Simulation of Quench Propagation in a Double-Helix Superconducting Magnet with COMSOL MultiPhysics

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Abstract

Quench in a superconducting magnet is an electro-thermal instability induced by a local energy input in the winding. Quench can be created from a defect in the material, lower critical current areas in the winding or external energy input. A typical local quench starts as a hot spot, creating a resistive transition of the superconductor that propagates along the winding. HTS conductors exhibit low normal zone propagation velocities (NZPV) making quench detection challenging since the voltage across the superconducting winding increases very slowly. Quench detection is critical to the development of power applications of high temperature superconductivity (HTS) and therefore quench detection and propagation analysis is part of any superconducting magnet design. The peak temperature during a quench strongly depends upon the magnet topology, type of superconductor, operating temperature and speed of detection. Magnesium Diboride conductors present a NZPV in the range of a few cm/s at 20 K, which is orders of magnitude lower than that of low temperature superconductors, making fast detection challenging. During a quench, it is desirable to spread the dissipated energy as uniformly as possible throughout the winding in order to limit the peak temperature in the superconductor. Double-Helix (DH) magnets, as shown in figure 1 for different pole configurations, are based on modulated helical winding; one turn describes a long sinusoidal path in the magnet allowing the heat to spread both in axial and azimuthal directions during a quench. The paper presents the numerical analysis of quench propagation in a DH magnet wound with a commercially available MgB_2 wire in a fiber-glass composite matrix and operating at 20 K. The quench is induced by a small heater located on the first layer of the magnet close to the peak field area. The quench dynamics, peak temperature along with detection requirements are derived from the simulation results and reported. Figure 2 shows an example of simulation of a quench propagating in a low temperature superconducting solenoid; the iso-surface represents the volume above the superconductor critical temperature.

Figures used in the abstract

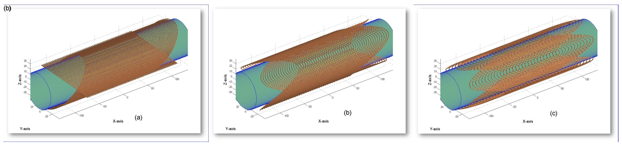

Figure 1: Double Helix winding configurations (a) Dipole – (b) Quadrupole – (c) Sextupole

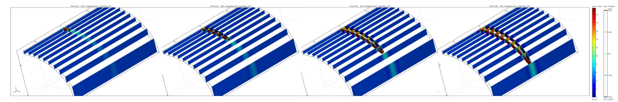

Figure 2: Quench propagation in a superconducting solenoid. Color represents the temperature, the iso-surface shown the area above the critical temperature of the superconductor