Environmental Controls on the Thermal Performance of Submarine High Voltage Cables

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Introduction

The generation of power offshore has recently seen a large amount of interest and investment. Submarine power cables are essential tools in transferring electrical power from these offshore generation sites, to where it is consumed back on land. In addition, initiatives like the European Supergrid use submarine HV interconnectors to link electrical infrastructure on a national level. This helps to improve efficiency, and reduce total power generation and its associated costs.

HV cables have been studied extensively in terrestrial soils. How their behaviour alters when buried under the seafloor is essentially unknown, despite key differences between the two respective environments. In order to make full use of these assets, accurate current ratings must be obtained.

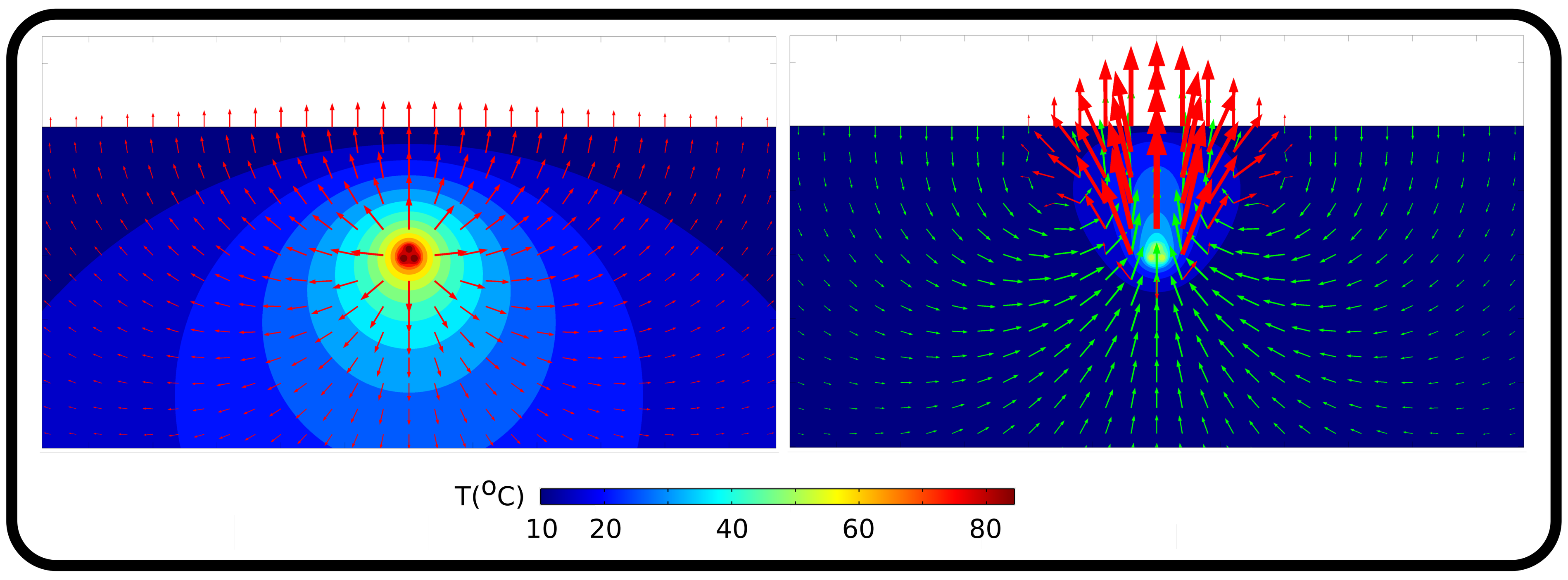
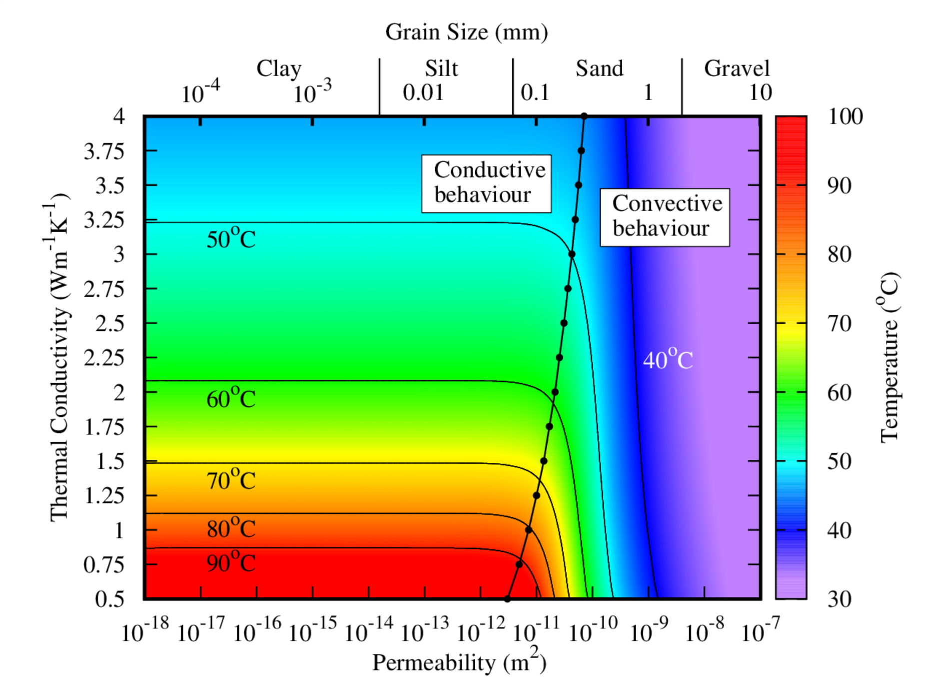


