# Development of Advanced Insulator Inspection Robot for 345kV Suspension Insulator Strings

Joon-Young Park, Jae-Kyung Lee, Byung-Hak Cho, and Ki-Yong Oh

***Abstract*—In our previous paper, we developed the prototype of an insulator inspection robot system for suspension insulator strings in 345kV power transmission lines. However, the prototype robot has some problems. To solve such problems, we newly developed an advanced version of our robot system. This robot's frames were made of a flexible carbon composite instead of a rigid aluminum material, which makes its installation process easier. In addition, the robot measures the distribution voltage of an insulator together with its insulation resistance, thereby providing more information for its analysis and diagnosis. We confirmed its effectiveness through experiments.**

***Index Terms*—Inspection, Insulator, Robot, Suspension Insulator String.**

## I. INTRODUCTION

The inspection operation of insulators in power transmission lines is essential for their stable maintenance, because an insulator failure has been known as a major cause of power failure. To this end, various inspection methods have been developed such as a buzz method[1], a potential measurement method[2], a resistance measurement method [3] and an electric field measurement method[4].

**Fig. 1 Insulator inspection operation in Korea**

In Korea, Korea Electric Power Corporation(KEPCO) has performed the inspection operations for all the insulators once every five years by adopting the electric field measurement method since 2000. However, its field tests showed that this method had the following problems: first, this method cannot detect a faulty insulator that is placed at the end of an insulator string, and secondly, its tool contacts more than two insulators at once, which is undesirable from the viewpoint of insulation. And finally, using a manual tool may give inaccurate results when a human worker has unstable posture in 345kV lines where workers should be more than 3.5 meters away from the closest power line to secure their safety.

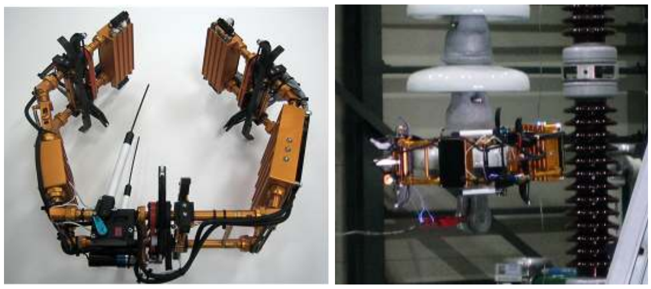

**Fig. 2 Prototype of insulator inspection robot system**

As a solution to such problems, we previously developed the prototype of an insulator inspection robot system for live-line suspension insulator strings by adopting a wheel-leg moving mechanism and an insulation resistance measurement method[5]. However, the prototype has the following problems.

(1) To be installed on an insulator string, the robot's wing should be opened. For this purpose, the prototype has a wing opening module that consists of rigid aluminum frames and two springs. Its opening process requires high force under live-line condition, however, because it could be achieved by using a lengthy hot stick from a distant place.

(2) As mentioned before, the prototype measured only insulation resistance to detect faulty insulators. However, the insulation resistance of an insulator can be affected by environmental pollution and humidity[6], which makes its diagnosis very difficult.

To solve these problems, we newly developed an advanced version of our robot system. This robot's frames were made of a flexible carbon composite instead of a rigid aluminum material, which makes its installation process on an insulator string easier. In addition, the robot measures the distribution voltage of an insulator together with its insulation resistance, thereby providing more information for its analysis and diagnosis. Finally, we confirmed its effectiveness through experiments including a live-line test.

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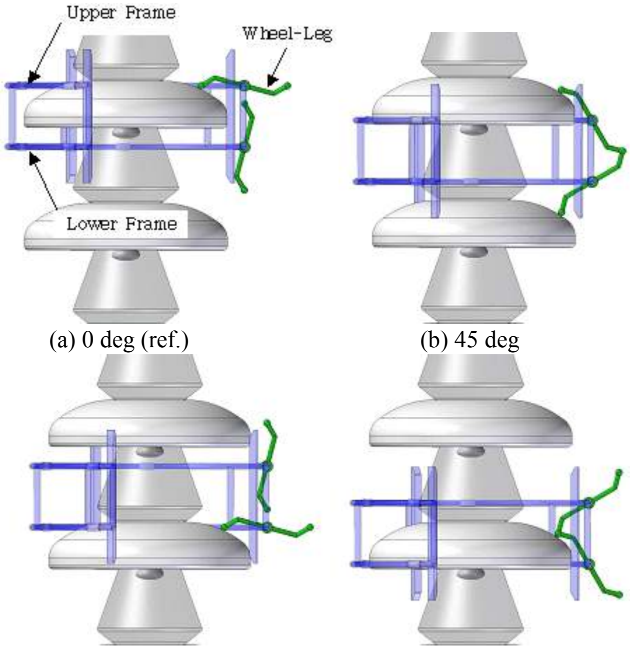
## II. Robot Mechanism

