Teaching Future Engineers About Superconductors For Power Applications With An App

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Abstract

High-Temperature Superconductors (HTS) can be superconducting in liquid nitrogen (77 K), holding immense promises for our future. They could enable disruptive technologies such as nuclear fusion and power applications. In a power system, for instance, high short-circuit currents can exceed the operational current of a power system by more than ten times, putting at risk many equipment in the system. The Superconducting Fault Current Limiters (SFCL) can limit the prospective fault current without disconnecting the power system, becoming more and more important in future grids. With a growing interest in modeling and commercializing SFCLs, a requested challenge is how to teach and to explain their operation to students and future engineers. To help them visualize the potential use and benefits of an SFCL, we created a simulation app. This app, developed in COMSOL Multiphysics® and downloadable from the HTS Modelling Website, allows students to investigate the electro-thermal response of a Resistive SFCL (RSFCL). The heat equation is solved in 1-D (temperature variation across the thickness of the tape) within the Heat Transfer interface (ht) and it is coupled with an equivalent circuit model (current sharing between the various layers of the tape) of the RSFCL conductor, modeled in the Electric Circuit interface (cir). The 1-D domains represent the layers constituting the HTS coated conductor, namely silver, Hastelloy and superconducting layer.
A sinusoidal voltage signal is imposed on the circuit, while a load resistor R_Load draws the nominal current from the source. A switch in parallel to the load resistor, when closed, simulates the fault occurring at a given time and draws the fault current through a resistor R_fault. In the simulations, the geometrical parameters as well as the superconducting properties of the device can be modified. In a previous work of ours, this model was used to evaluate the electro-thermal response of an SFCL using different resistivity models [1]. The importance of the amount of silver stabilizer necessary to protect the device from over-heating occurring during a fault current can be investigated with this app. In addition, the effects of having a sharp nonlinear transition from the superconducting to the normal state (intrinsic property of the superconductor) to obtain a current limitation can be well explored for a better understanding. This app can be helpful for students to acquire knowledge of the roles played by the various parameters, helping the instructor to teach the students about the consequences of superconductors in real-life applications, without the prerequisite of extensive modeling or experimental setup.
[1] N. Riva, F. Sirois, C. Lacroix, W.B.T. de Sousa, B. Dutoit, F. Grilli - Modified E-J model of REBCO tapes for numerical simulations in the overcritical current regime, DOI: 10.1088/1361-6668, 2020

Figures used in the abstract

Figure 1

Figure 2

Figure 3