Faculty of Electrical Engineering

IMPROVING DIRECT TORQUE CONTROL PERFORMANCE OF 3-LEVEL CHMI FOR INDUCTION MACHINE BY UTILIZING THE CONSTANT SWITCHING METHOD AND INCREASED SAMPLING FREQUENCY OF THE CONTROLLER

Sundram A/L Ramahlingam

Master of Science in Electrical Engineering

2017

APPROVAL

I hereby declare that I have read this dissertation/report and in my opinion this dissertation/report is sufficient in terms of scope and quality as a partial fulfillment of Master of Science in Electrical Engineering (Power Electronics and Drives).

Signature	:	....
Name	:	....
Date	:	....

DECLARATION

I declare that this thesis entitled "Improving Direct Torque Control Performance Of 3-Level Chmi For Induction Machine By Utilizing The Constant Switching Method And Increased Sampling Frequency Of The Controller" 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	:	....
Date	:	....

DEDICATION

To my parents, almighty God,

supervisor Dr Auzani bin Jidin,

friend Logan Raj Lourdes Victor Raj,

and others for their support, care and patience.

ABSTRACT

Excellent torque control has been a focus of research in AC drives since last decades due to its important requirements for many industrial applications. Spurred on by rapid developments in the embedded computing systems, two popular approaches namely Field Oriented Control (FOC) and Direct Torque Control (DTC) were used to obtain excellent torque control. Obviously, both approaches use the space vector modulation (SVM) technique to reduce torque ripples as well as produce a constant switching frequency. However, the use of SVM complicates the control structures of FOC and DTC, which somehow increase the sensitivity control and hence may degrade the control's accuracy. Moreover, the selection of voltage vectors is inappropriate, particularly for application of two-level inverter which offers limit number of voltage vectors. This thesis aims to reduce torque ripple and produce a constant switching frequency in DTC by replacing the hysteresis controller and two-level inverter with a PI based torque controller and three-level cascaded H-Bridge multilevel inverter (CHMI), respectively. By employing the three-level CHMI, it provides a greater number of voltage vectors as compared to that offered in the conventional two-level inverter which gives more options to select the most optimal voltage vectors. The analysis of effects of selecting different voltage vectors on DTC performances are carried out to identify the most optimal vectors that can be chosen to improve torque control performances for every operating condition. The identification is made with the aid of vector diagrams and some equations, i.e. equations of torque rate, slip angular frequency and torque capability. This thesis also presents detail explanation and calculation of optimal PI parameter tuning strategy consecutively to improve torque control with reduced torque ripples. The proposed DTC control algorithm can be optimally executed at high computation rate by totally using C-coding with DS1104 controller board. The effectiveness of the proposed method is verified via simulation and experiment results, as well as comparison with the conventional DTC method. The results have shown that the torque ripple in the proposed method can be greatly reduced about 9.54%.