### A. Wheel-leg Moving Mechanism

Like the prototype, the advanced version of our robot system adopted the wheel-leg moving mechanism. To help readers' understanding, we briefly introduce this mechanism here.

Fig. 3 shows the conceptional description of its downward movement procedure, and its upward movement can be achieved in reverse order. As seen in this figure, the mechanism touches the porcelain skirts of insulators by turns with two wheel-legs, thereby moving along the insulator string. The wheel-leg mechanism can climb one insulator per 180 degrees of rotation.




(a) 0 deg (ref.) (b) 45 deg

(c) 90 deg (d) 135 deg

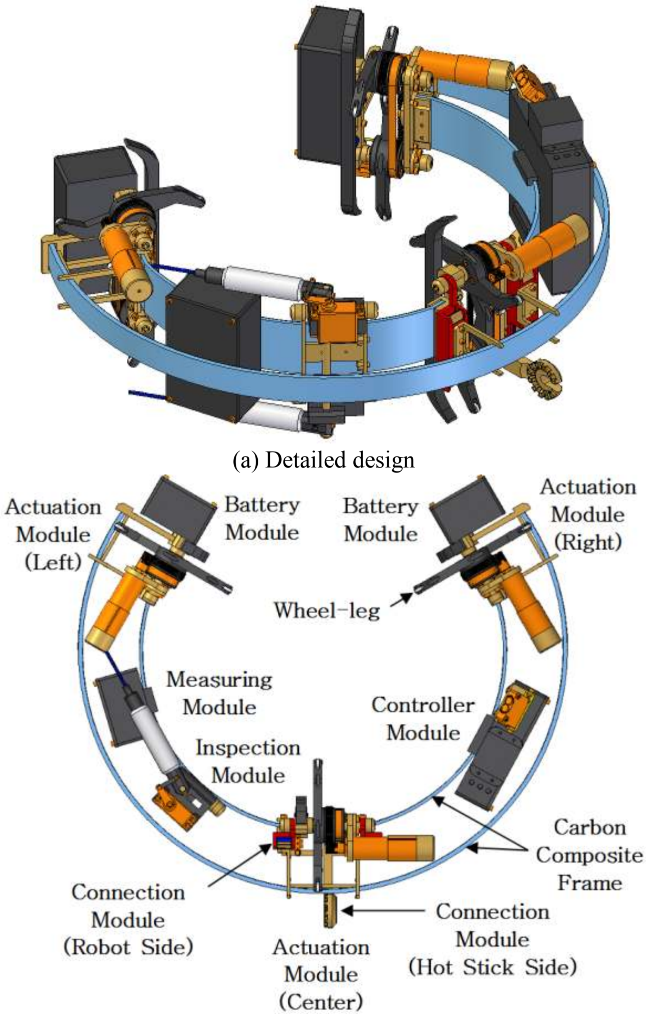
**Fig. 3 Downward movement of wheel-leg mechanism**

### B. Overall Structure

Fig. 4 shows the detailed design of the advanced insulator inspection robot mechanism whose application target is a 210kN insulator, which is widely used in the suspension insulator strings of 345kV power transmission lines in Korea. The overall structure of the robot mechanism consists of three actuation modules using the wheel-leg moving mechanism, an inspection module to electrically detect a live-line insulator, a connection module that couples up the robot to a hot stick, a measuring module, a controller module, and two battery modules.

