

## A Type of Substation Insulator Cleaning Robot

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### Abstract

The core product of this project is the insulator strings cleaning robot, which cleans the insulator strings without power cut and solves the main problems that insulators are currently facing. The robot uses dry ice as its cleaning means, and uses dry ice particles to form an insulating layer on the surface of the insulator to achieve the effect of non-contact cleaning and realize the electrified cleaning. The robot achieves 360° completely cleaning of the insulator strings through the arc-shaped mechanical claws and the rotating brush. At the same time, the robot is equipped with a perfect control and monitoring system, which can timely detect the insulator string that will affect the operation safety, and immediately perform the cleaning work to avoid the flashover breakdown accident. Through the manual operation of the robot, labor input for human cleaning is greatly reduced, and unexpected accidents during power scrubbing are avoided, which greatly reduces safety risks and reduces accidental injury insurance and damage compensation costs. According to the high cleaning efficiency and the short cleaning cycle, the time and cost of each cleaning work is reduced.

### Keywords

Insulator string ,robot,power cut ,electrified cleaning ,dry ice cleaning.

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### 1. Introduction

With the development of society and the improvement of industrial level, the continuous construction of high-voltage transmission stations such as substations has greatly improved the efficiency of civil electricity use. At the same time, the safe operation of power systems has become a crucial issue. Among them, the substation's insulator string is often affected by complex natural environmental factors, forming difficult-to-clean dirt on its surface, causing accidents such as flashover or corona, causing substation trips and large-scale power outages, and even causing casualties. This not only reduces the production efficiency but also brings great hidden dangers to the safe operation of the power system. So we put forward the substation insulator string cleaning robot project to solve these problems.

Insulator flashover is the main cause of tripping faults in substation power supply, mostly in the late winter or early spring. Frequent flashover trips have a negative impact on normal power supply. In severe cases, it can also cause disconnection accidents, which brings great hidden dangers to safe power supply.

The introduction of this project has opened up new ideas for the cleaning of insulators. The robot can be carried out without power cut, completely avoiding hundreds of millions of power outages per year, ensuring the personal safety of electric workers, improving work efficiency and not causing secondary pollution, not only ensuring the safe operation of the power system. It is more in line with the concept of modern environmental friendliness, and contributes to the construction of smart grids that use advanced technology to comprehensively improve safety, economy and efficiency!

## 2. Product Hardware Structure

### 2.1 Moving Part

The moving part of the insulator cleaning robot is a robot moving body mechanism. Using the design concept of the tracking trolley, the 8-channel gray sensor, single-channel gray sensor, infrared sensor and other line sensors are used to realize the robot entering and leaving the work area according to the plan, automatically reach the insulator for cleaning.

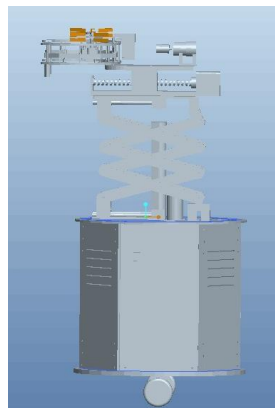
The movement part mainly consists of cylindrical body, universal wheel, motor, air pump, control circuit board and other electrical components. The robot is powered by a built-in rechargeable battery, which drives the motor to drive the universal wheel to move. The patrol line sensor identifies the planned layout on the substation road surface.

### 2.2 Insulation Structure

In order to meet the needs of electrified cleaning, insulator cleaning robots are designed to use insulating materials (including bolts, brackets, connecting rods, etc.). The robot body member uses a glass fiber composite material, the non-standard parts to be designed by itself use MC nylon, and the purchased standard parts use non-glass fiber. The robot's motor and the high-voltage AC equipment maintain a safe distance while maximizing the distance. The control circuit board is fixed to the bottom of the robot with an insulating material. Since dry ice easily liquefies water molecules in the air, droplets or even mists are generated on the surface of the device and on the robot cleaning device, reducing the insulation properties of the device and the robot. An air drying and filtration system is added to the air pressure system to reduce water molecules and impurities in the air and to reduce droplets attached to the surface of the dry ice. Designed to maximize insulation performance.

### 2.3 Support Part

The insulator string cleaning robot support part is an important part of the robot support cleaning part, and is composed of a lifting frame. This project refers to the truss structure of the fire ladder and designs a foldable electric crane.



As shown in the figure, the lifting frame is lifted by an electric push rod. When the robot is working, the motor rotates, and the push rod pushes the lift to the upper cleaning part to the highest position of the insulator string. As the cleaning work progresses, the lifting frame descends step by step to complete the cleaning of each insulator piece. After the cleaning work is completed, the crane is lowered to the lowest point and moved to the next insulator position.

