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SENSORLESS SPEED DRIVES OF PERMANENT MAGNET SYNCHRONOUS MOTOR USING MODEL REFERENCE ADAPTIVE CONTROL

Raihana binti Mustafa

Master of Science in Electrical Engineering

2015

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SENSORLESS SPEED DRIVES OF PERMANENT MAGNET SYNCHRONOUS MOTOR USING MODEL REFERENCE ADAPTIVE CONTROL

RAIHANA BINTI MUSTAFA

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

2015

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DECLARATION

I declared that this thesis entitle "Sensorless Speed Drives Of Permanent Magnet Synchronous Motor using Model Reference Adaptive Control" 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 : Raihana Binti Mustafa

Date : ....

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APPROVAL

I hereby declared that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Electrical Engineering (Power Electronics and Drives).

Signature	:	…………………………………
Supervisor Name	:	Associates Professor Dr. Zulkifilie Bin Ibrahim
Date	:	…………………………………

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DEDICATION

To my beloved father, mother, my little sister and family

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ABSTRACT

In high performance drives, speed and torque controls of permanent magnet synchronous motors are usually attained by the application of position and speed sensors. However, speed and position sensors require the additional mounting space, reduce the reliability in harsh environments and increase the cost of the motor. Therefore, many studies have been carried out and reported to eliminate the speed and position sensors such as back electromotive force, signal injection, and others. However, these techniques have the drawbacks such as sensitive to machine parameter and others. The research focuses on investigation an evaluation of the sensorless speed control of surface mounted permanent magnet synchronous motor (SMPMSM) drives controlled by PI speed controller based on MRAC combined with V-I model and reactive power model. A Model Reference Adaptive Control (MRAC) has been chosen in this research based on its simplicity, good stability, and requires less computation. The SMPMSM is controlled using the principle of rotor flux orientation. Current control is performed in rotor reference frame based on SVPWM. The drives is simulated using SIMULINK/ MATLAB and the hardware implementation is based on dSPACE (DS1103). PI speed and current controllers are at first designed and the controller parameters are manually tuned to obtain steady state stability. A detailed investigation of the varies operating points; different speed command, forward-reverse speed operation, inertia variation and different speed command profiles. The overshoot/undershoot, settling time, and rise time of the speed response are used to evaluate the controller and speed estimation methods. The simulation and experimental with MRAC combined with V-I model speed estimation method results have proved that the drives is robust to the inertia variation, load rejection properties, speed variation and different initial speed profiles. Finally, the experimental investigation in MRAC combined with V-I model speed estimation method is performed in order to confirm the theoretical findings.

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ABSTRAK

Didalam pemacu berprestasi tinggi, kelajuan dan kawalan daya kilas motor segerak magnet kekal kebiasaannya digandingkan dengan aplikasi sensor posisi dan kelajuan. Walau bagaimanapun, sensor tersebut memerlukan ruang pemasangan tambahan, malah ia mengurangkan kecekapan dalam persekitaran yang tidak mesra disamping meningkatkan kos motor. Oleh itu, banyak kajian telah dijalankan dan dilaporkan bagi tidak menggunakan sensor kelajuan dan posisi seperti kaedah daya gerak elektrik undur (BEMF), suntikan isyarat, dan lain-lain. Walau bagaimanapun, teknik ini mempunyai kelemahan seperti sensitif kepada parameter mesin dan lain-lain. Kajian ini memberi tumpuan kepada siasatan penilaian kawalan kelajuan tanpa sensor kelajuan bagi pemacu motor segerak yang permukaannya dipasang dengan magnet kekal (SMPMSM) yang dikawal oleh pengawal kelajuan PI gabungan kawalan adaptasi model rujukan (MRAC) model V-I dan model kuasa reaktif. MRAC telah dipilih dalam kajian ini berdasarkan strukturnya yang mudah, kestabilan yang baik, dan kurang memerlukan pengiraan. SMPMSM dikawal menggunakan prinsip orientasi fluk rotor. Pengawal arus dilakukan di dalam bingkai rujukan rotor berdasarkan SVPWM. Pemacu ini disimulasi menggunakan SIMULINK / MATLAB dan perlaksanaan perkakas adalah berdasarkan dSPACE (DS1103). Pengawal PI bagi kelajuan dan arus direkabentuk terlebih dahulu dan parameter pengawal diubah suai secara manual bagi mencapai keadaan kestabilan yang mantap. Penyiasatan yang terperinci dijalankan pada titik operasi yang berbeza; arahan kelajuan yang berbeza, operasi kelajuan ke hadapan-belakang, perubahan inersia dan profil arahan kelajuan yang berbeza. Lajak/lajak bawah, masa pengenapan, dan masa naik digunakan untuk menilai pengawal dan kelajuan melalui kaedah anggaran kelajuan. Simulasi dan keputusan eksperimen dengan penggunaan MRAC yang digabungkan dengan V-I model melalui kaedah anggaran kelajuan telah terbukti dengan keteguhan terhadap perubahan inersia, gangguan beban, perubahan kelajuan dan profil pendahuluan kelajuan yang berbeza. Kesimpulannya, kajian dan eksperimen dengan penggunaan MRAC yang digabungkan dengan V-I model melalui kaedah anggaran kelajuan telah dilakukan bagi mengesahkan penemuan teori tersebut.

