§15. Development of Conduction-Cooled LTS Pulse Coil

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We have been developing a 1 MW, 1 sec UPS-SMES for a protection from a momentary voltage drop and an instant power failure. A conduction-cooled low temperature superconducting (LTS) pulse coil has excellent characteristics, which is adequate for a short-time uninterruptible power supply (UPS). The LTS coil has better cost performance over the HTS coil and the conduction cooling has higher reliability and easier operation than the conventional cooling schemes. To demonstrate the high performances of the LTS pulse coil is a key technology of the UPS-SMES, we have fabricated a prototype LTS pulse coil with stored energy of 100 kJ and have conducted cooling and excitation tests.

The coil was wound with a circular cross sectional high specific heat conductor, consisting of an NbTi compacted strand cable extruded with low purity aluminum. The conductor was wound while twisted along with the direction of the coil's magnetic field, reducing the AC loss. The prototype 100 kJ class conduction-cooled LTS pulse coil retained the structure of a GFRP frame and used a coiling wire of NbTi/Cu formed strands. They had an outer diameter of 5.9 mm, coated in a circular cross sectional aluminum through Kapton tape acting as electrical insulation. The coil has a total of 67 turns x 14 layers while twisting the conductor, thus forming a coil section 303 mm in the inner diameter, 516 mm in the outer diameter, and 409 m in length. Figure 1 shows the inner structure of the coil. Once the initial winding layer is complete, a spacer made of Dyneema FRP (DFRP) and a Litz wire are alternately inserted between layers in the circumferential direction. The heat flow through the longitudinal direction of the coil is secured by Litz wires. Figure 2 shows the structure of the cooling and excitation test apparatus. Two GM cryocoolers are applied to generate 3 W of cooling capacity at 4K and 120 W at 50K, respectively. Through the Litz wire withdrawn from the coil edge, the coil is conductively cooled to 4K, while the low and high temperature ends of the high temperature superconducting current lead, accepting a rated current of 1000 A, are also cooled by conduction.

The coil was cooled from 300 K to 4 K within 3 days, which indicated the excellent thermal characteristics of this coil. Steady-state operation at the rated current of 1000 A was verified and over current test of 1230 A was also confirmed. Current shut-off test from 1230 A with a time constant of 1.37 s was successfully performed without normal transition. The temperature rise in the coil was limited to 0.8 K, which indicated a sufficient safety margin for the rated pulse discharge from 1000 A to 707 A in 1 sec. Repeated excitation of a triangular waveform with the peak current of 1000 A and ramp rate of 50 A/s was also tested. The temperature rise in the coil was limited to 1.1 K, which shows availability of continuous pulse operation because of the outstanding heat removal characteristics of this coil.

The developed conduction cooling LTS pulse coil is applicable not only to the SMES for compensating for instantaneous voltage drops but also to various uses of the superconducting coil which require pulse excitation. Accordingly, the extended applications are likely to open up for the previously limited usage of the superconducting coil.

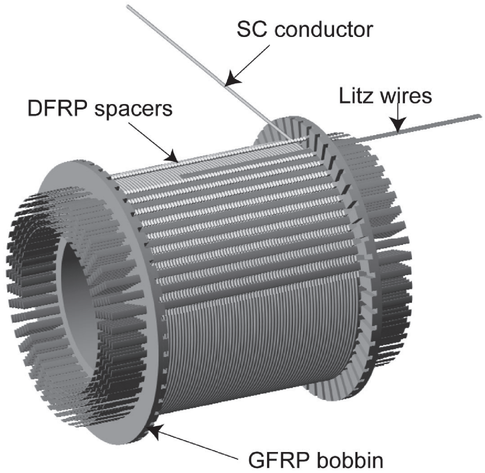

Fig. 1. Structure of conduction-cooled LTS pulse coil.

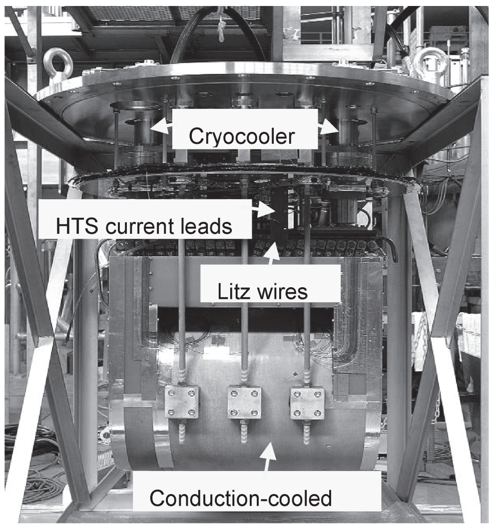

Fig. 2 . Cooling and excitation test apparatus for conduction-cooled LTS pulse coil.

References

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