

Analysis Of The Electromagnetic Wave Produced By Partial Discharge Measured Using Loop Antenna In Air Insulation

Michael Stevano Sinurat¹, Farida Gultom²
^{1,2}Faculty Of Engineering, Efarina University, Indonesia

ARTICLE INFO

Article history:

Received Jan 20, 2023
Revised Jan 25, 2023
Accepted Jan 31, 2023

Keywords:

Partial discharge
Electromagnetic wave
Loop antenna

ABSTRACT

This study discusses the measurement of partial discharge in air insulation. Partial Discharge measurement is very important to know the condition of electrical equipment. Partial discharge causes are not only old equipment, but also from set-up errors and insulation problems. In this research, partial discharge measurement is using non-electric method. The non-electric method uses a loop antenna sensor that detects electromagnetic waves generated by partial discharge. Modeling the occurrence of partial discharge with a needle-plate electrode at a distance of 1 cm with air insulation. Partial discharge measurement parameters include Background Noise (BGN) measurements, Partial Discharge Inception Voltage (PDIV) and Partial Discharge Waveforms. The different parameters of each discharge were analyzed based on the given voltage level. The resulting data is a discharge wave obtained from an oscilloscope. The resulting data is processed using origin software so that it can determine the characteristics of the amplitude, duration of rise time and fall time of the discharge that occurs. From the results, it is known that the amplitude and duration of the rise time and fall time is greater at discharge with a higher voltage. The discharge characteristics depend on the applied voltage.

This is an open access article under the [CC BY-NC](#) license.



Corresponding Author:

Michael Stevano Sinurat,
Faculty Of Engineering,
Efarina University, Indonesia
Email: michaelssinurat@gmail.com

1. INTRODUCTION

Human life certainly cannot be far from the source of electricity. Electricity is very beneficial for humans, among others, as a source of lighting, heat-producing, producing motion, and others. Electric energy is produced by power plants that are far from consumers. The distribution of electrical energy is carried out using high-voltage equipment such as cables, transformers, and other high-voltage equipment in the substation. High-voltage equipment that works continuously can cause degradation in isolation over time. The degradation of the isolation of high-voltage equipment can cause damage to the high-voltage equipment. Avoiding damage or failure of the electric power system can be done by measurement of high-voltage equipment resistance. One way of measuring

isolation can be done by measuring partially on high-voltage equipment. (Huang, 2021)(Hu et al., 2019)

The diagnosis of electrical equipment is very necessary to prevent breakdown or sudden damage to the equipment that causes the disruption of the electric power system. Measurement of insulation material is one of the diagnoses of high voltage electrical equipment.(Huang, 2021) Measurement of some is very important to find out to determine the condition of electrical equipment. Some of the high-voltage equipment will produce several signals such as impulse current, electromagnetic waves, vibrations, light, and heat. In general, these problems occur in electrical equipment that has long been used.(Vinet & Zhedanov, 2011a) Damage to electrical equipment 80% is caused by the problem of high voltage equipment isolation. This problem can interfere with the reliability of the equipment or electrical system itself. So the electrical system requires monitoring to maintain the quality of the isolation. (Chen et al., 2019)

In this study, the measurement or detection was carried out using a non-electric method using an antenna loop to detect the electromagnetic waves produced. This study also aims to determine the characteristics of a part of the exhaustion in the isolation of air measured using loop antennas. Characteristics of the penetration include measurement of background noise, partial discharge inception voltage, and waveforms of coating. Each characteristic of the exhaustion was compared to 3 variations of voltage, namely 5 kV, 6 kV, and 7 kV. Partial discharge measurements are done by modeling the needle electrode. The study will also discuss the experimental circuit and comparison of measurement results at each voltage.(Bhattacharya & Chatterjee, 2022)(Gizatullin et al., 2020)



Figure 1. Corona Discharge

Partial / Partial Discharge (IEC 60270) is a locally local electricity phenomenon that connects partially or part of the isolation between the conductor and what occurs both on the surface of the conductor and in the conductor (void). (Vinet & Zhedanov, 2011b)Some can occur in solid insulation, liquid insulation material, and gas insulation material. In general, some can be caused by the concentration of local electric stress in isolation and can also occur due to high-voltage equipment. There are 3 main things that can be a source of occurrence, namely internal water (the presence of cavities between dielectric or in certain dielectric), corona (occurs around the conductor), and surface coat (occurs on the surface due to contamination). The source of the occurrence as shown in Figure 1.

Partiality is a process of charge movement that is influenced by electric fields and magnetic fields. Silent electric charge (Q) only has an electric field and does not have a magnetic field. When the electric charge moves or changes to time, it produces an electric field (E) and a magnetic field (B) which is perpendicular to the direction. Figure 2 shows the direction of the movement of electric fields and magnetic fields.

