Comparison Between Phase Resolve Partial Discharge and Pulse Sequence Analysis Approaches Using Surface Tracking Data

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DECLARATION

I declare that this thesis entitled "Comparison Between Phase Resolve Partial Discharge and Pulse Sequence Analysis Approaches Using Surface Tracking Data is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature :

Name : UMANANTINI A/P POOVANESWARAN

Date : 30/1/2023

APPROVAL

I hereby declare that I have checked this report entitled " Comparison Between Phase Resolve Partial Discharge and Pulse Sequence Analysis Approaches Using Surface Tracking Data ", and in my opinion, this thesis fulfils the partial requirement to be awarded the degree of Bachelor of Electrical Engineering with Honours.

Signature :

Supervisor Name : DR NUR HAKIMAH BINTI AZIZ

Date : 31/1/2023

DEDICATIONS

I would like to dedicate the success of this project research especially to my parents which is my father Poovaneswaran a/l Sellan and my mother, Theresammal a/p Arokiam . This report will be dedicated to them because I want to thank that for all the sacrifices that they made for me while I have been studies at this university. Secondly, this dedication is given to my siblings who have helped in terms of advice, finance and encouragement support to make this report. Next, I would like to express a lot of gratitude to my supervisor, Dr Nur Hakimah Binti Aziz and my friends that give a lot of helped while completing this Final Year Project.

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ABSTRACT

Partial discharge (PD) is one of the most common types of ageing processes in electrical insulation. PD detection is a defined method for determining the status of insulation in electrical assets like machines and power cables. PD in high-voltage (HV) insulating systems are caused by a variety of local faults, resulting in insulation deterioration and equipment life span reduction. It is critical to link the observable PD patterns to the parameters of the defect and, eventually, to establish the type of defect in order to ensure the dependable and long-term operation of HV equipment. The most popular representation of PDs is the phase-resolved partial discharge (PRPD) pattern. This classical approach often utilises the statistical features in representing the unique PRPD pattern of different types of PD source. Pulse sequence analysis (PSA) is another pattern recognition technique which is claimed to have more meaningful interpretation of PD phenomenon than PRPD. The key parameter of PSA is the change of electric field between consecutive PD pulses which is reflected in the change in voltage due to the excitation waveform. Both PRPD and PSA patterns can be plotted from the PD measurement of IEC 60270 technique. The key parameters for PRPD are the phase angle and the charge magnitude while for PSA are the occurrence voltage of consecutive PD pulses. Since the occurrence voltage of PD pulse in PSA is related to the phase angle of PRPD in the sinusoidal formula, this study therefore, aims to investigate the relationship between PRPD and PSA using PD data from the previous surface discharge experiments of Midel. The PRPD pattern form a sinusoidal waveform according to the quadrant of the phase angels and the resulting PSA pattern of each PRPD cluster will be traced and described. The outcome of this study will contribute to the knowledge of PD analysis and to known the relationship between the PRPD(phase and discharge) and PSA according to the cluster of pattern.

