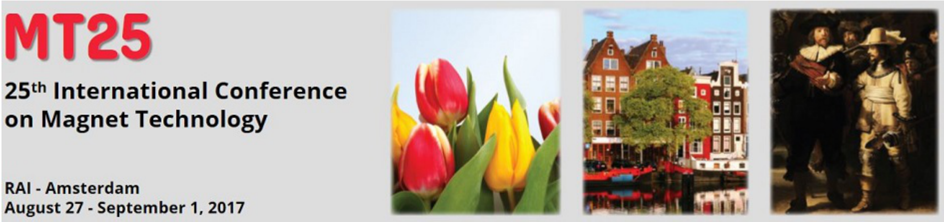

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Coupled electro-magnetic, thermal, mechanical analysis of a quench in the high luminosity LHC Nb3Sn quadrupole magnet

Thursday, 31 August 2017 11:00 (15 minutes)

Modelling the behavior of a superconducting magnet is challenging due to interdependent, nonlinear, multi-domain and multi-scale phenomena occurring during fast transients. A modelling technique based on a lumped-element equivalent system was recently proposed, which efficiently simulates electro-magnetic and thermal transients in a magnet. The model, named LEDET (Lumped-Element Dynamic Electro-Thermal), includes a network of RL loops mutually coupled with the magnet's self-inductance, which simulate the coupling between the magnet and local inter-filament and inter-strand coupling currents developed in the superconductor. The dynamic response of the magnet when subjected to applied voltages, such as during current cycles, fast energy extraction, or CLIQ (Coupling-Loss Induced Quench system) discharges, is correctly reproduced. Furthermore, the heat dissipated as ohmic and coupling losses, exchanged between adjacent conductors, and dissipated to the cryogenic bath are calculated, as well as the conductor temperature variations. Finally, the Lorentz forces acting on each strand are computed. A 2D mechanical model of the magnet was developed in Ansys©, including the coil and its shell-based support structure. The stresses occurring in the coil are analyzed by coupling the LEDET and the Ansys model at a number of selected steps in the time domain. The main contributions to conductor stress are the Lorentz forces and the thermal stress due to the conductor heating. As a case study, the Nb3Sn quadrupole magnet for the LHC upgrade to higher luminosity is considered. Strain measurements performed during magnet cool down, powering, and fast discharge are used to validate the model. Simulation results allow estimating the peak temperature and stress reached in the superconductor during and after a quench.

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