Inherently safe designs of fibre optic cables integrated in three-core submarine power cables

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ABSTRACT

This paper shows, by means of simple analytical calculations as well as detailed line modelling, how fibre optic cables integrated in three-core AC submarine power cables could cause failures to the entire power cable. Such failures have been reported in the industry. The paper shows that there are inherently safe designs of integrated fibre optic cables, even if including metallic components such as a metallic water barrier.

KEYWORDS

Offshore Cables, Fibre Optic Cables, Induced Voltage

INTRODUCTION

In recent years, several faults on three-core submarine cables have been reported, where the root cause has been assigned to the interaction between the power cable and the metallic part of the integrated fibre optic cable (FOC). These types of faults have especially been reported in the offshore wind industry, on export cables (e.g. reported by the Offshore Wind Program Board [1]).

This paper presents calculations of the possible fault mechanisms for different FOC designs, whereby it is shown that it is plausible that the energy induced in the metallic parts of some FOC designs could be the root cause of electrical breakdown of three-core submarine cables, in case part of the FOC is damaged.

The evaluation takes the “physics first” approach, which is to calculate the level of induced currents and voltages in the FOC using the laws of electromagnetic induction, for a typical export cable design. This is done first with simple models and well-proven formulas, which bring forth the main mechanisms at play. To prove that some designs are inherently safe, a detailed analysis is made, using a more comprehensive line model. Examples will be given for different FOC designs integrated in a typical submarine export cable for offshore wind in normal operation,

Although the formulas used in this paper are readily available and similar conclusions have been reported from several sources, a similar investigation of the interaction between the power cable and the metallic part of an integrated FOC has not, to the knowledge of the authors, been formally brought to the attention of the industry. At the time of writing this paper, the only publicly available reference found on this issue was [2], which although it presents a safe integrated FOC design in line with this paper, it provides only little details on how the obtained results have been reached.

Some of the calculation tools used in this paper have been developed during a master thesis work at the Technical University of Denmark, in cooperation with Ørsted Offshore, in 2017.

Cable design

It is the common design of the three-core submarine cables (illustrated in Fig. 1), which lays at the base of the problem. Since the integrated FOC is placed asymmetrically in the interstice of the power cable, this leads to a significant induced voltage in the metallic components of the FOC, due to the magnetic induction from the currents in the power cores.

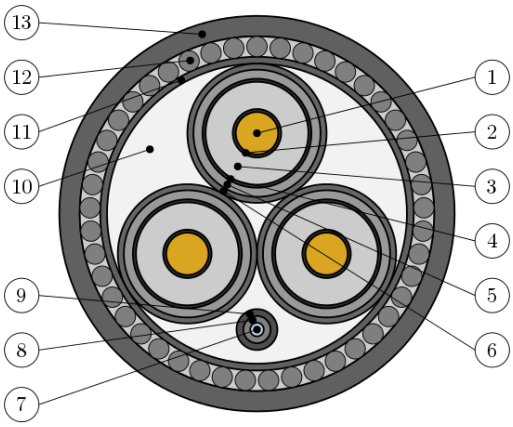

Fig. 1: Main components of a three-core AC submarine export cable: *1 conductor, 2 conductor screen, 3 insulation, 4 insulation screen, 5 metallic sheath, 6 PE jacket/sheath, 7-9 FOC, 10 filler, 11 binder, 12 armour, 13 outer serving*

FOC designs

Three FOC designs with different resistances of the metallic parts have been evaluated. Their construction designs are illustrated in Fig. 2.

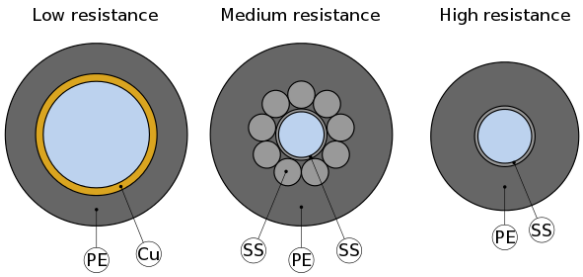

Fig. 2: Construction of the considered FOC designs

Only FOC designs with metallic radial water barrier have been investigated, since it is considered that currently there are no sufficiently reliable solutions available with pure polymeric designs for offshore applications.

SIMPLIFIED MODEL

Analytical formulas of mutual inductance

The main formula used for the mutual inductance is based on Carson’s equations – or rather a commonly used