INVESTIGATION ON NON-LINEAR GRADING MATERIAL AS STRESS CONTROL ON MEDIUM VOLTAGE CABLE TERMINATION

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ABSTRACT

Power cable terminations are widely used in power system networks for a last few decades. A proper design of cable termination is essential in reducing the electric field distribution around the end of high voltage cable. At the termination of cable, the electric field was usually the highest, for the insulation layer was cut in this place. And with the high electric field at the cutting point, there were surely partial discharge occurs. In order to overcome this issue, some sorts of method were proposed. Stress control geometry method and non-linear properties of Zinc Oxide Microvaristor method have been used in this research. The aim was to find an optimal solution for the electric field distribution. An 11kV power cable has been modelled for this study by using Finite Elements Method (FEM) computational solution. The model has been used to simulate the electric field distribution in the cable termination. The structure of terminations and the critical parts in this design were also defined through literature. A non-linear grading has been applied to several design of layer insulation. The proposed model was used to covers the point that generate high fields at screen cable insulation. Material properties play a key role in suppresses electric field spread throughout termination area. Based on the switching point of about 1kV/cm the material changes its conductivity significantly. In this way it prevents the occurrence of electric fields which are above this switching point. Different thicknesses also were introduced to get a better design and economically to produce in cost advantages. This research successfully examines the effectiveness for both methods in controlling field stress at cable screen termination.

ABSTRAK

Penamatan kabel kuasa digunakan secara meluas dalam rangkaian sistem kuasa selama beberapa dekad yang lalu. Apabila lapisan penebat penamatan kabel dipotong, keadaan ini akan menghasilkan medan elektrik yang tinggi. Medan elektrik yang tinggi pada pemotongan lapisan penebat kabel ini, akan terhasilnya pelepasan medan elektrik . Untuk mengatasi isu ini, beberapa jenis kaedah telah dicadangkan. Kawalan tekanan kaedah geometri dan ciri-ciri yang tidak linear iaitu Zink Oksida *'Microvaristor'* telah digunakan dalam kajian ini. Sasaran utama kajian ini adalah untuk mencari penyelesaian optimum bagi taburan medan elektrik. Kabel kuasa 11kV telah dimodelkan untuk kajian ini dengan menggunakan '*Finite Element Method'* (FEM) penyelesaian pengiraan. Model ini telah digunakan untuk simulasi taburan medan elektrik penamatan kabel. Struktur penamatan dan bahagian-bahagian penting dalam reka bentuk ini juga ditakrifkan melalui literatur. Bahan penggredan yang tidak linear telah digunakan untuk beberapa reka bentuk lapisan penebat. Model yang dicadangkan telah digunakan untuk melindungi kawasan yang menghasilkan medan elektrik tinggi pada penebat kabel skrin. Sifat sesuatu bahan memainkan peranan penting dalam menyekat medan elektrik merebak di seluruh kawasan penamatan kabel. Berdasarkan titik pensuisan kira-kira 1kV/cm sifat bahan akan berubah kepada pengaliran yang berlawanan dengan ketara. Dengan cara ini, ia menghalang terhasilnya medan elektrik yang tidak diperlukan di atas titik pensuisan ini. Ketebalan penebat yang berbeza juga telah diperkenalkan untuk mendapatkan reka bentuk yang lebih baik dan ekonomi bagi menjimatkan sebarang kelebihan kos. Kajian ini membuktikan keberkesanan untuk kedua-dua kaedah dalam mengawal tekanan medan elektrik di skrin kabel penamatan telah berjaya.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATION

HV	-	High Voltage
MV	-	Medium Voltage
LV	-	Low Voltage
ZnO	-	Znic Oxide
XLPE	-	Cross-Linked Polyethylene
FEM	-	Finite Element Method
2D	-	Two Dimension
IEC	-	International Electrical Commission
LDPE	-	Low Density Polyethylene
HDPE	-	High Density Polyethylene
PD	-	Partial Discharge
kV	-	kilo Volt
LSR	-	Linked Silicone Rubber
mm	-	Milimeter
m	-	Meter
SiR	-	Silicone Rubber
E	-	Electric Field
εr	-	Relative Permittivity
σ	-	Conductivity

CHAPTER 1

INTRODUCTION

1.1 Introduction

Power system is become vital nowadays**.** Purposes of the power system are to provide energy or electrical power from source (power generation) to the consumers in a safe and reliable way. Figure 1.1 shows the high voltage (HV) transmission is one of the most important part of the system because it delivers almost all powers that generated by power plants. Electric power can be transmitted by overhead power lines or underground power cables. Underground cables are commonly used in low voltage and medium voltage solutions.

