Measurement and Analysis of Partial Discharge of Medium Voltage Power Equipment

Chih-Ju Chou
Deparment of Electric Engineering
National Taipei University of Technology
Taipei Taiwan
cjchou@ntut.edu.tw

Chien-Hsun Chen
Department of Electric Engineering
National Taipei University of Technology
Taipei Taiwan
yoshine76@gmail.com

***Abstract*—The partial discharge measurement is gradually becoming an important preventing maintenance for power apparatuses with voltage level of higher than medium voltage. In practical, however, field measurement of partial discharge is easily suffered by interferences. The measurement compatible to the apparatuses and environmental features should be considered and different discharge models should be analyzed. This paper is aimed to measure partial discharge of medium voltage power equipment under use. Firstly, the measurement method by using high frequency current transformer (HFCT) is introduced, and then, the various partial discharges including internal discharge, along-surface discharge and tip discharge are modeled and energized to measurement. Furthermore, the discharge waveform features and phase distribution characteristics are analyzed for identifying the type of partial discharge. The measurement and analysis results for actual case are compared with the standard discharge pattern data of laboratory, which show that the proposed measurement and analysis have well representative. This can provide the basis for the establishment of the partial discharge database of medium voltage power equipment , which is also required for development of partial discharge automatic identification system.**

Keywords*—*words: medium voltage power equipment ; partial discharge; phase map

I. Introduction

The partial discharge is one of measurements to evaluate whether the insulation is aged [1, 2]. Because the partial discharge is an irreparable damage for the insulation of high voltage power equipment, the partial discharge detection has been used in the factory testing and the electric charge testing. The measurement can evaluate the status of the insulation so as to improve the system stability and decrease the loss of economic and human life by the broken equipment [3, 4].

For the high voltage power equipment, the switchgear panel is related to the power system and the equipment may contain switch, fuse, circuit breaker, current transformer, potential transformer, power cable and so on. The effective of the insulation of the equipment mentioned above may degrade in long-term operation. In addition, insufficient grounding distance, insufficient clearance distance, poor contact, or environment quality are also the reasons for the insulation aging. Before the insulation breakdown, the equipment may in the process of partial discharge. Therefore, the partial discharge measurement for the medium voltage power equipment becomes the important issue.

The main measurements for the partial discharge of high voltage power equipment can divide into two types: offline detection and on-line detection [5]. The offline detection needs the equipment power off so the application is usually used in the factory test and maintenance. The on-line detection is no need for power off and can use many sensors to measure the partial discharge. Therefore, the on-line detection is the main measurement in the recent years [5-7].

According to the suggestion for high frequency and very high frequency in IEC 62478 [8], this research uses high frequency current transformer (HFCT) to measure partial discharge for high voltage switchgear panel which below 35 kV. The various partial discharges including internal discharge, along-surface discharge and tip discharge are modeled and energized to measurement. The measurement results of discharge waveform features and phase distribution characteristics are analyzed for identifying the type of partial discharge. Furthermore, the measurement and analysis results for actual case are compared with the standard discharge pattern data of laboratory, and the feature can be used to establish the database of partial discharge. In addition, the proposed method can be applied as a reference for development of partial discharge automatic identification system and provide the solution for users monitor the partial discharge of high voltage switchgear panel in the long term.

II. High Voltage Power Equipment and the Device for Measuring Partial Discharge

The main function of the high voltage switchgear panel is to control and protect the operational safety of the power system. The internal structure of VCB high voltage switchgear panel, which contains CB, PT, Cable, Busway, voltage insulator and so on. The components mentioned above have the insulating material and the effect of insulation material may degrade by the human error or time so that the partial discharge may occur.

Partial discharge refers to the phenomenon that the discharge occurs between electrodes and it caused by the defect of the internal insulating material or the surface or the defect in process manufacturing is as shown in Figure 1. The energy of partial discharge is low in the early stage so it hardly affects the insulation material. When the partial discharge occurs in the long term, the effect of insulation material may gradually degrade and it may cause insulation breakdown and even cause the loss of economic and human life.

