Comparison of Partial Discharge Characteristics Detected by RC Detector and Rectangular Antenna

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Abstract—This study discusses the method of measuring and detecting Partial Discharge (PD) in high voltage electrical equipment that has the characteristics of being veiled with metal. This research uses the UHF (Ultra High Frequency) method based on IEC 60270 and RC Detector to detect and measure PD. This method uses electromagnetic wave energy emitted by PD sources from the metal box. Use this method to get detection and measure without having to activate the test object. Then the sensors used in testing in this study are rectangular spiral antennas and RC detectors. In addition, various stresses will be tested. The measurement results then compare when evaluating the PD between the Rectangular Spiral antenna and the RC Detector to determine the sensitivity level of the rectangular spiral antenna. The test results show the measurement of partial release of rectangular spiral antenna is greater than outside the metal box and measurement using RC Detector is more sensitive than using a rectangular spiral antenna sensor.

Keywords—Partial discharge, RC Detector, Spiral Rectangular Antenna, Box metal, high voltage equipment

1. INTRODUCTION

The substation (GI) is a place for electrical systems that function to regulate the flow of electricity from upstream to downstream (from power stations to loading). In a substation (GI) there are various kinds of high voltage equipment that are large, where most of this high voltage equipment is covered by metal. For example, transformers and Gas Insulated Switchgear (GIS). The equipment certainly has a problem, such as making adjustments, insulation errors and incompatibility with the required voltage / power level. 80% of the problems are in insulation problems, resulting in Partial Discharge and breakdown of the insulation [1][4][5][6]. Problems with insulation can interfere with the reliability of the system so supervision is needed on the quality of electrical equipment insulation. Taking measurements is one method to determine the quality of an insulation system. Measurements that can be done are measurements using sensors that can work on-line, namely measurements using UHF sensors. UHF sensor can work by utilizing one of the effects of partial discharge, namely electromagnetic waves [1][2][9].

2. BACKGROUND

2.1 Partial Discharge

Partial Discharge according to IEC 60270 is a partial local discharge of electricity which only bridges some of the insulation between the conductor and that occurs close to the conductor [3]. This electrical discharge occurs on an insulating medium that is located between two electrodes that have a voltage difference, where the discharge does not connect the two electrodes perfectly. Partial discharge at the bottom is the release of charge due to the ionization of the gas in the isolation system when the voltage is in a critical value [4][13].

2.2 Electromagnetic Wave Radiation

When the discharge event occurs, the free electron charge that is initially stationary then accelerates and slows down caused by external energy. This acceleration and deceleration process will produce varying electromagnetic fields that can emit out of PD locations that change with time [11][12][10].

Static charges only have an electric field emitted radially. As a moving charge, this will produce an electric and magnetic field. The electric field at each point closest to the charge, will move with the speed v in the x direction can be calculated in:

\[ E = \frac{q}{4\pi \varepsilon_0 R^2} \frac{1}{R} U_r \]  

(1)
Where \( R^2 = r^2 + x^2 \), \( x \) is the displacement distance and \( r \) is the distance from the charge to the observer after moving the distance \( x \). The magnetic field caused by these moving particles can be calculated using the Biot-Savart law, so that it is obtained:

\[
B = \frac{\mu_0 Q (\vec{u} \times \vec{u}_r)}{4\pi r^2 x^2}
\] (2)

### 2.3 High voltage equipment with Metal Box

Power Switchgear is one of the high voltage equipment that is shaped with a metal enclosure. The design of the switchgear is completely enclosed on all sides and with sheet metal (except for ventilation openings and inspection windows) which contains the main electrical circuit for switching, using buses and connections. Access to the interior in metal, has provided a door or cover that can be removed and opened or closed \([7][13]\). Under normal conditions, the active part in a closed metal box is insulated with gas, solid, liquid and is not connected directly to the metal chamber. Electrically, the metal has been connected directly to the ground so it is safe when the equipment is touched by humans or technicians \([13]\).

### 3. EXPERIMENTAL SETUP

![Figure 1](image)

**Figure 1** A series of experiments

Research steps:

a. Prepare the equipment and arrange the circuit according to Figure 1 (note: when arranging to connect the grounding stick to the circuit)

b. When testing, please remove the grounding stick that is attached to the circuit.

c. Measure Background Noise (BGN) when the AC voltage is turned on but still 0 volts (BGN On).

d. Next raise the AC input center gradually, until the first Partial Discharge (PDIV) appears. Take data 50 times.

e. Increase the voltage up to 6.5kV, observe and retrieve PD data, PD positive waves, PD negative waves 50 times. Repeat for the 7.5 kV voltage level.

f. Lower the AC voltage to 0V, turn off the power supply. Attach the grounding stick to the equipment.

g. Repeat the experiment without using a metal / aluminum box.

### 4. MEASUREMENT RESULTS

In PD data retrieval using a metal box, as well as a rectangular spiral antenna as a partial discharge sensor and RC Detector that functions as a comparison, so that the 2 channels on the oscilloscope can be used to collect data simultaneously. The spiral antenna sensor used will be measured by two conditions, namely the spiral antenna placed in a metal box with a distance of 20 cm and 35 cm outside the box from the source of partial discharge (plate needle electrode). This laying function is to get a comparison of the results of PD measurements on the sensor inside the metal box with outside the metal box. In taking partial discharge data, measurements are made with a variation of 2 voltage levels, namely 6.5 kV and 7.5 kV. Data obtained from each measurement in the form of .csv format. This raw data is processed using Microsoft Office Excel software and plotted using the OriginPro 9 software. The results of processing in the form of waveform data will be displayed in the following graphs and tables.

