Development of an industrial space charge measurement facility for extruded HVDC full scale cables

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ABSTRACT

In the frame of the study of space charge evolution on HVDC full size cables, a space charge measurement bench based on the Thermal Step Method has been developed by Nexans and the University of Montpellier. This development is described in the present communication. Preliminary measurements on full size cables under voltage, giving an insight of the sensitivity of the bench, are presented.

KEYWORDS

Space charge, HVDC extruded cable, Thermal Step Method.

INTRODUCTION

Extruded HVDC cables are submitted during service to various stresses, such as voltage ripples from the converters, temperature gradients, polarity reversals and impulses. Furthermore, when in operation, the average electric field in a cable dielectric is in the range of 15 kV/mm, which is the threshold where space charges injection and accumulation take place.

Space charge accumulation in the cable dielectric induces electric field distortions, which are able to accelerate the ageing of the cable system and may lead to premature failures.

Space charge measurement methods have been developed and extensively used to study laboratory samples, like plates and miniature cables [1]-[5]. While the information gathered from laboratory samples help to increase the understanding of the intrinsic behavior of the dielectrics, they do not allow to completely take into consideration synergetic effects such as electric fields, by-products, temperature gradients and semi-conductor/dielectric interfaces on the space charge evolution within the insulation of the cable systems.

In order to seek for the synergetic effects on the electric field distortions in the cable insulation, an industrial facility, aiming at measuring space charge distributions in extruded HVDC full scale cables by using the thermal step method (TSM), has been developed at Nexans High Voltage Competence Centre of Calais, together with the University of Montpellier. This development and its first outcomes are described in this communication.

THEORETICAL BACKGROUND

In order to have access to an electrical signal from which the electric field distribution in the cable dielectric can be estimated, a transient perturbation must be applied to the device under test. In the case of the thermal step method, the transient perturbation is a temperature step.

When a thermal perturbation is applied to the insulating layer of a cable, a temporary local space charge disequilibrium is induced. This is reflected at the cable electrodes (conductor and outer semiconductor) by the variation of the induced charges. This gives rise to a measured current named thermal step current. Assuming that dielectric permittivity of the cable insulation is homogenous, the thermal step current is given by:

$$I(t) = -\alpha\, C \int_{Re}^{Ri} E(r) \frac{\partial \Delta T(t,r)}{\partial t}\, dr \qquad (1)$$

with α the thermal step physical constant, C the electrical capacitance of the thermally excited part of the cable, R_e and R_i the external and the internal radius of cable dielectric, $\Delta T(t,r)$ the relative variation of the temperature within the dielectric and $E(r)$ the electric field distribution in the radius direction.

During measurements under applied DC field, in order to provide a compensation for the polarization and the conduction current during the measurements, a second cable (namely the compensation cable) is used. This configuration is called the double capacitor configuration and is fully described in [6]. As the cable potential is maintained during the measurements with the double capacitor configuration, the ageing of the cable is not interrupted.

Thermal steps can be applied either on the cable conductor (inner heating technique) [7] or on the outer surface of the cable insulation. The latter can be performed by injecting a controlled short circuit current in the metallic screen of the cable [7]. Although this method allows to characterize a long cable length (several tens of meters), it induces parasitic currents to the measured thermal step signal which may be tricky to eliminate. Another method is to thermally excite a section of the studied cable outer semiconductor by using a cold liquid (outer cooling technique). With this method, the magnitude of the applied thermal steps is more reproducible as it does not rely on the ambient temperature. Furthermore, it generates a very limited amount of parasitic signals. The outer cooling technique has been selected for the development of the described bench.

DESCRIPTION OF THE TSM FULL SIZE BENCH

A picture of the bench is given in Figure 1. It is composed of (from left to right) a buffer tank, a cold tank and a hot tank of 1500 l, 1500 l and 200 l, respectively. The use of the buffer tank will be described in the following section.

The bench has been designed to allow thermal step