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Comparison of Sensor Sensitivity to Cable Partial Discharge Phenomenon

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***Abstract*—Partial discharge is a breakdown of the voltage caused by the inability of insulation to withstand the voltage. Partial discharge can occur on the inside. The surface of the insulation can even create arcs. PD modeling is proposed by experts and analyzed by mathematical models. Experiments for the presence of PD were carried out in 3 types, namely internal discharge, surface discharge, and tip discharge. Different results of PD intensity were obtained in each of these types. In this practicum, three experiments were carried out: calibration of the PD sensor, PDIV (Partial Discharge Inception Voltage), Background noise, and Waveform. So we get a value that can indicate the value and form of PD.**

Keywords—Partial Disharge, HFCT, RC, Antenna, PDIV, background noise, waveform,

I. Introduction

According to IEC 60270, Partial Discharge is an electrical discharge that connects partial insulation between a conductor and possibly other adjacent conductors. In line with this, [1] Explains that Partial Discharge is a problem that often occurs in insulators of high-voltage equipment, such as transformers, generators, motors, and electrical cables.

Several factors affect the partial discharge process. Among them are pollution, material damage due to vibration, has approached its durability period, and others. This is in line with the explanation [2]. It is argued that the insulation characteristics will deteriorate over time due to various factors such as long-term operation, insufficient ground clearance, insufficient clearance, poor contact, or poor environmental quality for insulation aging.

Several tests were carried out in this activity related to the Partial Discharge phenomenon. The tests include:

1. We compared the three sensors' sensitivity to measure partial discharge, namely RC Detector, HFCT, and Antenna Sensor. This test is carried out with the help of a tool called the High Voltage Partial Discharge (HVPD) pC Calibrator. By entering some required values using HVPD, the PD value of each sensor will be measured and displayed by the oscilloscope. The amount of charge measured on the oscilloscope is then compared with the amount injected by the HVPD.
2. Background noise testing tests signals that do not come from the test object detected during partial discharge testing.
3. PDIV testing is a voltage test to determine a specific voltage that can produce PD.
4. Waveform testing gives a voltage of 5 kV, 6 kV, and 7 kV, which of the three types of the applied voltage will produce a different waveform.

II. Literature Review

A. Definition of Partial Discharge

Partial discharge is a discharge phenomenon (spark) between the electrodes caused by internal/surface insulation material defects or defects in the manufacturing/installation process. The energy generated by the partial discharge will be converted into an electromagnetic signal that can be used to evaluate the intensity, source, and type of partial discharge. The measurement of the electromagnetic signal, which consists of measuring eddy current, grounding transient voltage, and microwaves, produces several variations of partial discharge characteristics such as internal discharge, along-surface discharge, and tip discharge.

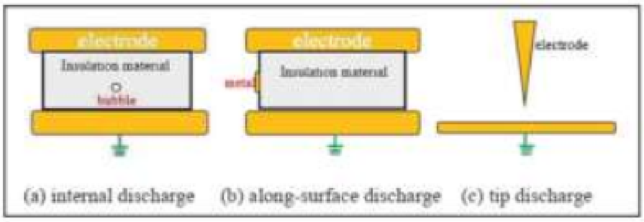


Figure 1. Map of Cianjur

- Due to long-term operation and vibration, the internal discharge produces eddy currents that flow through the grounding equipment.
- Due to the uneven metal surface, tip discharge occurs at metal joints (equipment connections).
- Along-surface discharge is caused by surface dust and moisture.

B. Partial Discharge Measurement

This type of partial discharge test can be performed in online or offline network status. The tests carried out are component age tests, continuous monitoring, and observation of partial discharge behavior. The results obtained are the discharge waveform, the characteristics of PDIV (Partial Discharge Inception Voltage), and the partial discharge phase distribution.

This discharge characteristic is generally a consequence of the local electric voltage concentration on the insulating surface. In general, the discharge appears as a pulse less than 1 s in duration. However, more continuous forms can occur, such as the so-called pulseless discharge in gas dielectrics.

"Corona" is a partial discharge that occurs in a gaseous medium around a conductor far from solid or liquid insulation. Partial discharges are often accompanied by sound, light, heat, and chemical reactions.