ABSTRAK

Nyahcas separa (PD) adalah salah satu jenis proses penuaan yang paling biasa dalam penebat elektrik. Pengesanan PD ialah kaedah yang ditentukan untuk menentukan status penebat dalam aset elektrik seperti mesin dan kabel kuasa. PD dalam sistem penebat voltan tinggi (HV) disebabkan oleh pelbagai kerosakan tempatan, mengakibatkan kemerosotan penebat dan pengurangan jangka hayat peralatan. Adalah penting untuk memautkan corak PD yang boleh diperhatikan dengan parameter kecacatan dan, akhirnya, untuk menentukan jenis kecacatan untuk memastikan operasi peralatan HV yang boleh dipercayai dan jangka panjang. Perwakilan PD yang paling popular ialah corak pelepasan separa fasa (PRPD). Pendekatan klasik ini sering menggunakan ciri statistik dalam mewakili corak unik PRPD bagi jenis sumber PD yang berbeza. Analisis jujukan nadi (PSA) adalah satu lagi teknik pengecaman corak yang didakwa mempunyai tafsiran yang lebih bermakna bagi fenomena PD berbanding PRPD. Parameter utama PSA ialah perubahan medan elektrik antara denyutan PD berturut-turut yang dicerminkan dalam perubahan voltan akibat bentuk gelombang pengujaan. Kedua-dua corak PRPD dan PSA boleh diplot daripada pengukuran PD teknik IEC 60270. Parameter utama untuk PRPD ialah sudut fasa dan magnitud cas manakala untuk PSA ialah voltan kejadian denyutan PD berturut-turut. Oleh kerana voltan kejadian nadi PD dalam PSA berkaitan dengan sudut fasa PRPD dalam formula sinusoidal, maka kajian ini bertujuan untuk menyiasat hubungan antara PRPD dan PSA menggunakan data PD daripada eksperimen nyahcas permukaan midel sebelumnya. Corak PRPD membentuk bentuk gelombang sinusoidal mengikut kuadran malaikat fasa dan corak PSA yang terhasil bagi setiap kelompok PRPD akan dikesan dan diterangkan. Hasil kajian ini akan menyumbang kepada pengetahuan analisis PD dan untuk mengetahui hubungan antara PRPD(fasa dan nyahcas) dan PSA mengikut kelompok pola.

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CHAPTER 1

1.1 BACKGROUND AND MOTIVATION

Under high electric field stress, partial discharge (PD) is an electrical discharge event that does not completely bridge the electrodes between an insulating system. Delamination's, cavities, joints, or voids in the insulating system of high voltage components such as power generators, transformers, power transmission lines, and power cables are common locations for PD.

Due to the higher breakdown strength of the insulation material than the fault site, PD typically occurs at the defect areas within the insulation system [1]. There are typically four basic forms of partial discharge, though the term varies, and each one can happen for a variety of reasons and lead to varying levels of harm. Which is corona discharge, surface discharge, arcing discharge and lastly void(internal) discharge. From this four type author choose surface discharge to analysis the relationship between PRPD and PSA.

Surface discharge, known as surface tracking, occurs when a discharge travels along the surface of insulation. It's one of the most destructive kinds of partial discharge. The two most typical causes of surface discharge are contamination and weathering of the insulator surface. This sort of discharge occurs in medium- and high-voltage equipment when insulation fails, frequently owing to high humidity or inadequate maintenance [2]. Surface discharge is frequently caused by moisture penetration.

1.2 PROBLEM STATEMENT

The goal of this study is to determine the connection between PRPD and PSA patterns. The PRPD representation, in which the fluctuation of PD pulses (either in amplitude or repetition rate) is commonly represented by statistical quantities, has traditionally been the most prevalent approach. Later, the PSA technique included the PD phenomenon. PSA investigates the link between two consecutive PD pulses and the physical processes that take place within the confined degradation region. PSA is said to provide a more relevant interpretation of the PD phenomena than PRPD.

The PD measurement of the IEC 60270 approach can be used to plot both PRPD and PSA patterns. The phase angle and charge magnitude are important characteristics for PRPD, while the occurrence voltage of consecutive PD pulses is important for PSA. Because the occurrence voltage of the PD pulse in PSA is related to the phase angle of PRPD in the sinusoidal formula, this study intends to evaluate whether there is a relationship between PRPD and PSA. The study will utilise PD data from prior surface discharge experiments with mineral, midel and also pfae oil. To the best of author's knowledge, no work has reported the relationship between the PRPD and PSA pattern. The outcome of this study might reveals that PRPD is not related to PSA. But if they are related, this study will give a new knowledge on the PRPD and PSA approaches aiding the researchers in deciding between both approaches.

1.3 OBJECTIVE

1. To compare the PD pattern of surface discharge between PRPDA and PSA approaches.
2. To investigate the relationship between PRPDA and PSA pattern using surface discharge data.

