

Development of Distribution Line Wrapping Robot

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Abstract: Electric power industry is the most important basic energy industry in the development of national economy, and it is also the basic industry related to the national economy and people's livelihood. With the progress of modern science and technology, automation equipment has been widely used in all walks of life. With the development of new energy and the continuous expansion of the power grid, the power industry, as a traditional energy industry, faces problems such as high labor intensity and low efficiency as well as wiring errors and test quality, which seriously lag behind the development needs of the distribution network. The demand for automation equipment has increased significantly. The outer layer of the metal core of the distribution line has protective insulating rubber skin. However, strong wind, exposure, rain corrosion, foreign objects in trees and other falling scratches will lead to the damage of the insulating layer, which will seriously affect the safety of the line. At present, before manual maintenance, it is necessary to have a power outage before operation, leading to huge power outage loss caused by emergency repair. Meanwhile, in the power industry, there are not a few accident cases in which people are killed or injured in emergency repair at high altitude. Changing the traditional manual control mode into automatic control mode, reducing the control difficulty and strengthening the control of machinery and equipment can effectively solve various existing problems and highlight the universality and operability of the electrical system.

1. Introduction of Insulating Winding Robot for Distribution Lines

The technical research of insulating wrapping device started around 2010 and is still developing. Scholars at home and abroad have carried out a series of work on the insulating wrapping technology of distribution lines, but most of them analyze a certain side problem theoretically or technically, which is still far from the practical application. Up to now, there is no report on the successful application of insulating wrapping device in distribution line in engineering [1].

Based on the previous research, our team has developed a new series of miniaturized devices for insulating wrapping or insulation damage repair of high-voltage overhead bare wires according to the characteristics of high labor intensity, high risk factor, long construction period, large power loss and large investment [2-3] and the fastening principle of insulating wrapping materials and the structural characteristics of insulating wrapping tools. Compared with the existing insulation transformation measures, the insulating wrapping device is not restricted by power failure and environment, which can greatly save the insulation transformation cost. Using the series miniaturization device of the insulating wrapping device, the insulating wrapping operation of 10KV distribution lines is carried

out, which saves a large amount of manpower and material resources and improves the modern optimized operation of industrial robots. [4] With high economic benefits and a very broad market application space.

2. Technical Design of Insulating Wrapping Device for Distribution Lines

2.1. Product Performance

Design and development of insulating wrapping device for distribution lines, including overall scheme design, design and development of mechanical structure, circuit, control and communication system, etc. The whole device is divided into walking mechanism, lifting mechanism, conveying channel, wrapping unit, shearing mechanism, nailing mechanism, circuit control box, charging tray and other parts. It has the functions of online walking, package repair, nailing and sealing, and can realize insulating wrapping of distribution lines up to 30 meters at a time [5]. Figure 1 shows the device design and physical diagram.

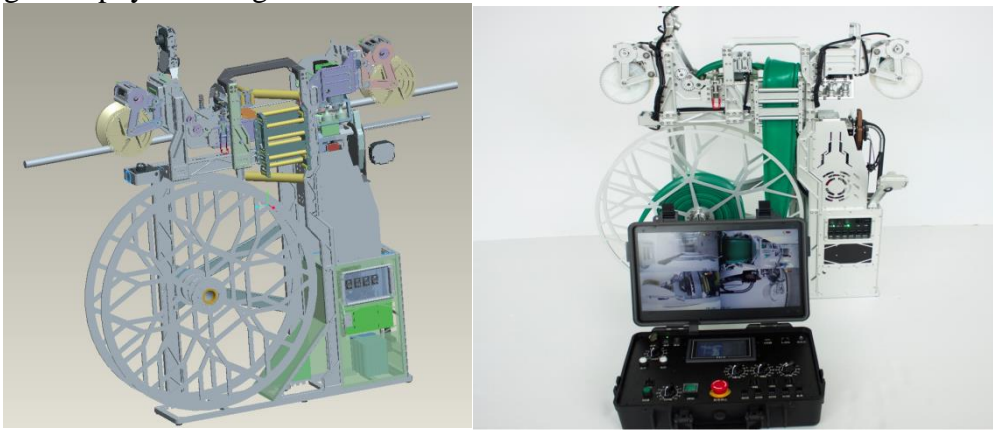


Figure 1: Device design and physical diagram

Overview of main functions of each unit of robot:

(1) Conveying unit: it has the functions of conveying and guiding. One end of the conveying structure is connected with the package outlet of the charging tray, and the other end is connected with the feed inlet of the clamping structure; it is mainly responsible for conveying the insulation protection sleeve on the tray to the clamping unit. The transportation of insulation protection sleeve is the first step in the whole wrapping process. Whether the conveying unit can work safely and stably is related to whether the whole wrapping process can be successfully completed, as shown in Figure 2.



