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Analysis of quench in HTS conductors for fusion applications: a novel 1D thermal-hydraulic modeling approach

Several new conductor designs for fusion applications, based on High Temperature Superconducting (HTS) materials, have been proposed worldwide in the recent past. Most of them are based on the twisted-stacked-tape cable (TSTC) idea: a stack of HTS tapes, whose superconducting layer is made of rare-earth-barium-copper oxides, is twisted, soldered and embedded in a copper tube, constituting a macro-strand. Few macro-strands are then twisted together to make an HTS cable. The cable is inserted in a stainless-steel jacket which provides mechanical support to the cable and confinement for the forced-flow of supercritical helium in the interstitials between the macro-strands.

The interplay among the geometry, material properties and the He flow conditions makes the thermal-hydraulic (TH) modeling of fast transients, e.g., quench, unsuitable with the widely adopted TH codes developed for low temperature superconducting magnets, because of the thermal gradients building up in the macro-strands between the SC stack and the copper tube, and between different macro-strands.

A novel approach is proposed in the present work, which allows modelling each macro-strands, accounting separately for the SC stack and the copper tube. Compressible Euler-like equations describe the He flow in each interstitial fluid region. The dynamic distribution of the transport current between the macro-strands completes the picture.

The model developed is applied to the study of the quench in a conductor made of CroCo macro-strands –a recent design proposal made by the Karlsruhe Institute of Technology and based on the TSTC idea. A comparison with the modeling approach adopted for quench simulations in LTS conductors is carried out.

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