Guest Editorial Special Issue on More Electric Aircraft

I. Introduction

ELECTRIFICATION is a remarkable trend in the aviation industry. Electric machines and power electronics systems have been increasingly embedded in aerospace applications. In this field, the abovementioned systems are mainly used for flight control, engine starting/generating, propulsion, environmental control, braking, and fuel and hydraulic pumps.

The power density, operating efficiency, integration degree, and reliability are critical performance indicators, which present complex mutual coupling and conflicting requirements that need to be carefully considered. Furthermore, the specific external environment and load characteristics of the aviation applications will pose challenges for the design and control of the electric machines and power electronics systems.

This Special Issue aims to collect advanced theoretical and technological research findings in the design and control of electric machines, power converters, drives, and systems in More Electric Aircraft (MEA). This Special Issue totally contains 31 articles with original research work and four technology review articles. The articles are categorized by their topics in the following.

II. Electric Machines and Drives

Compared with conventional commercial transport aircraft, the latest generation of civil aircraft is characterized by more electric machines. The Boeing 787 and the Airbus A380 both have significantly larger electrical systems than any previous aircraft. Furthermore, the increased use of electric energy has led to rapid technological development, especially in the field of power electronics and motor control.

To enhance the power density of the electrical machines, in "A review of thermal designs for improving power density in electrical machines," Dong *et al.* reviewed and discussed a variety of thermal designs. According to the cooling capacity and additional mass, the thermal designs for different applications of electrical machines in the MEA were analyzed, and the reliability and cost were discussed as well. In "Comparison of Si and SiC EMI and efficiency in a two-level aerospace motor drive application," Perdikakis *et al.* explored the tradeoff between the efficiency and electromagnetic interference of the SiC components. Two converters were built with SiC MOSFETs and Si IGBTs, respectively, and experimental results demonstrated that the SiC converter achieved higher efficiency, while the EMI performances were comparable. To reduce the weight and improve the power density, Wu *et al.* proposed a SiC-based five-phase integrated modular motor drive in "Design and analysis of an integrated modular motor drive for more electric aircraft." The converter was directly connected to the end-turn windings of the motor with the motor and the converter being cooled by an integrated water-cooled housing. In "Stable and robust design of active disturbance rejection current controller for permanent magnet machines in transportation systems," Diab *et al.* proposed a new current control method for permanent magnet machines based on the active disturbance rejection control technique. The method was able to guarantee a set performance to avoid unstable operation.

In future aircraft generations, power-by-wire actuators, such as electromechanical actuators, will become an important enabler for more electric system architectures. According to the electromechanical actuation system, in "Filter design and optimization of electro-mechanical actuation systems using search and surrogate algorithms for more-electric aircraft applications," Gao *et al.* studied a dc filter design and optimization problem for dc electrical power distribution systems onboard MEA. According to the electromechanical actuation of flight control surfaces, Kowalski *et al.* presented the rotor position detection method for the permanent magnet synchronous motors in "Anisotropy Identification for electromechanical flight actuators with sensorless rotor angle detection." A high-fidelity and computationally efficient model of the limited-angle torque motor was proposed in "Modeling and analysis of limited-angle torque motor considering nonlinear effects," by Yu *et al.*, which can completely consider the nonlinear effects.

As the aviation industry keeps moving toward more electric solutions, the electrical power generation on aircraft is playing an increasingly important role. In "Challenges and opportunities for wound field synchronous generators in future more electric aircraft," Wang *et al.* presented a detailed overview of historical power generation systems on aircraft. The current state of the art of wound field machines was compared with other generator families, and the main challenges for improving the power density of wound field machines were discussed as well. The basic hybrid excitation modes of the field winding-based flux adjustable permanent magnet machine were analyzed and compared by Wang *et al.* in "General topology derivation methods and control strategies of field winding based flux adjustable PM machines for generator system in more electric aircraft." Wu *et al.* proposed a permanent magnet compensated pulsed alternator with a Halbach array rotor for the power supply of the high-energy

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weapons on the MEA in "Permanent magnet compensated pulsed alternator for driving air-based loads."

With the development of the aerospace technology, the research of starter/generator is getting more attention. To improve the fault-resilient capacity of the switched reluctance starter/generator systems, in "Fault diagnosis and tolerant control strategy for position sensors of switched reluctance starter/generator systems," Chen *et al.* presented a fault diagnosis and tolerant strategy for position sensors, which can be used in nonuniform variable speed conditions. Based on the model prediction technology, Song *et al.* proposed a multiobjective optimization control method for the embedded switched reluctance starter/generator in "Model predictive control of switched reluctance starter/generator with torque sharing and compensation." In "Power transistors fault diagnosis method of SR S/G for more electric aircraft with cross-leg current analysis," Chen *et al.* proposed a fault diagnosis method for power converter of the switched reluctance starter/generator system through the distortion analysis of the cross-leg current.

