§22. Study on Stability of a High Temperature Superconducting Coil for SMES

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In large high temperature superconducting (HTS) coil such as SMES coil, normal zone propagation velocity is one of the key protection parameters and is expected to be different from that of HTS single tape due to different thermal properties such as heat capacity, thermal coductivity and heat transfer to the coolant. Although stability of HTS conductor has been investigated both experimentally and theoretically, most of researches were focused on HTS conductor connected with conduction cooling system. Therefore, we investigated the characteristics of normal zone propagation in HTS single tape cooled by liquid nitrogen to establish quench-protection technique for large HTS coil for SMES system.

HTS conductor has unignorable resistance even in the lower operating current than critical current. Therefore, the higher critical current would be better for HTS conductor for HTS SMES coil system due to exposed large magnetic field. In such the large coil system, conductor strength is also one of the important parameters because large electromagnetic force is applied on the conductor. Therefore, as the first step in this research, we searched for a suitable HTS conductor for HTS SMES coil system. We finally adopted a silver-sheathed BSCCO-2223 tapes sustained by stainless steel. The expected critical current at 77 K is about 100 A.

In HTS conductor, it is difficult to observe thermal and electromagnetic behaviors, such as normal zone propagation, due to much larger heat capacity than that of LTS conductor. In the measurement of normal zone propagation velocity, especially in HTS conductor, it is very important and difficult to make localized initial quenching spot by heater because required quenching energy of HTS conductor is much larger than that of LTS conductor. This causes that the longer heater pulse, the longer initial quenching zone and the larger magnitude of heater pulse, the more intensive temperature rise; this sometimes causes burning out of the conductor. Therefore, we investigated suitable condition of heater operation for adequate initial normal spot. We prepared short samples 0.5 m in length of a silver-sheathed Bi2223 tape conductor, 3.20 mm wide and 0.21 mm thick, with the critical current of 15 A. The sample conductor was immersed in a bath of liquid nitrogen. Several sets of voltage taps and Copper/Constantan thermocouples were attached on the surface of the conductor to monitor time-varying resistance and temperature distribution around normal spot. Stainless steel tape, 3 mm wide and 0.2 mm thick, was adopted as a heater and the operating current of the heater was controlled by a pulse generator to change the magnitude of joule heating. Temperature distribution and voltage between tapes were repeatedly measured as functions of heater length and the magnitude and operating time of heater pulse. It was found that in the same joule heating at the heater, the heater pulse with the larger magnitude and shorter operating time was more effective and less damageable in conductor than that with the smaller magnitude and longer operating time.

Based on this result, we investigated thermal and electromagnetic behaviors around a resistive spot in the HTS conductor. The measurement was performed as a function of transport current. An experimental result of voltage traces at the operating current of 80, 90 and 100 A are shown in Fig.1. The sample conductor was burned out at the operating current of 100 A. Fig.1 implies that even at the higher transport current than critical current of 15 A, temperature around initial normal spot was gradually decreased and finally returned to superconducting state. In large HTS coil system, however, the effect of heat transfer may be much smaller than that of single tape. Therefore, the further investigation of thermal and electromagnetic behaviors within HTS coil is required to establish quench-protection technique for large HTS SMES coil system.

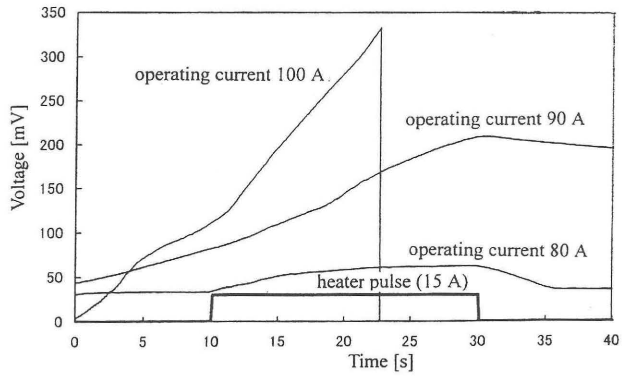

Fig.1 Voltage traces for a silver-sheathed Bi2223 tape at 77K.