#### 4.1 Background Noise

Before collecting waveform data, the background noise (BGN) data collection will be performed first. BGN measurement aims to determine the maximum noise and minimum noise that appears on the oscilloscope. This noise can come from the measurement circuit, the environment, and from the sensor itself. BGN measurements are made after the voltage source is turned on, but still in 0 V condition on the voltage selector. The BGN ON measurements are taken when the system conditions are not really at 0 kV, but at 1.2 kV. This happens because the voltage regulator used cannot 'create' 0 kV in the system.

| Sensor | Magnitud BGN (mV) inside | Magnitud BGN (mV) outside |
|--------|--------------------------|--------------------------|
|        |                          |                          |
4.2 PDIV
PDIV (in kV units) is the voltage PD appears for the first time when the source voltage is increased gradually. Breakdown voltage is the amount of voltage when a breakdown occurs between the two needle-plate electrodes 15 mm apart. In this measurement, PDIV was observed to appear for the first time possibly on the RC sensor detector, on a rectangular spiral antenna located 35 cm from the partial discharge source. In the antenna placement experiment outside the box the first time observed on the RC detector is when the input voltage is at the 4.89 kV voltage level, while the rectangular antenna is at the 4.96 voltage level.

**Table 2 Measurement of PDIV experiments in a metal box**

| Sensor     | Antena Spiral | Rectangular | PDIV |
|------------|---------------|-------------|------|
| RC Detektor | 10.4          | -11.2       | 8    |
|            | 11.68         | -11.36      | 10.08|
| BGN +      | BGN -         | BGN +       | BGN -|

**Table 3 Measurement of PDIV experiments outside the metal box**

| Sensor     | Antena Spiral | Rectangular | PDIV |
|------------|---------------|-------------|------|
| RC Detektor | 4.73          | 4.89        |      |

Based on the PDIV measurements above, it appears that the RC detector has a greater sensitivity than rectangular antennas, besides measurements outside the metal box it is more difficult to observe PDIV. The rectangular spiral antenna with the best position for observing PDIV is the closest to the PD source, which is inside a metal box.

4.3 Partial Discharge Parameters
4.3.1 Waveform and Peak-to-peak voltage

- PD waveforms at 6.5 kV voltage level

**Table 5 PD waves at 6.5 kV voltage level inside a metal box**

| Sensor     | PD Waveform – | PD Waveform + |
|------------|---------------|---------------|
| Rectangular Antenna | 4.86          | 4.96          |
| RC Detektor     | 4.73          | 4.89          |
Antena Spiral
Rectangular

RC Detektor

Table 6 PD waves at 6.5 kV voltage level outside the metal box

| Sensor          | PD Waveform – | PD Waveform + |
|-----------------|---------------|---------------|
| Antena Spiral   | ![Image]      | ![Image]      |
| Rectangular     | ![Image]      | ![Image]      |
| RC Detektor     | ![Image]      | ![Image]      |

- PD waves at 7.5 kV voltage level

Table 7 PD waves at the 7.5 kV voltage level inside the metal box

| Sensor          | PD Waveform – | PD Waveform + |
|-----------------|---------------|---------------|
| Antena Spiral   | ![Image]      | ![Image]      |
| Rectangular     | ![Image]      | ![Image]      |
Table 8 PD waveforms at 7.5 kV voltage level outside the metal box

| Sensor       | PD Waveform – | PD Waveform + |
|--------------|---------------|---------------|
| Antena Spiral Rectangular | ![Waveform Image] | ![Waveform Image] |
| RC Detektor  | ![Waveform Image] | ![Waveform Image] |

The results of Vpp voltage measurements on all sensors are summarized in table 9

Table 9 Measurement of Vpp PD antennas outside and inside the metal box

| Sensor       | Outside Measurement | Inside Measurement |
|--------------|----------------------|--------------------|
|              | 6.5 kV | 7.5 kV | 6.5 kV | 7.5 kV |
| Rectangular  | 12 | -8.4 | 13.6 | -13.6 |
| RC Detektor  | 87.29 | -20.80 | 115.75 | -25.80 |

5 DATA ANALYSIS

a. Very high noise levels appear so they can mask the reading of the PD signal.
b. With an increase in voltage level, there is also an increase in peak-to-peak voltage, including the placement of sensors with different distances.
c. There is a greater attenuation of electromagnetic waves which is proportional to the addition of the distance of the PD source to the antenna, this is based on the measurement results inside and outside the metal box.
d. The appearance of a significantly reduced PD signal is PD during a negative cycle. This is due to the nature of corona in air, where electrons are easier to release during negative cycles, so there is no need for too high voltage to generate PD signals in negative cycles. Because the PD voltage is not too large, so the PD voltage that is read in the rectangular spiral antenna outside the box becomes smaller.
CONCLUSION
From the results of calculations and analysis, several conclusions can be drawn, namely:

a. Without metal box, the percentage of Vpp decrease in PD signal from a distance of 23 cm to 35 cm is 72% for all voltage levels.

b. With metal boxes, the percentage of Vpp decrease in PD signal when inside and outside the box is 40% for all voltage levels.

c. The best position of a rectangular spiral antenna to detect a PD source in electrical equipment with a closed metal box is inside the metal box itself.

d. Based on the results of the RC Detector experiment is more sensitive than the antenna loop sensor.

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