Comparative study of XLPE cable cores and factory joints subjected to TB 722 Wet Ageing Testing

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ABSTRACT

Wet-design submarine cables rated up to 72,5 kV shall undergo the Qualification of Wet Dielectrics according to Cigre TB 722. This paper describes 66 kV XLPE cable cores and tape-molded flexible factory joints which have been subjected to 50 and 500 Hz wet ageing tests according to this recommendation. The results show that the breakdown voltage for the cable cores after completion of wet ageing using different test regimes (50 Hz and 500 Hz) are not equivalent. An increase of the test voltage to 3U_0 accelerated the ageing process. Furthermore, it was found that the wet-ageing performance is lower for the taped factory joints than for the extruded cable cores.

KEYWORDS

66 kV, XLPE cables, wet design, wet-ageing, qualification of wet dielectric, factory joints, tape-molded, extruded, flexible, TB 722, material ageing, development tests, guidelines, saturation, voids, test regimes, inter-array

INTRODUCTION

Submarine cables have been developed for decades and with the rapidly increasing power of wind turbines, voltage levels of inter-array cables have increased from 36 kV to a maximum system voltage of 72,5 kV [1]. This voltage level is expected to further increase to 145 kV [2]. Wet design cables are becoming more attractive for both static and dynamic applications. In such cables, water molecules are allowed to diffuse into the polymeric cable insulating system over time. Since subsea high voltage cable cores and factory joints have until recently been used in dry service conditions only, the industrial knowledge on their performance when subjected to water is less known.

Ageing parameters can be influenced by electrical stress level, frequency, temperature and ageing time. The susceptibility of the XLPE insulation system to the ageing depends in particular on material cleanliness, smoothness and the cleanliness of material interfaces and defects such as ionic inclusions, voids or mechanical defects [9].

The major ageing mechanism in wet design XLPE insulated cables is water treeing. There are two types of water trees: vented trees and bow-tie trees. Vented trees are initiated at material boundaries (semicon to insulation) and grow along the axis of the electric field. Inception sites are typically water soluble contaminations (water electrolyte) [5]. Vented trees are the most frequent cause for electrical breakdowns [8]. Bow-tie trees are initiated from voids or contaminations in the insulation and grow along the electric field. The size of a bow-tie tree is related to impurity size, type (electrolyte) and it's radial position. Bow-tie tree lengths are normally saturating after some time with a limited length of typically some hundreds of microns [3].

The main purpose of this paper is to study the difference between extruded cable cores and tape-molded factory joints, as well as the effect of the frequency and electric field magnitude on the ageing performance of high voltage XLPE insulating systems.

TEST OBJECTS

All cable cores included in the tests have been produced on a CCV triple-cross extrusion line. An aluminium conductor has been selected to provide a wider range of applicability.

The same material was used for the conductor and insulation screens, being a fully bonded, semi-conductive EEA-based copolymer. Insulation has been made of an XLPE homopolymer insulating compound (LDPE-based). Construction details for the cable cores are summarized in Table 1.

Table 1. Cable core dimensions

Conductor material	aluminium solid
Conductor size	ϕ17,3 mm (240 mm²)
Conductor screen thickness	1,9 mm
Insulation thickness	7,2 mm
Insulation screen thickness	0,9 mm
Radial water barrier	none

Factory joints (FJs) have been installed in a tape-molded technology using the same materials as the originally extruded cable core. An in-house, state-of-the-art tape extrusion line is operated in a clean room environment with a hermetic material feeding system and an on-line optical quality assurance system to ensure a high material cleanliness and a continuous quality level. Production space for insulating and semi-condcutive tapes is separated from each other in dedicated clean rooms to avoid risk of cross-contamination. Determination of cross-linking parameters and thermo-mechanical behaviour of factory joints (Figure 1) are typically made as a FEM simulation and further confirmed on a full-scale model by so called 'parameter joint' for each cable type, conductor material and cross-section.

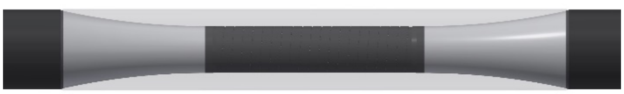

Figure 1. Sketch of the factory joint