The current or voltage pulse is generated from the partial discharge in the tested object. The pulses are measured using a suitable detector circuit, which has been inserted into the test circuit for testing purposes.

- Background noise is a signal detected during the PD test, which does not originate from the test object.
- Partial discharge inception voltage is the applied voltage at which repeated partial discharges are observed for the first time on the test object; the voltage applied to the object gradually increases from a lower value before any partial discharge. In practice, the initial voltage Ui is the lowest applied voltage at which the magnitude of the PD pulse quantity equals or exceeds a specified low value. Partial discharge extinction voltage (Ue) applies the voltage at which repeated partial discharges cease to occur on the test object when the voltage applied to the object gradually decreases from the higher value at which the number of PD pulses is observed.

C. Partial Discharge Source Electrode Model in High Voltage Electrical Equipment

PD testing and diagnostics on high-voltage equipment are essential to determine the condition of the equipment and prevent the occurrence of interference or more serious equipment damage due to PD. The following is the PD phenomenon of a PD source and the general flow of PD measurements on high-voltage equipment:

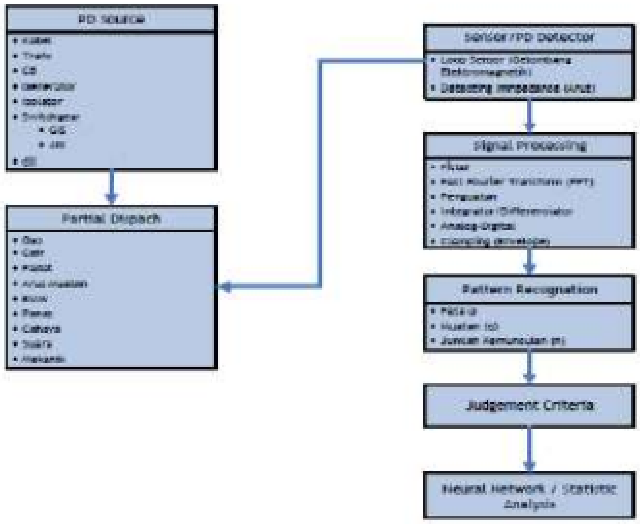


Figure 2. PD phenomenon and general PD measurement flow in high voltage equipment

Measuring PD in the time domain (t) is done using an Oscilloscope, while in the frequency domain (f), it is done using a Spectrum Analyzer.

Diagnosis of partial discharge in high-voltage equipment refers to the standards that have been determined as follows:

1. IEEE Standard 400-2001: “IEEE Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems”.
2. IEEE Standard 1434-2002: “IEEE Trial Use Guide to the Measurement of Partial Discharge in Rotating Machinery”.
3. Standard IEC 60270-2000/BS EN 60270-2001: “High–Voltage Test Techniques – Partial Discharge Measurements”.

In this practice, measurements are made to diagnose PD using two conventional methods (electrical methods), namely the RC Detector and HFCT methods. General Electrode Model:

1. Homogeneous field

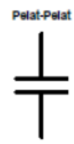


Figure 3. Model of the PD Source Electrode of plates

2. Symmetrical field

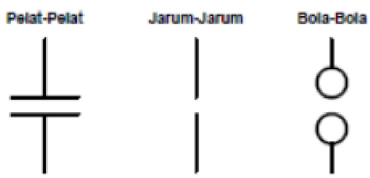


Figure 4. Model of PD Source Electrode in Symmetrical Field

3. Non-homogeneous non-symmetrical field

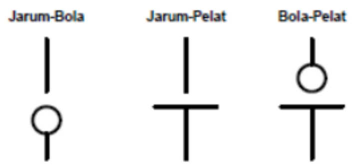


Figure 5. Model of PD Source Electrode in Non . Field

Homogeneous Non Symmetrical

PD usually does not occur inhomogeneous fields. PD can happen in a homogeneous field due to voids that change permittivity (ε) in a material. For symmetrical areas, PD is possible only in the needle-needle configuration. In the composition of balls and plates, PD does not occur unless there is a Void. The possibility of PD is very high in nonhomogeneous–nonsymmetric fields. A homogeneous lot must be symmetrical, while an asymmetrical field is not necessarily homogeneous.

