Measurement of Partial Discharge inside Metal Enclosed Power Apparatus using Internal Sensor

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***Abstract*—Partial discharge detection by detecting the released energy in form of electromagnetic wave during discharge using Ultra-High Frequency (UHF) antenna is one method to determine insulation system quality in high voltage system. UHF PD detection method has several advantages over conventional PD detection system such as IEC 60270 method. The advantages of UHF PD detection system are the capability to directly detect PD signal without firstly shut down, the installation system and their immunity from environmental noise. Nowadays most of electrical equipment are in form of metal enclosed model. This paper deals with measurement of PD occurrences inside metal enclosed equipment using internal sensor. The loop antenna is used for PD measurement. The experimental results show that the presence of metal box gives significant change on the PD signal detected by using loop antenna. Without metal box, the measurement sensitivity decreases because of the high level of background noise. The metal box acts as electromagnetic wave shielding and reduces the external noise. When the loop antenna placed inside metal box, the measurement sensitivity increases because of the low level of background noise inside metal box.**

Keyword—**partial discharge, metal box, loop antenna**

I. Introduction

High voltage insulation is the most important part of a high voltage equipment used in an electric power system. The main task of the insulation is to withstand a high electric field between phases or phase and neutral. In excessive high electric field due to the appearance of field enhancement sites like void or protrusion, partial discharge (PD) may occur. The appearance of discharges or leakage current in electrical insulations may indicate insulation aging and in long term this may further reduce the integrity of the insulation leading to the failure of the equipment[1-2]. Diagnosis of PD is considered to highly represent the actual condition of the equipment. PD measurement as described in IEC 60270 requires equipment to be shut down. PD measurement using a UHF antenna, offers benefit because it can be done in the online condition[3-26].

Meanwhile, most of the high voltage equipment was made in form of metal enclosed models. Metal-enclosed power switchgear is a switchgear assembly completely enclosed on all sides and top with sheet metal (except for ventilating openings, HV bushing and inspection windows) containing primary power circuit switching or interrupting devices, or both, with buses and connections.

Since electrical parts inside metal enclosure is hard to be accessed, then one of the best way to detect PD inside metal enclosed electrical equipment is by using UHF sensors/antennas. This experiment compares PD occurrences inside of metal enclosures and PD occurrences with and without metal enclosures.

II. Experimental Setup

A. Introduction

Experimental setup was arranged as shown in figure 1. Artificial PD source was put in the center inside aluminum box (sized 50 x 50 x 50 cm3) to simulate metal enclosed electrical equipment. Sensors that used to measure PD were loop antenna and HFCT. The loop antenna was placed inside metal box, 23 cm from PD source. The measurement result by loop antenna was compared with the measurement result by high frequency current transformer (HFCT). Then, the measurement was repeated with the aluminum box was removed.

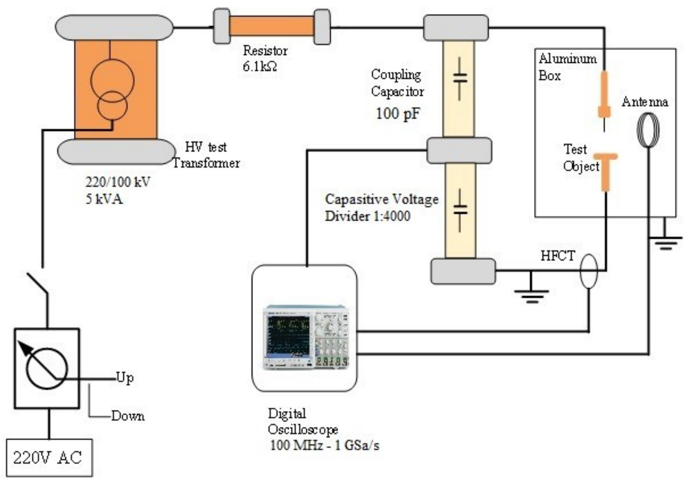


Figure 1. Experimental setup

Partial discharges occur when high voltage applied to the artificial PD source. The partial discharges voltage were detected by HFCT and loop antenna and measured by digital oscilloscope. The data from digital oscilloscope transferred to a personal computer for further analysis to show phase of PD occurrences, magnitude of discharges and PD pulse number which will be shown in Φ - q - n pattern.

