ANALYSIS ON PARTIAL DISCHARGE WITHIN A VOID IN A POLYMERIC INSULATION

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DECLARATION

I declare that this thesis entitled "ANALYSIS ON PARTIAL DISCHARGE WITHIN A VOID IN A POLYMERIC INSULATION 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 candidature of any other degree.

Signature :

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Date : 5^{TH} JULY 2021

APPROVAL

I hereby declare that I have checked this report entitled "ANALYSIS ON PARTIAL DISCHARGE WITHIN A VOID IN A POLYMERIC INSULATION" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Electrical Engineering with Honours

Signature :

Supervisor Name : MADAM ANIS NIZA BINTI RAMANI

Date : 6 July 2021

DEDICATIONS

To my beloved mother and father, Haseah binti Ismail and Zakaria bin Ramli.

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ABSTRACT

The localization dielectrical breakdown (DB) of a small portion of rigid or fluid electric insulation (EI) under high voltage (HV) voltage is the partial discharge (PD) in electrical engineering (which does not fully bridge the gap between the two conductors). High-voltage power cable partial discharge (PD) due to deficiency phenomenon may occur in its isolation system. The dielectric is normally the insulating product where the polymer materials are polymeric. Repeating PD process may present the deffect. The defect site may cause isolation failure because of bridges between electrode isolation. As a result, the entire cable will break down. Thus, cable insulation device PD behavior analysis has been used widely to track the state in operation of the power cables. A void cavity for cable insulation under high electrical field is one of the most common PD sources. In this paper, measurements of PD activity within the insulation layer of low-density polyethylene (LDPE), polypropylene (PP) and cross-linked polyethylene (XLPE) was performed. A comparison type of experiment within different material cable insulation was also present by comparing its parameter. The different cases of the paper was analysed in varying situations of voids and isolating. This study will compare the perception of the PD phenomena in different cable insulation.

ABSTRAK

Pemecahan dielektrik penyetempatan (DB) sebahagian kecil penebat elektrik tegar atau bendalir (EI) di bawah voltan tinggi (HV) adalah pelepasan separa (PD) dalam kejuruteraan elektrik (yang tidak merapatkan jurang antara kedua konduktor). Pelepasan separa kabel kuasa voltan tinggi (PD) kerana fenomena kekurangan mungkin berlaku dalam sistem pengasingannya. Dielektrik biasanya merupakan produk penebat di mana bahan polimer bersifat polimer. Proses PD yang berulang dapat menimbulkan kesan buruk. Tapak kecacatan boleh menyebabkan kegagalan pengasingan kerana jambatan antara pengasingan elektrod. Akibatnya, keseluruhan kabel akan rosak. Oleh itu, analisis tingkah laku PD peranti penebat kabel telah digunakan secara meluas untuk mengesan keadaan operasi kabel kuasa. Rongga kekosongan untuk penebat kabel di bawah medan elektrik tinggi adalah salah satu sumber PD yang paling biasa. Dalam kajian ini, pengukuran aktiviti PD dalam lapisan penebat polietilena berketumpatan rendah (LDPE), polipropilena (PP) dan polietilena bersilang silang (XLPE) dilakukan. Jenis perbandingan eksperimen dalam penebat kabel bahan yang berbeza juga hadir dengan membandingkan parameternya. Kes yang berbeza dari kertas dianalisis dalam pelbagai situasi kekosongan dan pengasingan. Kajian ini akan membandingkan persepsi fenomena PD dalam penebat kabel yang berbeza.

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LIST OF ABBREVIATIONS AND SYMBOLS

DB	Dielectrically Breakdown
PD	Partial Discharge
EI	Electric Insulation
HV	High Voltage
CD	Corona Discharge
BD	Brush Discharge
PE	Polyethylene
PP	Polypropylene
FDM	Finite Difference Method
PRPD	Phase Resolved Partial Discharge
AC	Alternating Current
DC	Direct Current
XLPE	Cross-Linked Polyethylene
EPM	Ethylene Propylene Rubber
EPDM	Ethylene Propylene Diene Monomer
CE	Controlled Expansion
PTFE	Polytetrafluorethylene
CC	Covered-Conductor
PAS	Passive Automation Systems
APD	Arc Protection Device
IEC	International Electrotechnical Commission

CHAPTER 1

INTRODUCTION

1.1 Overview

This chapter provides the introduction of project background on electrical ageing in polymeric insulation causes by cavities. It also includes the research motivation, problem statement, objective and scope.