D. General Electrode Model for PD. Modeling

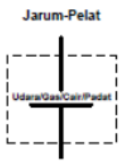


Figure 6. General Electrode Model for PD . Modeling

The chamber must first be vacuumed for PD experiments with liquid media, and the liquid does not have to fill the section.

E. Electrical Methods for Measurement and Diagnosis of PD

PD measurement with the electrical method directly measures the voltage on the RC Detector based on the leakage current from the PD process. The following circuit is a primary circuit for measuring PD with the Electrical Method.

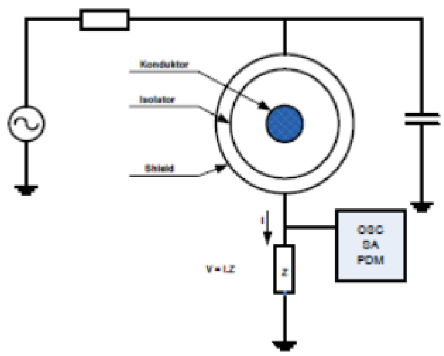


Figure 7. Basic Circuit for Measurement and Diagnosis of Partial Discharge by Electrical Method

Based on Figure 7 above, the primary circuit for measuring and diagnosing PD by the electrical method consists of: 1. Source (AC, DC, or impulse). 2. The limiting resistance has a function so that the current entering the circuit is not too large. 3. High voltage electrical equipment. 4. Coupling capacitor has a function to drain partial discharge current at high frequency to flow to Z detecting impedance and oscilloscope/spectrum analyzer. 5. Z detecting impedance determines the voltage that arises due to partial discharge. The value of the impedance Z is based on the impedance of the electrical equipment of 50 ohms, and the goal is that the value is the same as the impedance of the equipment to be measured so that the signal to be measured is not reflected due to the impedance difference. Several alternatives can be made to get a Z value of 50 ohms, including: a. Installing R = 50 ohms b. Make a series of Tee or Phi 6. Oscilloscope or Spectrum Analyzer as the output of the above circuit.

III. Methodology

A. Scheme and Working Principle

Partial discharge experiments to be carried out are using two electrical methods, namely RC Detector and HFCT. The working principle is as follows.

a. A high voltage source in the form of a step-up transformer is used to supply voltage to the experimental circuit.

b. R limiter serves to limit the current flowing in the circuit. The selection of the value of R must pay attention to the ability or current limit that can be withstood by the source, cable, and high voltage equipment to be tested.

c. The needle electrode serves as a model object that allows PD to occur

d. The coupling Capacitor serves to pass high-frequency current from the Partial Discharge signal. The selection of the capacitance of the coupling capacitor must be more excellent than the capacitance of the high voltage equipment being tested so that when charging C, the equipment is complete faster, and in discharge conditions, it will be a current source (PD current) to be measured.

e. Z detecting impedance, in this case, in the form of an RC circuit that functions to convert current into a voltage which will be observed through an oscilloscope.

f. HFCT detects PD by detecting the high-frequency current generated by the PD.

g. Loop antenna serves to detect PD with non-conventional methods, namely detecting electromagnetic waves generated by PD; loop sensors used must detect high-frequency PD waves of the order of 1 MHz - 1 GHz.

h. Oscilloscope to display the V value of the PD signal.

B. Trial Procedure

Sensitivity test of partial discharge measurement sensor between RC Detector, HFCT, loop antenna using pC Calibrator.

1. Set up the oscilloscope, change the Source, and change to Normal Mode. 2. Connect the PC Calibrator to the Channel 1 Oscilloscope. 3. Observe the value of the PD voltage that

appears—taking a sample of 10 variations of PD load. 4. Adjust the Volt/div and Time/div for each load variation until the PD voltage is measured. 5. Connect the PC Calibrator to the RC Detector, then connect the RC Detector to Channel 2 Oscilloscope. 6. Observe the value of the PD voltage that appears—taking a sample of 10 variations of PD load. The value of the PD load variation is the same as in the previous test. 7. Adjust the Volt/div and Time/div for each load variation until the PD voltage is measured. 8. Connect the PC Calibrator to the HFCT, then connect the HFCT to the Channel 3 Oscilloscope. 9. Observe the value of the PD voltage that appears—taking a sample of 10 variations of PD load. The value of the PD load variation is the same as in the previous test. 10. Adjust the Volt/div and Time/div for each load variation until the PD voltage is measured. 11. Connect the PC Calibrator to the loop antenna, then connect the loop antenna to the Channel 4 Oscilloscope. 12. Observe the value of the PD voltage that appears—taking a sample of 10 variations of PD load. The value of the PD load variation is the same as in the previous test. 13. Adjust the Volt/div and Time/div for each load variation until the PD voltage is measured.