B. *Artificial PD source*

The partial discharges signal were generated by artificial PD source using a needle-plane with a gap of 1.5 cm. The steel needle with tip radius of 10μm and curvature angle of 30o. This model generates corona discharges which is a type of partial discharge commonly found in high voltage insulation system. The needle-plane electrode kit is shown in figure 2. The electric field at the tip of the needle electrode is estimated by using the following equation[27]:

$$E_m = \frac{2V}{r\,\ln\left(\frac{4d}{r}\right)}$$

where V is the applied voltage, r is the radius of the needle tip and d is the electrode separation.

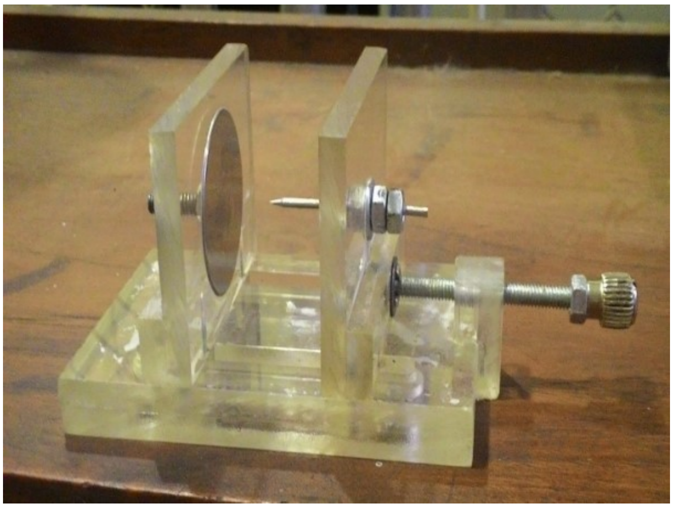


Figure 2. Needle-plane electrode system

B. PD charge calibration

PD charge calibration using a pulse calibrator was held before main experiment. The PD charge calibration process was done for HFCT sensors. To determine the apparent charge detected by loop antenna, comparison data from HFCT will be used. Figure 3 shows the result of PD charge calibration on HFCT.

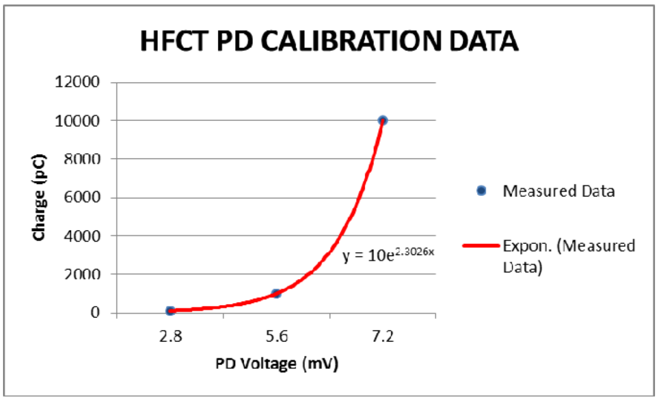


Figure 3. Charge calibration result of HFCT

The value of released charged when partial discharge occur detected by HFCT was the same value of the released charge read by loop antenna since the partial discharge generated from same electrodes and measured simultaneously.

C. *Measurement Item*

From this experiment, will be measured and obtained several parameters such as: PD inception voltage (PDIV): the minimum voltage when initial PD starts to occur; PD Waveform consists of Vpeak-peak, Vpositive-peak andVnegative-peak; PD Phase and charge magnitudes.

