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Quench Protection for the HTS Magnet in the Helical Fusion Reactor

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Design activities of the LHD-type helical fusion reactor FFHR-d1 and -c1 are progressing at NIFS. The high-temperature superconductor (HTS) is a promising option for the helical coil conductors. In addition to high cryogenic stability and low refrigeration power at elevated temperature operations at >20 K, it is proposed that the helical coils of large-diameter and complex-shape be constructed by connecting conductor segments using the advantage of HTS. A proto-type large-current capacity HTS conductor sample was fabricated and achieved 100 kA at 20 K, 5.3 T.
In our previous studies, the hot-spot temperature, defined as the maximum temperature reached during a normal-transition and a subsequent emergency current discharge, has been calculated by a one-dimensional finite element method (FEM). The thermal diffusion along the longitudinal direction of the conductor is the governing equation, while the percolation model is used to describe the superconducting characteristics of the ReBCO HTS tapes. The obtained hot-spot temperatures are 205 K and 456 K at the current density of the helical coils of 25 and 40 A/mm², respectively, corresponding to the FFHR-d1 and c1 designs. In the case of FFHR-c1, the temperature significantly exceeds the allowable limit. In the present study, the feasibility of applying the non-insulation coil winding concept is examined by numerical calculations, as an alternative and efficient quench protection method, which has been intensively studied for small HTS coil applications. The trade-off between the current and heat transferring capability among conductors and limitation of excitation time should be discussed.

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