PhD in Physics

Research Title: Multi-physics modelling of superconducting cables for application in nuclear fusion

Multi-physics modelling of superconducting cables

Funded by	Eni S.p.A.

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Context of the research activity	The proposed research activity is focused on the multi-physics modelling of superconducting cables for application in nuclear fusion. The superconducting materials are fundamental for the nuclear fusion devices that work with the magnetic confinement of the fusion plasma. The superconducting cables are used for the electromagnets that are needed for generating strong magnetic fields. Therefore, the design of superconducting magnets is a critical step in the fusion device project. The peculiar electromagnetic behavior of superconductors (Meissner effect, vortex state, nonlinear current-voltage and resistance vs temperature characteristics) has to be taken into account carefully. At the present state-of-the-art, a quantitative modelling of the superconducting physics is still lacking for designing complex devices like fusion magnets. The scope of this research activity consists in the formulation of a phenomenological model, which accounts for the peculiar behavior of the superconducting materials. Special attention will be devoted to novel superconducting compounds, both high temperature superconductors (HTS) and iron-based ones (IBS). The modelling will be performed

	mainly with the FEM software Comsol Multiphysics®, aiming at formulating a multi-physics framework with coupling between electromagnetism and thermal diffusion. The design and modelling of superconducting windings, which are the essential components of the fusion magnets, will be accompanied by the study of the ancillary parts (cooling stage, thermal shielding, quenching protection). When applicable, selected experiments will be performed in order to validate the basic predictions of the multi-physics model.

Objectives	The following objectives are expected for the present proposed research activity: 1) Implementation of state-of-the-art existing electromagnetic models of superconductors in Comsol Multiphysics®; 2) Design of basic geometries for superconducting windings, aimed at the design of electromagnets for fusion application; 3) Electromagnetic simulation of superconducting windings (in particular, HTS and IBS); 4) Elaboration of multi-physics models for coupling the electromagnetic and the thermal fields (nonlinear electromagnetic response of superconductor plus thermal diffusion); 5) Design of complex superconducting windings for simulating parts/sections of electromagnets for nuclear fusion reactors; 6) Multi-physics simulation of complex superconducting windings; 7) Study of ancillary components of the superconducting electromagnets: cooling stage, thermal shields, quenching protection system; 8) Validation of selected simulation predictions with experiments.

Skills and competencies for the development of the activity	Knowledge of classical electrodynamics; knowledge of basic superconducting phenomenology; experience with FEM simulations, in particular, COMSOL Multiphysics®