Effect of Polarity Reversal on breakdown in HVDC Cable Insulation - Space Charge Behaviour

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ABSTRACT

Power cable insulation when stressed with DC observes charge injection and space charge formation. In HVDC systems with LCC topology, polarity reversal is observed and it is found that voltage reversal significantly degrades the cable insulation. The injected space charge in reversal scenario becomes a necessity to investigate to understand the breakdown mechanism. In this work LDPE planar samples are stressed at high field and subjected to different polarity reversal intervals. The space charge is measured and consequent effects on breakdown is studied. A correlation between charge transfer with polarity reversal interval is found and effect on breakdown is presented.

KEYWORDS

Polarity Reversal, Space Charge, Field Enhancement, Charge Packet, Reversal Interval.

INTRODUCTION

HVDC transmission and distribution due to its many advantages has begun to dominate the world power market. The conventional HVDC systems are based mostly on the Line Commuted Converter (LCC) topology. The VSC based topology still being in its infancy majority systems employ LCC topology for HVDC power transfer. At the same time the power transfer using underground power cable technology has also gained momentum and is considered as a suitable means for DC transmission. The underground power cables currently in use are polymeric insulation based with XLPE (base LDPE) being used as the primary insulating medium.

Under the influence of DC stress, space charge accumulation plays an important factor in assessing the insulation condition. Space charge formation leads to localized field distortion resulting in accelerated aging of the material. Charge injection in the bulk of the material is observed on the application of field and based on the nature of the charge formation (Homo or Hetero) the field distortion is determined. In case when a polarity reversal occurs the field change in conjecture with the distorted space charge field may further aggravate the degradation of the insulation. The LCC topology works with reversal of polarity to change the direction of power flow. Due to either planned or unplanned polarity reversal the insulation material matrix is stressed and subsequent degradation is expected. Since majority of HVDC systems are based on LCC topology the study of polarity reversal on the space charge dynamic becomes a necessity. Although there are standards for partial discharge characterization and polarity reversal withstand tests, they are limited to product evaluation. The aging dynamics and material degradation needs to be studied further for better life prediction.

Life estimation of insulation under the influence of polarity reversals has been studied and life models have been suggested with limitations. Inverse power law-based life model inclusive of polarity reversal has been given in [1] where the charge dynamics was not discussed. Effect of leakage current on the charge flow dynamics of the insulation has been studied and charge characterization has been done in [2]. The charge injection was discussed and charge transfer was studied but the exact space charge effect was missing. Study on the effect of temperature gradient on space charge under effect of polarity reversals has been given in [3]. The temperature gradient effects have been prioritized and study has been conducted at lower fields. Space charge dynamics in composites under polarity reversal has been shown in [4]. A bipolar charge transfer model has also been used to predict the space charge effects in [5]. The effects of reversal times and duration has been studied in these and subsequent effect on insulation has been established. It was found that quick reversal under the influence of high field was an area that has not been explored and from the existing literature the effect of reversal time and field on the insulation was significant.

In the current study the authors have attempted to understand the space charge dynamics of LDPE under the influence of polarity reversals. Two different reversals have been used and a high field has been selected. Planar LDPE samples have been used for the testing purposes. Charge injection, settlement and imminent conversion of charge (homo to hetero and vice versa) has been observed and reported in this work. The layout of the paper is as follows: Experimental Setup and Conditions, Space Charge profiles for positive and negative cycles, Discussions followed by conclusive remarks.

EXPERIMENTAL SETUP AND CONDITIONS

Thin sheet samples of LDPE were made with a thickness of 100µm. Granules were heat treated in hot roll mill and then using a hydraulic press at 120˚C for 10minutes the required thickness of the samples was achieved.

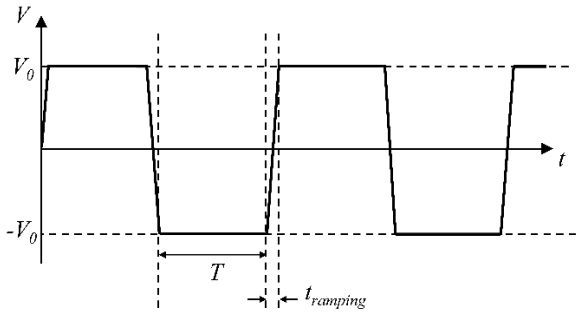

Fig. 1: Profile of the ploarity reversal voltage used for experimentation