Quench Propagation and Detection in a YBCO Racetrack

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Abstract

High temperature superconductors (HTS) such as YBCO coated conductors show great promise for future application where high magnetic field is needed. The superconducting state only exists under a critical surface defined in the (J,T,B) space, with J being the current density carried by the superconductor, T the operating temperature and B the applied magnetic flux density. Therefore electro-thermal instabilities can occur when one of the critical values of J, T or B is exceeded. Quench is the process by which a current carrying superconducting conductor changes rapidly and irreversibly from the superconducting state to the non-superconducting state (normal state) creating a dissipative area leading to an increase of the temperature. As a result, a hot spot may potentially damage the superconductor if left unprotected. During a quench in a HTS magnet, the normal zone spreads throughout the coil (Figure 1), raising the voltage across the winding that can be used for detection. A detection voltage threshold is implemented to detect the quench and take protective actions. When the voltage reaches the set threshold, the current in the winding is decreased exponentially in order to simulate the discharge of the energy stored in the magnet in an external resistor. A COMSOL® model was developed to simulate the quench propagation in a HTS magnet as well as the detection and protection. The model uses thermal and magnetic studies and is highly non-linear and anisotropic with the magnetic field (magnetic field distribution was performed and displays in Figure 2). The winding electrical and thermal properties have been homogenized so as to speed up the simulation. The quench analysis of a YBCO racetrack is studied with varying parameters, including operating temperature, current density and conductor topology. COMSOL Multiphysics® was used in this study because of its ability to perform multiphysics simulations, handle highly non-linear problems and its parametric analysis capabilities allowing for automated determination of the minimum quench energy. This work was performed as part of a NASA sponsored project on the influence of the conductor and winding configuration on the quench behavior in the rotor winding of a superconducting machine.

Figures used in the abstract

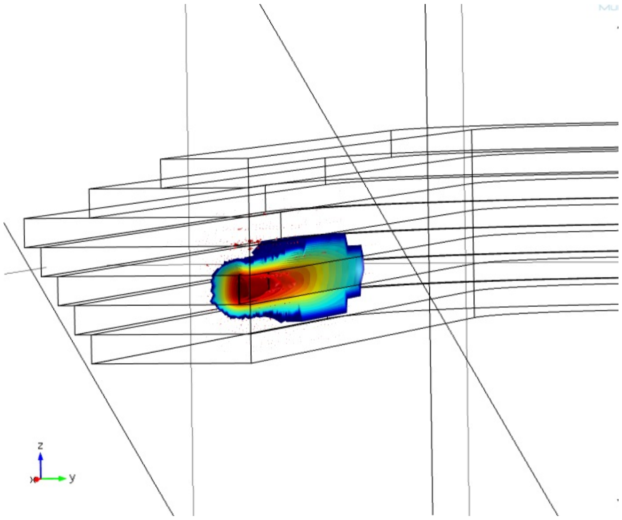

Figure 1: Normal zone front in the winding during the quench

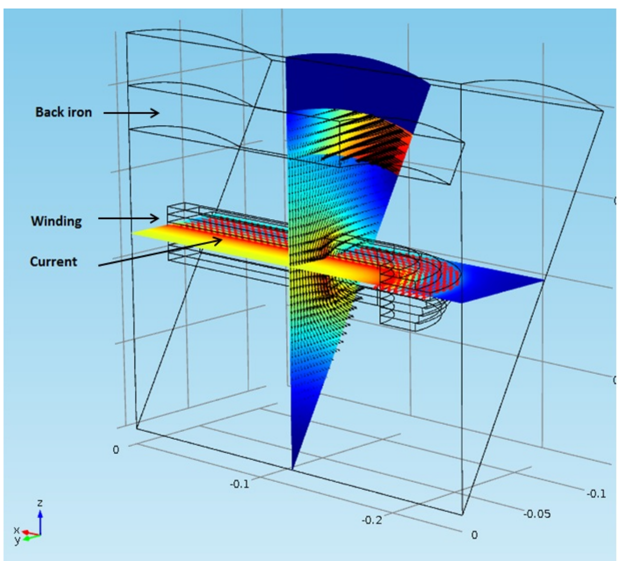

Figure 2: Magnetic field distribution in one fourth of the winding