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Numerical Studies of High Field-Rate Losses in Cable-In-Conduit-Conductors Carrying Transport Current

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In large size conductors for the Central Solenoid (CS) and Poloidal Field (PF) coils of tokamaks, the AC losses set the operating limits for the magnets, especially during the plasma start up. In terms of losses, the startup of the plasma current (breakdown) can be particularly challenging, as the flux density rate can reach values as high as 10 T/s. At such high-field rates, the cable is partially saturated by the screening currents, and the classic treatment for the ac losses is no longer valid. In this work we extend the pioneering model developed by Ogasawara et al. for high field rates in cable-in-conduit conductors carrying a dc transport current. We used 1D numerical methods for calculating the coupling, hysteresis and dynamic resistance losses contributions. The losses were determined as a function of transport current and external varying field. A 2D Finite-Elements model has also been implemented by means of commercial software. A single, but field-rate dependent coupling time constant, nτ(dB/dt), has been introduced in order to account for the multiple induced currents loops typical of a multi-stage cable-in-conduit-conductor. The behavior of nτ vs. dB/dt is based on the experimental results from the most recent SULTAN tests on the rectangular DEMO Low Field conductor, in which trapezoidal field pulses have been employed. The developed 1D and 2D numerical models were applied to the computation of the ac loss of the PF and CS coils of the Divertor Tokamak Test (DTT) Facility, in its reference plasma scenario. The numerical results, that have also been compared with those obtained using the validated THELMA code, show that the energy loss is reduced with respect to the losses obtained with classical models, especially at the plasma startup, where the saturation effects become dominant.

Category

Electromagnetics modelling of LTS and HTS magnets

Keywords

ac loss, saturation, high field-rate, tokamak, magnet coils

Primary author: Dr DE MARZI, Gianluca (ENEA - Energia Nucleare ed Energie Alternative)

Co-authors: Dr MUZZI, Luigi (ENEA - Energia Nucleare ed Energie Alternative); Prof. BRECHI, Marco (UNIBO - University of Bologna); CAVALLUCCI, Lorenzo (UNIBO - University of Bologna); Dr UGLIETTI, Davide (EPFL - École polytechnique fédérale de Lausanne); Dr DELLA CORTE, Antonio (ENEA - Energia Nucleare ed Energie Alternative)

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