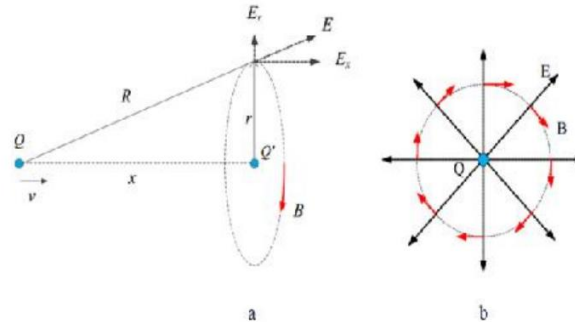


Figure 2. The direction of the electric field and magnetic field (Dustin H. Froula, 2001)

2. RESEARCH METHOD

A. Testing Object

The scale model used in this study is Corona Discharge. Partial discharge signals are generated by artificial sources using needle electrodes with a distance of 10 cm. The diameter of the needle is 1 mm with a needle tip of 3 μm and a needle angle of 30°. The plate needle electrode model is shown in Figure 3.

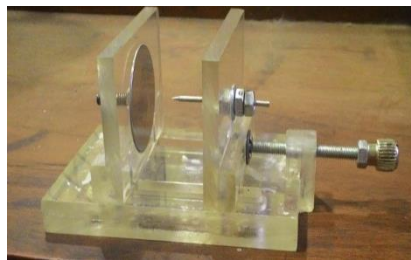


Figure 3. Needle-plate electrode

In this study, the measurement of partial discharge by using an antenna loop sensor to measure the electromagnetic waves produced by the coat. The distance of the antenna loop with the electrode is 10 cm. The type of sensor used in the measurement of peter as shown in Figure 4.



Figure 4. Loop Antena

The test circuit is indicated by Figure 5. The high voltage source of the test comes from the 200V/100KV transformer supplied from the 220 V power supply. There is an antenna loop that functions to measure electromagnetic waves from the penetration that occurs.

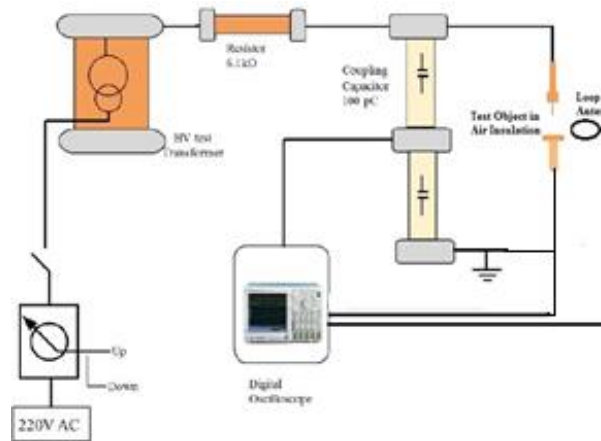


Figure 5. Test circuit

Partial discharge measurements are done using loop antenna sensors. The data used is an average of 40 times data collection with 3 variations of voltage levels, namely 5 kV, 6 kV, and 7 kV in air insulation. Data obtained from each measurement in the form of a .csv format from Osiloscop. This data is processed using Microsoft Office Excel software and plot using the 2016 Originpro software. The characteristics observed in this measurement are in the form of:

- PDIV (Partial Discharge Inception Voltage) positive and negative
- Positive and negative waveforms

3. RESULTS AND DISCUSSIONS

A. Partial Discharge Inception Voltage (PDIV)

The PDIV measurement is the voltage at which the discharge activity appears for the first time when the source voltage is gradually increased. In this study the PDIV observed was negative PDIV with positive PDIV in air isolation. In this test, PDIV was observed 60 times and then the average was taken.

1) Negative Partial Discharge Inception Voltage

Negative PDIV is the first negative discharge signal to appear. Figure 6. Shows the negative PDIV image detected by the loop antenna sensor in air isolation. Negative PDIV appear when the voltage source in 3.73 kV.

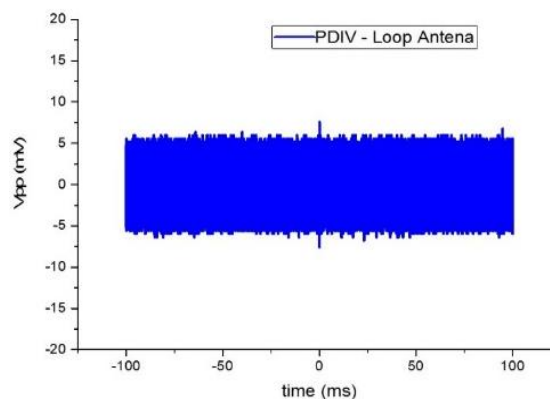


Figure 6. Negative PDIV

2) Positive Partial Discharge Inception Voltage

Positive PDIV is the first positive discharge signal that appears. Figure 7 shows a positive PDIV image detected by the loop antenna sensor in air isolation. Positive PDIV appear when the voltage source in 4.06 kV.

