Diagnosis Technologies for Transmission & Distribution (T & D) Products

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Abstract

A Gas Insulated Switchgear (GIS) accommodates a current interrupter unit and main circuit in a hermetically sealed container and is insulated by a sulfur hexafluoride (SF_6) gas. It is a major constituent element of a substation facility, and requires high reliability and safety. To realize the labor saving and streamlining of the related maintenance and inspection work as well as the reduction of failure occurrence rate of GIS, the market currently calls for the transformation on the maintenance method from the Time Based Maintenance (TBM) to the Condition Based Maintenance (CBM). Against such background, we have been working on the development of maintenance technologies to monitor the status of GIS, detect a sign of failure, and perform diagnosis to check any equipment. Since the condition monitoring device is designed to grasp signs of failure before the occurrence of equipment failure, it can provide benefits to the customer in terms of extension of equipment operational life, streamlining of inspection work, and reliable and safe operation of facility equipment. We improved the reliability of our condition monitoring device by passing tests stipulated JEC Standard in Japan and by conducting non-standard performance verification tests.

1 Preface

For the maintenance of the Gas Insulated Switchgear (GIS), the Time Based Maintenance (TBM) is commonly applied. For labor-saving and streamlining of maintenance work and for the reduction of the failure occurrence rate, the importance of the Condition Based Maintenance (CBM) is highlighted. The CBM refers to a maintenance method under which the status of equipment or facility is continuously monitored, and if any abnormality is found, maintenance work is conducted. Since the condition monitoring device can grasp a sign of failure before the occurrence of equipment failure, we can set up a retrofit or renovation plan in advance, thus providing benefits to the customers of extension of equipment operational life, streamlining of inspection work, and offering reliable and safe facility equipment operation.

In 2008, we commercialized the vacuum monitoring unit (VM-100) that monitors the vacuum degree in the Vacuum Interrupter (VI). Since then, this product has been delivered to both customers at home and abroad. As a successor model, we have newly developed the condition monitoring device (CMD-200). In addition to the regular function of monitoring the degree reduction of the VI vacuum, it now monitors and diagnoses the presence of partial discharges inside the GIS, trends in gas pressure, and operating time of the installed units. This paper introduces the features of the condition monitoring device and shows the results of the JEC Standard tests and other additionally performed non-JEC Standard reliability verification tests.

2 Specifications and Construction

Fig. 1 shows an external appearance of the condition monitoring device (CMD-200). This product is composed of three components: the instrumentation board, the monitoring/communication board, and the power board. The instrumentation board measures various data and the monitoring/communication board gathers and saves the data from the instrumentation board so that it can identify the presence of any sign of failure.

The front panel has status display LEDs, operation buttons, and a USB port. By using the front panel, an operator can check the designated items status, perform the operation and data retrieval. Dimensions of the panel are W140 × H220 × D133mm. This product is put inside the Cubicle type Gas Insulated Switchgear (C-GIS) for indoor or outdoor installation. Fig. 2 shows the condition monitoring device installed in the C-GIS.

Fig. 1 Condition Monitoring Device (CMD-200)

External appearance of condition monitoring device (CMD-200) is shown. This product is put inside the Cubicle type Gas Insulated Switchgear (C-GIS) for indoor or outdoor installation.

Fig. 2 Condition Monitoring Device Installed in the C-GIS

A condition monitoring device installed in the C-GIS is shown. It is installed inside the enclosed panel door of the C-GIS.

3 Features

Table 1 shows a list of diagnostic spots, diagnostic Items, and diagnostic methods. The four items in the table can be diagnosed.

3.1 VI Vacuum Degree and Main Circuit Insulation Monitoring

The sensor installed inside the tank for C-GIS receives and measures (1) discharge pulse signals generated during the occurrence of VI vacuum leakage and (2) partial discharge pulse signals generated during the occurrence of main circuit insulation failure. On the received signals, the frequency filters and time-limit filters located in the diagnosis unit pick up the specific components and judge the signal level.

Fig. 3 shows the monitoring system for the VI vacuum degree and the main circuit insulation.

Table 1 List of Diagnostic Spots, Diagnostic Items, and Diagnostic Methods

A list of diagnostic spots, diagnostic items, and diagnostic methods is shown. The product can cover four diagnostic items.

Diagnostic spot	Diagnostic item	Diagnostic method
VI	Vacuum degree	Detection of pulses upon the occurrence of vacuum leakage
Main circuit	Insulation	Detection of partial discharge pulses
Tank	Gas leakage	Identification of trends in gas pressure
Mounted devises (VCB, DS and ES)※	Operating time	Identification of operating time based on control current value and auxiliary switch contact timing

