Effect of Water Filled Voids on the Thermo-Electrical Behaviour of XLPE Insulated Cables using FEA Method.

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ABSTRACT

The presence of water filled voids within HV XLPE insulation constitutes a major concern for cable manufacturers and power utilities. Indeed, these defects can contribute under service conditions to the degradation of the XLPE insulated cables performances by several discharge mechanisms. In this paper, a two dimensional (2D) axial symmetric model geometry of a water filled cavity within XLPE cable has been developed using software based on Finite Element Analysis (FEA) method. The simulation model was performed to investigate the effect of watery void parameters on the thermo-electrical behaviour of HV XLPE cable under service stress conditions. Simulation results showing the electric field distortion profile, temperature distribution in the insulated cable with respect to cavity geometric factors and operating parameters are presented. The obtained results show how much the increase in temperature within the watery bubble under critical overloaded conditions might cause a water physical state change, promoting then a risky situation by discharge mechanisms at long term.

KEYWORDS

XLPE cables, Water filled voids, Thermo-electrical behaviour, Simulation model, Finite Element Analysis (FEA).

INTRODUCTION

Although the use of high technology process and the improvements made in the manufacture of HV Cross Linked Polyethylene (XLPE) cables, some difficulties in terms of reliability still exist due to anomalies and defects [1].The presence of defects for instance, water filled voids in the insulating material of high voltage (HV) cables constitutes a main concern for the cables manufacturers and electrical power utilities. Their existence in the insulated power cables is also linked to wet environment where the cables are expected to work.

Numerous studies have reported the possible mechanisms of moisture penetration and water adsorption of insulating materials from the environment [2, 3]. According to many hypotheses, the water condenses at defects such as contamination, voids or interfacial cavities by the effect of electrical stress [4, 5]. In addition, a physical damage due to mishandling of the cable can moreover allow water permeation into the insulation even the high safety design of the insulated cable [6].

The presence of moisture in cables surroundings may alter the main characteristics of the insulating material and therefore the reliability of XLPE insulated cables. Indeed, the watery void as aging factor can modify the insulation thermo-electrical behaviour characterized by huge electrical stress and temperature values within the cable insulation under service conditions. This situation may be followed by XLPE cables performances deterioration by several discharge mechanisms [7, 8]. In fact, under some critical conditions the watery cavity may be subjected to physical changes especially at high temperatures causing the water vaporization and then a probable partial discharges appearance. Numerous works in a cable context [9-12] have indicated that the partial discharges could lead to an accelerated aging of the cable through discharge mechanisms by water trees under wet environment and electrical trees at long term.

In this paper, a two dimensional (2D) axial symmetric model geometry containing a water filled cavity within XLPE insulated cable has been developed using software COMSOL Multiphysics based on Finite Element Analysis (FEA) method [13]. The simulation numerical model was performed to investigate the effect of watery void parameters on the thermo-electrical behaviour of the studied cable under service stress conditions. Simulation results showing the electric field distortion profile, temperature distribution in the insulated cable with respect to cavity geometric factors (size and location) and operating parameters (applied currents and voltages) are presented and discussed. The obtained results show how much the rise in temperature within the spherical watery bubble under critical overloaded conditions can cause a water physical phase transformation, promoting then a perilous situation by discharge mechanisms at long term.

MODELLING

A two-dimensional (2D) axial symmetric model geometry of a defect (water filled void) within XLPE insulated cable which has been developed using software COMSOL Multiphysics based on Finite Element Analysis (FEA) method is shown in figure1. The developed model consists of a watery spherical cavity of D_c diameter which is located at L position from the cable core centre, an homogenous dielectric material (XLPE) and two electrodes; HV (conducting core) and grounded (G) ones. The insulation envelop, in which we compute the distribution of the electric field, is limited by two semi-conductor layers that form the radial boundaries of the study area. Therefore, the cable inner radius (R_1) representing the active electrode is connected to the HV potential and the cable outer one (R_2) at the ground part (G), takes the null potential value. This constitutes the limit conditions of the electrostatic problem. The boundary conditions of the thermal problem have also to be considered taking into account the temperature of the soil which is the ambient temperature (20°C) for the present study.