MODELLING OF XLPE NANOCOMPOSITE POWER CABLE USING COMSOL MULTIPHYSICS

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This project report is dedicated to my beloved mother and father. I give my deepest expression of love and appreciation for the encouragement and support that you gave and the sacrifices you made during this master program.

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ABSTRAK

Laporan ini membentangkan pemodelan kabel polyethylene (XLPE) bersalut nano terlindung dengan kehadiran lompang menggunakan menggunakan perisian COMSOL Multiphysics. Lompang sama ada dengan medium udara atau air adalah salah satu faktor yang menyebabkan degradasi penebat kabel. Kehadiran lompang di dalam kabel berlaku semasa proses penghubung silang di mana penembusan wap air berlaku. Dengan menggunakan perisian COMSOL Multiphysics mungkin menjadi kaedah terbaik untuk menyiasat taburan medan elektrik dan pengagihan medan potensial lompang dalam kabel. Kaedah elemen terhingga adalah salah satu daripada kaedah berangka terkini yang digunakan untuk menganalisis elektrik dan pengagihan medan potensi lompang dalam kabel kuasa. COMSOL Multiphysics adalah salah satu alat berkuasa yang melaksanakan kaedah unsur terhingga dengan menyelesaikan persamaan Poisson. Dalam laporan ini, perbandingan kedua-dua jenis bahan kabel XLPE seperti kabel XLPE tulen dan kabel bertebat nano yang dibuat dalam penyiasatan elektrik dan pengagihan medan potensi lompang dalam kabel dengan menganalisis dan membandingkan corak graf dihasilkan oleh dua jenis bahan penebat kabel. Keputusan yang diperolehi daripada simulasi COMSOL menunjukkan medan elektrik dipengaruhi oleh jenis lompang, lokasi lompang dan kehadiran zarah nano di dalam penebat XLPE.

ABSTRACT

This report presents modelling of a nano-insulated cross-linked polyethylene (XLPE) cable with the presence of voids using COMSOL Multiphysics software. Void either with the medium of air or water is one of the factor that causes degradation of the power cable insulation. The void that presence in the power cable is occur during cross linking process where the penetration of water steam happened. Using COMSOL Multiphysics software might be the best method in investigating the electric field distribution and potential field distribution of the void in the power cable. Finite element method is one of the latest numerical methods use in analyze the electrical and potential field distribution of the voids in the power cable. COMSOL Multiphysics is one the powerful tools that implement the finite element method by resolving Poisson's equation. In this report, comparison of both type of the XLPE cable materials such as pure XLPE cable and nano-insulated cable are made in investigating the electrical and potential field distribution of the voids in the cable by analyze and compare the graph pattern generated by two types of the cable insulation material. Simulation results indicate that the electric field distribution is influenced by the type of the void, void position and presence of nanoparticle in the XLPE insulation.

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LIST OF ABBREVIATIONS

XLPE	-	Cross-linked Polyethylene
HVDC	-	High Voltage Direct Current
DC	-	Direct Current
FEM	-	Finite Element Method
PVC	-	Polyvinylchloride
PE	-	Polyethylene
2D	-	Two Dimensional
3D	-	Three Dimensional
m	-	Meter
V/m	-	Volt per meter
SiO_2	-	Silicon Dioxide
E	-	Electric Field
V	-	Potential
Ɛ	-	Relative Permittivity
Ɛr	-	Relative Permittivity of the Insulating Material
$Ɛ_0$	-	Free Space Permittivity
D	-	Electric Displacement of the Conductor
E_a	-	Electric Field of Cavity
r	-	Radius of the Conductor
r_c	-	Cavity Radius
r_z	-	Radius of the Area Influenced
ε_c	-	Permittivity of the Cavity
ε_i	-	Permittivity of the XLPE
n	-	Normal Component
ρ	-	Free Space Charge
ρ_s	-	Surface Charge

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Electricity is useful and important for everyone where it used to power up most of the electrical equipment such as mobile phone, computer, lighting, and others essential appliances. Without electricity, it may interrupt and give rise to certain problem such as industry may have stop production, people have to stay in dark and others inconvenience of the lifestyle.

According to the recent development either in technology or lifestyle, the demand of the electricity keeps increasing over the years. The increase in the demand of the electricity have been a huge concern to the energy utilities where they must make sure sufficient of supply is available in the system. Apart from that, energy utilities have to ensure that the electricity supply is always reliable and stable. In order to ensure the stability of the electricity supply to the consumer, power cable is one of the main component in the power system need to be taken care properly. Any damage occurred on the power cable will cause power interruption. Most of the damage occurred on the power cable is due to damage in the power cable insulation.

