FEM Modeling of Electric Field and Potential Distributions of MV XLPE Cables Containing Void Defect

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Abstract

Introduction: Failure in cable insulation is generally preceded by a degradation phase that may last several years. A significant cause of cable system failures is the breakdown of electrical insulation between the electrodes. The operational stresses that occur in cable insulation which include thermal, mechanical and electrical effects will vary with time and can cause degradation due to the resulting physical and chemical changes in cable properties. It is widely recognized, irrespective of the causative mechanism, that degradation results in partial discharges (PDs) being generated at the degradation site(s). PDs are small electrical discharges produced by local enhancement of the electrical stress due to conditions around the fault. The internal discharge in insulation material and/or at its interface is caused by the strong and inhomogeneous electrical fields that are usually caused by voids, bubbles, or defects. Treeing discharge is also associated with internal discharge, and it starts from conducting particles or a void in solid insulation. This paper investigates the electric stress within an armoured XLPE insulated cable containing a void-defect. The finite element model of the performance of an armoured XLPE MV underground cable containing void-defect is developed using the COMSOL multiphysics. Use of COMSOL Multiphysics (Electrostatic model): A two-dimensional model of a single-core Cross-Linked Polyethylene (XLPE) cable containing a void-defect has been developed using the COMSOL multi-physics environment. The electrical field distribution in a typical cable construction, is described by a two-dimensional field model. The model is solved for a non-degraded system configuration as a base for further analysis. In addition, an air-filled void is introduced into the model cable insulation to investigate the effect of void presence on the XLPE electrical field insulation system. The mathematical field model for electrical field distribution in the air-filled void is created in respect of the single-phase XLPE cable field model. The electric field intensity is obtained from the negative gradient scalar potential. Results: The finite element model of the performance of an armoured XLPE MV underground cable is developed using the COMSOL Multiphysics. A map of the electric field strength within the MV cable insulation is presented. Figure 1 shows the electric field and equipotential distribution within the cable at the point in the AC cycle where the conductor potential is at its maximum value. The field strength is strong on the conductor's surface and the weaker at the outside of the cable insulation. It can be shown that due to the cable concentric construction, the electric field strength is high around the conductor and less at a distance from the conductor. The equipotential lines are

close to each other where the electric field intensity is high and vice versa. The equipotential field lines are parallel to the ground sheath. The figure shows the rotational symmetry of electric field around the conductor, which is expected due to the symmetry of the cable. The electric field lines. The effects of the void-defect within the insulation are given in Figure 1. Figure 2 shows the result of inserting a void-defect of size 1 mm on the left to the conductor at a particular instant where the conductor is at its maximum value. It shows the distortion of the electric field distribution caused by the void-defect. The void electric stress is higher than the electric stress of XLPE insulation material. The radial electric stress of XLPE insulation material around the void is higher than that of an axial electric stress. Conclusion: COMSOL Multiphysics software is used to model the electric field and potential distributions within a XLPE armoured cable in the presence of an insulation void.

Figures used in the abstract

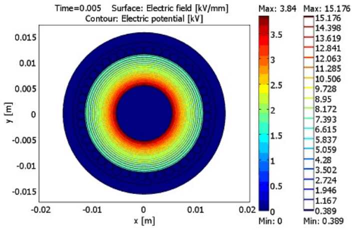

Figure 1: The electric field and equipotential distribution through the XLPE cable cross-section at the time 0.005 seconds.

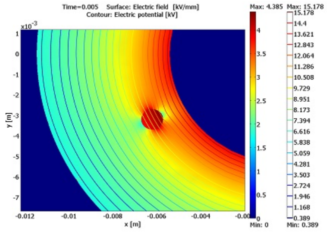

Figure 2: Effect of void-defect on electric field distribution.