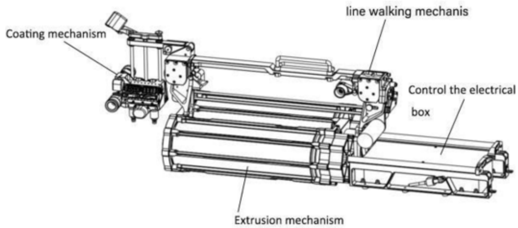

Figure 1. Design diagram of a miniature live coating robot.

The line walking mechanism realizes functions such as robot walking along the line, equipotential, mileage recording, and anti detachment. The extrusion mechanism extrudes the liquid insulation material from the coating tank and transports it to the coating mechanism to wrap the bare transmission wire. The control system is divided into two parts: the robot main control system and the ground end control system, with bidirectional data communication between the two through wireless Ethernet. The main control system of the robot is used to directly control the robot's line walking, coating and other operations, and to capture the operation images, which are real-time transmitted to the ground end. The ground end control system integrates parameter modification, image display, and remote control. Construction personnel can carry out remote control operations on the robot by holding a remote controller.

In response to the characteristics of distribution lines being relatively close to the ground, the micro live coating robot designed in this article will cancel the mature automatic online and automatic wire hanging mechanisms [8], and use insulated bucket arm trucks for micro live coating robots to hang wires; By using a single high torque motor to drive the two upward walking wheels of the cable arm to rotate simultaneously through a belt, the robot can walk along the line. Compared with the existing coating robots that use two independent motors to drive the two walking wheels separately, it can reduce the weight of one deceleration motor; A simple manual locking device is designed to replace the automatic anti release mechanism composed of motors, screw rods, anti release wheels, and guide components, achieving the robot's anti release function and greatly reducing the robot's weight.

3.2. Design of Storage Bucket

Design a double material tank and double screw extrusion mechanism, as shown in figure 2. Two paint cans are fixed within the frame at a certain distance. The extrusion motor can drive two screw rods to move forward or backward simultaneously through gear transmission. The tail ends of the two screw rods are connected through a connecting plate, and both ends of the connecting plate can slide along the guide grooves on the two guide frames through rollers. The front ends of the two screw rods are respectively connected to the extrusion blocks at the tail of the two material tanks. Under the action of the screw rods, the two extrusion blocks move forward simultaneously, which can simultaneously extrude the liquid insulation coating inside the material tanks from the coating outlets of each self material tank. The coating outlet is connected to the coating nozzle through a plastic hose. After the coating is extruded from the material tank, it enters the nozzle through the plastic hose. During the robot's line walking process, the bare transmission wire can be coated.

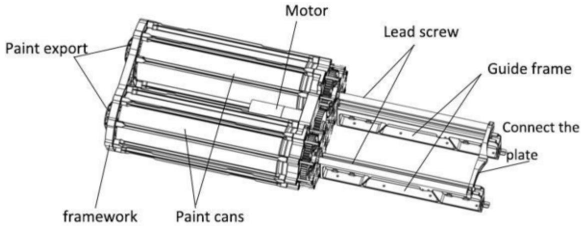

Figure 2. Design Drawing of Storage Bucket.

The connecting frame on the extrusion mechanism adopts a combined hollow structure, which can minimize the weight of the extrusion mechanism.

3.3. Design of Wire Gluing Nozzle

As shown in figure 3, the wire gluing nozzle is installed on the top of the rear wiring arm through a spring hinge, which can rotate around the top shaft and automatically swing towards the distribution wire side under the action of spring force. During the coating operation, under the action of spring force, the coating nozzle and the bare power distribution wire can automatically maintain a coaxial state, ensuring that the thickness of the insulation coating layer is uniform and consistent.

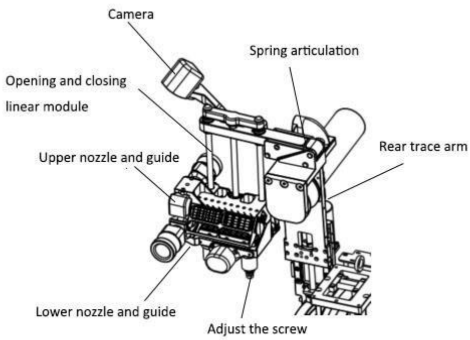

Figure 3. Design Drawing of Wire Adhesive Spray Head.

The coating mechanism is composed of upper and lower nozzles, upper and lower guide components, opening and closing linear modules, opening and closing motors, connecting plates, spring hinge supports, etc.. The upper and lower nozzles are respectively fixed on the upper and lower guide components, with the upper guide component located at the movable end of the opening and closing linear module and the lower guide component located at the fixed end of the opening and closing linear module. When the robot is lifting and hanging wires, the opening and closing linear module is in an open state. After hanging wires, the opening and closing motor drives the upper guide component to move downwards through the opening and closing linear module. When the upper guide component touches the bare power distribution wire, the lower guide component moves upwards until the upper and lower nozzles are closed. After the nozzle is closed, the insulation coating operation can be carried out.

When the nozzle is closed, the upper nozzle guide is in rolling contact with the bare wire through two V-shaped rolling bearing groups, while the lower nozzle guide is in rolling contact with the bare wire through a V-shaped rolling bearing group. A screw adjustment device is designed at the bottom of the lower nozzle guide element to adjust the relative position of the zigzag rolling bearing group and adapt to different wire diameters of distribution bare wires. For distribution bare wires with different wire diameters, corresponding specifications of nozzles are designed for coating operations on distribution bare wires with different wire diameters.

A camera is installed on the upper part of the wire gluing nozzle, which can take real-time photos of the coating operation. Ground construction personnel can view it in real time through the display screen.

4. Conclusions

This article innovatively designs a lightweight live insulation coating robot with a light and thin appearance, long endurance, and long operating mileage to address the issue of insufficient adaptability of existing self online insulation coating robots. Compared with the self starting insulation coating robot, this robot has no self starting function, but its appearance is light and thin. It is specially designed with a bidirectional handle, which is very convenient for construction personnel to manually hang the line. It is suitable for work scenarios with small phase spacing and close distance to the trees below. The robot has also innovatively designed a power integrated dual power wheel line walking mechanism. Compared with independent drive and dual power wheel line walking mechanisms, only one driving motor is needed, reducing the weight of the driving mechanism, optimizing the structure, and cooperating with the overall weight, the robot's relative driving ability is greatly improved, increasing its actual climbing ability, and enabling the robot to perform insulation coating on overhead lines with larger slopes. In addition, the robot has also optimized and improved the control strategy of the insulation coating robot, achieving multi machine collaborative operation. It can simultaneously apply insulation coating to the vertical three-phase bare wires, and has added the automatic adjustment function of insulation coating thickness. The application of this robot will effectively compensate for the shortcomings of existing self starting insulation coating robots and achieve the goal of expanding application scenarios.

Acknowledgments

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