Environmental Monitoring Technology to Support Facility Maintenance

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Abstract

Electrical equipment used over long periods of time deteriorates due to a variety of factors. We have developed and are offering services that monitor environmental stress, which significantly affects the rate of deterioration.

These include devices that measure low concentrations (on the order of tens of ppb) of corrosive gases and devices that monitor for signs of poor continuity in auxiliary relays and other control devices with electrical contacts. We are also developing devices that predict and monitor insulation degradation trends based on electrical cubicle temperature, humidity, dew point temperature, and contamination levels.

These environmental monitoring devices quantify the environmental stress levels of equipment, helping to improve the installation environment and slow deterioration. This contributes to supporting customer's facility maintenance activities, prevention of troubles caused by environmental factors, and reducing the risk of failure.

1 Preface

Medium-voltage or high-voltage substation equipment operates in a variety of environments. Typical stressors, such as temperature, humidity, dust, and corrosive gases, affect the probability of equipment failure, so facility maintenance plans, including inspections and part replacement, must be tailored to the operating environment.

For about 20 years, our company has been working to prevent failures and accidents by utilizing thermal imaging devices and partial discharge detectors to quickly detect phenomena associated with deterioration. However, unexpected malfunctions can occur in substation equipment depending on the operating environment. To address this issue, we are developing environmental monitoring devices and providing related Operation and Maintenance (O & M) services to monitor the installation environment. In doing so, we recommend preventive maintenance measures to mitigate deterioration, and support the improvement of equipment reliability. This paper introduces the environmental monitoring devices we have developed so far and the newly upgraded features.

2 Environmental Monitoring Devices

2.1 Environmental Gas Monitor

2.1.1 Background and Purpose

Various environmental factors adversely affect electrical equipment. Among these, corrosive gases, such as hydrogen sulfide gas, can corrode and deteriorate electrical equipment even at low concentrations of only a few tens of ppb, significantly impacting the reliability of the equipment through poor continuity and insulation.

To ensure stable long-term operation of electrical equipment, it is extremely important not only to understand the deterioration state of the equipment but also to understand these environmental factors.

2.1.2 Features

This device enables continuous, long-term measurement of low-concentration corrosive gases on the order of tens of ppb, which have previously been difficult to measure.

The target gases are hydrogen sulfide, nitrogen dioxide, sulfur dioxide, chlorine, ammonia, and ozone. By replacing the various sensors, the concentration of each gas can be measured. The monitor also features an external output function (4-20 mA), which, when combined with a logger or

transmission device, facilitates recording and understanding of environmental changes, enabling efficient monitoring and management of electrical equipment. Fig. 1 shows the environmental gas monitor.

2.1.3 Monitoring Examples

In sewage treatment plants and incineration plants, corrosive hydrogen sulfide gas is generated during the treatment process, which can corrode electrical equipment. Therefore, we verified the effectiveness and performance quantification (visualization) of this device at a sewage treatment facility. A high correlation of hydrogen sulfide gas concentrations was observed between this device and gas detector tube. Fig. 2 shows a comparison of the measurement results of this device and gas detector tubes. Fig. 3 also shows an example of confirming the effectiveness of a photocatalytic corrosive gas decomposition device (AirPurif※1) in reducing hydrogen sulfide gas in a control panel.

2.1.4 Future Developments

This device enables us to quantify (visualize) corrosive gases, allowing us to propose appropriate countermeasures and responses tailored to the installation environment (operating conditions). This condition-based maintenance (CBM) solution service is expected to significantly contribute to optimizing our customers' facility maintenance plans.

2.2 Environmental Diagnostic Sensor

2.2.1 Background and Purpose

A variety of environmental stressors, including temperature and humidity, dust, and corrosive gases, are among the factors that contribute to the deterioration of electrical equipment. Monitoring these installation environments and quickly elimi-

Fig. 1 Environmental Gas Monitor

It shows an external appearance of the environmental gas monitor. This is a joint development product made by the company and Meiden Hokuto Corporation. It makes a long-time monitoring of corrosive gases in low concentration.

