Full Scale Wet Age Testing of XLPE Insulated Power Cables in Salt Water

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ABSTRACT

Offshore wind 66kV array cables with wet or semi-wet design are now in use. Representative wet age data for such cables in saline water was required to demonstrate adequate predicted life. Full scale testing at both 50Hz and 500Hz has been completed and the results compared to similar tests on 20kV cables in tap water. The results showed good equivalence, especially when compared in terms of average electrical stress at breakdown. For the chosen insulation system, CIGRE TB 722 acceptance criteria were exceeded.

KEYWORDS

Offshore Wind; 66kV Array Cables; Wet Age Testing;

INTRODUCTION

Wet age testing protocols undertaken by most cable suppliers, and as specified in relevant standards, have primarily been carried out on scaled (for instance 20 kV or 15 kV) cable samples and in tap water.

The growth in the market for offshore wind farms, has resulted in wet, or semi-wet, cable designs being widely deployed in submarine power cable array networks. Such applications are typically at 33kV or 66 kV, and at 66kV may use higher electrical stress levels than at 33kV, reducing conservatism. Additionally, the operating medium is saline rather than tap water.

Within the published literature there is limited data to provide confidence of correlation between different testing regimes (for instance between 50Hz and 500Hz at high electrical stress, between voltage, electrical stress levels, and insulation thickness range, and to quantify the effect of ageing in saline rather than tap water).

The recently published CIGRE Technical Bulletin 722 'Recommendations for Additional Testing for Submarine Cables from 6 kV to 60 kV (U_m = 72.5 kV)', recognises these constraints, and recommends wet-age testing in saline conditions. Furthermore it calls for the 'cable community to publish findings in the above areas', towards re-evaluating what the industry requirements should be. This paper is intended to assist in this evolution.

The need for representative accelerated lifetime testing to demonstrate adequate life as a key development area for offshore wind farm cables was identified, and investments made in appropriate test infrastructure and in completing a programme of long-duration testing.

To minimise risk associated with scaling effects, the new test capability enables long-term wet-age and step-breakdown testing at full-scale on 66 kV cables aged in saline water. In the period 2015 to 2019, a series of full-scale, long-term wet-ageing tests (at both 500 Hz and 50 Hz) have been carried out on 66 kV XLPE insulated cables in saline conditions. The results have been compared to a substantial dataset of results from conventional 'harmonised long duration' (HD605 5.4.15) wet ageing tests, for the same insulation system.

Microscopic and moisture concentration analysis has also been carried out to assess the effects of ageing both during and after completion of the long-duration tests.

This paper presents the test methodology, summarizes the results of the full-scale testing in saline conditions, and compares these results with results of conventional, scaled testing.

DEFINITIONS OF CABLE DESIGNS

The following cable design definitions are used in this paper:

'Wet' design – no water barrier and the outer semi-conducting layer of the power core is in direct contact with the water

'Semi-Wet' design – a polymeric jacket over the power core, (which will limit rate of water vapour ingress)

'Semi-Dry' design – metallic foil radial water barrier with a longitudinal glued overlap and bonded to an outer polymeric jacket

'Dry' design – continuous hermetic metallic water barrier (such as lead extrusion, or longitudinally welded metallic sheath).

ELECTRICAL STRESS CALCULATION

Electrical stresses are calculated using the following equations from IEC60840.

Electrical stress at the conductor screen:

$$E_i = \frac{2 \times U_0}{d \times \ln\left(\frac{D}{d}\right)} \qquad [1]$$

Electrical stress at the insulation screen:

$$E_o = \frac{2 \times U_0}{D \times \ln\left(\frac{D}{d}\right)} \qquad [2]$$

Where:

E_i = Electrical stress at conductor screen under voltage U_0 (kV/mm)

E_o = Electrical stress at insulation screen under voltage U_o (kV/mm)

U_o= Rated voltage between conductor and screen (kV)

D = Nominal diameter over insulation (mm)

d = Nominal conductor screen diameter (mm), i.e. nominal inner diameter of the insulation