ENERGETICS

DM 630/DTT - Study and development of advanced cryogenic solutions for superconducting magnetic fusion devices and application to DTT facility

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Context of the research activity	The PhD project aims at developing and qualifying reliable system-level, numerical models to be used in support of the design and operation of future tokamaks. The dynamic model of the refrigerator will be used to support the definition of the cold tests of the DTT superconducting coils. Progetto finanziato nell'ambito del PNRR a valere sul DM 630/2024 – CUP E14D24002370004
	Most of the existing large-scale cryogenic plants for fusion devices are first-of-a-kind, tailored plants designed by the suppliers and operated with several manual interventions of operators trained (sometimes by trial-and-error procedures) during the plant commissioning. Therefore, the construction of new tokamak experiments will benefit from the development of numerical models of such plants, capable to implement and test suitable automatic control strategies. These system-level models should be qualified to ensure reliability and should be fast to allow parameter scan in support of the design team, but also sufficiently detailed to allow the test of sophisticated controls to be adopted during the operation. The target of the present project is therefore the optimization of the design of new, efficient and cheap refrigerators for superconducting magnetic fusion devices being built around the world, with special reference to DTT facility. Besides being efficient, the advanced refrigerator concepts must also satisfy safety requirements, reducing the risk of damaging safety-important or unreplaceable components in the plant, and must be sufficiently flexible to be standardized and allow a series production, as opposed to the costly tailored production pursued so far in the fusion field. This aim will be pursued by suitable reliable numerical models, being

Objectives	presently developed and qualified, such as the cryogenic circuit module of the state-of-the-art 4C code. The project work breakdown structure can be broadly divided in three subtasks: 1) The candidate will spend some training periods in He refrigerator design and operation at ENEA Frascati premises. This will allow the candidate to understand how a He refrigerator is operated and controlled, as well as all the possible major safety concerns, to proper implement control strategies in the model and simulate safety-relevant transients. At this stage, the candidate will also acquire some familiarity with the clients of the refrigerator, such as superconducting magnets and pellet injection system, but also cryopumps and thermal-shield. 2) The candidate will develop the Modelica model of the tokamak He refrigerator using the 4C code. Also the model of all its clients will be developed, as it is required to simulate all possible transients, including the accidental ones. Whenever needed, detailed CFD models of severe (e.g. loss of coolant and loss of vacuum) accidents will also be developed; they will be also qualified against existing data (if available), possibly collected under controlled conditions, e.g. during the cold tests of the DTT coils in the Frascati Coil Cold Test Facility (to be carried out in the forthcoming years). 3) The reliable model will be applied to simulate the normal operation, supporting the refrigerator optimization depending on the different operating conditions and control strategies of the clients. Different solutions will be compared to select the best option. In parallel, deterministic safety analyses will be carried out, simulating the most relevant accidental transients to prove the capability of the design to face such severe conditions, protecting the integrity of safety-relevant and unreplaceable components.

Skills and competencies for the development of the activity	The ideal candidate is a strongly motivated student with a background in thermal-hydraulic plant modeling. Knowledge of object-oriented programming is required, with special reference to Modelica. The experience in superconducting coil test campaigns is also valuable, as well as the knowledge of the cryogenic technologies.