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# Holistic numerical simulation of a quenching process on a real-size multifilamentary superconducting coil

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Superconductors play a crucial role in the advancement of high-field electromagnets used for particle accelerators, magnetic resonance imaging, fusion reactors, and many other high-end technological applications. Unfortunately, their performance can be compromised by thermomagnetic instabilities, wherein the interplay of rapid magnetic and heat diffusion can result in catastrophic flux jumps eventually leading to irreversible damage. This issue has long plagued high-$J_c$ $Nb_3Sn$ wires at the core of high-field magnets. Moreover, the stochastic nature of these magnetic flux avalanches poses a serious challenge to the development of prevention measures such as quench detection criteria. In this study, we introduce a groundbreaking large-scale GPU-optimized algorithm aimed at tackling the complex intertwined effects of electromagnetism, heating, and strain acting concomitantly during the quenching process of superconducting coils. We validate our model by conducting comparisons with magnetization measurements obtained from short multifilamentary $Nb_3Sn$ wires and further experimental tests conducted on solenoid coils while subject to ramping transport currents. Furthermore, leveraging our developed numerical algorithm, we unveil the dynamic propagation mechanisms underlying thermomagnetic instabilities (including flux jumps and quenches) within the coils. Remarkably, our findings reveal that the velocity field of flux jumps and quenches within the coil is correlated with the amount of Joule heating experienced by each wire over a specific time interval, rather than solely being dependent on instantaneous Joule heating or maximum temperature. These insights have the potential to pave the way for optimizing the design of next-generation superconducting magnets, thereby directly influencing a wide array of technologically relevant and multidisciplinary applications.

## Topic

Applications in large instruments such as high-field magnets, medical magnets and accelerator magnets

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