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Title

Evaluation of hybrid electric powertrain topologies and their integration in future aircraft concepts for general aviation

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Abstract

In order to achieve the ambitious goals set by the European commission in the “Flightpath 2050” document, technological improvements in all aviation disciplines will be necessary. This is especially true for the field of aeronautical engines. With the introduction of new propulsion system architectures and the associated alternative energy sources for power generation, considerable changes to the aircraft design are required. This however offers an opportunity for a wider design space and novel aircraft concepts. There are several different powertrain topologies being studied in the literature today. They range from all-electric and hybrid electric topologies all the way to a turboelectric topology, consuming all propulsive energy from fuel. While the introduction of electric propulsion systems would lead to an elimination of CO_2 emissions, the specific power and specific energy of battery and hydrogen-based fuel cell systems are significantly lower than those of conventional aeronautical engines using kerosene. In particular, considering the overall system requirements of an aircraft. Therefore, all-electric propulsion systems are currently only considered to be feasible for small aircrafts and short distance missions based on the state-of-the-art technologies. A promising alternative to reduce in-flight emissions lies in the combination of different technologies resulting in hybrid electric propulsion topology. This could be, for example, fuel cells and batteries coupled with a gas turbine or the combination of an electric generator and an internal combustion engine. Consequently, these power and propulsion systems would allow for more degrees of freedom in the design space as well as in terms of operating strategies. Due to the increased complexity of these novel powertrain topologies and its relevance for the design process, the decision for one specific topology is not trivial.

This paper gives an overview of the existing powertrain concepts and the corresponding topology as well as the operating modes. Then a methodology for evaluating the novel powertrain topologies during the conceptual design phase is presented. This methodology can be applied to the individual requirements of a specific aircraft concept. Based on the requirements, the choice of specific criteria and their weighting factors ought to be adapted accordingly. In this study, the evaluation methodology was applied to an aircraft design process in the DLR project Future General Aviation Aircraft (FGAA) and the criteria were selected accordingly. Using the selected criteria, the various benefits and drawbacks of each topology will be derived and analysed. The evaluation results are used to find the most promising topologies for the project. In addition, a sensitivity study of the used methodology was conducted, displaying the influence of the weighting factors on the final outcome. Furthermore, an integration concept of the selected powertrain topology for the FGAA aircraft concept is presented. In an iterative process, all necessary powertrain components are sized and integrated based on the performance requirements of the aircraft concept. In a last step the possible operating modes of the powertrain topology during several mission stages are introduced.

By further developing such novel power and propulsion system architectures, future sustainable aviation can be enabled. In order to provide first proof of concept, the implementation in the general aviation sector is deemed to be a suitable application.