Research on new type of live working robot system for overhead transmission lines

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Abstract. The volume and weight of live working maintenance robots are directly related to the practicality and flexibility of operation and promotion. Therefore, it further optimizes the redundant mechanism of the streamlined mechanical system, adopts a modular design hardware monitoring and a control platform, uses small-sized and light-weight components, uses energy-efficient lithium batteries as energy, and comprehensively considers application scenarios and operating habits for integrating them. The ergonomic industrial design incorporates features such as high security, high reliability, and friendly human-machine interface. Through the combination and implementation of the above methods, it further meets the design requirements for miniaturization, multi-function, and lightweight of robots. While ensuring the battery life and the ability to operate with reducing the volume and weight of the system equipment, it is convenient for the robot to get on and off the line and the movement control of the operation.

1. Introduction
According to the requirements of live repair work on high-voltage transmission lines for live work tools and their operating procedures, considering the principle and characteristics of the same type of live working robots, robotic arms, and manipulators at domestic and abroad, and combine the existing technical level to propose a general design of operating robots. The plan is based on the principle of miniaturization, instrumentalization, and single function. It integrates the existing power tools and robots, integrates technologies such as automatic control, protection, communication, and industrial design, and conducts wire function inspections, cleansing of foreign conductors, and anti-vibration. Hammer removal is a key functional design [1-2]. For the characteristics of live working, determining the structural parameters of the operating robot; complete the system planning and mechanical structure design. According to the idea that the host working platform is separated from the functional heads, the on-site collocation and isomorphism is combined with the principle of ergonomics to complete the overall planning and design.

In 1988, Sawada et al. of Tokyo Electric Power Co., Ltd. of Japan developed an OPGW inspection mobile robot. The robot body is too heavy (100kg) and large, the inspection efficiency is low, and the application is limited [3]. Since 2006, Montambault and Pouliot have developed and developed a new generation of inspection robot based on HQ LineROVer, the robot adopts a cross-border barrier and the inspection efficiency is low [4]. The Institute of Automation of the Chinese Academy of Sciences, Shandong University, and the Zunyi Power Supply Bureau jointly carried out research on the “ll0kV transmission line automatic inspection robot” and designed a three-arm suspended inspection robot. The mechanical organization of the inspection robot is relatively complex. It is difficult to control when crossing obstacles and the efficiency is not ideal [5]. The patrol robot designed in this article can...
go online and offline, and has multiple functions. The patrol robot and the ground control station can realize remote control and design a long-distance wireless communication system. The weight is light, and the battery capacity is large, which can meet the requirements of long-time cruising. With the combination of three types of frequency synthesizing technology, such as variable-mode phase-locked frequency synthesis, direct digital frequency synthesis, and hybrid frequency synthesis, which are equipped with excellent sensors, wireless video and wireless remote control simultaneously, defects in transmission lines can be accurately detected.

Through robotic operation, the human labor is reduced, the efficiency is greatly improved, labor costs are reduced, and the work surface and frequency of operations can be greatly improved [6-7]. Due to the indirect operation method, the danger is reduced, and the dangerous accidents such as electric shocks and falling from high altitudes are reduced, so that the life safety of operators can be protected more effectively. Compared with the manual operation, it is necessary to reasonably grasp the accuracy requirements, to be cautious and to complete the task carefully, to use the working robot to liberate the operator, and the robot automatically completes the operation, which greatly reduces the difficulty of the operation [8]. The use of robots to operate, the control is reasonable, the quality of the work is significantly improved, power outages are reduced, and power supply reliability is improved [9].

2. Features

According to the specific conditions of the live working operation of the transmission line and the operational requirements for different functions, the overall design plan should be determined as a split-combined robot. It is composed of a host-loading platform (host) and the end-effect execution robots and manipulators (abbreviated as the head) of each function. The overall structure is composed of a combination of separate bodies; the host has an independent online function; the system includes lithium batteries, DC motor drive, video observation, manual remote control combined with sensor signal feedback program automatic control operation form. The overall technical requirement is a lightweight multi-functional electrified maintenance platform, which has a certain amount of on-line automatic work capabilities, and also has a variety of work functions that are manually assisted.

The host computer consists of a wireless video system, a lithium battery power supply system, a remote control signal system, a control circuit system, an automatic on-line system, and a walking system. On-line live working heads include: tension clamp head, shock hammer replacement head, insulator replacement head, wire repairing head, foreign body cleaning head, etc., as shown in figure 1. According to potential classifications, it is classified into ground potential operation, intermediate potential operation and equipotential operation; according to operation mode, it is divided into insulation glove operation and insulation pole operation.

