Design of rescue equipment for high altitude electrical operation

Xiaojun Mao 1*, Yunfeng Zhang 2, Zhan Wang 3, Wangxin Pan 2, Weilin Zhang 4, Jie Wang 1, Jingen Song 4, Xiaobo Hu 1

1 Zhejiang Power Transmission and Transformation Engineering Co., Ltd., Hangzhou, China
2 Training Center, State Grid Zhejiang Electric Power Co., Ltd., Hangzhou, China
3 Wenzhou Power Suppl Company, State Grid Zhejiang Electric Power Co., Ltd., Wenzhou, China
4 State Grid Zhejiang Electric Power Co., Ltd., Hangzhou, China

*Corresponding author’s e-mail: 17955182@qq.com

Abstract. In view of the fact that there are few kinds of robots can cross over obstacles in high-altitude electric power operation. Meanwhile, the existing robots are difficult to rescue falling workers, therefore, a robot that can walk over obstacles on the power transmission line is developed to solve the difficulty of high-altitude electric power transmission line rescue. The operating environment of the rescue robot for high-altitude transmission line is analyzed, and the obstacle jumping movement and rescue mode of the rescue robot are planned. The mechanical mechanism of rescue robot is designed. The robot is simple in structure, and can bear 500kg weight. It has strong mobility and wide range of application.

1. Introduction
Power transmission line is one of the most important infrastructures of energy Internet in China. The security and stability of its running state is an important premise of power transmission and an important guarantee of energy development in China. With the continuous development of China's power grid, high-altitude transmission lines are under rapid construction. Because the transmission line for a long time in complex geography and unpredictable environmental changes of natural conditions, transmission line failure is inevitable, in order to protect the safety of the overhead transmission line, with multi-function can span a variety of obstacles on the transmission line robot development has gradually become a hot spot, and there are many institutions at home and abroad have carried out extensive research.

The existing robots that can cross obstacles can be divided into line patrol robots that can detect fault of the line de-icing robots that can remove ice from the line and rescue robots that can work on the line. In 1988, Sawada et al. [1] of Tokyo electric power company developed the optical fiber composite aerial ground line inspection robot, which uses the human-like climbing principle to span the pole tower, but its weight and size are relatively large. Peungsungwal et al. [2] in Thailand designed a self-powered wire patrol robot, which can directly obtain power from the high-voltage power line, but can only crawl along the power line between two towers without obstacle avoidance ability. Expliner, designed by Paulo Debenest et al. [3] of HiBot, Japan, can walk on 4-split-wire and adjust the center of mass of the case,
but cannot walk over obstacles on 4-split-wire. Liu guofeng [4] of Nanchang University designed a line patrol robot with one arm drive and two arms to cross obstacles, which can cross all obstacles on the ground. Serge Montambault et al. [5, 6] from Hydro-Quebec Research Institute in Canada developed HQLineROVer patrol robot, which was originally used to remove ice accumulated on power lines, but gradually developed into a multi-purpose mobile platform for line patrol, maintenance and other purposes. Cao lei et al. [7] proposed a circuit de-icing robot, which uses the impact force of triangular cutter fixed at the front end to clear the icing, and has the advantages of small body, high de-icing efficiency and can clear the icing with a thickness of 20mm. Leap han et al. [8] designed a single-step rescue operation robot, which can solve the problem of manually pulling back the inspection robot when it fails on the ground.

All the high-voltage transmission line robots mentioned above bear relatively small loads, and when the power construction personnel cannot save themselves in case of accidents, these robots cannot undertake the task of manned rescue [9]. In order to solve the above problems, a manned rescue robot with the ability of obstacle surmounting is proposed as a solution. According to the working environment and functional requirements of the robot, it is designed as a suspended three-arm roller rescue robot, and a hanging basket is set under the robot, which can be used for the workers who are temporarily unable to move during the rescue process to recover. At the same time, the working environment of the rescue robot is described. The movement and rescue mode of the rescue robot were studied. Solidworks is used to conduct 3D modeling of the mechanical body and various mechanisms of the rescue robot. The rescue robot is simple in structure, stable in operation and can bear a load of 500kg.

