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Design and Scaling of a 40-MW-class Electric-Wire-Interconnect-System (EWIS) for Liquid-H_2 Fuel-Cell Propulsion

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***Abstract* – The aerospace industry is the last major transportation industry working to transition to hybrid-electric technology for propulsion. Nearly exponential growth is occurring recently for electric aircraft development, with reportedly more than 300 companies started worldwide in the last 2-3 years. As of 27.Apr.2022, pre-orders for electric aircraft exceeded 5,500 aircraft and $29B sales, even though many aircraft have not been certified for flight yet. The goals for electric drivetrain components are difficult and aggressive, as set by ARPA-E ASCEND to achieve ~ 93% efficiency at the system level and > 12 kW/kg for the electric motor drive combined with a thermal-management-system (TMS). And for the NASA SUSAN program the goals for major components are to simultaneously achieve ≥ 99.5% efficiency and power densities of 30-50 kW/kg for the major components, and ~ ≥ 95% efficiency for the system. Strong efforts worldwide are considering different technology approaches; however, it is generally understood that cryogenic/superconducting technologies have potential to meet those goals.**

The electric-wire-interconnection-system (EWIS) of an electric drivetrain is known to have by-far the largest mass fraction of all the components. This paper studies the EWIS of a 40-MW-class electric drivetrain, and compares different wire technologies including cryogenic metals, superconductors, and 'conventional' metals at ambient temperatures. The mass and heat loss scaling laws of the components of the electric drivetrain are required for varying power/voltage /ampacity levels (0-40 kA) and power-wire distribution architectures, which is a focus of this work. Electric power system components studied thus far include metal conductors (Cu-clad-Al (CCA), Al 99.999% 'hyperconductor'), busbars, current leads, metal/superconducting T-joints, high temperature superconducting (HTS) Y,RE-Ba-Cu-O cables, and cryoflex tubing. A weight and efficiency analysis of a 40 MW power drivetrain system will be provided, and material options for the EWIS will be compared. Superconductors might be considered the best technology options, with up to 30x less heat loss, and ability to cool with gaseous H_2 which is much simpler than cooling with liquid H_2.

***Keywords (Index Terms)* – Electric aircraft, hybrid-electric propulsion, MW-class electric drivetrain, electric power system, electric wire interconnect system, superconductor, busbar, tee junction, current leads, ultrapure Al, Copper-clad aluminum, electric wires, current density, liquid hydrogen, fuel-cell, efficiency, power density**

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