Design of Full Automatic Inspection Robot and Optimized Modification of Overhead Ground Transmission Line

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Abstract. In order to achieve the full autonomous inspection of the robot along the overhead ground line, a new type of robot operation mode is proposed by considering the overhead ground line and the robot as a whole. According to the characteristics of obstacles encountered by the robot, the optimization design of the overhead line and the structure design of the robot body are carried out. By transforming the line, a obstacle-free path suitable for the robot was build to pass through, which simplifies the obstacle crossing action and improves the obstacle crossing efficiency.

1. Introduction
Overhead transmission line is one of the main power transmission equipment, its safe and stable operation directly affects the reliability of power supply system.

Because the overhead lines are exposed to the wild for a long time, broken strand, foreign object and corrosion often happen. If not timely repair and replacement, small breakages and defects can expand and eventually lead to serious accidents that cause widespread blackouts and huge economic losses. Therefore, the transmission lines must be regularly inspected to detect the defects, taking scientific measures to eliminate potential risks timely and ensuring the safety of power supply.

Traditionally, workers use telescopes to detect the lines. In this way, workers often face bad weather, which leads to time-consuming, inefficient and poor accuracy. With the development of science and technology, robots have been used in the field of high voltage power line detection. The research on the inspection robots of transmission lines abroad has a long history. For example, “LineScout” of Hydro-Quebec research institute in Canada[1-2], “Expliner” of KEPCO in Japan[3] and “Ti” of EPRI in America[3] are most representative. The domestic research is late, but a series of technical achievements have been achieved. The most type robots are “LineBot” of Wuhan University[4-5] and “Ground inspection robot” of the National Academy of Sciences[6]. However, these robots still use multiple arms to overcome the obstacle alternately. This solution of the robot leads to complex mechanical mechanism, poor automation and low safety. Because of these reasons, the application of the transmission line inspection robots has been greatly hindered.

This paper presents the Full Automatic Inspection Robot that can cross any obstacles(dampers, straight towers, resisting-tensile towers, etc.) of overhead ground transmission lines without any obstacle striding movement. The application of barrier-free accessibility technology of this robot has realized the automatic inspection from substation to substation, which benefits for application generalization and improves the automation of transmission lines.
2. Total solution
For the robot, the obstacles on the overhead ground wire mainly include press-connect-tubes, dampers, straight towers and resisting-tensile towers. After analysis, we found that the press-connect-tubes and dampers are small in size and can be directly pressed by the robot. But the other two are obstructions, especially resisting-tensile towers have large spans and intricate lines, the robot cannot pass directly. Traditionally, the robot usually adapts to the lines by designing its own complex mechanical structures and overcomes obstacles in a complicated way, resulting in large size, heavy mass, difficult control, low efficiency and inability to be autonomous.

Therefore, we take the research method of overhead transmission line and inspection robot as a whole system. By simplifying the mechanical structure of the robot and building a obstacle-free path to improve its mobility. This solution not only does not change the original characteristics of the transmission line, but also can achieve full and automatic operation and inspection of the robot.

Figure 1. Major obstacles of overhead ground transmission lines.
1. Straight tower; 2. Press-connect-tube; 3. Damper; 4. Resisting-tensile tower; 5. Transmission line inspection robot

3. Optimized design of overhead ground wires
The straight tower and resisting-tensile tower are connected with ground line in different ways. So, it is necessary to optimize the design of specific schemes.

3.1. Modification of straight tower
Ground transmission line and straight tower are connected vertically with suspension clamp, U-shackle and suspension insulator string, etc. These objects block the robot's forward path. In order to reduce the complexity of the mechanical structure of inspection robot and improve the passing efficiency, it is proposed that the structure of the above blocking fittings be transformed into a non-blocking structure. The modified ground suspension clamp is shown in figure 2. The suspension clamp is designed as “C” type, so that the robot can pass through its center directly without any obstacle-crossing action, which greatly improves the efficiency of the robot rolling over the straight tower.

Figure 2. Unmodified & Modified Suspension clamp
3.2. Modification of Resisting-tensile tower

The resisting-tensile tower of transmission line has different shapes, sizes and angles of rotation, which makes it very difficult for the robot to cross. According to the overall project plan, setting up auxiliary guide rails on the outside of the tower to guide the robot to pass smoothly as shown in Figure 3. The guide rail adopts two circular rails parallel to each other, which consists of guide device, rigid rail, flexible rail and tower connectors.

