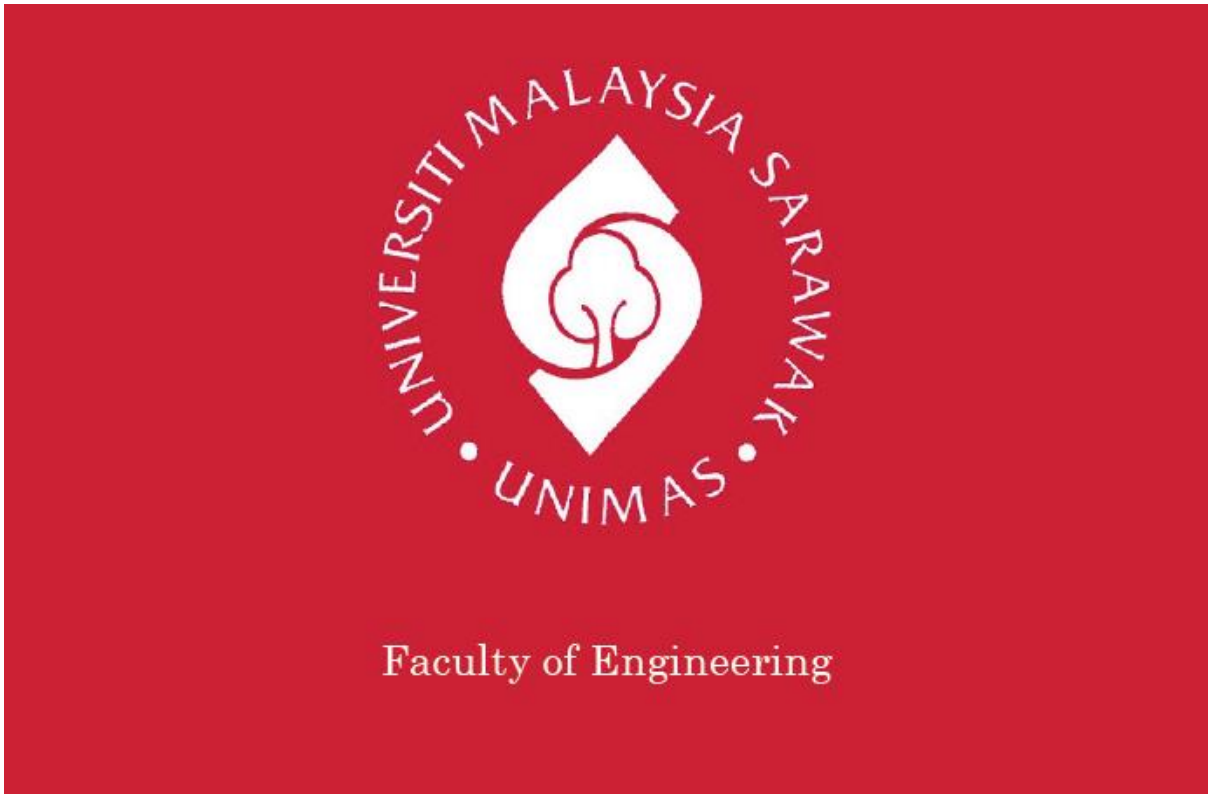

SIMULATION OF DEFECTS ON MEDIUM VOLTAGE CROSS - LINKED POLYETHYLENE (XLPE) CABLE INSULATION USING FINITE ELEMENT ANALYSIS

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Bachelor of Engineering (Hons)

Electrical and Electronic Engineering

2019

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KELVIN JUING ANAK TINGGOM

A final year project report submitted in partial fulfilment of
the requirement for the degree of
Bachelor of Engineering (Hons) Electrical and Electronics Engineering

Faculty of Engineering
Universiti Malaysia Sarawak

2019

UNIVERSITI MALAYSIA SARAWAK

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ABSTRACT

Cross-Linked Polyethylene (XLPE) is one of the types in polymer that is used as the insulator in power cable. This type of insulation is widely used in the medium voltage due to it necessarily being installed. In addition, this insulation is economically attractive as it is less expensive compare to the most advance and strong material type in insulation material choices. The problem in this XLPE cable is the degradation which caused by the partial discharges that have been initiated at the specific location where the abnormalities had occurred toward the XLPE material. Partial discharge is small electrical discharges caused by massive electrical stress modification due to the fault circumstances. In this work, electric field distribution and its strength is observed by finite element analysis. The defect that will be observed is air void, vented water tree and bow-tie water tree. Each defect sizes will be manipulated, and the location of the defect being located are changes where it will place on the insulator which is closer to the conductor, middle of the insulator and far from conductor. Next, the rated voltage will be varying to compare the electric field distribution. The design and modelling of the cable in this work will be conforming to IEC 60502-2 Standard. As result, the electric field intensity will be increased when there is the defect occur on the insulator. The vented water tree defect gives the highest value of electric field intensity followed by the bow-tie water tree and air void defect. In air void defect, the electric field intensity will increase when the size of defect is increased. This is due to the different relative permittivity that have been injected in the defect during simulation which resulting to the non-uniform electric field line distribution on the insulator and electric field stress occur.