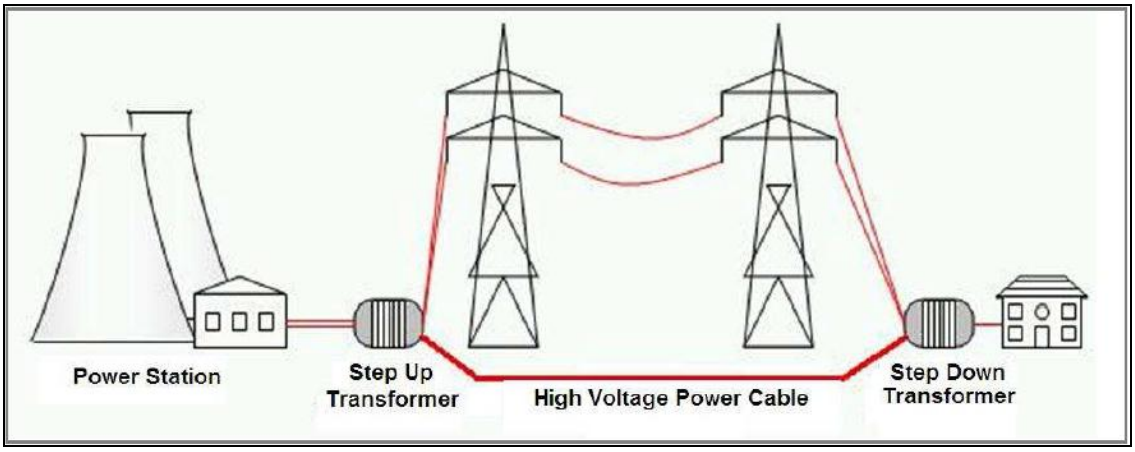


Figure 1.1: HV power cable in an electricity power system transmission

Utilization power cable becomes extremely high due to usage of electric power. A good characteristic of cable must be considered to ensure there are no breakdowns occur during power transmission and distribution process. Distribution of power has been a frequently improving branch ever since the invention of electricity. High voltage is needed to get high efficiency in distribution of electricity [1-2]. Higher voltages lead to a smaller current and therefore a smaller conductor cross section to transfer a certain amount of power as well as can reduce the cost [2].

The development of cable accessories requires basic understanding of the stress caused by the electric field in different parts of the insulating structures. Material properties and product design play a key role in the durability of terminations and joints. As the voltage goes high, even if the losses become considerably less, the insulation failure becomes critical.

Dielectric plays important parts in electrical system to insulate the potential charge materials with the earthed object (including human). Failure in dielectric can cause electrical breakdown or short circuit in which may introduced the risk of faulty/damage to the equipment as well as causing potential danger to human. In general, dielectric can be formed of solid like glass, porcelain, or composite polymer materials, gases such nitrogen and sulphur hexafluoride and liquid such mineral oils. These dielectric materials mainly used power transformer of high voltage apparatus such as cable, insulator and etc. [3].

Cable networks strongly depend on the performance of the way of attached cable accessories. Therefore, to improve the behavior of the electric field in a medium voltage termination and a joint, Zinc Oxide Microvaristor was introduced for stress control on high voltage cable in this project. The optimization of these issues was done using simulation software called COMSOL Multiphysics. Through this, couple of simulations would be conducted on various designs of power cables as well as type of material that have been chosen.

1.2 Effect of Termination on Power Cable Insulation

Power cables are very importance in power transmission and distribution systems. Terminations are the basic accessories of the power cables. They are required to make connections between lines or to an electrical apparatus. The various aspects are considered while designing the stress control cable terminations because they must have the same integrity as their associated cables while making the connection both all indoor and outdoor applications. The parts of termination must highly prevents with stress cone control because it will cause discharges and lead to breakdown.

1.3 Problem Statement

Improper installation of HV cable system in the field can generate different typical defects in cable accessories. It can be stress on the cable and can cause effect electric field. The insulation of the cable must maintain due to the high-voltage stress, ozone produced by electric discharges in air. The cable system must prevent contact of the high-voltage conductor with other objects or persons. Cable termination must be designed to control the high-voltage stress to prevent breakdown of the insulation because this circumstances is easy to affect breakdown. If no stress were applied, discharges could occur and the life termination would be limited depending on the stress at the end of shield and the discharge resistance of the primary dielectric [4].

However, the most common defects caused by bad workmanship are wrong position of stress cone, and pollutants left in cable termination. Wrong position of stress cone is usually resulted from not following installation instruction, and this can result in stress cone does not contact well to outer-semiconductor layer, and leaving void inside cable termination. Left pollutants are usually caused by casually attitude, irregular edge of out-semiconductor and irregular surface of insulation. These defects will enhance potential gradient and electric field that lead to breakdown or partial discharge [5]. This problem can be addressed by designing stress cone shape and using non-linear grading material such as ZnO Microvaristors.

1.4 Objective

The purpose of this project is to investigate the alternative approach to the existing technique for optimizing field distribution on cable screen termination in controlling high field stress that will affect the reliability of the power cable especially at the termination or joint parts. The main objectives for this project are:

- To investigate the problem of the environmental issues that related to the solid insulation for medium cable.
- To propose an optomize technique for controlling high electric field region at cable screen termination.
- To evaluate the performance of different material properties in controlling the distribution of electric field in medium voltage cable terminations.
- To examine the effectiveness of non-linear grading material in controlling electric field stress at the cable termination.

1.5 Scope Project

This research focuses on single core high voltage power cable. High voltage cables have various type of shielding [6-7]. For this project used cross-linked polyethylene (XLPE) polymer was used as insulation in high voltage power cables and ZnO microvaristor as stress control field material. For the whole project, largely depends on the ageing of cable and search:

- Finite Element method (FEM) has been used computational simulation for analyze electrical field stress at screen cable termination.
- This research deals with primary insulation cross-linked polyethylene (XLPE) material and semi-conducting insulation.
- Focused on 11kV potential for copper conductor and asymmetrical two-dimensional (2D) mode.
- In modeling geometric structure, this project assumes cable termination profile in ideal condition without nearby structures.

1.6 Project Outline

This study is divided into five chapters. The introduction and the information about the purposes of high voltage cable, problem that normally occur during cable terminations and electric field controlling constitutes Chapter 1. Chapter 2 outlines the review of power cable, power cable structure, and also electric parameter. In Chapter 3, the simulation procedure computer analysis is reviewed and Zinc Oxide Microvaristor modelling. The results and evaluation of the simulation are explained in Chapter 4. The effect of different electric field controlling methods include by applying non-linear material are discussed in this chapter. Finally, in Chapter 5, conclusion of the study and future work are covered.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter describes the basic theories that have been used to analyze the data obtained from the design process and simulation. Power cables are divided into three groups which are low voltage, medium voltage and high voltage. Low voltage cable solutions are rated from 300/500 V to 600/1000 V, medium voltage from 1.8/3 kV to 20.8/36 kV and cable solutions greater than 20.8/36 kV are called high voltage [8]. Stress cone of cable can be categorized depending on company design to or material used that covered the outer semi-conducting layers [9]. These circumstances will give impact during termination or jointing cable. Improper circumstances intense partial discharge issue and corona occur surrounding the cable. It is very dangerous for human usage and failure transmit power in overhead line. It is also might cause environmental defect, ageing and also electrical stress otherwise increase of cost. According to the International Electrotechnical Commission (IEC) International Standard 60270, Section 3.1 published in 2000, the definition of partial discharge is:

"Localized electrical discharge that only partially bridges the insulation between conductors and which can or cannot occur adjacent to a conductor. Partial discharge is in general a consequence of local electrical stress concentrations in the

insulation or on the surface of the insulation. Generally such discharge appears as pulses having duration of much less than 1µs" [10-11].

