

**DEVELOPMENT OF S-PWM
VOLTAGE SOURCE INVERTER FOR
INDUCTION MOTOR DRIVES**

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SUPERVISOR DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Master Engineering in Mechatronics

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STUDENT DECLARATION

I hereby declare that the work in this thesis is my own except for quotation and summaries which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for award of other degree at Universiti Malaysia Pahang or any other institutions.

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TABLE OF CONTENT

DECLARATION

TITLE PAGE

ACKNOWLEDGEMENT	ii
------------------------	----

ABSTRAK	iii
----------------	-----

ABSTRACT	iv
-----------------	----

TABLE OF CONTENT	v
-------------------------	---

LIST OF TABLES	ix
-----------------------	----

LIST OF FIGURES	x
------------------------	---

LIST OF APPENDICES	xiii
---------------------------	------

LIST OF SYMBOLS	xv
------------------------	----

LIST OF ABBREVIATIONS	xviii
------------------------------	-------

CHAPTER 1 INTRODUCTION

1.0. Research Background	1
--------------------------	---

1.1. Problem Statement	2
------------------------	---

1.2. Objective	4
----------------	---

1.3. Scope	4
------------	---

1.4. Thesis Outline	5
---------------------	---

CHAPTER 2 LITERATURE REVIEW

2.1. Induction Motor, Drives System and Ecological	6
----------------------------------------------------	---

Interest	
----------	--

2.1.1. Induction Motor Parameters Extraction	6
----------------------------------------------	---

Induction Motor Nameplate Data	6
--------------------------------	---

Parameters Extraction	7
-----------------------	---

2.1.2. Variable Speed Drives (VSD) Control Scheme	8
Field Oriented Control (FOC)	9
Direct Torque Control (TOC)	18
2.1.3. Ecological Footprint	22
2.2. Inverter Module In Induction Motor Control	22
2.2.1. Inverter Bridge, Element and Topology	23
2.2.2. Sinusoidal Pulse Width Modulation (S-PWM)	29
2.2.3. S-PWM Invertor and Induction Motor Drives Integration	32
2.2.4. SV-PWM Inverter for Induction Motor Drives	35
2.3. Summary	36

CHAPTER 3 METHODOLOGY

3.1. System Simulation: Matlab-Simulink	44
3.1.1. Sinusoidal Pulse Width Modulation	45
3.1.2. Induction Motor	46
3.1.3. Induction Motor Open Loop Control	49
3.1.4. Simulation Verification	50
3.2. Circuit Design: Multisim	51
3.2.1. Buffering	52
3.2.2. Modulating Sinusoidal Wave Phase-1 Generator	53
3.2.3. Modulating Sinusoidal Wave Phase-3 Generator	53
3.2.4. Modulating Sinusoidal Wave Phase-2 Generator	57
3.2.5. Center Aligned Triangle Wave Generator	58
3.2.6. Comparator	59
3.3. Hardware Implementation And Verification	60

3.3.1. Opto-isolator	62
3.3.2. IR2130 Bootstrapping	62
3.3.3. Experimental Testing Setup and Settings	64
CHAPTER 4 RESULTS AND DISCUSSION	
4.1. System Simulation	67
4.1.1. S-PWM Inverter	67
Induction motor performance	67
Harmonics Content	74
4.1.2 . SV-PWM Inverter	75
Induction motor performance	75
Harmonics Content	80
4.1.3. S-PWM and SV-PWM Inverter Comparative Analysis	81
4.2. Circuit Simulation	83
4.2.1. Buffering	83
4.2.2. Modulating Wave Generator	83
4.2.3. Carrier Wave Generator	85
4.2.4. Comparator	88
4.3. Real Hardware Implementations	89
4.3.1 Sinusoidal, Triangle and Comparator Modules	90
4.3.2 Induction Motor Integration	91
CHAPTER 5 CONCLUSION AND RECOMMENDATION	
5.0. Introduction	98
5.1. Conclusion	98
5.2. Future Recommendations	100

