



Faculty of Electrical Engineering

**HARMONICS MINIMIZATION OF A THREE PHASE
CASCADED H-BRIDGE MULTILEVEL INVERTER**

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Master of Science in Electrical Engineering

2016

**HARMONICS MINIMIZATION OF A THREE PHASE
CASCADED H-BRIDGE MULTILEVEL INVERTER**

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**A thesis submitted
in fulfillment of the requirements for the degree of Master of Science
in Electrical Engineering**

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2016

DECLARATION

I declare that this thesis entitled “**HARMONICS MINIMIZATION OF A THREE PHASE CASCADED H-BRIDGE MULTILEVEL INVERTER**” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : Afiqah Binti Sabari

Date :

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality as a partial fulfillment of Master of Science in Electrical Engineering.

Signature :.....

Supervisor Name :Assoc Prof Ir Dr Rosli Bin Omar

Date :.....

DEDICATION

To my beloved mother and father

“I am only one, but I am one. I cannot do everything, but I can do something. What I can do I ought to do. And what I ought to do by the bless of ALLAH, I will do”

ABSTRACT

For more than two decades, multilevel inverter technology has drawn tremendous interest among researchers from industry and academia in recent years due to its superior performance. In this regards, the main objectives of this thesis are to study, modeling, design and develop a prototype of a three-phase cascaded H-Bridge Multilevel inverter (CHB-MLI) based on Newton-Raphson technique that aims to analyze the performance of the inverter output for harmonic minimization. The source codes programming based on Newton-Raphson method was developed, and then stored into the Digital Signal Processing (DSP) TMS320F2812. The proposed controller based on Newton Raphson was applied to CHB-MLI. The optimization of this system had managed to minimize the harmonic contents of the inverter output. Besides, the experimental results of the developed prototype are discussed. In addition, the performance of the proposed system was compared between simulation and experimental results for both Optimization and Non-optimization techniques. The Optimization of this system had been capable in reducing the harmonic contents of the inverter output. Thus, optimization and Non-optimization of the CHB-MLI system had been successfully demonstrated in this study. Finally the development of a three phase CHB-MLI based on DSP, its controller and power electronic devices would be a challenging future research in minimize the content of harmonic of the inverter output.

ABSTRAK

Selama lebih dua dekad, teknologi penyongsang pelbagai peringkat telah menarik minat hebat sekali dalam kalangan para penyelidik dari industri dan ahli akademik sejak tahun kebelakangan ini akibat prestasinya yang unggul. Dalam konteks ini, objektif utama tesis ini untuk kajian, permodelan, rekabentuk dan membangunkan sebuah prototaip yang Jambatan-H Jujukan Berbilang Aras Litar Penyongsang (JHJ-BALP) untuk tiga fasa berdasarkan teknik Newton Raphson yang bertujuan untuk menganalisa prestasi litar penyongsang bagi pengurangan pengeluaran harmonik. Sumber kod pengaturcaraan berasaskan kaedah Newton Raphson telah dibangunkan, dan kemudian disimpan ke dalam Pemprosesan Isyarat Digital (PID) TMS320F2812. Pengawal yang dicadangkan adalah berdasarkan Newton Raphson dan ia digunakan untuk (JHJ-BALP). Pengoptimuman sistem ini telah berjaya untuk mengurangkan pengeluaran kandungan penyongsang harmonik. Selain itu, keputusan ujian prototaip dibangunkan juga telah dibincangkan. Di samping itu, prestasi sistem yang dicadangkan adalah dibanding antara simulasi dan uji kaji bagi memperoleh keputusan teknik pengoptimuman dan tidak-pengoptimuman. Pengoptimuman sistem ini telah berupaya mengurangkan kandungan keluaran penyongsang harmonik. Oleh itu, pengoptimuman dan tidak-pengoptimuman sistem (JHJ-BALP) telah berjaya dibuktikan dalam kajian ini. Akhirnya pembangunan tiga fasa (JHJ-BALP) berdasarkan (PID), pengawal dan peranti elektronik kuasa memberi cabaran dalam penyelidikan masa hadapan bagi mengurangkan kandungan pengeluaran penyongsang harmonik.