Observation of Background Noise, PDIV and PDEV, and PD Waveform using a series of High Voltage Diagnostic Lab experiments:

1. Using the same experimental circuit as the calibration test circuit, but for this experiment, the pC Calibrator is no longer used. 2. Conduct the second test, namely Background Noise, to detect signals that do not come from the test object to obtain an accurate PD signal. Setting the OFF and ON voltage on the voltage regulator is done to get Background Noise OFF and ON. Observations were made through an oscilloscope on the three sensors. 3. In the third test, the voltage is gradually applied to the test circuit using a voltage regulator to obtain negative and positive PDIV and PDEV. 4. In the fourth test, voltages of 5 kV, 6 kV, 7 kV were applied to the test circuit to obtain positive and negative PD waveforms.

IV. Findings And Discussion

A. Finding

The results of the experiments carried out are obtained in the form of calibration data which has 16 different data on each sensor. Sensors used include RC detector, HFCT, and loop antenna sensors. The value of the calibration results is presented in table 1 below

Table 1. 3 Sensor Calibration Results

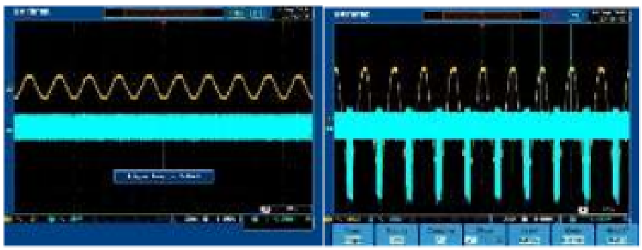
Ukuran Muatan	RC Sensor (mV)	HFCT sensor (mV)	Antena sensor (mV)
1pC	6	12	10
2pC	6	12	12
5pC	7.2	12	10
10pC	8.8	4.8	12
20pC	10.8	4.8	10
50pC	14.8	5.6	12
100pC	36.8	12.8	10
200pC	75.2	16.8	12
500pC	204	60	24
1nC	408	132	50
2nC	1000	280	108
5nC	3400	760	320
10nC	5800	1520	640
20nC	2640	376	140
50nC	12600	2200	136
100nC	13600	2400	800

The second experiment is to detect background noise. The test voltage has not been applied to the test object in this experiment. Observation of wave behavior displayed by the three sensors on the oscilloscope shows the difference between noise and PD signals. From the results of these experiments, we compare the values between background noise when on and background noise when off. The data is presented in the following table 2.

Table 2. Background Noise Measurement Results

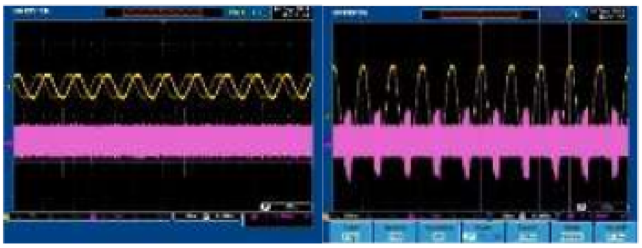
Background noise (mV)					
RC Detector		HFCT		Antena	
B-ON	B-OFF	B-ON	B-OFF	B-ON	B-OFF
10.24	7.24	6.4	5.2	12	9.6

The third experiment was continued by gradually applying the voltage to the test object being observed and then seeing the magnitude of the applied voltage until PD appeared for the first time. Observations were made on the three sensors: RC, HFCT, and loop antenna. The following is the PD output waveform detected on the three sensors.



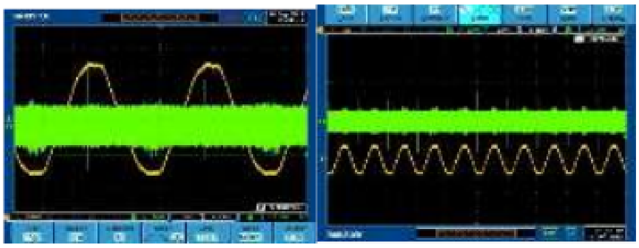
(a) (b)

Figure 8. PDIV RC (a) Positive wave, (b) Negative wave.



