EFFECT OF SEMICON-INSULATION INTERFACE ON SPACE CHARGE FORMATION IN HVDC POLYMERIC CABLES

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ABSTRACT

This paper deals with the analysis of the insulation/semicon interface as regards space charge injection and accumulation in the insulation bulk. Comparing space charge characteristics, originating from experimental measurements and relevant to different semicon/insulation combinations, it can be observed that the semicon may play an increasing role in charge injection as temperature rises, with an extent depending on the kind of semicon used. In addition, the type of insulation affects also the space charge accumulation, depending on trap distribution.

KEYWORDS

HVDC, polyethylene, semiconducting material, insulating material, charge injection, space charge accumulation threshold.

INTRODUCTION

Much effort has been spent to expand the use of polymeric cables (usually limited to HVAC) to HVDC power links [1]. This would provide tangible environmental and economic benefits with respect to mass-impregnated cables traditionally used in HVDC applications. Polymeric cables, however, seem to be greatly affected by space charge build-up, particularly when DC voltage is applied [2-4]. Space charge accumulation is considered, indeed, to be one of the main factors responsible for ageing acceleration in cable insulation, due to local electric field enhancement produced by accumulated charge, particularly in the presence of voltage polarity inversions.

Space charge build up is a complex mechanism that is yet to be fully explained. Generally, if the electric field is larger than a given threshold, i.e. the threshold for space charge accumulation, charge injection from the electrodes, promoted by field and temperature, may prevail over charge extraction/recombination [4]. This causes accumulation of space charge in traps located in the insulation bulk that hold the excess charge injected by the electrodes for times depending on trap depth which, in turn, may be associated with chemical/morphological structure of the insulating material. It has been observed that the amount of charge injection and accumulation may depend significantly on the contact between electrode and insulation. In particular, since a semiconductive layer is interposed between metal electrodes and insulation of a polymeric cable, the interface between semicon and insulation is thought to have a significant effect on space charge build-up in insulation.
Experimental tests were performed on mini-cable specimens having different combinations of insulation (INS1, INS2) and semiconductive materials (SC1, SC2), with the aim of investigating the way the semicon-insulation interface affects space charge accumulation. In particular, space charge measurements were carried out on these specimens at different electric field and temperature values, to obtain the characteristics of charge accumulation as a function of field and temperature.

TEST PROCEDURES

In order to measure space charge accumulation characteristics for each insulation system, space charge measurements were performed by means of the Pulsed Electro Acoustic (PEA) technique on mini-cable and plaque specimens [5]. Before testing, a thermal treatment was applied to cable models and plaques for 5 days at 80°C and for 3 days at 70°C, respectively, with the aim of expelling in principle all crosslinking by-products [6].

Two kinds of specimens, made by insulating/semi-conducting materials were considered for testing:

1) Press-moulded plaques, consisting of a two-layer sandwiches, one insulating layer, 0.5 mm thick, and one semiconducting layer, 0.5 mm thick.
2) Cable models, reproducing HV cables on a reduced-scale (mini-cables), consisting of three layers: inner semicon (0.7 mm thick), insulation layer (1.5mm thick) and outer semicon (0.15 mm thick). The conductor diameter is 2.8 mm (Fig. 1).

Two different XLPE-based insulating materials (INS1 and INS2) and semiconducting materials (SC1 and SC2) were evaluated, giving rise to insulation systems with different permutations of semicon/insulating materials. In particular, the combinations INS1-SC1, INS2-SC1, INS2-SC2 for the plaques and INS1-SC1, INS2-SC1, INS1-SC2, INS2-SC2 for the mini-cables were used for experimental testing.

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