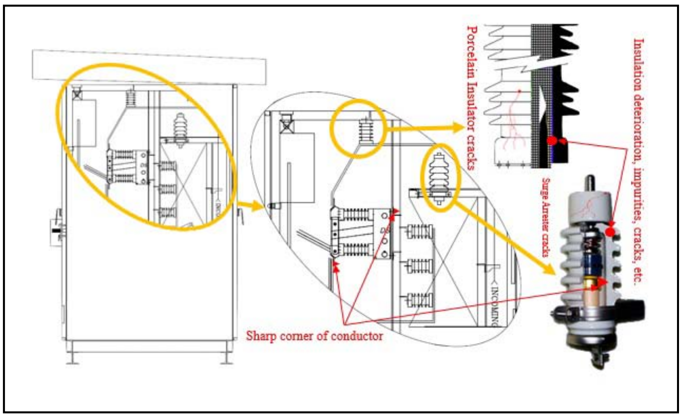

Fig. 1. The defect of high voltage switchgear panel

The energy of partial discharge will convert into electromagnetic signal, light energy or chemical reactions in the space. However, the electromagnetic signal can use to evaluate the intensity, source, and type of partial discharge so that it is popularly applied in the online monitoring. The measurements of the electromagnetic signal contain the eddy current measurement, the transient earth voltage measurement, and microwave measurement and so on [9].

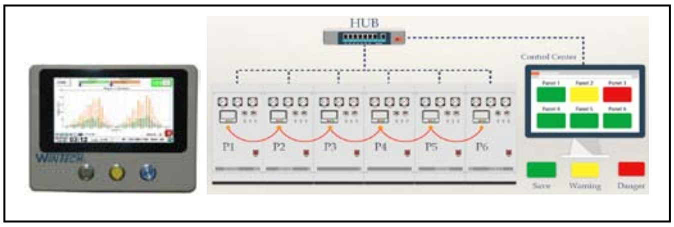

Fig. 2. The online partial discharge monitoring system

The measurements of the electromagnetic signal mentioned above use different sensors to measure the electromagnetic signal of partial discharge. For example, HFCT sensor is used to measure the eddy current. TEV sensor is used to measure the transient earth voltage. UHF sensor is used to measure microwave.

The signal measured by the sensor is converted into the voltage signal and let the partial discharge equipment detect. Figure 2 shows an example that the partial discharge equipment with the method of electromagnetic signal measurement and is used for online monitoring high voltage switchgear panel in the long term. Each switchgear panel installs the partial discharge monitor, and the evaluation results are transmitted to the central processing computer of users. The information provide users to know the insulation status for each switchgear panels.

In order to improve the accuracy of the evaluation results, avoiding noise in the field and building the partial discharge database are needed. Therefore, the following section will introduce the different types of the partial discharge and each features through models proposed in this research.

III. Analysis of Partial Discharge Signature

A. *Equipment of partial discharge*

When the internal high voltage power equipment has the partial discharge, the eddy current will flow through the equipment grounding and HFCT convert eddy current into voltage signal and the signal is analyzed by the partial discharge detector. This research uses HFCT sensor to measure the partial discharge signal and the sensor specification is as shown in Reference [10]. Coaxial cable connects the sensor with the oscilloscope [11]. The partial discharge signals are analyzed by the software. In addition, the results can be established the database.

B. *Modeling of partial discharge*

The typical models of partial discharge for high voltage power equipment are as shown in Figure 3, including internal discharge, along-surface discharge, and tip discharge. Tip discharge usually occurs at the metal joint where the equipment connection because the metal surface is not flat. Along-surface discharge is caused by dust on the surface and moisture. The types of partial discharge mentioned above can be eliminated by offline routine maintenance. The reason for the occurrence of internal discharge is caused by the long term operation or the vibration. This fault type is the main aim for the partial discharge detection because the internal discharge is eliminated only by replacement of equipment. However, the different types of partial discharge have different characteristic of discharge pattern. The following will introduce the simulation of discharge pattern and it may be applied as a reference for diagnosis of partial discharge.

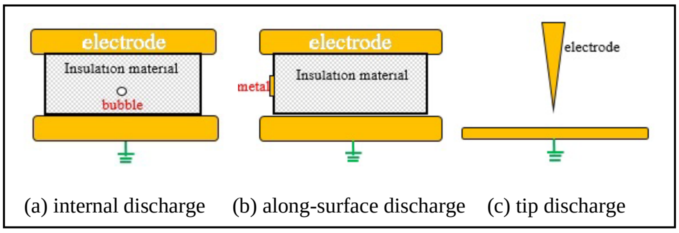

Fig. 3. The typical models of partial discharge

C. *Experiments and Results*

1) *Experiment of internal discharge*

The models of internal discharge consist of two epoxy resins which are square shape and the length is 45 mm and the thickness is 7 mm. One hole was drilled on the positive electrode. The drilling diameter is 1 mm and the depth is 0.5 mm. This research uses silicone to stick these two epoxy resins. The characteristic of discharge phase diagram and waveform of internal discharge are as shown in Figure 4. In Figure 4, the intensity of discharge for positive half-cycle and negative half-cycle are the same but the number of discharge of positive half-cycle is more than that of negative half-cycle. The reason for the phase distribution is symmetrical and the discharge waveform for two half-cycles is same are that the physical structure of the two electrodes is symmetrical. The probability of positive half-cycle is higher because the defect is closed to the positive electrode. The offset for phase of discharge and phase of applied voltage is slight. The distribution of the eddy in the model of internal charge is obvious and the shape of phase distribution is sector. The range of intensity of discharge is width but it still within the certain phase area. The main range of frequency of internal discharge for HFCT sensor is 1 MHz to 60 MHz and the length of signal is less than 400 ns.