Figure 2: Physical diagram of design and processing of conveying unit

(2) Lifting and walking unit: it is mainly responsible for the lifting and walking tasks of the robot on the overhead bare wire. The lifting of the robot is the main way for the robot to switch working modes. The lifting mechanism adopts the scissor mechanism to realize the lifting and lowering of the robot body. The wrapping process is carried out simultaneously with the robot's online walking. The motor drives the pulley to roll, thus realizing the walking of the robot on the overhead line [6], as shown in figure 3.

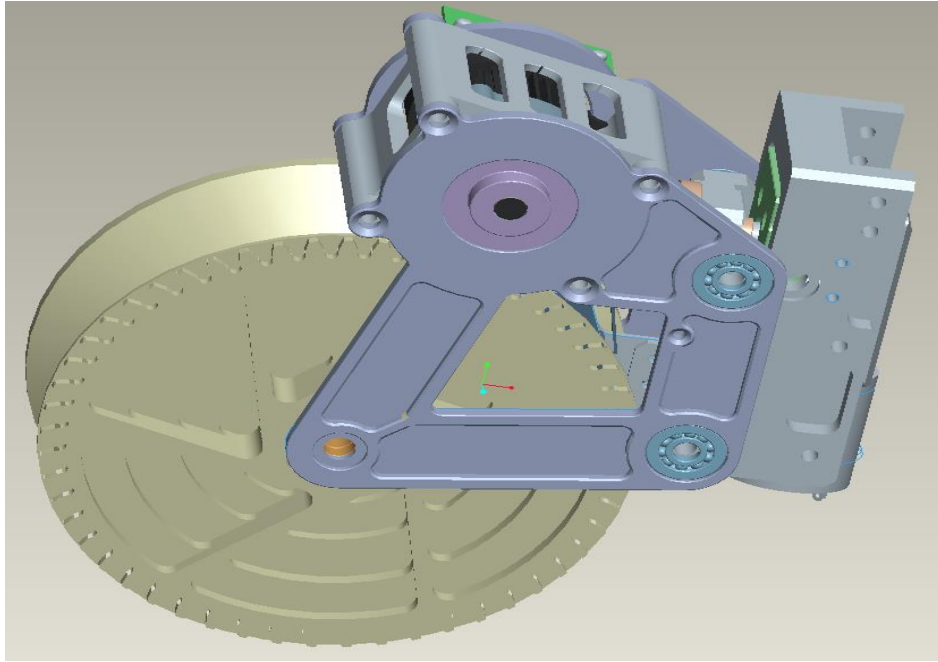


Figure 3: Design drawing of walking module

(3) Charging tray unit: the charging tray is a large storage tray, which is installed on the whole robot bracket and can rotate freely. The wrapping tape is wound and stored in the charging tray, and it is gradually pulled out with the wrapping, as shown in Figure 4.



Figure 4: 30m insulating wrapping sheet installed on the tray unit

(4) Clamping unit: composed of six clamping wheels and connected with the conveying structure, it is mainly responsible for clamping the insulation protection sleeves conveyed to both sides of overhead bare wires. With the robot body walking on the line, the opening and closing of three pairs of clamping wheels is repeated to complete the wrapping of the bare wire, as shown in Figure 5.