REFERENCES	101
APPENDICES	108

LIST OF TABLE

Table 2.1	Summary of reviewed literatures	38
Table 3.1	S-PWM simulation settings	64
Table 3.2	IM drives experimental testing settings	66
Table 4.1	Summary of the simulated S-PWM and SV-PWM based IM drives performance	82
Table 4.2	Selected data within 500ms trianlge wave sample for varied R_v	86
Table 4.3	S-PWM inverter testing results	97

LIST OF FIGURES

Figure 2.1	Single-phase equivalent circuit of induction motor in stationary condition with phase diagram	9
Figure 2.2	Induction motor control using field coordinates	13
Figure 2.3	Field-oriented control scheme of the electric vehicle	14
Figure 2.4	Vehicle drives mechanical transmission system protection by decrease of the motor flux	15
Figure 2.5	Direct Torque Control for IM scheme	21
Figure 2.6	McMurray's voltage source inverter single phase bridge with the proposed resonant snubbers and auxiliary diodes; G refers to Gate Turn-off thyristor (GTO), C_s refers to snubber capacitor, L_s refers to snubber inductance, S_n and S_p are the antiparallel ordinary thyristors, C_{op} and C_{on} are the DC-Link capacitors	24
Figure 2.7	Elementary Form of Center-Tapped Supply Mapham's Converter for resistive load (R)	25
Figure 2.8	Yu, Wilson, Babaa, Feng, & Moore's Inverter Bridge	26
Figure 2.9	Multilevel IGBT bridge topology THD improvement	28
Figure 2.10	S-PWM sampling (a) Natural double edge sampling; (b) Uniform (Regular) double-edge sampling; (c) Comparison of the modulation processes	29
Figure 2.11	Block diagram of the proposed IMD incorporating the constant V/Hz technique	32
Figure 3.1	Flowchart of system simulation	44
Figure 3.2	Nameplate of the tested IM	47
Figure 3.3	IM tests setup (a) Lab-Volt variable power supply 8525 and data acquisition 9063; (b) Shaft locking	48
Figure 3.4	Flowchart of circuit simulation	52
Figure 3.5	Unity gain inverting amplifier and Sine-1 circuit	52
Figure 3.6	Sine-3 circuit	54
Figure 3.7	3-phase sine wave generator module	54
Figure 3.8	RC-circuit	55

Figure 3.9	Non-inverting amplifier with two times voltage gain	56
Figure 3.10	Sine-2 circuit	57
Figure 3.11	Center-aligned triangle wave generator	58
Figure 3.12	Single circuit PWM comparator	59
Figure 3.13	Flowchart of hardware implementation	61
Figure 3.14	Single phase PWM optocoupler circuit	62
Figure 3.15	IR2130 bootstrapping with SKM200G123D	63
Figure 3.16	IM drive with S-PWM inverter system	65
Figure 4.1	Fundamental electrical elements at IM stator terminal incorporating S-PWM Inverter	70
Figure 4.2	Electrical and mechanical elements of IM stator and shaft incorporating S-PWM inverter (a) Line voltage (V_{ab}); (b) Stator current (i_{sa}); (c) Rotor speed; (d) Electromagnetic torque	73
Figure 4.3	(a) FFT analysis of the v_{ab} with S-PWM inverter; (b) FFT analysis of the i_{sa} with S-PWM inverter	74
Figure 4.4	Coordinate transform in IM drive	76
Figure 4.5	Fundamental electrical elements at IM stator terminal incorporating SV-PWM inverter	77
Figure 4.6	Electrical and mechanical elements of IM stator and shaft incorporating SV-PWM inverter (a) Line voltage (V_{ab}); (b) Stator current (i_{sa}); (c) Rotor speed; (d) Electromagnetic torque	79
Figure 4.7	(a) FFT analysis of the v_{ab} with SV-PWM inverter; (b) FFT analysis of the i_{sa} with SV-PWM inverter	80
Figure 4.8	Voltage-follower as buffer for <i>Function Generator</i> and UUT interfacing	83
Figure 4.9	Multisim simulation of RC circuit, V_{buffer} (Blue) and V_{RC} charging (Red)	84
Figure 4.10	3-phase sine generator, V_{sine-1} (Red), V_{sine-2} (Yellow) and V_{sine-3} (Blue)	84
Figure 4.11	Center-aligned triangle wave, $V_{carrier}$	85
Figure 4.12	Oscillation error at 90% of R_V	86

