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Thu-Af-Po.03-05: Design, fabrication, and operation of a nested cryogenic high purity aluminum winding armature for a partially superconducting motor

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High-purity aluminum armatures present a viable alternative to traditional superconducting armatures, which can face quench issues during AC operation despite their high-power density. Leveraging the low electrical resistance and lightweight properties of high-purity aluminum at cryogenic temperatures, this study presents the development of an armature for a 500 kW partially superconducting motor operating in liquid nitrogen. To maximize the cooling performance of the high-purity aluminum winding and enhance armature performance, careful consideration of the contact area between the winding and liquid nitrogen is crucial. In this study, a nested winding structure is adopted, and the ratio between the conductor and cooling channels is optimized. Through multi-physics analysis, the optimal current density and geometry, which maintain a temperature below the insulation breakdown limit while considering cooling performance, are determined. Furthermore, a mechanically robust bobbin structure that maximizes the cooling area is designed. Subsequently, nested windings are implemented using high-purity aluminum wire. The armature is then operated at the target current density to measure losses and analyze the performance of the final 500 kW motor. Based on the experimental results obtained with liquid nitrogen, the performance under other cryogenic conditions, such as using liquid hydrogen (LH2) and liquefied natural gas (LNG), will also be analyzed.

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