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Title

First Order Thermal Analysis Methodology for Hybrid-Electric Propelled Aircraft in Early Design Stages

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Abstract

The growing societal demand for zero-emission transportation and significantly greener aircraft has initiated serious research into electrification options of aircraft configurations and components [1][2][3]. One potential possibility under scrutiny is the turboelectric configuration using a kerosene-fueled engine which drives a generator providing enough electrical energy to operate and propel the aircraft. However, this approach leads to unprecedented amounts of electric power distributed through the aircraft. Even though the efficiencies of components such as generator, motors, converters, etc. have efficiencies of 95% or higher, for megawatt class aircraft this still results in very large amounts of low-quality heat dissipated throughout the architecture that need to be rejected. The necessary heat rejection is posing serious challenges for an efficient thermal management system.
The proposed paper is a sequel to our previous paper [4] that identified the starting point and way forward for a thermal analysis methodology applicable in preliminary design stages using a minimal amount of aircraft data. The paper focuses on the enhancements achieved in estimating the heat distribution using a nodal approach, comprising dynamic thermal analysis over the full flight profile, updated compartment model to describe the configuration in reduced thermal model terms, and step-by-step implementation of the integration of (sub-)system interactions. Each compartment or component is assigned to be a node. Each node is interconnected with other nodes allowing the exchange of heat. The thermal exchanges are described using straightforward mathematical relations for conduction, convection and radiation. Input for this nodal approach is a given typical flight profile describing the required thrust, altitude, and Mach number at each moment. Outputs are the power demands, heat rejection and resulting nodal temperatures over time. The method is intended to show how input parameter variations (e.g. the component efficiencies, assumed heat transfer coefficients, and failure cases) impact the heat rejection of components and thereby the required thermal management system.

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References

[1] J.H. Kim, K.S. Kwon, S. Roy, E. Garcia, and D. Mavris, “Megawatt-class Turboelectric Distributed Propulsion, Power, and Thermal Systems for Aircraft”, AIAA paper 2018-2024, 2018.

[2] R. Larkens, “A coupled propulsion and thermal management system for hybrid electric aircraft design – a case study”, MSc. Thesis, Technical University of Delft, October 2020.
[3] P. Abolmoali, A. Donovan, S.S. Patnaik, P. McCarthy, D. Dierker, N.Jones, and R. Buettner, “Integrated Propulsive and Thermal Management System Design for Optimal Hybrid Electric Aircraft Performance”, AIAA paper 2020-3557, 2020.
[4] J. van Muijden and V.J.E. Aalbers, Thermal Management Principal Analysis of Hybrid-Electric Aircraft with Turboelectric Propulsion Using Distributed Propulsors, paper presented at 9th European Conference for Aeronautics and Space Sciences (EUCASS), Lille, France, 28 June – 1 July 2022.