1.2 Project Background

The content of this report were carefully designed to address the different study cases of partial discharge occur in insulation. Electrical insulation actually the most critical components of high voltage equipment to be maintained throughout its operation against mechanical, thermal and electrical stresses [1]. Partial discharge (PD) can occur when insulation defects in high voltage equipment are present and the effect could be detrimental to the device in the long term [2]. For ages years, partial discharge applied as an effective condition monitoring tool for assessing dielectric degradation processes [3]. For the classification of sources in isolating electric wires the study of phase resolved partial discharge patterns (PRPD) was examined [4]. The development of internal discharge was a known technique of degradation, so that the transformation of the growth of the electric tree led to a complete isolation failure [5-7].

Due to imperfections inside the insulation material, a failure of the polymeric isolated HV cables can occur much earlier than their life expectancy. Sometimes due to the extruded building process, imperfections are produced and may be cavities, pollutants, splits and protrusions [8].

Refering to [9], a significant amount of references can be found to the influence of stresses like radiation, corona or partial releases (PD) on ageing. A few decades ago, Dakin attempted to use the principle of reaction rate and the model Arrhenius to establish an interpretation of the thermal aging [10]. In addition to many further throughout studies and the definition of the agreed criteria, which may direct accurate thermal-degradation processes, thermodynamic models (Eyring model) [11-19] have not been achieved far enough afterwards about the effects of temperature and the thermal restriction characteristics.

1.3 Motivation

Currently due to their strong mechanical, chemical and electrical insulation properties, polymeric materials are commonly used in electrical and electronic devices. There's a slightly different case of electrical ageing due to it cavity properties. Most of the work is performed in the effect of the electric field, from AC to DC and repetitive impulses, on polymeric material aging has been involved in recent decades, and we can still not assume that there is a response and a simple and efficient thermal aging model. Therefore, phenomenological models for electrical stress durability have been created for the design of electric insulation using basic laws that can correlate with experimental findings in accelerated life testing and allow extrapolation to design stress.

In particular, exponential models or inverse-power models were widely used (deriving from some similarities to the thermal endurance law), and they are still used today. Besides imagining phenomenological descriptions of electrical life, attempts were made and still are made to explore the modes in detail. The electric field allows isolating objects and systems to get old. Component discharges or corona discharges on the basis of electrical apparatus loss is one of the first modes considerations.

1.4 Problem Statement

PD usually occurs at cable joints and terminations in high voltage cables, where many works have recorded on this, [21-24]. However, if there are defects within the cable insulation, PD may also occur when the electrical field reaches the air breakdown strength at the defect sites. Isolation defect forms are typically unknown and caused by insufficient manufacturing or bad workmanship in the installation. Therefore, it is very important to track PD operation on high voltage cables, and information on PD patterns from cables with various types of defects is crucial. One of the ways to obtain this data is by testing PD on recognized defects or producing traditional artificial defects inside cable insulation. The issue in this paper needs to be highlighted is that the void cavity has an effect on polymeric insulation. The insulation material is continually degraded by PDs, which inevitably results in a decomposition of isolation

[6-9]. PD is an electrically localized discharge, as defined by IEC60270, which partially connects the insulation between two conductors [10].

This paper attempts to investigate the partial discharge of a polymeric isolation in a void cavity. As the supply sector moves to condition-based management schemes, partial discharge increasingly becomes an integral part of electrical property management. The remaining arrangements are, however, applicable to AC schemes. The expanded use of DC connections for the interconnector of submerged and long-distance land for equal control of DC properties is an essential decision. Nevertheless, the successful introduction of such controls currently faces many hurdles, notably the absence of awareness of DC component discharge in comparison with AC [25].

