



Faculty of Electrical Engineering

**PERFORMANCE OF MULTILEVEL INVERTERS FOR HARMONIC
REDUCTION IN DYNAMIC VOLTAGE RESTORER APPLICATION**

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Master of Science in Electrical Engineering

2018

**PERFORMANCE OF MULTILEVEL INVERTERS FOR HARMONIC
REDUCTION IN DYNAMIC VOLTAGE RESTORER APPLICATION**

NORSYUHADA BINTI NORDIN

**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

2018

DECLARATION

“I declare that this thesis entitles “Performance of Multilevel Inverters for Harmonic Reduction in Dynamic Voltage Restorer Application” 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 the candidature of any other degree.

Signature :

Name : Norsyuhada Binti Nordin

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 of the award of Master of Science in Electrical Engineering (Industrial Power).

Signature :

Supervisor Name : Assoc Prof Ir Dr Rosli Bin Omar

Date :

DEDICATION

This thesis dedicated to my family for all their endless supports.

ABSTRACT

Multilevel inverters are known for their initial usage in high-voltage and high-power applications. This thesis presents the analysis and design of the Three-Phase Cascaded H-Bridge Multilevel Inverters (CHB-MLI) for three and five levels based on Newton-Raphson technique for harmonic reduction in Dynamic Voltage Restorer (DVR) application. The performance of the inverter outputs to reduce harmonics is crucial for DVR applications. Two DC sources were applied for two types of CHB-MLI. These types of inverters used Newton-Raphson method as their controllers. The main aim of this thesis is to design, model, construct, and conduct laboratory testing upon CHB-MLI of a three and five levels prototype for DVR application. The design of suitable multilevel inverters is very important for DVR purposes, so that the AC output voltage waveforms of the inverters have low content of harmonics during energy conversion process from DC to AC of the proposed inverters. The Digital Signal Processing (DSP) TMS320F2812 was used as a tool in order to create the coding based on the Newton-Raphson technique controller. The coding was developed, and then stored into the Digital Signal Processing (DSP) TMS320F2812 for output processing of the waveform of the inverters. The proposed controller using Newton-Raphson technique was applied to both three and five level of CHB-MLI. The optimization of this system has managed to reduce the harmonic contents of the inverters output. The performance of the developed prototype was tested using source codes of the programming for optimization technique. The experimental results of the developed prototype for both three and five levels were monitored and analysed. In addition, the performance of the proposed system was compared between simulation and experimental results for the optimization technique. The simulation and experimental results had shown the effectiveness of the proposed system in reducing harmonic. The waveforms in term of current and voltage were smooth and contain low contents of harmonic. Types of waveforms for five level of CHB-MLI which were more suitable to be used in the DVR applications.

