AP7-1-INV

Dynamo-type HTS Flux Pumps: Physics and Applications

*Chris W. Bumby[1], Andres E. Pantoja[1], Ratu C. Mataira[1], Mark D. Ainslie[2], Zhenan Jiang[1], Rodney A. Badcock[1]

Robinson Research Institute, Victoria University of Wellington, New Zealand[1]
Bulk Superconductivity Group, Department of Engineering, University of Cambridge, UK[2]

HTS magnet coils require large DC currents to be continuously injected from an external supply which is conventionally achieved using metallic current leads which penetrate the cryogenic envelope. These leads impose a significant heat load on the cryogenic system, due to both resistive dissipation and heat conduction. The resulting cooling-power requirements constrain the design of the overall magnet system, increasing system cost, footprint and weight. A preferred solution would be to eliminate the metal current leads entirely, and this talk will discuss a novel superconducting device which can achieve this goal - the HTS dynamo.

HTS dynamos are a type of superconducting flux pump. These unusual devices induce a DC current to flow around a closed superconducting circuit, formed between a magnet coil and the flux pump. During operation these devices output a small 'time-averaged' DC voltage, which is sufficient to overcome resistive losses incurred at normal-conducting soldered joints in the circuit. As a result a 'quasi-persistent' DC current can be maintained within the superconducting coil.

The HTS dynamo is topologically identical to a conventional ac alternator. It employs a permanent magnet rotor to apply a rotating magnetic field to a thin film of superconductor, such as a ReBCO coated conductor wire. In the normal-conducting state, the time-averaged DC output voltage from this device is zero, as expected from Faraday's law. But when cooled into the superconducting state, the output voltage is observed to now include a non-zero DC component, which acts to continuously inject current into a series-connected inductance (such as an HTS magnet coil). To understand this somewhat counter-intuitive experimental result, we present results from both experiment and finite element modelling. These illustrate the important role played by eddy currents in the HTS tape which experience a non-linear resistivity, and give rise to partial rectification of the AC emf. Building on this understanding, we have now developed improved dynamo designs, which are capable of injecting currents of >1 kA into a closed HTS circuit. We will conclude by discussing some potential applications of HTS dynamos in the excitation of high-current high-field magnet systems.

Keywords: Superconducting Flux Pumps, HTS Dynamo, Quasi-persistent Current, Finite Element Model