Comprehensive Diagnostic Evaluation Method for Power Receiving Substation Facilities and Various Live-Line State Diagnostic Technologies

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Abstract

To evaluate for the state of deterioration in substation facilities, there is a useful method which uses the evaluation points. For the maintenance field, we applied a diagnostic evaluation method based on the risk level. This method is devised so that the influence degree for each facility of the diagnostic object is taken into consideration. By this diagnostic approach, the social or economic influence degree for each substation is added to the evaluation points defined by conventional deterioration diagnosis so that evaluation can be accomplished based on more realistic risk level. In addition, we calculated costs for repairing the critical items revealed by deterioration diagnosis and renovation services. We also produced the resultant evaluation points assumed to carry out such repair services as an output of the result of secondary diagnosis. We devised a comprehensive diagnostic evaluation method for substation facilities by clarifying the cost performance.

1 Preface

Recently, for renovation project of substation facilities, verifying the adequacy is essential. We help our customers in their decision to renovate their facilities or extend the operational life. We offer renovation proposals to our customers based on our facility diagnosis by the deterioration evaluation table.

This paper introduces the comprehensive diagnostic evaluation method which is an improved evaluation method built on the conventional deterioration evaluation method. We also introduce an example of environmental diagnosis and partial discharge diagnosis adopted in the latest evaluation.

2 Comprehensive Diagnostic Evaluation Method for Substation Facilities

As a method of deterioration diagnosis for substation facilities, we devised an advanced and comprehensive diagnostic evaluation method. We factor the importance of facilities and cost performance and still utilize the conventional deterioration evaluation table of deterioration grade evaluation points. We offer this service to our customers as a guide for the extension of operational life of the facility by partial renovation or overall renewal of the facilities. The deterioration evaluation table utilizes the recommendations from the Telecommunication Facility Deterioration Diagnosis (Power Facility Edition) by the Ministry of Land, Infrastructure and Transport, Japan. In addition, this method employs a stricter evaluation scoring method based on the results of our diagnosis.

2.1 Example of Evaluation

There was a 15 years old outdoor cubicle since installation. To judge if this cubicle should be renovated for the extension of its operational life, we applied our comprehensive diagnostic evaluation method. We evaluated key units like switchgears inside the cubicles. We established a summary table of each panel and an overall one for substation facilities. We made a comprehensive evaluation by examining the influence level to the loads if any of the panel fails. Table 1 shows the summary table

Table 1 Summary Table of Comprehensive Diagnostic Evaluation of Transformer Panel for Lighting

The risk levels are calculated based on the evaluation points and failure influence degrees by each equipment. In addition, the cost effectiveness is clarified by calculation on paper after the completion of countermeasures taken.

			Primary evaluation							Secondary evaluation (Repair predicted evaluation)				
No.	Equipment		Evaluation points	Failure occurrence level	Influence degree	Risk level	Evaluation	Treatment	Approx. cost (thousand yen)	Evaluation points	Failure occurrence level	Influence degree	Risk level	Evaluation
1	Distribution panel		33.0	4	8	32	Risk preventive needed	Detailed inspection required	150	29.5	3	8	24	Risk preventive needed
2	Equipment in distribution panel	Relay LDG	17.2	2	7	14	Allowable	Replacement recommended	100	17.2	2	7	14	Allowable
3		Oil-immersed transformer	6.4	1	10	10	Allowable	Oil analysis, oil replacement	500	4.8	1	10	10	Allowable
4		LBS	66.4	7	8	56	Immediate treatments needed	LBS replacement needed	150	11.3	2	8	16	Allowable
Influence degree (Max.)			10					Approx. total cost	900	10				
Failure occurrence level (Max.)			7							3				
Risk level			70							30				
Risk evaluation			Immediate treatments needed							Risk preventive needed				
Comments														

of comprehensive diagnostic evaluation of transformer panel for lighting. For the primary evaluation, we calculated an approximate cost for renovation. For the secondary evaluation, another evaluation was carried out to assess the effect from the renovation. As a result, cost performance of renovation was clarified. Thus, we were able to provide accurate estimates to the customer how the repairs should be made and whether the renovation should even be made or not. In parallel to the progress of this updating program, we produced graphs according to the evaluation result of the summary table for the visualization of the project. **Fig. 1** shows a comprehensive diagnostic evaluation graph of a transformer panel for lighting.