ACKNOWLEDGMENT

All praises be to Allah S.W.T, The Most Gracious, The Most Merciful for Guidance and Blessing. First of all, I would like to express my gratitude and special thanks to my supervisor and also my advisor Assoc Prof Ir Dr Rosli Bin Omar. I cannot say thank you enough for his tremendous support and help. I am very grateful for the opportunity to continue my study through a project he gave to me. Without his encouragement and guidance, this thesis would not materialize. An addition, thanks to Mr Azhar Bin Ahmad for his interest in this work and holding the post of my co-supervisor in this research. I am also very thankful to UTeM for sponsoring this research through the Malaysian Technical University Network (MTUN) with research Project Code: MTUN/2012/UTeM-FKE/4 M00012 and Fundamental Research Grant Scheme (FRGS) with research Project Code: FRGS(RACE)/2012/FKE/TK02/02/1 F00151 belonging to my Principal Supervisor. Other than that, I feel a deep sense of gratitude to my parents, Sabari Bin Siraj and Siti Marpungah Bt Sipon because for their encouragement and moral support during my studies at Universiti Teknikal Malaysia Melaka (UTeM). Last but not least, I would like to take this opportunity to express my gratitude to the people who have given me support in the successful to complete this research project.

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LIST OF ABBREVIATIONS

AC	Alternating Current
DC	Direct Current
CHB-MLI	Cascaded H-bridge Multilevel Inverter
FC	Flying Capacitor
NR	Newton Raphson
DSP	Digital Signal Processors
GUI	Graphic User Interface
IGBT	Insulated Gate Bipolar Transistor
PWM	Pulse Width Modulation
SVPWM	Space Vector Pulse Width Modulation
IEC	International Electric Code
PCB	Printed Circuit Board

LIST OF SYMBOLS

f	AC power frequency
f_s	Sampling frequency
f_{sw}	Switching frequency
I	Current, absolute value
V_s	Voltage Source
V_{ref}	Voltage Source reference
θ	<i>Angle</i>
Σ	Summation

LIST OF PUBLICATION

Journal

- Rosli Omar, Afiqah, Marizan Sulaiman, Krismadinata. "Harmonic Reduction of Cascaded H-bridge Multilevel Inverter Based on Newton-Raphson" International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 3 (2015) pp. 6569-6580.
- Mohammed Rasheed, Rosli Omar Afiqah Sabari, Marizan Sulaiman. " Validation of a Three-Phase Cascaded Multilevel Inverter Based on Newton Raphson(N.R) " Indian Journal of Science & Technology ISSN : 0974-5645 (Accepted)

Conference

- Afiqah Sabari, Rosli Omar, Marizan Sulaiman, Mohammed Rasheed, "Optimization and Non-optimization of H-bridge Cascaded Multilevel Inverter" IEEE conference publications, Clean Energy and Technology (CEAT) 2014, 3rd IET International Conference on Date 24-26 Nov. 2014.

CHAPTER 1

INTRODUCTION

1.1 Background

The multilevel inverter concept has been employed to decrease harmonic distortion (Gobinanth, K., & Mahendran, S., 2013) in the output waveform without decreasing the inverter power output. It has several advantages, such as lower switching frequency and switching losses, lower voltage device evaluation, lower harmonic distortion, high power quality waveform, higher efficiency, reduction of electromagnetic interference (EMI), and interfacing renewable energy sources, such as photovoltaic to the electric power grid (S. Suresh Kota, 2012). Nevertheless, at present, three common topologies of multilevel inverter have been proposed, which are diode-clamped, flying capacitors (FCs), and cascaded H-bridge (CHB) (Akshay K. Rathore, & zjoachim Hotlz, 2010).

Furthermore, the type of multilevel inverter that uses a single DC source rather than multiple sources is the diode-clamped multilevel inverter. Meanwhile, the FC type is designed by a series connection of capacitor-clamped switching cells.

Lastly, the CHB type, which can be series or parallel connected, also consists of a series of H-bridge cells to synthesize the required voltage from several separate DC sources, which are recoverable from batteries, fuel cells, renewable energy or ultra-capacitor (Panda, Kaibalya Prasad, Sahu, Bishnu Prasad, & Samal, 2013). Besides, this CHB topology has the least components for a given number of levels (Colak et al., 2011). Thus, CHB is more advantageous among other multilevel inverter topologies. Moreover, an appropriate switching angle has to be generated by using optimizing techniques to control the switching frequencies of each semiconductor switches connected. Thus, insulator gate bipolar transistor (IGBT) is an example of semiconductor switches that are switched on and off in any ways to keep the percentage of total harmonic distortion (THD) to its minimum value. These switches also have low block voltage and high switching frequency.

1.2 Problem Statement

Multilevel inverters, an approach for harmonic cancellation, have gained worldwide interest. They provide an output with desired waveform that exhibits multiple-steps voltage-levels with minimum distortion. Besides, the modulation control signal is required in a multilevel inverter to generate the synthesized desired output waveform. This is to generate the desired fundamental frequency while minimizing higher-order harmonic content.

In fact, four control methods are commonly used in the multilevel inverters. These methods are traditional PWM control, selective harmonic minimization, space vector