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Thermal analysis of powering and protection transients in a superconducting magnet for medical applications

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SIGRUM (Superconducting Ion Gantry with Riboni's Unconventional Mechanics) project comes from the strong collaboration between 'Centro Nazionale di Adroterapia Oncologica'(CNAO), in Pavia, Italy, and CERN. This centre, relying on CERN experience in accelerator particles, wants to improve cancer treatments with a novel superconducting ion gantry structure.
The magnet is operated at a temperature of 4.5 [K] and a nominal current of 2144 [A] generating a 3.3 [T] magnetic field in magnet aperture. For this magnet design, at nominal current the current-sharing temperature is about 6 [K].
Above this value the magnet quenches, losing its superconducting properties, with the subsequently magnetic field drop and losing the control on the beam.
The project wants to assess the impact of transitory losses on the magnet thermal transient, proving that the actual magnet design does not need any special features to improve the cooling in order to limit the coil peak temperature below 6 [K].
A thermal transient analysis has been performed with a COMSOL© model generated by STEAM-SIGMA in order to investigate on the temperature increase in the whole superconducting combined function magnet during repetitive triangular 60 seconds-long power cycles (0.1 [T/s]).
The thermal analysis has proved that, in the reference operating condition, and even under conservative assumptions (both for the losses and cooling features), repetitive magnetic cycling does not result in excessive temperature (below 6 [K]) during repetitive power cycles.
Furthermore, a parametric analysis has been performed to investigate on worse scenarios than the reference one, changing the cooling features and the transitory losses amplitude, in order to understand in which scenarios the quench may occur.
Finally, a quench protection system based on the energy-extraction has been proposed. The quench transient has been simulated using STEAM-LEDET. The magnet self-protectability has been evaluated.

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