Abstract

Superconducting accelerator magnets with increasingly high magnetic fields are being designed to improve the performance of the Large Hadron Collider (LHC) at CERN. One of the technical challenges is the magnet quench protection, i.e., preventing damage in the case of an unexpected loss of superconductivity and the heat generation related to that. Traditionally this is done by disconnecting the magnet current supply and using so-called protection heaters. The heaters suppress the superconducting state across a large fraction of the winding thus leading to a uniform dissipation of the stored energy. Preliminary studies suggested that the high-field Nb_3Sn magnets under development for the LHC luminosity upgrade (HiLumi) could not be reliably protected using the existing heaters. In this thesis work I analyzed in detail the present state-of-the-art protection heater technology, aiming to optimize its performance and evaluate the prospects in high-field magnet protection.

The heater efficiency analyses focused on the time delays from heater activation to normal zone initiation in the coils. I developed a numerical simulation tool CoHDA (Code for Heater Delay Analysis) to model the heat transfer from the heater to the cables and estimate the delay based on the superconductor critical surface. All the important parameters relative to the heater, the cable, and the magnet operation conditions were included. The simulation results were validated experimentally using measured data from several R&D Nb_3Sn quadrupoles and dipoles. Then, a method based on parametric sweeps was utilized to optimize the heater layouts. The goal was to minimize the delay to quench the entire coil, taking into account the different field regions. New heater designs were proposed for the Nb_3Sn R&D prototype LHQ and the HiLumi quadrupole QXF. Finally, I simulated the heaters in high temperature superconductor magnets, which are being considered for the LHC energy upgrade. Consequently, I proposed technology improvements to increase the heater energy in order to meet the requirements also in these very high-field magnets.