Note. ※VCB: Vacuum Circuit-Breaker DS: Disconnecting Switch ES: Earthing Switch

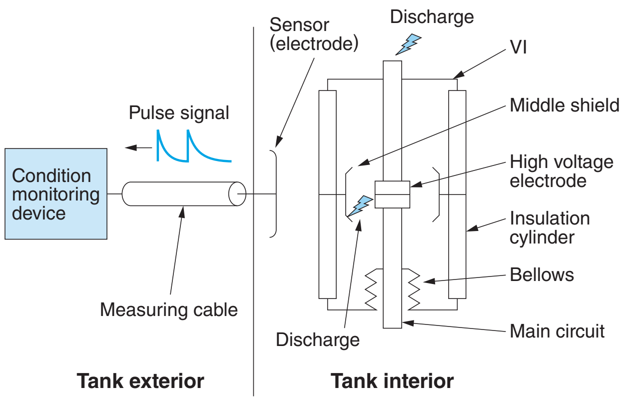

Fig. 3 Monitoring System for VI Vacuum Degree and Main Circuit Insulation

The monitoring system for VI vacuum degree and main circuit insulation is shown. Discharge pulse signals are received at a sensor in the C-GIS tank.

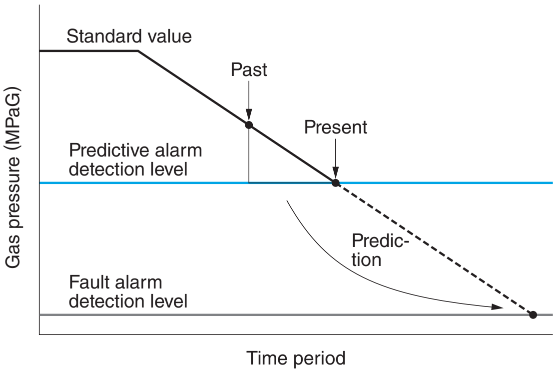

Fig. 4 Monitoring System for Tank Gas Leakage

The monitoring system for tank gas leakage is shown. When the gas pressure reaches the predictive alarm detection level, the period until the fault alarm generation moment is predicted based on the present gas pressure value and one previous point.

Table 2 List of the JEC Standard Tests (JEC-2500-2010/JEC-2501-2010)

A list for JEC Standard Performance Tests is shown. It was confirmed that the all tests were successful.

Performance	Test items	Overview of test items
Insulation	Power-frequency voltage	2kVrms-1min
	Lightning impulse voltage	±4.5kV-3times
EMC	Radio wave noise	Transceiver, Mobile phone, Wireless LAN-10s
	Damping oscillation noise	2.5kV, 1MHz-2s
	Electrostatic noise	Contact discharge: 8kV, Gaseous discharge: 15kV-10times
Vibration/ Shock	Constant vibration	16.7Hz, 0.4mm-10min
	Shock	300m/s^2, 11ms (Half wave)-3times

3.2 Tank Gas Leakage Monitoring

The initial gas pressure is set as the baseline value for comparison and a predictive alarm is generated when the gas pressure lowers to the predictive alarm detection level predetermined by the diagnosis product. According to the pressure gradient between the past and the present, the product predicts the estimated period to reach the fault alarm detection level. Fig. 4 shows the monitoring system for tank gas leakage.

3.3 Operating Time Monitoring for the Loaded Equipment

The product monitors each operating time of the Vacuum Circuit-Breaker (VCB), Disconnecting Switch (DS), and the Earthing Switch (ES). The switching operation time of the VCB is continuously monitored based on the control current value and auxiliary switch contact timing. The switching operation time of the DS and ES is always monitored based on the timing of operating contact. The two steps of alarm are possible to set a predictive alarm and fault alarm. Each alarm is generated when the condition deviates from the preset range.

4 Test Result

Table 2 shows a list of the JEC Standard Tests (JEC-2500-2010/JEC-2501-2010) which refers to "Electromagnetic Compatibility Test of Protective Relay." Each verification test was conducted on the individual condition monitoring device. The test results show the clearing of all the test item requirements under the JEC Standard. Before the product release, in order to verify the performance, we conducted other various reliability tests (other than above JEC Standard test). We conducted such tests by putting the product inside the C-GIS. We confirmed satisfactory test results.

4.1 DS Switching Surge Test

Equipment with electronic devices generally requires verifying sufficient reliability against high-frequency surges generated in the main circuit. For this reason, we checked for any malfunction due to switching surge voltage generated by the DS in the no-load charging circuit. The test conditions revealed that the applied voltage was $84/\sqrt{3}$ kV. A cable (900pF) was connected as a load, and switching was respectively repeated 200 times continuously. The test result indicated that the monitoring device did not cause any malfunction even under the switching surge voltage generated. Fig. 5 shows the behavior of the discharge at the time of DS switching surge test.

4.2 Short-Circuit Surge Test

In addition to the aforementioned DS switching surges, it was also necessary to consider short-circuit surges generated when VCB fault currents were interrupted. The test conditions were that the applied voltage was 84kV, the breaking current was 31.5kA, and a current breaking failure was simulated in a domain where the installed VCB could not interrupt the fault currents. We confirmed the product did not have any malfunction even under such generated switching surge voltage.