In this case, partial discharge occurred in the high-voltage built-in Load Break Switch (LBS) in the transformer panel for lighting. Considering the potential future of the switchgear, the risk level in consideration of the influence degree was 56 and it was 70 as an overall switchgear level. These figures implied that immediate measures needed to be taken. When the LBS was replaced, its risk level went down to 16 and the risk level of the entire switchgear was 30. These risk levels were equal to the target low figures that need to be reviewed during the next inspection. This will be conducted under the planned power outage. We evaluated that the life work to extend the facility's performance was appropriate.

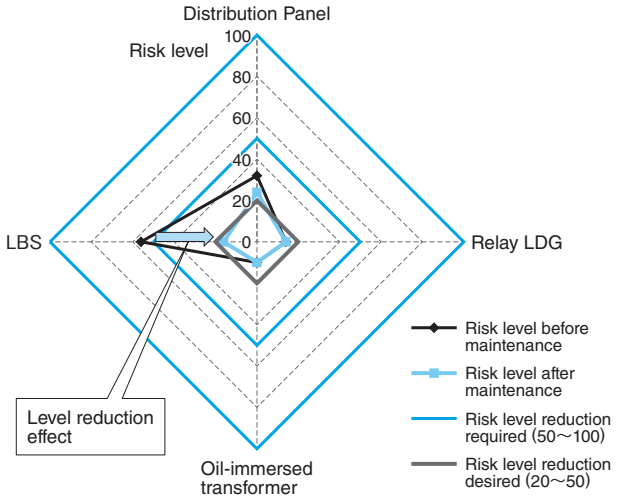


Fig. 1 Comprehensive Diagnostic Evaluation Graph of Transformer Panel for Lighting

The risk levels were expressed in a graph and we realized visualization of the evaluation results.

2.2 Environmental Diagnosis

The evaluation table of the comprehensive diagnostic evaluation method includes items of operating environmental evaluation such as amount of pollution and presence of corrosive gases in the environment. In our evaluation items, the pollution degree (equivalent adhesive salinity density, adhesive ion analysis) of the subject switchgear for deterioration evaluation is measured. In doing so, we conduct a more accurate environmental evaluation.

For an environmental evaluation on a project site, we measured the equivalent adhesive salinity density of the switchgear in a substation which was in operation for more than 5 years after the last inspection and maintenance. We compared this time-collected data with the ones measured shortly after the previous inspection and maintenance, and estimated the pollution level.

Fig. 2 shows the prediction graph of transitions in contamination levels as the value of the equivalent adhesive salinity density. According to the result of this diagnosis, it is obvious that the level of pollution in the Electric Room A is higher than the other electric rooms in three places. In this manner, it is possible to propose adequate cleaning frequency and environmental improvements. By combining the data of temperatures and humidity with those of level of pollution together, we will be able to expect application of this method to the environmental diagnostic system mainly for the risk assessment of occurrence of tracking phenomena on the insulation surface.

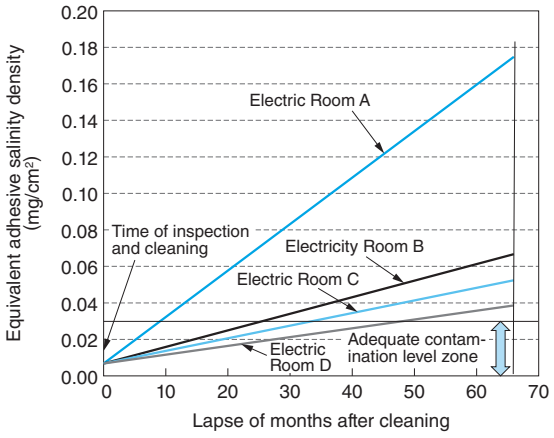


Fig. 2 **Prediction Graph of Transitions in Contamination Levels as the Value of Equivalent Adhesive Salinity Density**

Intervals of inspection and cleaning can be optimized by prediction of transitions in contamination level.

2.3 Partial Discharge Diagnosis

For the evaluation of deterioration in electrical facilities, the status check of deterioration level around insulations is important. We usually measure insulation resistance when the facilities are shut down, and carry out partial discharge diagnosis while they are in operation.

In the case of electrical facilities with high voltages, insulations give rise to harmful phenomena of partial discharges if there are insulation deterioration, surface contamination, or contact failure. Under the comprehensive diagnostic evaluation method, we detect the presence of discharge phenomena and add it in the evaluation.