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LIST OF PRINCIPAL NOTATION

V_d	-	d-axis stator voltages
V_q	-	q-axis stator voltages
i_d	-	d-axis stator currents
i_q	-	q-axis stator currents
V_α	-	α-axis stator voltages
V_β	-	β-axis stator voltages
i_α	-	α-axis stator currents
i_β	-	β-axis stator currents
L_d	-	d-axis stator currents
L_q	-	q-axis stator currents
θ_r	-	rotor electrical position
ω_e	-	rotor electrical angular velocity
Ψ_m	-	flux linkage
Ψ_d	-	d-axis stator flux linkages
Ψ_q	-	q-axis stator flux linkages
R_s	-	stator winding resistance
ω_r	-	rotor electrical speed
ω_m	-	rotor mechanical speed
P	-	pole pairs
V_{ab}, V_{bc}, V_{ca}	-	line voltages

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V_{dc}	-	DC supply voltage
f	-	fundamental frequency
τ_i	-	integral time constant
$U_{(t)}$	-	control output
K_p	-	proportional gain
K_i	-	integral gain
e(t)	-	tracking error
ρ	-	$d/_{dt}$
J	-	total mechanical inertia
B	-	total damping coefficient
ε	-	estimation error
i_{abc}	-	phase currents
V_{abc}	-	phase voltages
V_{ref}	-	Reference voltage
T_{em}	-	Torque electromagnetic
PC	-	Computer
T_L	-	Load torque
I_s	-	Supply current
P_{in}	-	Instanteneous power
T_s	-	Settling time
P	-	Proportional
PI	-	Proportional-Integral
PID	-	Proportional-Integral-Derivative
PD	-	Proportional-Derivative

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K_t	-	Torque constant

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‘*’	-	Commanded value

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LIST OF APPENDICES

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LIST OF ABBREVIATIONS

AC	-	Alternate Current
AI	-	Artificial Intelligence
ANN	-	Artificial Neural Networks
ADC	-	Analog-to-Digital Control
DAC	-	Digital-to-Analog Control
DC	-	Direct Current
DSP	-	Digital Signal Processor
DTC	-	Direct Torque Control
EKF	-	Extended Kalman Filter
ELO	-	Extended Luenburger Observer
EMF	-	Electromagnetic Force
FPGA	-	Field Programmable Gate Array
FLC	-	Fuzzy Logic Control
IGBT	-	Insulted Gate Bipolar Transistors
IPMSM	-	Interior Permanent Magnet Synchronous Motor
I/O	-	Input/Output
LPF	-	Low Pass Filter
MRAC	-	Model Reference Adaptive Control
MOSFET	-	Metal Oxide Semiconductors Field Effect Transistors
PMSM	-	Permanent Magnet Synchronous Motor

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