ABSTRAK

Penyongsang berbilang aras terkenal dengan penggunaan awal mereka dalam aplikasi voltan tinggi dan berkuasa tinggi. Tesis ini mempersembahkan analisis dan mereka bentuk Jambatan-H Jujukan Berbilang Aras Litar Penyongsang (JHJ-BALP) tiga fasa untuk tiga dan lima tahap berdasarkan teknik Newton-Raphson untuk pengurangan harmonik dalam aplikasi Pemulih Voltan Dinamik (PVD). Prestasi keluaran penyongsang dalam pengurangan harmonik adalah amat penting dalam aplikasi PVD. Dua sumber bekalan AT digunakan pada dua jenis JHJ-BALP. Semua jenis penyongsang ini menggunakan teknik Newton-Raphson sebagai pengawal. Tujuan utama tesis ini ialah mereka bentuk, model, membina, dan menjalankan ujian makmal ke atas prototaip JHJ-BALP yang telah direka bentuk bagi tiga dan lima tahap untuk aplikasi PVD. Mereka bentuk JHJ-BALP yang sesuai untuk tujuan PVD supaya keluaran voltan AU bagi penyongsang mempunyai kandungan harmonik yang rendah semasa proses penukaran dari Voltan AT ke AU terhadap JHJ-BALP yang dicadangkan. Pemprosesan Isyarat Digital (PID) TMS320F2812 digunakan sebagai alat untuk menjana kod berasaskan kepada pengawal teknik Newton-Raphson. Kod yang dihasilkan kemudiannya disimpan dalam PID TMS320F2812 untuk pemprosesan keluaran gelombang bagi penyongsang. Pengawal yang dicadangkan menggunakan teknik Newton Raphson dibekalkan kepada kedua-dua JHJ-BALP untuk tahap tiga dan lima. Pengoptimuman sistem ini telah dapat mengurangkan kandungan harmonik pada keluaran penyongsang. Prestasi prototaip yang dibangunkan diuji dengan menggunakan kaedah kod program teknik pengoptimuman. Hasil keputusan ujikaji dari prototaip yang direkabentuk untuk tahap tiga dan lima diperhatikan dan dianalisa. Selanjutnya prestasi sistem yang dicadangkan dibandingkan dengan keputusan simulasi dan ujikaji untuk teknik pengoptimuman. Hasil keputusan simulasi dan ujikaji menunjukkan keberkesanan sistem yang dicadangkan dalam mengurangkan harmonik. Bentuk gelombang bagi arus dan voltan adalah berbentuk sinusoidal yang mempunyai kandungan harmonik yang rendah. Jenis gelombang untuk tahap lima bagi JHJ-BALP adalah lebih sesuai digunakan dalam aplikasi PVD .

ACKNOWLEDGEMENTS

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 Prof. Dr. Nasrudin Bin Abdul Rahim 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 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 mom, Siti Minah Binti Abdul 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.

TABLE OF CONTENTS

	PAGE
DECLARATION	
APPROVAL	
DEDICATION	
ABSTRACT	i
ABSTRAK	ii
ACKNOWLEDGEMENTS	iii
TABLE OF CONTENTS	iv
LIST OF TABLES	vii
LIST OF FIGURES	viii
LIST OF APPENDICES	xvi
LIST OF ABBREVIATIONS	xvii
LIST OF SYMBOLS	xviii
LIST OF PUBLICATIONS	xix
CHAPTER	
1 INTRODUCTION	1
1.1 Introduction	1
1.2 Problem Statement	2
1.3 Objectives of Research	3
1.4 Motivation of Research	3
1.5 Scope of Research	4
1.6 Contributions of Research	4
1.7 Organization of Thesis	5
2 LITERATURE REVIEW	7
2.1 Introduction	7
2.2 The Basic Function and Components of a Dynamic Voltage Restorer (DVR)	7
2.2.1 Series Voltage Injection Transformers	8
2.2.2 Energy Storage	9
2.2.3 Passive Filters	9
2.2.4 Voltage Source Inverter (VSI)	10
2.3 Topologies of Multilevel Inverter	11
2.3.1 Diode-Clamped Multilevel Inverter	13
2.3.2 Flying Capacitors Multilevel Inverter	17
2.3.3 Cascaded H-Bridge Multilevel Inverter (CHB-MLI)	21
2.3.4 Advantages and Disadvantages of Multilevel Inverters	26
2.3.5 Space Vector Modulation (SVM) for Three-Level Inverters	28
2.4 Definition of Harmonics	31
2.5 Harmonic Sources	32
2.5.1 Effect of Harmonic Distortion	33
2.5.2 Harmonic Measurement	34
2.5.3 Harmonic Spectrum	34
2.6 Types of Controllers and Modulations used in Multilevel Inverter	35

