§16. Validation of the High Performance Conduction-Cooled Prototype LTS Pulse Coil for UPS-SME

Mito, T., Chikaraishi, H., Maekawa, R., Baba, T., Yokota, M., Morita, Y., Ogawa, H., Yamauchi, K., Kawagoe, A., Sumiyoshi, F. (Kagoshima Univ.), Iwakuma, M. (Kyusyu Univ.), Hemmi, T. (Graduate Univ. for Advanced Study), Okumura, K., Kuge, A. (Technova), Abe, R., Nakamura, A. (Shibuya Kogyo Co.)

A conduction-cooled low temperature superconducting (LTS) pulse coil has been developed as a key technology for UPS-SMES. We have been developing a 1 MW, 1 s UPS-SMES for a protection from a momentary voltage drop and an instant power failure. A conduction-cooled LTS pulse coil has excellent characteristics, which are adequate for a short-time uninterruptible power supply (UPS). The LTS coil has better cost performance over the HTS coil at present and 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. To demonstrate the high performances of the LTS pulse coil, we have fabricated a prototype coil with stored energy of 100 kJ and have conducted cooling and excitation tests. The successful performance test results including current shut-off test with a time constant of 1.3 s and repeated excitation of a triangular waveform with high ramp rate are reported in the paper (1).

UPS-SMES as a protection from momentary voltage drop and power failure are required for industrial fabrication facilities such as semiconductor chip production equipment or large-sized experimental facilities for big science such as a nuclear fusion experimental device. A five-year project to develop UPS-SMES is being started from 2002 fiscal year as one of the research promotion programs of the New Energy and industrial technology Development Organization (NEDO). We have developed a 100 kJ class UPS-SMES in order to do a principle actual proof. According to the successful results of the cooling and excitation tests, we have proceeded to construct 1 MJ LTS pulse coils used for 1 MW, 1 s UPS-SMES.

The design of conduction-cooled pulse coil is determined by the temperature margin during pulse operation. The temperature increase of the prototype coil after 1 s discharge is estimated as 6.7 K assuming an adiabatic condition in which the heat transfer from the SC conductor to the DFRP spacers and other winding components was neglected. According to the performance test, the prototype demonstrated its high potentiality for the SMES applications. In fact, the performance values well exceeded the prototype design. Thus, the compact design of an actual system can be achieved and the running cost will be substantially reduced. Effective thermal design, arrangement of bundled Litz wires, leads to these high performances of the prototype. Further, the supporting structure with Dyneema FRP (DFRP) spacers in the coil winding enhances the thermal performance. Since the coil consists of copper, aluminum, epoxy resign and DFRP, these materials have relatively high thermal diffusivities below 10 K. The time constants of thermal diffusivities for each component with the total amount of thickness used in the coil are estimated approximately 1 s around 4 K. Therefore, the heat generated within the coil was dissipated within the winding with a very short period. So, the spatial temperature distribution within the coil becomes negligibly small against heat generations. The detailed analysis including the heat transfer during the pulse operation and the comparison with the experimental data have been carried out in the paper (2).

We have successfully developed the conduction-cooled prototype LTS pulse-coil for UPS-SMES. The performance tests validate the design and fabrication technique of the coil. As a matter of fact, the data exceeded the design performance such as; the stored energy was 200 kJ instead of design value of 100 kJ. Since the coil was designated for a pulse operation, the effective thermal diffusivity results in the rapid temperature stabilization. Consequently, the design philosophy has been established and the much compact system with a high efficiency can be developed.

TABLE I
SPECIFICATIONS OF THE SC CONDUCTOR

Conductor type	Aluminum coated NbTi/Cu compacted strand cable
Conductor diameter	5.8 mm
Critical current	3740 A @ 5 T, 4.2 K
Coupling time constant of AC loss: $A^*\tau$ [1]	82 msec for face-on (FO) orientation 10 msec for edge-on (EO) orientation
Compacted strand cable	1.55 × 3.36 mm
Aluminum coating	Al- 1197
RRR of Al coating	9.85

TABLE II
SPECIFICATIONS OF THE LTS PULSE COIL

Specification	100 kJ Prototype coil	1MJ Full size coil
Dimension of the coil windings		
Inner diameter: 2a1	0.305 m	0.600 m
Outer diameter: 2a2	0.509 m	0.804 m
Length: 2L	0.402 m	1.098 m
Total turn number	67 x 14 layers = 938 turns	183x 14 layers = 2562 turns
Coil inductance	0.20 H	2.00 H
Maximum magnetic field	2.2 T	2.48 T
Magnetic stored energy	100 kJ	1 MJ
Operating current	1000 A	1000 A
Coil weight	400 kg	1,100 kg

References

1) Mito, T. et al., "Validation of the High Performance Conduction-Cooled Prototype LTS Pulse Coil for UPS-SMES", IEEE Trans. Appl. Supercond, Vol. 16, No. 2, (2006), pp.608-611.

2) Kawagoe, A. et al., "Heat Transfer Properties of a Conduction Cooled Prototype LTS Pulse Coil for UPS-SMES", IEEE Trans. Appl. Supercond, Vol. 16, No. 2, (2006), pp.624-627.