Fig. 2: Example solutions for one sediment with a permeability of $10^{-14}m^2$ (left), and one with a permeability of $10^{-10}m^2$(right). The red arrows show heat transfer, while the green ones denote the fluid vector field. Conductive heat transfer is present in both scenarios, but only the high permeability simulation experiences significant convective heat transfer.

Fig. 3 (right): Dependence of conductor temperature on permeability and thermal conductivity. A line indicating the point at which 20% of heat transfer is by convection is also shown.



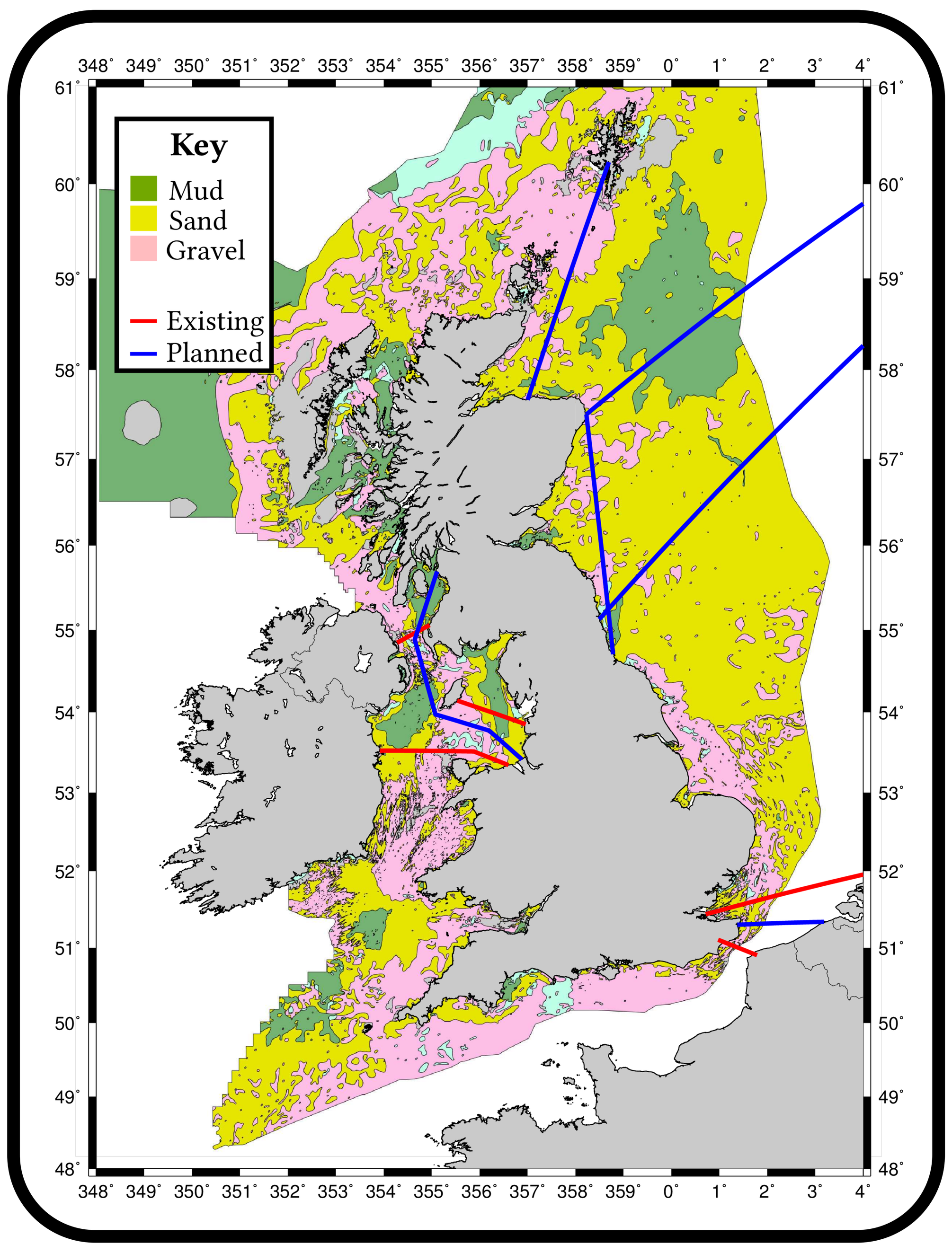


Fig. 1 (left): Some existing and planned HV cable routes around the UK are displayed, along with data on sediment grain size taken from the British Geological Survey.

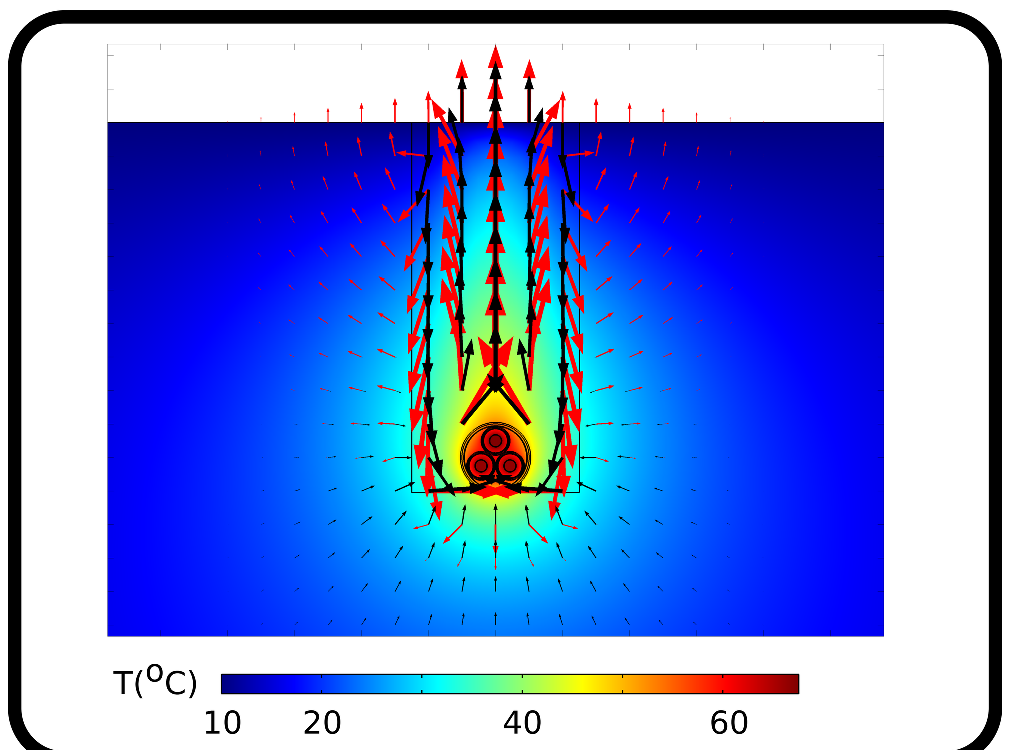


Fig. 4 (above): The permeability of the trench material in this simulation is set to 100 times that of the background sediment. If the conditions are right, a convection cycle can be established within the trenched region. The fluid velocity field is shown in black.

