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Study Committee B3

Substations and Electrical Installations

Paper ID_B3-10739

Development of sensing tools for construction of digital substations and enhancement of reliability through early identification of facility abnormalities

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Motivation

- Power transmission and distribution companies in Japan are facing challenges such as a decrease in personnel and the aging of equipment.
- Information and Communication Technology (ICT) and Internet of Things (IoT) technologies are becoming increasingly advanced. Utilizing such digital technologies will help to resolve these issues.
- The authors have a considerable amount of maintenance data and know-how, and when combined with digital technology, the outcome will be improved maintenance and reliability.

Method/Approach

- Our method/approach is different from newly-installed equipment and existing equipment for realization of digital substation.

(For newly-installed equipment and full digitalization)

- Past failures are also reviewed, and monitoring items and sensors useful for abnormality and degradation diagnosis, life assessment, and maintenance efficiency improvements are determined.
- Smart GIS can detect about 90% of cases of technical trouble leading to electrical accidents, main circuit performance abnormalities, and switching function abnormalities via sensors. Full digitalization, which aids such equipment maintenance, is applied to newly-installed equipment.

Method/Approach

(For existing equipment and partial digitalization)

- Existing equipment is somewhat more difficult to digitalize compared to new installations, but existing equipment is also more likely to cause problems, so the need for its digitalization is high.
- It is important to partially digitalize such equipment. Here, the technology for constantly monitoring the partial discharge (PD) of bushings is presented after this page.

Processing of sensor acquisition information and system construction

- The application of sensors to smart equipment and the construction of an upper-level transmission network are carried out with the construction or replacement of equipment.
- The sensor information is stored in a server, which enables online monitoring from a remote office such as a control center.
- The authors are also investigating the use of this data to predict abnormal trends through big data analysis in conjunction with equipment management systems, to automate maintenance planning based on equipment diagnosis results, and to link the information with asset management systems.

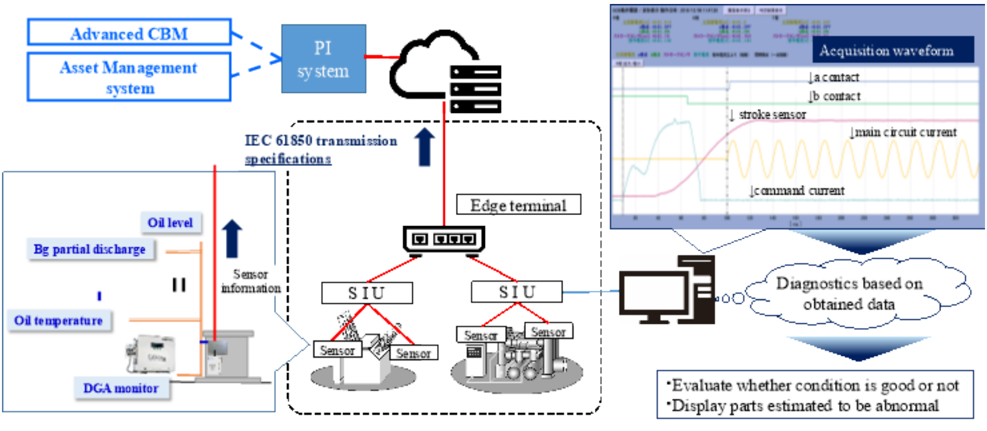

Figure 1 Network systems with smart sensors in substation equipment

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continued

Smart GIS

- Figure 2 shows the locations of smart GIS sensors, and Table Ⅰ shows monitoring items and sensors implemented.
- Gas pressure monitoring in GIS with higher accuracy becomes possible by carrying out corrections using atmospheric pressure in addition to tank temperature, along with slow leak detection using trend data in addition to assessments using reference values, and the early detection of gas leakage through seal performance degradation.
- Instantaneous pressure rises of an internal GIS fault may be caught, and the location may be specified without carrying out gas analysis in the field.
- In this paper, another smart equipment such as GIS and SIS are presented at detail.

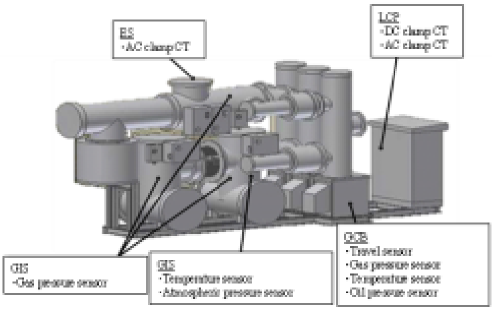

Figure 2 300 kV smart GIS sensor implementation

Table Ⅰ Smart GIS monitoring items and sensors implemented

Equipment	Monitoring items	Sensor	Purpose		
			Degradation diagnosis	Life assessment	Efficiency of maintenance
GIS Overall	Gas pressure	Gas pressure sensor	✓	✓	✓
	Slow leak	Temperature sensor			
	Fault location	Atmospheric pressure sensor			
GCB	Operating characteristics	DC clamp CT	✓		✓
		Travel sensor			
		Temperature sensor			
		Auxiliary switch			
	Operation mechanism energy storage	DC clamp CT	✓		✓
		AC clamp CT			
		Oil pressure sensor			
	Contact consumption	AC clamp CT		✓	✓
		Travel sensor			
		Auxiliary switch			
DS/ES	Operating characteristics	DC clamp CT	✓		✓
		Operation check switch			
		Temperature sensor			
	Contact consumption	AC clamp CT		✓	✓
		Operation check switch			

Diagnostic algorithms

- Data acquired by various sensors are first stored in the integration equipment.