PD in the insulation is the main cause of aging and failure in insulated cables [3]. The discharges result in "electrical treeing" that leads to deterioration and breakdown of the insulation and eventually to cable failure.

2.2 Power Cable

Power cable technology evolved since 1880s when the need for power distribution cables became pressing. Cable is a conductor which is insulated electrically and protected mechanically for the safe use of it. The main features found on the cable construction are conductor, insulator and sheath which are protection for human safety. Cable is the channel used for a system of transmission and distribution of electrical energy. The residential and industrial loads today have a highest request towards their growing density. This requires a tough construction, greater service reliability, increased safety, and better appearance. These difficulties are easily overcome by the used of underground cables and a trouble-free service is achieved under a variety of environmental conditions [11].

There are two ways to transmit and distribute the electrical energy which is by overhead line transmission or by using underground cable. Earlier underground cables were mainly used in or near densely populated areas and were operated at low or medium voltages only, but the present day requirements seek to use them even at extra high voltages for longer distance [11]. Advantage of using overhead line transmission, it support a high voltage with the longer distance. Increased working voltages of the overhead lines require the cables to be insulated for such voltages in order to meet the requirements of the overhead lines.

A power cable consists of the three main components, namely, conductor, dielectric and sheath [11]. The conductor provides the conducting path for the current. The insulation or dielectric withstands the service voltage, and isolates the conductor with the object. The sheath does not allow the moisture to enter, and protects the cable from all external influences like chemical or electrochemical attack, fire, etc. Figure 2.1 illustrate classification of power cable which is consists of insulation of cable, conductor commonly used and sheath for covered the outer semi-conducting layers.

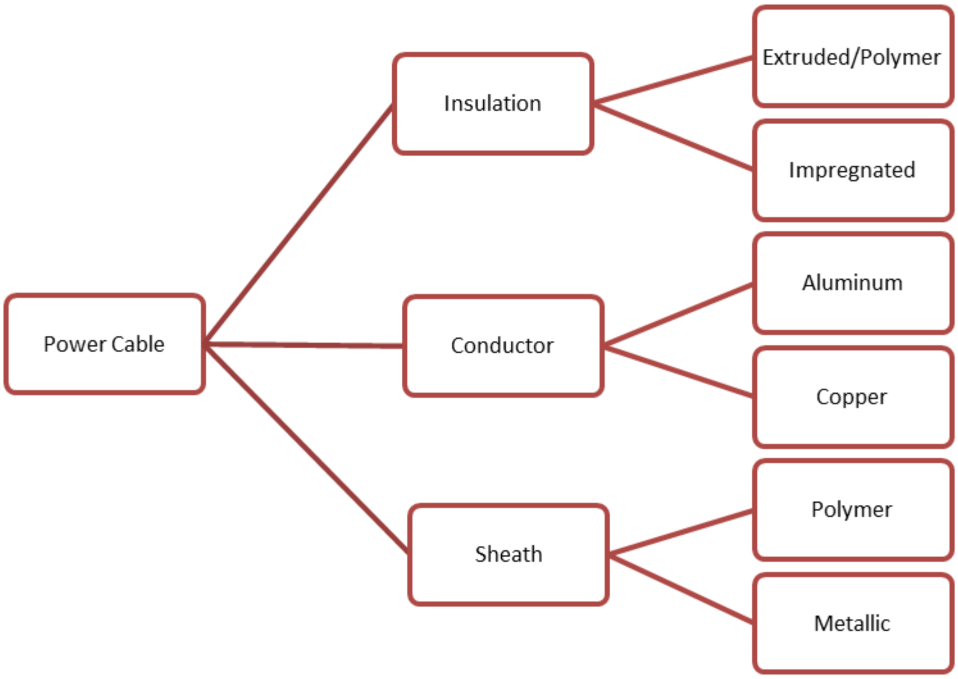


Figure 2.1: Classification of Power Cable

2.2.1 Extruded Polymeric Cables

The development of high voltage such as LDPE, HDPE or XLPE cable systems goes back to the 1960's. Since technology have improved significantly, providing reliable and maintenance-free products to the utility industry production and material [12]. Cross-linked polyethylene (XLPE) is the one of the major types of extruded dielectric insulation. XLPE has high insulation resistance and low dielectric constant. XLPE has emerged as the generally preferred insulate and in the voltage range 60-187 kV [13]. It has advantage of a higher permissible operating temperature of 90^{o}. Nevertheless, the first commercial length of 275 kV XLPE cable was installed in Japan.

Figure 2.2: Extruded Polymeric Cable

Modern XLPE cables consist of a solid cable core, a metallic sheath and a non-metallic/polymer outer covering. The cable core consists of the conductor, wrapped with semiconducting tapes, the inner semiconducting layer, the solid main insulation and the outer semiconducting layer. These three insulation layers are extruded in one process. The conductor of high voltage cables can be made of copper or aluminum and is either round ended of single wires or additionally segmented in order to reduce the current losses [12].

