Evaluation and Optimization of AC Losses in a Fully Superconducting Machine in Off-shore Wind Applications

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Abstract
Off-shore wind turbines are becoming an integral part of future large-scale renewable energy generation initiatives. There is consensus that the scale-up of offshore wind turbines to the 10-MW power range requires the deployment of the progress in superconducting (SC) technologies. Several partial and fully SC machine designs have been proposed and demonstrated for off-shore direct-drive wind turbines. In theory, fully SC machines can further improve the efficiency and power density of wind turbines with a reduced levelized cost of energy. However, fully SC machines pose many technical challenges that must be addressed before commercial production is possible. One key challenge in fully SC machines is the high AC losses generated in the armature winding. These losses pose a significant barrier to high-speed applications, but direct-drive wind turbines that operate at low frequencies are expected to incur manageable AC losses.

Most of the fully SC machine designs proposed in literature are primarily focused on EM designs. However, practical implementation of such designs heavily relies on the accuracy of AC loss estimations and the specific cryogenic heat extraction method used. For the design of feasible machines, an extensive effort is required to minimize these losses and validate the AC loss models. This presentation provides a detailed evaluation of the AC losses in a 10-MW, fully SC machine with an optimized machine topology to manage AC losses. We study an inside-out synchronous machine with MgB$_2$ race track coils and present a rigorous AC loss calculation based on EM finite element analysis (FEA). Our simulation results are validated against experimental data for an individual race track coil.