

# Design of the Wire Repair Tool for the Maintenance Robot with Electrification Used in Substation

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**Keywords:** Open-type Substation, Wire repaired, Worm and Gear, Remote Control.

**Abstract:** The power transmission lines in open-type substation which long-term exposure to the outdoor environment easily occurs in the phenomenon of wire breakage in the harsh environment of wind and sun. The broken wire in lines would appear the phenomenon of vibration breakage due to the role of external forces when working. The further expansion of the steel core aluminium strand would lead to a decrease in the mechanical strength of the line, and then resulting in a safety accident. The wire repair tool is the special operation tools for the maintenance robot with charged used in substation, which is clamped by the mechanical arm installed at the end of the robot. The wire repair tool with power transmission mode of the worm and gear and the remote control mode to repair the damage wire of the power transmission line in the open substation, and then reduces the danger level effectively.

## 1 INTRODUCTION

As the scale of substation expands gradually, the stability of transmission lines in substations will directly affect the reliability and stability of users. The power transmission lines in open-type substation which long-term exposure to the outdoor environment, under the bad environment and the external force, prone to broken phenomenon. If the wire is not repaired in time, it will not only affect the transmission efficiency for a long time, but also affect the mechanical strength of the line. Power transmission and transformation line carries the risk of breaking, and then cause the safety accidents. According to the relevant provisions, it can be seen that the loss of damage of the wire at the same place exceeds 5% but less than 17% of the total tensile force and the cross-sectional area does not exceed 25% of the total cross-sectional area of the conductive part, repairing with a repair tube. In the current stage, the work of wire repair is mainly repaired by artificial repair, the use of wire crimping pliers as a crimping tool and the use of repair pipe on the broken wire repair. The work of artificial wire is high in strength, low in efficiency, unable to be charged and a low degree of automation, there is a certain security risks. There are certain safety hazards. Researchers of State Grid Shandong

Institute of Electrical have improved the wire hydraulic plier, and the control mode is changed from manual to remote controlled operation, as shown in Figure 1, which is used for 10kV distribution network operations. The Quebec Water Research Institute in Canada developed the wire crimping repair tool is mainly used for overhead lines, only applies to the line inspection robot, cannot be used in the substation power transmission line. At present, there is no related research about the wire repair tool which is used in substation for the electric maintenance robot of substation.



Fig.1 The wire hydraulic plier

In order to solve the problems existing in the above research, overcome the difficulties and

limitations of the wire repair operation in the substation, improve the efficiency of the wire repair work, reduce the labor intensity of the operator, improve the mechanical strength of the damaged wire, and ensure the stability of the power supply of the substation. According to the repair requirements for damaged line of 220kV and below the voltage level substation and the operating requirements for the substation electromechanical operation of the robot, a wire repair tool is designed to conduct the repair mission which is used for the maintenance robot with charged used in substation.

## 2 DESIGN OF MECHANICAL STRUCTURE

The wire repair tool is mainly composed of a repair clip, a pair of clamping fingers and clamping arm, the interlocking device and transmission mechanism, the power input device, the proximity switch, control box and clamping handle. The schematic diagram of the wire repair tool is shown in Figure 2. The repair clip is made with material of aluminum, which thickness is 2mm. The material of aluminum sheet can make the repair clip has good ductility and mechanical strength, and it cannot spread the aluminum strand of the broken wire. The main role of the interlocking device is to loose stranded strand straight and close the wire to repair clip clamping easily, and then improve the repair efficiency. The interlocking device uses POM which is the insulating material to prevent the tip discharge from occurring during contact with the wire. The clamping fingers are the executing agencies at the end of the tool and make the repair clip to produce the deformation to achieve the purpose of wire repair in the operation of the clamping arm. The clamping fingers are also made by POM. A miniature camera is installed in the center of the repair clip and the position of the wire can be observed in real time. Both ends of the clamping arm are equipped with proximity switches to control the travel of the clamping arm. The transmission mechanism using worm gear drive mechanism, with the advantages of single-stage speed ratio of worm gear mechanism to transfer power to the clamping fingers for operation. The power input device is the power source of the wire repair tool, and the motor drive mode is adopted to facilitate precise control, and the actuator is connected to the transmission mechanism by the decelerating mechanism of the servo motor. The clamping handle is the manipulator

clamping part of the tool, the main body of the clamping handle is made of hard aluminum alloy, and the anti-wear material is used in the clamping part with the handle in order to achieve the purpose of the use of lightweight and ease of use. The clamping handle can be replaced periodically.

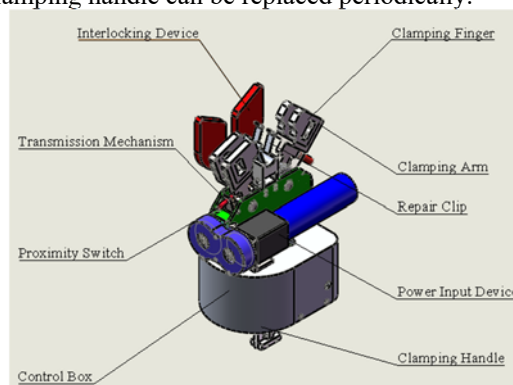


Fig.2 The schematic diagram of the wire repair tool

## 3 DESIGN OF CONTROL SYSTEM

The control system of the wire repair tool is mainly composed of the remote control terminal, the wireless transceiver, motor and actuator and Beckhoff control system. The block diagram of control system for the wire repair tool is shown in Figure 3. The remote control terminal sets the start-stop and status button, respectively corresponding to the motor's start-stop and state control. The communication between remote control terminal and Beckhoff controller through WIFI wireless, Beckhoff controller according to the collected key information output corresponding to the digital to EL2024 digital output module when press the button. Digital output module connected with the transmitter so that the transmitter can automatically send the corresponding signal to the receiver, and the receiver connected with the motor. So that the motor could start and stop, forward and reverse by the remote control terminal. The control flow diagram is shown in Figure 4.

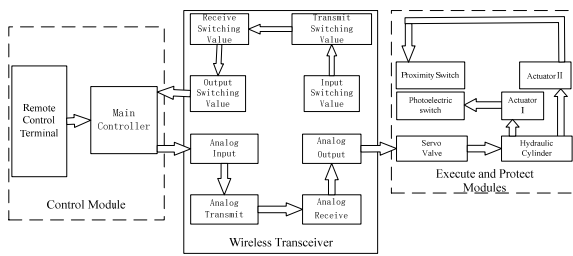


Fig.3 The block diagram of control system for the wire repair tool

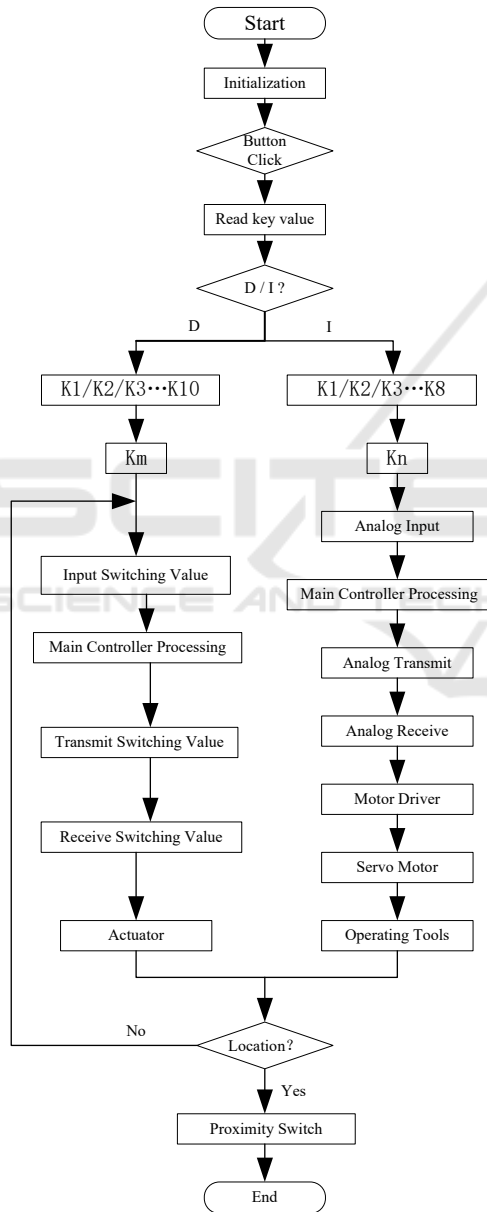


Fig.4 The control flow diagram

(1) Motor control

The remote control terminal output a continuous control signal (set to "-127 ~ 127") ,and the remote terminal communicates with Beckhoff controller through WIFI wireless, and the receives the signal (-127 <X <127) at the same time, and then output a 0 to 5v analog signal to EL4104 after DA conversion. The EL4104 module is connected with the analog wireless transmitting device and outputs the analog signal to the transmitting device, the wireless transmitting device and the wireless receiving device. The wireless receiving device outputs the "0-5V" analog signal. The wireless receiving device are connected with the motor driver "IN1", and then the analog signal is outputted to the "IN1" port to complete the control of the motor.