Figure 4.13	S-PWM natural sampling simulation using LM311	88
Figure 4.14	S-PWM circuit and IR2130 driver	90
Figure 4.15	Channel 1 represents V_{mref} while Channel 2 represents V_{sine-1}	91
Figure 4.16	Channel 1 represents V_{sine-1} while Channel 2 represents V_{sine-3}	91
Figure 4.17	Channel 1 represents V_{sine-1} while Channel 2 represents V_{sine2}	92
Figure 4.18	Channel 1 represents V_{sine-2} while Channel 2 represents V_{sine-3}	92
Figure 4.19	$V_{carrier}$ at minimum frequency	93
Figure 4.20	(a) $V_{carrier}$ misshaped at 1.5 kHz (b) $V_{carrier}$ at maximum frequency	94
Figure 4.21	(a) Channel 1 represents $V_{carrier}$ while Channel 2, 3 and 4 represent V_{sine1} , V_{sine2} , V_{sine3} respectively; (b) Channel 1, 2, 3 represent $PWM1$, $PWM2$, and $PWM3$ respectively (measured at comparator module output)	95
Figure 4.22	Developed S-PWM VSI with IM#1 integration	96

LIST OF APPENDICES

A-1	Induction Motor Test	108
A-2	Induction Motor Test Results	110
B-1-1	Induction Motor Control System: S-PWM Inverter	113
B-1-2	S-PWM IM: Line to Line Voltages (V_{LL})	114
B-1-3	SPWM-IM: Switching Current and Voltage The First Leg of IGBT	115
B-2-1	S-PWM Inverter: Discrete 3-Phase PWM Generator	116
B-2-2	Discrete 3-Phase PWM Generator: Pulse Pattern Description (V_{ll})	117
B-3	Discrete 3-Phase PWM Generator: 2- Level Type	118
B-4-1	Discrete 3-Phase PWM Generator: U_{st}	119
B-4-2	U_{st} : 3-Phase Sine-Waves	120
B-5-1	Carrier Generator: Centre-Aligned Triangle	121
B-5-2	Carrier Generator: Centre-Aligned Triangle Wave	122
C-1-1	Induction Motor Control System: SV-PWM Inverter	123
C-1-2	SV-PWM-IM: Switching Current and Voltage The First Leg of IGBT	124
C-1-3	SV-PWM-IM: Line to Line Voltages (V_{LL})	125
C-2-1	SV-PWM Inverter: Discrete SV-PWM Generator	126
C-2-2	Discrete SV-PWM Generator: Pulse Pattern Description (V_{ll})	127
C-3	Discrete SV-PWM Generator: Determine Reference Vector (U^*)	128
C-4	Discrete SV-PWM Generator: SV Modulator Pattern #1	129
C-5	Discrete SV-PWM Generator: SV Modulator Pattern #2	130

C-6	SV Modulator Pattern #1: Determine the sector of U^* based on alpha (rad). Also, determine if the sector number is odd	131
C-7	SV Modulator Pattern #1: Compute Time Duration of Switching States (T_a, T_b, T_o)	132
C-8	SV Modulator Pattern #1: Generate Pulse Pattern	133
D	Phase Shifter Sine-3	134

LIST OF SYMBOLS

ξ	Electromotive force
ω	Electrical rotational speed
σ	Leakage factor
ϕ	Magnetic flux
\mathfrak{I}	Magnetomotive force
ρ	Radius of cylindrical coordinate system
τ	Torque
μ_0	Electromagnetic permeability of free space
B	Magnetic field density
C	Capacitance
f	Frequency
H	Magnetic field intensity
i	Current
L	Inductance
m	Modulation
M	Mutual inductance
n	Mechanical rotational speed
N	Number of windings
p	Number of pole
P	Real power
q	Charge
Q	Reactive power
R	Resistance

