HTS Current Lead Development

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Introduction

The development of several Series Connected Hybrid magnets is underway at the NHMFL, each requiring a pair of low heat-load 20-kA leads for the superconducting outsert. As part of the lead development effort, a pair of binary N_2-cooled 10-kA prototype leads is constructed and tested. Dimensions of the leads were chosen to allow replacement of the conventional helium-vapor cooled copper leads in the NHMFL 45-T Hybrid Magnet system. Upgrading to more efficient leads can sufficiently reduce the heat load on the cryogenic system to allow operation on one liquefier (instead of two) thereby providing redundancy, reduced operating cost and less stressful operation of the cryogenics.

Design Approach

The leads consist of a copper resistive section cooled by N_2 vapor in self-demand mode, electrically in series with a superconducting section optimized to minimize the heat load to the cold end. An integral shunt protects the superconducting section during fault conditions. The LN_2 delivery system is controlled using optical level sensors in a reservoir inside the leads. Details are given in references [1] and [2].

Experimental

The leads including a LN_2 delivery system are designed and constructed in-house. A pair was tested in a cryostat with the cold ends in liquid helium and connected in series via a superconducting short. Voltage taps, temperature sensors and a N_2 mass flow meter monitor performance of the leads. The helium evaporation rate is used to determine the cold-end heat load.

Results and Discussion

The assembly process of the leads and all supporting systems were completed this year. Testing in steady state conditions revealed a N_2 delivery system and resistive section that function as expected. However, the conductor used in the HTS section has significantly degraded over time, limiting the steady-state current carrying capability of the leads to 4.9 kA. This falls short of the specifications for replacement leads of the 45-T Hybrid. Future leads require either continued in-house development on the HTS section or the incorporation of ready-made commercial elements. Pumping on the N_2 vent was effective in reducing the temperature of the reservoir and increasing the steady-state current carrying capacity of the HTS section to 5.4 kA. Current levels of 8 to 10 kA were reached in transient conditions using 100 to 400 A/s ramp rates.
The observed heat leak to the cold end is less than half of the value expected based on thermal conduction alone, despite the unexpected Ohmic dissipation in the HTS section, due to the beneficial effect of convective heat exchange. Scaling the technology up to 20 kA appears straightforward.

Conclusions

Self-demand Nitrogen cooled 10 kA binary leads were constructed and tested. The technology applied in the resistive section and the LN_2 delivery system is robust and the lead behavior is generally well understood. To prevent degradation of the HTS conductor is it necessary to seal the conductor in an early stage. Development and testing of this 10-kA lead pair represents a significant milestone in the development of 20-kA binary leads for future NHMFL Series Connected Hybrids.

Acknowledgements

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References

[1] Miller, J.R. *et.al*, IEEE Trans. on Applied Superconductivity, **15**, 1492, (2005)
[2] Weijers, H.W. *et.al*, IEEE Trans. on Applied Superconductivity, **in print**, (2008)