Sediment Thermal Properties and the Implication for the Performance of Sub-Seabed HV Cables

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Abstract - Offshore windfarms and the potential for a European Mega-Grid are generating huge interest in the use of subsea electricity transmission High Voltage (HV) cables. These cables are typically buried 1-2 m beneath the seabed in the wide range of substrates (muds, sands, gravels and even bedrock) found on the continental shelf. Critical to the performance of these cables is the rate of heat transfer into the surrounding sediment particularly as the operating temperature of HV cables can be up to 70^{o}C. Sediment physical and thermal properties control the sediment ability to balance the cable heat generation (from electrical losses) with transfer to the surrounding sediments. However, the thermal properties[1] of seabed sediments are poorly understood as are the implications for changing seabed properties with such an anomalously high heat source in the near surface sediments (e.g. Cable thermal rating[2]; generation of convection cells; decreased bed stability; enhanced chemical reactions; and micro-biological breakdown).

In order to understand the performance of HV cables in the marine environment we are undertaking a series of fundamental experiments with a pair of custom built tanks, capable of being filled with a range of saturated sediments and into which a controlled heat source (operating temperature range ambient to 100^{o}C) and up to 100 thermocouples (TC) can be placed. We present here initial results for the response of a saturated fine sand (mean grain size of 2.051 φ and D_{50} of 2.065 φ: with an average water content of 37.4%) to a heat source operating over a temperature range of 30-80 ^{0}C.

The measured TC temperatures were used to generate time dependent heat flow surfaces; recording the changing heat transfer regimes through the rising, stabilised and cooling temperature phases, as the applied input heat spreads through the sediment. In addition the average thermal diffusivity (0.7095 x 10^{-6} m^2s^{-1}), thermal conductivity (2.0646 $Wm^{-1}K^{-1}$) and volumetric heat capacity (2.91 Jm^{-3} K^{-1}) were calculated. The thermal diffusivity estimates were similar for different input heat using the same fine sand sediments. These preliminary measurements will be followed by extensive series of experiments utilising a full range of sedimentary grain sizes.

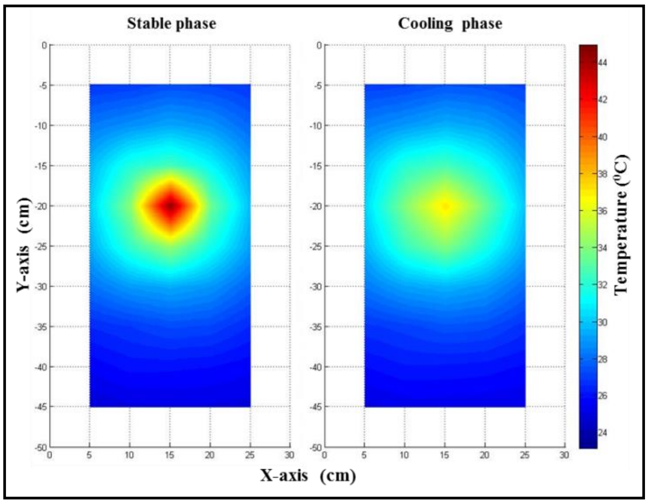

Figure 1: Time dependent heat flow surfaces generated during the stabilised (after 1100 minutes) and cooling (after 1450 minutes) temperature phases; as a (50v, 12w) constant input heat spreads through the fine sand sediments. The heat source was turned off after 1430 minutes.

[1] T. W. Kim, Y. K. Cho, and E. P. Dever, "An evaluation of the thermal properties and albedo of a macrotidal flat," *Journal of Geophysical Research-Oceans,* vol. 112, Dec 19 2007.

[2] D. J. Swaffield, P. L. Lewin, and S. J. Sutton, "Methods for rating directly buried high voltage cable circuits," *IET Gener. Transm. Distrib.*, vol. 2, pp. 393-401, May 2008.