(a) (b)

Figure 9. PDIV HFCT (a) Positive wave, (b) Negative wave.



(a) (b)

Figure 10. PDIV loop antenna (a) Positive wave, (b) Negative wave.

The test results in the experimental circuit by applying the voltage gradually from the lowest voltage value to a specific voltage value that gives rise to PD.

Table 3. Value of Negative PDIV Voltage

	RC	HFCT	ANTENA
Nilai Tegangan (mV)	0.034	0.014	0.015

Table 4. Positive PDIV Voltage Value

	RC	HFCT	ANTENA
Nilai Tegangan (mV)	1.08	1.06	1.16

B. Discussion

From table 1 obtained a graph that shows the results of the calibration carried out. The graph is presented in Figure 11.

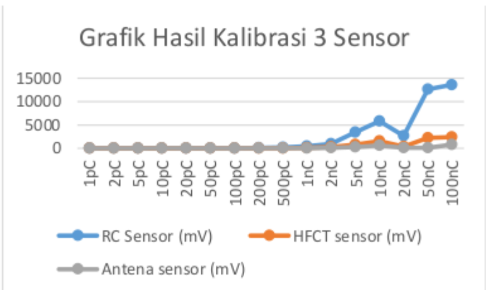


Figure 11. Graph of 3 sensor calibration results

Figure 11 shows an increase in the 10 nC charge. However, at the 20 nC charge, the PD value drops again. The PD value increased dramatically at a charge of 50 nC, likewise with HFCT sensors. However, the antenna only experienced a slight increase. For antenna sensors at pico-sized loads, the PD value is highly uncertain. Sometimes it increases, and sometimes it decreases even though the load continues to be enlarged. This is caused by the working principle of the PD itself. PD is the activity of the charge moving through the insulation. When these charges collide with each other, it will issue a signal that is captured by the antenna. Therefore, the smaller the charge, the more difficult the signal will be to be picked up by the antenna.

In HFCT, when the charge is in pico size also experiences an exciting event. Several sizes of charge in pico are the same even though the charge value is enlarged. This is because HFCT utilizes electromagnetic fields to capture PD signals. When the charge flows large enough, there will be a current flow in the HFCT. So the smaller the charge, the smaller the electromagnetic field generated. This is what makes the insensitivity of HFCT in measuring the charge very small.

V. Conclusion

From the results of the experiments that have been carried out, the following conclusions can be drawn. 1. The RC sensor is a more sensitive sensor for detecting PD signals. 2. Sensor Antenna can only be used to detect PD signals locally. 3. HFCT sensors and Antenna sensors cannot be used to detect PD loads on pico Coloumb size loads. 4. Noise appears caused by light, vibration, vehicle ignition, sound, and radio signals. 5. Moisture causes a PD-type tip discharge, as in the 7 kV test. 6. PDIV and PDEV are used as PD limit parameters of electrical equipment.

Reference

[1] CHOU, Chih-Ju; CHEN, Chien-Hsun. Measurement and analysis of partial discharge of high and medium voltage power equipment. In: 2018 7th International Symposium on Next Generation Electronics (ISNE). IEEE, 2018. p. 1-4

[2] FU, Pengyu, et al. A high sensitivity partial discharge current measurement method for the high voltage IGBT. In: 2017 Sixth Asia-Pacific Conference on Antennas and Propagation (APCAP). IEEE, 2017. p. 1-3.

[3] JANNAH, Roro Roudhotul; KHAYAM, Umar. Design, implementation, and testing of partial discharge signal pattern recognition and judgment system application using statistical method. In: Proceedings of the Joint International Conference on Electric Vehicular Technology and Industrial, Mechanical, Electrical and Chemical Engineering (ICEVT & IMECE). IEEE, 2015. p. 314-318.

[4] AHMED, Z.; KLUSS, J. V.; WALLACE, D. A. Partial discharge measurements and techniques for pattern recognition and life prediction of medium voltage XLPE cables. In: 2018 IEEE International Conference on High Voltage Engineering and Application (ICHVE). IEEE, 2018. p. 1-4.