S	Apparent power
s	Slip
t	Time
v	Voltage
w	Work
Z	Impedance
ℓ	Length
M	Modulating waveform value
S	Sample hold modulating signal

LIST OF ABREVIATIONS

AC	Alternating Current
ADC	Analog digital converter
AMS	Analog mixed signal
CAD	Computer Aided Design
DC	Direct Current
DF	Distortion factor
DTC	Direct Torque Control
EDS	Electrical drives system
EM	Electric machine
EMF	Electromagnetic force
FFT	Fast Fourier transform
FLC	Fuzzy Logic Controller
FOC	Field Oriented Control
HCF	Harmonic current factor
IM	Induction Motor
KCL	Kirchhoff current law
KVL	Kirchhoff voltage law
PDM	Pulse duration modulation
PDM	Pulse length modulation
pf	Power factor
PID	Proportional Integral Differential
PSO	Particle Swarm Optimization
PWM	Pulse Width Modulation

q-axis	Quadrature axis
RF	Radio frequency
S-PWM	Sinusoidal Pulse Width Modulation
SV-PWM	Space Vector Pulse Width Modulation
THD	Total harmonic distortion
VSD	Variable Speed Drives
VSI	Voltage source inverter

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ABSTRAK

Cage-IM (Motor Induksi Sangkar) merupakan salah satu penggerak utama dalam pelbagai sektor industri. Ia berkemampuan untuk menjana tork pada julat yang luas, kuat dan kukuh serta kos kitaran hayat yang lebih murah berbanding lain-lain motor. Walau bagaimanapun, dengan keringkasan model binaannya, cage-IM adalah lebih sukar untuk dikawal. Ini adalah disebabkan oleh gandingan lapangan (field) dan angker (armature) di mana pemagnetan pemutar adalah bergantung kepada bahagian pemegun (stator). Cara yang paling mudah untuk memandu cage-IM adalah dengan pelaksanaan perintang secara sesiri di terminal pemegun. Tetapi teknik ini tidak sesuai untuk IM berkuasa tinggi sebagai haba yang dilesapkan pada perintang akan membuat operasi IM kurang cekap darisegi penggunaan tenaga. Pelaksanaan litar cycloconverter di sisi lain pula adalah agak kompleks dan kurang cekap kerana peranti ini akan menggunakan suis kuasa di kawasan aktif dan bukannya pada mode suis. Sebaliknya, Voltan Source Inverter (VSI) melaksanakan S-PWM untuk memberikan kuasa laras untuk IM. Gelombang S-PWM mengawal pensuisan jambatan suis kuasa untuk mewujudkan penukaran DC ke AC. Dalam kajian ini, topologi jambatan 3-fasa McMurray dilaksanakan. Ini 2 levels 3 legs topologi adalah antara yang paling biasa dipraktikkan. Pemacu IM gelung terbuka berdasarkan S-PWM VSI disimulasikan menggunakan SIMULINK. Hasil simulasi dianalisis melalui perbandingan dengan SV-PWM VSI untuk mengesahkan model simulasi tersebut. Voltan dan arus di terminal pemegun diukur dan dianalisis pada peringkat transien dan juga peringkat malar untuk mengkaji herotan harmonik dan juga prestasi IM. Hasil menunjukkan bahawa S-PWM VSI mampu memacu IM dengan masing-masing 80.23% dan 16.86% jumlah harmonik herotan untuk voltan dan arus. Pada keadaan transien, 265% tork elektromagnet terlajak berlaku dan sistem mengambil 0.2s untuk mencapai peringkat malar. Hasil prestasi ini adalah konsisten untuk Kelas B bagi IM NEMA. Litar S-PWM direka dengan bantuan perisian SPICE. 3 fasa gelombang sinus, gelombang segi tiga sejajar pertengahan, modul 3-fasa komparator S-PWM dilaksanakan dengan konfigurasi amplifier operasi litar dan IC tertentu. Litar yang direka digunakan untuk pelaksanaan perkakasan sebenar dan keputusannya dibandingkan dengan keputusan simulasi. DC ofset, gangguan ringing, amplitud dan frekuensi kesilapan berlaku pada model perkakasan sebenar yang mana tidak kelihatan dalam hasil simulasi. Ralat ini diuruskan oleh pelarasan manual gelombang rujukan modulasi (V_{ref}), isyarat pembawa ($V_{carrier}$) walaupun pelarasan tombol Rv dan juga jumlah voltan yang dibekalkan daripada IC (V_{CC} , V_{EE}). Pengasingan antara modul litar kawalan (penjana S-PWM) dan bahagian voltan tinggi pada jambatan dilaksanakan dengan menggunakan IC pengganding opto. Bagi integrasi IM, pemacu jambatan IR2130 digunakan untuk menyediakan *deadtime* untuk pasangan gelombang S-PWM serta menyambungan litar kawalan dengan modul IGBTs dan IM. Modul S-PWM inverter ini mampu memacu Cage-IM berkuasa kuda 0.4 sehingga pada kelajuan maximum. Modul ini dapat mendorong penggunaan kuasa yang lebih baik berbanding dengan pelaksanaan perintang secara sesiri di terminal pemegun.