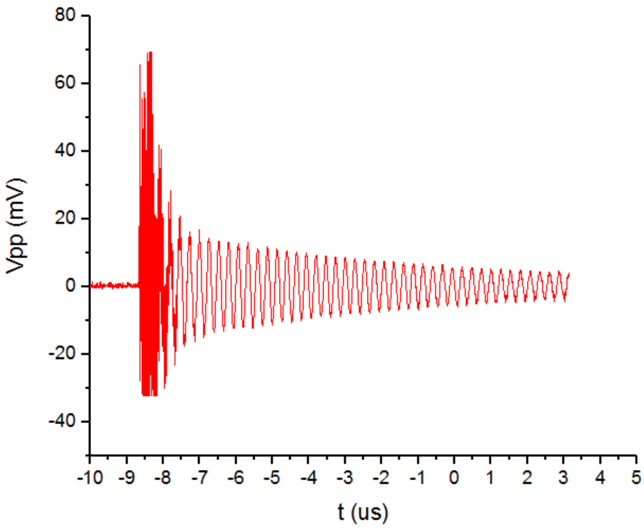
III. MEASUREMENT RESULTS

A. *Partial Discharge Inception Voltage (PDIV)*

The PDIV measurements was done by using loop antenna. The loop antenna was placed on the distance of 23 cm from the sensors. For the experiment without a box, PDIV detected by using the loop antenna is 3.73 kV. For the experiment using a box, PDIV detected by loop antenna is 3 kV experiment by using. The PD magnitudes Vpp at PDIV without metal box and with metal box detected by loop antenna are 42.4 mV and 20.8 mV.

B. *PD waveform*

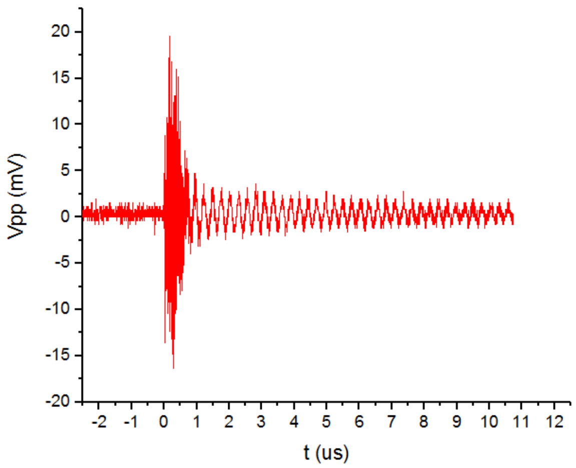
Figure 4 shows negative PD waveform in the air (corona discharge) was measured by using antenna loop at 6 kV voltage level for the experiment without metal box.



PD –

Figure 4 Negative PD waveform in the air (corona discharge) was measured by using antenna loop at 6 kV voltage level without metal box

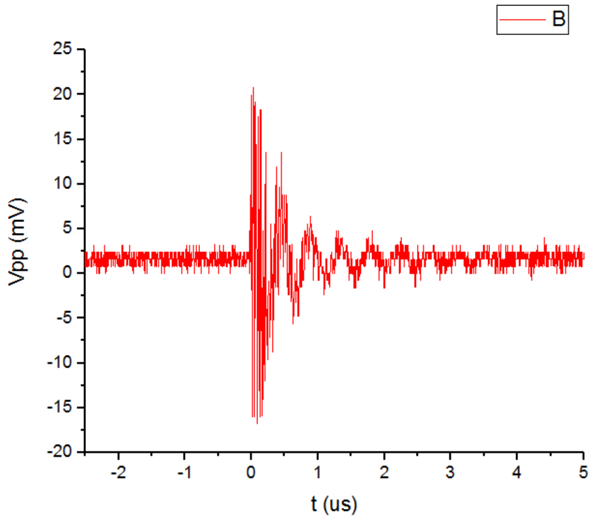
Figure 5 shows positive PD waveform in the air (corona discharge) was measured by using antenna loop at 6 kV voltage level for the experiment without metal box.



