Study of non-contact sensor output degradation for power transmission and distribution lines

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Introduction

In modern society, ensuring the safety of power transmission and distribution to households is critical to the functioning of our living infrastructure. Many transmission and distribution lines are installed outdoors. Natural disasters such as typhoons, torrential downpours, and lightning strikes have intensified due to recent global warming. These events have led to an increase in short-circuit accidents on transmission lines, threatening the stable supply of electricity (1)(2).

However, rainwater and accumulated dirt on sensor surfaces are known to alter the state between the sensor and the conductor, leading to attenuation of the measurement signal. Installing a cover over the sensor has been proposed as a countermeasure to prevent this phenomenon. Assuming the distance between the dirt on the cover and the wire decreases, this study conducted tests to determine how distance affects output fluctuations.

Test Method

By comparing the voltage to the steady-state value based on the voltage division ratio and the capacitance generated by the space between the wire and the sensor, it is possible to detect abnormalities in the wire. The voltage is measured based on the voltage division ratio determined by the stray capacitance, which is the capacitance generated in the space between the wire and the sensor, and the impedance value of the capacitor installed inside the sensor. The output voltage is calculated using the following formula: Each character corresponds as follows:[S: Plate area d: Distance between plates Z1: Impedance value of stray capacitance Z2: Impedance value of internal capacitance Vout: Output voltage Vo: Line-to-line voltage]

$$Z_1 = \frac{1}{2\pi f C} = \frac{1}{2\pi f \frac{d}{S}} \qquad V_{out} = \frac{Z_2}{Z_1 + Z_2} V_o$$

In this study, a wire carrying 240.0 V AC was placed approximately 30 mm away from the center of the sensor, and the output value was measured under steady-state conditions. To quantitatively measure contamination, the following tests were conducted with aluminum foil covering the measurement area at the center of the sensor.

[1] When the aluminum foil was placed at the center of the sensor

[2] When the aluminum foil was placed approximately 10 mm away from the sensor's center.

We examined how much the output decreases when the distance parameter varies during output voltage calculation by comparing these two tests. For test [2], the distance was set to 10 mm to simulate contamination adhering to the cover and ensure that the aluminum foil did not touch the sensor.

The reduction rate calculated for comparison was determined using equation 1.

$$Reduction\ Rate = \frac{[Initial\ Value - Measured\ Voltage\ Value]}{Initial\ Value} \times 100\ \ [\%] \ldots equation\ (1)$$

Results and Discussion

Table 1: Measurement Results for Each Test

	Initial Value[mV]	Reduction Rate [%]
Test [1]	8.80	29.56
Test [2]	8.20	28.78

Compare the reduction rates of Tests 1 and 2. The reduction rate was measured to be approximately 29% for Test [1] and 28% for Test [2]. We believe the output decreased because a new capacitance formed when a material with a different dielectric constant was introduced between the sensor and the wire. This caused a deviation in the voltage division ratio. Furthermore, even if the distance changes during installation and the sensor and wire are connected in series, the composite impedance value of the newly generated capacitance remains unchanged. Therefore, we concluded that moving the sensor farther away would have little effect on output fluctuation.

References

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