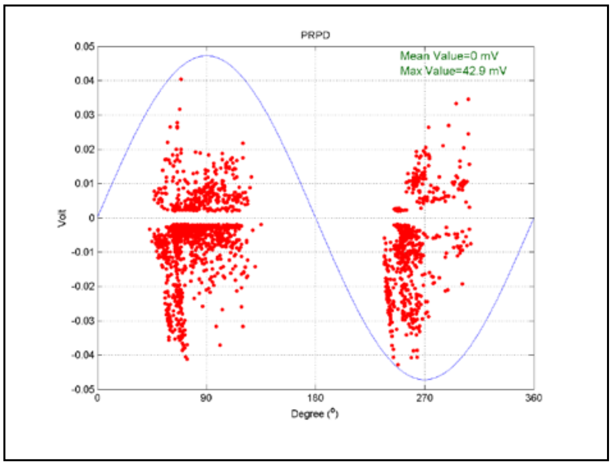

Fig. 4. The typical models of partial discharge

2) Experiment of along-surface discharge

The models of along-surface discharge consist of an epoxy resins which is square shape and the length is 45 mm and the thickness is 12 mm. A 7mm x 2mm copper foil is stick to one side of the epoxy resins and the distance between each electrode is 5 mm. The characteristic of discharge phase diagram and waveform of along-surface discharge is as shown in Figure 5. In Figure 5, the intensity and number of discharge for each positive half-cycle is similar but the phase is asymmetrical. The reason for the intensity of negative half-cycle looking uniform distribution than that of positive half-cycle is that the physical structure of the two electrodes is symmetrical. But there has several discharge paths between the electrode and the copper foil so that the phase distribution of discharge is asymmetrical. The shape of phase distribution is similar as mound. The main range of frequency of along-surface discharge for HFCT sensor is 50 MHz to 60 MHz and the length of signal is less than 400 ns.

3) Experiment of tip discharge

The models of tip discharge consist of a needle and a ground electrode, which diameter is 1 mm and 70 mm respectively. The distance between the needle and the ground electrode is 20 mm. The characteristic of discharge phase diagram and waveform of tip discharge is as shown in Figure 6. In Figure 6, for the positive half-cycle, the distribution of discharge is intensive and the shape of phase distribution is similar as a horizontal line but the intensity of discharge is low. The reason for the distribution and intensity of discharge looking wide and high are that the physical structure for the model is asymmetrical. The main range of frequency of tip discharge for HFCT sensor is 60 MHz to 70 MHz and has a little feature when the frequency below 100 MHz and the length of signal is less than 400 ns.

