Simulation of Flux Density in a Hybrid Coil SMES Using COMSOL Multiphysics

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Abstract

Energy storage is an essential component for hybrid power system using non-conventional energy resources. Batteries, compressed air energy storage, pumped hydro plants etc. have been developed for storage. However, these have demerits like losses involved in energy conversion and time delay. Superconducting Magnetic Energy Storage (SMES) can be a good alternative as it stores electrical energy in the form of magnetic energy involving no loss during supplying the same. Solenoidal or toroidal low temperature superconducting coils (LTS) are in use for SMES [1]. First and second generation high temperature superconducting (HTS) coils are in operation either independently or with LTS coils in hybrid mode [2,3]. Such a hybrid coil made of BSCCO - 2212 (inner coil) and Nb-Ti (outer coil) was designed [3]. Thermal runaway and excitation tests of the prototype made of the same coil were performed [4,5]. In this work, the 3-dimensional magnetic field distribution of this hybrid coil is simulated using COMSOL Multiphysics. 3D Magnetic Fields section of the AC/DC module is considered for geometry (Figure 1). Preset Studies>Stationary option is selected for DC operation. The coil current densities are Jh,0 = 26.575 A/mm2 (HTS) and Jl,0 = 69.633 A/mm2 (LTS) as declared in Global Definitions> Parameters section. 3D model is built using the Work Plane and Revolve options. Magnetic Insulation is applied at different boundaries. The magnetic vector potential A is initialized to null component-values. The External Current Densities 1 and 2 are declared in the general Cartesian coordinates for both the outer and inner coils. Predefined Coarse meshing of Free Tetrahedral type is selected with Custom Maximum Element Size. The entire model with mesh is built using Build All option and the results are studied using 3D Plot Group>Volume Plot and Slice Plot. Figures 2 and 3 show the magnetic flux density distribution in the LTS and HTS coils of the hybrid coil SMES. The simulations clearly depict the high concentration of the field in the regions near the windings of coaxial solenoids. The peak field is nearly 7.4075T. The experimental value obtained was about 8T [3]. This closely agrees with the simulated value. In this simulation we neglected the slight pitch of the solenoidal coils. Hence, there may be some deviations from the actual field flux density distribution and this is reflected in the results.

Figure 4 shows that the field density falls to a low value outside the solenoid (desirable for an SMES) with a sudden descent due to the presence of air gap in between the inner and outer coils.

Reference

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3. K Koyanagi, K Ohsemochi et al., “Design of a High Energy-Density SMES Coil With Bi-2212 Cables,” IEEE Trans. on Applied Superconductivity, 16 (2), 586-589 (2006).
4. H Kojima, N Hayakawa et al., “Thermal Runaway Characteristics of Bi-2212 Coil for Conduction-Cooled SMES,” IEEE Trans. on Applied Superconductivity, 17 (2), 2010-2013 (2007).
5. T Tosaka, K Koyanagi et al., “Excitation Tests of Prototype HTS Coil With Bi-2212 Cables for Development of High Energy-Density SMES,” IEEE Trans. on Applied Superconductivity, 17 (2), 1959-1962 (2007).

Figures used in the abstract

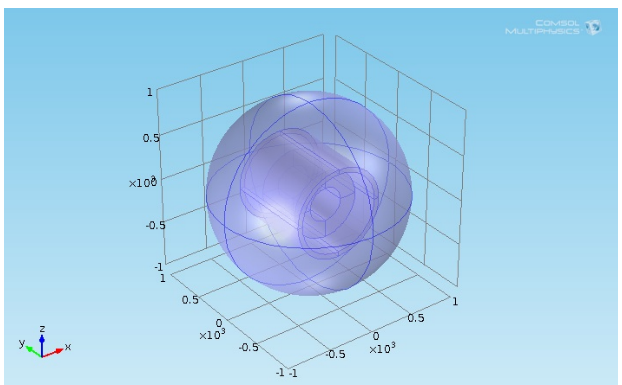

Figure 1: Model Geometry.

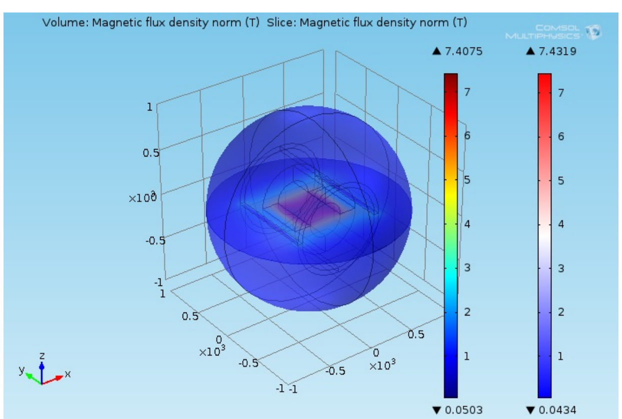

Figure 2: Volume and slice plots showing magnetic flux density.

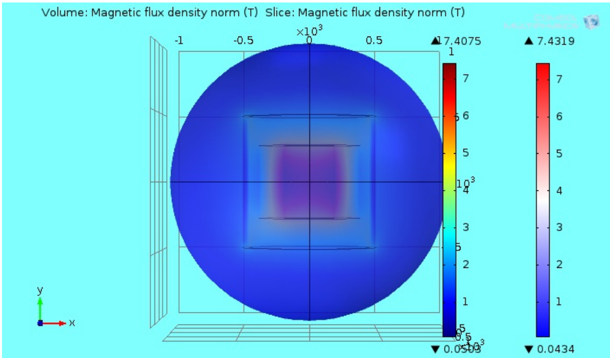

Figure 3: Volume plot seen from a direction normal to x-y plane.

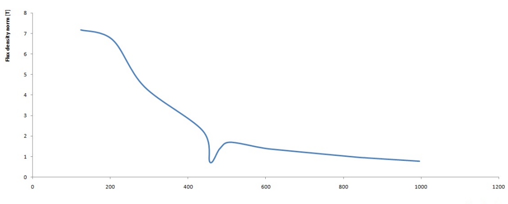

Figure 4: Flux density variation with x for y = 1.56675mm, z = -2.27×10^(-13)mm.