Cryogenically Cooled Electric Power Train for Electrified Aircraft Propulsion

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***Abstract*— Hybrid and Series Turbo Electric Aircraft architectures have their benefits with respect to fuel burn and CO_2 emissions. However, it is extremely difficult to beat the combined power density and efficiency of a gas turbine engine of a single-aisle aircraft (20MW class) using state-of-the-art electric drive train technologies. Hence Raytheon Technologies is working with DOE ARPA-E to develop next the generation of an electric propulsion system based on a superconducting motor, its motor drive and a cryocooler. In a series turbo-electric system, Multi-MW class turbo-generators generate the electric power which is then distributed to various electric propulsion motors and their drives. Such an electrical system is heavy as it produces a lot of heat which must be rejected to the ambient. Currently, carbon-neutral liquid fuels, especially cryo-fuels such as Bio-LNG (liquid form at 120K) and Liquid Hydrogen (liquid at 20K), offer a formidable heat sink before the fuel is combusted in a turbo-generator to generate electricity. Using cryo-fuel as a heatsink the power density and efficiency of the electric drivetrain can be drastically improved over state of the art. In this ARPA-E program, the fully superconducting motor (2.5MW) is operating at 20K while the motor drive (2.5MW) is operating at 120K. This approach yields very high power density and efficiency of the drive train components (>12.5kW/kg and >93% respectively – goals set by ARPA-E considering a 20MW electrified aircraft grand challenge). Ultra-light cryocoolers are essential to provide the necessary thermal capacitance between the heat sink and the heat source. In the case of Bio-LNG as a cryo-fuel for the gas turbine, a cryocooler is needed to bring the motor coolant temperature down from 120K to 20K. However, if LH_2 is used as a cryo-fuel, depending on the design, the need for a cryocooler may be eliminated or minimized considerably. Accordingly, this paper will highlight the desired metrics of the superconducting electric drive train for electrified aircraft propulsion and touch on the challenges in meeting them.**

***Keywords (Index Terms)* — Electric Aircraft, superconducting motor, liquid hydrogen, Bio-LNG, cryocooler, carbon-neutral liquid fuels.**

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