1.5 Objective

In this work, the measurement and simulation of PD activity within void was analysed based on comparison of different test and parameter on other paper cases.

The main objectives of this paper are:

1. To compare the results in experiment of partial discharge.
2. To analyse the effect of void in term of partial discharge.
3. To study the difference material used in insulation.

1.6 Scopes

The scopes of this paper are:

1. Using material of low-density polyethylene (LDPE), polypropylene (PP) and cross-linked polyethylene (XLPE).
2. Analyse the partial discharge of void cavity in different material.
   - To study the effect of various applied stresses and cavity conditions on PD activity.
3. Comparing different material based on its test result.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

In this chapter, the key studies related to this research are reviewed. It includes the studies on insulator formation. It is also consisting of insulator construction, insulator type, XLPE insulation, covered-conductor overhead system representation, partial discharge and the previous cases of study in partial discharge of polymeric insulation.

2.2 Insulator Formation

A center of the fiberglass rod is made of polymer isolators covered by polymer weather sheds. Manufacturers employ various shed materials, styles and building techniques. The base polymer materials used are synthetic rubber, EPM, EPDM, CE and polytetrafluorethylene (PTFE or Teflon). This basic material is mixed with different fillers, including aluminum trihydrate, to achieve the desired electrical and mechanical properties.

The EP rubbers rely mainly on the alumina trihydrate to prevent carbonate degradation. The EP rubber surface is being subjected to ultraviolet light and a possible electrical arching. It is eventually reduced to White Alumina material. The alumina can affect the wet flashover stage of the insulator. While silicone rubbers include alumina trihydrate, hydrophobicity is used to prevent flow of leakage and arcing.

Many manufacturers have individual sheds slid over the rod of fiberglass. Though CE material was cast onto the rod like a single housing, the maker of silicone rubber isolator used a continuous molding process to form a permanent housing on the rod of fiberglass. On the rod a manufacturer installed a sheath, slid the sheds over the sheath and vulcanized them.

The fitting of metal ends to a roll is combined using various technologies, including the compression of metal end mounting on a roll (the most common procedure today), the insertion into a fiberglass sheet of the wedges, the cutting into a cone of the end of the roll, or the fitting of the end to the roller [26].

2.2.1 Insulator Construction

The center is the principal building of the insulator. The center is the composite's internal isolating component. It is mechanically designed to support a load. It consists primarily of glass fibers put in the resin matrix to achieve optimum tensile strength. It's accommodation, besides that. The center is outside the cabinet and it guards against the weather. It can be built with season sheds. In some designs of composite isolators, a sheath made of isolated material between the weather sheds and the heart is used. It's part of the housing that sheath. Interface in the construction act as the surface between distinct materials is an interface. The following are examples of interfaces in composite isolators:

- Glass fiber/impregnating resin
- Filler/polymer
- Core/housing
- Housing/weather sheds
- Housing/end fitting
- Core/end fittings

Season sheds are also the polymeric insulation. The Watersheds are isolating components designed to increase the leakage gap and provide a disrupted water drainage path. In addition, the final fit is transferred by the final fitting to the center of the mechanical load. They're usually made of aluminum. The connection area is the end fitting portion of the connecting zone that transmits the load to the coupler, the tower, or another isolator [26]. As seen in Figure 2.1, the insulating portion is presented.

