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Study Committee A1
ROTATING ELECTRICAL MACHINES
Paper ID_10742

On-line Partial Discharge Monitoring System for Diagnosis of Insulation Condition in Generators

Hideyuki NAKAMURA Makoto TAKANEZAWA Takashi HARAKAWA Tomoaki TAKAHASHI Akira FUJIMOTO Abdullah AJLAN
Toshiba Energy Systems & Solutions Corporation, Japan

Motivation

- Monitoring and diagnosis for generator condition are very important to ensure the reliability of generators and to avoid an unplanned outage. Online partial discharge (PD) monitoring and diagnosis of the insulation condition of rotating machines can help avoid unplanned outages and reduce maintenance costs.
- The sensors of some online PD monitoring systems have difficulties that they should be installed inside generator or connected directly to a high-voltage line.
- A new on-line monitoring system for partial discharge with non-contact sensors with a high-voltage line has been developed and they are installed at the Isolated Phase Bus outside the generator.

Method /Approach

Fig1 shows a non-contact sensor for IPB. And Fig2 shows the proposed on-line PD monitoring system.

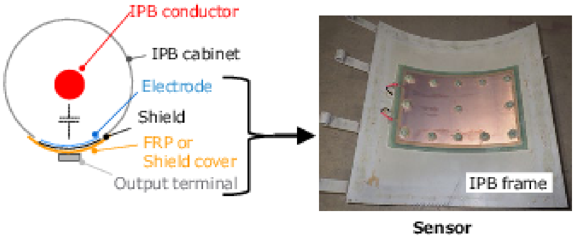


Fig.1 Non-contact senor installed on IPB frame

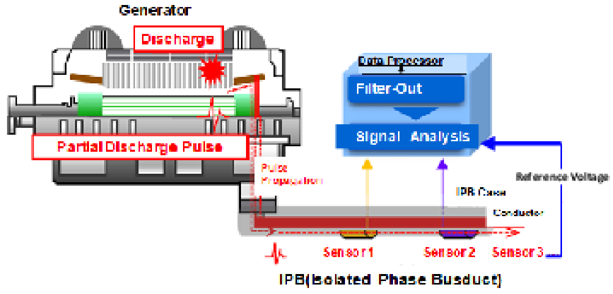


Fig.2 The proposed on-line PD monitoring system

We had verified the circuit characteristics of a non-contact sensor for IPB. Next, we had developed the noise separating technique and the measurement method of the reference voltage waveform non-contact with the main circuit.

Experimental steps

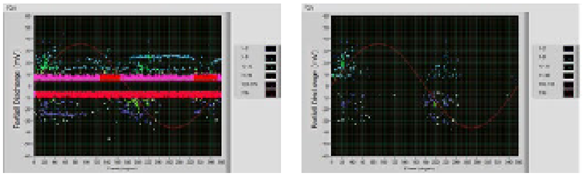
Two experiments carried out to evaluate the detection performance of PD measurement system.

1) Validation on a model bar
2) Validation on an actual generator in the factory

Measuremt result in the field

We carried out PD measurements by the proposed PD monitoring system of 5 operating generators as described in the paper.

Fig 3 shows U phase PRPD (phase resolved partial discharge) pattern of the measurement results of the 80 MVA class air-cooled generator. From the PRPD pattern after noise-separating processing, discharge pattern, discharge phase, discharge magnitude, and frequency of discharge occurrence can be clearly seen. In this figure, PD was detected between 0 °-90 ° phase and 180 °-270 ° phase, and characterized by symmetrical mostly rounded shapes. These PDs are believed to be due voids and gaps in insulation layer of stator coils, as in the previous example.



(a) Before noise separation (b) After noise separation

Fig.3 Field test data of 80 MVA Generator

Conclusion

We have developed a new on-line PD monitoring system with non-contact sensors for generators. The features of the proposed system include the following:

1) Utilization of non-contact sensors that are easily installed on the IPB of existing power stations
2) A capacitive coupling is used that there is no direct connection between IPB conductor and sensors
3) Risk from PD monitoring systems posed on the generator main circuit is minimized
4) Practical phase correction system without directly measuring the operating voltage waveform
5) Effective noise separating technique

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APPENDIX 1/2

Characteristics of a non-contact sensor

Fig.4 shows the sensor equivalent circuit. C is the capacitance between the bus-bar and a sensor, R is detection resistance and Co is the capacitance between a sensor and IPB frame.

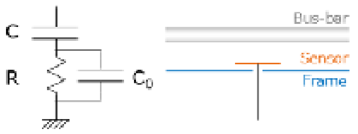

Fig.4 PD sensor equivalent circuit

Fig.5 shows the frequency characteristics of a sensor for a sine wave signal. Its parameters are Co and R.

R should be adjusted to obtain the desired frequency characteristics, because the value of Co depends on the IBP to be measured.

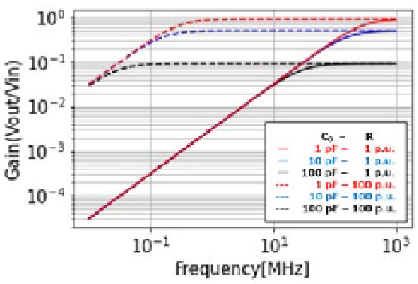

Fig.5 Detection sensitivity (Frequency characteristic)

In on-line PD detection systems, it is necessary to take into consideration two things: first is to place sensor electrode apart enough from the IPB conductor, and second is to minimize capacitance of the gap between sensor electrode and IPB frame. Also, it is a must to pay enough attention to the electrical insulation characteristics of the gap between the IPB conductor and sensor electrode.