In the aircraft, the majority of the energy is used for propulsion. To further enhance the aircraft-level efficiency, technologies for electric propulsion systems, including pure electric and hybrid electric variants, have gained increasing attention. In "Analytical modelling of a double-rotor multiwinding machine for hybrid aircraft propulsion," Zhao *et al.* presented a double-rotor multiwinding machine for the propulsion system of the hybrid-electric aircrafts. Different operation modes to cope with various flight tasks were elucidated. In "Innovated approach of predictive thermal management for high-speed propulsion electric machines in more electric aircraft," Dong *et al.* proposed a predictive thermal management system for the propulsion electric machines. The power losses at different operation statuses were described analytically. Cooling was actively adjusted according to the efficiency, and the energy consumption of the cooling system was also optimized. Mahvelatishamsabadi *et al.* investigated the feasibility of converting a conventional fixed-wing direct-drive propeller airplane to an electric extremely short takeoff and landing airplane in "Electric propulsion system for exceptionally short takeoff and landing electric air vehicles." The effects of runway length and cruising speed on the electric motor specifications were addressed. According to the electric propulsion, an exact analytical model for slotless PMSM with segmented Halbach PMs was proposed based on the subdomain method in "Field prediction and validation of a slotless segmented-Halbach permanent magnet synchronous machine for more electric aircraft" by Song *et al.* In "Multiphase PMSM with asymmetric windings for more electric aircraft," Zhao *et al.* presented a multiphase permanent magnet synchronous motor for the MEA propulsion. The stator winding parameters were modified to make the motor more suitable for the working condition of MEA and improve the efficiency of the motor. In "Multi-vector predictive current control for five-phase PM motor by using hybrid duty modulation technology," Tao *et al.* presented a multivector finite control set model predictive current control scheme for the five-phase motors, which can improve the operational performances without increasing computational burden. To deal with the low thermal stability of the high-temperature superconductor machine during the quench, Wang *et al.* applied a no-insulation coil technique on the rotor windings in "No-insulation high temperature superconductor winding technique for electrical aircraft propulsion." A grading turn-to-turn resistivity was proposed to maintain the high thermal stability of the coil. Based on the aircraft dimensions and thrust requirement, a procedure for deriving a suitable voltage and current for an electrical propulsion system was proposed in "Optimal voltage and current selection for turboelectric aircraft propulsion networks," by Ibrahim *et al.*, which took the feasibility and minimum mass as the boundary and target, respectively. In "Partial discharge investigation of form-wound electric machine winding for electric aircraft propulsion," Wang *et al.* presented the partial discharge investigation of the form-wound winding in high-frequency electric machines for electric aircraft propulsion. The partial discharge activity was enhanced due to the decrease in air pressure. The partial discharge pattern recognition and failure precursor were concerned as well.

III. Power Conversion and Distribution

In the MEA framework, the number of airborne electrical equipment is increasing very rapidly, which significantly enhances the requirements on the capacity and quality of the power system. The power conversion and distribution are getting more and more attention, and many aspects are concerned, such as energy efficiency, network complexity, system stability, thermal management, and so on.

In "Power electronic converters in electric aircraft: Current status, challenges, and emerging technologies," Dorn-Gomba *et al.* provided a comprehensive analysis of state-of-the-art power electronics in electric aircraft. Challenges for forthcoming power electronics in response to the future trends of the electrical network were explained, and the emerging technologies were discussed as well.

In "Data mining based model simplification and optimization of an electrical power generation system," Dai *et al.* proposed a multiphysics model simplification approach for more-electric equipment based on the data mining. The optimal Latin Hypercube-based experiment was used to generate data, and the fusion algorithm was applied to reduce the design space. Enalou *et al.* designed a twin-shaft turbofan engine emulator for the experimental support of the electric power transfer concept in "Time-scaled emulation of electric power transfer in the more electric engine." The emulator can replicate the basic behavior of the engine to allow for conducting tests in a scaled environment without an actual physical engine.

To assess the stability of the electrical power distribution system of the MEA, the input impedance of multiple active bridge converters was investigated with the transfer function in "A generalized input impedance model of multiple active bridge converter" by Yang *et al.* In "A multi-port power conversion system for the more electric aircraft," Gu *et al.* proposed an electrical power distribution system based on the multiport power converters, which allows a ring power distribution while galvanic isolation is still maintained. The superior

performances offered by the segmented machine were illustrated as well.

Chen *et al.* performed an overview of the recent advances and trends on the multipulse rectifier technology and its application in MEAs in "Evaluation on the auto-configured multipulse AC/DC rectifiers and their application in more electric aircrafts." The system topologies, transformer configurations, harmonic reduction schemes, case study, practical selection and design guidelines, and applications were concerned. The state-of-the-art of high-conversion high-voltage dc–dc converters was reviewed for a modern aerial vehicle's power distribution system in "An overview of high-conversion high-voltage DC–DC converters for electrified aviation power distribution system" by Swaminathan *et al.* Two main architectures of such converters were presented, and the circuit diagrams and their features and shortcomings were highlighted with comparisons. In "A low-THD two-switch PFC DCM boost rectifier for aviation applications," Sadilek *et al.* introduced a two-switch, single-phase, power-factor-correction, discontinuous-conduction-mode boost rectifier. By injecting a feedforward signal, it features zero-voltage switching turn on and low input-current total harmonic distortion.

In "A three-phase single-sensor based Cuk-derived PFC converter with reduced number of components for more electric aircraft," Gangavarapu *et al.* presented a Cuk-derived power factor corrected converter for MEA, which benefits from the limited components, high efficiency, and less control effort. Aiming to minimize the power fluctuation of the generators with the battery–supercapacitor hybrid energy storage system, Wang *et al.* proposed a novel adaptive online power management algorithm based on the Lyapunov optimization method in "Adaptive online power management for more electric aircraft with hybrid energy storage systems." An uncertainty and disturbance estimator based robust voltage control scheme was proposed for the dual-active-bridge converter in "Uncertainty and disturbance estimator based robust tracking control for dual-active-bridge converters" by Wu *et al.*

In "Optimal design and synthesis of MEA power system architectures considering reliability specifications," Recalde *et al.* proposed a formulation to synthesize the power system architecture, which optimizes the main aerospace drivers and complies with safety specifications by introducing reliability and resiliency constraints in the network design optimization. Nolan *et al.* proposed a power management and control method for the superconducting distribution network in "Voltage based current compensation converter control for power electronic interfaced distribution networks in future aircraft," which exploits the fast acting measurement and response capabilities of the power electronic interfaces to maximize current supply to critical loads and reduce the impact of the temperature rise.

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