Comparative Measurement of Partial Discharge Using Spiral Antenna with RC Detector on High Voltage Equipment

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Abstract. Partial discharge is a partial electrical discharge event in isolation that is not directly connected between the two conductors, which discharges can occur either near or not on the conductor. An Archimedean spiral antenna is created to detect partial discharges in high voltage equipment. Electromagnetic waves produced by partial discharge will be detected by the antenna which has a frequency range of 300 MHz - 3 GHz. The next measurement of partial discharge uses an RC detector. The purpose of this study was to determine the performance of Archimedean spiral antennas which were then compared to RC detectors. Based on the results of tests carried out as many as 50 times, both the spiral arsenic antenna or the RC detector showed good results. Antennas get slightly lower yields, due to the reduction in the flow of electromagnetic waves on the metal walls of high voltage equipment. Whereas RC detector is better by displaying more sensitive results.

Keywords— partial discharge; spiral antenna; UHF sensor; RC detector;

1. Introduction
Partial Discharge can occur in insulation until breakdown occurs in the insulation. The existing problems can reduce the reliability of the equipment and the electrical system itself [1]. The presence of PD is a sign of insulation damage. PD detection is important so that engineers can check the condition and diagnose problems with insulation [2]. Measurement is the exact method needed to determine the quality of an insulation system. The results of these measurements we can classify an insulation system needs maintenance actions, repairs, or even the change of equipment [3]

Measurements can be made online, one of which is using a UHF (Ultra High Frequency) sensor. UHF sensor functions to receive the results of the form resulting from the occurrence of partial discharge, namely electromagnetic waves [4]. UHF sensor used in this research is Archimedean spiral antenna sensor. RC detector is a means of detecting current impulses due to partial discharge which will be converted into a voltage that can be measured using an oscilloscope [5].
2. Backgrounds

2.1. Partial Discharge

Based on the IEC 60270 standard, Partial Discharge is a phenomenon of electrical discharge that occurs locally [6]. This PD connects in part or not completely from the insulation between the conductors. PD can occur on the surface of a conductor or in a conductor. This release in a short time can occur in a conductor because the electric field is not homogeneous [7]. If this PD continues, the insulation will suffer damage little by little, where the dielectric strength of the insulation will decrease. This will lead to failure of insulation or breakdown [8].

2.2. Partial Discharge Source

Internal discharge can occur in the cavity (voids) in a solid or liquid dielectric. The effect that occurs as a result of this is the spread of energy within a certain time [9]. If the electric field in the cavity (void) is high enough and the insulation strength of the gas in the cavity is exceeded, then PD will occur [10]. Surface Discharge appears at different insulation boundaries [11]. Surface Discharge when observed only at initial stresses, there is no visible PD compared to Internal Discharge. But if the voltage increases, streamers begin to form on the surface and a PD pattern can be found [12]. Corona Discharge occurs in the gas dielectric in the presence of a homogeneous field. Corona is a continuous discharge that occurs around electrodes that have small curvature or sharp edges [13].

Partial discharge will produce energy such as impulse currents, electromagnetic waves, sound vibrations, light, and heat [14]. PD detection and measurement sensors in this study fall into the category of detecting PD signals in the form of electromagnetic waves that appear when PD occurs [15].

2.2.5 Electromagnetic Wave Radiation

In the event of a discharge, the charge of the free electrons that were initially stationary can change forces to become fast moving and slowed down by external energy. The process of acceleration and deceleration can produce varying electromagnetic fields that radiate out of the PD location that changes with time [16].
Power Switchgear is part of high voltage equipment that has a metal cover layer. The whole side of the equipment is covered with metal except for the ventilation and inspection windows [17]. This equipment is the main electrical circuit for switching, with buses and connections [18]. Access to the interior in the metal is provided by a door that can be opened. If under normal conditions, the active part in the closed metal is insulated with gas, solid, liquid and not connected directly to the metal layer of cover. The metal is connected directly to the ground so it is safe if touched by humans [19].

