# Abstract

Adopting more efficient electric technologies in the aircraft industry has been gaining attention with the objectives to decrease fuel consumption and reduce environmental impact. The backbones of more electric technologies are power converters to interface between loads and power grids. For aerospace applications, these power converters must be both compact and light, and hence, realization of high power density converter (HPDC) is necessary. Pulse width modulation (PWM) technique with high switching frequency is commonly employed in HPDC design but it results in large harmonic contents. To achieve high power density, increasing the switching frequency of the power converter has also become a necessity. Hence, practically all HPDCs require passive filters to meet the stringent power quality requirements. For all the filter configurations, LCL filter is the most popular choice in grid-connected power converter systems for its excellent performance. However, it is also a major contributor of the overall weight of a HPDC, especially the inverter-side inductor, which requires to suppress higher frequency harmonic contents at the inverter side. The main focuses of this thesis are to explore various design techniques in size and weight reduction of passive filters.

This thesis is divided into six chapters. Chapter 1 describes the research motivation and objective. Chapter 2 reviews the output harmonic filter in power inverter, with emphasis of HPDC in aerospace applications, total harmonic distortion (THD), output harmonic filter, magnetic components design and thermal management. Then the design challenges are summarized.

Chapter 3 describes a comprehensive design flow of the LCL filter for a 50-kW, 60-kHz two-level Silicon Carbide (SiC) inverter for high-power aerospace applications where space constraint and harsh ambient temperature environment are critical. To meet the space constraint requirement, reduction of the inductor size is necessary. Specific design attention is made on a customized

amorphous cored inductor with a detailed study of on the relationships of inductor weight, core width and total surface area with respect to air-gap length. To overcome the harsh ambient temperature environment, a liquid cooling system of the amorphous cored inductor is also carefully designed.

Chapter 4 explores and investigates magnetic integration of inductors for a three-phase LCL filter on delta yoke composite core. Using the conventional rectangular core as the baseline design reference, the proposed delta yoke core achieved a weight reduction of close to 10% without affecting the filter's performance. The inductances based on both shapes were calculated and verified through magnetic circuit analysis and 3-D finite element analysis (FEA) simulation. Hardware prototypes of the integrated inductor with both the conventional rectangular and the proposed delta yoke cores were fabricated and tested with a three-phase inverter circuit to verify the design validity.

Chapter 5 presents the benefits of interleaving three phase voltage source converters (VSCs) to improve the power density. Then, to further improve power density of HPDC, different levels with power converter includes 2-level, 3-level, and 5-level configurations will be investigated, with two types of 3-phase power grids, the 3-phase 3-wire and 3-phase 4-wire power grids.

Chapter 6 analyses the common mode inductor, includes the extraction of common mode (CM) and differential mode (DM) inductances of a common mode choke (CMC) using 3D finite element method (FEM). The effects of CM and DM currents on the magnetic core saturation, the parasitic capacitance of a CMC, and different core structures on the performance are evaluated.

Finally, chapter 7 concludes the thesis, and recommends the future work.