Heat Transfer in HV Cable Systems Under the Seafloor

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Submarine HV Cables are becoming increasingly crucial to modern power transmission strategies as initiatives like offshore wind-farms and the European supergrid are developed. There has been much research into the thermal behaviour of land-based cables. However, the performance of sub-seafloor cables has not been extensively investigated despite crucial differences between the two environments. For example, the seawater overlying marine cables provides an effective heat sink, as well as a destination domain for upwardly convecting pore fluid. There are two primary processes for heat transfer within a porous sediment: conduction and convection[1]. In steady state, heat transfer is described by

$$Q_{in} = \frac{-\lambda}{c_p \rho} \nabla^2 T + \mathbf{u} \cdot \nabla T \tag{1}$$

where the terms on the right hand side refer to conduction and convection respectively. The contribution to the total heat transfer from conduction is a function of temperature only. By contrast, convective flux is linked to fluid transport within the medium's pore space, and requires certain conditions to become significant. The exterior cable temperature is therefore directly related to the contribution to heat transfer from convection.

2D FEM models have been developed to investigate the thermal and geophysical conditions required for the onset of convection around a buried cable. The intrinsic permeability (itself a function of other quantities, including sediment grain size, porosity and grain shape.[2]) and thermal conductivity of the porous medium, as well as the cable burial depth all have a noticeable impact on the thermal behaviour. The most important factor is permeability, which is likely to vary over several orders of magnitude between different sediment types (much more than any other relevant quantity).

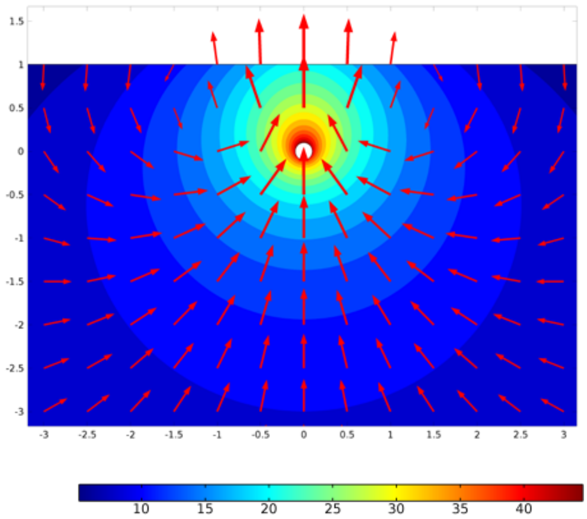

Fig. 1: An example simulation where conduction and convection both make a comparable contribution to heat transfer. The permeability is $1 \cdot 10^{-11} m^2$; the red arrows qualitatively represent the total heat flux (not to scale).

The conductor temperature is an important limiting factor in determining the cable current rating. The equilibrium temperature largely depends on the rate of heat dissipation into the surrounding environment. Understanding the environmental controls that determine the efficiency of heat transport in marine sediments is therefore essential for accurate predictions of subsea cable ratings.

[1] Kaviany, M., "*Principles of Heat Transfer in Porous Media*", Springer, New York (1995)

[2] Bear, J., "*Dynamics of Fluids in Porous Media*", American Elsevier, New York (1972)