Thermal Rating of J tubes using Finite Element Analysis Techniques

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ABSTRACT

The thermal continuous rating of a wind farm export cable is often limited by the section through a J tube from an offshore platform down to the sea bed. As no internationally standard method exists, a range of calculations are used. This paper develops a 3D Finite element analysis model, which is compared to two previously published methods. The FEA predictions have demonstrated that in some cases a 2D cross section model could be used to predict the continuous rating, which validates the key assumption within the previous analytical models. Furthermore by comparing the continuous seasonal ratings, it is evident the previous analytical methods predict a more conservative rating than the FEA model.

KEYWORDS

J tube, Current Rating, Finite element analysis

NOMENCLATURE

A	surface area [m^2]
D	diameter [m]
L	length of the J tube air section [m]
Pr	prandtl number
T	total thermal resistance [KmW^{-1}]
Wc	power dissipation from the cable surface [Wm^{-2}]
W_e	power dissipation from the J tube to the ambient [Wm^{-2}]
W_i	power dissipation from the cable surface to J tube [Wm^{-2}]
c	empirical constant used in calculating h_{hb}
g	gravitational acceleration (9.81 ms^{-2})
h_{era}	combined radiation and convection heat transfer coefficient for the cable surface [Wm^{-2}K^{-1}]
h_{hb}	heat transfer coefficient
k	thermal conductivity (Wm^{-1}K^{-1})
n	empirical constant used in calculating h_{hb}
q'	thermal loss within a cable component [Wm^{-1}]
q'_{conv_ext}	convective flux from J tube surface to ambient [Wm^{-2}]
q'_{conv_int}	convective flux from cable surface to J tube [Wm^{-2}]
$q'_{rad_{int}}$	radiation flux from cable surface to J tube [Wm^{-2}]
$q'_{rad_{ext}}$	radiation flux from J tube surface to ambient [Wm^{-2}]
q_{solar}	solar radiation [Wm^{-2}]
q'_{total}	total thermal loss within the cable [Wm^{-2}]
r	radius [m]
α	Absorptivity
β	coefficient of volumetric expansion of air [K^{-1}]
θ	Temperature [K]
$\Delta\theta_c$	temperature difference between the maximum conductor temperature and the cable surface [K]
$\Delta\theta_p$	temperature difference between the cable surface and the tube [K]
$\Delta\theta_s$	temperature difference between the tube and the ambient [K]
θ_{max}	Maximum conductor temperature [K]
σ	Stefan Boltzmann constant
ρ	reflectivity, which is equal to 1-ε
ε	emissivity of surface
υ	kinetic viscosity [m^2s^{-1}]

Subscripts

IR	inside surface of J tube
OR	outside surface of J tube
a	armour
air	air
amb	ambient surrounding J tube
c	conductor
i	dielectric
J	Cable surface
s	sheath

INTRODUCTION

The installation of offshore wind farms presents a complex set of cable rating challenges which need to be considered, as compared to standard on-shore cable installations [1]. This study investigates the thermal profile of the export cable from a wind farm as it passes through the J tube of an offshore platform and runs down towards the sea bed. This section of the cable route may often present a limit on the continuous current rating of the whole route.

Whilst there are published standards to predict the thermal rating of a buried cable [2,3], there are no internationally agreed standards for predicting the thermal rating of an export cable within a J tube. This study has reviewed a series of different modeling approaches to investigate the thermal profile within the J tube.

The study starts by reviewing two previously published methods to predict the thermal continuous (steady state) rating of a J tube. Due to their analytical or empirical origins these methods do not consider a complete set of physical processes. To overcome these limitations this study has developed a 3D finite element analysis (FEA) model of a cable system within a J tube. The temperature profile predicted by the FEA model is considered in detail,