AP2-1-INV

Superconducting motors for aircraft propulsion: the Advanced Superconducting Motor Experimental Demonstrator project

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The European Union-funded ASuMED project started in May 2017 with the purpose of demonstrating the benefits of a new, fully superconducting motor for reaching the targets established by the FLIGHT2050 plan. The project aims at a motor power density of 20 kW/kg using a high-temperature superconducting (HTS) stator. The rotor will use HTS stacks operating like permanent magnets. A highly efficient cryostat for the motor combined with an integrated cryogenic cooling system and associated power converter will be used. This presentation will provide a general overview of the prototype that is currently being built and tested soon.
The motor design was decided by using an analytical calculation tool for multicriterial optimization and by following the specifications provided by Rolls Royce. The stator integrates the cryogenic cooling circuit into the superconducting winding system while using less than 10% of the stator space for the complete cooling supply system. The winding structure is also the flux generator for magnetizing the superconducting rotor.
The AC losses in the stator were evaluated with aptly developed numerical models which incorporate the angular field dependence of the critical current of the superconducting tapes, derived from measurements with fields up to 6 T.
Advanced numerical modeling was used to calculate the magnetization of the tape stacks of the rotor, optimize their design, and study the effects of cross-field demagnetization on the trapped field.
For the inverters, a “Dual-Two-Level” topology, consisting of two classical Two-Level inverters placed on each ends of the windings, was chosen. For such a topology, all ends of the motor windings need to be open and therefore are not connected in the standard star configuration.
The rotor cryostat design is particularly challenging because of the cryogenic operating temperatures, the cooling requirements and the rotating parts, which include a rotary seal. A number of alternatives based on different heat transfer mechanisms were analysed, showing that a forced convection based system using gaseous helium is the optimal solution for the rotor cryostat.
Airborne cryocooler systems were investigated, and their mass was found to be compatible with an airborne application thanks to the use of light heat exchangers and an optimized cycle.

Keywords: Superconducting motors, Aircraft propulsion, HTS coated conductors, AC losses

AP2-2-INV

S Design and test of a superconducting generator for aircraft application

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More electric or all-electric aircraft are seen as a viable solution for improving efficiency, reliability, maintenance in compliance with environmental commitments. This is why many concepts have been developed for a progressive electrification of aircraft with generators, motors and secondary functions as flight control. The benefits of electrification are significant and include: noise reduction, greenhouse gas emissions, pollutants and energy consumption.
For the reasons mentioned above, the aircraft manufacturers wish to develop an aircraft using electric or hybrid energy. Progress in the field of electric motors for the propulsion of cars or ships is a first technological approach for aeronautics. In addition, the technology of YBCO superconducting tapes and pellets is now ripe and ready to be used for aeronautical applications.

In this paper, we present a new topology of superconducting machine. The inductor of the actuator is composed with two superconducting and a classical elements. The first one is a large superconducting coil producing an axial magnetizing field. The second element is a set of superconducting pellets placed inside of the superconducting coil. These pellets shields the magnetizing with the diamagnetic response of the superconducting materials. The magnetic flus density is then modulate between a low value near a pellet and a high value elsewhere. The last part of the machine is two classical armature windings made with copper wire. These windings are placed on both sides of the superconducting system. In this way, we built an axial flux machine. The designed nominal power is 50 kW at 5000 rpm and an operating temperature of 30 K. The cryogenic cooling is provided by a circulation of helium under pressure. No-load, short circuit and load tests have been carried out and extrapolation to a 1 MW machine is in progress.

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AP2-3

Electromagnetic Analysis of Fully Superconducting Motor for Electric Aircraft

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In order to reduce carbon emissions, there is considerable interest in all-electric aircraft for transportation. Fully superconductor motors will be required to meet the high specific weight requirements, which are > 13 kW/kg for the NASA N3-X plane. This paper summarizes the results of electrogmagnetic analysis generated using the FEMM magnetics code, along with the Lua scripting language, to determine the optimum motor configuration. For AC loss considerations, the analysis assumes Bi-2212 stator windings and both iron-tooth and air-core designs are considered.

Keywords: Superconductor, Motor, Optimization, AC Loss