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Wed-Af-Po.11-02: Multiphysics verification and validation of STEP toroidal field cable and remountable joints

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The Spherical Tokamak for Energy Production (STEP) is a prototype fusion power plant, planned to be operational in the 2040s. The STEP concept depends for its continuous operation on a system of high-temperature superconducting (HTS) magnets. The Toroidal Field (TF) magnets are required to be re-mountable, allowing for the vertical maintenance strategy adopted by the STEP programme. Verified and validated multiphysics analysis is essential for design and performance prediction of the STEP TF cable, re-mountable joints, and coils.

Electrical, Electromagnetic (EM) and structural-thermoelectric analysis of joint resistance has been performed in FEMM, ANSYS, APDL and COMSOL, using different formulations and degrees of complexity. The results are compared to test results, and a strategy is proposed for future analysis, which must consider the global EM forces acting on the joints. Transient thermal-EM analysis of cables to be tested at the SULTAN facility has been performed in ANSYS CFX and ANSYS APDL and verified against the H4C code developed by Politecnico di Torino for HTS cables. This analysis includes thermal hydraulics for the coolant channel, and in the case of ANSYS CFX a 3D CFD region. The fluid-thermo-electric model is used to determine the critical current and temperature behaviour of short cables along with voltage and temperature measurements. This is a multi-pronged approach to verify the critical current of cables. Structural analysis has been performed on ANSYS mechanical and verified against short cable tests. This has been used to size the TF cable tested at SULTAN with remountable joint.

This work leads to a structural-thermo-electric model capable of capturing the current distribution, joint resistance, joint pressure distribution, structural loads, stresses, strains and impact on critical current for a remountable TF coil at scale.

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