2.2.2 Impregnated-Type Cable

This type of cable is divide into three which is mass-impregnated paper-insulated cables (solid type), fluid-pressurized cable type, and gas-pressurized cable type. All this type has own characteristic to transmit the electrical energy. Generally, for the lapped cable type are conductors, conductor screen, cellulose paper insulation, insulation screen, impregnating compound, metallic sheath to achieve a water-impervious barrier [14]. The outer finish might be an extruded plastic jacket.

Impregnated paper became the most common form of insulation for cables used for bulk transmission and distribution of electric power, particularly for operating voltages of 12.5kV and above. Paper insulated cables were improved considerably with introduction of the shielded design of multiple conductor cables by Martin Hochstadter in 1914. From that, the cable is known as Type H [14-15]. The cable consisted of two concentric conductors insulated with wide strips of paper applied helically around the conductor and saturated with rosin-based oil as shown in figure 2.3 below [16].

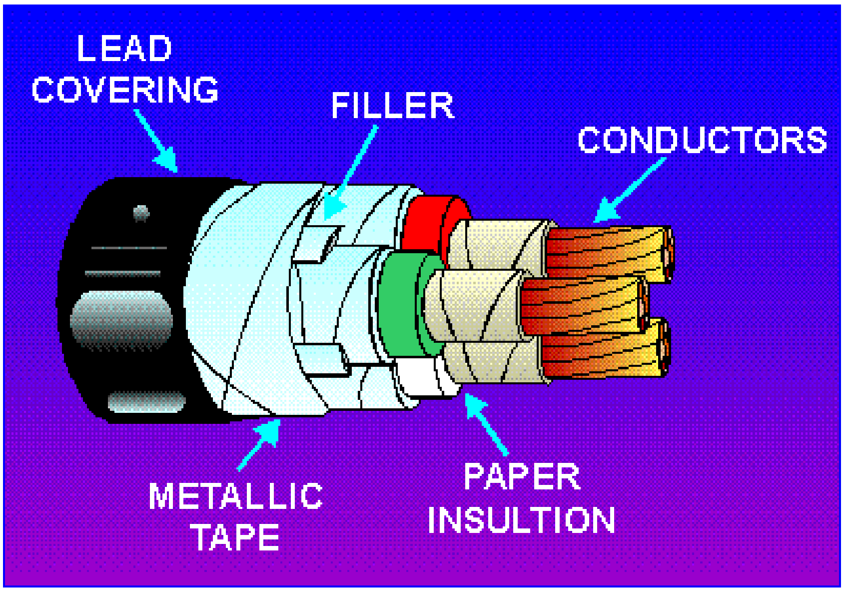


Figure 2.3: Impregnated-Type Cable

Figure 2.4 shows each is insulated from the others by silk and cotton thread. Because the insulation in this type of cable is not subjected to high voltage, , meaning to say for low voltage the use of thin layers of silk and cotton is satisfactory an contain many small conductors.

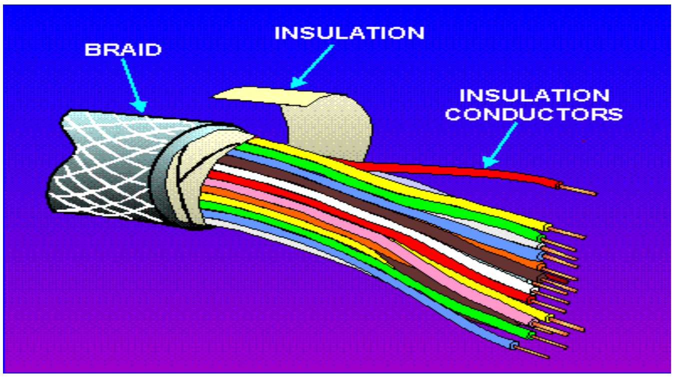


Figure 2.4: Cable containing many conductors

2.3 Cable Specification

Table 2.1 shows some sort of specifications or details for cable includes of conductor, conductor shield, insulation, insulation shield, and etc. Designing geometric of cable can be followed by this study of specifications

Table 2.1: Cable Type Specification [15]

Description	11kV
Conductor	• Plain stranded annealed Copper wires c/w longitudinal water blocking features. Copper to have conductivity of 100%. Minimum cross-sectional area 300 mmsq.
Conductor shield	• Shall consist of an extruded semi-conducting thermosetting compound (non-metallic) applied over the conductor. • Minimum thickness <0.8mm • DC volume resistivity <100000Ωcm • Maximum void size at the insulation interface <0.005mm.

Insulation	• High quality, dry-cured, heat, moisture, ozone and corona-resistance, XLPE. Suitable for operation in wet n dry locations. • Dielectric constant at 90º C < 2.5 • Power factor of insulation at 90º C < 0.1% • Nominal thickness > 20mm • Minimum thickness > 18mm • Maximum void size <0.05mm • Maximum contaminant size <0.125mm
Insulation shield	• Shall consist of a semi conducting XLPE compound simultaneously extruded onto the insulation. It shall be firmly bonded to the insulation. • Minimum thickness >1.0mm • DC volume resistivity < 50,000 Ω-cm at maximum conductor temperature at normal operation. • Maximum void size at the insulation interface < 0.05mm • Maximum protrusion at the interfaces <0.125mm
Extrusion process	• The conductor shield, insulation and insulation shield shall be extruded by simultaneously triple extrusion process.
Swelling tape	• A semi-conducting non-woven or woven, non-biodegradable (synthetic) swelling tape is to be applied over and under the metallic screen for continuous longitudinal watertight barrier throughout the cable length.
Metallic screen	• Metallic screen shall be in the form of concentric round wire shield consisting uncoated copper wires helically applied over the swelling tape. • It shall be sized to carry the rated fault current.

