Three-Phase AC-DC Converters for More-Electric Aircraft

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ABSTRACT

The concept of More-Electric Aircraft (MEA) is significantly changing the airborne electrical power system design: more electrical equipment are used to replace the conventional hydraulic, pneumatic and mechanic means. In order to guarantee the power quality of the system, several challenges have to be tackled because of the high performance and reliability requirement for MEA. One of the them is the harmonic distortion limit defined by the airborne environmental standard DO-160E, and another is the system potential stability problem because the power electronics loads dominate the total power consumption on MEA.

This thesis introduces a nonlinear average current control method for three-phase PWM rectifiers to address the first challenge. This method is a generalization of single-phase PFC nonlinear average control based on dual-phase control. Only dc-rail current is used as feedback signal such that the current sensing requirement is reduced. A mixed-signal control implementation based on an FPGA is introduced. Both the current control performance and the simplicity of the control implementation are proven by a 2 kW prototype. Moreover, different factors that have effect on control performance are discussed, and recommendations are provided for practical applications.

Line-frequency converters, mostly multi-pulse diode rectifiers still dominant in practical applications. The method called ‘harmonic linearization’ is applied in this thesis to develop small-signal input impedance of multi-pulse rectifier with IPT or without IPT. Analytical mathematical models are derived based on the Fourier analysis of a so-called mapping function that describes the operation of diode rectifiers. Furthermore, the method of double-Fourier is extended to analyze mapping functions by defining a 3D waveform. The results can not only applied to model small-signal responses of a diode rectifier, but also used to study large-signal behavior such as steady-state harmonic performance under different line condition.

Based on the developed mathematical models, stability problems due to the dynamic interactions in an example line-frequency converter system are analyzed based on a proposed method. Instead of assessing the system performance on the dc side, such method works on the ac side by studying two decoupled sequence-based subsystems of a

three-phase system. It explains how a large dc-bus capacitor helps to stabilize the dc output voltage. Besides, passive stabilization techniques, namely dc-side dampers and ac-side dampers, are also investigated.