ABSTRAK

Cross-linked polyethylene (XLPE) ada salah satu jenis polimer yang digunakan sebagai bahan penebat di dalam wayar kuasa. Jenis penebat ini selalu digunakan dalam voltan serdehana kerana keperluan permasangan yang harus diikuti. Tambahan pula, penebat ini mempunyai tarikan ekonomi yang tinggi di mana penebat ini memerlukan kos yang rendah selain mempunyai daya tahan bahan yang kuat dan penambahbaikan yang telah dilakukan sejak diperkenalkan. Wayar XLPE ini mempunyai masalah tertentu di mana ia mudah terdedah kepada pengurangan jangka hayat normal akibat perlepasan separa yang berlaku terhadap kawasan yang mempunyai kecacatan dalam bahan. Perlepasan separa adalah perlepasan kecil elektrikal yang mampu mengakibatkan perubahan tekanan elektrikal akibat berlakunya keadaan yang salah. Perlepesan ini kerap berlaku di dalaman bahan penebat atau di permukaannya kerana medan electrik menjadi lebih kuat dan tidak menentu daripada biasa. Biasanya, perkara sebegini berlaku akibat terdapatnya lohong udara, kecacatan, rongga dan sisa pepajal logam di dalam bahan XLPE disebabkan oleh proses pembuatan and penyebab terjadinya pokok air. Di dalam projek ini, pengagihan medan elektrik dan kekuatannya akan diperhatikan dengan mengunakan simulasi analisis unsur terhingga (FEA). Kecacatan yang akan diperhatikan adalah rongga udara dan pokok air. Kecacatan pokok air akan terbahagi kepada dua iaitu pokok air berliku dan pokok air terikat. Saiz kecacatan tersebut akan dimanipulasi dan lokasi berlakunya kecacatan dalam penebat juga akan diubah Seterusnya, kadar voltan juga akan akan ditukar untuk melakukan perbandingan terhadap pengagihan medan elektrik apabila berlakunya kecacatan didalam penebat. Setiap ukuran wayar yang digunakan dalam projek ini berlandaskan kepada standard IEC 60502-2. Oleh itu, kecacatan yang berlaku dalam penebat benar-benar membuat kekuatan medan elektrik meningkat. Kecacatan pokok air berliku memberi nilai kekuatan yang paling diikuti kecacatan pokok air terikat dan rongga udara. Dalam kecacatan rongga udara, kekuatan medan elektik semakin meningkat apabila saiz kecatatan tersebut meningkat. Hal ini terjadi akibat ketelusan relatif di dalam kecacatan adalah berbeza dengan penebat di mana hal ini membuatkan garis medan elektrik menjadi tidak sekata dan tekanan tinggi.

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ABBREVIATIONS

AC	-	Alternating current
DC	-	Direct current
EF	-	Electric Field
EPR	-	Ethylene Propylene Rubber
FEA	-	Finite Element Analysis
PD	-	Partial Discharge
PE	-	Linear Polyethylene
PVC	-	Polyvinyl Chloride
XLPE	-	Cross-Linked Polyethylene

NOMENCLATURE

A	-	Ampere
°C	-	Celsius
kV	-	Kilovolt
m	-	Meter
mm^2	-	Millimeter square
MV/m	-	Mega Volt per meter
V	-	Voltage
ε_o	-	Relative permittivity constant ($8.85 \times 10^{-12}\ F/m$)
ε_r	-	Dielectric constant of the material
µm	-	Micrometer
%	-	Percent

CHAPTER 1

INTRODUCTION

1.1 Project Background

Generally, this work is conducted in order to observe the Cross-Linked Polyethylene (XLPE) cable under various defect which are void and water trees as it will be investigated using Finite Element Analysis (FEA). The work was simulated based on single core medium voltage transmission cable as a case study.

An electric cable or also known as power cable is an assembly of one or more electric conductors which is used to carry the electric current. Electricity is generated by the power plant and it is sent to the consumer's electrical load by using transmission line. There are different voltage levels classification on transmission line from the very beginning of power generation. There are five voltage levels on transmission line which are Low Voltage Level (below 1000V), Medium Voltage Level (1000V to 69kV), High Voltage Level (Below 100kV), Extra High Voltage Level (230kV to 800kV) and Ultra High Voltage Level (over 800kV)[1]. In order to convey the electric current is sent to intended location of the electrical load, electrical insulation or dielectric is provided to highly isolate the conductor from other surfaces or paths through which the current might flow.