1.4 PROJECT SCOPE

The scope of this project is fully based phase resolved partial discharge (PRPD) and Pulse Sequence Analysis (PSA) pattern of surface discharge. The PD data from the previous surface discharge experiment is utilised. The surface discharge experiment was conducted using IEC 60270 measurement. The experiment is carried out by the ester oil which is mineral, Midel and Pfae oil. Samples that receive for Midel oil almost 3 type samples. While for mineral and Pfea received 1 sample. All the experiment is done within 1 minute time duration. For this research used 3 sample for Midel data to compare the relationship for PRPDA and PSA pattern. The analysis and graph plotting will be in MATLAB R2021b.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Partial discharges (PD), which are set on by defects in the insulation of transformers, might eventually cause the insulating material to break down and result in electrical breakdown[3]. Therefore, it's crucial to find partial discharges early. The ageing status of transformers can be revealed through PD measurements, allowing estimates of their lifetime to be made. Consequently, PD testing is essential in order to prevent high voltage equipment from issues before they occur.

The operator who is knowledgeable with PD matters can categories a variety of PD patterns. Pattern is a term used to describe a collection of traits that define an individual. A pattern in classification is made up of the variables x and w, where x is a group of observations or features (feature vector), and w is the idea that underlies the observation (label). The capacity of a feature vector to distinguish examples from various classes is correlated with its quality. While examples from different classes should have various feature values, examples from the same class should have similar feature values.

A pattern recognition system can be implemented using either a statistical technique or a structural approach[4]. Different methods are used by each strategy to carry out the description and classification duties. Combining statistical and structural methodologies into a pattern recognition system, hybrid systems are sometimes referred to as a unified approach to pattern recognition [4]. In order to distinguish between data from various groups based on the quantitative characteristics of the data, statistical pattern recognition builds on well-established notions in statistical decision theory. Statistical methods based on similarity (e.g., template matching, k-nearest neighbors), probability and clustering are employed as classifiers within the classification problem (e.g., k-means, hierarchical).

Among this research, above pattern recognition term going to use to finding the relationship between the pulse resolve partial discharge and also the phase sequence analysis. The phase resolved partial discharge (PRPD) pattern and pulse sequential analysis (PSA) approaches are two extensively used methods for measuring and analyzing PD activity[5].

Based on the patterns obtained, these strategies can be used to identify between different forms of PD. Based on the patterns obtained, these techniques can be used to distinguish between different types of PD.

2.2 PARTIAL DISCHARGE

The partial discharge (PD) phenomena are inextricably linked to the operation of any high-voltage device, such as power lines, cables, generators and motors, switchgears, and transformers. Whatever type of electrical power device has been affected by PD, it may produce major insulation system defects in the long run [2],[6]. PD diagnostics are now recognized as a critical component of electrical power fleet maintenance and reliability management. Although there are numerous PD measuring methods that are widely used and understood, further development, particularly in the areas of measurement results interpretation, measurement procedure simplification, and, above all, apparatus application under normal on-site operating conditions, remains a critical issue. The type of the PD source as well as the ambient conditions have a strong influence on the physical quantity values recorded during a measurement [1]. Any changes to the environment or PD generating settings have a significant impact on the final results obtained in [3].

Under high-voltage stress, partial discharge (PD) is a localized dielectric breakdown of a tiny piece of a dielectical insulating system. [7] The IEC 60270-2000 standard defines partial discharge as "a localized electrical discharge that only partially crosses the insulation between conductors and can or cannot occur near to a conductor," and it can destroy liquid and solid insulation systems irreversibly. Partial discharge occur as a consequence of ;

- Increased electric field intensity causes partial discharge to occur (weak design or over stress)
- Overheating in a specific area (creation of voids and bubbles)
- Insulation material defects or weaknesses
- Abrasion of cast resin delamination
- Mechanical tension (vibration)
- Water tree planting

We can uncover critical faults and check the condition of the insulating systems using PD analysis. Because PD is often the first sign of a full insulation breakdown, power transformers, generators, instrument transformers, cable systems, and switchgear have been inspected for PD for many years. Insulation can be made of solid, liquid, or gaseous elements, or any combination of the three. The term "partial discharge" refers to a wide range of discharges[8]. The influence of discharges continues, resulting in the creation of hollow gas-filled tubes. In one of research Autor discuss[9] about the type of partial discharge. These various types of partial discharges, as shown schematically in Fig. 2.1, will be discussed in greater depth.