Arc contact in GCB

- GCB arc contact residual life is evaluated by calculating the breaking energy proportional to the contact consumption.
- Contact consumption amount V per opening operation is proportional to the opening current integral over.
- Reference value of breaking current integral was set as cumulative breaking current when the rated breaking current in the type test was interrupted 10 times.

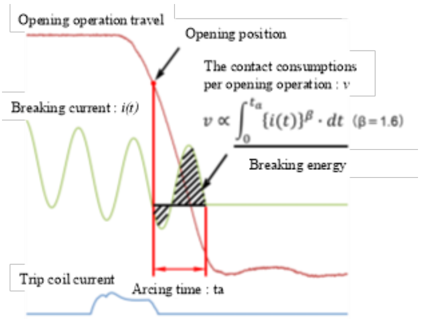

Figure 3 Method for calculating the contact consumption

Gas leakage

- The gas leak monitoring is evaluated by calculating the total gas quantity in the tank and monitoring the trend.
- Gas leak rate is calculated by first approximation from the trend data for the total gas quantity.

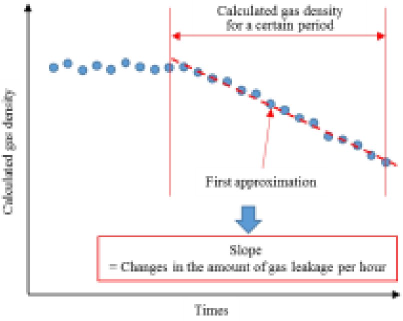

Figure 4 Calculation method for gas leak rate

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Maintenance of RIP bushing

- TEPCO PG has experienced dielectric breakdown incidents of resin impregnated paper bushings in oil insulated switchgear caused by electrode peeling due to moisture absorption in paper, and has carried out PD diagnosis using an AE sensor.
- Surface current sensor has been applied in the PD diagnosis for resin impregnated paper bushing since 2020.

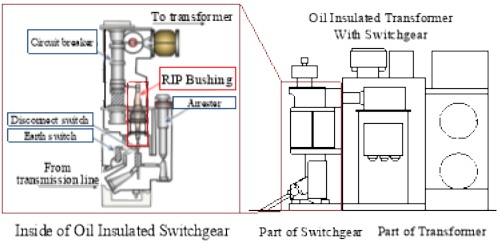

Figure 5 Application of resin bushings in oil insulated switchgear

On-line PD monitoring device with automatic diagnosis

- A stationary on-line monitoring device, the composition of was developed along with a manufacturer. The device simplifies the sensor assembly by limiting the monitored object to the RIP bushing in the oil filled equipment.
- It is possible to implement less expensive hardware in the monitoring device if the frequency and volume of PD events has been clarified previously.

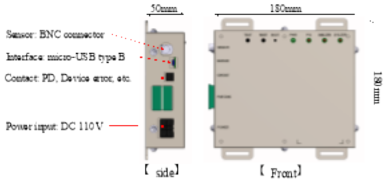

Figure 8 Appearance of stationary on-line PD monitoring device with automatic diagnosis

Discharge detection test

- This study produced the relationship between the charge quantity of PD and sensor output and frequency characteristics in the AE sensor and surface current sensor.
- A maximum of 38 kV was applied to the test bushing in the tank, and we confirmed the correlation between the magnitude of each sensor output signal and the amount of discharge.

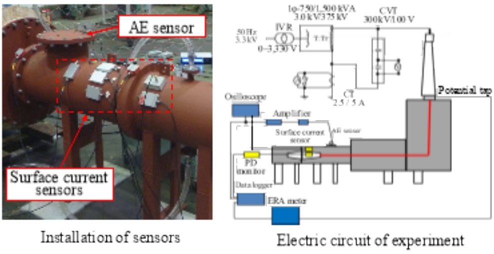

Figure 6 Construction of experimental system

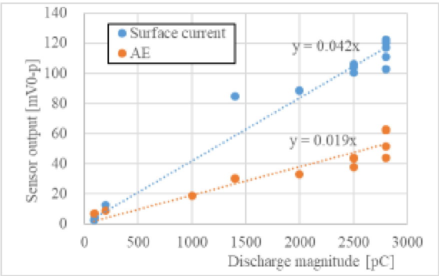

Figure 7 Experiment results of correlation between sensor output and amount of discharge

Field noise and threshold value setting

- Measurement results of field noise were 10 ~ 40 $mV_{0\text{-}p}$ (zero to peak voltage) in each substation.
- Although there is a need to detect the PD of as small a level as possible, the threshold value should be set at 84 mV0-p (deserving equal to amount of discharge at 2 000 pC) for the following reasons.

✓ Noise occurs at about 40 mV0-p in the field.

✓ As on-line monitoring was realized, conservative control value setting was unnecessary.

(PD of several tens of thousands pC or more is observed before breakdown.)

Schedule and application effects

- About 60 stationary on-line monitoring devices have been installed on the top 20% of high-risk equipment (high moisture content in paper) in 2021.
- It is scheduled to be installed on all 270 units of the same type of equipment in our company after 2022.
- Installation on all units is expected to be a savings of 2970 hours/year in maintenance time.

Conclusion

- Smart enhancement of various devices has been discussed.
- To further enhance the diagnostic algorithms, sensor data is being extracted from actual machines, and correction methods are being reviewed.
- This diagnostic algorithm is used in SIU at present, it will be mounted on the data server of the higher rank in future.