![Figure 3. 3D graphical of modified guide rail](image)

1. guide device; 2. flexible rail; 3. rigid rail; 4. resisting-tensile tower

The guide device is set at the front end of the whole rail to guide the robot to get off the ground line. As shown in Figure 4. The slope at the front and the arc at the back of the device gradually lead the robot away from the line and tower, so that the robot can run along the rail.

![Figure 4. The guide device](image)

Flexible guide rail including two types of flexible joints can be adjusted adaptively in both horizontal and vertical directions as shown in Figure 5. Specifically, the horizontal flexible joint can adapt to different sizes of pole towers, and the vertical flexible joint can adapt to all kinds of line sag. The number of these two joints can be adjusted according to different types and sizes of towers, thus forming a whole smooth rail.

![Figure 5. Horizontal and vertical flexible joint](image)

4. Mechanical structure of the robot

The ground wire has been modified to form a obstacle-free passageway. Because of the arch connection between the guide rail and the ground wire and the slope of the line, the robot is required to have the ability of varying curvature. This robot adopts two wheel-arm composite mechanisms with
the same structure, which is mainly composed of driving arms, grippers, locking joints, battery control box and monitoring devices. Among them, the front and back two driving arms of the robot have the same structure, and each driving arm is composed of driving wheel device, lifting device and guide device.

Figure 6. 1. Driving arms; 2. Locking joints; 3. Grippers; 4. Battery control box; 5. Monitoring devices; 6. Driving wheel device; 7. Lifting device; 8. Guide device.

Locking joints act as locking and loosening the driving arm. When the robot runs along the straight line, the locking of the rotating joint ensures that the driving wheel runs along the straight line. When the robot crosses the tension tower, the rotating joint is released. At this time, the driving arm can rotate freely in a certain range to provide the robot with variable curvature profiling motion.

5. Obstacle-crossing process of the robot
When the robot runs in the straight line, the robot grippers are in the open state and the locking joint is in the locked state, which can directly press over the damper and cross the straight tower. As shown in Figure 7.

Figure 7. Running in the straight line
- a: Pressing over the damper
- b: Crossing the straight tower

When the robot crosses the tension tower, it needs multi-joints cooperation. The obstacle crossing process is as follows:
- When the whole robot rolls to the front end of the bridge rail, the guide wheels of the robot rise and contact with the bottom of the rail, and then the locking joint is unlocked. At this time,
under the combined action of the driving wheel and the guide wheel, the robot can follow the arc of the bridge rail to gradually get off the ground line. As shown in Figure 8a.

- When the robot is running on the bridge rail, in order to ensure safety, the robot rolls slowly. As shown in Figure 8b.
- When the robot reaches the other end of the rail, the above joints do the opposite action to 8a. As shown in Figure 8c.

![Figure 8a: Touching the bridge](image1)
![Figure 8b: Rolling on the rail](image2)
![Figure 8c: Reaching the end of the rail](image3)

**Figure 8. Crossing the tension tower**

### 6. Application testing

In order to verify the function and performance of the automatic inspection robot for overhead ground transmission line, a large number of experimental research and application tests have been carried out on outdoor simulated training line and 500kV actual line. Figure 9 shows the operation test of the robot on the 500kV overhead transmission line in the training sub-center of State Grid Shandong Electric Power Company Jining Power Supply Company. After many tests, the obstacle-crossing rail matches well with the overhead ground wire, and realizes its self-adaptation to the sag and horizontal steering of the ground wire. The robot can run steadily along the rail, smoothly across the dampers, straight towers and tension towers, etc., completing the detection image acquisition of the line and its hardware, achieving the expected effect.

![Figure 9: Robot online testing](image4)

### 7. Conclusion and Prospect

According to the general idea of optimizing and improving the overhead ground line, an optimizing and improving scheme is put forward. The blocking obstacle of the line is transformed into a non-blocking obstacle suitable for robot to cross. The structure form and the principle of the mobile platform of overhead ground transmission line inspection robot are put forward pertinently, which realizes the appropriateness. Realizing the function of profiling motion of the rail with variable curvature reduces the complexity of the mechanical structure as much as possible, reduces the obstacle-crossing action and improves the traveling efficiency of the robot.

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