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AC losses in TF magnets during JT-60SA commissioning: experimental analysis and simulations

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During the integrated commissioning of JT-60SA tokamak, the superconducting magnets have experienced several tests such as current ramps or fast discharges. The time variations of the associated magnetic field have induced AC losses in the winding pack (WP), i.e. hysteresis and coupling losses, and in the casing, i.e. eddy currents losses, of the toroidal field (TF) coils.
From the thermo-hydraulic sensors installed in the tokamak in the inlet and outlet of the coils and of the TF casings, we have carried out enthalpy balances to estimate the total transient heat loads generated by AC losses. For JT-60SA TF, the current ramp is limited to 25 A/s, thus the associated AC losses were small compared to those of the fast discharges tests with time constants of the order of 14 s performed at several currents up to the nominal value of 25.7 kA; for this reason, we have focused our analysis on such events.
In parallel, we have computed the AC losses generated in the TF from the knowledge of the magnetic self-field map and the current profiles measured during the fast discharges. The hysteresis losses modeling is achieved using magnetization measurements of a TF strand at ENEA during production over large temperature and magnetic field ranges, the coupling losses one using magnetization measurements of a TF CICC performed at CEA, and the eddy currents losses one using the inductance model presented in JT-60SA Plant Integrated Document (PID).
We then present a comparison between these experimental and first theoretical analyses, to assess and discuss the consistency of the two approaches at the first order, i.e. at the energy balance level. In a second step, in an attempt to deepen and increase the realism of our approach, we present and compare the results of several quasi-3D coupled thermal/thermo-hydraulic simulations performed using TACTICS code with the temperature sensors measurements during the experiment. These simulations aim at representing the TF magnet thermal and thermo-hydraulical response to transient heat loads at a more detailed scale to better anticipate the magnet stability in future operations. In order to consider a realistic value of the TF casing/WP contact thermal resistance, which is an important driving parameter, we have performed a parametric study during which we have varied this parameter and used the enthalpy distribution between the WP and the casing as a figure of merit.

Keywords

JT-60SA, TF, AC losses

Category

Tools to support commissioning and operation phases of superconducting magnet systems

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