Radial water barrier	• A radial water barrier consisting of laminated aluminum tape (PE/AL/PE) is to be incorporated under the PE over sheath.
Outer protective covering	• The oversheath shall be extruded black PE (ST_7) supplied over the laminated aluminum tape. • The oversheath shall be treated with non-hazardous and effective termite repellent. • Nominal thickness <4.0 mm • Smallest thickness at any point >85% of nominal thickness. • Each last section of cable terminating into GIS switchgear, transformer or any other cable box inside or outside a substation building and where the cables are installed on the bridge, the cable shall have a fire-retardant serving complying to IEC 60332 part 3.
Over conducting layer	• The outer surface of the oversheath shall have a baked on graphite conducting layer to serve as an electrode for the voltage test on the oversheath.

2.4 Damage in High Voltage Cable

2.4.1 Ageing

The occurrence of discharges within insulation cavities and the generation of an electrical tree that highest in cable breakdown is the one off aging process in polymeric insulated power cables [17]. It is assumed that at the electrical field exceeding a threshold value, the space charge formed by the PD progresses within the insulation via channel emanating from the cavity. Penetration depth x is determined by the electrical field at the tip of the channel. This process is argued to produce the well-known tree-like structure.

Figure 2.5 illustrate defect of power cable because of ageing problem upon frequently electric discharge occur surrounding insulation layer.

Figure 2.5: Defect of power cable because of Ageing

2.4.2 Improper termination Cable

The purpose of a cable termination is to connect an insulated cable to a circuit. The termination also protects the cable mechanically, keeps moisture out form the cable and helps to keep the oil inside an oil impregnated paper cable. The structure of a cable termination depends on cable type, used voltage and installation environment. For example terminations used outside must be mechanically strong and completely waterproof. If termination process done without follows the rule will give dangerous impact to customer and damage the HV equipment and in the while increase the cost for maintenance fee [18].

The cable termination must withstand the same electric stress that the cable does. It is important to note that the electric field rises remarkably at the end of the screening and some sort of grading is required. There are different techniques for implementing the grading. Geometric grading can be implemented by adding a cone-shaped (stress cone) insulation on top of the cable insulation and the end of the screening. Another solution is to add a shaped layer of insulation with a different permittivity than the surrounding insulation on top of the cutting point of the screening [18].

Figure 2.6 shows breakthrough could also be an effect of quality issues in the stress control mass or even in the cable insulation. Wrong electric properties in the mass could lead to a much higher electric field at the cutting point of the screening. Improper structure of the mass could also lead to a breakthrough if air bubbles were left inside the termination. Partial discharges generated inside the air bubbles would start to slowly burn the insulation and could lead to failure.

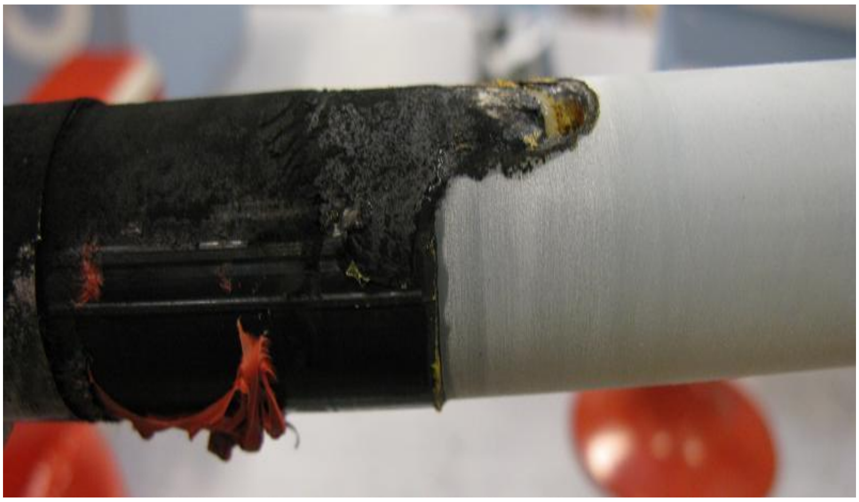


Figure 2.6: Improper Termination excite breakdown occur

2.4.3 Defect by Environmental Condition

Defect accidently cause by the oxidation process. When the cable is exposed to moisture and oxygen, it will result in rust. This case may lead the cable cannot work properly, such as shown in figure 2.7 below:

(a) (b)

Figure 2.7: Environmental Defect

2.5 Insulation

The vast majority of conventional power cables are insulated with either solid extruded dielectrics or liquid-impregnated papers. The use of the former now generally dominates the distribution power cable field, whereas the latter is still extensively used in high-voltage power transmission cable. Although the solid extruded insulating materials have undergone marked changes with time, the changes in the liquid-impregnated papers have been substantially not too vital [19]. Insulating materials are used in electric devices to keep current from flowing where it is not desired. Generally, the thicker the insulator, the higher the voltage can sustain. In recent years natural rubber has been completely replaced by synthetic rubbers and plastics as cable insulation [20].

Many types of XLPE cables of the first generations are suffering from a degradation problem known as water treeing. This will gradually decrease the voltage withstand of the cable and eventually a breakdown will occur. The dielectric compounds as insulates for power cable should possess the several main properties, for instant:

- High insulation resistance
- High dielectric strength
- Good mechanical properties
- Preferably non-hygroscopic, but if hygroscopic it should be provided with an economical water-tight covering or sheath.
- Capable of being operated at high temperatures
- Low thermal resistance
- Low power factor.

2.6 Electric Parameter

The type of cable to be used will depend upon the working voltage and service requirements. In general, a cable must fulfill the some necessary requirement such as electric field, electric stress and capacitance of the cable.

2.6.1 Electric Field

The electric field is defined as the force per unit charge that would be experienced by a point charge at a given point.

$$E = \frac{F}{q} \tag{2.1}$$

Vectors represented as an electric field which continuous entity. Vectors are drawn as extended arrows which represent the field at the end of the vector. When using vectors to represent the field it's good to note that we can't draw them all because the field still exists at every point in space even if we cannot draw a vector everywhere as shown in figure 2.8 below.

