New Generation of Accessories for EHVDC extruded power transmission applications

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ABSTRACT

The behaviour of HVDC cable accessories is strictly dependant on insulation characteristics related to temperature and is strongly influenced by space charge accumulation phenomenon along the interface between the cable and accessory. In this paper, a specific test regime and new design approach are proposed for the development of joints and terminations for 525/600 kV HVDC cable accessories.

KEYWORDS

HVDC, Extruded cables, Accessories, CIGRE' Technical Brochure TB496

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INTRODUCTION

DC Voltage is the preferred solution for long distance power transmission because of the reduced power loss compared to AC, for this reason HVDC cable connections have been in service for many years. Improvements to AC/DC conversion stations and the use of extruded insulation on cable systems has led to increased applications of HVDC transmission lines around the world.

Lately, innovation surrounding HVDC extruded cables has been concentrated on the development of new compounds with better performance under DC voltage, while on joints and terminations innovations have been centered around component materials, accessory design, and jointing methods. Meanwhile, the main topics that the R&D community have been focused on regarding HVDC joints and terminations are: aging of materials, space charge accumulation at the interface between extruded cable and accessory, and the interpretation of failure mechanisms.

Design criteria for HVDC cable accessories differ completely from those used for HVAC applications. While many components of joints and terminations are similar in AC and DC accessories, the electrical stress distribution inside the accessory, and the behavior of the materials under DC voltage are very different. For this reason, specific tests and computer simulation programs have been developed for HVDC cable accessories.

Accessories with pre-molded EPR components have demonstrated excellent performance when installed on 320 kV DC extruded cables and have now been developed for applications up to 525/600 kV DC thanks to new materials and an innovative design, which includes both geometrical and non-linear electric stress control systems.

To optimize the design of new joints and terminations, incorporating new materials for HVDC applications at 525/600 kV and above, development tests and enhanced electrical performance tests were carried out on both reduced size models and full-size prototypes. In this paper, the design criteria are presented as well as the definition of new methodologies to assess the best solutions for this innovative application.

DESIGN AND THEORETICAL ASSESSMENT

The development calculations considered within this paper refer to three different geometrical configurations:

- Model 2, equivalent to a 24kV AC cable system;
- Model 3, equivalent to a 90kV AC cable system;
- Full Size, refers to a 525/600 kV DC cable system.

When evaluating HVDC one must consider that the material conductivity, which drives and affects the field distribution, is dependent on both the local field and the local temperature as per the following formula [1]:

$$\sigma(\theta,E)=\sigma_0\cdot e^{\alpha(\theta-\theta_0)+\beta(E-E_0)}$$

Where:

$\sigma(\theta, E)$ = conductivity as function of temperature and electric field [S/m];
θ = temperature [ºC or K];
E = electric field [kV/mm];
σ_0 = conductivity in [S/m] at temperature θ_0 = temperature [ºC or K] and at the field E_0 [kV/mm].

The implementation of thermo-electric FEM analysis was required to analyze the coupled effect of temperatures and electric gradients inside the joint and consequently evaluate the correct resistive field.

FEM Modeling: Mechanical Analysis

To begin the study, an analysis was performed to evaluate the geometry of the joints in their expanded state, mounted over the cable insulation. 2D axis-symmetric FEM mechanical analysis was performed adopting proper hyper-elastic models for the three materials involved in the expansion. The main outputs obtained were the following: