Electrothermal FEM simulation of relevant test conditions of a 525 kV HVDC cable joint including nonlinear field grading material

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ABSTRACT

This work presents a generic 525 kV HVDC joint model including a nonlinear field grading material. COMSOL Multiphysics is used to perform electrothermal simulations of relevant test conditions for an HVDC joint such as DC, AC and transient voltages. Generic material properties are presented which are used for all simulations and the electric field is evaluated at relevant locations. It is shown how to implement dielectric losses in COMSOL depending on the type of the applied voltage. The results show that the electric field stress is successfully controlled by the nonlinear field grading material under all relevant voltages.

KEYWORDS

HVDC, cable joints, nonlinear field grading, electrothermal simulation, conduction losses, dielectric losses.

INTRODUCTION

High voltage direct current (HVDC) power transmission is becoming increasingly competitive to high voltage alternating current (HVAC) power transmission, especially for bulk power transmission over long distances. In case of long onshore cable systems a huge number of cable joints is needed to connect the single cable lengths which are limited in length due to transportation capabilities. It is understandable that these cable joints need to undergo testing during development, qualification and after installation. Together with these very demanding tests it is essential to perform simulations to understand the electric field and temperature distribution. The aim of this paper is to present and discuss the simulation results of important test conditions of a 525 kV HVDC cable joint as defined in IEC 62895 [1] and Cigré TB 852 [2].

CASE STUDY

In this chapter the used generic joint model together with all relevant generic material properties are presented.

Generic 525 kV HVDC cable joint model

The joint geometry used in all performed simulations is shown in Figure 1. The model includes the cable end comprising of a conductor (6), a connector (1) and the cable insulation (5). The joint rubber body comprises an inner (2) and an outer deflector (7) both made out of conductive rubber. Furthermore, the main insulation body consists of two layers, an insulating rubber material (3) and a special nonlinear field grading material (FGM, 4). For the cable insulation material cross-linked polyethylene (XLPE) and as a base polymer for the materials in the joint body ethylene propylene diene monomer rubber (EPDM) are assumed in this case study. As certain material properties are needed to perform electrothermal simulations, generic material properties are presented in the next chapter.

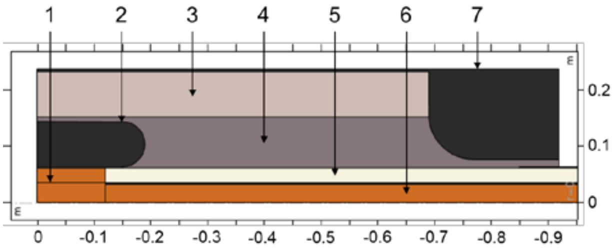

Figure 1: 525 kV HVDC cable joint used for case study

Generic material properties

When running electrothermal FEM simulations, thermal and electrical properties are required. The focus in this chapter is on relevant electrical properties, especially the electrical conductivity depending on temperature *T* and electric field stress *E*. For the electrical conductivity of insulating materials many different models exists as described in [3] and [4]. In this work a commonly applied model is used for the XLPE and the joint insulation (hereafter always referred to as EPDM) as shown in Eq. 1.

$$\sigma(E,T) = \sigma_0 \cdot \exp(a \cdot T + b \cdot E) \qquad (1)$$

In Eq. 1 σ_0 is the base conductivity and the parameters a and b the temperature and field coefficients. The used generic parameters in the performed simulations are shown in Table 1 and for better visualization the electrical conductivities are plotted for two different temperatures over the electric field stress in Figure 2.

Table 1: Conductivity model parameters

Parameter	XLPE	EPDM
σ_0 in S/m	$1 \cdot 10^{-16}$	$3 \cdot 10^{-16}$
a in 1/°C	$5 \cdot 10^{-2}$	$8 \cdot 10^{-2}$
b in mm/kV	$5 \cdot 10^{-2}$	$7 \cdot 10^{-2}$

As shown in Figure 2 it is assumed for this case study that the XLPE is in general less conductive and also has a lower temperature and field dependency compared to the EPDM.

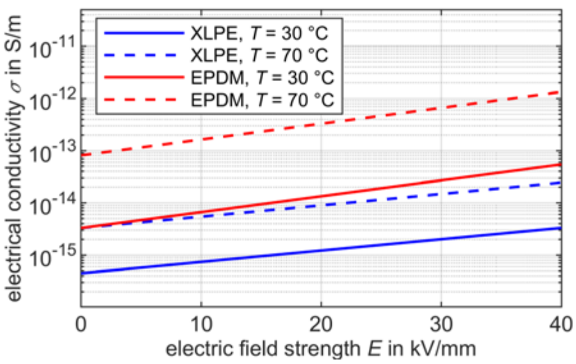

Figure 2: Electrical conductivity for XLPE & EPDM