§13. Development of 1 MJ Conduction-Cooled LTS Pulse Coil for UPS-SMES

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We have been developing a 1 MW, 1 s UPS-SMES for a protection from a momentary voltage drop and an instant power failure. As a key technology of the UPS-SMES, a conduction-cooled Low Temperature Superconducting (LTS) pulse coil with a stored energy of 1 MJ has been developed. A conduction-cooled LTS pulse coil has excellent characteristics, which are adequate for a short-time uninterruptible power supply (UPS). The conduction cooling has higher reliability and easier operation than the conventional cooling schemes such as pool boiling with liquid helium or forced flow of supercritical helium.

A low AC loss and a high stability are required for the superconducting (SC) conductor. The SC conductor of a NbTi/Cu compacted strand cable extruded with an aluminum has been developed. The coil shape is a single solenoid of 183 turns × 14 layers wound on the GFRP bobbin. The Dyneema FRP (DFRP) spacers and the Litz wires (braided wires of insulated copper strands) are inserted in each layer. The DFRP spacers have a good thermal conductivity along with Dyneema filaments, which enhance the heat transfer from layer to layer in the windings. On the other hand, the Litz wires increase the heat transfer from turn to turn in the windings and enable conduction cooling of the coil by attaching the end of the Litz wires directly to the cold heads of the cryocoolers. The total copper cross-section of the Litz wire is 6,120 mm^2.

Fig. 1 shows the inside of cryostat. The coil was connected with three GM cryocoolers which have cooling capacity of 4.5 W at 4 K and 240 W at 50 K. Whereas the coil cold mass is 1,100 kg and the heat loads are 2.3 W at 4 K and 186 W at 65 K. Fig. 2 shows the cool-down characteristics of the coil. It took approximately two weeks to cool-down the coil as exclusively utilizing cryocoolers. The spatial temperature distributions within the coil were negligible during the cool-down, which indicated good thermal properties of the coil. To evaluate the thermal performance of the coil, the coil current was reduced rapidly from the rated current of 1000 A with a time constant of 4 s. Fig. 3 shows the temperature increase in the coil during the discharge. Due to the AC loss of 447 J, the temperature of the coil increased from 3.9 K to 4.4 K. However, the temperature increase of the coil was only 0.5 K. It means that the heat generated by the AC loss was well distributed within the coil winding and was also transferred to the cold heads of cryocoolers during a few second. Since the components of the coil have high thermal diffusivities at the cryogenic temperature below 10 K, the enhanced thermal diffusivity of the coil results in the rapid temperature stabilization.

We have successfully developed the 1 MJ conduction-cooled LTS pulse coil. The high performance of the conduction-cooled coil has been demonstrated by the cooling and excitation tests and its applicability was also confirmed by the energy extraction tests as the UPS-SMES.

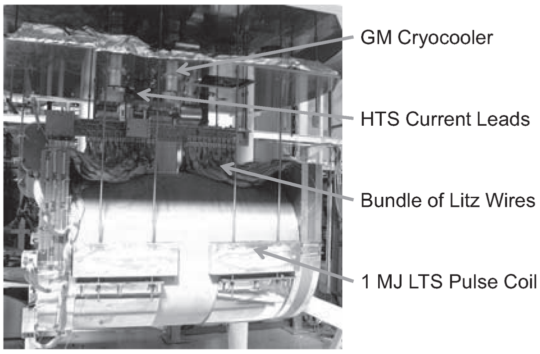

Fig. 1. Assembled 1MJ conduction-cooled LTS coil before installing cryostat.

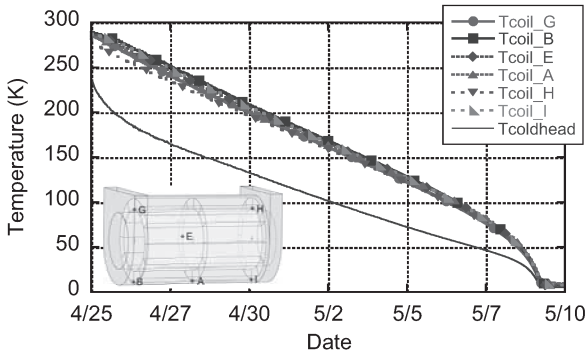

Fig. 2. Cooling curves of 1MJ conduction-cooled LTS coil.

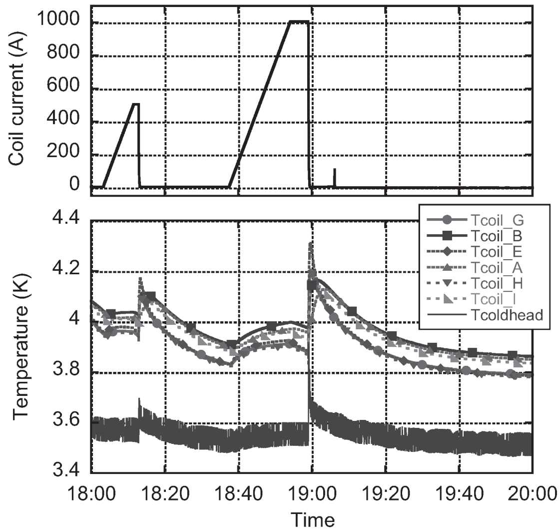

Fig. 3. Coil current and temperatures during discharge test.

1) Mito, T. et al., "Development of 1 MJ Conduction-Cooled LTS Pulse Coil for UPS-SMES", IEEE Trans. Appl. Supercond, Vol. 17, No. 2, (2007), pp. 1973-1976.