2.6.1	Selective Harmonic Elimination PWM (SHE-PWM)	35
2.6.2	Space Pulse Width Modulation (SPWM)	37
2.6.3	Pulse Width Modulation Techniques	38
2.6.4	Sinusoidal Pulse-Width Modulation	39
2.6.5	Space Vector Pulse-Width Modulation	43
2.6.6	Selective Harmonic Elimination	44
2.7	Summary	45
3	RESEARCH METHODOLOGY / SYSTEM DESIGN	47
3.1	Introduction	47
3.2	Overall Research Methodology	47
3.2.1	Phase 1	49
3.2.2	Phase 2	49
3.2.3	Phase 3	49
3.2.4	Phase 4	50
3.2.5	Phase 5	50
3.3	Fourier series	65
3.4	Mathematical Technique of Switching via Newton-Raphson	66
3.4.1	3-level Multilevel Inverters	69
3.5	A Hardware Prototype of a Three-phase 5-level of a CHB-MLI	72
3.6	Prototype Development of a Three-Phase CHB-MLI for Five and Three Level Experiment Circuits	73
3.7	Summary	74
4	RESULTS AND DISCUSSION	76
4.1	Introduction	76
4.2	Simulation of a Three Phase CHB-MLI for Three and Five levels	76
4.2.1	Simulation Results for Optimization of a Three-Phase Five Level CHB-MLI Model with $M_a = 0.84$	77
4.2.2	Simulation Results of a Three-Phase of CHB-MLI for Five Level ($M_I = 0.68$)	84
4.2.3	Simulation Results for Optimization of a Three-Phase Three level CHB-MLI Model with $M_I = 0.84$	90
4.2.4	Simulation Results for Non-Optimization of a Three Phase Three Level CHB- MLI with ($M_I = 0.68$)	95
4.3	Experimental Results of a Three-Phase CHB-MLI with Different Modulation Index values	99
4.3.1	Optimization Experimental Results of a Three-Phase 5-level CHB-MLI ($M_I = 0.84$)	100
4.3.2	Non-optimization Experimental Results of a Three-Phase five-level CHB-MLI ($M_I = 0.68$)	107
4.3.3	Optimization Experimental Results of a Three-Phase Three-level CHB-MLI ($M_I = 0.84$)	114
4.3.4	Non-Optimization Experimental Results of a Three-Phase Three-level CHB-MLI ($M_I = 0.68$)	119
4.4	Summary	124
5	CONCLUSION AND FUTURE WORK	125
5.1	Introduction	125

5.2	Conclusion	125
5.3	Achievement of Research Objectives	126
5.4	Significance of Research Findings	127
5.5	Future Work	127
REFERENCES		129
APPENDICES		137

LIST OF TABLES

TABLE	TITLE	PAGE
2.1	Switching Pattern for Three-Level Diode-Clamped Inverter	16
2.2	Switching Pattern for a Five-Level Diode-Clamped Multilevel Inverter	17
2.3	A Possible Switching Combination for the 5-Level Flying Capacitor Converter	21
3.1	The Values of Switching Angles and Voltage THD of a CHB-MLI for 5-level	68
3.2	The Values of Switching Angles and Voltage THD of a Three-Level CHB-MLI	71
3.3	Switching Pattern for Five-Level Inverter	71
3.4	Switching Pattern for Three-Level Inverter	72

LIST OF FIGURES

FIGURE	TITLE	PAGE
2.1	The Circuit of Conventional DVR (Nielsen, et al., 2005)	8
2.2	Power Circuit of a DVR (Perera, et al., 2006)	11
2.3	One Phase Leg of a Three-Level Inverter (Kiruthika, 2012)	12
2.4	Diode Clamped Multilevel Inverter Circuit Topologies (a) Three-Level and (b) Five-Level	15
2.5	Capacitor-Clamped Multilevel Inverter Circuit Topologies (a) Three-Level (b) Five-Level	20
2.6	An H-Bridge Multilevel Inverter	22
2.7	Repeated Zero-Level Switching Pattern	23
2.8	Swapped Zero-Level Switching Pattern	24
2.9	Phase Output Voltage Waveforms of a Five-Level Topology CHB-MLI with Two Separate DC Sources.	25
2.10	Switching States of a Three-Level (Hua CC et al., 2007)	31
2.11	(a) Separated Fundamental and Harmonic Waveforms, and (b) Waveform Resulting from Summation	32
2.12	Harmonic Spectrum of a Sample with Distorted Wave	35
2.13	Classification of Multilevel Modulators Methods (Tolbert, 2000)	39
2.14	Sinusoidal Pulse-Width Modulation (Tolbert, 1999)	40
2.15	Modified Sinusoidal PWM Technique (Tolbert, 1999)	41