ABSTRAK

Kecemerlangan kawalan dayakilas telah menjadi fokus dalam penyelidikan pemacuan arus ulang-alik semenjak beberapa dekad sebelum ini disebabkan keperluan penting bagi banyak aplikasi industri. Didorong oleh perkembangan pesat dalam sistem pengkomputeran tertanam, dua pendekatan popular iaitu Kawalan Berorientasikan Medan (FOC) dan Kawalan Dayakilas Langsung (DTC) telah digunakan untuk mencapai kawalan dayakilas yang cemerlang. Jelas sekali, kedua-dua pendekatan menggunakan teknik Modulasi Vektor Ruang (SVM) untuk mengurangkan riak-riak dayakilas dan juga menghasilkan sebuah frekuensi pensuisan yang malar. Walaubagaimanapun, penggunaan SVM merumitkan struktur kawalan bagi FOC dan DTC, yang boleh meningkatkan kepekaan kawalan dan seterusnya boleh menurunkan ketepatan kawalan. Tambahan lagi, pemilihan voltan vektor adalah tidak bersesuaian, terutama bagi penggunaan penyongsang dua peringkat yang menawarkan bilangan voltan vektor yang terhad. Tesis ini mensasarkan untuk mengurangkan riak dayakilas dan menghasilkan sebuah frekuensi pensuisan yang malar dalam DTC dengan menggantikan kawalan histeresis dan penyongsang dua peringkat masing-masing dengan sebuah kawalan dayakilas berasaskan PI dan penyongsang berganda peringkat lata jejambat-H. Dengan menggunakan tiga peringkat CHMI, ia menyediakan bilangan voltan vektor yang lebih banyak berbanding dengan yang ditawarkan dalam penyongsang konvenyenal dua peringkat yang memberi lebih opsyen untuk memilih voltan vektor yang paling optimal. Analisis bagi kesan-kesan pemilihan voltan vektor yang berbeza terhadap prestasi DTC dilakukan untuk mengenalpasti vektor yang paling optima untuk dipilih bagi menambahbaik prestasi kawalan dayakilas bagi setiap operasi keadaan. Pengenalpastian ini dilakukan dengan bantuan rajah vektor dan beberapa persamaan, iaitu persamaan kadar dayakilas, frekuensi sudut gelinciran dan keupayaan dayakilas. Tesis ini juga membentangkan penerangan terperinci dan pengiraan bagi strategy pelarasan parameter PI yang optimal untuk menambahbaik kawalan dayakilas dengan pengurangan riak-riak dayakilas. Cadangan kawalan algoritma DTC boleh secara optimal dilaksanakan pada kadaran pengiraan yang tinggi dengan sepenuhnya menggunakan kod-C dengan papan kawalan DS1104. Keberkesanan bagi cadangan kawalan disahkan melalui keputusan-keputusan simulasi dan eksperimen, dan juga perbandingan dengan kaedah konvensyenal DTC. Keputusan-keputusan telah menunjukkan bahawa dayakilas dalam kaedah cadangan boleh dikurangkan dengan jelas kira-kira 9.54%.

ACKNOWLEDGEMENTS

I acknowledge, with gratitude, my debt of thanks to Dr. Auzani bin Jidin for his generous guidance with expertise, ancouragement, understanding and patience on assisting me throughout my research and until the completion of my thesis.I would also like to thank everyone who have contributed to this thesis particularly my friend and co-researchers Logan Raj Lourdes Victor Raj and Khairi Rahim for their undisputed support and encouragament.This research was fully supported and funded by Universiti Teknikal Malaysia Melaka. I am grateful to this institution for providing me the platform and support through scholarship and reasearch grant to complete this study.Finally, I would like to thank my both parents and family members for their moral support, financial support, encouragement and tollerence throughout my study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

AC	-	Alternating Current
ADC	-	Analog Digital Converter
CFTC		Constant Frequency Torque Controller
DC	-	Direct current
DAC		Digital Analog Converter
DSC	-	Direct Self Control
DSP	-	Digital Signal Processor
DT	-	Sampling period
DTC	-	Direct Torque Control
FPGA	-	Field Programmer Gate Array
FOC	-	Field Oriented Control
IGBT	-	Insulated gate bipolar transistor
IM	-	Induction Motor
LB	-	Lower band
SVM	-	Space vector modulated
UB	-	Upper band
VSI	-	Voltage Source Inverter

LIST OF SYMBOL

d, q	-	Direct and quadrature of the stationary reference frame
d^r, q^r	-	Real and imaginary axis of the rotor
i_s, i_r	-	Stator and rotor current space vector in stationary reference frame
R_r, R_s	-	Rotor and stator resistance
$L_r\ L_s$	-	Rotor and Stator self-inductance
L_m	-	Mutual inductance
$\bar{\Psi}_s, \bar{\Psi}_r$	-	Stator and rotor flux linkage space vector in reference frame
i_{rd}, i_{rq}	-	*d* and *q* components of the rotor current in stationary reference frame
i_{sd}, i_{sq}	-	*d* and *q* components of the stator current in stationary reference frame
v_{sd}, v_{sq}	-	*d* and *q*-axis of the stator voltage in stationary reference frame
Ψ_{sd}, Ψ_{sq}	-	*d* and *q* components of the stator flux in stationary reference frame
$\bar{v}_s$	-	Voltage vectors
n	-	Numbers of phase
$i_a, i_b\ i_c$	-	Phase current a, b and c
L	-	Self-inductance
T_e	-	Electromagnetic Torque
T_{reff}	-	Reference of torque