Water Tree Simulation on Underground Polymeric Cable Using Finite Element Method

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

***Abstract*—Most insulation failures in polymeric underground cables have been caused by the formation of water tree in the polyethylene insulation that leads to electrical tree. Electric field intensity is fundamental to water tree growth, hence studying and modeling water tree in a cross-linked polyethylene (XLPE) insulation is vital as insulation failure is frequently triggered by water tree. The aim of this study is to determine the electric field intensity and to identify the electric potential distribution in XLPE insulation used in the underground medium voltage cable which are affected by water tree. Finite Element Method is used to perform the simulation works. The Electrostatic numerical models of 11kV single core XLPE cable affected by the variations of water tree models and size of water tree are analyzed. The two types of water tree, vented tree and bow-tie tree are modeled in the simulation and the properties of the models were set by the experimental value found in the literature. The simulation results revealed that regardless of water tree type, size, length, shape, dimension or location, water tree contributes to higher electric field at the affected region and thus reduces the dielectric strength of cable insulation. Nevertheless, the relative permittivity, shape, length and location of water tree induce a significant variation of electric field intensity in the insulation. The electric field is found to be more intensified at the region where water tree is closer to the conductor. Therefore, electrical tree is more likely generated from the vented water tree initiated from the outer surface of the insulation that grows towards the conductor rather than the other types of water tree.**

***Index Terms*—Finite Element Method; Underground Polymeric Cable; Water Tree; XLPE insulation.**

I. Introduction

Underground cables have become more popular in recent years because they are less susceptible to environmental damage and have an advantage in densely populated area where land is aesthetically sensitive. In Medium Voltage underground cables, the most insulation failure in polymeric cables reported is due to formation of water tree in the polyethylene insulation that lead to electrical tree.

Water treeing have been being first described by Kitchin and Pratt in 1958 and the degradation of polyethylene due to water tree was first reported by Miyashita in 1969 [1]. Thus, studies on water tree have been continuously investigated for almost five decades and there is vast research about the water tree degradation [2].

Water treeing is a degradation phenomenon developing in dielectric insulation exposed to sufficient electric fields [3, 4] and relative humidity in the cable insulation exceeds a value of 70% [5]. Formation of a tree-like feature of voids and micro channels filled with water in the direction of electric field is result for the reduction of electrical breakdown strength in the cable insulation. This phenomenon has unfavorable effect to electric field distribution in cable insulation which reduces the dielectric breakdown potential of the cable and eventually causing catastrophic breakdown of the cable.

The water tree grows at a slow process and may take months or even years to grow and propagate. Water tree may propagate and breach the entire insulation and as they grow, the dielectric strength of the insulation getting lower that will cause electrical trees [6, 7]. The growth of water tree is first, the initiation of water tree, then the alone growth of water tree and finally, with the presence of water trees growth in the insulation, distribution of electric field is transformed which causes electrical stress in a cable insulation.

There is a vast research and report on the water treeing mechanism in the literature, but the simulation of water treeing in medium voltage underground cables has received little attention and was not widely reported. Electric field intensity is the fundamental of the water tree growth and it is difficult to observe or show the increase in the electric field. The effect of electric field intensity and electric potential due to water treeing in cable insulation can be observed through the simulation of electric field distribution based on a finite element method (FEM). Furthermore, the knowledge of transformation in electric field distribution across the insulation which causes dielectric breakdown can guide experimental effectively. The main objective of this study is to observe and simulate the electric field and electric potential distribution in the XLPE insulation used in medium voltage underground cable (11kV) affected by water tree using finite element method. Furthermore, it is also to observe the electric field distribution and compute the electric field stress exerted by water tree inside cable insulation with various water tree conditions and water tree models.

II. Simulation Procedure

The simulation workflow of this study is illustrated as shown in Figure 1. Two-dimension models are used for the simulation of the electric field. Field lines are perpendicular to equipotential lines and directed from conductor to the outer