Analysis of Partial Discharge Spectrum Based on Ultra-High Frequency Detection Method

Qiao Guan\textsuperscript{1a}, Baofeng Xi\textsuperscript{1} and Chen Zhang\textsuperscript{1}

\textsuperscript{1} State Key Lab.of Electrical Insulation and Power Equipment, Xi’an Jiaotong University, Xi’an, Shaanxi 710049 China
\textsuperscript{a}email: 1334345788@qq.com

Abstract. Oil immersed power transformer is the most widely used large power transformer in power system and its insulation structure is mainly composed of oil, paper and other solid insulation materials. Partial discharge monitoring is an effective means to find dielectric faults of transformer in an early stage of development. Ultra-high frequency (UHF) partial discharge detection technology has high detection frequency and strong anti-interference ability, which is suitable for transformer online detection. In this paper, five typical transformer discharge models are built, and the discharge spectra of each model are measured by a UHF sensor. The test results show that the surface discharge and wedge discharge most occurs near the voltage peak, the discharge phase distribution of floating part discharge is very wide, the internal air gas discharge mostly occurs in the area where the absolute value of voltage increases, and the point-to-plane discharge has a typical polarity effect.

1. Introduction
Power transformer is one of the most important equipments in power system. The research shows partial discharge (PD) is the main factor to destroy the insulation strength of transformer\cite{1}. Therefore, the on-line monitoring of PD is of great significance.

At present, the pulse current method based on IEC 60270 standard is mostly used in the on-line monitoring of PD\cite{2}. The prominent problem of this method is the poor anti-interference ability. Compared with the traditional pulse current method, Ultra-high frequency (UHF) detection method has the advantages of strong anti-interference ability\cite{3}\cite{4}. However, the UHF Detection method has not been popularized at present.

In this paper, the PD of transformer is tested based on UHF method. Specifically, the characteristics of PD are summarized, which provides a scientific basis for PD pattern recognition based on the UHF detection method.

2. PD models and test circuit

2.1. Transformer discharge models
According to the oil paper insulation structure of the transformer, five typical discharge models are designed\cite{5}. The specific structure is as follows:

2.1.1. Internal air gap discharge
The internal air gap discharge model is shown in Figure 1 (a). Two layers of 2mm thick oil immersed insulating paperboard are sandwiched with a layer of insulating paperboard with through holes. In order
to prevent transformer oil from entering the air gap, a very thin layer of epoxy resin adhesive is used between insulating cardboard.

2.1.2. Surface discharge
As shown in Figure 1 (b), the diameters of the upper and lower plate electrodes are 25mm and 80mm respectively.

2.1.3. Floating part discharge
In Figure 1 (c), a piece of copper is fixed on the pressboard. In order to better control the part, where the discharge occurs, a sharp angle of the copper is facing the high voltage electrode.

2.1.4. Point-to-plane discharge
In Figure 1 (d), the cone angle of the needle electrode is 20°, and the radius of curvature is 0.2mm. In addition, the distance between the needle tip and the pressboard is 1.5mm.

2.1.5. Wedge discharge
As shown in Figure 1 (e), the diameter of the spherical electrode is 25 mm and it is close to the pressboard.

All models are placed in the oil cup. The pressboard shall be immersed in oil for 24 hours before the test, and the oil is placed in a vacuum drying oven for 48 hours.

2.2. Test circuit
The experiment was conducted in a PD shielding room, and the circuit diagram of the test is shown in Figure 2.
In Figure 2, $T_1$ is an autotransformer and $T_2$ is a no PD test transformer. $Z_p$ is a protective resistor, and $Z_m$ is an measuring impedance. $C_k$ is a coupling capacitor, and $C_x$ is above-mentioned PD model. The UHF sensor converts electromagnetic waves into voltage and transmits it to PD test system through a 50 $\Omega$ coaxial cable.

It is worth mentioning that the equipment included on the dotted line is placed in the shielding room.

3. Results & Discussion
For each discharge model, 10 samples were used for the PD test. In this way, the deconcentration of the results can be decreased. The discharge spectra of the five models are as follows.

3.1. Internal air gap discharge
In Figure 3, the discharges in the positive and negative half cycles are almost generated at the same time, and the shape of the spectrum is also very similar. In addition, discharge mostly occurs in the areas where the absolute value of voltage increases. With the increase of voltage, the discharge intensity increases, but the change of phase characteristics is not obvious.
3.2. Surface discharge
As shown in Figure 4, the spectral shape of surface discharge shows a typical rectangular distribution, and most discharges occur around the voltage peak.

![Figure 4. Surface discharge](image)

3.3. Floating part discharge
The spectrum of suspended discharge is shown in Figure 5, which shows that its discharge phase distribution is very wide. With the increase of voltage, the discharge intensity of negative half cycle is significantly higher than that of positive half cycle.

![Figure 5. Floating part discharge](image)
3.4. Point-to-plane discharge
Under the same voltage, the number of discharges is less than that of floating discharge. Moreover, the model of point-to-plane discharge has a typical polarity effect, and the number and amplitude of discharges in the positive half cycle are much less than those in the negative half cycle. The spectrum is shown in Figure 6.

![Figure 6. Point to plane discharge](image)

3.5. Wedge discharge
The initial voltage of the wedge discharge is high. With the increase of voltage, the discharge occurs near the voltage peak. However, the discharge intensity is lower than that of surface discharge at the same voltage.

![Figure 7. Wedge discharge](image)
4. Conclusions
Because there is no electrical connection with equipment, UHF detection method has the advantages of high precision and strong anti-interference ability. UHF on-line detection method will become a trend in the future. This paper summarizes the characteristics of UHF signals generated by partial discharge, which provides service and reference for on-line monitoring and fault diagnosis of transformer.

The internal air gas discharge mostly occurs in the area where absolute value of voltage increases; The discharge phase distribution of floating part discharge is very wide; The surface discharge and wedge discharge most occur near the voltage peak, and The latter has lower discharge intensity; The model of the point-to-plane discharge has a typical polarity effect.

However, UHF detection methods have not formed a unified test standard. At present, there is no effective technology for UHF quantification, which is also the key to the research of UHF detection technology.

Acknowledgments
The authors gratefully acknowledge the support of TBEA Smart Energy Co., Ltd and the experimental condition of State Key Laboratory of Electrical Insulation and Power Equipment in Xi’an Jiaotong University. And this work was supported by the Research Project on On Line Monitoring of Partial Discharge in Transformer (10422020201001).

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