Thermal rating of Dynamic 3-core AC cables

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ABSTRACT

This paper evaluates how to do thermal rating on dynamic cables. Methods for calculations of thermal resistances, screen resistance, screen current as well as results from FEM modelling of reference cases are presented. The result from modelling is also compared to a measurement on a real installation with good correlation.

KEYWORDS

Dynamic cables, Current rating, FEM, Bend stiffener, 3-core, AC,

INTRODUCTION

Dynamic submarine 3-core cables have in the last years gone from being a custom-made special product for a few projects to a frequently requested product in many applications, for example floating wind turbines. This also requires a clear and uniformed way of doing current rating of such cables.

Dynamic cables can both have a design that is different from normal static offshore cables as well as several challenging installation situations. The IEC 60287 standard [1] might not be well suited for thermal rating of this kind of cable design and installation conditions which forces the cable designer to seek other solutions such as FEM. This paper describes the process of thermal rating of a dynamic three-core AC cable and discusses different challenges such as thermal resistance of cable layers, screen losses and installation situations.

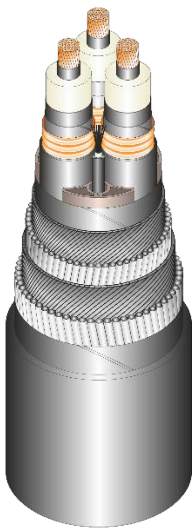

Fig. 1. Example of a dynamic cable

An example of a dynamic cable is shown in Fig. 1. Dynamic cables differentiate from standard submarine cables by the lack of lead sheath. Instead, the screen is made of copper wires for lower voltages (wet design) while a metal sheath, for example smooth or corrugated copper, is used for higher voltages (dry design). Special care is put into the mechanical properties of the armour layer and its bedding which usually means thicker layers here. The cable has an outer cover made of extruded PE instead of a polypropylene yarn.

Some design features such as the corrugated sheath together with several non-standard installations makes these cables difficult to do thermal rating for. This will be further discussed in this paper.

THERMAL RESISTANCES

A cable with corrugated sheath is typically manufactured with a standard core with conductor and insulation layer and then a thick layer of bedding by for example swellable tape. A corrugated metal sheath is added on this bedding making valleys of the corrugation to be pushed into the bedding while creating air gaps in the peaks. A PE material is extruded on the outside of the corrugation. The extrusion process prevents air gaps in the outer layer.

The thermal resistance between conductor and sheath, T_1, and the thermal resistance between sheath and armour, T_2, are both affected by the corrugation. The rating standard gives guidance on how to calculate the thermal resistance. The suggested method is to calculate it considering a smooth sheath with the average diameter as of the corrugation [1].

A study in FEM is performed to validate the accuracy of this method for a section consisting of several layers and with air gaps under the corrugation. This model is created in axisymmetric 2D where each layer of the core is modelled. In the conductor a loss of 30 W/m is added and a constant temperature of 20 °C is set to the outside of the core jacket. The setting of isothermal boundary condition on the core jacket can be discussed as this surface is likely not an isotherm in a three-core cable. It does however follow the principle of TB880 [2] where the core is calculated separately with this assumption. Following that methodology, it is considered correct to use this boundary condition.

Simulations are performed for variations of length between each corrugation peak and height between peaks and valleys. The impact of the corrugation is analysed and compared to an IEC calculation.

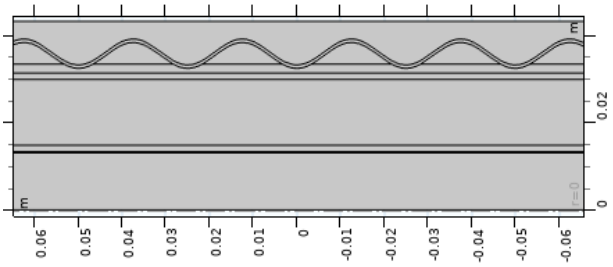

Fig. 2. Overview of the FEM model. Loss is added to the conductor and temperature of 20 °C to outside core.

The thermal resistances between 2 layers can be estimated with the temperature difference divided with the loss, i.e. T_1 and $T_{2\,core}$ can be calculated as

$$T_1 = \frac{T_{cond} - T_{sheath}}{30}\ K \cdot m/W \qquad [1]$$

and

$$T_{2\,core} = \frac{T_{sheath} - T_{jacket}}{30}\ K \cdot m/W\ . \qquad [2]$$

For the IEC calculations it is assumed that the air can be neglected, and all voids are filled with swellable tape with thermal resistivity 12 K·m/W.