PD +

Figure 5 Positive PD waveform in the air (corona discharge) was measured by using antenna loop at 6 kV voltage level without metal box

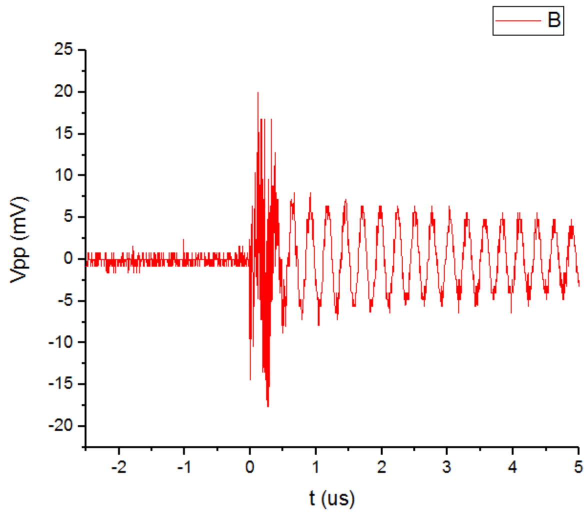
Figure 6 shows negative PD waveform in the air (corona discharge) was measured by using antenna loop at 6 kV voltage level for the experiment with metal box (4b).



PD –

Figure 6 Negative PD waveform in the air (corona discharge) was measured by using antenna loop at 6 kV voltage level using metal box

Figure 7 shows positive PD waveform in the air (corona discharge) was measured by using antenna loop at 6 kV voltage level for the experiment with metal box.



PD +

Figure 7 Positive PD waveform in the air (corona discharge) was measured by using antenna loop at 6 kV voltage level using metal box

C. PD pattern

The PD pattern (φ, Vpp, n) in the air (corona discharge) was measured by using antenna loop at 6-kV voltage level. Figure 8-9 shows PD Pattern measured by loop antenna at a distance of 23 cm without metal box and with metal box, respectively. The amount of PD that detected without using metal box and using metal box for each antenna is 288 and 436 pulse.

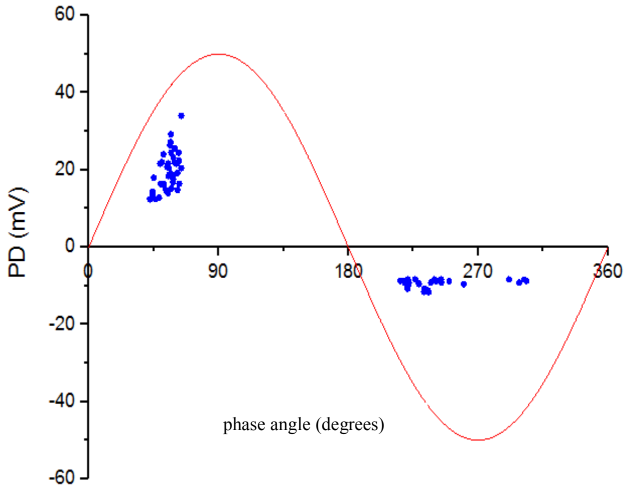


Figure 8 PD Pattern measured by loop antenna at a distance of 23 cm without metal box

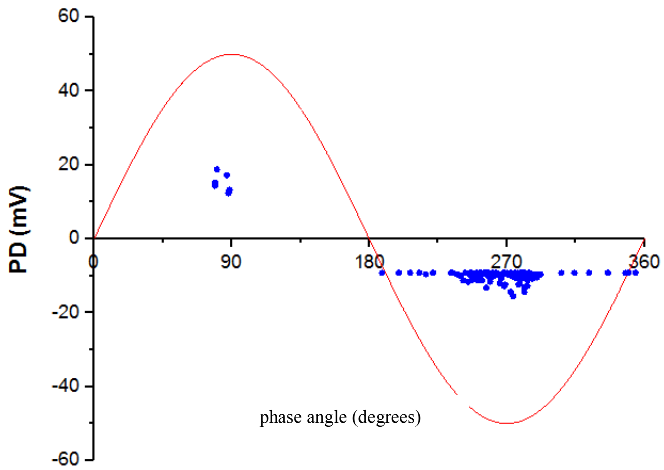


Figure 9 PD Pattern measured by loop antenna at a distance of 23 cm using a metal box (antenna was placed inside a box)

