Thermal rating of submarine cables installed in J-tube using Lumped Element Method

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ABSTRACT

Currently, no standard exists to take into account the thermal limiting point imposed to a cable installed inside a J-tube, above sea level. Previous works proposed Finite Element Method or analytical calculation in order to rate the current ampacity, by considering thermal properties between cable serving and J-tube inner surface constant along the length. This paper presents an extension of these works by proposing a method based on lumped element method, which is more adaptable. This model will be then compared to previous results in order to be validated.

KEYWORDS

J-tube, I-tube, Current Rating, Lumped Element Method, Submarine cables

INTRODUCTION

With the development of offshore energies, the thermal limiting point located in the J-tube above sea level must be explored. Indeed, in order to avoid damages caused by high temperatures, industrials have to decrease current rating following a de-rating coefficient created in 1988. International standards IEC 60287 calculate the current rating for different cases [1][2], but none exists for a J-tube installation.

Driven by Anders [3] and Hartlein & Black [4] articles, some previous works [5][6] proposed a model based on energy balance,. A comparison between analytical results and Finite Elements Method (FE) was done in [6], showing good agreements. However these models simplified thermal phenomena between cable serving and J-tube inner surface by simplifying correlations, avoiding complex physics like turbulence. Also, thermal transfers remain constant along the length. But it is easily imagined that a thermal stratification caused by the hot and light air will cause a non-constant thermal behaviour of the cable along the length. Furthermore, no access to transient state is provided by these models, whereas it is realistic for offshore wind farms: short-circuits or daily load variations. By these observations, an extension of their work is proposed in this paper, using Lumped Element Method, and giving access to a great flexibility: thermal stratification, accordance with IEC 60287, transient state, and remains fast for industrial uses.

DESIGNS

The main objective of a J-tube is to protect a cable from the sea bed to the platform, installed for example on ship, wind turbine or oil platform. To simplify the problem, it will be considered that the cable is centred inside the cylinder. In Richard Chippendale's articles [5][6], it is considered 3 sections: cable + J-tube under sea level, cable + J-tube above sea level, then the last section where there is no more J-tube, serving and armour; each phase being separated.

In order to compare our model to previous ones for a validation, characteristics will be kept. So a generic 1000 mm² 132kV 3 phases SL type XLPE insulated cable, centred inside the tube, will be studied. It is considered here that the cable is sealed on the top.

PREVIOUS WORKS

Thermal exchanges

In Chippendale's articles, it was proposed a Finite Elements analysis [5] and an analytical model [6] to represent a cable in a J-tube. This system is divided into 3 sections represented in **Figure 1**.

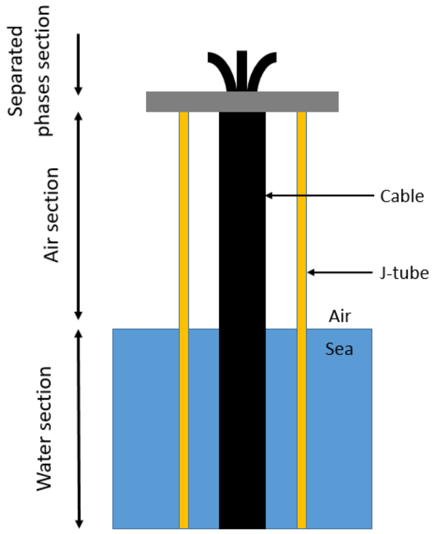

Figure 1 : Representation of a J-tube system as introduced in [5]

To consider only thermal aspects, international standards IEC 60287 were used to represent the cable. A SL 3 phases type cable can be represented by an electrical network taking into account different losses (in cores, screens and armour) and thermal resistances (between a core and a screen, screens and armour, armour and