ABSTRACT

Cage induction motor (Cage-IM) is one of the main prime mover in many industrial sectors. It provides wide range of torque production, robust and lower life cycle cost relatively to other types of motor. However, with the constructional simplicity, cage-IM tradeoff control complexity. This is due to the coupling of field and armature where the rotor magnetization is depends on the stator part. The simplest way to drive cage-IM is by implementation of series resistor at the stator terminal. But this technique is not suitable for high power IM as the heat dissipated at the resistor will make the operation of IM less power efficient. The implementation of cycloconverter circuit offers other alternative but the circuit is quite complex and less efficient as the device will used power switches at active region instead of switch mode. On the other hand, Voltage Source Inverter (VSI) implementing S-PWM to provide adjustable power to the IM. S-PWM waveforms control the switching of the power switches bridge to create DC to AC conversion. In this research, the 3-phase McMurray bridge topology is implemented. This 2 levels 3 legs topology is among the most commonly used in real application. An open loop IM drive implementing S-PWM VSI is simulated using SIMULINK. The results are comparatively analyzed through comparison with SV-PWM VSI to verify the system simulation model. Voltage and current at the stator terminal are measured and analyzed at transient and steady state to study the harmonics distortion as well as IM performance. The results shows that S-PWM VSI is capable to drive IM with 80.23% and 16.86% total harmonics distortion for voltage and current respectively. At transient state 265% electromagnetic torque overshoot occurs and the system took 0.2s for setting time. This performance results are consistent for NEMA Class B IM. The S-PWM circuit is designed with the aid of SPICE software. A 3-phase sinusoidal waves, a Centre-aligned triangle wave, 3-phase S-PWM comparator modules are implemented with operational amplifier circuit configurations of specific ICs. The designed circuits are applied for real hardware implementation and the results are compared with the simulated results. DC offset, ringing noises, amplitude and frequency errors occur on the real hardware model which are not presented by the simulation results. These errors are managed by manual adjustment of the reference modulating wave (V_{ref}), carrier signal ($V_{carrier}$) though R_v adjustment knob and the amount of supplied voltage of the ICs (V_{CC} , V_{EE}). The isolation between control circuit module (S-PWM generator) and the high voltage side of the bridge is implemented using opto coupler ICs. For IM drives integration, IR2130 bridge driver is used to provide deadtime to S-PWM wave pairs as well as interface the control circuit with the IGBTs module and IM. The developed S-PWM inverter module is capable to drive 0.4 hp cage-IM at rated speed with better power utilization as compared to the conventional variable resistance implementation.

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