

Superconducting electric machines and cryogenic power electronics for high-efficiency, reliable and power-dense eNERGY conversion

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S. Vaschetto¹, L. Frosini², C. Concari³

¹ *Politecnico di Torino, Dipartimento Energia*

² *Università degli Studi di Pavia*

³ *Università degli Studi di Parma*

The PRIN2022 project SYNERGY investigated the application of cryogenic and superconducting technologies for electrical machines and drives, targeting high-efficiency, reliable and power-dense energy conversion. The project involved Politecnico di Torino on superconducting electrical machines, the University of Parma on cryogenic power electronics and control, and the University of Pavia on diagnostic techniques. In particular, the project focused on the application of High-Temperature Superconductors (HTS) in rotating electrical machines and on the key open research questions that still limit their widespread practical deployment. The activities combined multiphysics modelling, characterization of ReBCO tapes and magnetic materials at 77K, and tests on reduced-scale electrical machines immersed in liquid nitrogen. Dedicated multiphysics models were developed to include superconductors in electrical machine simulations, including a 2D slot model for AC-loss estimation and for assessing the effect of leakage magnetic fields on HTS tapes. Hybrid experimental-numerical procedures were used to estimate the performance of electrical machines equipped with superconducting windings, highlighting benefits and practical limits due to AC losses, magnetic-field orientation, and the potential reduction of the critical current when HTS tapes are embedded in electrical machine slots. Overall, SYNERGY contributed modelling tools, experimental evidence and design guidelines supporting the transition of superconducting electrical machines from exploratory concepts toward model-driven engineering solutions.

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