IEEE-CSC, ESAS and CSSJ SUPERCONDUCTIVITY NEWS FORUM (global edition), Issue No. 57, Oct 2024

Quench Protection Analysis and Strategy for the STEP TF Coils

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***Abstract*–The Spherical Tokamak for Energy Production (STEP) is a prototype fusion power plant, planned to be operational in the 2040s. The STEP reactor concept depends for its continuous operation on a system of high-temperature superconducting (HTS) magnets. Quench protection is key to ensuring successful operation of superconducting magnet systems, and in this presentation the progress made on the STEP toroidal field (TF) coil quench protection system will be discussed. The initial focus was on developing a self-protecting non-insulated coil, which could accommodate local heating in a quench event without intervention. This behaviour has been successfully demonstrated in the literature on small-scale pancakes wound from individual HTS tapes. In small pancake coils, the radial resistance is provided by the contact resistance between tapes. In the case of the STEP TF coil, it was hoped that sufficient radial resistance could be provided by stainless steel ribs in between turns. However, the large size (and resulting cross-section area for radial current flow) means that the coil cannot be operated unless an additional resistive layer (in the form of partial insulation) is wrapped around each turn. In addition to local heating, a more realistic and concerning operational scenario is that of open circuit discharge, which would occur in the case of a power supply failure. This scenario has been assessed with different values of resistivity for the partial insulation, spanning a range of five orders of magnitude, and all cases analysed resulted in an unacceptable heat distribution. A fully insulated concept with integral quench heaters, where the heaters are driven by the stored energy in the coil, has been analysed and demonstrates acceptable heat distribution. This system relies on fast quench detection to inform switching to open circuit, for which radio frequency interferometry is being developed to monitor changes in the density of the gaseous helium coolant.**

***Keywords (Index Terms)*–STEP, spherical tokamak, toroidal field coil, quench, partial insulation, heater, simulation**

IEEE-CSC, ESAS and CSSJ SUPERCONDUCTIVITY NEWS FORUM (global edition), Issue No. 57, Oct 2024. Presentation given at ASC 2024, Sept 2024, Salt Lake City, Utah, USA.