IV. ANALYSIS AND DISCUSSION

A. Comparison of Partial Discharge Detected by Internal Loop Sensor with and without Metal Box

Table 1 shows the comparison of background noise (Vpp BGN ON), negative PD inception voltage (PDIV-), Vpp detected by internal loop sensor with and without metal box at PDIV. BGN ON with box is lower than one without box. PDIV- with box is lower than one without box. V_{pp} at PDIV with box is lower than one without box.

Table 1. PDIV Parameters

Parameters	With Box	Without Box
V_{pp} BGN ON	10.5 mV	27.2 mV
PDIV -	3 kV	3.73 kV
V_{pp} at PDIV	12 mV	31.2 mV

These results are explained as follows. The metal box acts as the shielding of electromagnetic wave noise. The presence of the metal box reduces the external electromagnetic wave noise so that BGN ON in the presence of the metal box is lower than one without metal box. These result cause PDIV in the presence of metal box is lower than one without metal box.

Table 2 shows the comparison of Vpp of PD waveform, rise time of PD waveform (tr), and fall time of PD waveform (tf) detected by internal loop sensor with and without metal box at 6 kV applied voltage. V_{pp} of PD waveform at 6 kV with box is higher than one without box. Rise time of of PD waveform at 6 kV with box is higher than one without box. Fall time of PD waveform at 6 kV with box is higher than one without box.

Table 2 PD Waveform at 6 kV

Parameters	With Box	Without Box
V_{pp} (mV)	79.2	69.6
t_r (ns)	15.593	10.137
t_f (μs)	18.789	5.026

These results are explained as follows. In the presence of metal box the EM wave propagates and encounter metal box. In this situation the EM wave may be absorbed or reflected by metal wall. V_{pp} of PD waveform at 6 kV with box is higher than one without box because of the superposition of the EM wave reflected by the wall of metal box.

Table 3 shows PD number and PD maximum detected by internal loop sensor with and without metal box. Number of PD with box is more than one without box. Maximum PD with box is higher than one without box.

Table 3 PD Pattern at 6 kV

Parameters	With Box	Without Box
∑PD	436	288
PD max (mV)	79.2	69.6

These results are explained as follows. The lower of BGN in the presence of metal box increases the PD measurement sensitivity so that the number of PD detected by loop antenna in the presence of metal box is more than without metal box.

B. Effect of the Presence of Metal Box on Partial Discharge Detected by Internal Loop Sensor

The measurement results shows that the application of metal enclosure gives significant change to the PD occurrences detection by the UHF sensor (loop antenna). Detection of PD occurrences when the loop antenna placed inside metal enclosure makes the sensitivity of PD occurrences of the loop antenna increase due to the low level of background noise inside metal enclosure. While, when the loop antenna placed outside metal enclosure, the sensitivity of the antenna decreased due to the high level of background noise.

III. CONCLUSION

This paper discussed the measurement of partial discharge inside metal enclosed power apparatus using internal sensor.

The results are concluded as follows:

1. Application of metal enclosure gives significant change to the PD occurrences detection by loop antenna.
2. Detection of PD occurrences when the loop antenna placed inside metal enclosure makes the sensitivity of PD occurrences of the loop antenna increase, since the low level of background noise inside metal enclosure.
3. When the loop antenna placed outside metal enclosure decrease the sensitivity of the antenna since the high level of background noise.

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