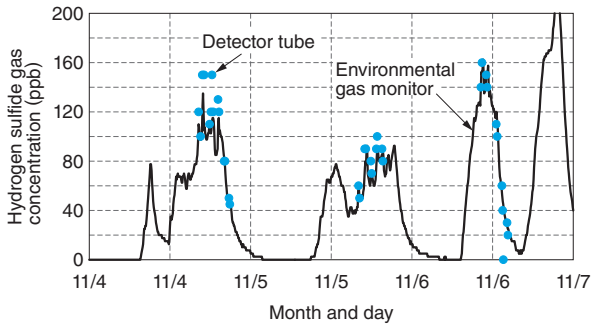


Fig. 2 Comparison Example on the Gas Concentration Measurement Results between Gas Detector Tube and Environmental Gas Monitor

Based on a comparison between the gas detector and this device, a high correlation has been confirmed.

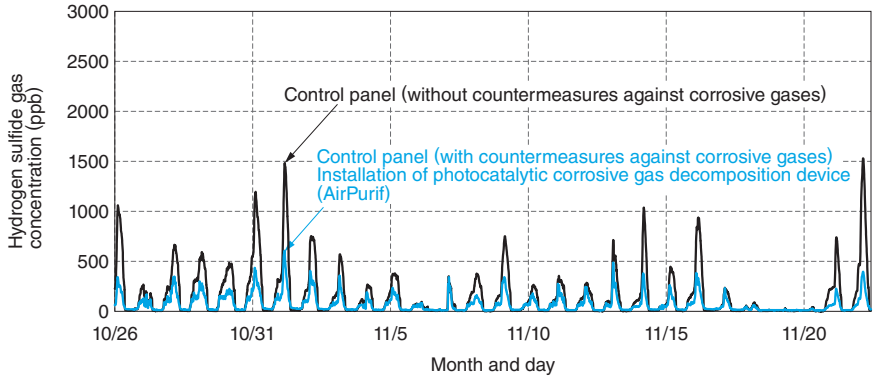


Fig. 3 Confirmed Example of Effect of Hydrogen Sulfide Gas Reduction

This allows confirmation of the difference in hydrogen sulfide gas concentration (reduction effect) depending on whether or not a photocatalytic corrosive gas decomposition device (AirPurif) is installed. It also allows confirmation of concentration fluctuations due to the operation status of the equipment (once per day).

Fig. 4 Electrical Contact Deterioration Trend Sensor

This shows the appearance of the electrical contact deterioration trend sensor. This is a practical level sensor (auxiliary relay) that monitors corrosive environments by detecting increases in contact resistance.

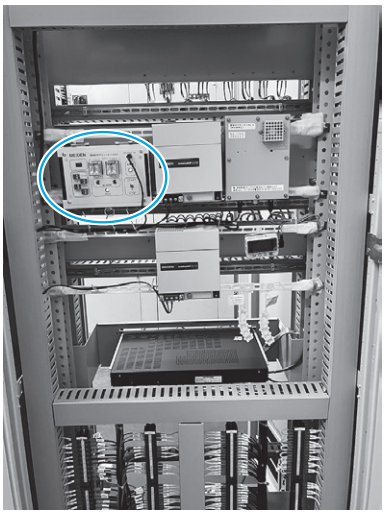


Fig. 5 Installation Status of an Electrical Contact Deterioration Trend Sensor Inside a Cubicle

An example of the installation of an electrical contact deterioration trend sensor inside a cubicle is shown.

Fig. 6 Electrical Insulation Contamination Degradation Trend Sensor

This shows the appearance of the electrical insulation contamination degradation trend sensor (prototype). The contamination accumulation sensor monitors the trend of insulation degradation.

nating or mitigating factors that adversely affect equipment are extremely important for preventive maintenance.

The electrical contact deterioration trend sensor monitors for signs of poor contact continuity due to corrosion and contamination of control equipment at the actual equipment level. Additionally, the electrical insulation contamination deterioration trend sensor, currently under development and verification, uses a contamination accumulation sensor to predict signs of insulation degradation due to changes in the contamination level and ambient temperature and humidity within the electrical cubicle.

2.2.2 Features

(1) Electrical Contact Deterioration Trend Sensor: This compact, lightweight, on-site stationary sensor can be installed inside a cubicle. It exposes auxiliary relays, which are sensitive to the same corrosive environment as those used in the actual equipment, to the actual environment and continuously monitors contact resistance, a barometer of corrosion progression. **Fig. 4** shows the appearance of the electrical contact deterioration trend sensor. **Fig. 5** shows an example of its installation within a cubicle. In addition to standalone use, this sensor can also be used for real-time remote monitoring using its communication functions[1].

