High Voltage Stress Distribution Phenomena on Liquid and Solid Insulation Material Using Finite Element Method

Yanuar Z. Arief[1], Nor Asiah Muhamad[2], Mohd Hafiez Izzwan Saad[1], Syazwan Nazri[3], Siti Nur Anina Othman[3], and Mohd Fikri Hilmi Mohd Taib[3]
[1]*Department of Electrical and Electronic, Faculty of Engineering, Universiti Malaysia Sarawak (UNIMAS), 94300 Kota Samarahan, Sarawak, Malaysia.*
[2]*School of Electrical and Electronic Engineering, Universiti Sains Malaysia (USM), 14300 Nibong Tebal, Penang, Malaysia*
[3]*Institute of High Voltage & High Current, Faculty of Engineering, Universiti Teknologi Malaysia (UTM), 81310 Johor Bahru, Malaysia.*
ayzulardiansyah@unimas.my

***Abstract*—Electric field stress has been a major problem in high voltage phenomena that can lead to electrical degradation and thermal losses. Recent research found that with the development of existing liquid insulator (mineral oil, vegetative-based oils) and solid insulator (epoxy) will enhance the electrical, mechanical and thermal properties of high voltage insulation. This study investigates the properties of the electric field distribution, electrical potential and heat flow across the liquid insulating material (mineral oil, coconut oil, palm fatty acid ester oil and FR3) and solid insulating material (cross-linked polyethylene/XLPE, polyvinyl chloride (PVC), polymethyl methacrylate (PMMA) and epoxy) using finite element method (FEM). The aim of this study is to get a better understanding on the electric field distribution including heat transfer under high voltage stress for research purposes. The study was carried out using liquid test cell (according to IEC 60897) and solid test cell (according to CIGRE Method II). The result from this study will give a better understanding to interpret the phenomenon of electric field distribution, electrical potential and heat flow as the increase of the electrical stress.**

***Index Terms*—Electric Field Distribution; Finite Element Method; High Voltage Stress; Liquid and Solid Insulation Material.**

I. INTRODUCTION

The design of high voltage (HV) equipment requires full knowledge of the electric field distribution and ways to control such electric field. Understanding of the insulation failure modes requires some knowledge of the electric field concepts. For the case of solid and gas interface, the electric field is distorted at the boundary.

For AC applications, the dielectric material can get charged. It may be charging of insulator due to corona or other types of discharges giving rise to a surface charge density. It will enhance the total surface field on the gas side. Solid - gas, solid - vacuum, solid-liquid or solid-solid interface needs careful consideration. The higher value of the electric field may accelerate the degradation and lastly will damage the insulation. The application of controlled electric field consists of cable terminations, HV bushings, potential transformer and circuit breaker.

The electric field distribution can affect the partial discharge (PD) pattern. If the equipotential line of the electric field is compressed at a certain point in the insulator, as it slowly degrades the insulation and lastly leads to a complete breakdown of equipment. Then, electric stress values must be controlled to design the high voltage equipment.

There are many research works conducted to form a good insulating material that has a resistant to chemical, thermal, electrical degradation, and have good mechanical properties. A good insulating material will lower the cost of maintenance because such insulator can withstand for a longer period. Recent developments in the use of solid insulator as an excellent insulator with good characteristics have been reported. However, the concept of high voltage stress distribution in liquid and solid insulation material is not clearly understood. Thus, this research work will simulate the liquid and solid dielectric materials and analyze their electrical and thermal properties for research purposes according to experimental works on partial discharges research.

A. Liquid insulation

Transformer oil basically referred to the insulating oil in a power transformer. After undergoing subsequent treatment, transformer oil is formed through extraction from crude petroleum oil. Based on this, it is called mineral insulating oil or mineral oil. Transformer insulating oil has a highly refined mineral oil and excellent electrical insulating properties. Therefore, such properties will enable transformer oil to be stable in elevated temperature. Basically, transformer oil acts as an insulating material in the transformer. It serves as a cooling medium which helps to absorb the generated heat during core and winding and transfer it to the last surface of the transformer [1]. Mineral oil has been used as transformer oil since a long time ago. There are two ways to produce mineral oil which is crude petroleum and refining petroleum. Basically, petroleum oil is extracted from crude petroleum. Hydrocarbon is one of the contents in the mineral oil. We can get high quality of crude petroleum, when it undergoes refining process [1, 2]. Mineral oil is usually used in high voltage equipment and transformer it low viscosity and good insulating material properties. It also contributes to the excellent in transformer operation due to its low relative permittivity. Awareness of the importance of mineral oil has been spread around the world and gives the low cost however, due to its poor biodegradability, the environment will be in