PARTIAL DISCHARGE DETECTION FOR CONDITION MONITORING OF AN 11-KV XLPE CABLE

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A thesis submitted
In fulfillment of the requirement for the award of the Degree of
Master of Engineering (Electrical)

Faculty of Electrical and Electronic Engineering
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DEDICATION

This is special dedicated to

my beloved husband,
Qamarul Ezani B. Kamarudin,

my lovely newborn son,
Muhammad Ammar Syafiq,

and my family for their continuous love and prayers ,

also to all my friends for their patient , kindness and cooperation .
I wish to thanks all of you for your support during my studies in UTHM.

May God bless all of them.

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ABSTRACT

High voltage insulation failure has been a main cause of high voltage systems for a long time now. It is found that this phenomenon occurs due to the existence of partial discharge in voids found in insulation of cables, especially XLPE (Cross-linked polyethylene) cables. Partial discharge normally exists in voids in cables which are produced accidentally during the extrusion process of cables. However, improvisation of XLPE cables from one generation to another generation has reduced voids gradually and thus, reducing the threat of partial discharge. Yet, the effects of partial discharge could not be underestimated as it would lead to serious breakdown and electrical apparatus failure. Therefore, partial discharge testing by using a partial discharge detector is one of the main tests used to determine the quality of the XLPE cable so that the necessary steps and precautions can be made on the cable if the cable does not meet the requirements of the test. In this project the insulation condition of an XLPE cable with different types of artificial defects will be tested for partial discharge and the results analysed and discussed. The complete procedures for doing the testing are also described in this thesis.

ABSTRAK

Kerosakan penebatan voltan tinggi telah menjadi punca utama terhadap sistem voltan tinggi sejak kebelakangan ini. Didapati bahawa fenomena ini berlaku disebabkan oleh kewujudan discas separa di dalam ruang atau lubang yang didapati pada penebatan kabel terutama kabel jenis XLPE *(Cross-linked polyethylene).*Discas separa kebiasaannya wujud di dalam ruang atau lubang pada penebatan kabel yang berlaku ketika proses penyemperitan kabel. Walau bagaimanapun, inovasi terhadap kabel telah berlaku dari satu generasi kepada satu generasi untuk mengurangkan ruang pada kabel dan seterusnya mengurangkan kejadian discas separa. Sehingga kini, kesan terhadap discas separa tidak dapat dihapuskan dan ia akan menyebabkan berlakunya pecah tebat yang serius dan seterusnya berlakunya kerosakan perkakasan eletrik. Oleh sebab itu, pengujian discas separa dengan menggunakan pengesan discas separa TE 571 adalah merupakan pengujian yang penting untuk menentukan tahap kualiti kabel XLPE maka langkah yang sepatutnya diambil terhadap kabel tersebut boleh dilakukan jika kabel tersebut tidak memenuhi kriteria yang ditetapkan. Projek ini akan membincangkan tentang keadaan penebat kabel XLPE yang mempunyai kerosakan buatan yang berbeza berdasarkan kepada pengujian discas separa dan prosedur yang lengkap untuk melakukan pengujian discas separa dibincangkan dalam tesis ini.

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PD	-	Partial Discharge
HV	-	High Voltage
XLPE	-	Cross-linked polyethelyne cable
kV	-	Kilo Volt
SF_6	-	Sulphur Hexafluoride
IEC	-	International Electrotechnical Commission
UTM	-	Universiti Teknologi Malaysia
PVC	-	Polyvinyl Chloride
PE	-	Polyethylene
EP	-	Ethylene-propylene
pC	-	Pico Coulomb
nC	-	Nano Coulomb
MHz	-	MegaHertz
DGA	-	Dissolved gas analysis
HPLC	-	High performance liquid chromatography
K	-	Kilo
τ	-	Cable transit time
ε_r	-	relative permittivity of the dielectric
AKV	-	Coupling quadripole
M	-	Mega
f	-	Frequency

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CHAPTER I

INTRODUCTION

1.0 Introduction

Partial discharge detection is nowadays a very well established method for monitoring the insulation condition of an electrical apparatus. The breakdown of insulation while in service can cause considerable damage to an apparatus and to the system to which it is connected. It has been recognized that failures of this type often may be related to the occurrence and severity of partial discharges within voids and/or on the surface of the insulation. Testing of high voltage apparatus for partial discharges has long been recognized as an important part of quality control for these devices [1].

Partial discharge, as implied by its name, is a type of localized discharge resulting from transient gaseous ionization in an insulation system when the voltage stress exceeds a critical value. The ionization is localized over only a portion of the distance between the electrodes of the system. The resultant partial discharge signals appear as very small magnitude, fast rise pulse (10-100ns) with irregular waveshapes. Partial discharges do not cause complete breakdown of the dielectric [2].