Static charges only have an electric field emitted radially. Static charges are moving charges, which will produce electric and magnetic fields. The electric field at each point closest to the charge moving with velocity v in the x direction can be calculated as:[20]

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

In addition there is a magnetic field. The magnetic field caused by these moving particles can be calculated using Biot-Savart's law, so that it is obtained:

\[ B = \frac{\mu_0}{4\pi} \frac{q(v_x \mu_x, v_y \mu_y)}{r^2} \]  

3. Experiment and results

PD data retrieval on a metal box using a spiral antenna sensor and RC detector as a comparison. The spiral antenna is placed in a different position, inside and outside the metal box. 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. The following is a series of tests with a metal box experiment scheme.
PD data collection was carried out at level 6 kV with 50 times of data collection. Data obtained from each measurement was processed using Microsoft Office Excel software and plotted using OriginPro 9 software. The results of processing are waveform data and phase patterns.

PDIV (Partial Discharge Inception Voltage) is the voltage value when the PD activity appears for the first time. In the initial test by placing the antenna inside a distance of 35 cm, PDIV was observed to appear first on the RC detector sensor and then the Archimedean antenna within 35 cm from the partial discharge origin. 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 first antenna that appears is the Archimedean antenna at the 4.94 kV voltage level.

From table I, can be seen the value of the measurement results in the magnitude of the partial discharge signal in the following table:

### Tabel I. PDIV measurement of antenna experiments outside the metal box

| Sensor          | Antenna Spiral Archimedean | RC Detector |
|-----------------|----------------------------|-------------|
| PDIV -          | ![Waveform](image1.png)    | ![Waveform](image2.png) |
| PDIV +          | ![Waveform](image3.png)    | ![Waveform](image4.png) |

From table I, can be seen the value of the measurement results in the magnitude of the partial discharge signal in the following table:

### Tabel II. Measurement of the antenna PDIV voltage outside the metal box

| Sensor          | Vs (kV) |
|-----------------|---------|
| Antenna Archimedean | 4.94   |
| RC Detector     | 4.89    |

PDIV testing or partial discharge first occurred at 4.89 kV voltage level. PDIV observations were made on the RC detector sensor and then the Archimedean spiral antenna. Both sensors have a high sensitivity. In this test, PDIV was first observed to appear on the RC sensor detector, the Archimedean antenna is 35 cm from the partial discharge source.
Tabel III. PDIV measurement of sensor experiments in a metal box

| Sensor | Antenna Spiral Archimedean | RC Detector |
|--------|----------------------------|-------------|
| PDIV+  | ![PDIV+ measurement](image) | ![PDIV+ measurement](image) |
| PDIV-  | ![PDIV- measurement](image) | ![PDIV- measurement](image) |

Tabel VI. Measurement of the antenna PDIV voltage inside the metal box

| Sensor               | Vs (kV) |
|----------------------|---------|
| Antenna Archimedean  | 4.77    |
| RC Detector          | 4.73    |

Based on the PDIV measurements above, the first measured PDIV test occurs at the 4.73 kV voltage level. PDIV observations were made on the RC detector sensor and the Archimedean spiral antenna at the 4.77 kV voltage level.

4. Conclusion

The purpose of this study was to determine the ability of Archimedean spiral sensors in detecting partial discharge. The RC detector is a comparison sensor as a sign that a partial discharge has occurred. Retrieval of data 50 times can confirm the accuracy of the recorded data. Comparison of sensor positions when placed outside and inside in an effort to find out the propagation of electromagnetic waves from partial discharge. The weakness of this study is the large amount of noise that occurs around the laboratory. Researchers require to know in advance the value of background noise on, in order to know the true PD value occurs. The measurement results show that sensors outside the greater the level of PDIV voltage that occurs. In contrast to sensors inside a metal box, which has a low PDIV value, or the occurrence of PD is faster. Future studies will focus on comparing rectangular and spiral antenna models to find out which is the most effective sensor for PD detection.
5. References

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