(2) Electrical Insulation Contamination Degradation Trend Sensor: Performance degradation (insulation degradation) of electrical insulation used in electrical equipment is significantly affected by surface contamination and changes in ambient temperature and humidity. These environmental changes are correlated with leakage current from insulation. This sensor is a small, lightweight, on-site stationary type that can be installed within a cubicle. It uses sensors such as comb-shaped electrodes to detect accumulated contamination and predict the progression of insulation degradation from leakage current trends. **Fig. 6** shows the appearance of the prototype electrical insulation contamination degradation trend sensor, and **Fig. 7** shows an example of its installation within a cubicle[2].

2.2.3 Monitoring Examples

(1) Electrical Contact Deterioration Trend Sensor:

Fig. 7 **Installation of an Electrical Insulation Contamination Degradation Trend Sensor Inside a Cubicle**

An example of the installation of an electrical insulation contamination degradation trend sensor inside a cubicle is shown.

Fig. 8 shows a monitoring example at a sewage treatment plant. Compared to the monitoring room, where corrosive gas concentrations were extremely low, data from the electrical room of the treatment facility showed an increase in contact resistance within just a few days, indicating high environmental stress. This could lead to poor contact in control equipment and other system failures.

(2) Electrical Insulation Contamination Degradation Trend Sensor: We installed this sensor in our outdoor JIS-certified cubicles to collect data and verify its effectiveness. **Fig. 9** shows a measurement example. Under conditions where condensation is likely to occur inside the panel (low humidity number level(※2)), an increase in leakage current can be confirmed. Based on the contamination level inside the cubicle, it is expected that insulation degradation of key equipment will be predicted.

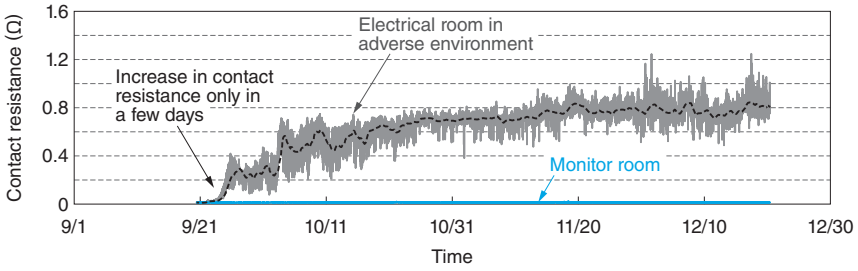


Fig. 8 **Monitoring Example**

This shows the change in contact resistance over time in each electrical room. In the electrical room with a poor environment, an increase in contact resistance can be seen in just a few days.

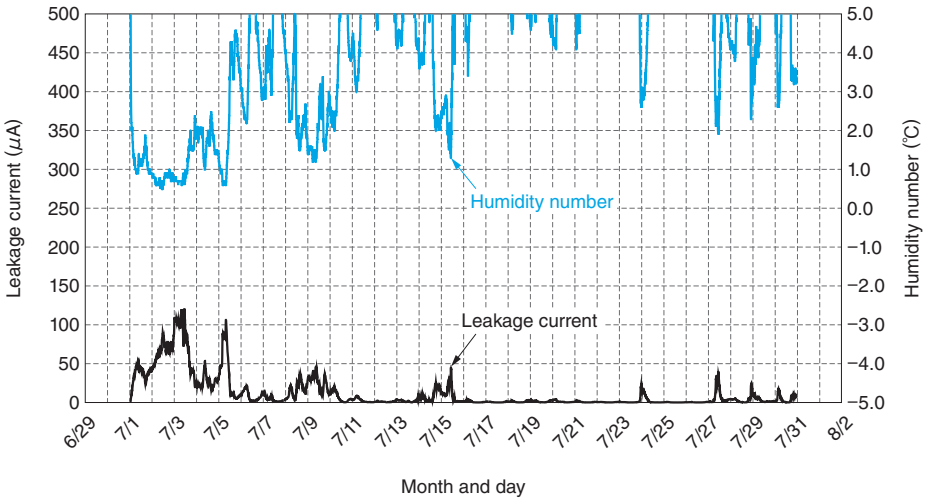


Fig. 9 **Measurement Example**

This shows the change in leakage current due to contamination and moisture absorption. In environments prone to condensation, an increase in leakage current can be confirmed, allowing for prediction of insulation degradation. The smaller the humidity number (the difference between the temperature inside the panel and the dew point), the greater the increase in leakage current.