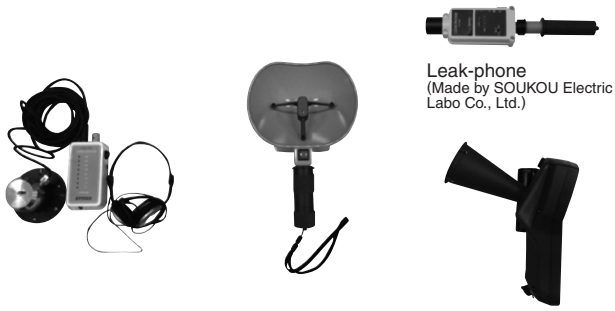
Along with the occurrence of partial discharges, a variety of phenomena such as generation of ultrasonic sound, electromagnetic waves, ultraviolet rays, impulsive current, light and heat emission, and deterioration in insulations are taking place. In this paragraph, for example, methods of partial discharge detection through ultrasonic sound, electromagnetic waves, and ultraviolet rays are introduced.

(1) Partial discharge diagnosis by ultrasonic wave detection

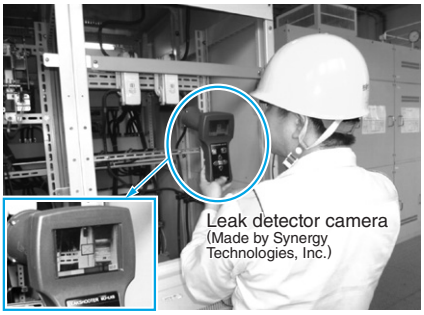
Since frequencies of partial discharge sound cannot be heard by human ears, we usually employ high-frequency measuring instruments such as high-frequency microphones and Acoustic Emission (AE) sensors for diagnosis. Fig. 3 shows an example of partial discharge diagnosis detected by an ultrasonic microphone. Fig. 4 shows an example of waveforms obtained from partial discharge diagnosis by using an AE sensor. Fig. 5 shows a view of partial discharge diagnosis by an AE sensor.

(2) Partial discharge diagnosis by electromagnetic wave detection

Partial discharges also give rise to electromagnetic waves. When these waves are detected, it is possible to grasp the presence of partial discharges. In this case, however, there can be environmental electromagnetic waves (noise) that have no relation to the partial discharges. For this reason, it is necessary to exclude this type of background noise. As a countermeasure, we use a partial discharge diagnostic unit that is capable of electromagnetic wave detection. This equipment is applicable to high-voltage switchgears and cubicles. For this equipment, we install antennas both inside and outside the cubicle to make comparison operation. In so doing, we remove external noise. Fig. 6 shows



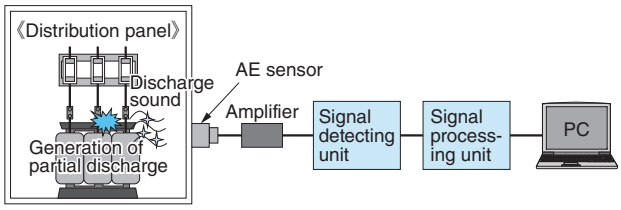
(a) Various high-frequency measuring instruments (commercial products)



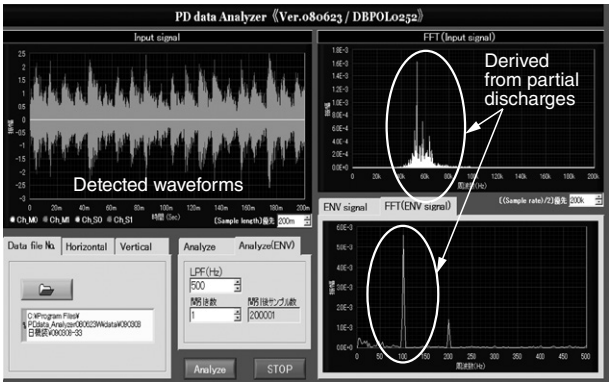
(b) A view of diagnosis by a corona detector with a camera

Fig. 3 **Example of Partial Discharge Diagnosis Detected by Ultrasonic Microphone**

Various high-frequency measuring instruments and a view of partial discharge diagnosis are shown.



(a) System configuration for partial discharge measurement by an AE Sensor



(b) Example of partial discharge signal analysis

Fig. 4 **Example of Waveforms Obtained from Partial Discharge Diagnosis by Using an AE Sensor**

System configuration for partial discharge measurement and an example of partial discharge signal analysis are shown.