(2) Limited control

The proximity switch would be triggered when the clamping finger moved to the limit position, and the proximity switch outputted a voltage signal of 5V. The proximity switch outputted signal is connected to the wireless transmitter, and the voltage signal is inputted to the wireless transmitter. Since a wireless transceiver can only transmit two signals, the limit position of one clamping finger is detected and the other is synchronized. The wireless transmitting device communicates with the wireless receiving device, the wireless receiving device synchronously outputs a voltage signal (12V) to the wireless receiving device. The output of wireless receive device is connected with the EL1144 module and outputs the signal to the one of the channel. The controller corresponds to receiving the high and low voltage signal to control the motor's start-stop when the proximity switch corresponds to the high and low voltage signal.

## 4 THE PROCESSING OF REPAIRING

The wire repair tool is held by the mechanical arm and the repair process is shown in Figure 5. The wire repair tool is clamped by the mechanical arm, and the mechanical arm holds the wire repair tool to enter from the undamaged side of the wire. The mechanical arm clamps the wire repair tool slowly moves from the damaged side to the undamaged side, in order the clamping fingers could align the wire through videos from the camera on the wire repair tool. The broken wire is closed under the action of the interlocking device. The mechanical arm stops

moving when the center position of the repair clip is on the broken wire through the camera to observe, and then the motor of the wire repair tool is controlled by the remote controller to conduct the repair work. The proximity switch on the wire repair tool can detect the position of the clamping arm to control the travel of the work. When the job is completed, the clamping arm is rotated in the opposite direction under the action of the motor, and the position of the clamping arm is detected by the proximity switch, and then the motor would stopped after the clamping arm fully opened. The mechanical arm holds the wire repair tool to move directly below the wire after the repair clip is clamped in 3 times (the repairing work), and the wire repair tool is pulled out of the wire.

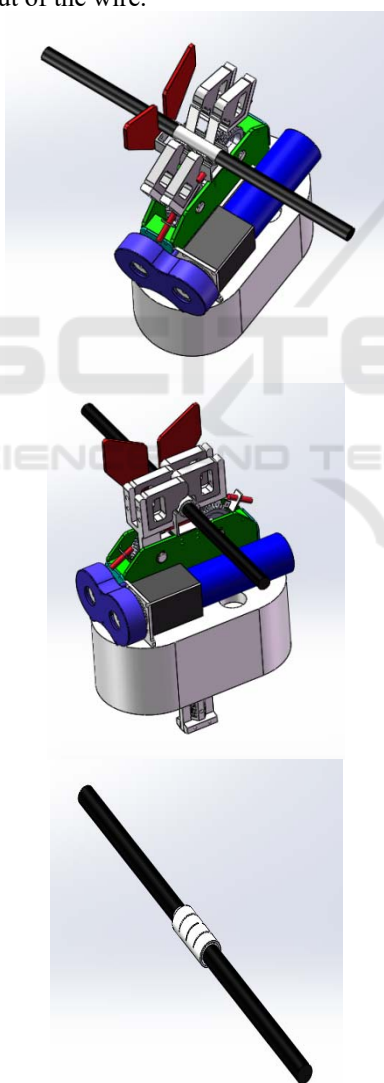


Fig.5 The repair process of the wire repair tool

## 5 CONCLUSIONS

The work of wire repair in open type substation is of great significance to the safe and stable operation of substation. At this stage, the repair work in the substation is mainly in the stage of manual with power failure, which is in a low degree of automation and poor economic efficiency. This paper designs a wire repair tool for the maintenance robot with charged used in substation, which can repair the damaged wires in the substation without power failure. The wire repair tool adopts the transmission mode of the worm and gear and the control mode of the remote control operation to repair the power transmission line which is broken in open type substation. The design of the wire repair tool for the maintenance robot with charged used in substation can improve the operation of automation, reduce the number of blackouts, and improve economic efficiency at the same time.

## ACKNOWLEDGEMENTS

Key Technology and System Research of Robot for Operation and Maintenance of Grid Equipment (Technology project of China Southern Power Grid Co., Ltd. No. 090000KK52150073)

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