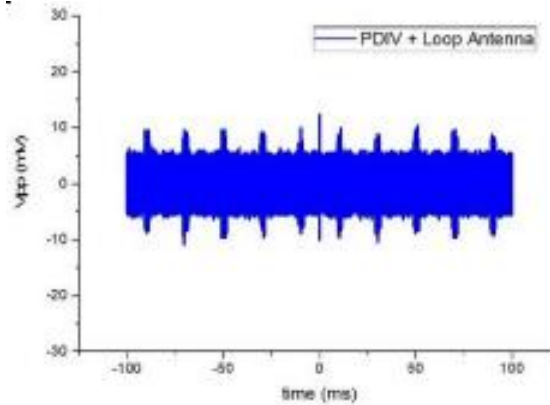


Figure 7. Positive PDIV

The data shows that the positive PDIV voltage is slightly higher than the negative PDIV, which means that the negative discharge wave will appear first, then the positive discharge. The results of measuring the PDIV value on the loop antenna show that the positive PDIV voltage value is slightly higher than the negative PDIV voltage value, thus indicating that at the needle-plate electrode, the negative discharge will occur before the positive discharge. This is because in the case of the needle-plate electrode, a very nonhomogeneous electric field occurs at the tip of the needle electrode. An increase in the voltage at the needle electrode (V) will increase the non-homogeneous electric field strength around the needle tip. The increase in electric field strength will affect the increase in the ionization energy of gas molecules (U) so that ionization of gas molecules occurs locally around the tip of the needle. This ionization causes gas molecules to lose electrons to produce positive ions and free electrons.

B. Partila Discharge waveform

There are two forms of discharge waves namely negative discharge waves and positive discharge waves. Negative discharge waves occur in negative cycles and positive discharge waves occur in positive cycles. The discharge waveform is taken 60 times. The waveforms you are looking for include negative discharge and positive discharge waveforms measured using a loop antenna at a voltage of 5 kV, 6kV and 7 kV in air isolation.

1. Positive Partial Discharge Waveform

The negative discharge waveforms were measured using a loop antenna with a voltage of 6 kV in air isolation as shown in Figure 8.

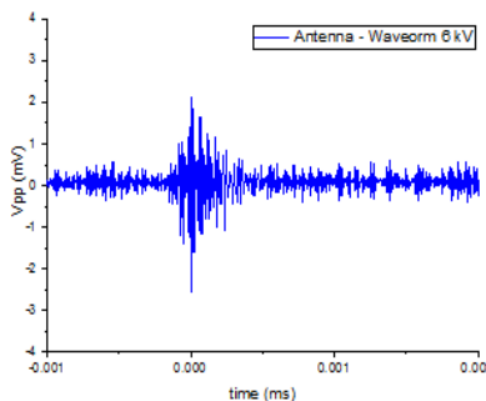


Figure 8. Positive Partial Discharge Waveform

The positive discharge waveforms were measured using a loop antenna with a voltage of 6 kV in air isolation as shown in Figure 9.

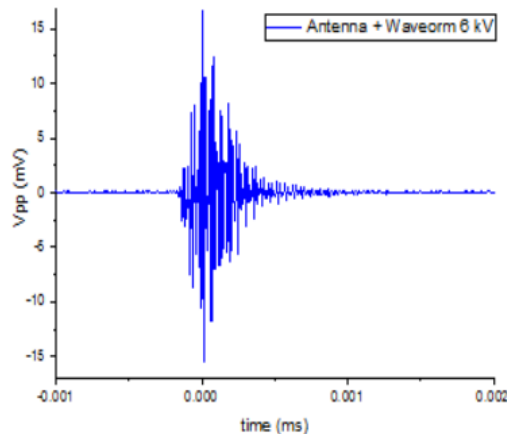


Figure 9. Positive Partial Discharge Waveform

From the measurement results, the rise time, fall time and Vpp of the negative discharge waveforms were measured using a loop antenna in air isolation as shown in table 1.

Table 1. rise time, fall time and Vpp of the negative discharge waveform

Voltage Sources	Rise Time (ns)	Fall Time (ns)	Vpp (mv)
5 kV	54	392	7.92
6 kV	68	444	8.66
7 kV	84	488	9.29

From the measurement results, the rise time, fall time and Vpp of the positive discharge waveforms were measured using a loop antenna in air isolation as shown in table 2.

