PhD Thesis Description

Improving Reliability and Performance of Electric Aircraft Propulsion Chain Using Polyphase Machines and Hydrogen Fuel Cells

Places to realize the PhD thesis

ESTACA–Campus Ouest
Parc Universitaire Laval-Changé
Rue Georges Charpak BP76121 53061- LAVAL

And

Laboratoire GEEPS
3-11, rue Joliot Curie Plateau de Moulon
91192 Gif sur Yvette Cedex

Partnership and Funding

ESTACALAB and GeePs with a funding from CSC.

The requested Profile

Master degree in Control with skills in Electrical Engineering, Flight Control and Flight Mechanics

Context and objectives

Nowadays, Air traffic contributes significantly to global warming even though its share of total pollution is less important comparing to urban and maritime traffic. Thus, aviation is trying to design and to produce new aircrafts to reduce air pollution. Hybrid and electric aircrafts are among the solutions suggested today by manufacturers to contribute in CO_2 emission reduction. For example, flying schools are today using electric aircrafts of two or four passengers. In the propulsion chain, four permanent magnet synchronous machines associated to propellers are used in order to ensure reliability using a material redundancy. In addition, a battery with four packs is associated to four three-phase inverters to supply four electric machines. The major problem related to the power source is the battery autonomy, which limits the frequency of flying for several mission flies. Currently the battery used in the electric propulsion chain is useful for one only one-flight mission profile.

The objective of this project is to design an electrical propulsion chain with hydrogen fuel cells and multiphase actuators. The number of redundant elements in both will ensure high reliability and efficiency.

In the multiphase actuators, polyphase machines are used and sized taking account specification such as mass constraint, power [1, 2, 3] and resistive torque of propellers. This design allows to reduce the size and to deal with faults reducing material redundancy of the actual propulsion chain.

For the power source, hydrogen fuel cells are selected and will be sized [4, 5] according to the power of the polyphase machines in order to increase the autonomy and the frequency of flight.

Based on the design of polyphase machines, equivalent analytical models with physical parameters have to be deduced for simulation [1]. The simulation consists to develop a simulator of an electric aircraft of two passengers where flight control, flight mechanics are associated to the designed electric propulsion. In addition, a validation in healthy operation mode will be carried out using a flight mission profile.

For reliability, faults will be created in the propulsion chain namely on the current and position sensors, power stages and machine phases in order to study their effects on the electric propulsion chain during flight. This part will allow us to conclude about the designed polyphase machines as a future candidate technology for the next generation of electric aircrafts.

The selected faults to be studied are based on their occurrence rate per fly hour. Indeed electrical faults related to the power electronic stages and the designed polyphase machine are the most frequent faults, which can occur in an electric propulsion chain. These faults can manifest themselves in the form of a short circuit between the turns of a stator winding or an open circuit phase of the polyphase machine or as a short or open circuit in the inverter (deterioration of a diode or a transistor of one of the arms, etc.) [6, 7]. In addition, sensors could be also exposed to faults where we need to study their impact on the operation of the propulsion chain.

Based on the diagnosis of electrical and mechanical faults, some approaches will be suggested to deal with faults in order to keep good performance and stability [8,9]. Electrical/material redundancies of the propulsion chain with different configurations will be suggested to deal with the different faults. For the selected configurations, a performance comparison will be carried out in order to select the best one.

Finally, the work could be extended by a validation on reduced scale test bench of one actuating system with the sized polyphase machine associated to a propeller. A mission profile will be used to validate the operation of the electric propulsion chain in healthy and faulty operation modes where some faults will be created in order to validate the best configuration of the propulsion chain.

Keywords:

Electric propulsion chain, polyphase machine, hydrogen fuel cell, aircraft, flight control, flight mechanics, design, constraints, redundancy, configuration, reliability, faults, stability, performance.

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Contacts

Rabia Sehab, ESTACA, Enseignant Chercheur Senior (Encadrant)
ESTACA Campus Ouest, Laval
E-mail: rabia.sehab@estaca.fr
Téléphone : 02.43.59.47.27

Cristina Morel, ESTACA, Enseignant Chercheur HDR (Encadrant)
ESTACA Campus Ouest, Laval
E-mail : cristina.morel@estaca.fr
Téléphone : 01.76.52.12.40

Guillaume Krebs, GEEPS, Enseignant Chercheur HDR, (Directeur de thèse)
Group of electrical engineering - Paris, CNRS, CentraleSupélec, Univ. Paris-Sud, Univ. Paris-Saclay, Sorbonne Univ.
E-mail : guillaume.krebs@geeps.centralesupelec.fr
Téléphone : 01.69. 85.15.05