2. Operation environment and scheme design of rescue robot

2.1 Rescue Robot Operating Environment

Aerial work personnel in the daily maintenance and maintenance work, it's usually on the wire walking, after the crisis occurs, in need of help in places that are between the two towers, the tower, the rescue robots do not need the driving route only in a stage of wires, the working environment available figure 1 (a) circuit is described, mainly includes the tower, wire and insulator, spacer, etc. The operator was suspended under the lead because of the safety rope, so the rescue robot walked on the bottom lead to prevent the lead from affecting the rescue work. The driving route of rescue robot can be divided into two structural forms as shown in figure 1(b): barrier-free traverse section and traverse section with spacer.
2.2 **Design of rescue robot**

Through the analysis of the working environment and driving path of the rescue robot, the rescue robot crosses the obstacle by means of off-line and bypass from the side. It is designed as a three-arm suspension double-roller structure, and each of them is equipped with a locking mechanism under the walking wheel, to prevent off-line. In this way, when one arm is crossing the obstacle, there are still two arms on-line, which is not for the rescue robot. Only the safety is higher, and the center of gravity is more stable, and the ability to resist wind deviation is stronger. The rescue robot uses electric hoist to rescue the workers when it reaches the falling place. At the same time, in order to prevent the workers from being unable to move after being rescued, a hanging basket for rest is installed under the rescue robot. The overall structure of the rescue robot is shown in Figure 2. The walking of the rescue robot depends on the walking mechanism. The up and down and left and right movement of the walking mechanism is realized by the screw pair. In the process of walking, the rescue robot can act as a brake by reversing the walking wheel and play a fixed role in the rescue process to prevent the rescue robot from moving. The locking mechanism is composed of the rack and pinion drive, cylindrical rack cover and walking wheel support. Driven by the motor, the gear drives the cylindrical rack and pinion to move back and forth in the cylindrical rack cover, so as to realize the locking and relaxation of the wire, providing protection for the rescue robot and preventing it from falling down the line. The hanging basket is a place to rest the construction workers who are temporarily unable to move. The main function of electric hoist is to transport operators to the hanging basket.

![Figure 2. Overall mechanism sketch of rescue robot](image)

1- road wheel; 2- wire; 3- Travelling wheel bracket; 4- lock mechanism; 5- screw pair; 6- support frame; 7- nacelle; 8- electric block;

The operation process planning of rescue robots mainly includes two parts: one is the obstacle surmounting process of rescue robots; the other is the rescue process of workers. Firstly, the rescue robot travels on the wire through a walking wheel mechanism. When encountering obstacles, the three mechanical arms cooperate with each other and adjust their postures by imitating the monkey climbing strategy, so as to cross the obstacles. Secondly, when the rescue robot arrives at the site where the operator falls, it brakes, and then uses electric hoist to rescue the operator, and puts it in the hanging basket. Then the rescue robot takes the operator back to the pole and tower to achieve the rescue mission for the fallen personnel.

There are many types of obstacles on high voltage transmission lines, but the movement process of rescue robot across various types of obstacles is similar, so the typical obstacle spacer bar is used as an
example to demonstrate the crossing. Simplify the spacer in Figure 1 (b) and draw only the walking line of the rescue robot. The specific steps are as follows:

- **Figure 3. Sketch of obstacle surmounting process for rescue robot**

  a) The rescue robot walks on the wire. When the current arm is close to the spacer bar, the robot stops moving, as shown in Figure 3(a).

  b) The locking mechanism releases the locking state. The screw in the spiral pair of the forearm moves up some distance, which causes the travelling mechanism to move up and the travelling wheel to detach from the lead, as shown in Figure 3(b).

  c) The spiral pair in the forearm moves to the right for some distance, so that the walking wheel in the forearm is staggered with the wire, as shown in Figure 3(c).

  d) The screw rod in the spiral pair of the forearm moves down for a certain distance, so that the walking wheel of the forearm is at the same height as the walking wheel of the latter two arms, preventing the forearm from being too high and interfering with the spacer during obstacle crossing, as shown in Figure 3(d).

  e) The robot walks forward for the right distance, with the forearm over the spacer, as shown in Figure 3(e).

  f) Reverse operation step 4), step 3) and step 2), so that the walking wheel in the forearm is placed on the wire again, as shown in Figure 3(f).

  g) The middle arm and the rear arm of the robot repeat the above steps separately to make the rescue robot cross the obstacle.
When the rescue robot arrives at the operator's falling place, it stops and brakes to prevent the rescue robot from sliding on line during the rescue process, which affects the rescue, as shown in Figure 4(a). Then the rescue personnel accompanying the rescue robot will tie the rope in the electric hoist to the operator and rescue the operator back to the hanging basket, as shown in Figures 4(b) and 4(c). Finally, the operator will return with the rescue robot. Go to the iron tower.

