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A Parallel Simulator of Quench in Superconducting Magnets[1]

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Abstract. In a superconducting magnet the null resistivity of the cable allows to run a very intense electrical current without dissipating heat. During operation, a region of the superconducting wire can turn to normal state (*quench*) with possible damage due to intense heat dissipation. Quench simulation is thus a necessary step during magnet design; it is a multi-physics computational problem that ends up very easily with tens of millions of equations in as many unknowns. In this paper we attempt an HPC approach for quench simulation.

Keywords. multi-physics, transient analysis, parallel solver, finite volume method, heat equation, quench, superconducting magnet, MPI, OpenMP

1. Introduction

A superconducting magnet is an electromagnet made from coils of superconducting cable. In the most common case, the superconducting cable is made of superconducting wires, possibly merged in a matrix of normal metal (Al, Cu) as thermal and electrical stabilizer. The magnet is kept at cryogenic temperature by various means, in order to keep the wires in the superconducting state. In such state, an intense electrical current can flow in the cable without dissipating heat by Joule effect, thanks to the null resistivity of the wire. High magnetic fields (often required in magnetic resonance imaging, mass spectrometers, and nuclear particle accelerators) are then obtained, with a reduced power consumption.

Occasionally, due to various reasons, the magnet can undergo a phenomenon known as *quench*: a region of the wire loses superconductivity and becomes *normal*, thus presenting non-null resistivity and dissipating heat for Joule effect, with a strong rise of temperature that may expand the normal zone to nearby regions and ultimately lead to possibly permanent damages.

Thus, in the design phase of a superconducting magnet, it is important to make use of a *quench simulator* in order to properly size the cooling system and the safety devices to be triggered in case of a quench.

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