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A-formulation method for full 3D FEM computation of the superconducting magnetization

A-formulation is the basic approach for solving electromagnetic problems using FEM. Utilizing time derivatives of vector potential allows computing of the critical current density distribution in agreement with the critical state model. Previously, such superconductor's representation in 2D delivered results in AC losses estimation for single wires, cables and coils with good agreement with the experiments. Unfortunately, only small part of superconducting device allows a 2D simplification. A correct interpretation for time derivative of the vector potential in 3D space requires to introduce an additional condition for current density distribution inside the superconducting domains. With such modification the modeling procedure based on A-formulation can be extended to 3D problems in superconductors.

Proposed method was used for 3D simulation of superconducting cube, placed in alternating magnetic field. Afterwards, computed current distributions in cube's cross-sections show decent agreement with those obtained by three other numerical methods –H-formulation (FEM), Minimum Electro-Magnetic Entropy Production (MEMEP) and Volume Integral Method (VIM). Experimental testing of our approach continued on modeling the magnetization of BSCCO cylinder and of single and multilayer configurations of ReBCO tapes helicoidally wound on cylindrical former. For all experiments, superconductors were magnetizing in transverse external magnetic field orientation (perpendicular to the main axis of the cylinders). Computed magnetization loops for mentioned cases show good agreement with experiments and confirm the method validity at least for used frequency range –tens of Hertz.

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