Partial Discharge Diagnosis for a Generator Potential Transformer Based on Epoxy Insulators Including Voids

Soon-Yong Kim†, Sung-min Park*, Sang-Youn Byun* and Soo-Hwan Chin*

Abstract – A generator potential transformer fault can induce a power plant trip. Voltage ratio and tan delta measurements are performed in KHNP for management of potential transformer aging. In this paper, partial discharge measurement for the generator potential transformer is introduced as an additional aging diagnosis method. IEC 60270 is adopted as the test criteria, and several MHz measurement center frequencies are also used for site environmental conditions including abundant signal noise. Developed partial discharge test equipment consists of an AC dielectric tester, a partial discharge pulse analyzer, and a partial discharge diagnosis system. Partial discharge pattern and inception voltage are analyzed based on epoxy insulators including the void and the metal particle.

Keywords: Potential transformer, Partial discharge, Epoxy insulator, Diagnosis

1. Introduction

The potential transformer installed in the generator of a nuclear power plant is used to measure the output voltage of the generator, and the measured value is used for monitoring and relay operation in nuclear power plants. An incorrect voltage value by potential transformer malfunction or failure can be related to a power plant trip, and the potential transformer is classified as SPV (Single Point Vulnerabilities) equipment. There have been several domestic and foreign potential transformer fault cases; they caused power plant trip, power plant overhaul process delay, inaccurate generation output display, and loss of external power source. A diagnostic method for potential transformer health is required for preventing dielectric breakdown of the potential transformer. Voltage ratio and tan delta measurements are performed by KHNP (Korea Hydro & Nuclear Power) during power plant overhaul as a potential transformer aging management strategy. The voltage ratio is useful for diagnosis of the insulator state between windings, and tan delta is effective for diagnosis of the general aging state of the insulator. However, these approaches are not sufficient to diagnose a partial discharge induced by local defects. Partial discharge diagnosis skills for cables and transformers have been developed for field application[1-3], but research on potential transformer partial discharge is at an early stage. Potential transformers normally use an epoxy insulator, and a concentrated electric field is induced by defects in the insulator. Consequently, the concentrated electric field can cause insulator degradation and dielectric breakdown. Voids are representative defects for the epoxy insulator, and partial discharge occurs repetitively in such voids.

In this paper, a partial discharge diagnostic method is proposed for potential transformers of nuclear power plant generators. Various epoxy insulator samples incorporating voids and metal particles are used to obtain partial discharge measurement data. IEC 60270 is adopted as the test criteria, and several MHz measurement center frequencies are also used for site environmental conditions including abundant signal noise[4]. Developed Partial discharge test system consists of an AC dielectric tester, industrial personal computer, oscilloscope, coupling capacitor, high frequency current transformer sensor, and a partial discharge diagnosis device.

2. Test Object

2.1 Epoxy insulator

It is difficult to acquire partial discharge patterns from commercial grade potential transformers. As potential transformer uses epoxy as an insulation material, an epoxy insulator incorporating voids and metal particles is required to obtain the partial discharge pattern instead of using potential transformers installed at a power plant site. Five types of epoxy insulator samples are manufactured as follows.
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A. Voids not contacted to poles
B. Voids contacted to the HV pole
C. Metal particles not contacted to poles
D. Metal particles contacted to the HV pole
E. Epoxy crack from the HV pole to the surface

Fig. 1. Sample A.

A partial discharge signal follows the windings to both poles. The signal is propagated to a coupling capacitor via the upper + pole or a high frequency current transformer sensor via the lower - pole.

2.2 Potential transformer

Fig. 3 shows the potential transformer used in KHNP. It is made by General Electric, and has a 200:1 ratio and a 24kV primary side. At Fig. 3(b), H denotes the high voltage side, and the low voltage side has two ports, X and Y. C is the capacitance of the insulation, and \( C_H, C_{HL}, \) and \( C_{HT} \) are the capacitance between the high voltage winding and the enclosure or the low voltage winding of the potential transformer. Although \( C_L, C_T, \) and \( C_{LT} \) have a defect, it is difficult to detect the partial discharge signal because the voltage level is too low. If there is a defect around the high voltage winding, the partial discharge signal can propagate through windings and the enclosure.

3. Partial Discharge Test Equipment

Partial discharge for the potential transformer can be diagnosed by energizing the low voltage side by CPC100 made by OMICRON, because the potential transformer has both high voltage and low voltage sides. An AC dielectric tester is required for the test oriented epoxy insulator because it does not have a high voltage and low voltage side. The AC dielectric tester made by PHENIX, having maximum 30kV RMS, provides power to the epoxy insulator or the high voltage side of the potential transformer, and a coupling capacitor is also connected to the AC dielectric tester as a partial discharge path. The
Partial discharge signal is transferred to MPD600 and MCU502 via the coupling capacitor, and an industrial PC running a partial discharge analysis program shows the quantity and pattern of partial discharge. A conceptual diagram of the partial discharge test equipment is shown in Fig. 4, and the established partial discharge test equipment is shown in Fig. 5.

![Partial discharge test equipment configuration.](image)

**Fig. 4.** Partial discharge test equipment configuration.

![Established partial discharge test equipment.](image)

**Fig. 5.** Established partial discharge test equipment.

### 4. PD Pattern Acquisition

Partial discharge patterns are acquired from epoxy insulator samples and potential transformers using the AC dielectric tester. They have different partial discharge inception voltages and patterns. Fig. 6 shows the partial discharge patterns and inception voltages. Partial discharge was not detected at the sample E. Measurement center frequency is 180kHz, and bandwidth is 300kHz based on IEC 60270. When center frequency is changed to higher value, partial discharge patterns are disappeared or distorted shown in Fig. 7. Partial discharge pulse can be detected by the oscilloscope. The pulse shape is clear when the suitable sampling rate is used. Fig. 8 shows the partial discharge pulse shape of sample C, and it has 400ns sampling rate.

![Partial discharge patterns of the samples.](image)

**Fig. 6.** Partial discharge patterns of the samples.

![PD patterns at the higher f_center.](image)

**Fig. 7.** PD patterns at the higher f_center.

![PD pulse shape of sample C.](image)

**Fig. 8.** PD pulse shape of sample C.
Figure 9. Partial discharge pattern of a PT sample.

Figure 10. Partial discharge test at KHNP plant site.

The partial discharge pattern presented in Fig. 9 is acquired from potential transformers that have been used in a thermal power plant and replaced after an adjacent accident. The pattern also follows the sinusoidal power source voltage, but a slightly different discharge pattern is obtained at each half cycle. Partial discharge diagnosis is performed targeting potential transformers in the KHNP plant site, and there were no unusual findings, such as that seen in Fig. 10. The corona discharge is induced by a metal angle installed at the electrode, and the corona disappears after the metal angle is eliminated.

5. Conclusion

Partial discharge patterns of epoxy insulators and potential transformers are acquired. Based on these partial discharge patterns, defect types of epoxy insulators can be estimated. Epoxy insulators have similar discharge patterns, but potential transformers have slightly different discharge patterns at each half cycle. It is difficult to standardize the quantity of partial discharge because the discharge quantity is strongly affected by environmental condition, and defect type and shape. As the next research step, a comparison of the partial discharge of potential transformers between high voltage side energization of the potential transformer via an AC dielectric tester and low voltage side energization of the potential transformer via CPC100 will be performed. The CPC100 test is for power plant site application convenience in KHNP. Established partial discharge patterns and diagnosis method will be useful for power plant site partial discharge test of potential transformers.

References


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