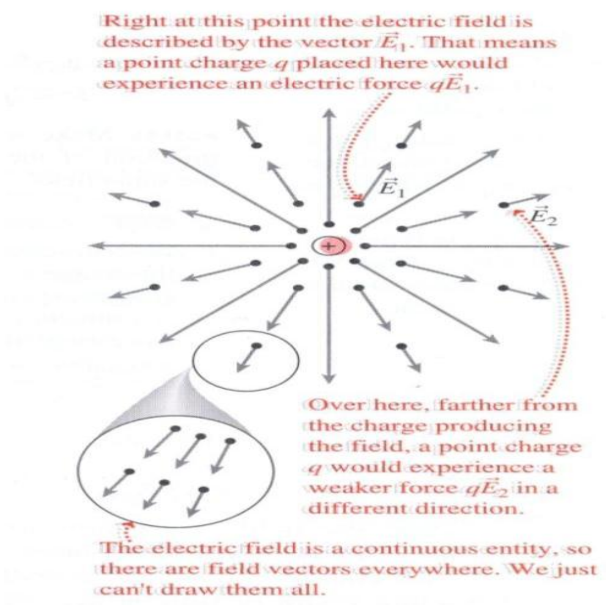


Figure 2.8: Electric field represented as vectors

Figure 2.9 (a) and (b) shows more practical way to visualize electric fields than using vectors is to use electric field lines. Field lines are continuous lines whose direction is everywhere the same as that of the electric field. Field lines start at positive charges or at a negative charge or extend to infinity.

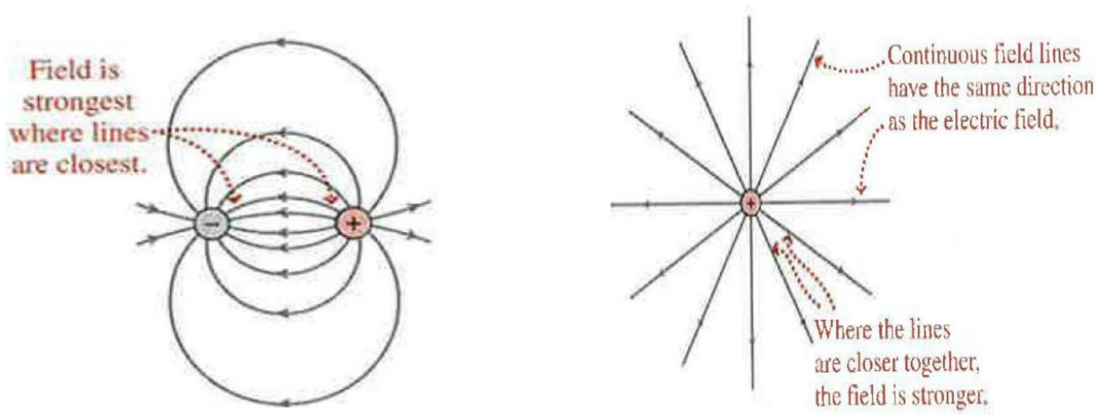


Figure 2.9: Field lines used to visualize the electric field

Based on Coulomb's law we can conclude that the field is stronger where the lines are closer to the charge and weaker when they are farther apart. This allows us to study the field's relative magnitude and direction from field line pictures [21].

2.6.2 Electric Stress

Normally, cable modeled as a coaxial cylinder system. The electric stress at any point in the insulation material is given by equation [22].

$$E\,(x) = \frac{U}{x \ln \frac{r_o}{r_i}} \tag{2.2}$$

U = Applied voltage

r_i= Conductor radius

r_o= Sheath radius

x = radial distance to any point in the insulation.

From equation 2.2, it can be seen that the bigger value of sheath radius, the bigger value will electric stress produce. This will related to the equation below.

$$Emax = \frac{U}{r_i \ln\frac{r_e}{r_i}} = maximum\ stress \tag{2.3}$$

It occurs on the surface of the conductor which is the most probable location for instantaneous failure. This is more likely to occur if serious insulation defects are near the conductor surface [22].

$$Emin = \frac{U}{r_o \ln\frac{r_e}{r_i}} = minimum\ stress \tag{2.4}$$

The minimum stress occurs at the outer sheath and it becomes a critical factor if insulation defects are in the vicinity of the outer sheath. The mean stress (i.e. *E* min) across the insulation is critical if insulation defects are uniformly located throughout the bulk of the material.

2.7 Zinc Oxide Microvaristor Material

This material is the crucial material in this project as a material to control stress in cable accessories. ZnO microvaristor can be found inside heat-curing silicone (HTV) or liquid addition-cross linked silicone rubber (LSR). Those polymeric material matrices have an elastic property. The elasticity is necessary to make easier in assemble cable accessories. Figure 2.10 shows the field conductivity of the ZnO microvaristor material. When switching point reached at 10kV/cm, the material changes its conductivity extremely. In this way it prevents the occurrence of electric fields which are above this switching point.