2.16	Cascaded H-Bridge in Multilevel Inverter for Three-Phase Nine-level	42
2.17	Sinusoidal Pulse-Width Modulation for Nine Levels Inverter	43
2.18	Space Vector Diagram (a) Three-Level; (b) Five-Level; (c) Seven-Level (Gupta, 2005)	44
3.1	Flowchart of the Proposed Methodology	48
3.2	The Proposed Topology of a Three-Phase Five Level CHB-MLI	51
3.3	The Proposed Topology of a 3-Phase 3-Level CHB- MLI Model	52
3.4	Simulation Model of a CHB-MLI for Three Level	53
3.5	Simulation Model of a CHB-MLI for Five-Level	53
3.6	Switching Block Model	54
3.7	MATLAB SIMULINK Software Control PWM.	54
3.8	The Construction of the Gate Drive Combined with CHB-MLI	56
3.9	The Development of a Single-Phase Five Level CHB-MLI	58
3.10	The Development of a Single-Phase Three Level CHB-MLI.	59
3.11	Digital Signal Processor (DSP) TMS320F2812	60
3.12	TMS320F2812 Architecture	61
3.13	Input Switching Pattern of 5V	62
3.14	Output Switching Pattern of 15V	63
3.15	Switching Pattern for S1, S2, S3 and S4 (15V)	64
3.16	Switching Pattern for S5, S6, S7 and S8 (15V)	64
3.17	General flow-chart of NR of the CHB-MLIs	66
3.18	The Overall Experimental Set-Up for the Prototype of Five-Level CHB-MLI Inverters	74

3.19	The Overall Experimental Set-Up for the Prototype of Three-Level CHB MLI Inverters.	74
4.1	Upper Switches Timing Diagram for S1, S2, S3, and S4 at Phase A with MI=0.84 for $\theta_1 = 17.06^\circ$ and $\theta_2 = 43.53^\circ$	78
4.2	Lower Switches Timing Diagram for S5, S6, S7, and S8 at Phase A with MI=0.84 for $\theta_1 = 17.06^\circ$ and $\theta_2 = 43.53^\circ$	78
4.3	Upper Switches Timing Diagram for S1, S2, S3, and S4 at Phase B with MI=0.84 for $\theta_1 = 17.06^\circ$ and $\theta_2 = 43.53^\circ$	79
4.4	Lower Switches Timing Diagram for S5, S6, S7, and S8 at Phase B MI=0.84 for $\theta_1 = 17.06^\circ$ and $\theta_2 = 43.53^\circ$	79
4.5	Upper Switches Timing Diagram for S1, S2, S3, and S4 at Phase C MI=0.84 for $\theta_1 = 17.06^\circ$ and $\theta_2 = 43.53^\circ$	80
4.6	Lower Switches Timing Diagram for S5, S6, S7, and S8 at Phase C with MI=0.84 for $\theta_1 = 17.06^\circ$ and $\theta_2 = 43.53^\circ$	80
4.7	Output Voltage Waveform for Optimization of 5-Level CHB-MLI with MI=0.84	81
4.8	Harmonic Spectrum for Output Voltage Waveform of 5-Level CHB-MLI with MI=0.84	82
4.9	Output Voltage Waveform for Optimization of 5-Level CHB-MLI with MI=0.84	83
4.10	Harmonic Spectrum for Output Current Waveform of 5-Level CHB-MLI with MI=0.84	83
4.11	Upper Switches Timing diagram for S1, S2, S3, and S4 at Phase A with MI=0.68 for $\theta_1 = 8.774^\circ$ and $\theta_2 = 68.155^\circ$	84

