MODELING AND CONTROL OF HIGH-PERFORMANCE SINGLE-PHASE POWER FACTOR CORRECTION CONVERTERS

by

Min Chen

An Abstract of a Thesis Submitted to the Graduate

Faculty of Rensselaer Polytechnic Institute

in Partial Fulfillment of the

Requirements for the degree of

DOCTOR OF PHILOSOPHY

Major Subject: Electrical Engineering

The original of the complete thesis is on file
In the Rensselaer Polytechnic Institute Library

Examining Committee:

Jian Sun, Thesis Adviser

Joe H. Chow, Member

Leila Parsa, Member

Sheppard J. Salon, Member

David A. Torrey, Member

Rensselaer Polytechnic Institute
Troy, New York

October, 2006
(For Graduation December 2006)

ABSTRACT

Conventional current control methods of single-phase power factor corrected (PFC) ac-dc converters rely on wide bandwidth feedback control to achieve sinusoidal input current waveform and unity power factor. A switching frequency of at least 1000 times higher than the input fundamental frequency is usually required to achieve the necessary control bandwidth. For digital control implementation, the sampling frequency must also be as high as the switching frequency. These methods cannot meet the requirements of applications in high frequency systems, such as airborne power systems where the line frequency is in the range of 360 - 800 Hz, and are not suitable for low-cost digital implementation.

To overcome these problems, new feedforward current control and nonlinear current control methods are developed in this work. Compared to existing feedforward current control for boost single-phase PFC converters, the new feedforward current control further reduces harmonic current distortion especially around the zero-crossing of the input voltage. The method is also generalized to other boost-derived topologies. The proposed nonlinear current control is based on integrating the current of the power switch on a cycle-by-cycle basis, and utilizes a feedforward duty ratio signal to achieve stable operation. This nonlinear control method achieves better control performance than all existing control methods, and also facilitates low-cost digital implementation.

This work also investigates low-frequency input impedance modeling of boost single-phase PFC converters. Unlike existing low-frequency input impedance modeling method based on double averaging, the proposed method uses harmonic balance to develop a small-signal model that is valid below the line fundamental frequency. The resulting model confirms to the definition of impedance and can be used to study dynamic interactions of PFC converters with the source.