2.2.4 Future Developments

We will utilize this sensor in our O & M services to help optimize customer's facility maintenance plans, including responding to environmental factors that vary from facility to facility, and implementing part replacement and repairs, thereby contributing to preventing equipment problems caused by environmental factors and reducing the risk of failure.

2.3 Insulation Degradation Monitoring Device (Insulation Degradation Early Sign Monitoring)

2.3.1 Background and Purpose

We developed an insulation degradation monitoring device that monitors environmental stressors, such as temperature, humidity (dew point temperature), and contamination level (equivalent salt deposition density), to detect signs of insulation degradation. We are currently testing and enhancing its functionality. This device uses a formula based on our own testing to estimate the contamination level accumulated over a year based on the annual amount of airborne dust at the measurement location. It then calculates the humidity number from the temperature, humidity, and dew point temperature of the insulation surface to predict insulation degradation. **Fig. 10** shows the device's exterior and configuration.

In addition to this functionality, we have added demand monitoring of humidity level, an important indicator for condensation alarms, a function to notify in advance the need for measures to prevent condensation and insulation degradation, a digital output (DO) for operating the dehumidifier, and a mobile phone (LTE) communication function for easily displaying and checking the status on the screen from an external device. We are currently testing[(3)] these features.

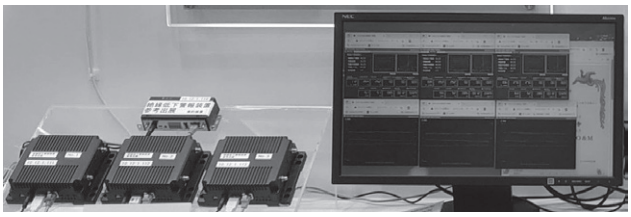
2.3.2 Added Functions

(1) Humidity Number Demand Function: Monitoring humidity number, which indicates the likelihood of condensation, is a key indicator for preventing insulation degradation. Therefore, we believe that predicting humidity number one hour in advance will function as a highly accurate monitoring device.

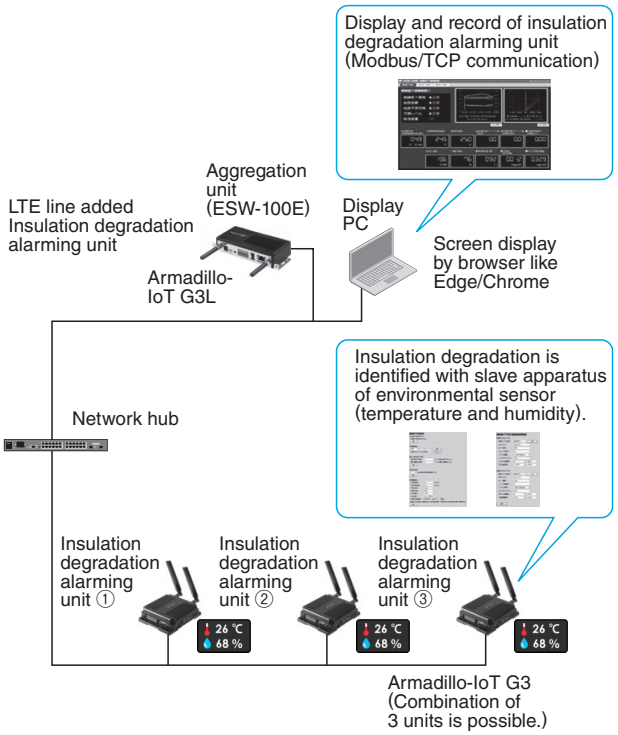
Previously, an alarm for a warning level of insulation resistance degradation was issued when the humidity number was below 3℃, the predicted equivalent salt deposition density was at a medium contamination level, and the relative humidity was at 70%. In addition, we have added a function that manages the 10-minute moving average and humidity number change trend, creates a demand graph of the likelihood of condensation, and issues a pre-condensation alarm if the rate of increase exceeds a certain level. This prevents humidity number degradation before it occurs. **Fig. 11** shows an example of a humidity number demand graph.

(2) DO Function: During the device's testing process, we confirmed that the insulation degradation prediction function worked well, so we added a new DO function. This allows for more efficient operation of the dehumidifier.

(3) LTE Communication Capability: Previously, the monitoring system only used Ethernet. However, with this upgrade, we have implemented LTE communication capabilities over mobile phone lines,



(a) External appearance



(b) Configuration image

Fig. 10 Insulation Degradation Monitoring Device

This shows the exterior and configuration of the insulation degradation monitoring device.

