Modeling the thermal distribution of submarine three-core XLPE cable with respect to the buried depth and thermal conductivity of the soil

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ABSTRACT

A 2D thermal modeling of a 35 kV ac submarine cable was studied in this paper. A high temperature of 88 °C in the three-phase conductors was calculated under the buried depth of 1m. The temperature gradient of 6-9 °C was found in the XLPE insulation layer. As the buried depth decreases, the temperature of the conductor, the insulation and the optical fiber unit decrease. An increase in the thermal conductivity of the soil leads to the reduction of the cable temperature. The thermal conduction, thermal convection, and thermal flux are discussed in this work.

KEYWORDS

Submarine cable; thermal modeling; buried depth; thermal conductivity of soil; temperature gradient; thermal flux.

INTRODUCTION

Submarine cables are usually subjected to thermal stress due to the power loss under service condition. In the case of AC submarine cable, the losses that result from the large current in the conductors, the dielectric loss in the insulation and the ring current in the armor and screen could generate the thermal issues in the whole cable structures. IEC 60287 standard has already proposed the guidelines for the loss calculation in the cable [1, 2], which is beneficial to the estimation of the cable characteristics and its design for the application.

Several papers studied the electric and thermal modeling of the power cables, especially for the thermal and power loss estimation [3-6]. In the case of three-core submarine cables, the IEC 60287 Standard is developed in terms of power losses, metal loss factors and conductor ampacity, which is useful to predict the losses of cable. The comparison of power losses and ampacity estimation in submarine cables between the finite element modeling (FEM) and IEC verified the general IEC 60287 standard [6]. However, the IEC standard overestimates the armor loss and underestimates the screen sheath loss [5, 6]. The FEM modeling, especially for the HV three-core cables in consideration of loss factor improvement probably enhance the accuracy [6]. Additionally, a thermal model for the single core wind farm cables on the basis of the correction of the geometric factor G for the thermal resistance of the metallic sheath was proposed by the FEM analysis [7]. Similar thermal simulation results in the HVDC submarine cables were conducted by simplifying the thermal conductivity of the equivalent layers [8].

The material and geometric characteristics can be modified by the FEM method for the better improvements of the simulation. However, it is still a limitation for the accurate estimation the power losses, heat transfer in the submarine cables under service. The heat transfer and dissipate are closely related to surrounded environments. For instance, the thermal conductivity of the soil and the thermal convection between the cable surface and the seawater vary during the cable operation. That is of importance to the thermal stability of the served submarine cables.

This paper mainly studies the influence of the buried depth and thermal conductivity of the soil on the thermal distribution in a 35 kV three-core submarine cable. The cables that installed to the diffident buried depths will change the heat transfer with the surrounded medium, resulting in the temperature remained in the cable geometry. The temperature gradient and the thermal flux are discussed in this work.

STRUCTURE OF CABLE MODELLING

A 2D FEM cable structure model is built in Fig. 1. The structure refers to a 35 kV three-core submarine cable, which is typically used in the offshore oil and gas platform. The main components include the metallic conductors, the XLPE insulation, the shield layer, the lead sheath, the optical fiber, and the armor wire. The basic information for the thermal parameters is described in Table 1.

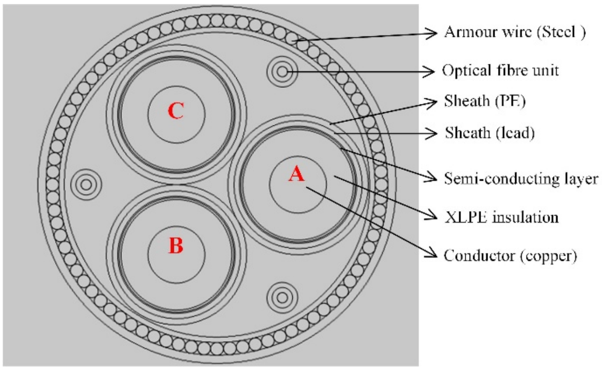

Fig. 1: 2D structure of a 35 kV submarine cable consisting of all components.

MODELING METHODOLOGY

The material characteristics and power loss calculation are determined by the IEC 60287 [1-2]. Although some publications have shown that the IEC formulation gives rise to the underestimation of the cable ampacity [9, 10]. It is still effective to analysis the loss and thermal distribution using the IEC standard 60287 for the medium voltage cables. The loss factors of the sheath and armor are calculated by the IEC 60287 [1]. The sheath loss λ_1 is derived for the pipe-type SL cables, accounting for the losses from the circulating currents. The armor loss factor λ_2 is the reduction losses in armor caused by the sheath screening effects. Both λ_1 and λ_2 are determined by the