ECE 590 I
POWER & ENERGY SYSTEMS SEMINAR

Monday, September 20, 2021, 3:00 – 3:50 p.m.

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CHEETA Year 2 Review

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The Center for High-Efficiency Electric Technologies for Aircraft is a multi-disciplinary consortium of several research institutions with the aim of enabling commercial all-electric aircraft. Results from Year 2 of the grant will be summarized, with a focus on electrical systems research and superconducting machine design. Future plans will also be discussed.

Multiphysics Optimization of Rotating Cryogenic Machine Topologies for a Hydrogen-Powered, Electric Propulsion Commercial Aircraft

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The Center for Cryogenic High-Efficiency Electrical Technologies for Aircraft (CHEETA) is a NASA-funded project that aims to design an ultra-efficient (efficiency > 99%) electrical drivetrain system with high specific power motor (>25 kW/kg) for commercial aviation. The system uses liquid hydrogen not only as the energy source for the fuel cells but also as the cryogen. This eliminates the bulky cryocooler-cryogenic systems which would be otherwise required, thus enabling superconducting (SC) electric motor propulsion. Furthermore, a liquid cryogen has various other advantages, including excellent thermal management, and the ability to exploit the low resistivity of "conventional" conductors like copper or aluminum. This talk considers a 40 MW regional airplane and analyzes the feasibility of three motor topologies: (1) a conventional cryocooled machine, (2) a fully SC machine and (3) a partially SC machine. In each machine topology, active shield, iron shield, inner and outer rotor configuration are investigated. Low ac loss MgB2 cables, Hyper Al conductors are considered for armature windings and HTS and MgB2 cables are considered for field windings. In addition, permanent magnets (PM) are explored as an alternative to SC field windings.

The many tradeoffs between these topologies necessitate a detailed comparison study. Generally, fully SC design uses back iron to contain the flux within the machine, thus enhancing the air-gap field and reducing the amount of SC needed but results in low specific power. An active shield topology uses shield coils to eliminate back iron and increases specific power results in design complexity. Also, the risk of quenching in SC windings and rotor cooling impacts SC machine reliability. Partially SC machine topologies use conventional copper wires in the armature and improves reliability. A PM motor with SC armature coils simplifies the rotor cooling. However, demagnetization of the magnets under fault conditions needs to be analyzed. In this talk pros and cons of each topology at the required power level are analyzed, and the optimal motor topology for enabling commercial electric aircraft is identified.