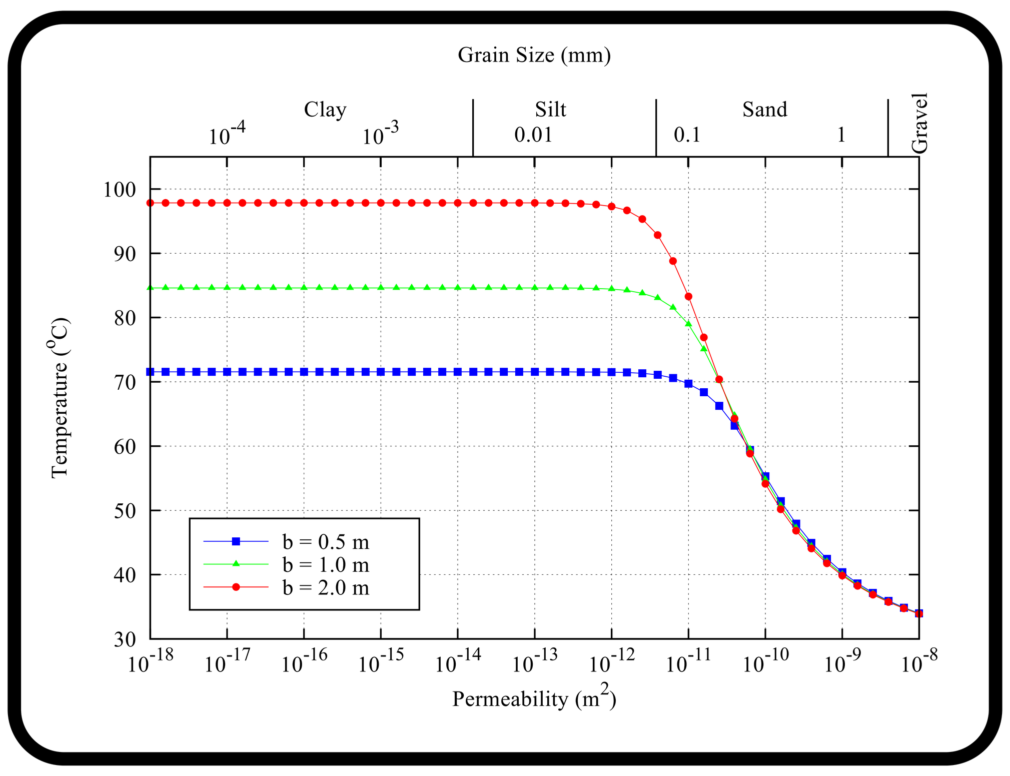


Fig. 5 (right): Dependence of the cable conductor temperature on burial depth. Due to the dynamic nature of the marine environment, migration of sedimentary bedforms can alter the depth of the sea bed by up to ~1m per month.

Modelling

We have developed finite element method (FEM) numerical models to investigate how variations in certain environmental parameters (sediment permeability, thermal conductivity, and cable burial depth) affect the transfer of heat from HV cables in the surrounding sediment. The models account for both conductive and convective heat transfer within the porous sediment, and encorporates a conductive model for the cable itself. The parameters were selected based on the range of variability exhibited between different natural sediments. The permeability has by far the largest range, and was therefore expected to play a prominant role in determining how heat generated within the cable is dissipated through the surrounding sediment.

Conclusions

At low permeabilities, the simulations are largely consistent with IEC 60287. Above ~$10^{-11}m^2$, convection becomes significant and modelled cable temperatures are lower than those predicted by IEC 60287. Marine sediments occur naturally with permeabilities that span this $10^{-11}m^2$ value.

In the abscence of convection, conductor temperatures are sensitive to variations in sediment thermal conductivity and burial depth.

Augmenting current ratings calculations to encorporate convective heat transfer for submarine HV cables may result in a higher current carrying capacity, or a reduction in the required conductor size. Determining *in situ* permeability is challenging, but essential for determining the effectiveness of heat transfer through marine sediments.