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

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Thermal behavior in a normal-state region of a large-scale high temperature superconducting (HTS) coil for SMES may be quite different from that of low temperature superconducting (LTS) coil due to much larger heat capacity of HTS conductor than LTS one. This means that basic concept of coil protection in HTS coil differs from that of LTS. Although stability, including thermal behavior, in a short sample of HTS conductor cooled by cryocooler has been investigated, the protection system of large HTS coil as well as a short sample of HTS conductor cooled by LN_2 has not been discussed sufficiently yet. Therefore, we investigated thermal behavior of a short sample of HTS conductor cooled by LN_2 to establish a protection technique of large-scale HTS coil for SMES.

Quench current degradation against abrupt increase of operating current has been observed in a short sample of LTS conductor. The quench current degradation is caused by joule heating in a region that current density becomes larger than its critical current density due to relatively slower penetration of magnetic flux within conductor than the increasing rate of magnetic flux density generated by operating current. Since it may be considered that HTS SMES coil may experience such the abrupt changing of operating current, we investigated thermal behavior, especially influence of joule heating generated by the abrupt increase of operating current on stability of HTS conductor.

We prepared several samples of 500 mm in length of silver sheathed Bi2223 tape. Five sets of voltage taps are attached at equal interval of 100 mm to observe local temperature. The sweep rate of operating current was changed between 10 A/s and 100 kA/s. The voltage, i.e. temperature, increased with the sweep rate of operating current, especially at the sweep rate above 1 kA/s; this sweep rate of 1 kA/s is almost the same with that of LTS conductor. The measured voltage-current traces at the sweep rates of 10 A/s and 25 kA/s are shown in Fig. 1. In the case of 25 kA/s, temperature increased even at the operating current below 20 A, while almost zero voltage in the case of 10 A/s. The voltage trace of 25 kA/s, however, finally overlapped with that of 10 A/s at the operating current above 45 A. This means that HTS conductor cooled by LN_2 could maintain stable condition against transient joule heating due to abrupt changing of operating current.

It is very important to investigate protection technique of large-scale coil system to ensure stable coil operation without any damages. Therefore, we analytically investigated thermal behavior of HTS conductor without cooling effect of LN_2; this assumes a condition that coil temperature is higher than that of LN_2 due to its evaporation. In simulation, we assumed a heat disturbance applied to the conductor during its operation and temperature distribution was investigated as a function of the coil temperature at the moment when applying a disturbance. One of the simulated results of required time for temperature increase of a HTS tape from its initial coil temperature to 500 K is shown in Fig.2. Fig.2 shows that temperature of HTS conductor without cooling effect of LN_2 may reach 500K within one minute due to some disturbances even if initial coil temperature is 77K. The simulated results imply that absence of LN_2 may result in non-recovering quench and damage of HTS coil in a short time. Since thermal behavior in a short sample of HTS conductor may be different from that of large-scale HTS coil, we will discuss thermal behavior of an HTS coil both experimentally and analytically.

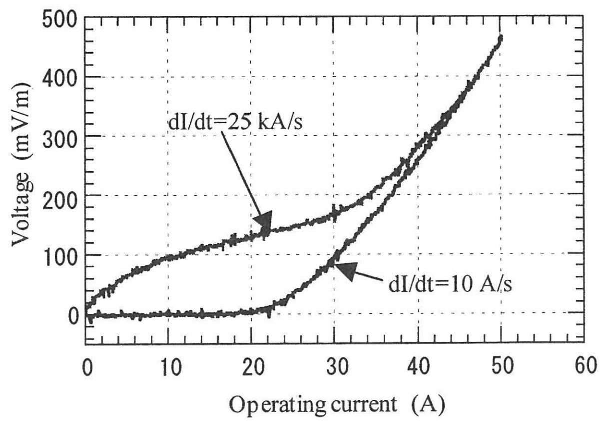

Fig.1 Experimental result of V-I characteristic in a short sample of HTS tape as a function of sweep rate of operating current.

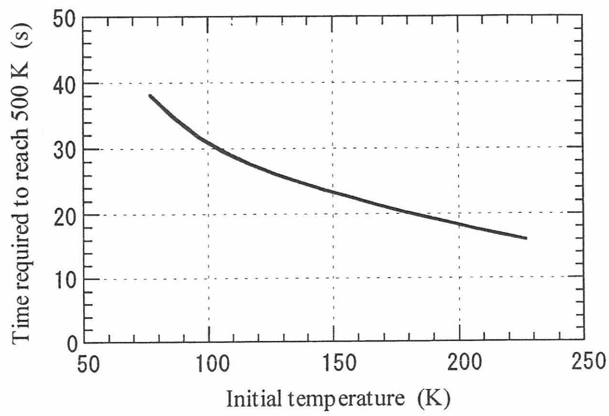

Fig.2 Computed result of required time for temperature increase of HTS tape from its initial temperature to 500 K.