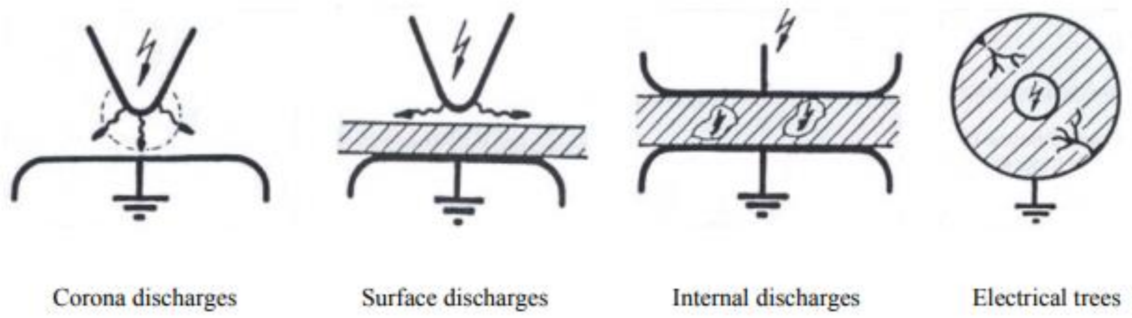

Figure 2.1: Type of Partial Discharge[10]

Corona Discharge: This typical type of partial discharge happens when discharge is made into the air directly from the conductor's sharp surface. (This is what generates the noise and RF emissions.) Corona usually doesn't pose a threat to safety or harm. Then, Surface Discharge: Surface discharge, also known as surface tracking, is the movement of a discharge along the surface of insulation. It has the potential to be among the most harmful partial discharges. The two most frequent causes of surface discharge are contamination and insulator surface weathering. This type of discharge occurs in medium- and high-voltage equipment when insulation fails, typically as a result of excessive humidity or inadequate maintenance. Surface discharge is also frequently caused by moisture ingress. Void (internal) discharge is typically brought on by an issue with the solid insulation of cables, bushings, GIS junction insulation, and other components. In most cases, void discharge will keep growing until it completely destroys insulation, which is quite harmful.

Since the data using comes from earlier surface discharge experiments with midel oil, we'll use the surface discharge defect type in this study. The surface discharge defect type is the most suitable to use in this research, since it is highly related to the experiments that have been conducted using midel oil.

2.3 SURFACE DISCHARGE

When a strong field component runs parallel to a dielectric interface (such as a solid/liquid or solid/gaseous interface), surface discharges occur. These discharges propagate from phase to phase or from phase to ground through fractures in the insulation, polluted routes on the insulation, or between components with insufficient electrical clearance[11]. Condensate, dirt, cleaning product residues, oils, and greases can all cause contamination. Water can condense on the surface of insulators even if the substation heating is turned off, resulting in eventual electrical breakdown[12].

Surface discharges in high-voltage equipment frequently result in dielectric degradation due to depolymerization and other chemical reactions that cause surface erosion[13]. Terminations of cables and end-windings of stators are common areas for surface discharges in electric apparatus. The several stages of PD-induced deterioration at the insulator surface are depicted in Fig. 2.2.

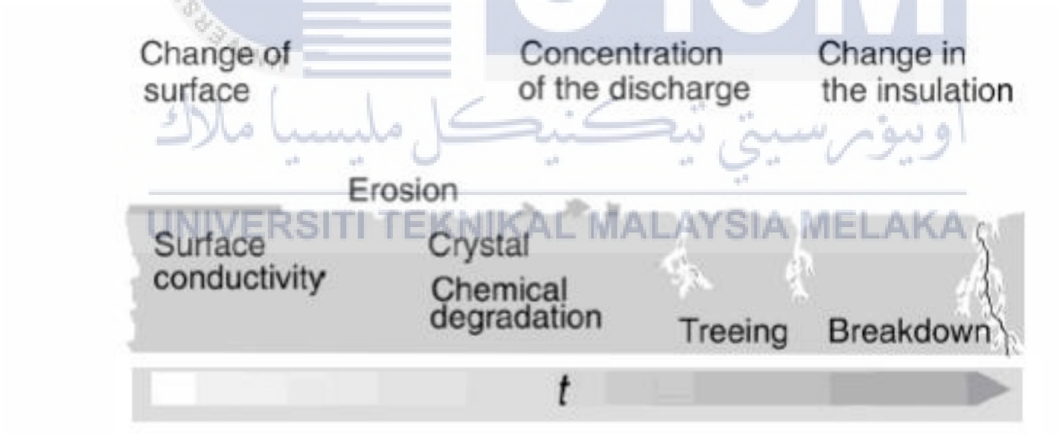

Figure 2.2 : Stages of PD induced damage at the insulator surface[10]