Therefore, good quality of the power cable insulation will ensure the power system in the stable condition. Electric power cable has evolved by time to time to tally with the present technology. Evolvement of power cable from PVC type to the addition of the nano filler in the power cable insulation at current technology.

Addition of nano filler in the power cable have improved the electrical characteristics of the power cable where it reduces the risk of partial discharge [1].

1.2 Background of Study

Power cable is one of the essential component in the power system especially used in the overhead line and underground lines. Most of the power cable expensive to be replaced in term of the installation cost. Therefore, it is important to have a good cable insulation where can be used for many years without cause any power interruption due to failure of the cable. The condition of the insulation system is determining the cable lifetime due to insulation system continuously encounter stresses such as thermal, electrical, mechanical, chemical and environmental stresses. Presence of the voids [2] might cause degradation of the cable insulation which leads the failure of the cable. Cable insulation material is the most important component need to be considered properly in order to ensure no failure happened.

The development of the cable insulation material from the PVC in the year 1913 introduced by Friedrich to present where the nanocomposite XLPE cable introduced by the Lewis in year 1994. For the past few decades since year 1955 introduced by Gilbert, cross-linked polyethylene (XLPE) cable is widely used in the transmission and distribution industry due to its outstanding features such as good dielectric strength, resist to solvent, dielectric permittivity is low and low loss factor as well, good dimensional stability and behavior of the thermo-mechanical.

There is drawback in the usage of the XLPE power cable due to the formation of the space charge and treeing which decreases the service time of the power cable. Formation of the space charge [3] due to penetration of the water steam during cross-linking process and wrong extrusion. These leads to the formation of the voids in the power cables which enhance the partial discharge [1] to be occurred.

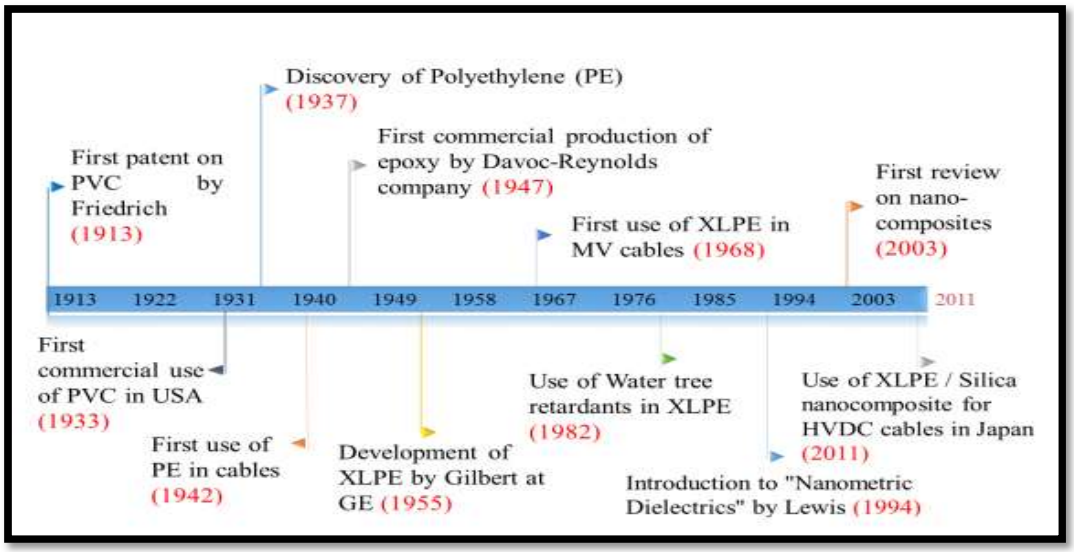

Figure 1.0 Development of the cable insulation material over the years.

In the year 1994, Lewis had introduced nanometric dielectric which drawn interest to many researchers on this nanocomposite material as this material able to act as barrier in the formation of the space charge and treeing which eventually improve the quality of the cable insulation where the lifetime of the cable can be prolonged. Nano filler [4] that infused in the XLPE cable have excellent characteristics than the pure XLPE cable where it improves breakdown strength and high resistance to the water and electrical trees. Besides that, nanocomposite cable has potential in reducing the space charge formation in the power cable. Improvement in the XLPE cable insulation material able to prevent the failure of the cable where the risk of the partial discharge able to be reduced.