### C. Actuation Module

To keep the balance of the robot mechanism, the robot has three pairs of actuation modules that adopted the wheel-leg moving mechanism. As seen in Fig. 5, the actuation module is composed of upper and lower wheel-legs, a timing belt and pulleys, a belt tensioner, a DC geared motor, a spur gear, a skid bar, and a sensor. The upper wheel-leg is driven directly by the DC geared motor, while the lower one by the force transmitted through the timing belt. As the sensor for positioning wheel-legs, a micro photoelectric sensor is used.




(a) Detailed design

(b) Overall structure

**Fig. 4 Robot mechanism**

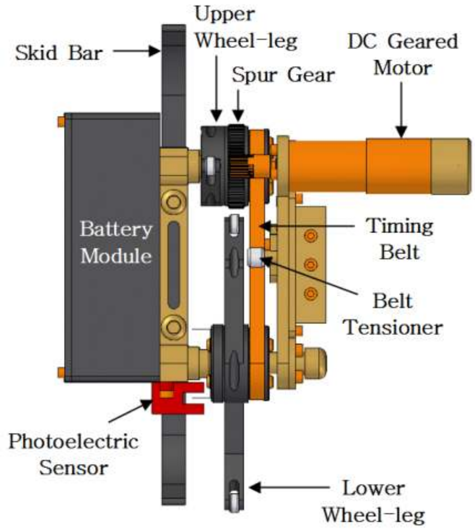



**Fig. 5 Actuation module**

### D. Inspection Module

Fig. 6 shows the inspection module, which includes a rotational shaft driven by an RC servo motor, and two detection rods mounted on the rotational shaft. To measure the insulation resistance of the insulator, the detection rods are brought into contact with the cap of a live-line insulator by rotating the rotational shaft.



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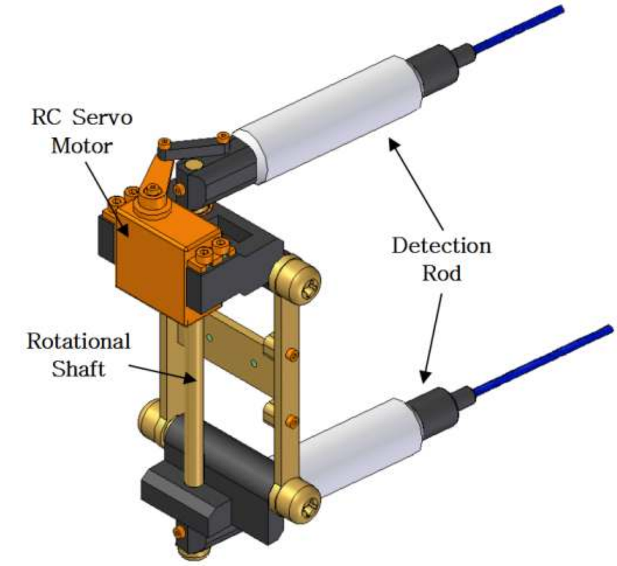



