UNIVERSITI TEKNOLOGI MARA

FULLY-CONTROLLABLE PWM FOR SPMC WITH BI-DIRECTIONAL OPERATIONS

MOHD ASYRAF BIN RONGI

Thesis Submitted in fulfilment
of requirements for the degree of
Master of Science

Faculty of Electrical Engineering

April 2015

CONFIRMATION BY PANEL OF EXAMINERS

I certify that a Panel of Examiners has met on 16th December 2014 to conduct the final examination of Mohd Asyraf Bin Rongi on his Master of Science thesis entitled "Fully Controllable PWM For SPMC With Bi-Directional Operations" in accordance with Universiti Teknologi MARA Act 1976 (Act 173). The Panel of Examiners recommends that the student be awarded the relevant degree. The panel of Examiners was as follows:

Suhana Binti Sulaiman, PhD
Senior Lecturer
Faculty of Electrical Engineering
Universiti Teknologi MARA
(Chairman)

Sukreen Hana Binti Herman, PhD
Senior Lecturer
Faculty of Electrical Engineering
Universiti Teknologi MARA
(Internal Examiner)

Anis Nurashikin Binti Nordin, PhD
Associate Professor
Faculty of Engineering
Universiti Islam Antarabangsa Malaysia
(External Examiner)

Siti Halijjah Shariff, PhD
Associate Professor
Dean
Institute of Graduates Studies
Universiti Teknologi MARA
Date : 24 April, 2015

ABSTRACT

Dependency on bulky external hardware, high memory bits consumption for generating digital control signals, and the lack of flexibility to control the SPMC (Single Phase Matrix Converter) are of major concerns. Thus the focuses of this research are to further optimize the whole SPMC system to be more compact and portable with less dependency on external hardware, to design a digital control signal generator module with much lesser memory bits consumption, and to develop a fully controllable control signals that can fully control the SPMC for bi-directional operations which are AC to DC (rectifier) and DC to AC (inverter) operations. Firstly, literature review on the previous work, as well as studies on FPGA (Field Programmable Gate Array) and SPMC hardware was done. Followed by simulation works using ModelSim for digital control signal generator modules' output simulations, as well as using Matlab Simulink (MLS) for SPMC's R-load voltage and R-load current output simulations. When simulations results are consistent with theoretical readings, hardware experiments were conducted including the use of Altera DE2-70 FPGA board and real SPMC hardware. Experiment results were then compared with simulation results for performance and consistency checking. Major findings include the use of CORDIC (COmputer Rotation DIgital Computer) to replace the Look-Up Table (LUT) method for generating one of the control signals, resulting in much reduced memory bits usage. Also by fully utilization the Altera DE2-70 FPGA board, control signals can be fully adjusted and controlled without the need of external hardware equipments.

TABLE OF CONTENTS

CHAPTER ONE
INTRODUCTION

1.1 INTRODUCTION

Concerned with the need of energy efficient technology or green technology, lots of research has been made for further optimizations in term of power consumption reductions. Eliminating unnecessary hardware components, avoiding the use of bulky external equipments, and also the use of efficient algorithm for a design, are some of the keys to optimize for energy efficiency. One of the most critical research areas for applying the green technology is in power electronics field, with the power conversion devices such as the Matrix Converter (MC) is of an interest research.

MC offers an "all silicon" solution [1] potential for both bi-directional (AC-DC and DC-AC) conversions. The Single Phase Matrix Converter (SPMC) consists of a matrix of input and output lines with four bi-directional switches connecting the single-phase input to the single-phase output at the intersections [2]. SPMCs are extensively used in various DC driven portable applications supplied from an AC utility, conventionally AC-DC converters, DC-AC converters, which are also called rectifiers and inverters. SPMC is developed using diodes and thyristors to provide controlled and uncontrolled DC/AC power with unidirectional and bidirectional power flow [3].

There are many switching devices for the SPMC and the Insulated Gate Bipolar Transistor (IGBT) is the preferred choice for implementing the four quadrant switches (4QSWs) in the SPMC [4]. IGBT integrates the features of a Metal-Oxide Semiconductor Field Effect Transistor (MOSFET) and a Bipolar Junction Transistor (BJT). In other words, IGBT is a cross between the MOSFET and BJT transistors. The IGBT has the output switching and conduction characteristics of a BJT, but it is a voltage-controlled device like MOSFET. In general, IGBT has the advantages of high current-handling capability of a BJT with the ease of control of a MOSFET [5].

In power electronics system such as the SPMC, control electronics plays an important role for performance. There are several techniques of controlling the