Electromagnetic coupling in HV and EHV three-core submarine cables during test and operation

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ABSTRACT

An analysis of the electromagnetic phenomena related to fibre optic cables (FOC's) integrated in three-core submarine cables has been studied. Some FOC designs are proven to be risky which also some recent reported cable failures have supported. The design of three-core cables with integrated FOC must be viewed as a system of components affecting each other. It is shown that the best candidate for successful operation is to use a FIMT (Type 1 herein).

KEYWORDS

XLPE, three-core cable, wind energy, fibre optic cable, FOC, electromagnetic, induced voltage

INTRODUCTION

The number of HV and EHV XLPE three-core submarine cables has increased over the past years. This is mainly due to an increased rate of installations of export cables from offshore wind-farms, long distance interconnections as well as offshore platform connections for the oil and gas industry.
For these three types of applications, the three-core cables must transmit high electrical powers over long distances, even if there is a tendency that the off-shore platform connections, still require lower ratings compared to the other two types of applications. However, offshore platform connections may include other type of challenges, e.g. higher power frequency and larger harmonic content.
Another common factor of all applications is the need for reliable optical communication. The FOC (Fibre Optical Cable) is normally integrated into the three-core cable during the layup process.
Unfortunately, the experience from especially the wind-farm offshore industry, which require high rating over long distances, has revealed that some three-core cable designs with integrated FOC, have failed.

The aim of this paper is to analyse the overall system design of three-core cables during test and operation, with focus on operation.

From a cable design point of view, the following cable elements must be paid extra attention:

- Filler design
- Inner sheath design
- FOC design

From a test and operation point of view the following parameters are of high importance:

- Grounding schemes
- AC voltage levels and harmonics
- AC power frequency
- Transients
- Length of cable system
- Interfaces between different cable designs

Submarine three-core cables must be designed for a wide range of conditions in voltage, currents, frequencies and distances.
Unlucky combinations of all parameters above and/or poor designs of cable elements have sometimes reached to failure/damage. This paper will address some of these unlucky situations from an electro-magnetic perspective.

BACKGROUND

During the last 10 years, several failures have occurred in three-core cables. In most cases, the failures are not originating from external damage, which otherwise is the most common cause to cable breakdown according to Cigre' [1]. Most failures are instead originating from cable design issues, FOC design issues and/or a combination of other system issues. It may be difficult by certainty to find the root cause in every case but the FOC design plays a major role for the negative experience. It must already now be mentioned, that not all FOC's have critical designs.
Several cable failures have occurred around UK and North Sea. Reference [4] suggests that 7 failures have occurred in three-core cables only in UK since 2011. This is also supported by the fact that the insurance cost for an export cable now may reach to 75% of the total project cost according to insurance companies. The total cost for the failures is estimated to £160m in UK.

Based on the complexity and the various conditions for the different applications used, the three-core cable must be designed as a system component. Therefore, for example, Cigre' TB490 [2] only accepts system qualifications of three-core cables above 36 kV.
However, in TB490, the FOC is not considered as a system element in the design. No electrical tests are given to verify the integrity of an FOC integrated in three-core cables. In TB623 [4], the FOC must be checked by OTDR after tensile bending test, coiling test, dynamic fatigue test etc. However, any design verification tests as system component are not covered in [2] or [3].

TYPICAL CABLE AND FOC DESIGNS

The three-core cable designs used for wind farm export cables are different, due to different preferences from the manufacturers. A typical three-core cable with integrated FOC's is shown in Figure 1. The fillers containing FOC's are applied with a conducting lip. If then both the metal sheath and FOC's are applied with semi-conducting plastic sheaths (SC sheaths), all metal elements including armour should have the same voltage potential as the surrounding water. However, this is true only under ideal conditions. Small deviations in FOC design, filler design and/or inner plastic sheath and tape materials may have a detrimental effect on the cable performance during test or operation.