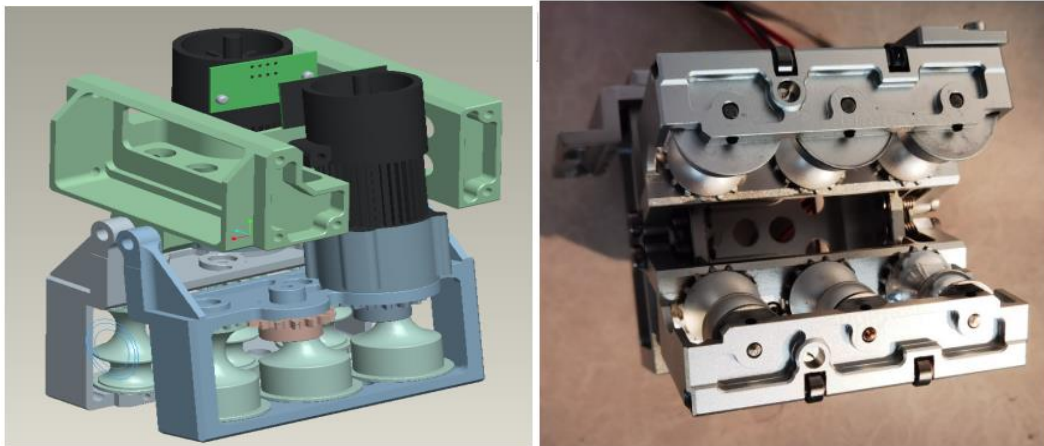


Figure 5: Physical drawing of clamping unit design and processing

(5) Nailing unit: it is the last step of robot wrapping, mainly responsible for nailing and fixing the wrapped insulation protection sleeve to prevent the buckle from being loose, as shown in Figure 6.



Figure 6: Physical drawing of nailing unit

When the insulating wrapping robot carries out wrapping operation, the main working process is as follows:

- (1) Firstly, placing the robot on the overhead bare wire, at which time the robot is suspended.
- (2) Controlling the lifting motor of the robot to start working, so that the robot body rises to the walking state. At this time, the walking motor of the robot starts working.
- (3) After the robot reaches the area for wrapping, the lifting motor drives the shearing mechanism, so that the robot body rises to the working state. When the walking motor drives the whole machine to walk on the line, the robot starts to carry out insulating wrapping.
- (4) As the robot walks on the line, the insulation protection sleeve in the charging tray is released, and the conveying unit conveys the insulation protection sleeve to the clamping unit through the guide wheel. The pressing wheel presses the protection sleeve conveyed to the overhead bare wire to complete the insulating wrapping operation.
- And (5) finally, nailing and fixing the buckled insulation protection sleeve through the nailing unit to ensure the fastening of the insulation protection sleeve.

2.2. Technical Scheme, Method and Technical Route

2.2.1. Development of Wireless Communication Remote Control System

After installing the mobile client of power distribution line insulating wrapping device, it can send control signals to the main control microcontroller through Bluetooth to control the device. It can display information such as motor status, insulation distance recognition status and alarm. The running state of the device can be controlled through the remote control handle, iPad or mobile APP.

The main functions of the upper computer software are: 1. Controlling the action or movement of the manipulator; 2. Controlling the overall movement of the device; 3. Controlling the action of the bracket; 4. Communicating with the lower computer through the serial port; 5. Emergency stop. Through the upper computer, users can directly send control commands to the computer, and various control signal changes are displayed on the screen. The commands sent by the upper computer are first given to the lower computer, and then the lower computer interprets them into corresponding time sequence signals according to directly control the corresponding equipment. The lower computer reads equipment status data (generally analog) from time to time, converts it into digital signals and feeds them back to the upper computer. The upper computer communicates with the lower computer through the serial port, so as to realize the movement and wrapping of the distribution line insulating wrapping device; at the same time, the data of the camera is collected through USB port to complete the real-time image display function. The remote control box is shown in Figure 7.



Figure 7: Remote control box

2.2.2. Adapting Interface Connected with the Mechanical Arm End with Quick Tool Change Function

The insulating wrapping device can be combined with the climbing platform developed in the early stage, and the software in the background can be compatible with each other. The device is compatible with the interface of the mechanical arm. After it is connected with the interface of the mechanical arm end, the insulating wrapping operation is carried out. The quick-change device meets the requirements of compact overall structure and lightweight design of electric power operation device, and has sufficient load capacity. The control part of the device is connected with the interface operated by the working platform and the insulating rod to carry out the insulating wrapping operation.