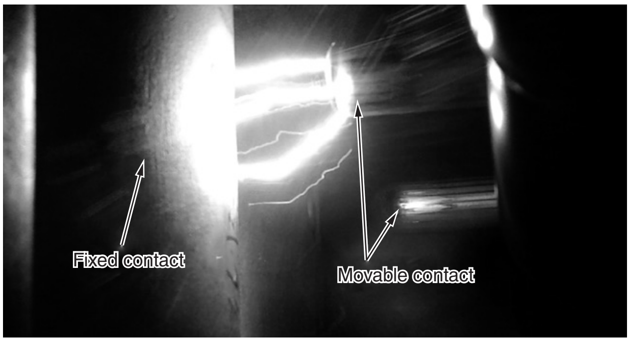

Fig. 5 Behavior of Discharge at the Time of DS Switching Surge Test

The behavior of discharge at the time of DS switching in the C-GIS is shown.

4.3 VCB Switching Surge Vibration Test

The vibration generated during VCB switching operation may cause reduced life-span of a product or its gas density sensors and may cause a malfunction. By putting the product inside the C-GIS, we conducted a continuous switching test using the VCB that will cause a strong vibration effect. The test result shows that there was no malfunction of the product before or after testing. In addition, we measured the distortion in gas density sensors during the VCB switching operation and conducted the acceleration measurement test. The test shows that the distortion and acceleration value were equal to or less than the reference value.

4.4 Sensor Reliability Test

4.4.1 Accelerated Deterioration Test

As a reliability test for the pressure measuring gas density sensor applied to the diagnostic product, we conducted a long-term accelerated degradation test and confirmed the output was stable. For this testing, two gas density sensors were attached to the test tank filled with a sulfur hexafluoride (SF_6) gas (0.16MPaG). The ambient temperature of thermostatic chamber was set at 70℃ Constant and we conducted the test for 11.5 months (equivalent to about 30 years by conversion at 20℃). **Fig. 6** shows the output characteristics for the accelerated degradation test. Variation in output against the initial value of the reference value for the sensor is about −4.5% equivalent to 30 years by conversion. This product may malfunction if −4% of output change occurs. If we correct the variation of the sensor output every three years, this would be equivalent to a maximum of about −0.45% deviation. In doing so, we could secure sufficient reliability.

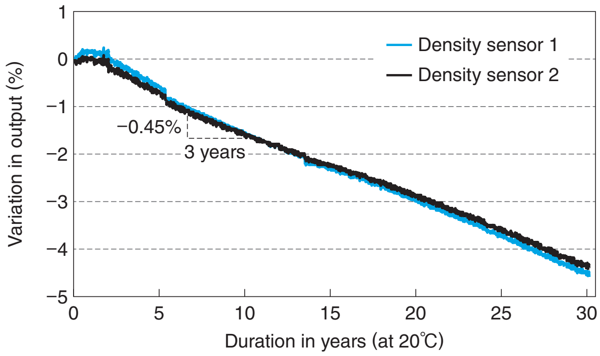

Fig. 6 Output Characteristics for Accelerated Degradation Test

The output characteristics at the time of accelerated degradation test are shown. In approximately 30 years (conversion at 20℃), about −4.5% of output variation arises against the initial pressure value of the reference value for the sensor.

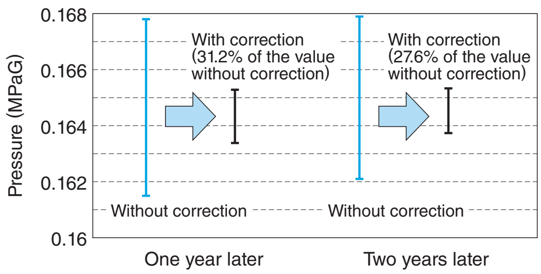

Fig. 7 Output Characteristics for Field Test

The output characteristics for the field test are shown. For both values in one year and two years later, output variations are suppressed by the thermal correction.

4.4.2 Field Test

A gas density sensor for pressure measurement was put inside the C-GIS and we conducted the field test for two years. **Fig. 7** shows the output characteristics for the field test. One year after the start of testing, the output deviation was 0.0061MPa. We corrected the variation into 0.0019MPa (31.2% before correction) as a result of thermal correction by means of the ambient temperature. When the output level was compared between the value of one year later and that of two years later, the value of two years later shows the output characteristics slightly raised overall. With this data, we confirmed that the data matches well the result of the accelerated degradation test.

As indicated by the accelerated degradation characteristics described in **4.4.1** above, we can reduce an error due to output variations by correcting the output variation value every three years. When we make thermal correction as per **4.4.2** above together with the variation correction of the sensor output every three years, we can make more accurate gas pressure monitoring. In doing so, such actions will lead to the prevention of malfunction of the diagnosis product.

5 Postscript

This paper introduced our condition monitoring device. In addition to the JEC Standard tests, the surge test and the switching vibration test were additionally carried out for the reliability test. With these extra tests, we confirmed that this monitoring device did not malfunction. By taking into account of the output characteristics of the pressure measuring gas density sensor to be applied to this diagnosis product, the monitoring accuracy for gas pressure was greatly improved.

Going forward, we will work on the use of the cloud computing services and we will streamline the monitoring and diagnosis work.