Contribution ID: **330** Type: **Invited Oral**

M3Or3A-01: [Invited] Cryogenic Thermal Management of Power Conversion Devices on Liquid Hydrogen Fueled Electric Aircraft

Wednesday 21 May 2025 14:00 (20 minutes)

Cryogenic propulsion with hydrogen-burning electric generators and fuel cells is a promising way to reduce aviation carbon emissions. Liquid hydrogen serves as aircraft fuel and a 20 K heat sink for superconducting and other electrical devices. Power electronics are a crucial component of an electric aircraft power system. As aviation transitions toward electric aircraft, power conversion systems with high efficiency and high-power density are needed. Power converters are required to connect AC devices, such as generators and motors, to the DC distribution bus. Conventional power electronics add significant heat load to cryogenic systems, requiring specialized interfaces between cryogenic and room-temperature conductors. Cryogenic power electronic systems completely change how aircraft power systems are designed and minimize the complexity of power transition between the room temperature and the cryogenic devices for power conversion.

Hybrid power and distributed propulsion systems will make future electric aircraft more efficient and environmentally friendly. However, a major challenge is that the necessary technology is not yet available for large commercial electric aircraft. One technology gap is high-efficiency, high-density power electronics, including cryogenic power electronics.

The primary motivation for developing cryogenic power electronic devices is to improve power density, enhance system-wide efficiency, and boost the reliability of these devices. This paper explores cryogenic power electronics through experimental studies on semiconductor devices, passive components, integrated circuits, and dielectric materials. It analyzes superconducting device requirements and cooling concepts essential for cryogenic systems. The study discusses principles for cryogenically cooled converters, achieving high efficiency using an advanced testbed that simulates varying temperatures and high-altitude conditions, cryogenic thermal insulation, and partial discharge tests at cryogenic temperatures. Cryogenic helium gas circulation is the primary mode of thermal management of cryogenic power conversion systems, and it is the primary focus of the modeling and experimental investigations.

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Session Classification: M3Or3A - [Special Session] Transportation III: High Power Components, Thermal Management