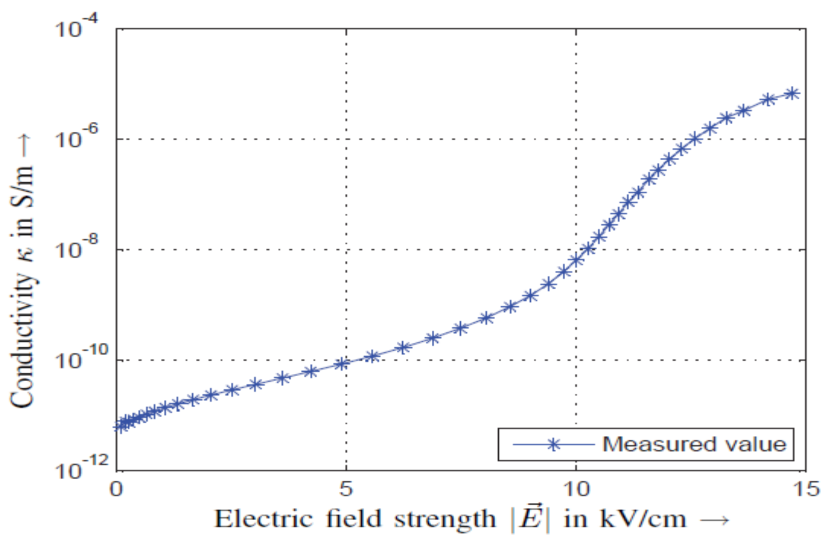
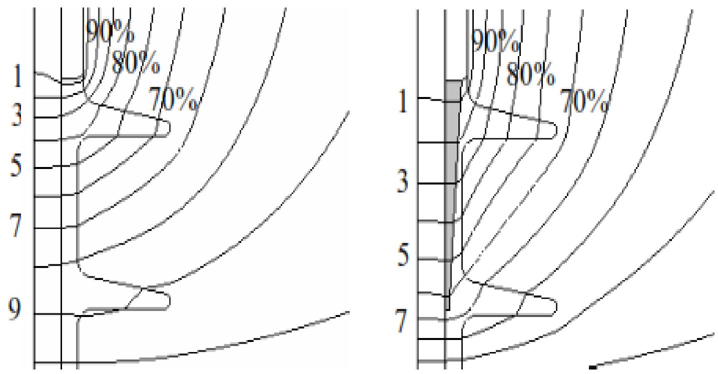


Figure 2.10: Characteristic for ZnO micrvaristor material

This material has been demonstrated by previous researcher. Zinc Oxide Microvaristor were proposed as grading material along the insulator. The electrical properties of the microvaristor compounds are characterised by a nonlinear field dependent conductivity. Figure 2.11 illustrate the proposed design, a short length of ZnO microvaristor compound layer is applied on th core of the insulator near the insulator HV and ground terminals. Figure 2.11 (a) shows equipotential line without non-linear grading and figure 2.11 (b) shows non-linear grading were applied. Results shows after apllied microvaristor grading material between copper and silicone insulation where 70% interval line refract away from the concerntrated point [23].



(a) (b)

Figure 2.11: Equipotential lines at 5 % interval for dry clean insulator.

Figures 2.12 show the corresponding electric field profiles along the leakage path for the clean and polluted graded insulators. As can be clearly observed, the field distributions on the insulator equipped with grading material under both surface conditions are improved. Peak magnitudes in the high field regions, particularly at the HVend are reduced by nearly 30%.

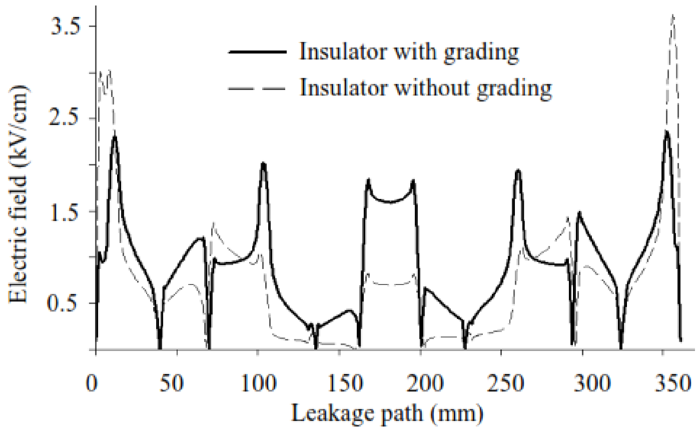


Figure 2.12: Tangential Electric Field along Dry-Clean Insulator

2.8 Corona effect at Termination Layer

Regarding previous study, focused on underground cable accessories used in medium voltage cable. Systems need a highly reliable stress control system in order to maintain and control the insulation level which is designed for estimated life times. Figure 2.13 shows the stress concentration at the end of the screen of medium voltage cables when no stress control system is used.

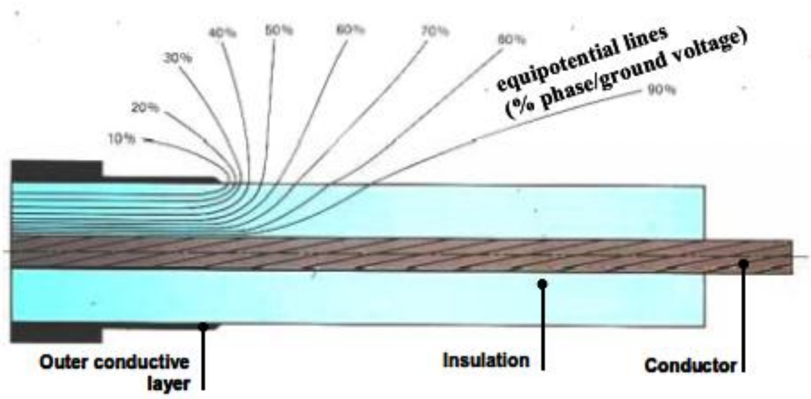


Figure2.13: Uncontrolled cable end – potential

The term ‘electrical stress control’ refers to the cable termination function of reducing the electrical stress in the area of insulation shield cutback to levels that preclude electrical breakdown in the cable insulation. Figure 2.14 shows breakdown occur at the edge of outer insulation layer when termination has been done. This paper focus on metal Oxide-Matrix stress control system to reduce field stress which has never been attempted before [6].

