A METHODOLOGY FOR THE ASSESSMENT OF HVDC-XLPE CABLE INSULATION

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ABSTRACT

The purpose of this work is to present and to discuss a methodology for the assessment of materials intended to HVDC-XLPE cables, particularly as regards the evaluation of the effects of material formulation on space charge accumulation within the insulation. Sample design, testing method and protocol and criteria used for the material evaluation are specifically considered.

It will be shown through several examples that criteria such as the Field Enhancement Factor (FEF) and the space-averaged charge density (Q_M) are indeed sensitive to material formulation.

The question of the representativeness of tests performed on flat specimens vs. model or full cables will be discussed.

KEYWORDS

HVDC, XLPE cable, material formulation, space charge, field enhancement factor, pulsed electro-acoustic method.

INTRODUCTION

From economic and environmental points of view, polymeric cables are more advantageous than mass-impregnated cables. If the use of synthetic material in AC has been a success, attempts made for adapting them to DC face a challenge mainly due to space charge build-up under constant electrical stress. The mechanisms behind space charge accumulation have been widely investigated during these last decades and it is admitted that the amount of charges trapped in the insulation bulk depends significantly on the nature of the contact between electrode and insulating material as it controls charge injection and extraction efficiency.
Space charges measurement in dielectrics has become rather common practice for investigating charge accumulation processes under electrical stress. A wealth of measurement system exists with their respective merit in terms of sensibility, sample geometry, measurement dynamics, etc. They represent interesting tools in the perspective of optimizing semicon / insulation materials formulation intended to HVDC cables provided adequate criteria are identified.
The aim of the present work is to present a methodology for cable materials screening, including:

- Manufacturing of plaque samples;
- Field and Temperature testing conditions;
- Measurement technique;
- Criteria for materials assessing;

The question of the representativeness of testing planar samples vs. model cables will also be addressed.

ISSUES IN SELECTING MATERIALS FOR HVDC APPLICATIONS

Correlation between insulation life and space charge

● Without polarity reversal

When the cable is intended to work with Voltage Source Converters - VSC system, the inversion of power flux is achieved by changing the current direction without inverting the voltage polarity. In that case, the insulation life is generally estimated through the well-known Inverse Power Law - a semi-empirical relationship giving the time to breakdown as a function of the maximum stress level through the insulation:

$$L = C.\left(\frac{1}{F_{\max}}\right)^N$$

where F_{max} accounts for the maximum electrical stress through the insulating material, N is the aging parameter also known as the Voltage Endurance Coefficient (VEC) and C is a constant.

Space charge accumulation under DC stress leads to local field enhancement within the insulating material hence decreasing the time to breakdown. Furthermore, it has been pointed out that space charge is likely to take part in the aging process (through the modification of the material structure **[1]**) and may act to increase the VEC. Considering a value of VEC of 10, in accordance with the *Cigré* recommendations for HV extruded cables **[2]**, a field enhancement of 10% of the Laplacian field leads a life reduction by a factor about 3 applying the Inverse Power Law model. For non-optimized insulation, the amount of space charge (and thus the field enhancement) mostly increases with the applied voltage. In order to keep an acceptable cable life, the design stress has then to be limited reducing thereby the power transmission efficiency (power per unit of the cable weight).

● With polarity reversal

Line Commutated Converters -LCC cable system requires voltage polarity reversals for changing the power flux. Hence cables have to be designed to withstand such kind of stress. In that case, It has been demonstrated **[3]** through accelerated life tests coupled to space charge measurements that the insulation life depends not only on the electrical stress level but also on different parameters related to the charge accumulation among which the amplitude of charge (Q_M) obtained after a polarization procedure under an applied field F_{app}, the charge depletion rate during depolarization (s) and the frequency of polarity inversion (f). According to the model proposed