The total weight of a single robot and end tool is required to be ≤30kg (not including insulated ropes, insulated rails, etc.), and the application scenarios and operating habits of the transmission line construction work should be taken into account to integrate into the industrial design. The product conforms to the principle of ergonomics. With small size, light weight, remote control, intensive design, fault alarm, perfect man-machine interface and so on.
3. Transmission line inspection robot design

Electrical energy is transmitted overheads via overhead transmission lines. Maintenance of high-voltage transmission lines are limited by various conditions. First, due to transmission lines, such as direct manual operation, there are potential safety hazards, and secondly, due to the environment or terrain of the high-voltage transmission lines. In geomorphology, there may be high-voltage power transmission lines that are difficult or impossible to reach or approach by human. Therefore, there is a need for automatic maintenance or repair of high-voltage power transmission lines. High-voltage transmission line robots have emerged. The existing high-voltage transmission line robots are usually used for high-voltage line inspections. Although they can replace manual inspections and have the advantages of stable operation and high efficiency, they cannot perform basic maintenance operations such as multi-dimension demolition of metal and line damage. Automatic repairing machine and insulator string replacement work.

The patrol robot designed in this paper has many functions. Different working hands are installed on the up and down moving worktable. The up and down moving worktable is installed on the front and rear moving worktable through the adjusting screw, and the control screw moves up and down along the worktable before and after the adjusting screw control. Move the table up and down.

3.1. Multi-dimensional hardware removal device

Overhead transmission lines are exposed to the air for a long time and affected by weather conditions such as wind, rain and ice, resulting in displacement of the shock-proof hammers and other electrical fittings installed on the conductors, rust deformation, or structural breakage. It is very difficult, especially for older overhead transmission lines with a long service life, it is difficult to carry out live work manually. Traditional manual inspections and live work are difficult to meet actual needs. In addition, the dimensions and models of overhead transmission lines are not uniform. The same types of hardware, different manufacturers of products are not the same; the same product, due to differences in the installation process and operating environment, the angle, position size will also have a greater change, resulting in individuals may be very different. Therefore, the use of automatic devices for automated cutting and removal is very difficult, and in the court of the operation, the wires must not be mishandled. Therefore, it is even more difficult to realize the automated removal of the metal fittings on overhead transmission lines.

![Figure 2. Schematic diagram of a multi-dimensional dismantling device.](image)

1-host, 2-rotating mechanism, 3-wire, 4-dimensional workbench, 5-cutting blade, 6-control module

The multi-dimensional dismantling device for metal can replace manual walking and operation on the wire, and can adjust the multi-dimensional angle of the cutter head to achieve the best position angle for cutting and removing the fixture without damaging the wire. Including the host machine and the head, there is a walking mechanism on the host machine, the power supply, controller and control circuit are provided in the host machine, and the insurance mechanism is arranged under the movement mechanism; the machine head includes a wire fixing sleeve and can control the cutting head To the moving multi-dimensional worktable and cutter head, the wire fixing sleeve is connected with the host through the rotating mechanism, the multi-dimensional worktable is fixed on the wire
fixing sleeve, the cutting tool head is mounted on the multi-dimensional worktable which is cut by the cutting motor and cutting. The cutter head consists of a power supply and a controller. The power supply and the controller are connected with the rotating mechanism and the walking motor through the signal wire. The multi-dimensional worktable is connected with the signal control end of the control motor and the cutting motor, as shown in figure 2.

3.2. Overhead transmission line damage automatic repair machine
Due to the damage locations of overhead transmission lines, some are far away from the towers, and some are located on the highly skewed transmission lines. Therefore, the overhead transmission lines will be walked and the pressure pipes will be carried to the damage location, and the autonomous devices will be used. After installation, clamping, tightening, and smooth retraction, there is a lot of difficulty, and the wires can’t be damaged during work. Therefore, at present, overhead transmission line repairing and entanglement mainly require artificial on-line operation. Inspection and repair work is very difficult, and the use of integrated pressure pipe repair requires that the line be disconnected and inserted into the pressure pipe. In particular, old overhead transmission lines with relatively long operating lives are not as strong as they are. Damage is a serious risk. They cannot be manually put on or out of line. Previous manual inspections and manual operations cannot meet actual needs.