In practice, four types of partial discharge may be identified; they are, namely, Internal Discharge, Surface Discharge, Corona Discharge and discharge in electrical trees [13]. In insulation systems with strongly inhomogeneous field

configurations or inhomogeneous dielectrics, the breakdown field strength can be locally exceeded without complete breakdown occurring within a short time. Under this condition of incomplete breakdown the insulation between the electrodes is only partially bridged by discharges. These partial discharges have considerable practical significance particularly for the case of stress by alternating voltages. Partial discharges cause deterioration of insulation materials and are a primary cause of insulation failure at moderate and high voltages especially due to surface or internal discharges or treeing. The electric strength of solid insulation may decrease greatly with time of voltage application if discharge occurs within gaseous inclusions, at sharp-edged conductors embedded in the solid and as a result of surface contamination.

Partial discharge measurement is a very well known method for assessing the quality of an insulation system of high voltage devices, because the life of high voltage equipment depends on the presence of partial discharge. The aim is to detect the initial destruction in the electrical insulation as a result of electrical stress. The presence of a multiplicity of different partial discharge sources and their appearance shows different physical and electrical characteristics. For the economic use of high voltage operational equipment, it is necessary to always know the condition of the equipment in service. That is the reasons why monitoring, analysis or diagnosis become a fixed part in power generating, transmission and distribution systems. In this area the partial discharge measurement is an important diagnostic tool.

A Partial Discharge (PD) measurement is used as one of the quality control test for extruded cables in the medium and high voltage range. The normal situation would be that partial discharges would not occur in such cables when energized to stresses usually required in specification. Occasionally, however, there will be an isolated defect which does produce PD [14].

Cables constitute one very important electrical apparatus for transmission of electrical energy by underground means. Large power transmission cables are of importance and hence testing of power cables is considered a must. Partial discharge measurement and the discharge locations are important for cables, since the life of

the insulation at a given voltage stress depends on the internal discharge. Also the weakness of the insulation or faults can be detected with the help of this test.

For maintenance purposes, early detection of discharges in cables is an important diagnostic tool to assess the cable condition and if possible to locate the defect, especially since it highly undesirable to have to remove the cables from the operation even for occasional Partial Discharge testing.

A point of significant practical implication is the fact that surge propagation in the cable is affected by attenuation as well as wave shape deformation. This fact is fully exploited in the partial detection method as the principal means for detecting and locating partial discharge occurrences in cables. Progress in cable insulation design, such as the inclusion of semiconducting layers to give a uniform electric field distribution, and hence result in less partial discharge occurrences and a better over voltage control, on the downside causes more significant PD signal deformation during propagation. Since an XLPE cable's insulation is very sensitive to partial discharges occurring within itself, fast PD detection by online monitoring is essential, and therefore a detectable signal is needed to be picked up at the monitoring terminals.

1.1 Partial Discharge Phenomenon: Terminology

Partial discharge is an electrical discharge that only partially bridges the dielectric or insulating medium between conductors. Examples are: internal discharges, surface discharges and corona discharges. Internal discharges are discharges in cavities or voids which lie inside the volume of the dielectric or at the edges of conducting inclusions in a solid or liquid insulating medium. Surface discharges are discharges from the conductor into a gas or a liquid medium and form on the surface of the solid insulation not covered by the conductor. Corona is a discharge in a gas or liquid insulation around the conductors that are away or removed from the solid insulation [11].

1.2 Background of the Problem

Testing of high voltage apparatus for partial discharge is an important part of quality control. Weak points in an insulation like voids, cracks and other imperfections lead to internal or intermittent discharges in the insulation. These imperfections being small are not revealed in capacitance measurements but are revealed as a power loss component. Partial discharge in voids may cause deterioration of solid insulation materials. They often start in voids enclosed in the insulation or at the interface defect. Partial discharge is a major source of insulation failure in a cable. The accurate location of the discharge is of crucial importance in on-site maintenance and repair. This project will concentrate on partial discharge detection to determine the insulation condition of the cable.

1.3 Objectives

The objectives of this project are:

i. To prepare the complete test procedures for partial discharge detection of XLPE cables by using the PD detector, TE 571.
ii. To test the condition of cable by the method of partial discharge detection.
iii. To detect the partial discharge of cable for assessing the likelihood of a fault on a cable containing an incipient defect.
iv. To study the partial discharge patterns and to interpret the condition of the cable with different types of artificial defects.