A Modelica-based environment for the simulation of hybrid-electric propulsion systems

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Abstract

In order to meet the challenging CO2 emission goals defined for aviation in Flightpath 2050 (compare European Commission, 2011), new disruptive aircraft developments are required to accelerate the progression of aviation technology. Similar to the automotive field, hybrid electric propulsions systems constitute a promising avenue for reducing the emissions by extending the aircraft design space. This extension includes the usage of electrical energy storages, and airframe integration concepts of the propulsion systems like boundary layer ingestion and distributed propulsion. Lately, numerous studies have been published and announced by NASA (SCEPTOR, STARC-ABL, SUGAR Volt) and companies in Europe (compare Siemens Extra 330, Airbus E-Fan X).

In this context, novel power train architecture topics emerge enquiring for a propulsion system modeling tool providing means for the analysis of various power train architectures and operation strategies as well as trade studies amongst them.

In this paper, such an analysis framework is presented in form of a novel Modelica library. The framework is meant to accompany the design process thought the different design stages ranging from basic concept studies to detailed architecture analysis. The main challenges that had to be tackled during the library development include:

- High modularity for changing the model fidelity level according to the current design detail
- High flexibility to accommodate the different powertrain architectures (compare figure)
- High flexibility in operation strategies
- Confining the model complexity in sub-models to generate well-conditioned equation systems
- Initializing the power train in an arbitrary state
- Structuring the problem in handy subsystems

The presentation depicts the hierarchical structure of the modeling approach, key modeling concepts and closes with exemplary brief demonstration of the analysis capabilities. Furthermore, the library provides means of coupling the power train models with aircraft models and a framework for a holistic hybrid electric aircraft analysis. The holistic analysis is necessary since the subsystems of an aircraft are strongly coupled. E.g. the additional drag caused by the cooling of the power train losses and the additional weight of the power train might cancel the drive train benefits partially or even surpass them.

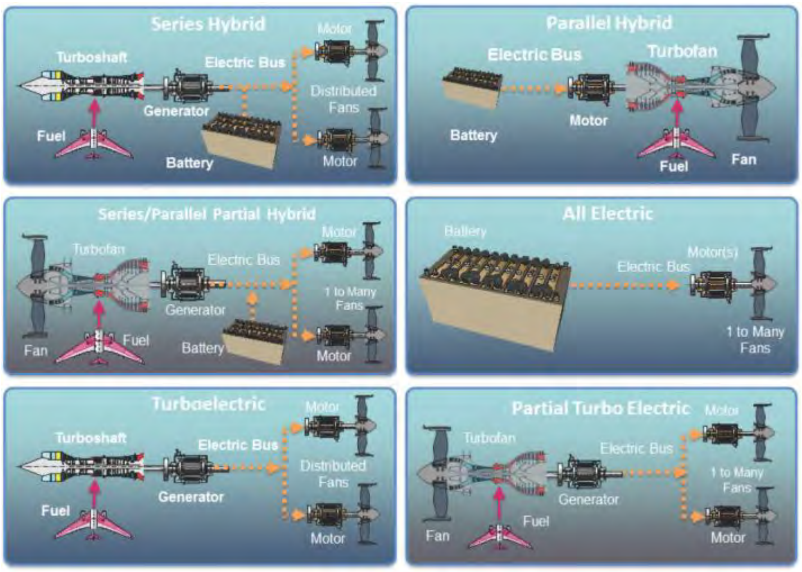

Figure 1. Categorization of the potential power train architectures for hybrid electric propulsion systems in aeronautics (National Academies of Sciences, Engineering, and Medicine, 2016).