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Thu-Mo-Po.08-03: Calibration of numerical simulations of hot spot generation in regular and CFD REBCO tapes based on electrical measurements

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Quench detection and protection of high-temperature superconductor (HTS) magnets remain a challenge. Even if the enthalpy margin of HTS conductors is two to three orders of magnitude than low-temperature superconductors (LTS) conductors, a normal zone can be induced by local critical current inhomogeneities or sudden heat load. Because of the high enthalpy and current margins of HTS magnets, the normal zone propagation velocity (NZPV) is low, making it difficult to detect a local quench. A higher NZPV is expected to facilitate quench detection.

In the last years, it has been demonstrated that the NZPV in REBCO tapes can be enhanced by at least one order of magnitude with the current flow diverter (CFD) concept. The CFD concept relies on increasing the current transfer length (CTL) between the superconducting layer and the stabilizer by inserting a patterned electrical resistance between the REBCO layer and the stabilizer or by using the buffer layers between the REBCO layer and the substrate. This increase of the CTL results directly in an increase of the NZPV.

To properly design quench detection systems, it is useful to understand the physics behind the formation of a normal zone in REBCO tapes and to develop numerical simulation models that predict accurately the quench behavior. This requires performing experiments to calibrate the models. In this work, the voltages generated by a hot spot in commercial and CFD REBCO tapes were measured. The measurements consisted in applying a constant current until a voltage threshold was reached, triggering an exponential decay of the current. Voltage thresholds were varied between 5 mV and 20 mV while the discharge time constant was set to 11 ms. The experiments were done in a bath of liquid nitrogen at ambient pressure (77 K). A NdFeB magnet was used to reduce locally the critical current by approximately a factor of 2.

The samples consisted in modified commercial REBCO tapes from SuperPower. The base samples were 10 cm long and 4 mm wide, including a 50 microns thick Hastelloy substrate and a 2.5 microns thick silver layer. From these base samples, two different architectures of REBCO tapes were fabricated. The first architecture, called "regular"tape, consisted in adding a 2.5 microns thick copper layer on both side of the sample, for a total of 5 microns of copper. The second architecture, called "CFD"tape, was first modified to include a highly resistive patterned layer (CFD layer) between the superconducting and the silver layer. Then, a 5 microns thick copper layer was deposited on the substrate side only.

In all experiments, for the same applied current, the threshold voltage was always reached faster with the CFD tape. Furthermore, in the case of the CFD tape, once current sharing between the superconducting and silver layers has started, a rapid and strong generation of voltage is observed, up to 50 times faster than in the regular tape. These results were used to calibrate the simulation models, in which an alternative to the traditional E-J power-law model for REBCO resistivity had to be implemented to obtain accurate results. Furthermore, these experiments demonstrated the need to consider magnetic diffusion effects in the calculations during the quench of CFD tapes.

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