2.2.3. Sending the Insulating Wrapping Device to the Auxiliary Device on the Line with the Operating Rod

Manipulator of the lifting device: the common manipulator is used with the angle adjusting device, and the quincunx lock of the angle adjusting unit turns to a certain angle and locks it, so that the mechanical gripper keeps a certain angle unchanged. It can also be matched with a separate remote controller. When the hanging height is not very high, a short rod is used alone. The short rod itself is equipped with a remote controller, which can transmit a semaphore to the manipulator's grasping end with a radio wave of 433MHZ through the electric control of the button. The semaphore is transferred to the motor of the manipulator's grasping part, and the motor rotates to finally control the opening and closing of the auxiliary gripper. When the height is relatively high, it can be controlled by the electric expansion unit. The electric expansion unit has a general control handle at the end. It not only has the original function of controlling the opening and closing of the manipulator, but also has the function of controlling the electric expansion unit. The length of the expansion unit can be changed by directly controlling the forward and reverse rotation of the motor [7-8].

The manipulator grips the hook from both sides, and is driven by the motor to drive the lead screw. The manipulator is equipped with a battery and a remote control receiver, which can control the opening and closing of its two claws by the remote control end. In addition, various mechanical arms and manipulators can adapt to the working environment in a short time during the production and manufacturing activities, which promotes the continuous improvement of production efficiency [9]. The fully opened distance of the manipulator is 250mm. Its clamping is realized by clamping from both sides to the middle, which is convenient to quickly and correctly align with the grounding hook when picking the hook. It is simple and efficient [10]. The lower end of the manipulator is connected with the insulating rod, and the locking and holding structure of torx nut is adopted, which is convenient for quick disassembly and assembly.

Electric expansion unit: the whole unit is composed of three insulating rods with a length of 2m, and the middle rod can be extended by a motor, with a maximum extension length of 1.5m. The whole unit includes a midpoint bracket, a tail counterweight, a control handle, a lead screw, a power supply and a control box, etc. Considering that the whole unit still needs to maintain good rigidity when fully extended, the maximum extension distance is set to be 1.5m. The height of the manipulator is raised and lowered through the stretching of the electric control rod, and finally the device is sent to the working position of the line. The lifting auxiliary device is shown in Figure 8.



Figure 8: Physical drawing of lifting auxiliary device

Control system: the whole device is transported to the work site by a trolley, and the trolley is deformed to form a triangle to support the electric expansion rod with high stability. Different types

of mechanical paws are installed on the electric expansion rod, and the angle is fixed and adjusted by the angle adjusting device. The meshing gear of the plum lock can ensure that the angle reaches the angle we want. The control handle at the bottom can control the expansion and contraction of the electric rod to send the manipulator to a corresponding height. When the height is relatively high, it can cooperate with the electric expansion unit. The electric expansion unit has a general control handle at the end, which not only has the original function of controlling the opening and closing of the manipulator, but also has the function of controlling the electric expansion unit. The final control is transmitted to the mechanical arm part to hang the device on the wire. A signal can be transmitted to the gripper end of the manipulator by the electric control of the button with a radio wave of 433MHZ. The signal is transferred to the motor of the gripper part, and the motor rotates to finally control the opening and closing of the auxiliary gripper.

3. Conclusions

We adopt the interface design of connecting with the mechanical arm end and the adaptive interface with the function of quick tool change, so that the insulating wrapping device can be put on and taken off the rural distribution network line through the mechanical arm to meet the practical application requirements of the insulating wrapping device. At the same time, the wrapping unit has been updated, which solves the key design and technology of wrapping material transportation, wrapping, cutting and binding, and realizes the insulating wrapping operation of distribution overhead cables with different wire diameters through the serialization design of gradual wrapping.

In the next step, we will try to achieve the market-oriented and product-oriented performance improvement (such as climbing ability), process improvement and cost reduction, realize the lightweight, miniaturization and serialization of distribution line insulating wrapping devices, and adapt to the requirements of different wrapping materials and lines with different wire diameters. At the same time, we will pay attention to the comprehensive optimization of design details, so as to truly play the application value of electrical automation technology, promote the functional improvement of industrial robots, and finally improve the modern optimized operation of industrial robots. We will also further expand the application scope of wrapping devices in other industries, laying a foundation for the application and industrialization of distribution line insulating wrapping devices.

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