COOLING-SYSTEM ANALYSIS AND DESIGN OF THE SUPERCONDUCTING OUTSERT IN THE SERIES-CONNECTED HYBRID MAGNET SYSTEM

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Introduction

The National High Magnetic Field Laboratory (NHMFL) is embarking on an effort to design and build a unique hybrid magnet system, the Series-Connected Hybrid (SCH). Novel because a Florida-Bitter resistive magnet (insert) is powered in series with a superconducting Cable-In-Conduit-Conductor (CICC) coil (outsert) rather than being powered independently and because the combination of uniformity and magnetic field is not yet available anywhere else. The magnet system should generate at least 36 T requiring 12 MW from a single power supply. The stored energy of the magnet is 53 MJ and operates at 20 kA. An eventual objective is to have multiple, specialized systems operating such that the user access time would increase. The target for the uniformity is 1 ppm to satisfy the requirements for its primary function, high-field NMR. However, it will be part of the magnet infrastructure at NHMFL and available for a broad spectrum of scientific experiments, each with different operating conditions.

Results and Discussion

The primary coil of the SCH outsert consists of an 18-layer solenoid wound with a CICC of multi-filamentary Nb_3Sn/Cu strands. The shield coil is also wound with CICC but uses NbTi/Cu strands. The conduit is constructed of a high strength alloy that confines slowly flowing supercritical helium (3.5 atm and 4.5 K) in direct contact with the cable strands. Cooling of the system relies on a helium liquefier to supply a flow of supercritical helium to the magnet. A buffer dewar provides a reservoir for peak demands.

The cooling design option with the highest flow to all the winding layers is selected and optimized (each layer has an inlet and outlet), aiming to reduce the time of evacuation of heat deposited due to AC losses and thus to sustain a wide range of duty cycles required by diverse science experiments, conducted with this magnet. Typically, many experiments will need multiple cycles (charging/discharging) with short, albeit variable, waiting time before each one. The charging cycles would have ramp rates of about 30 A/s to relatively high ramp rates, up to 500-600 A/s. The different ramp rate characteristics will result in different patterns of deposition and evacuation of heat due to AC losses in the outsert windings. All of these cases are carefully analyzed and discussed in [2]. A modified GANDALF code was used for the analysis. The modifications customized a set of circuit equations and added AC loss power density calculations [1, 2]. In so doing, time-varying distributions of magnetic field and strain in the winding layers were properly taken into account to maximize the simulation plausibility.

Conclusions

The Series-Connected Hybrid outsert behavior during multiple cycling was considered and analyzed. It was found that the magnet can sustain multiple cycles with a high ramp rate of 500 A/s and even higher with rather short time interval between the cycles, keeping sufficient temperature margins. It was also found that ramp rates of 30 A/s do not require any pause between magnet cycling for cryogenic recovery.

Acknowledgements

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References

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[2] Dixon, I.R.., *et al*., Presented at ASC'2006, Seattle (2006), paper 3LI02, to be published in IEEE Trans. Appl. Supercond.