Author studied about surface discharge behavior of various dielectric samples under DC. One in a series that examines the various common defect types that affect insulation systems, identifies their patterns, and comprehends the underlying mechanisms. This research explores the surface defect model, a frequent PD source in insulation systems that occurs over dielectric interfaces and is occasionally also known as creping discharge[14]. These kinds of discharges develop over time and deteriorate the insulation at gas-solid interfaces.

2.4 PD Detection

The author of this research [15] discuss an alternative with a better signal-to-noise (S/N) ratio is the UHF technique. For the purpose of determining the kind and location of defects, this method was initially developed for gas-insulated switchgear and then adapted to power transformers [84] and cable terminations (on-line) [85]. The key benefit of this approach is its capacity to pinpoint the PD's location by utilizing numerous UHF sensors and the "time-of-flight" technique (calculating the delay between the PD signal's arrival times at each sensor) [16].

These sensors are positioned all around the PD source, and the presence of PD may be determined by monitoring electromagnetic emissions that are caused by transient currents of PD that have frequencies between 500 and 1500 MHz. The coupler, which generates an output in the form of an oscillating voltage signal, detects the generated UHF signal. According to research, the UHF signal's magnitude is typically influenced by the strength of the current pulse, and as a result, it can be described as the corresponding PD magnitude [16].

2.5 PD Data Representation

The PD data can be represented in either phase-resolved or time-resolved format. The most common approach has traditionally been through the PRPD representation in which the variation of PD pulses (either in magnitude or repetition rate) is often represented by statistical quantities[8]. Later in 1990‘s, a more meaningful interpretation of PD phenomena was introduced in PSA approach. PSA examines the relationship between two consecutive PD pulses, which relates to the physical processes occurring within the localised degradation region.

2.5.1 Phase Resolve Partial Discharge

The phase and charge magnitude of PD occurrences are used in the PRPD approach [5]. The PD charge magnitude axis (y-axis) represents the range of magnitude observed, while the phase axis (x-axis) represents one full cycle of the applied voltage. On the x-axis of one voltage cycle, PD data within a predetermined number of applied voltage cycles are shown. As a result, a PRPD pattern demonstrates PD occurrences at a particular applied voltage phase with a specific charge magnitude within a specific number of applied voltage cycles.

The phase angle of the AC test voltage waveform is used to gather phase-resolved PD data. At the measuring stage,[15] three basic quantities of the PD pulse are quantified over a preset time duration for electrical detection: phase angle occurrence φ charge q, and voltage cycle occurrence n or PRPD patterns are terms used to describe how this data is presented. Instead of measuring discharge magnitude, the UHF detection method measures the output voltage from the UHF coupler which explain early.

Figures 2.3(a) show the PRPD pattern for different PD sources based on electrical and UHF detection, respectively. The scatter plot in Figure 2.3(b) shows the distribution of apparent charge, q, on unrevealing the information of n. In the other hand, allows inspection of the relative amplitude of the PD pulse (obtained from the pulse collected by the UHF sensor) on φ and n. This graph depicts PD activity in 50 cycle bursts, which is the complete data in 1 second, and is utilized to understand the data[17].