The automatic damage repair system for overhead transmission lines can replace the manual walking and operation on the conductors. It can achieve the purpose of repairing the local damage of overhead transmission lines by means of remote control and automatic equipment fastening and automatic disengagement. It is safe, convenient, quick and simple. Including the host and the crimping tube mounting head, there is a power transmission running mechanism, a power supply, a controller and a control circuit on the host. Under the running mechanism, there is an insurance mechanism to prevent the movements from being separated from the power transmission line; the pressure tube mounting head is fixedly mounted on a host machine and comprises a slide rail, left and right clamping arms, an electric clamping mechanism and an electric screw fastening mechanism installed on the two clamping arms. The left and right clamping arms are respectively passed through the slider and the clamping slide. The rails are connected and move along the slide rails in the opposite directions under the action of the electric clamping mechanism; the press-fitting pipe mounting slots and the bolt holes are symmetrically located on the opposite faces of the left and right clamping arms, as shown in figure 3.

![Figure 3. Schematic diagram of damage repair system for overhead transmission lines.](image)

1—Mainframe, 2—Electric screw fastening mechanism, 3—Clamping slides, 4—Controller, 5—Ground wire, 6—Repair tube, 7—Camera

3.3. Transmission line vertical insulator string bowl head dismantling device
The connection between the insulator string and the wire is connected through the groove at the bowl head of the bowl hanging plate on the wire through the ball hanging ring at the lower end of the insulator string. For safety reasons, the safety pin will be inserted after the insertion to prevent the ball
hanging ring. Therefore, in the replacement, it is generally required to manually complete the manual operation on the wire, especially in the case of live construction under electrified conditions, the preparation work for electrified work is complicated, the operation is laborious and the efficiency is low, and there is a safety risk.

Transmission line vertical insulator string bowl head dismantling device can replace manual on-line operation, safe and reliable, easy to carry, easy to operate, good applicability, saving time and effort. The dismantling device includes a main body platform and first and second mechanical arms installed on the main body platform. First and second telescopic motors and first and second mechanical fingers are respectively mounted on the first and second mechanical arms. The second telescopic motor is respectively fixed on the tail ends of the first and second robotic arms. The first and second mechanical arms are respectively provided with a telescopic slide, and a sliding expansion sleeve is slid on each telescopic slide, and two The sliding expansion sleeves are respectively sleeved on the first and second telescopic motor shafts, and the first and second mechanical fingers are correspondingly mounted on the sliding expansion sleeves on the first and second mechanical arms, and can slide along the expansion sleeves along the telescopic slide on the corresponding side arm moves back and forth as shown in figure 4.

![Figure 4](image)

1. body platform, 2. first robot arm, 3. second robot arm, 4. lifting mechanism, 5. electronically controlled clamping mechanism, 6. wire

**Figure 4.** Schematic diagram of the assembly and disassembly equipment of vertical insulator string bowl heads for transmission lines.

4. Conclusions
Overhead transmission lines are exposed to air for a long period of time. Under normal weather conditions such as strong winds, rain, ice and temperature, dynamic stress, breeze vibration, galloping, and secondary span oscillations can cause metal fatigue, rust deformation, or local cracks. The occurrence of partial fractures, broken strands, and other damage will reduce the current-carrying capacity, but it will result in serious accidents such as disconnection, drop, short-circuit, and power failure. The new overhead transmission line inspection robot is safe, reliable, easy to carry and operate, has good stability, and saves time and labor. It can be used instead of manual operation.

① The multi-dimension dismantling device for gold can be used to dismantle the various types of gold fittings on overhead transmission lines. It can adjust the multi-dimensional angle of the cutter head to achieve the best position angle for cutting and removing the fixture without damaging the conductor.

② Automatic transmission line damage repair machine can walk on the wire and video observation, damage to different specifications of overhead transmission lines, pressure pipe repair operations. The purpose of repairing the local damage of the overhead transmission line is achieved by means of...
remote control and automatic tightening and automatic disengagement of the equipment, which is safe, convenient, quick and simple.

③ The vertical insulator string head assembly and disassembly device of the transmission line can quickly and easily disassemble the bowl head of the insulator string, which reduces the risk of manual line operations. It has the advantages of safety, reliability, convenience of carrying, easy operation, good applicability, and time and labor saving.

Acknowledgments
This work is supported by The State Grid Corporation of Science and Technology Project (52153216000R).

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