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A Numerical Investigation on AC Losses in one module of the Central Solenoid of the ITER tokamak

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The investigation of electromagnetic transients in the superconducting coils of the ITER magnet system is important in order to compute the losses arising during time-varying operating conditions. The challenge of this analysis is related to the high number of degrees of freedom required to discretize large-scale magnets at the level required for AC loss computation. The Central Solenoid (CS) of the ITER tokamak is composed by six modules; each module is made up of 554 turns arranged in 40 pancakes, for a total length of about 6 km of Cable in Conduit Conductor. In this study, a methodology based on numerical simulations is proposed for the electromagnetic analysis of one module of the ITER CS. The electromagnetic THELMA code, developed at the University of Bologna (Italy), was previously used to analyse AC losses measured both in a straight ~4 m long sample of the CS conductor tested in the SULTAN facility at the Swiss Plasma Center (Villigen, Switzerland) and in the ITER Central Solenoid Insert coil, a single layer solenoid wound with a~43-m-long piece of the same conductor, tested at the premises of QST (Naka, Japan). The comparison of numerical and experimental results allowed identifying the main fitting parameter of the THELMA model, namely the interstrand conductance per unit surface.
In this work, the THELMA model is applied to the computation of AC losses in one module of the ITER Central Solenoid. The cable-in-conduit conductor is discretized at the last-but-one cabling stage and the numerical analysis is performed both at the single turn and at the single pancake level. The model results obtained at both levels of the analyses were compared to each other. A methodology was then developed in order to reduce the computational burden required by the analysis of the ~6-km-long conductor. This methodology, based on reducing the length of the analyzed cable and the number of turns involved in the computation, allows one retaining a high level of accuracy and analysing the losses in the whole CS module. The validation of the numerical approach is performed by comparison with the experimental results of the tests of the first CS module, performed at the General Atomics (GA) facility in Powey (US). The map of coupling and hysteresis loss distribution in the CS module is presented, thus identifying the most thermally stressed regions of the magnet.

Keywords

AC losses, Nb3Sn Magnets, Central Solenoid, Electrodynamic transients

Category

Electromagnetics modelling of LTS and HTS magnets

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