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Modeling of superconducting current limiter as an application of multiphysics finite element model

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Abstract. Modeling of superconducting power apparatus requires the solution of simultaneous differential equations which describes the coupled superconducting, electromagnetic, and thermal characteristics. Coupled problems require the use of multiphysics finite element method programs in which the solution of simultaneous differential equations can be done in parallel and/or sequential steps with processor and especially RAM memory represent the major constraint. We will address in this article the modeling of the transition into the normal state of a superconducting current limiter constituted by four parallel YBCO coated conductors with 12 mm width x 0.1 mm thickness each simulating cycles of operation under short circuit ac current.

Multiphysics modeling of physical phenomena has recently received great attention of researchers and instructors both as an analytical tools for simulating complex coupled problems [1] as well as a teaching tool of classical finite element modeling and analysis [2]. Solving simultaneous partial differential equations which describes coupled physics problems were done by specific softwares requiring a steep learning curve [3]. The COMSOL software has evolved from a Matlab-based software to a fully-fledged programming environment wherein coupled physics problems are solved by describing the geometry, the model and constitutive differential equations along with the boundary conditions without concerning which finite element to be used [4].

In this work we have studied the transient behavior of a superconducting current limiter based on a YBCO coated conductor [6]. We used a formulation from Roy et al. [7] which described the problem taking into account the current-voltage characteristic curve of a superconducting tape by a potential model; the Faraday and Ampere's law from Maxwell differential equations form coupled to heat equation for which a Neumann boundary condition is related to the heat convection for liquid nitrogen bath cooling. The Fig. 1 shows a schematic superconducting YBCO ($YBa_2Cu_3O_{7-x}$ ceramic) coated conductor produced by a MOCVD process. The critical current capacity at 77 K of this superconductor tape (size: 12 mm x 0.1 mm) is 220 A and the corresponding current limiter module made with four 40-cm length parallel conductors displayed the current-voltage waveform shown in Fig. 2.

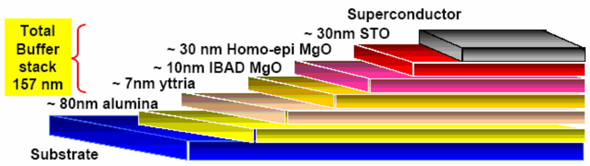

Figure 1: Schematic YBCO coated conductor.

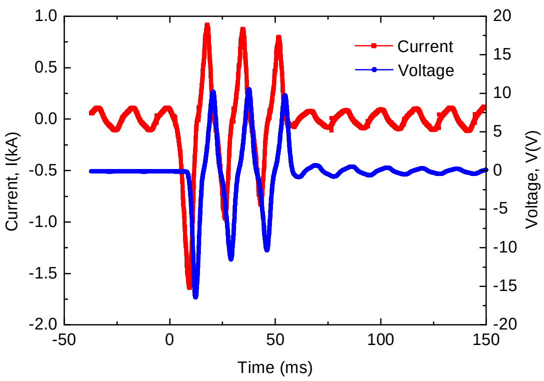

Figure 2: Current and voltage waveforms generated by a short circuit test of three cycles duration.

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