Control and application of ultra-high voltage insulator cleaning and detecting robot

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Abstract: With the development of global energy Internet and demand for UHV transmission, UHV transmission lines will increase rapidly and become more and more important for national economic development. The UHV transmission lines will increase year by year and become increasingly important to the economic development of the country. It is necessary to study the cleaning and detection technology of transmission line insulators that the insulators of UHVDC transmission lines such as large leakage rate, low detection efficiency and difficult cleaning of insulators. Therefore, the development of UHV transmission line insulator hot-line cleaning robot and detection integration has important engineering significance and practical value to improve the level of the operation of the UHV power transmission engineering maintenance, safe and reliable operation of the protection of UHV transmission lines. In this paper, the research on the integrated robot for live cleaning and detection of UHV transmission line insulators will greatly promote the live operation of UHV transmission lines in China. It can be directly applied to the live operation of UHV DC and can be promoted nationwide.

1. Introduction
At present, the UHV transmission line inspection is mostly dependent on manual inspection. The method is not only labor-intensive, high economic cost and high risk but also cannot meet the development requirements of modern power. The intelligent inspection robot has become a reality with the progress of industrial technology and the development of intelligent equipment [1]. It can effectively replace artificial inspection through the manipulation of the mechanical device. Though domestic starts relatively late, it is developing rapidly in the field. In the 1970s and 1980s, Japan's Kyushu Electric Power Co., LTD and Yaskawa Robot jointly developed an intelligent insulator detection robot [2] which was used for low-voltage line inspection. At the same time, Japan's Aichi Company and Shikoku Electric Power Company designed and developed a hydraulic driven mechanical working arm [3]. It can be used to clean insulators at higher altitudes and reduce human labor. Kuibei Hydropower Research Institute of Canada developed a new intelligent technology which can independently realize the local maintenance of the line including the detection and cleaning of insulators and the safety investigation of some transmission lines in the 1990s.[4]

The Shanxi insulator cleaning related work at the Beginning in the 1990 s. Lu [5] et al. design to develop a wind cleaning ring, with the help of wind the function realization of rotating cleaning. It can effectively improve the dirt lightning pressure but also got the national invention patent and international patent authorization. At the same time, Shaanxi Yinhe Electric Anti-pollution flashover Co., LTD has developed a single-rod portable and multi-voltage grade QBRQ type high-voltage live
cleaner [6] which can improve the labor efficiency of maintenance workers; Aiming at the 330kV transmission line unique in northwest China, Lanzhou Power Supply Company and Shanghai Jiao Tong University jointly developed a cleaning robot with retractable arms [7]. It tentatively solved the problem of the cleaning part of 550kV line insulators in northwest China.

2. Robot control system
In recent years, some lines have begun to adopt the mode of step-down operation as the development of UHV transmission lines in foreign countries has been neglected. The inspection work of UHV lines has not made great progress[8]. The uHV transmission line has ushered in the peak of development and great progress has been made in related work because the construction of energy internet in China. For example, the helicopter patrol and overhaul, unmanned aerial vehicle (uav) detection and fault early warning and the design and development of various kinds of intelligent detection devices. However, most studies of stay in the field of individual maintenance projects less for Multi-functional intelligent device. This paper mainly contant development and design of the integration of cleaning and inspection robot for uhv transmission line insulator cleaning and testing. It can reduce human labor and be charged for transmission line safe intelligent operation to provide some new ideas.

The robot is mainly composed of motion control system, image and video collecting system, power control system, communication system and AD measurement system[9-10]. The core of the motion control system is PC104 industrial computer which determines the motion state of the robot through the position sensor, limit sensor and other sensor. Then it controls the action of each motor which are 5 ELMO motor drivers. Video image acquisition system which mainly in the robot arm three tiny cameras and video servers on the basis of operation conditions on site for real-time video image acquisition through the local area network (LAN) transferred to the mobile terminal and ground base station. It can assist the robot workers make better the control decision and ensure the stability and security of the operation. The power management system ensures the reliability and safety of the system power supply through the control of the robot power supply. At the same time, it takes into account the voltage supply between each chip and unified and effective management of the overall voltage. The main controller of the power control module is ARM chip.