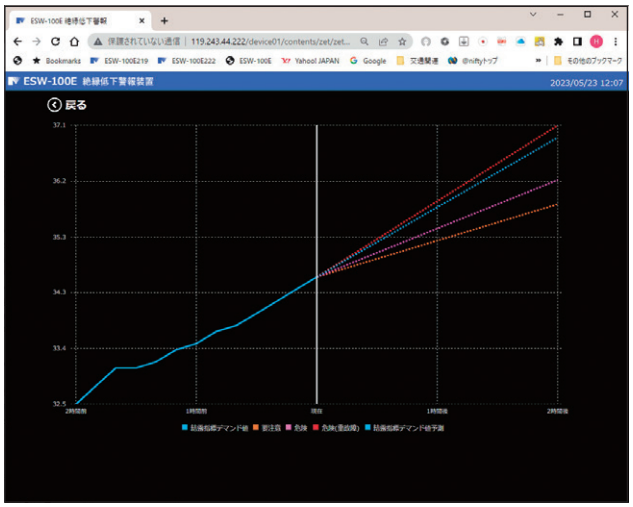


Fig. 11 Example of a Humidity Number Demand Graph

This shows an example of the condensation prediction function. Condensation is predicted by managing the humidity number trend.

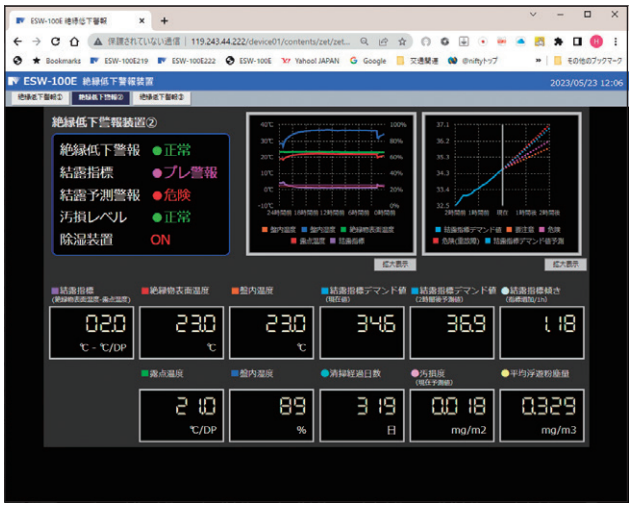


Fig. 12 Example of a Measurement Screen

This shows the measurement screen of the insulation degradation monitoring device. The display screen has been changed to accommodate the addition of the humidity number demand function.

making monitoring even easier. Since the data can be displayed on a standard browser, it can also be displayed on mobile devices such as smartphones.

2.3.3 Monitoring Example

This device was installed in a JIS-certified outdoor cubicle at our company, and we are currently continuing to verify data acquisition and effectiveness. Fig. 12 shows an example of the overall measurement screen.

2.3.4 Future Developments

This device is currently being used as a display screen for verification. In the future, we aim to make the screen easier to understand, improve the data output method, and integrate it with other installed environmental monitoring devices for practical use.

3 Postscript

This article presents some examples of our efforts in developing environmental Monitoring Technology.

Going forward, we intend to develop the integration technology for the environmental monitoring devices described in this paper and expand and promote it in our O & M services. This will help our customers plan and develop preventive maintenance plans (inspections, repairs, and upgrades), and we will strive to provide customer-driven services.

(Notes)

※1. AirPurif: An air purifier that uses Photocatalytic oxidation (PCO) to break down harmful gases and pollutants.

※2. The humidity number: Calculated by subtracting the dew point temperature from the air temperature, the humidity number is a weather forecasting term that indicates the amount of water vapor in the air (humidity). The smaller the value, the more water vapor the air contains, and the higher the humidity. A humidity number below 3℃ increases the likelihood of condensation, making clouds and precipitation more likely.

《References》

(1) Hitoshi Kiryu, Kazuhiro Noda: "Environment Diagnostic Technology that Supports Optimization of Facility Maintenance", Meiden Jiho Volume 369, 2024/No.4, pp.6-9

(2) "Development of an Electrical Insulation Contamination Degradation Trend Sensor", Meiden Jiho Volume 370, 2021/No.1, p.28

(3) Hitoshi Kiryu, Kazuhiro Noda: "Environmental Diagnostic Technology that Supports Optimization of Facility Maintenance", Meiden Jiho Volume 369, 2024/No.4, pp.6-9