Table 2. rise time, fall time and Vpp of the negative discharge waveform

Voltage Sources	Rise Time (ns)	Fall Time (ns)	Vpp (mv)
5 kV	84	541	28.86
6 kV	90	552	37.46
7 kV	92	612	49.42

From the results of measurements using a loop antenna at a voltage of 5 kV, 6 kV, and 7 kV in air isolation, it shows that the rise time of positive discharge waves and negative discharge waves is faster than the fall time of positive discharge waves and negative discharge waves. This is because the discharge waveforms in the form of impulses describe the movement of electrons as negative charge carriers and ions as positive charge carriers. The lighter mass of electrons causes the mobility of electrons to be much greater than that of ions so that the current due to the movement of electrons is large but immediately drops and contributes to the rise time region, while the current due to ions flowing for a longer time is small and contributes to the fall time region. The discharge waveform above shows that the discharge wave occurs rapidly on the order of nanoseconds. From the results of measurements using a loop antenna at a voltage of 5 kV, 6 kV, and 7 kV isolated gas (air) also shows that the magnitude of Vpp will be greater when the voltage is increased. So the magnitude of Vpp will affect the amount of voltage applied.

4. CONCLUSION

This study discusses the characteristics of the partial discharge that produces electromagnetic waves that are measured on the loop antenna sensor. The results of this study can be concluded as follows: Partial Discharge is a phenomenon of local electric discharge that connects partially or partially from the insulation between conductors and which occurs both on the surface of the conductor and inside the conductor. Discharge occurs earlier during negative waves than discharge on positive waves. As well as the magnitude of V_{pp} / positive discharge charge is greater than the negative discharge. From the measurement results of the loop antenna sensor waveform at a voltage of 5 kV, 6 kV and 7 kV it shows that the fall time is greater than the rise time in the discharge wave. This is because the discharge wave pulses in the form of impulses are composed of two charge carriers, namely negative charge carriers (electrons) and positive charge carriers (ions). So, the mass of electrons is lighter so that the electron mobility is much greater than that of the ions, the current due to electrons is large but soon runs out and contributes to the rise time area, while the current due to ions is smaller and flows over a longer period so the current due to ions contributes to the area fall time.

REFERENCES

- Bhattacharya, S., & Chatterjee, A. (2022). Digital project driven supply chains: a new paradigm. *Supply Chain Management*, 27(2), 283–294. <https://doi.org/10.1108/SCM-12-2020-0641>
- Chen, X., Zhang, H., Wu, C., Mao, S., Ji, Y., & Bennis, M. (2019). Optimized computation offloading performance in virtual edge computing systems via deep reinforcement learning. *IEEE Internet of Things Journal*, 6(3), 4005–4018. <https://doi.org/10.1109/JIOT.2018.2876279>
- Gizatullin, Z. M., Gizatullin, R. M., & ... (2020). Prediction of Noise Immunity of Computing Equipment under the Influence of Electromagnetic Interference through the Metal Structures of Building by Physical *... Researchers in Electrical* <https://ieeexplore.ieee.org/abstract/document/9039452/>
- Hu, X., Wong, K. K., Yang, K., & Zheng, Z. (2019). UAV-Assisted Relaying and Edge Computing: Scheduling and Trajectory Optimization. In *IEEE Transactions on Wireless Communications* (Vol. 18, Issue 10, pp. 4738–4752). <https://doi.org/10.1109/TWC.2019.2928539>
- Huang, Y. (2021). *Antennas: from theory to practice*. books.google.com. https://books.google.com/books?hl=en&lr=&id=iwhBEAAAQBAJ&oi=fnd&pg=PA11&dq=electrical+equipment+antenna+loop&ots=YMr0mRk_Rr&sig=a5oD_-hxtZFkgD9WQ7b4Dwb-aQw
- Vinet, L., & Zhedanov, A. (2011a). A “missing” family of classical orthogonal polynomials. In *Journal of Physics A: Mathematical and Theoretical* (Vol. 44, Issue 8). [dSPACE.uui.ac.id. https://doi.org/10.1088/1751-8113/44/8/085201](https://doi.org/10.1088/1751-8113/44/8/085201)
- Vinet, L., & Zhedanov, A. (2011b). A “missing” family of classical orthogonal polynomials. In *Journal of Physics A: Mathematical and Theoretical* (Vol. 44, Issue 8). [repository.unim.ac.id. https://doi.org/10.1088/1751-8113/44/8/085201](https://doi.org/10.1088/1751-8113/44/8/085201)