Final Testing of the Series-Connected Hybrid Magnet

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Introduction

The MagLab's Series Connected Hybrid (SCH) magnet is unique in the world providing up to 36 T with homogeneity < 1 ppm/cm and stability <1 ppm/hour without an NMR lock. An NMR lock is routinely used for further stability improvement. The magnet reached full field in 2016 and was operating in a commissioning mode in 2017 with normal user operations in 2018. It has been extremely successful, particularly for NMR studies of quadrupolar nuclei. However, the magnet has been observed to quench several times despite charging at low rates and the current leads produce more N2 vapor when the magnet is energized than was expected. In 2017 and 2018 investigations were undertaken to better understand these phenomena.

Experimental

In the first 4 months of 2017 the magnet was operating at a very slow charging rate (8.6 A/s average) with a single quench. We attempted to find a faster charging rate that would facilitate use. The magnet was charged and discharged repeatedly, each time at higher rates. We observed that the magnet reached full field successfully with a charging rate of 18 A/s but it quenched at 20 A/s. The magnet was put into service with a charging rate of 18 A/s and it quenched at this lower charging rate. The rate was subsequently lowered to 10 A/s for normal operations.

The current leads of the magnet carry 20 kA from room temperature to 4 K and are cooled by liquid nitrogen that intercepts them mid-way down, is boiled, and flows up through the leads before escaping near the top. In early 2017 it was observed that the leads produce as much nitrogen gas as predicted when the current is off, but significantly higher gas flow during full-field operation. In 2018 voltage taps were installed at points within the leads to measure the voltage distribution which, combined with current, gives an indication of the power distribution.

Results and Discussion

Typically magnets built from cable-in-conduit conductors can be reliably charged and discharged at higher rates than 10 A/s and this magnet was designed for a 36 A/s charging rate. A new set of stability calculations was run looking at sensitivity to input parameters such as the void fraction in the cables, the hydraulic friction factor between the helium and superconducting strand, the thermal strain in the superconducting strands, etc. The only explanation we could find to justify the slow charging rates was that the thermal compression in the strands' Nb_3Sn filaments must be significantly larger than anticipated [1]. The impact of this on the expected lifetime of the magnet is still being assessed.

The voltage measurements indicate there is more electrical power being dissipated in the top end of the leads during high-current operation than anticipated. This might be explained by poor solder joints or non-uniform nitrogen gas flow. The impact of this on the expected lifetime of the magnet is also still being assessed.

Conclusions

Despite >30 years of development of Nb3Sn CICC magnets, there are still new features being revealed. Either the conductor or the leads might degrade as the magnet is cycled.

Acknowledgements

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References

[1] Bird, M.D., *et al.*, IEEE Transactions on Superconductivity, submitted for publication.