ABSTRACT

DESIGN & CONTROL OF HIGH-POWER DENSITY GAN-BASED IMMD FOR ALL-ELECTRIC AIRCRAFT APPLICATION

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Transportation electrification has been a major focus of research across both academia and industry over the past few decades. In recent years, the rapid growth in the electric vehicle (EV) market share has demonstrated a paradigm shift, with consumers increasingly adopting EVs due to benefits such as lower operational costs, enhanced safety, and reduced environmental impact. While EVs continue to gain popularity, the electrification of aerial transportation has emerged as a promising and impactful extension of this trend.

A round-trip flight from Chicago to New York burns approximately 72,000 gallons of fossil fuel—roughly equivalent to one-eighth of the annual carbon footprint of an average person. Replacing conventional jet engines, which operate at an average efficiency of about 30%, with electric propulsion systems exceeding 92% efficiency could lead to substantial energy savings and environmental benefits.

However, electrifying aerial transportation presents new and more aggressive design challenges compared to those for ground vehicles. Critical targets such as high power density, efficiency, and reliability are more stringent, although looser financial constraints in aerospace applications provide more flexibility for design innovation.

This dissertation presents the design and control of an Integrated Modular Motor Drive (IMMD) optimized for all-electric aircraft applications. The proposed IMMD system is developed to meet strict power density and efficiency targets using state-of-the-art Gallium Nitride (GaN) power devices. A thorough evaluation process was conducted to identify optimal devices that offer a low-profile, high-performance solution suitable for modular integration.

The research encompasses multiple design iterations and prototype developments. Each version was rigorously tested, contributing to continuous performance improvements. The final prototype achieved an efficiency of 98.65% and a gravimetric power density of 43.96 $k\text{W}/kg$, confirming the efficacy of the proposed design for next-generation electric propulsion systems in aviation.