A FPGA-Based Power Electronics Controller for Three-Phase Four-Wire Hybrid Active Power Filters

by

Bo Sun

Master of Science in Electrical and Electronics Engineering

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Faculty of Science and Technology
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Supervisor

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Abstract

A FPGA-BASED POWER ELECTRONICS CONTROLLER FOR THREE-PHASE FOUR-WIRE HYBRID ACTIVE POWER FILTERS

by Bo Sun

Thesis Supervisor: Professor Man-Chung Wong
Co-Supervisors: Dr. Sai-Weng Sin, Dr. Ning-Yi Dai and Dr. Chi-Kong Wong
Electrical and Electronics Engineering

Nowadays, power electronics technology is widely used in improving power quality. The present development of power electronics trends towards small size, high efficiency, low power loss, high integration and so on. Following the developing trend, a FPGA-based power electronics controller for three-phase four-wire hybrid active power filters (HAPFs) is proposed in this thesis. The whole control strategy of HAPFs is included by the FPGA chip. The proposed FPGA-based power electronics controller can also be used in controlling active power filters (APFs).

The proposed FPGA-based power electronics controller utilized most advantages of FPGA device. The processing in FPGA is clock controlled so each processing is strictly accurate in time domain. Parallel processing extremely improves the processing efficiency so the FPGA-based power electronics controller can quickly generate switching signals for HAPFs. The bit width of the constant or variable in FPGA is freely defined. Long bit width is provided for guaranteeing accuracy or avoiding overflow. Short bit width is also provided for saving hardware resource and processing time. Since FPGA has rich I/O ports and they are configurable, the FPGA-based power electronics controller can be further developed to control HAPFs with more switches. Besides, the design in FPGA-based power electronics controller is mapped into actual circuit and meets many requirements of application-specific integrated circuits (ASICs). A power-electronics-application-specific (PEAS) controller may become true in future.

In this thesis, the research is not only concentrate on the implementation by FPGA but also focus on the compensation current detection algorithm. Many compensation current detection algorithms based on instantaneous power theories have been developed. However, most of them are only applicable when the source voltages are balanced and sinusoidal. Some existing and well-known compensation current detection algorithms are investigated and analyzed under two cases. Case one is source voltages are balanced and sinusoidal. Case two is source voltages are unbalanced and distorted. Modification is proposed. These algorithms and modified algorithm are compared. The most advisable one is adopted in the FPGA-based power electronics controller. Therefore, the proposed controller is applicable under the two cases.

The whole control strategy in FPGA-based power electronics controller is divided into several subsystems. Each subsystem is further divided into subsubsystems. Detailed implementation is provided in this thesis. Experimental results under the two cases are also given to show the validity of the proposed FPGA-based power electronics controller. Besides, experimental comparison of the FPGA-based power electronics controller and conventional DSP-based power electronics controller is provided. The compensation performance of FPGA-based power electronics controller is proved to be better.

Key words: FPGA-based power electronics controller, three-phase four-wire, HAPF, APF

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LIST OF ABBREVIATIONS

ADC. ANALOG TO DIGITAL CONVERTER

APF. ACTIVE POWER FILTER

ASIC. APPLICATION-SPECIFIC INTEGRATED CIRCUIT

BPF. BAND-PASS FILTER

DC. DECOUPLING CELL

DC/AC. DIRECT CURRENT/ ALTERNATING CURRENT

DDSRF-PLL. DECOUPLED DOUBLE SYNCHRONOUS REFERENCE FRMAE PHASE-LOCKED LOOP

DPF. DISPLACEMENT POWER FACTOR

DSP. DIGITAL SIGNAL PROCESSOR

FPGA. FIELD-PROGRAMMABLE GATE ARRAY

HAPF. HYBRID ACTIVE POWER FILTER

HDL. HARDWARE DESCRIPTION LANGUAGE

IC. INTEGRATED CIRCUIT

IGBT. INSULATED GATE BIPOLAR TRANSISTOR

IIR. INFINITE IMPULSE RESPONSE

IPM. INTELLIGENT POWER MODULE

IPEM. INTELLIGENT POWER ELECTRONICS MODULE

LF. LOOP FILTER

LPF. LOW-PASS FILTER

LSI. LARGE-SCALE INTEGRATION

LUT. LOOK-UP TABLE

OCC. ONE-CYCLE CONTROL

PEBB. POWER ELECTRONICS BUILDING BLOCK

PF. POWER FACTOR

PFC. POWER-FACTOR CORRECTION

PI. PROPORTIONAL INTEGRAL

PLL. PHASE-LOCKED LOOP

PWM. PULSE WIDTH MODULATION

RMS. ROOT MEAN SQUARE

SPWM. SINUSOIDAL PULSE WIDTH MODULATION

SRF. SYNCHRONOUS REFERENCE FRAME

THD. TOTAL HARMONIC DISTORTION

UC. UNIVERSAL CONTROLLER

VAR. VOLTAGE-AMPERE REACTIVE

VCO. VOLTAGE-CONTROLLED OSCILLATOR

VSI. VOLTAGE SOURCE INVERTER

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