4.12	Lower Switches Timing Diagram for S5, S6, S7, and S8 at Phase A with MI=0.68 for $\theta_1 = 8.774^\circ$ and $\theta_2 = 68.1550^\circ$	85
4.13	Upper Switches Timing Diagram for S1, S2, S3, and S4 at Phase B with MI=0.68 for $\theta_1 = 8.774^\circ$ and $\theta_2 = 68.155^\circ$	85
4.14	Lower Switches Timing Diagram for S5, S6, S7, and S8 at Phase B with MI=0.68 for $\theta_1 = 8.774^\circ$ and $\theta_2 = 68.155^\circ$	86
4.15	Upper Switches Timing Diagram for S1, S2, S3, and S4 at Phase C with MI=0.68 for $\theta_1 = 8.774^\circ$ and $\theta_2 = 68.155^\circ$	86
4.16	Lower Switches Timing Diagram for S5, S6, S7, and S8 at Phase C with MI=0.68 for $\theta_1 = 8.774^\circ$ and $\theta_2 = 68.155^\circ$	87
4.17	Output Voltage Waveform for Non-Optimization of 5-Level CHB-MLI with MI=0.68	88
4.18	Harmonic Spectrum for Non-Optimization Output Voltage Waveform of 5-Level CHB-MLI with MI=0.68	88
4.19	Output Current Waveform for Non-Optimization of 5-Level CHB-MLI with MI=0.68	89
4.20	Harmonic Spectrum for Output Current Waveform of 5-Level CHB-MLI with MI=0.68	89
4.21	Three Level Switches Timing Diagram for S1, S2, S3, and S4 at phase A with MI=0.84 for $\theta_1 = 17.06^\circ$ and $\theta_2 = 43.53^\circ$	90
4.22	Three Level Switches Timing Diagram for S1, S2, S3, and S4 at phase B with MI=0.84 for $\theta_1 = 17.06^\circ$ and $\theta_2 = 43.53^\circ$	91
4.23	Three Level Switches Timing Diagram for S1, S2, S3, and S4 at phase C MI=0.84 for $\theta_1 = 17.06^\circ$ and $\theta_2 = 43.53^\circ$	91

4.24	Output Voltage Waveform for Optimization of 3-Level CHB-MLI with $M_i = 0.84$	92
4.25	Harmonic Spectrum for Output Voltage Waveform of 3-Level CHB-MLI with $M_i=0.84$	93
4.26	Output current for Optimization of 3-Level CHB-MLI with $M_i = 0.84$	94
4.27	Harmonic Spectrum for Output Current Waveform of 3-Level CHB-MLI with $M_i=0.84$	94
4.28	Three Level Switches Timing Diagram for S1, S2, S3, and S4 at Phase A with $M_i=0.68$ for $\theta_1=8.774^\circ$ and $\theta_2 =68.155^\circ$	95
4.29	Three Level Switches Timing Diagram for S1, S2, S3, and S4 at Phase B with $M_i=0.68$ for $\theta_1 =8.774^\circ$ and $\theta_2 =68.155^\circ$	96
4.30	Three Level Switches Timing Diagram for S1, S2, S3, and S4 at Phase C with $M_i=0.68$ for $\theta_1 =8.774^\circ$ and $\theta_2 =68.155^\circ$	96
4.31	Output Voltage Waveform for Non-Optimization of 3-Level CHB-MLI with $M_i = 0.68$	97
4.32	Harmonic Spectrum for Output Voltage Waveform of 3-Level CHB-MLI with $M_i=0.68$	97
4.33	Output Current Waveform for Non-Optimization of 3-Level CHB-MLI with $M_i = 0.68$	98
4.34	Harmonic Spectrum for Output Current Waveform of 3-Level CHB-MLI with $M_i=0.68$	99
4.35	Upper Switches Timing Diagram for S1, S2, S3, and S4 for Phase A with $M_i=0.84$ for $\theta_1 =17.06^\circ$ and $\theta_2 =43.53^\circ$	101