### 2.4 Cleaning Part

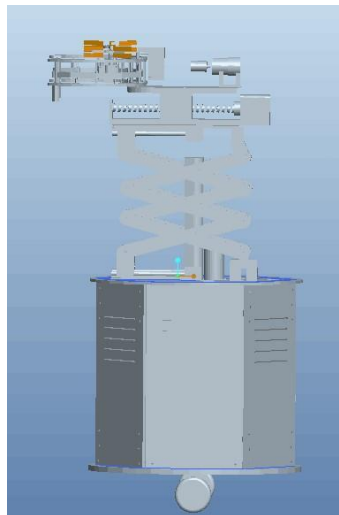
Cleaning part is the most important part of the robot, and it is the main part of the robot to clean the insulator. This part is the simple design of screw structure and mechanical claw to complete the cleaning work, with excellent performance and good stability. The low cost makes it easy to mass-produce and promote. The cleaning method is dry ice with brush cleaning method. New dry ice

technology can be added to form a thin layer of dry ice particles on the surface of the insulator. With the dry cleaning technology, the insulation effect of  $1+1>2$  can be achieved, and the electrification cleaning effect is good.

According to the safety distance specification of high-voltage equipment, the robot itself needs to maintain a certain distance from the insulator, which is accomplished by the screw structure. The motor drives the ball from the end of the lead screw, so that the claw is close to the insulator string from the position of the robot. At the same time, the mechanical jaws are designed as two double-layer circular arc mechanical jaws. After closing, they can cover the insulator pieces. The crawler track is built between the double-layer mechanical jaws. The rotating brush moves along the crawler track on the mechanical jaws to achieve cleaning of the entire insulator piece effect.

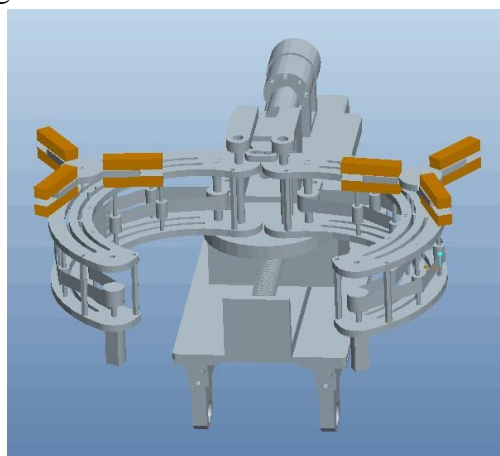
### 3. Working Process

The lifting frame is folded into the minimum height, this time in the non-cleaning state; the remote control robot moves steadily to the destination insulator string under this condition, as shown in Figure below:



After reaching the insulator string, the robot stops and the angle of the crane changes. At this time, the robot is in the ascending state; the robot is sent to the target height in this state.

The robot arm expands a larger angle and pushes it through the stepper motor to buckle the highest insulator piece, as shown in figure below:



Start air pump, rotate brush and begin cleaning, as shown in figure below:



After cleaning the insulators of the layer, the robotic arm expands the maximum angle, the lifter lowers the corresponding insulator pitch, and the robotic arm buckles an insulator to open the cleaning. Repeat the fifth step until the bottom insulator is cleaned.

#### 4. PC Software Design

We have developed a human-computer interaction interface, the working parameters of the device can be feedback transmitted to the maintenance personnel's mobile phone, and the operating state of the device is controlled by the remote control handle and the mobile phone APP. The upper computer software is written by C#. It has a friendly and beautiful human-computer interaction interface. Its main functions are: 1. Control the movement or movement of the robot; 2. Control the overall movement of the device; 3. Control the movement of the lifting frame; 4. Serial port Communication with the lower computer; 5. Emergency stop and so on.

Through the upper computer user can directly issue a control command to the computer, the screen displays various control signal changes. The command issued by the upper computer first gives the lower computer, and the lower computer interprets the corresponding timing signal according to this command to directly control the corresponding device. The slave device reads the device status data (usually analog) from time to time and converts it into a digital signal for feedback to the host computer.

The upper computer communicates with the lower computer through the serial port, thereby realizing the movement and wrapping of the insulator string cleaning robot; at the same time, the data of the camera is collected through the USB port, and the real-time image display function is completed.

#### 5. Product Advantages

At present, most of the insulator string cleaning robots at home and abroad use the high pressure water jet function for spray cleaning, and very few have high pressure dry ice blasting functions. For the automatic cleaning of insulator strings, there are no relevant research papers and achievements patents, and there are no practical products.

In recent years, the state has stepped up the planning and promotion of smart grids and built a number of smart grid demonstration zones. It can be seen that the industry will flourish. Insulator string cleaning robots, however, there is no automatic insulator string automatic cleaning device on the market. Therefore, this product is the first of its kind for the team to seize the opportunity to fill the gaps in the market. At present, there is no competitor and competition is low. . The emergence of our team's products is conducive to filling the gaps in China's relevant industrial chain. The successful implementation of this project will solve the problem of large-scale manual work of insulator strings in small and medium-sized substations, and will fill the current domestic and international cleanliness of insulator string cleaning industry chain. Blankness promotes the healthy development of the industry.

## 6. Conclusion

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