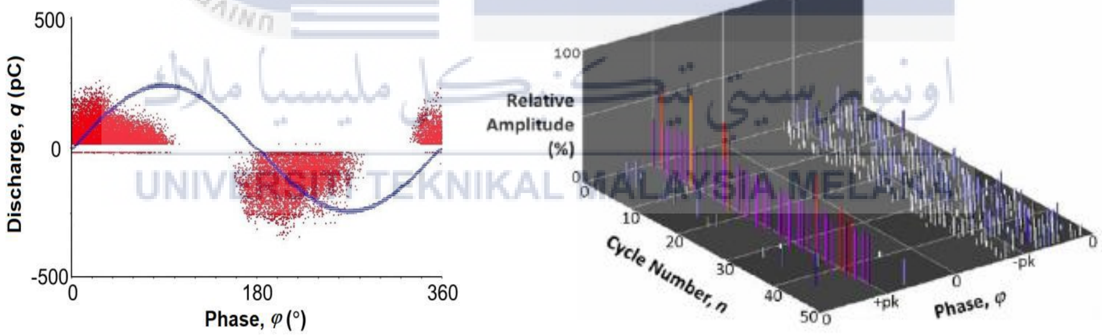

Figure 2.3 : PRPD Patterns(a) phase vs discharge[17] (b) three-axes from different PD sources.[15]

In the PRPD patterns of surface discharge from the experiment. The positive applied voltage cycle has fewer PDs than the negative applied voltage cycle, as shown in Figure 2.4 which refer to the research[5]. This is due to the fact that with a negative applied voltage, more electrons are easily available from the electrode, making it simpler to create more electron avalanches. Due to the electric field building up along the route of the electron avalanche on the material surface, the maximum PD magnitude occurs at a lower applied voltage during the negative cycle than during the positive cycle. Around 270 degrees of phase yields the largest PD charge magnitude.

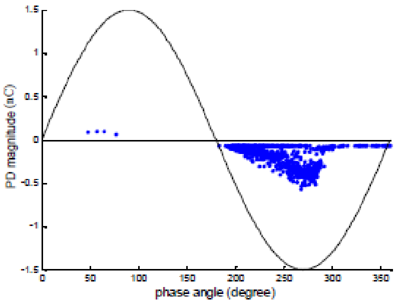

Figure 2.4 : PRPD Patterns phase vs discharge[5]:

2.5.2 Pulse sequence analysis

PSA interprets PD pulses as events within a sequence. This method is based on the idea that a sample's history and condition, including recent discharge events, influence the ignition and type of the next discharge pulse [11]. The local electric field and its change from the previous pulse, which are both reliant on the voltage difference between subsequent pulses, are crucial governing parameters of each discharge. Because of the build-up of space charges, the voltage variations do not occur at random, but rather in precise sequences that characterize the discharge processes in the defect [3].

The PSA technique is illustrated in Figure 2.5, where the solid circles indicate three PD pulses inside the reference cycle designated 1, 2, and 3. The instantaneous voltage, *u,* the voltage differential, *du,* and the voltage derivative with respect to time, *du/dt,* were added in [3] to indicate changes in consecutive PD 20 pulses. Considering consecutive PD pulses of 1 and 2, du and dt of pulse 1 can be determined using equations 2-1 and 2-2 where n = 1. Both equations can then be used to calculate du/dt.

$$du_n = u_{n+1} - u$$

$$dt_n = t_{n+1} - t_n$$

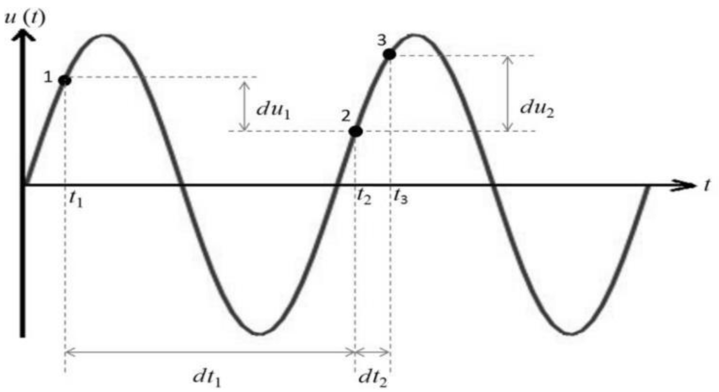

Figure 2.5 : Principle of the generation of the PSA Pattern [2]

The three parameters are usually plotted in a scatter graph, with the previous (*x*-axis) and