Thermal Ratings of Submarine HV Cables Informed by Environmental Considerations

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ABSTRACT

One important consideration in determining thermal ratings for HV cables is the effectiveness of the heat transfer through the surrounding medium in which the cable is buried. We have developed 2D finite element simulations to assess the influence that certain environmental parameters have on the dissipation of heat from submarine HV cables. Attention is paid to convective heat transfer through the sediment – a factor that is often considered of little importance. The simulations show that sediment permeability has a significant influence on the nature of the heat transfer, and hence the thermal ratings of submarine HV cables.

KEYWORDS

Submarine HV Cables, Finite Element Method, Thermal Ratings

INTRODUCTION

Thermal ratings of HV cables buried on land have been investigated extensively, making use of both analytical (e.g. IEC 60287[1]) and numerical techniques (e.g. [2,3,4]). The suitability of these approaches within the explicit context of cables buried under the seafloor has not been extensively investigated, despite obvious differences between the marine and terrestrial environments. Seawater, not air, lies above the burial sediment. This presence of a large body of water above the burial medium for submarine cables changes both the thermal situation and dynamics of the environment. For example migration of sedimentary bedforms can result in variations in the depth of the seabed of up to 5m per year[5] through mechanisms that are not operative on land.

It is well known that the thermal properties of the burial sediment have a large impact on the overall cable rating for HV cables buried on land[6]. Over the length of its route, it is highly likely that a submarine cable will encounter a variety of different sediment types (see Fig. 1), with differing thermal and physical properties. Understanding how the differences in environment from terrestrial cable scenarios might affect the dissipation of heat from submarine HV cables is critical for accurate ratings predictions. We have developed a numerical approach for evaluating the thermal ratings of submarine HV cables by using the finite element method to model parallel conductive and convective heat transfer in the marine sediment surrounding an HV cable[4]. Simulations are carried out for a full range of values for the relevant environmental parameters to assess their relative importance. Among the environmental characteristics of the system that have been investigated are: the sediment permeability, porosity, and thermal conductivity, as well as the cable burial depth.

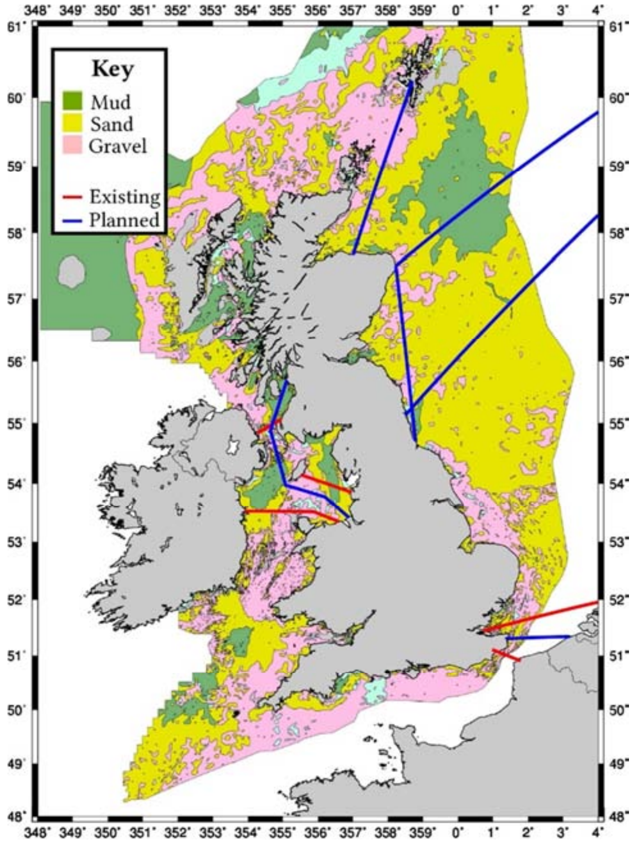

Fig. 1: Planned and existing cable routes around the U.K. along with sediment type. Contains British Geological Survey materials, copyright NERC 2014.

SETUP OF THE FEM MODEL

The equation that describes the transfer of heat in a steady state with the presence of a constant heat source, Q_i is[7]:

$$Q_i = -\lambda\nabla^2 T + \rho c_p \mathbf{u}\cdot\nabla T \qquad [1]$$

where λ ($Wm^{-1}K^{-1}$) is thermal conductivity, T *(K)* is temperature, ρ (kgm^{-3}) is fluid density, c_p ($Jkg^{-1}K^{-1}$) is fluid specific heat capacity, and **u** is the fluid velocity field. The two terms on the right hand side of equation 1 represent the heat transferred by conduction and convection respectively. The dynamics of the fluid permeating the sediment is assumed to be well described by Darcy's law, which characterises the velocity of a fluid in a porous medium:

$$\mathbf{u} = -\frac{1}{n\mu}\boldsymbol{\kappa}(\nabla p + \rho g\hat{y}) \qquad [2]$$

where n is porosity (the ratio of water to sediment grains), μ (Pa·s) is the dynamic viscosity, $\boldsymbol{\kappa}$ (m^2) is the permeability, p (Pa) the pressure, g the acceleration due