Fibre optic related failure modes of submarine power cables

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ABSTRACT

In this paper, an overview is given of fibre optic related failure modes for FOCs used in submarine power cables. This includes describing how FOCs are generally integrated in submarine power cables, the materials and construction used in manufacturing, an overview and explanation of the experienced stresses and resulting couplings between the FOC and other submarine cable components during different lifecycle phases such as manufacturing, testing, transport, installation and operation, and typical associated failure modes. Finally, this paper provides recommendations for submarine power cables, to safely and reliably include FOCs.

KEYWORDS

Fibre optic cable; Submarine power cable; Failure modes.

1. INTRODUCTION

The rapid growth in offshore wind farms and interconnectors have spurred a boom in the application of medium and high voltage AC and DC submarine power cable connections in the last decade. Submarine cable connections consist typically of three-core MV array cable connections between offshore wind turbines and the offshore high voltage substation (figure 1), three-core HV export cable connections to connect the offshore high voltage substation to onshore (figure 1), and three-core/ single-core HV/EHV cable interconnections for linking two or more offshore high voltage substations.

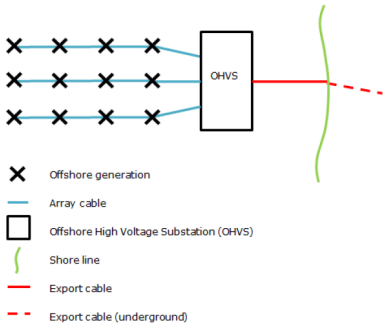

Fig. 1: Radial array submarine cable systems in combination with export cable systems [1]

Fibre optics are typically included inside these submarine power cable connections to; facilitate communication between both ends of the cable, enable control of offshore wind farms or offshore converter stations, enable distributed cable temperature measurements, and monitor the mechanical stresses experienced by the cable during transport and installation. Faults or damages within cables, may also cause unexplained optical attenuations within the fibre optics, which can then be used to accurately spatially locate the positions of such faults or damages in a cable. As such, fibre optics have become a very important and integral part of submarine power cables. These fibre optics are normally procured by cable manufacturers as a complete assembled fibre optic cable (FOC) that typically consists of the actual optical fibres enclosed in a sheathed, sometimes armoured, mechanical protective metal tube. This assembly is then integrated into the cable design with the power cores during the lay-up process, where it is typically placed in one or several interstice(s) before the power cable armouring is applied (see figure 2). The FOC is therefore mechanically, electrically, thermally and chemically coupled with the other submarine power cable components and will experience all coupling changes associated with the movement of the cable from a dry environment, during manufacturing and transport, into the wet environment of the seabed.

Fig. 2: Example of a submarine power cable construction with rope wormings [2]

Return of experience has shown that several of these couplings can lead to unwanted interactions, which can adversely affect the condition of any of the submarine power cable components both in the short and the long term.

Before laying-up, the power cores and the fibre optic cables are separately tested to verify that they have been produced with sufficient quality. However, these routine tests, as well as the current submarine power cable pre-qualification and type testing standards do not take into account the degradation effects due to the aforementioned coupling factors, and hence insufficiently verify the performance of the combined assembly during all of the cable's lifecycle phases. Multiple failures of cables during operation due to issues with this interaction between the FOC and the power cable have shown this.

In this paper, an overview is given of fibre optic related failure modes for FOCs used in submarine power cables. This includes describing how FOCs are generally integrated in submarine power cables, the materials and construction used in manufacturing, an overview and explanation of the experienced stresses and resulting couplings between the FOC and other submarine cable components during different lifecycle phases such as manufacturing, testing, transport, installation and