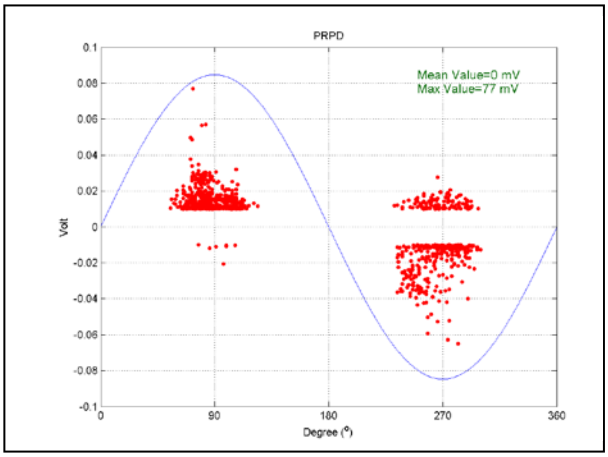

Fig. 5. The characteristic of along-surface discharge

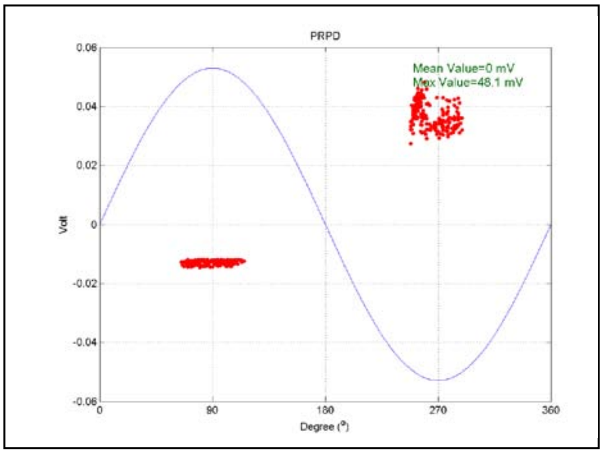

Fig. 6. The characteristic of tip discharge

IV. Field Detection of Partial Discharge Test Case

A. Case 1: An Oil-immersed transformer 34.5kV 750kVA in the factory

In the certain annual detection, HFCT sensor detected that the oil-immersed transformer had the signal of the partial discharge at the grounding line. After filtering the noise, the phase diagram and the waveform are as shown in Figure 7. The intensity of partial discharge for positive and negative half-cycle are similar but the number of partial discharge for positive half-cycle is much more. The result is similar as the experiment of internal discharge. The main range of discharge frequency is 20 MHz to 60 MHz and the length of signal is less than 600 ns. The partial discharge is already eliminated by replacement of insulating oil.

B. Case 2: 35 kV Power Cable in public transportation

The HFCT sensor detected that the power cable had the signal of the partial discharge at the grounding line in the routine maintenance. After filtering the noise, the phase diagram and the waveform are as shown in Figure 8. The intensity and number of discharge for positive and negative half-cycle are similar but the phase is asymmetrical. The result is similar as the experiment of along-surface discharge mentioned above. The main range of discharge frequency is 40 MHz to 70 MHz and the length of signal is 400 ns. The partial discharge is already eliminated by the cleaning.

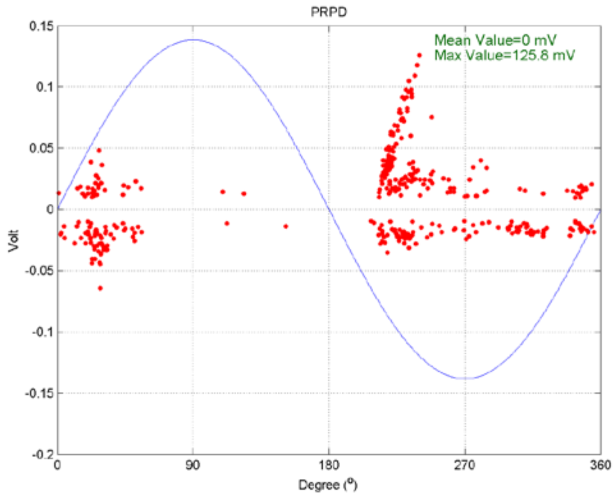

Fig. 7. The results in case 1

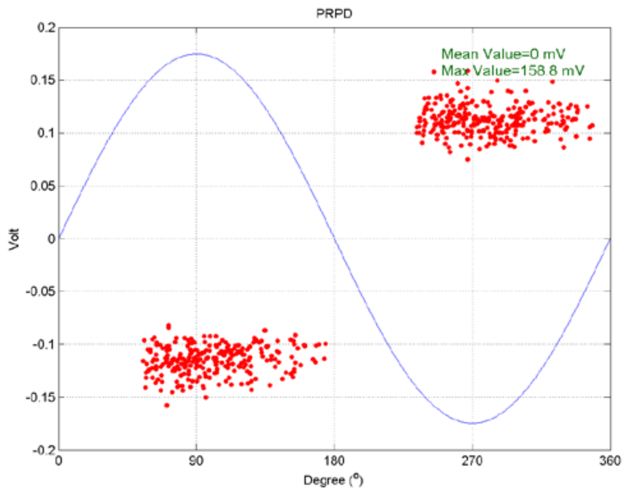

Fig. 8. The results in case 2

These two cases show that the partial discharge detection can find the fault in high voltage power equipment at early stage so as to prevent the insulation breakdown accident.

V. Conclusions

The research uses HFCT sensor to detect the partial discharge for high voltage power equipment below 35 kV. By energizing the three partial discharge experiment models, the characteristic of discharge phase diagram and waveform can be observed. The results for the comparison the experimental case with field case are concluded as follows:

1) The different defect of partial discharge model has different phase distribution.

2) The discharge phase distribution in each experimental case is similar as the field case but the phenomenon of the waveform is not the same as obviously for each.

Therefore, the phase distribution can provide the basis for recognizing the type of partial discharge and the partial discharge database will be applied as a reference for developing the partial discharge automatic identification system.

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