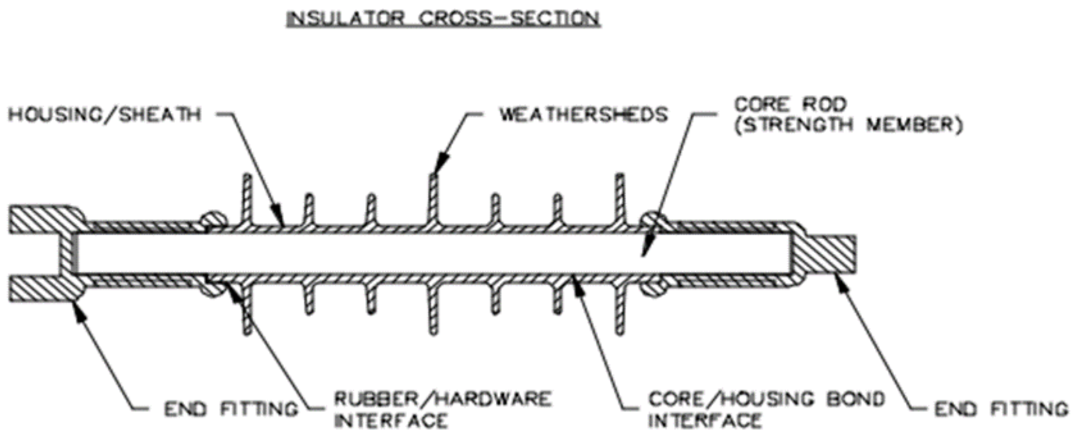


Figure 2.1: Insulator Components [26]

2.2.2 Insulator Type

The overhead conductors of the poles or towers should be supported so that currents from the conductors do not flow through supports, i.e. lines should be isolated from the subsides. This is achieved with the assistance of insulators to protect line conductors to protect aids. Insulators provide the insulation needed between lines and supports, thus eliminating any flow from the conductors to the floor [27]. In general, insulator types should have the following attractive insulative properties in the transmission lines:

- High mechanical power to resist the driver load, the wind, etc.
- High electric resistance to reduce leakage of the insulating layer into the earth.
- High relative insulator content permutability to ensure high dielectric power.
- Non-porous insulator material, free from impurities and cracks, would decrease permissiveness if not.
- High flashover perforation ratio.

2.2.2.1 Dead-End/Suspension Insulator

It is horizontally protected by the dead-end/suspension insulator. The hanger is supported vertically, as in Figure 2.2. The hanger insulator. Both of them appear to be very traced and twisted [26].

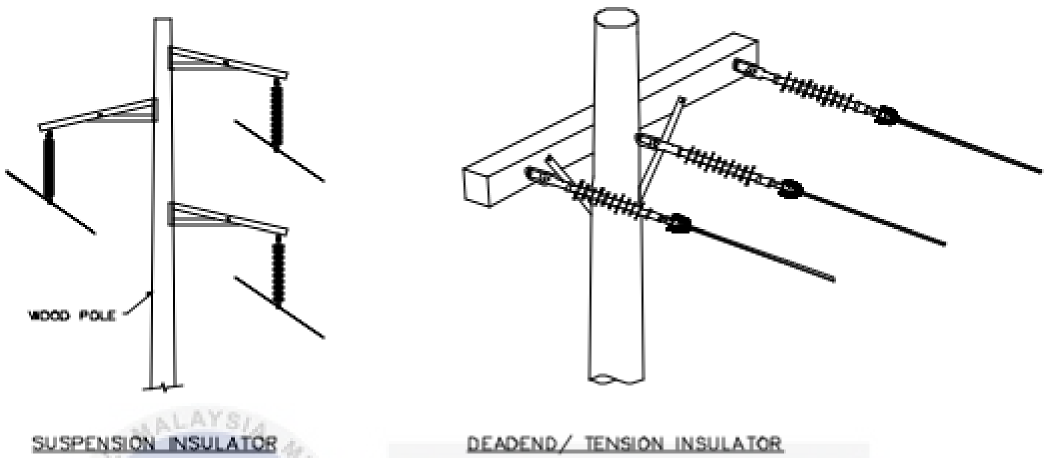


Figure 2.2: Dead-End/Suspension Insulator [26]

2.2.2.2 Line Post/Station Post Insulator

As seen in Figure 2.3 below, the post-insulator protects the line leader horizontally and vertically. It is tensile, heavy-duty and compressive [26].