4.36	Lower Switches Timing Diagram for S5, S6, S7, and S8 at Phase A with MI=0.84 for $\theta_1 = 17.06^\circ$ and $\theta_2 = 43.53^\circ$	101
4.37	Upper Switches Timing Diagram for S1, S2, S3, and S4 with MI=0.84 for Phase B $\theta_1 = 17.06^\circ$ and $\theta_2 = 43.53^\circ$	102
4.38	Lower Switches Timing Diagram for S5, S6, S7, and S8 for Phase B with MI=0.84 for $\theta_1 = 17.06^\circ$ and $\theta_2 = 43.53^\circ$	102
4.39	Upper Switches Timing Diagram for S1, S2, S3, and S4 for Phase C with MI=0.84 for $\theta_1 = 17.06^\circ$ and $\theta_2 = 43.53^\circ$	103
4.40	Lower Switches Timing Diagram for S5, S6, S7, and S8 for Phase C with MI=0.84 for $\theta_1 = 17.06^\circ$ and $\theta_2 = 43.53^\circ$	103
4.41	Optimization of Voltage Output Waveform of 5-Level CHB-MLI with MI=0.84	104
4.42	Optimization Harmonic Spectrum of Voltage Output Waveform of 5-Level CHB-MLI with MI=0.84	105
4.43	Optimization Voltage and Current Output Waveform of 5-Level CHB-MLI with MI=0.84.	106
4.44	Optimization Harmonic Spectrum of Current Output Waveform of 5-Level CHB-MLI with MI=0.84.	107
4.45	Upper Switches Timing Diagram for S1, S2, S3, and S4 at Phase A with MI=0.68 for $\theta_1 = 8.774^\circ$ and $\theta_2 = 68.155^\circ$	108
4.46	Lower Switches Timing Diagram for S5, S6, S7, and S8 at Phase A with MI=0.68 for $\theta_1 = 8.774^\circ$ and $\theta_2 = 68.155^\circ$	108
4.47	Upper switches Timing Diagram for S1, S2, S3, and S4 at Phase B with MI=0.68 for $\theta_1 = 8.774^\circ$ and $\theta_2 = 68.155^\circ$	109

4.48	Lower Switches Timing Diagram for S5, S6, S7, and S8 at Phase B with MI=0.68 for $\theta_1 = 8.774^\circ$ and $\theta_2 = 68.155^\circ$	109
4.49	Upper Switches Timing Diagram for S1, S2, S3, and S4 at Phase C with MI=0.68 for $\theta_1 = 8.774^\circ$ and $\theta_2 = 68.155^\circ$	110
4.50	Lower Switches Timing Diagram for S5, S6, S7, and S8 at Phase C with MI=0.68 for $\theta_1 = 8.774^\circ$ and $\theta_2 = 68.155^\circ$	110
4.51	Non-Optimization Voltage Output Waveform of 5-Level CHB-MLI with MI=0.68	111
4.52	Non-Optimization Harmonic Spectrum of Voltage Output Waveform of CHB-MLI with MI=0.68	112
4.53	Non-Optimization Current Output of 5-Level CHB-MLI with MI=0.68	113
4.54	Non-Optimization Harmonic Spectrum of Current Output Waveform of 5-Level CHB-MLI with MI=0.68	113
4.55	Three Level Switches Timing Diagram for S1, S2, S3, S4 at Phase A with MI=0.84	114
4.56	Three Level Switches Timing Diagram for S1, S2, S3, S4 at Phase B with MI=0.84	115
4.57	Three Level Switches Timing Diagram for S1, S2, S3, S4 at Phase C with MI=0.84	115
4.58	Optimization of Voltage Output Waveform of 3-Level CHB-MLI with MI=0.84	116
4.59	Optimization Harmonic Spectrum of Voltage Output Waveform Three Level of CHB-MLI with MI=0.84	117
4.60	Optimization Current Output of 3 Level CHB-MLI with MI=0.84	118