1.3 Problem Statement

High voltage power cable is one of the essential component in the power system which continuously exposed to variety of stresses such as thermal stress, electric stress, chemical stress, environmental stress and other stress that act on the cable insulation. These stresses that act on the cable which will eventually degrade the properties of the insulation. The lifetime of the power cable depends on the cable

insulation. It is important to have a good insulation for the cable to avoid any damage occurred which might interrupt the power system.

One of the major problem that causes the degradation of the power cable insulation is the presence of the voids. The voids can have medium of either air or water that can leads to shorten the lifetime of the power cable. Phenomenon that causes the presence of the voids in the power cable is due to penetration of the water steam during process of the cross-link. Besides that, mistake can also happen during operation of the cross link and wrong extrusion. Usually the size of the voids appear in the cable is about 1 μm to 20 μm. Apart than that, the position of the voids exists in the cable also give impact to the lifetime of the power cable as the voids near to the conductor have high electrical field distribution compare to the voids located further away from the conductor which enhance the partial discharge occurred.

Besides that, cable insulation material also play an important role in preventing the presence of the voids in the cable. Over the years, the cable insulation material had been developed from the PVC material to the XLPE material which show significance improvement in the quality of the cable insulation where the cable is long lasting. Depends on the material of the cable insulation, the voids present encounter different temperature and pressure on it. Proper design of the cable insulation material is needed to ensure the cable can be used for many years which is

cost efficient for the power utility company. In this project, nano-insulated XLPE power cable with the presence of the voids with different feature would be analyzed.

1.4 Objectives:

By referring to the problem statement mentioned above, this research was conducted with several meaningful objectives below:

1. To simulate the electric field distribution and potential field distribution in the nanocomposite XLPE power cable having void using COMSOL Multiphysics.
2. To analyse the simulation result by considering various factors such as void position, void size and others.
3. To compare the simulation result with the pure XLPE power cable.

1.5 Scope of Study

By referring to the objectives mentioned above, the limitation and assumption applied in this project is clearly elaborated as the followings:

1. This work focused on the XLPE power cable model only. Based on existing research, the study of the pure XLPE power cable with the presence of voids was investigated for the electrical field distribution and potential field distribution. It is proven that the voids near to the conductor have high electrical field than the voids further away from the conductor.

2. The focus of this study was on electrical field distribution and potential field distribution based on respective void feature only. Void feature considered in this paper is the void position and type of the void in the XLPE power cable.

3. This work also focused on comparison of the results obtained from the pure XLPE power cable and nano-insulated XLPE power cable by considering the presence of voids with different void feature.

1.6 Project Methodology

By referring to the objectives mentioned earlier, the following work methodologies have been planned:

1. A literature review on the technique used in analyzing the electric field and potential field distribution in the void presence in the XLPE cable using finite element method was carried out. Topic related article can be extracted from the conference papers, journal papers, online articles and electronic books from internet or digital library in UTM. Suitable application within each reference was gained.

2. A critical and strategic literature review of electric field and potential field distribution in the void presence in the XLPE cable using finite element method was performed. In order to propose algorithm, the existing flowchart and formulation have been analyzed. By having in depth literature review, it provides a good theoretical understanding about XLPE cable with the presence of void design considerations need to be taken in order to develop the algorithm.

3. A new modelling of a nano-insulated XLPE power cable with the presence of the voids will be developed using COMSOL Multiphysics software.

4. Verification of proposed modelling of a nano-insulated XLPE power cable with the presence of the voids will be performed by comparing the result output against FEMM software output which is available.

1.7 Project Report Structure

Chapter 1 describes the introduction of the XLPE power cable insulation that used in the power system. It includes the problem statement, objectives, the scope of this project work and the methodology used to apply in accomplishing this project report. Briefly explanation on this chapter will gauge the reader have a clearer picture on the overview of the project.

Chapter 2 presents the literature review on the techniques used to investigate the electrical field distribution and potential field distribution of the voids presence in the XLPE power cable. The data of the literature review was collected from the journal which extracted from the UTM digital library such as IEEE, Scopus, science

direct and others relevant journal. All the journal collected based on the project background which is related to the XLPE power cable insulation having cavities.

In Chapter 3, the mathematical modelling of the electrical field and potential field distribution of the XLPE power cable with the presence of the voids is described in detail. First and foremost, it will cover Poisson's equation in the modelling. In addition, this chapter will also cover the implementation of the mathematical modelling in the COMSOL Multiphysics software.

Chapter 4 starts with the validation of result simulated from the pure XLPE power cable containing voids and the simulation result of the nano-insulated XLPE power cable with the presence of voids will be presented and discuss upon.

Chapter 5 draws the conclusions for the work undertaken are presented and few possible suggestions for future work are highlighted as well.

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