Electrical insulation provides enough separation between the conductor and nearest electrical ground to avoid the initiation of dielectric failure. The cable insulator must able to withstand the heat and electric field strength produce from the conductor in order to make the power loses as minimum as it could [2]. Semiconducting material are use as insulator to prevent the high potential different between the conductor and the electrical ground at the outer surface of the cable. Impregnated paper insulated cables are used in the early 1920s for distribution and transmission purposes. This insulation consists of helically applied paper tapes with small gap between turn. Unfortunately, this type of insulation is very sensitive to moisture and it has complexity on jointing the metallic sheathing as it is necessary to prevent the water ingress [3].

In early 1960s, there has been a swing worldwide away from paper insulation to the polymeric type where polyethylene (PE) was rapidly expanding in the development of modern

underground residential distribution system in the United States which initial developed for 3 - 6 kV. In the 1980s, XLPE insulation were used for 11 – 33kV and it applied up to 500kV in the last few years to replace the medium voltage Paper Insulated Lead Covered (PILC) cable.

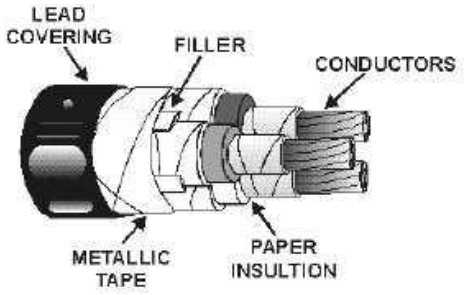

Figure 1.1: Three Core paper insulated lead sheathed cable[4]

That is because XLPE insulation has much better electrical, thermal, and mechanical performances compare to oilpaper insulation [5]. XLPE mainly is used for feeder medium voltage level cable in commercial and industrial application because it needs high initial cost due to additive of polyethylene and the cost manufacturing based on the need for massive, continuous vulcanizing (CV) tubes [2]. The structure of medium voltage XLPE insulation cable are shown in Figure 2. This cable is the combination from copper conductor (1), a semi-conducting layer (2), an XLPE insulation (3), a semi conducting shield (4), a copper tape screen serves as the earth conductor (5), a bedding (6), an aluminium wire armour (7) and a polyvinyl chloride (PVC) ground sheath [6].

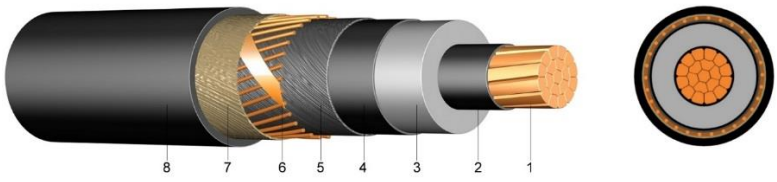

Figure 1.2: Single-core XLPE insulated cable [7].

Cable insulation have a life span where its failure is due to the degradation process. This said process will result in the breakdown of electric insulation between the electrode. The main reason for this failure is due to the defect in the insulation were void, water tree, cavities or solid material such as metallic inclusion during the manufacturing process. The present of this defect will forming the electrical tree in the insulation part of the cable which later will cause cable insulator to breakdown [8].

1.1.1. Type of Insulation Cable

There are many types of insulation for power cable. As mention at previous section, the paper insulation impregnated with mineral oil on PILC cable is the pioneer insulation that have been used in the power system. It is effective as a combination and widely used in the early development of power system as it provides reliable service. Unfortunately, it is susceptible to breakdown due to the presence of the moisture or in the event of high temperature or overheat. This type of insulation is limited to 70°C otherwise, the aging process will rapidly occur on paper insulation. other factor such as higher voltages, electrical stresses and carbonisation of the paper will catalyst the partial discharge event [9]. There are four basic polymeric insulants to replace paper as insulator that have been use throughout the world.

1.1.1.1.Polyvinyl Chloride (PVC)

This type of polymer is basically use for building wire and small wire as its main insulator for the core conductor. This is widely used in low voltage level where it is suitable for low power customer's appliances. The thermoplastic characteristic on this polymer are important that these cable insulations are not melt easily due to overload occurrence[9].

1.1.1.2. Linear Polyethylene (PE)

Polyethylene is the world-famous plastic where it is uses to make plastic bag, plastic bottle, toys and even a bullet prove vest. This polymer is the made from long chain hydrocarbon where it is an organic compound made which consist of carbon atom and two hydrogen. The chemical structure for this material can be seen in figure 1.3 below. This is linear PE are categorized as low-density polyethylene. It has low melting point compare to XLPE. So, this insulant can only be used for small current and voltage value [10]. This insulation type often uses in communication cable.