4.61	Optimization Harmonic Spectrum of Current Output Waveform Three Level of CHB-MLI with MI=0.84	118
4.62	Three Level Switches Timing Diagram for S1, S2, S3, S4 at Phase A with MI=0.68	119
4.63	Three Level Switches Timing Diagram for S1, S2, S3, S4 at Phase B with MI=0.68	120
4.64	Three Level Switches Timing Diagram for S1, S2, S3, S4 at Phase C with MI=0.68	120
4.65	Optimization of Voltage Output Waveform of 3-Level CHB-MLI with MI=0.68	121
4.66	Non-Optimization Harmonic Spectrum of Voltage Output Waveform Three Level CHB-MLI with MI=0.68	122
4.67	Non-Optimization Current Output Waveform of 3-Level CHB- MLI with MI=0.68	123
4.68	Non-Optimization Harmonic Spectrum of Current Output Waveform Three Level CHB-MLI with MI=0.68	123

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A1	Datasheet Optocoupler HCPL 3120A	138
A2	Datasheet IGBT	140
B1	Schematic Circuit (5-Level CHB-MLI)	141
B2	Schematic Circuit (3-Level CHB-MLI)	142
C1	Source Code 3-Phase 5-Level CHB-MLI Optimization (MI=0.84)	143
C2	Source Code 3-Phase 5-Level CHB-MLI Non-Optimization (MI=0.68)	151
D1	Source Code 3-Phase 3-Level CHB-MLI Optimization (MI=0.84)	157
D2	Source Code 3-Phase 3-Level CHB-MLI Non-Optimization (MI- 0.68)	163

LIST OF ABBREVIATIONS

AC	-	Alternating Current
CHB-MLI	-	Cascaded H-Bridge Multilevel Inverter
DC	-	Diode-Clamped
DC	-	Direct Current
DSP	-	Digital Signal Processors
FCs	-	Flying Capacitors
IEC	-	International Electric Code
IGBT	-	Insulated Gate Bipolar Transistor
MI	-	Modulation Index
PWM	-	Pulse Width Modulation
SHE-PWM	-	Selective Harmonic Elimination Pulse Width Modulation
SPWM	-	Sinusoidal Pulse Width Modulation
SVPWM	-	Space Vector Pulse Width Modulation
THD	-	Total Harmonic Distortion

LIST OF SYMBOLS

$f_{carrier}$	-	carrier frequency
$f_{reference}$	-	reference frequency
V_{ref}	-	Voltage Source reference
V_s	-	Voltage Source
f_s	-	Sampling frequency
f_{sw}	-	Switching frequency
I	-	Current, absolute value
f	-	AC power frequency

LIST OF PUBLICATIONS

The following publications have been achieved by this research work:

Journal

1. NorSyuhada, Rosli Omar, Mohammed Rasheed, Afiqah Sabari. "Optimization of a Three Phase Cascaded H-bridge Multilevel Inverter for Harmonic Elimination Based on Newton- Raphson" Journal: Australian Journal of Basic and Applied Sciences ISSN 0973-4562 Volume 10, Number 3 (2015) pp. 6569-6580.
2. Rosli Omar, NorSyuhada, Mohammed Rasheed, Marizan Sulaiman, Krismadinata and Afiqah Sabari "Comparison Performance of Multilevel Inverters for Harmonic Reduction in Dynamic Voltage Restorer (DVR) Application" World Applied Sciences Journal (WASJ) : Accepted.

Conference

1. NS Nordin, Rosli Omar, M Sulaiman, MFM Elias, "Comparative Study of Cascaded H-bridge Multilevel Inverter Model Based on Power Electronic Simulator (PSIM)" IEEE Conference Publications, Clean Energy and Technology (CEAT) 2014, 3rd IET International Conference on Date 24-26 Nov. 2014.
2. NorSyuhada Nordin, Rosli Omar, Krismadinata, Mohammed Rasheed, Afiqah Sabari, "Harmonic Minimization of a Three Phase Cascaded H-