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Quench Protection of the HL-LHC Hollow Electron Lens Superconducting Solenoid Magnets

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The High-Luminosity LHC project is an upgrade of the Large Hadron Collider (LHC) and comprises the installation of two Hollow Electron Lens (HEL) systems, each on one beam on each side of LHC point 4. The system allows for a controlled depletion of hadron beam tails and an enhanced hadron beam halo collimation. The system consists of 22 magnets with independently powered circuits, among which are seven solenoid magnets of five types. The largest solenoid is 1.6 m long, with 180 mm bore diameter and central field of 5 T at 330 A and 4.5 K.

The energy stored in each solenoid magnet ranges from 0.3 kJ to 495 kJ, with the total of 1.2 MJ, representing the majority of the total system stored energy. This contribution focuses on the quench protection of these seven solenoid magnets. All the magnets use the same Nb Ti/Cu rectangular wire with enamel insulation and are resin impregnated with pre preg between layers.

Based on STEAM-LEDET simulations, a quench protection scheme is devised, with focus on minimizing complexity and cost and respecting the limits of maximum peak voltage-to-ground and hot spot temperature of 500 V and 120 K, respectively. An energy-extraction-based quench protection is implemented for the two largest magnets to reduce recovery time after quench, whereas the other magnets are self-protected upon timely switch-off of the power converter. Active quench detection is based on voltage taps and relies on CERN's Universal Quench Detection System. Several quench scenarios are considered and presented, considering various wire and coils impregnation characteristics, induced eddy currents in the conducting cryoshields, and the effect of possible quench-back due to AC loss.

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