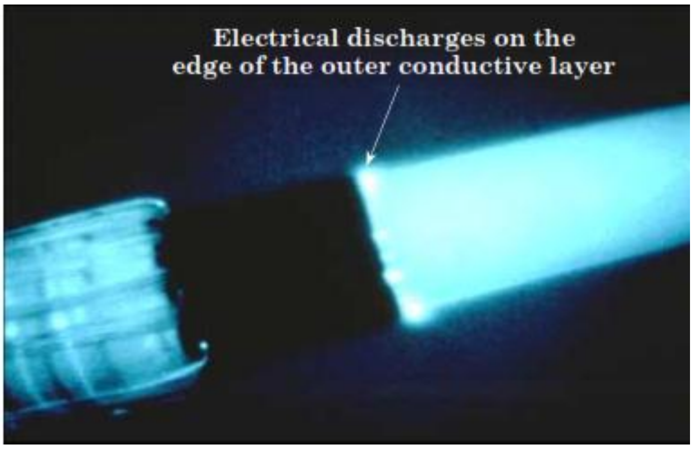


Figure 2.14: Corona at outer insulation layer

CHAPTER 3

METHODOLOGY

3.1 Introduction

To ensure this project will be succeeding, several characteristic of cable will be study to familiar with cable issues. This study investigates and evaluates different types of cable termination models by the finite element analysis (FEM) computer program. The basic steps in simulation procedure steps are explained in this chapter. The project must consider the cable material and FEM simulation. To achieve the outcome, some procedure must be followed. First step is to study about power cable and its properties. After that, electrical parameter of insulating and conductor also must be studied. There are several ways in gathering the information such as using references from the books and the most important references are referred to related journal, previous study, proceedings paper and conference papers.

The simulations with FEM software computer program are demonstrated in three basic steps which is preprocessing, solution procedure and postprocessing. Which mean, the preprocessing step involves the model properties (geometrical,electrical) input and meshing. In the solution procedure, the boundary each geometric conditions are applied and the program solves the potential values of the model. The graph plotting and reading of the output is done in the postprocessor step to evaluate the results.

The choice of the appropriate parameters is very important to verify the accuracy of the output in the analysis. Otherwise, incorrect results and even errors are obtained in the end of the analysis.

Figure 3.1 shows the flow chart for the whole process for this project of investigation Zinc Oxide Microvaristor for Stress Control on Medium Voltage Cable Terminations.

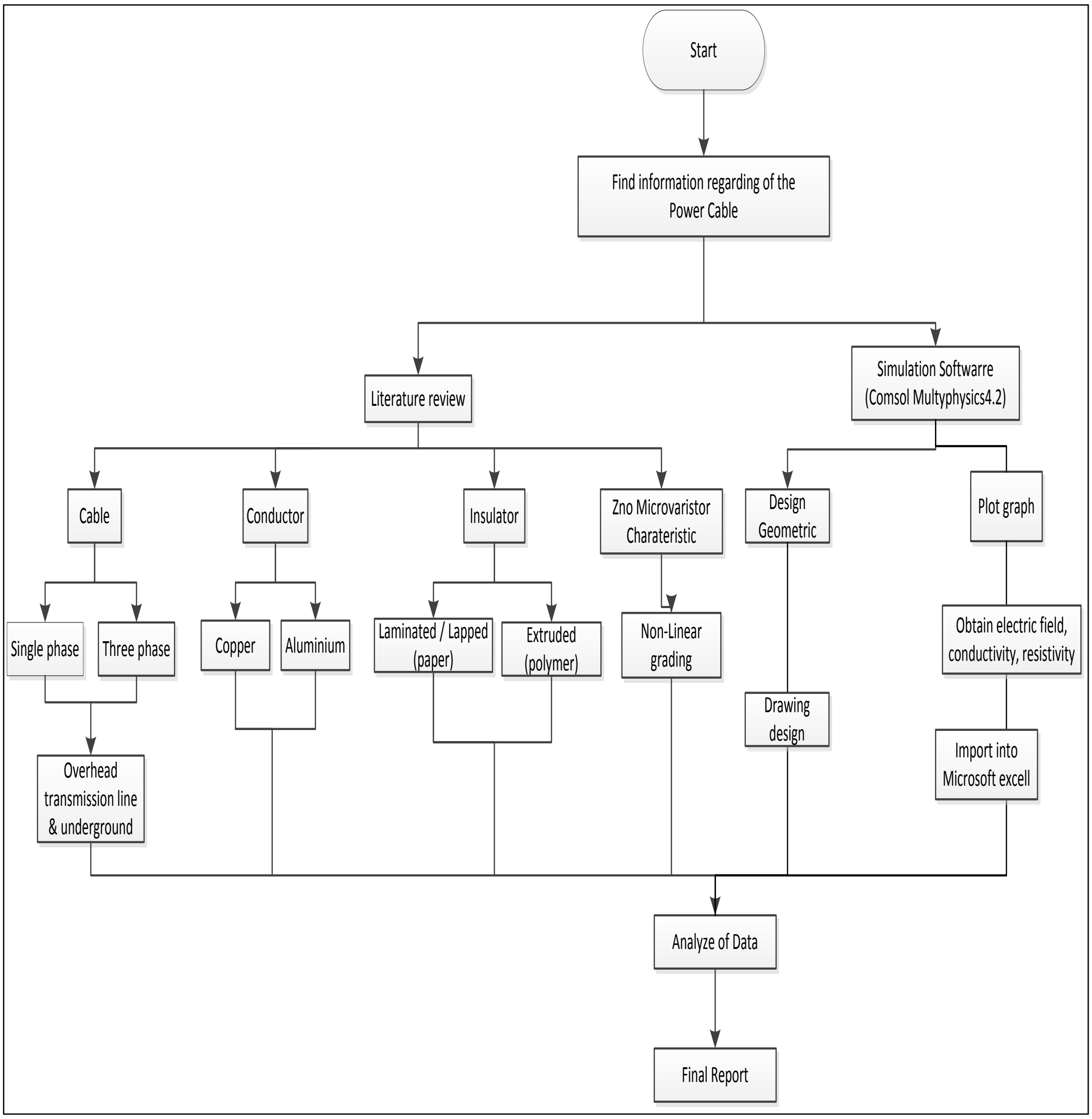


Figure 3.1: Flow Chart Project

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