Transient Stability Analysis of the Superconducting Outsert of the NHMFL Series Connected Hybrid Magnet System

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Introduction

National High Magnetic Field Laboratory continues to engage in an effort to design a unique 36-T Series Connected Hybrid (SCH) magnet system consisting of a Florida-Bitter resistive magnet (insert) powered in series with a superconducting cable-in-conduit conductor (CICC) winding (outsert) [1], [2]. The system uses a single 12 MW power supply that considerably reduces the whole system cost. The stored energy of the magnet is approximately 53 MJ at 20 kA. The new final design is suggested. It will be defined and based on the results of an R&D program involving testing of different CICC samples. For the moment, the new design of the outsert primary coil will consist of three radial sections designated as a low-field (LF) section, a mid-field section (MF), and a high-field (HF) section, each wound with a different CICC of multi-filamentary Nb_3Sn/Cu strands inside an "industry-standard" modified 316LN stainless steel jacket. There will be two groups of operational scenarios with large transient heat loads on the windings: (a) cyclic operation when the magnet is linearly ramped up to the field and then ramped down, cycle after cycle, and (b) magnet trips that are fast emergency dumps of the stored energy into an external dump resistor, controlled by the quench protection system, or through the power supply diodes and resistive insert. Understanding of the outsert stability during such dynamic regimes is critical in the specification of reasonable operating capabilities of the whole magnet system and requires a sophisticated thermo-hydraulic analysis that was done.

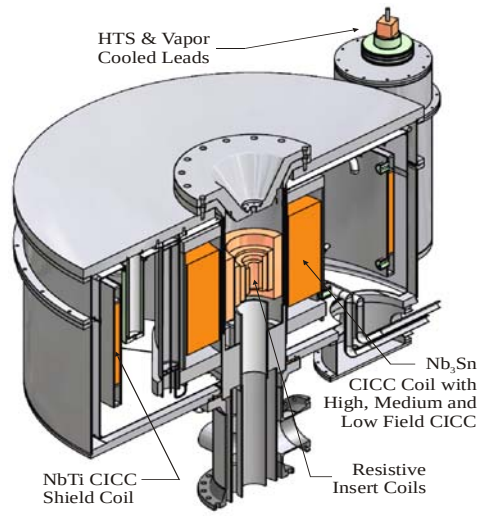

Fig. 1. Sectional view of the Series-Connected Hybrid.

Results and Conclusions

As was calculated, the stability margin is sufficiently high in the case of multiple fast ramp cycles (100 A/s rate) which require a 10 minutes long waiting time interval between the cycles to evacuate heat deposited in the winding due to a high level of AC losses during ramping. In the case when waiting between the cycles is excluded, the allowable ramp rate is supposed to be lower (25 A/s or less) to reduce AC losses. At the same time, an operational regime with multiple slow non-stop ramp cycles (at 20-25 A/s) is of great interest to potential users, too. In the course of further study, a safe regime of emergency discharge of the magnet was found with a long time constant (~11 s) – with the power supply diodes and the resistive insert.

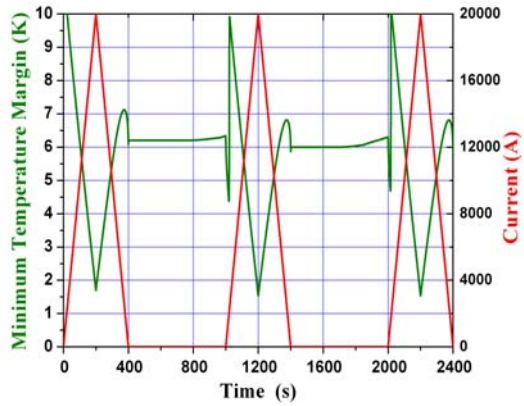

Fig. 2. Minimum temperature margin (olive) in the innermost layer of the HF section and magnet current ramp pattern (red) from multiple fast ramp cycles (100 A/s current ramp rate).

Acknowledgements

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References

[1] I.R. Dixon, et al., IEEE Trans. Applied Supercond., **17**(2), 1414-1417 (2007).
[2] A. Bonito-Oliva, et al., 20th International Conference on Magnet Technology, 2F01, August 2007.