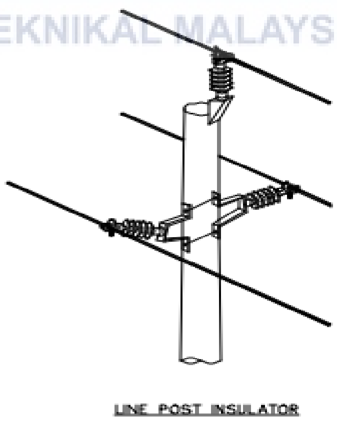


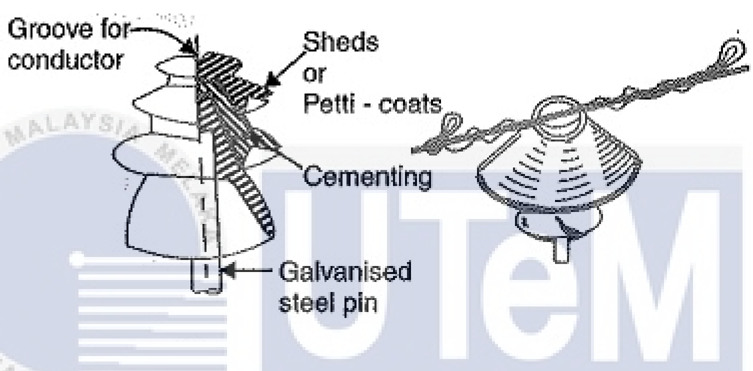
Figure 2.3: Line Post/Station Post Insulator [26]

2.2.2.3 Guy Strain Insulator

The guy's stress isolator insulates or insulates the guy's wire for corrosion protection, improved insulation standards, repair clearances or regular service and public safety or otherwise (joint-use). Tensile and torsional charges are present [26].

2.2.2.4 Pin Type Insulator

Section 2.4 displays the component segment of an insulator pin (i). As the name suggests, the pin style is attached to the arms on the shaft. The conductor can be housed on the upper end of the insulator. The driver goes into this groove and is bound in Figure 2.4 by the same substance as the conductor (ii).



(i) *(ii)*

Figure 2.4: Pin type Insulator [26]

Pin form insulators for transmission and delivery of electrical power up to 33 kV. Pin form insulators. The pin-like isolator is too voluminous and hence not cost-effective above 33 kV.

The causes of insulator failure are mechanical and electrical pressures, and insulators are required. The latter shape is primarily due to the line voltage and to the breakdown of the isolator. The electrical disintegration of the insulator will occur either by flash-over or perforation. Flashing over an arc takes place until the shortest distance between the line driver and the isolator pin (i.e. the earth) and the air holes are discharged. The arced distance (i.e., a +b + c) is set in Figure 2.5 for the insulator. When the flash over happens, the insulator continues to operate at its proper potential, until excess heat from the arc kills the insulator.

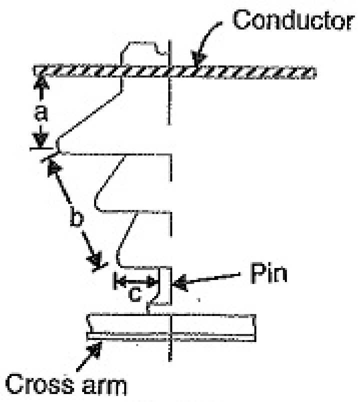


Figure 2.5: The Arcing Distance [26]

In the event of a puncture, the discharge occurs through the insulator body from conductor to pin when such a failure is involved, due to excessive heat, the insulator is permanently lost. In practice, in the insulator, adequate porcelain thickness is given to prevent the line voltage from puncturing. The ratio between punch strength and flash-over voltage is referred to as a safety factor as shown:

$$Safety\ factor\ on\ insulator = \frac{Puncture\ strength}{Flash - over\ voltage}$$

The safety factor value should be high enough that flickering happens until the insulator is perforated. For pin-style insulators, the value of the security factor is around 10 [27].

2.2.3 XLPE Insulation

The thermoset insulation material is XLPE or Cross-linked polyethylene. Crosslinking polymers is a method that alters the polymer chains' molecular structure so that they are more closely linked together and this crosslinking is carried out either by chemical or physical means. The addition of chemicals or initiators such as silane or peroxide to produce free radicals that form the crosslinking requires chemical crosslinking.

Physical crosslinking means subjecting the polymer, such as high-energy electron or microwave radiation, to a high energy source. The polyethylene (PE) material itself has excellent dielectric strength, high insulation resistance and a low dissipation factor at all frequencies, making it an ideal insulator, but its temperature