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STEAM Software Framework to Simulate Transients in Accelerator Magnets and Circuits

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A number of programs aimed at modeling electrical, magnetic, thermal, and mechanical transients in superconducting magnets and circuits were developed at CERN as part of the STEAM (Simulation of Transient Effects in Accelerator Magnets) project. The framework includes software to accurately model quenches in a superconducting magnet, either self-protected or protected by energy-extraction, quench heaters, CLIQ, or a combination of these. It includes finite-difference programs to tackle these problems for multipole and solenoid magnets (LEDET, both 2D and 3D) and for canted cos-theta magnets (ProteCCT). These programs include physics-driven methods to account for filament magnetization, coupling losses or eddy currents in metallic magnet components. In addition, a powerful routine to automatically generate finite-element models of superconducting magnets was developed (SIGMA), which allows benchmarking of other models and definition of magnet details with enhanced flexibility. Since modeling of quench in busbars was routinely performed, it became convenient to develop a dedicated COMSOL-based simulation tool to model this problem (BBQ). The STEAM project features also an R&D program for the 3D time-domain simulation of magnetothermal phenomena in coils and magnets based on high-temperature superconductors, using the finite element method. Finally, different tools that are effective for modeling specific problems can be coupled together within a cooperative-simulation (COSIM). A library of models of most LHC and HL-LHC superconducting circuits was systematically developed, validated, and versioned. A few example transients modeled by STEAM tools are presented, covering a wide range of magnet sizes and geometries, conductor parameters, and quench protection systems.The STEAM framework is offered to the community as a flexible, effective, and computationally-efficient software package for simulating powering and quench transients in superconducting circuits and magnets.

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