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Numerical simulation of the electro-thermo-mechanical behaviors of a high-temperature superconducting cable

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Abstract

The performance of a multi-layer composite superconducting tape depends on operating conditions, such as the applied field, temperature and stress. Therefore, accurate analysis of the electromagnetic-thermo-mechanical coupling behaviors of the high-temperature superconducting (HTS) cable is important to understanding the mechanism of interaction among different physical fields and the success of optimizing the design of the HTS cable structure. This paper develops a three-dimensional finite element model based on the twisted-stack slotted-core HTS cable structure for electro-thermo-mechanical analysis. Critical currents of a single multi-layer composite superconducting tape and the whole HTS cable structure are calculated. Profiles of the magnetic field, current density, temperature and stress are also obtained. It is found that the selection of tapes having higher critical current enhances the transport performance of the cable. Current densities are nonuniformly distributed in the stack. From the bottom to the top of the stack, the current density first increases and then decreases, in inverse relation to the magnetic field. Cooling with liquid helium improves the cable transport capacity. The temperature of the superconducting tapes is slightly higher than that of the aluminum core, but the stress in the aluminum core is greater than that in the superconducting tapes. The results imply that the transport capacity of the cable can be improved by selecting superconducting tapes with high critical current density and arranging them in stacks in a manner consistent with the