In addition to this function, ARM chip also collects information include voltage measurement data, trunk current detection data and position sensor data. The communication system is mainly to ensure the interconnection and communication between the electrical system components of the robot and the ground base on station and the mobile device terminal[11-12]. The cable communication is used for internal communication of the robot and WEFI wireless LAN communication is used for external communication of the robot in order to reduce signal interference. The robot adopts the mode of combining PC104 industrial computer and single chip microcomputer to ensure the operation capability and operation portability of the system. The powerful performance of the industrial computer ensures the operation efficiency of the robot while the single chip microcomputer ensures the portability of data collection and detection[13].
3. Principle and scheme design

Taking overhanging insulators and tensile insulators of high voltage transmission lines of 500 kV and above as the research object, the structural design of the robot is carried out. The structural design requirements of the insulator cleaning and testing robot should generally meet the following points:

(1) A small number of insulators should be short-connected as far as possible; (2) Can crawl smoothly on the insulator string; (3) The robot can be prevented from falling in the case of failure; (4) Simple operation of the upper and lower strings; (5) Providing enough space to install batteries and control box, there are two main climbing ways for the robot on the insulator string.

The peristaltic is the common way to make use of the friction force between the crawler and the insulator string surface to move forward. Although this way has continuous movement, the device is bulky and has poor adaptability. The alternate clamping type which the use of clamp. Clamp insulator steel cap or porcelain bottle part, flexible movement, good adaptability if the clamp steel cap. the claw movement stroke is larger. The clamping jaw movement schedule although small if the clamping insulation porcelain but the holding force can't be too big in case of damage of porcelain. Based on the research, summarized as insulator can be charged to clean wet cleaning and dry cleaning. Wet cleaning is the compound cleaning water cleaning combined with high pressure gas blowing. The equipment complex quality is bigger and because many of the transmission tower is located in the forest in our
country or the mountains, water transportation difficulties. Dry cleaning is not directly using the brush cleaning spray water compared with wet cleaning. The dry cleaning equipment is relatively simple. The quality of light easy to use relevant research shows that if brush cleaning force and arrangement is reasonable. Dry cleaning can obtain good effect insulator on-line detection can be divided into the power test and power test non-electricity tests including observation method. Ultraviolet imaging method ultrasonic detection method infrared temperature measurement method radio wave method and laser. Electric quantity detection method includes electric field measurement method, leakage current method and pulse current method. Compared with non-electric quantity detection method, electric quantity detection method is more simple and reliable.

4. Hardware optimization resistance

4.1 Equi-potential shield
The communication module and insulator resistance measurement and control module mainly adopts the method of equi-potential shield that is the aluminum alloy shielding box for loading. The shielding box wiring space plug lead and AD data acquisition circuit are conducted using foil paper parcel in order to reduce the outside strong electromagnetic environment interference. Meanwhile, it reduces the data transmission attenuation. Research shows that high-permeability materials can filter out most magnetic field lines in the external environment effectively reduce electromagnetic interference. It ensure that the internal circuit is in a safe working environment.

4.2 Optimize design routing
Optimize the layout and routing of multi-layer Printed Circuit Board (PCB) components to reduce interference and errors caused by the components themselves. The robot of multilayer PCB is multi-level multi-function integrated design while maintaining the robot portability to ensure its structure compactness. To ensure that each unit has a good electromagnetic compatibility and can avoid electromagnetic interference between the unit, do the compact structure, function, limit the volume of the robot. It is separated to the outermost layer and add a capacitor to coupling between it and the ground wire and set a disconnecting switch between the output high voltage and low voltage to reduce the impact for the lithium battery power supply board.

4.3 Protection of core components
The power supply of the main control module PC104 industrial computer and single chip microcomputer is optimized. In order to further strengthen the protection of the core components, the voltage is directly powered by lithium battery. The edges and corners of the shielding box used for loading should be designed as circular arc to suppress the distortion of the field strength at the tip and improve the distribution of the electric field around it. The double-layer shielding is used to maintain the accuracy of the measured data in the zero-electric field environment. At the same time, the digital signal power supply and analog signal power supply are isolated by inductor to avoid mutual interference between digital and analog.

5. Conclusion
The robot control system is mainly introduced in this paper the design and hardware circuit structure of the robot. Robot system elaborated the multi-layer distributed system between various modules function and the corresponding functions. The anti-interference design of the robot system can further ensure the safe and reliable operation of the robot in the complex electromagnetic environment.

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