**Fig. 6 Inspection module**

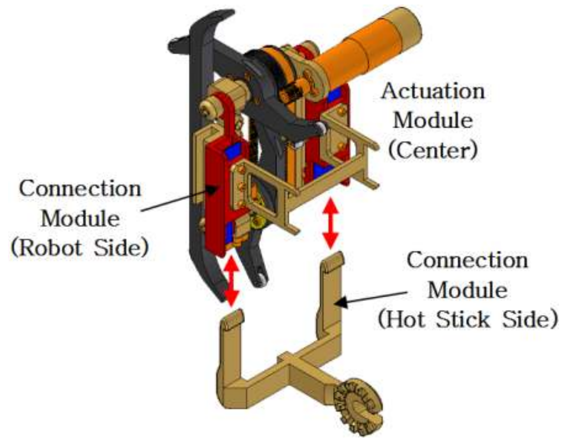



**Fig. 7 Connection module**

### *E. Connection Module and Frames*

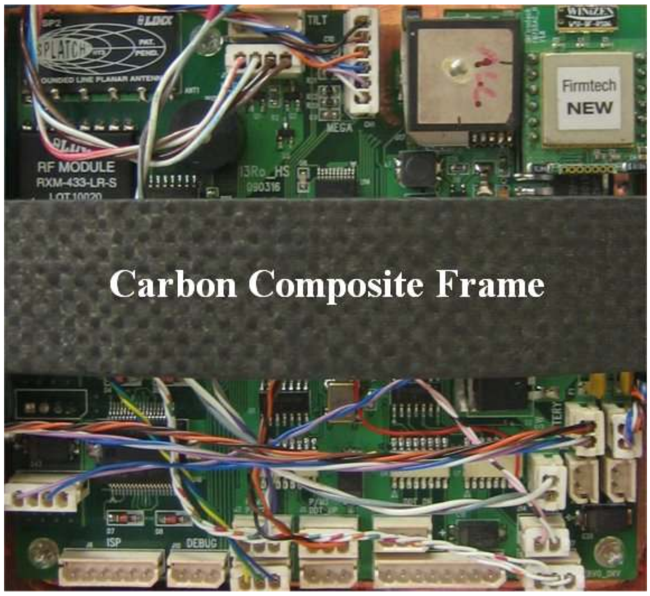
The connection module consists of a robot side module and a hot stick side module. For the robot's installation work, the hot stick side module is attached to the end of a hot stick, and then, is inserted into the robot side module. After the robot's installation on an insulator string, the hot stick side module is pulled out from the robot side module.

In order for a lineman to easily install or remove the robot, the robot's frames were made of a flexible carbon composite instead of a rigid aluminum material as shown in Fig. 4(b). Owing to their flexibility, the lineman can easily install the robot only by inserting the robot onto the insulator string.

## III. Electronic Modules

### *A. Controller Module*

Fig. 8 shows the control system for the robot. It consists of a local control station, a remote control and a monitoring station. The local control station plays a dedicated role in controlling the robot, while the remote control and the monitoring station are used for remote control and monitoring, respectively. The remote control and the monitoring station communicate with the local control station via 433MHz RF and Bluetooth wireless communication, respectively.




(a) Local control station


(b) Remote control and monitoring station

**Fig. 8 Control system**

The local control station was installed in the controller module of Fig. 4(b), and a tablet PC whose operating system was Windows XP was used as the monitoring station. The remote control generates a command corresponding to its each button, sending it to the local control station, which executes the command considering I/O status acquired from sensors. When finishing an inspection command, the local control station sends inspection results to the monitoring station.

### *B. Measuring Module*

The measuring module that uses both insulation resistance measurement and distribution voltage measurement consists of a high voltage converter, a high impedance measurement system, a distribution voltage measurement system, and a signal conditioner, as shown in Fig. 9.

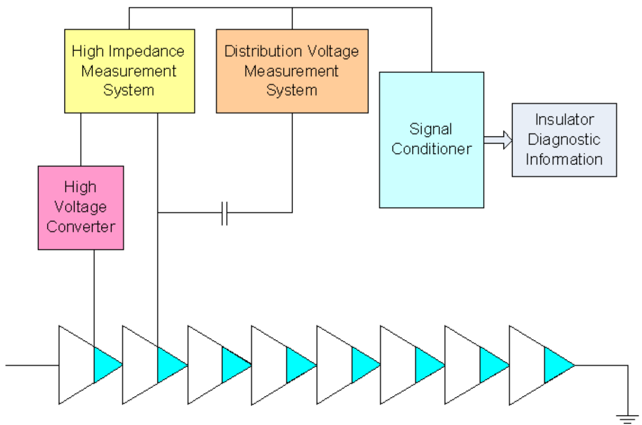



**Fig. 9 Structure of measuring module**

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## IV. EXPERIMENTS

Fig. 10 shows the developed inspection robot for live-line suspension insulator strings, which weighs only 2.97kg.

