Development and Set-up of a Non-intrusive Technique for measuring Space Charges in Specimens of DC cables

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ABSTRACT

This paper presents a procedure for designing a power converter to produce power pulses in the conductive parts of a cable (core or shield) for non-invasive space charge measurements with a thermal wave. Analytical and numerical thermal and electrostatic studies related to the temperature diffusion in the cable insulation are first presented, then the set-up and the design of the converter architecture are detailed. Experimental results show the ability for charge measurements within the insulation of a power cable in an entirely non-intrusive manner.

KEYWORDS

Thermal step method, Space charge, Multicellular power converters, Magnetic coupling.

INTRODUCTION

One of the main problems in HVDC cable development is space charge buildup, resulting from charge injection and trapping in the dielectric layer under high dc electric fields, coupled to the thermal gradient created across the insulation by the Joule heating of the conducting core during service. In HVDC cable development, space charges are currently measured with Thermal Step (TSM) or Pulse Electroacoustic (PEA) equipment, mounted around the external semicon of the cable. In these experimental setups, it is necessary to remove the shield and the protective layers of the cables, which is a major drawback for on-site and on-line measurements.

In the case of the TSM, the principle lies in the generation of a thermal wave on the semiconductor. The thermal wave diffuses through the insulation, slightly and reversibly disturbing its electrical equilibrium. The electrostatic rebalance of the system results in a capacitive current in the external circuit connecting the two semiconducting layers, i.e. the thermal step current (Figure 1) [1-2].

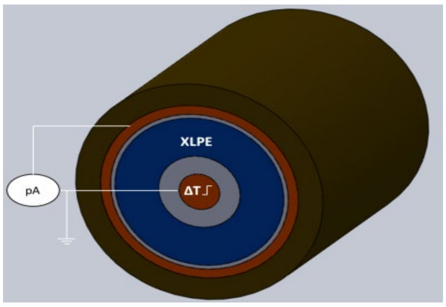

Figure 1 : Set up for space charge measurements in a power cable using the Thermal Step Method

Several methods can be used to heat an insulator and induce a measurable current, representative of the space charge distribution. The choice of the method depends on the dimensions and of the geometry of the insulation to be tested. Thus, for significant cable lengths (few meters), heating by laser or water-based system is not adapted, and, as previously stated, using such a principle involves the removal of the external layers of the cable, which prevents such a set-up to be used on-site or on-line. A possibility for overcoming these drawbacks is to produce the thermal step by Joule effect. This is the principle addressed in this paper. The present work concerns a novel compact and non-invasive approach for measuring space charge directly in the cable insulation, by using the non-destructive principle of the TSM without removing the cable sheath. The studied technique lies on the generation of a thermal perturbation by Joule effect, by heating the conductive parts of the cable (inner conductor or outer screen) with a strong current, provided by a power converter. The idea is to develop a prototype allowing studies on small-dimension cables in order to set the path for full-size set-ups.

THERMAL STEP METHOD

Geometry and simulation parameters

Numerical simulation is an essential tool for solving the equations governing heat transfer and electrostatics. In this context, we used the finite element method with COMSOL to simulate the coupled thermal and electromagnetic equations involved in the thermal step method. The model from Figure 2 was simulated in 2D-axisymmetric configuration, to take advantage of symmetry and to reduce computation time.

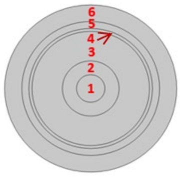

Figure 2 : Cross section of a power cable

1. Cable core **2**. Inner semi-con **3.** Cross-linked polyethylene insulation (thickness ~ 1.5 mm) **4.** Outer semicon **5.** Screen **6.** Outer sheath

The simulation considered three physics: heat transfer in solids, electrostatics and magnetics. Joule heating of the cable core results in heat conduction through the insulation; the parameters associated to the heat equation (to be solved for describing the diffusion of the generated thermal wave) are time, spatial coordinates (radius) and thermal properties of each cable layer. A time-depending study was performed to observe the results in terms of temperature diffusion and thermal step current. The mesh size was chosen in order to ensure a compromise between