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# JT-60SA TF Coils Quench Model and Analysis: Joule Energy Estimation with SuperMagnet and STREAM

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In the framework of the commissioning of JT-60SA Tokamak (Japan, beginning of 2021), all the coils (TFC, CS and EF) have to be energized with a set of reduced and then nominal current after they became superconducting at 4.5 K cooling temperature with supercritical helium flow in Cable-In-Conduit Conductors (CICC).
An important Issue is to predict the Joule Energy for all the magnet systems, in particular, the Toroidal Field Coils (TFC), in case of an incidental quench arises, as well as the respectively "hot spot" temperature, the maximal conductor temperature reached during the quench development. SuperMagnet code (CryoSoft), including THEA (Thermohydraulic 1-D CICC) and Flower (external cryogenic cooling circuit model), as well as Superconductor Thermohydraulical and Resistive Electrical Analytical Model (STREAM) have been used for these analyses and calculation.
Different TFC quench cases have been studied, in Tokamak configuration, with different quench initiation (Minimum Quench Energy) set as input at nominal current and at maximal magnetic field location (at inlet of CICC over few meters): either on only one Pancake or on each first turn of the 12 Pancakes. In this way, the determined maximal conservative Joule Energy, for one whole TFC quench is evaluated to be near 7 MJ and equal to 12 times the maximal Joule Energy per pancake. The integrated and detailed Joule Energy value depends strongly on quench initiation conditions and on the number of the entirely and rapidly quenched pancakes (quench propagation velocity with a maximum of 16 m/s).
Some further analyses have been performed on the acceptance quench test realized at the Cold Test Facility (CTF, CEA Saclay in 2018) on TFC02. This quench test has also been modelled with SuperMagnet and STREAM. The different calculation results, in particular helium temperature and pressure in upstream and downstream manifold are presented here and are in good agreement with the measurements. This analysis confirms, among others, that STREAM analytical model is valid for CICC coils cooled by forced flow of supercritical helium and can be useful for tokamak magnets protection during quench event and safe operation. This whole analysis has been useful also for the JT-60SA Tokamak magnets energization and commissioning phase.

## Keywords

Fusion, Superconducting Magnets, Quench, Thermohydraulics

## Category

Quench experiment, simulation and analysis for all classes of LTS and HTS magnets

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