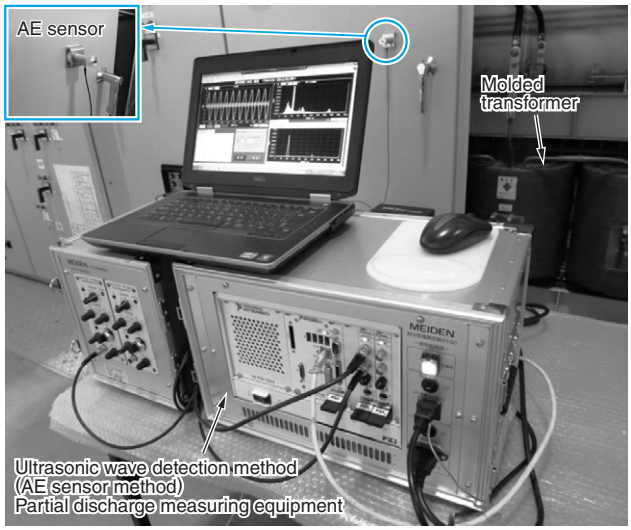
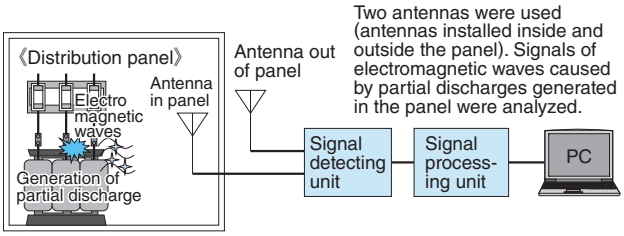
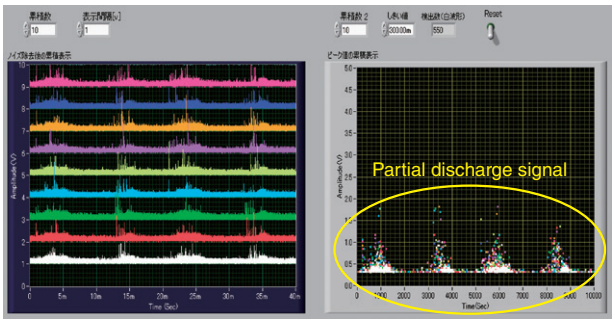


Fig. 5 **View of Partial Discharge Diagnosis by an AE Sensor**

A view of partial discharge diagnosis on a molded transformer is shown.



(a) System configuration for partial discharge measurement



(b) Example of partial discharge signal analysis

Fig. 6 **Example of Waveforms Obtained from Partial Discharge Diagnosis by Electromagnetic Wave Detection**

System configuration for partial discharge measurement and an example of signal analysis are shown.

an example of waveforms obtained from partial discharge diagnosis by electromagnetic wave detection and **Fig. 7** shows a view of partial discharge measurement by electromagnetic wave detection.

(3) Partial discharge diagnosis by using an ultraviolet camera

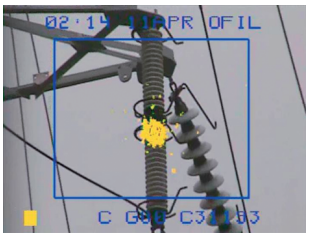
Ultraviolet rays are emitted by the effect of par-

Fig. 7 View of Partial Discharge Measurement by Electromagnetic Wave Detection

A view of partial discharge diagnosis by electromagnetic wave detection is shown.

(a) A view of diagnosis

(b) LBS



(c) 66kV steel tower

Fig. 8 Example of Partial Discharge Diagnosis by an Ultraviolet Camera

A view of partial discharge diagnosis by using an ultraviolet camera is shown.

tial discharges. When such ultraviolet rays are detected, it is possible to identify the location of partial discharge generation (insulation deterioration part). Fig. 8 shows an example of partial discharge diagnosis by using an ultraviolet camera.

3 Postscript

This paper introduced some cases of the comprehensive diagnostic evaluation method we devised, the related environmental diagnosis and partial discharge diagnosis adopted for this method.

Going forward, we will continue to develop more advanced diagnostic methods built on the use of the aforementioned comprehensive diagnostic evaluation method and the deterioration diagnostic method. At the same time, we will make proposals to our customers regarding proper facility management such as operational life extension or renovation advice.

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