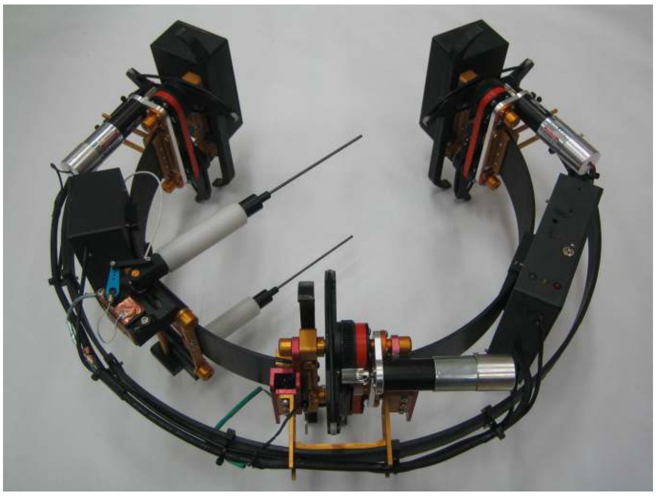

**Fig. 10 Developed advanced inspection robot system**

We first carried out its functional tests in a mock-up facility, and then, executed its live-line performance test in Gochang power testing center under 345kV live-line condition as shown in Fig. 11(a). A suspension insulator string in the test facility consists of 18 normal insulators where a 107MΩ reference resistor was connected parallel to the 5th insulator from a power line, which made the 5th insulator faulty because most of normal insulators have the resistance of over 20GΩ. The robot automatically traversed the insulator string to the side of the power line, and then returned to the ground side, while performing the inspection operations, which took 2.5 minutes. Fig. 11(b) and (c) give the insulation resistance and distribution voltage values of the 18 insulators measured by the robot system, respectively. These experimental results show that the developed measuring module can successfully detect faulty insulators under live-line condition.

## V. CONCLUSION

This paper presented the advanced insulator inspection robot system for 345kV suspension insulator strings. Compared with the previous prototype, the developed robot system is much easier to install due to flexible carbon composite frames, and is more reliable by providing more information on the characteristics of an insulator. The experimental results showed the effectiveness of the developed robot system in the field of live-line maintenance. We are now planning its field tests in actual power transmission lines under live-line condition.

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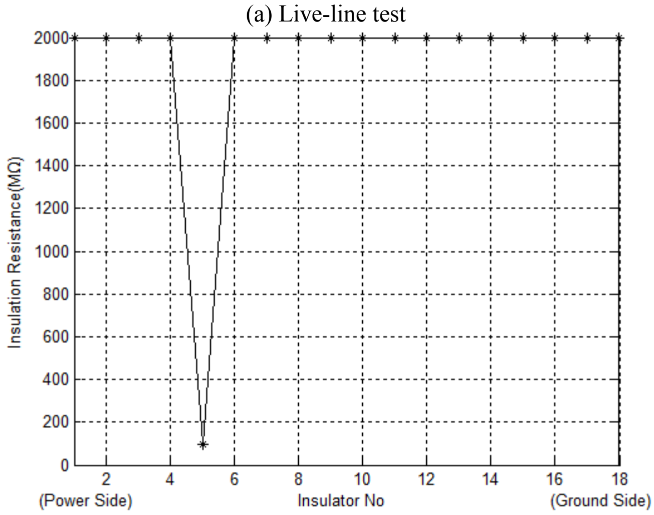
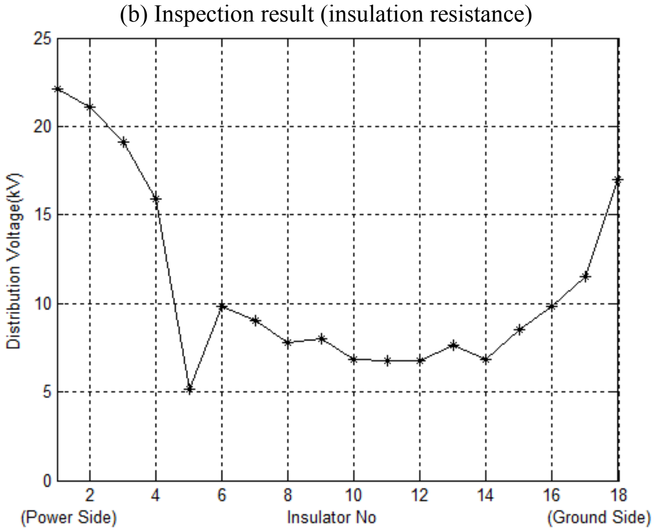
(a) Live-line test




(b) Inspection result (insulation resistance)




(c) Inspection result (distribution voltage)

**Fig. 11 Live-line performance test in Gochang power testing center**



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