Dynamic HV Cables for Floating Offshore Wind Applications: a thermally aged mechanical evaluation

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ABSTRACT

A dynamic cable was subjected to 100,000 fully reversed fatigue cycles on a novel dynamic fatigue test rig. The aim of the testing was to understand the cable longevity in extreme service environments. Power was applied to the cable cores during testing to simulate a current-induced thermal gradient inside the cable. Temperature and force response were measured throughout the test. The analysis of cable bending response has given some insights into the fundamental cable and component bending and thermal fatigue characteristics.

KEYWORDS

Bend fatigue test, bending stiffness, dynamic cables, thermal cycling fatigue test, thermal analysis, mechanical analysis, simulations, finite element analysis, modelled bending response.

INTRODUCTION

The good quality and durability of high-voltage (HV) systems, including cables, is essential in creating cost-effective windfarms [1]. As the sector moves towards deeper waters and floating offshore wind becomes necessary, HV cables will be required to endure complex dynamic motions, which would significantly reduce the working lifetime of the current iteration of HV cables. Dynamic cables will need to be robust not only against the harsh ocean environment and power-induced thermal cycling, but also fatiguing through repeated bending moments and oscillations, and the extra frictional heat this will cause. In this work we present a study on the combined effects of both heating and mechanical fatiguing of a three-phase 66 kV dynamic cable.

A dynamic cable, produced by Hellenic Cables, was subjected to one hundred thousand fully reversed fatigue cycles on ORE Catapult's dynamic cable test rig. The aim of the testing was to understand the cable longevity in extreme service environments via analysis of the cable, post fatigue testing. Power was applied to the cable cores during testing to simulate a current-induced thermal gradient inside the cable. Temperature and force response were measured throughout the test. Post-test analysis consisted of visual examination, analytical testing of the XLPE insulation to quantify ageing that may have occurred, and thermal analysis of all polyethylene layers to provide a full 3D map of temperature distribution.

Further to providing an overview of the fatigue test setup and findings, in this paper we consider how to mathematically model the system, which if verified, provides an easy and inexpensive route to predicting the total cable working lifetime. We developed a novel methodology to determine cable bending stiffness from the measured rig-bending force data. We created a novel 3D mechanical model of the bend test in operation, and separately, a local 2D model of the cable cross-section, which considers the helical layering of the different cable materials. The methodology was validated by correlating the test rig 3D and 2D cross section models with the experimentally measured bend-test results.

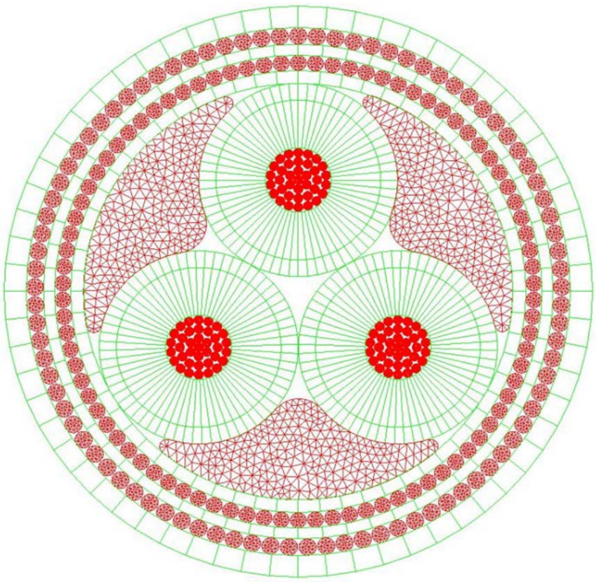

Figure 1: Schematic of the test cable showing the various elements of its construction.

Interestingly, the bending stiffness changes significantly over the period of mechanical oscillation, which is found to be related to both temperature and two-fold temporal effects. This manifested in a short-term reversible softening and a long-term irreversible softening of the cable. The temperature effects were investigated further by thermal analysis of the polymer layers using differential scanning calorimetry (DSC). DSC can be used with semi-crystalline materials to show the thermal history of the material has experienced [2]. Tens of samples, spatially distributed around the three-core bundle, allowed us to map thermal