Noise separating technique

We could separate signals coming from generator side (mainly PD signals) from signals coming from the power grid side (external noise) by using a time difference separation technique. In this separation method signal separation can be achieved by identifying signal time difference detected by several sensors placed in different locations. For example, given that there are two sensors A and B placed in the generator side and the transformer side, respectively, as illustrated in Fig. 6, if a signal is first detected by sensor A, then after some time (in range of tens of nanoseconds) detected by sensor B, this signal is said to be coming from generator side, and mostly probably is a PD signal. Conversely, if a signal is first detected by sensor B, then detected by sensor A, this signal is believed to a noise signal coming from the surrounding power system. Although distance between sensors may vary from one plant to another, our data shows that distance could be best in range of 2 m up to 20 m.

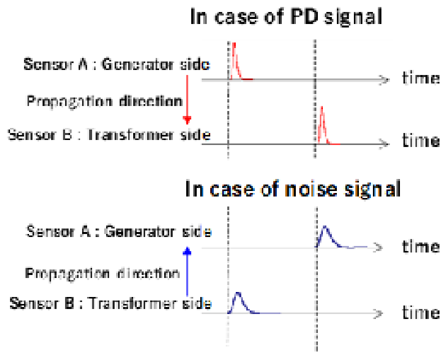

Fig.6 The principle of difference time separating technique

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APPENDIX 2/2

Measurement of reference voltage waveform

In the proposed system, in order to avoid the risk of exposing power station to any failure, we also made the measurement of the reference voltage waveform non-contact with the main circuit. Specifically, the signal of the non-contact PD sensor was used as the reference voltage waveform signal.

For phase correction, the phase correction value is calculated using network analysis, and then is input into phase shift equipment to perform the correction.

We had conducted a field test to verify our method. Fig. 6 shows the test circuit and Fig. 7 shows the results of the phase shift calculation by network analysis between the reference voltage waveform and the non-contact sensor signal.

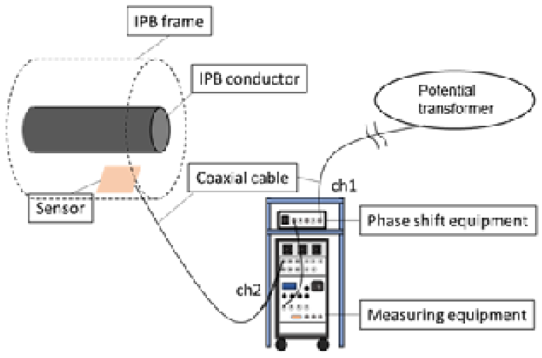


Fig.6 System configuration of phase correction tested on an 80 MVA turbine generator

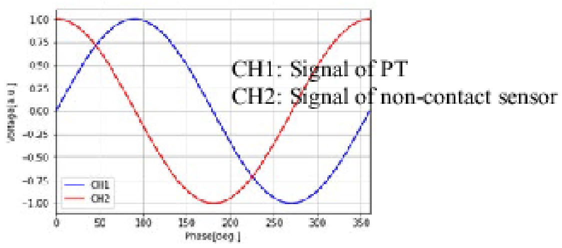
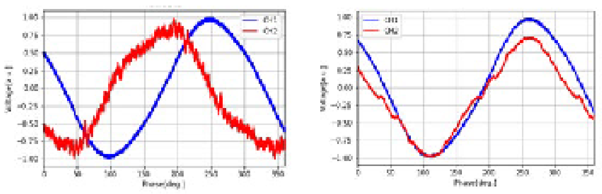


Fig.7 Network analysis result for 80 MVA turbine generator

Fig. 8 shows the results of phase correction test. Fig. 8(a) shows measurement data before phase correction and Fig. 8 (b) shows voltage waveform after phase about 90 ° shift correction. The voltage waveform of the non-contact sensor signal after phase correction almost matches the main circuit voltage measured directly from the potential transformer.



(a) Before phase correction (b) After phase correction

Fig.8 Result of field test before and after phase correction by approximately 90 ° of 80 MVA turbine generator

Validation on an Actual Generator

We validated the proposed PD measurement system on an actual generator of 1270MVA-26kV in our factory. Fig.9 shows the experiment setup of generator validation test

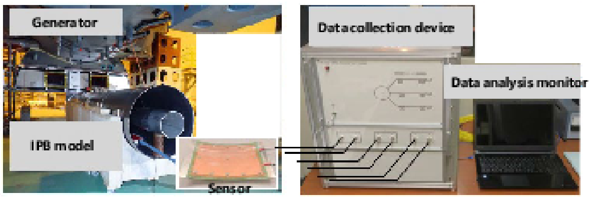
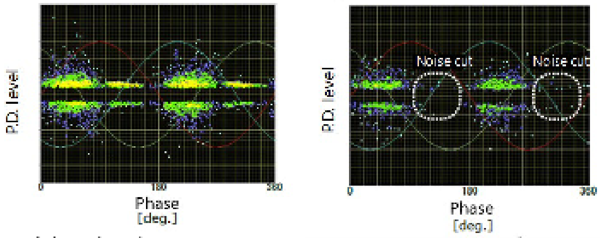
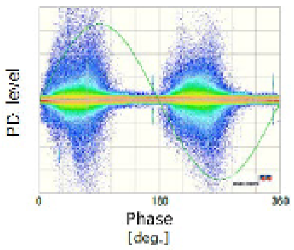


Fig.9 Experiment setup of generator validation test



(a) PD level before noise separation

(b) PD level after noise separation



(c) PD level for comparison detected by off-line system

Fig.10 Result of verification test of 1270MVA-26kV Generator