3. Structural design of rescue robots
According to the design idea of rescue robot, Solidworks 2015 was used to conduct 3d modeling. The 3d model of the rescue robot is shown in figure 5. It consists of a mechanical arm, a locking mechanism, a walking mechanism, a support frame and a hanging basket. The manipulator is composed of upper, middle and lower parts, in which the locking mechanism is installed under the walking wheel on the upper part of the manipulator, and the expansion of the push rod can be controlled synchronously with the rise and fall of the upper part of the manipulator to achieve the locking and relaxation of the conductor. The walking mechanism is installed in the walking wheel bracket on the upper part of the mechanical arm to drive the whole robot on the wire. The middle part of the manipulator is composed of an electric push rod, which drives the walking wheel bracket on the upper part of the manipulator to move up and down. The three mechanical arms are equidistant and parallel mounted on the support frame, and the left and right movement of the mechanical arm is realized through the electric push rod between the lower part of the mechanical arm and the support frame. Hanging baskets are places where people can rest.
3.1 Locking mechanism
The locking mechanism is shown in figure 6. It is a kind of rack and pinion transmission mechanism, which relies on the cylinder rack to move back and forth to realize the locking and loosening of the mechanism on the wire. It consists of cylindrical rack, gear, cylindrical rack cover, walking wheel support, motor, motor support and so on. The motor drives the gear to drive the cylinder rack to move back and forth in the cylinder rack to control the coordination and separation between the front end of the cylinder rack and the left end of the walking wheel bracket, so as to realize the locking of the conductor. Because of the structural characteristics of the cylindrical rack, it can rotate freely in the cylindrical rack sleeve to reduce the resistance force caused by the contact between the conductor and the clamping wheel under some circumstances.

![Figure 6. Lock mechanism](image)

3.2 Walking mechanism
The walking mechanism is shown in figure 7. It is composed of walking wheel, walking wheel shaft, coupling, walking wheel motor, etc. The walking motor drives the walking wheel to walk on the wire through the walking wheel shaft. In order to increase the contact area between the walking wheel and the wire and to adapt to different wire diameters, the walking wheel is designed into a variety of detachable forms. The key to the design of walking mechanism is the design of walking wheel. According to the characteristics of the conductor, the walking wheel is designed as a v-shaped copy structure. The walking wheel can tightly cover the conductor and bind the conductor in the structure together with the locking mechanism and the walking wheel bracket, so that the rescue robot has a higher safety in the process of driving. In addition, the v-shaped inner surface of the walking wheel is attached with a layer of polyurethane rubber material, which can increase the friction between the walking wheel and the wire, so as to prevent the occurrence of skidding during the walking process of the rescue robot.

![Figure 7. Walking mechanism](image)

4. Mechanical arm
The mechanical arm is shown in figure 8. It is composed of walking wheel bracket, electric push rod 1, electric push rod 2 and so on. The upper part of the electric push rod 1 is matched with the walking wheel bracket and fixed with nuts to prevent falling off. The electric push rod 1 controls the up and down
movement of the whole mechanical arm. The base is matched with the guide rail. Under the action of electric push rod 2, the base moves along the guide rail direction, thus driving the mechanical arm to move along the guide rail left and right.

![Figure 8. Mechanical arm](image)

5. Support frame
The support frame is shown in figure 9. It is composed of square tube, guide rail, electric hoist, beam 1, beam 2. The shape of the support frame is assembled from square tubes. In addition to guiding function, beam 1 can also prevent overturning moment given by the mechanical arm and wire. The guide rail and the base under the manipulator allow the manipulator to move freely along the axis of the manipulator. The main function of electric hoist is to rescue the dorp person. It is detachable and fixed on the beam 2 when in use.

![Figure 9. Support frame](image)

6. Conclusions
In summary, this paper mainly designs the mechanical part of the rescue robot. Firstly, a three-arm suspension double-roller rescue robot is designed for the special working environment and work tasks of the rescue robot. Then, the obstacle-moving action and rescue mode of the rescue robot are planned. Finally, based on the design scheme of the rescue robot, Solidworks built a three-dimensional model of the various mechanisms of the rescue robot. The rescue robot has a simple structure, can overcome obstacles autonomously and can withstand a weight of 500kg, and has wide application prospects in high-altitude rescue.
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