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Conceptual design optimization of Hybrid-Electric Regional Aircraft using SPPH architecture

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Abstract

The binding nature of sustainability goals set by the European Commission [1] has led aircraft manufacturers and research institutes to study new concepts with hybrid-electric propulsion (HEP), i.e. aircrafts using both energy sources (electrical and chemical) in the production of power. HEP concept itself leads to numerous benefits like the possibility so spread the electrical engines over the wing and get an increase of lift by aero-propulsive interactions.
Based on a design sizing method for hybrid electric aircraft already developed at TU Delft [2], the aim of the study has been to optimize a regional aircraft using HEP with a Serial Parallel Partial Hybrid (SPPH) architecture in the preliminary design phase.
In this process, the equilibrated lift and propulsive equations of the mechanics of flight have been plotted in a "power-loading diagram" for each flight phase including cruise, take-off "One Engine Inoperative", approach speed and runway length. Finally, a design point for minimum wing size or minimum power (Gas turbine and/or Battery) can be founded in this design space for each configuration studied.
In hybrid electric-fuel architectures, SPPH is the most generic as it covers all others, including serial, parallel, turbo-electric and full electric. Moreover, the use of two control parameters, a "supplied power ratio" Φ representing the amount of power given by the batteries with respect to the total amount of power drawn from all energy sources, and a "shaft power ratio" φ which represents the amount of shaft power produced by the electrical engines with respect to the total amount of shaft power produced by all engines at a given flight condition, can lead to get every configurations by setting an ad-hoc value for Φ and φ.
In this study, it has been demonstrated that a given value for a supplied power ratio, for example 0.5 meaning that the same amount of power coming from the electric and thermic sources is available in the aircraft, and taking a random value for shaft power ratio, lead to numerous design points contained inside a delimited space, so-called "carpet", which is represented in the power loading diagram. In this carpet itself, it's possible to find a particular design points at the corner of the domain, representing the optimum design configuration, i.e. an optimum φ for each flight phase.
The size of this carpet can be extended, and the corners shifted from place by relaxing the different constraints. Finally, minimal acceptable constraints for take-off and approach can be computed which represents a way forward for regulation evolutions for this kind of new aircrafts in the coming years.

References

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