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DIRECT TORQUE CONTROL OF INDUCTION MOTOR DRIVE

Muhd Zharif Rifqi Bin Zuber Ahmadi

Bachelor of Power Electronics and Drive

2012

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DIRECT TORQUE CONTROL OF INDUCTION MOTOR DRIVES

MUHD ZHARIF RIFQI BIN ZUBER AHMADI

A report submitte in partial fulfillment of the requirements for the degree of

Power Electronic and Drives

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTeM)

JUNE 2012

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SUPERVISOR DECLARATION

"I hereby declare that I have read through this report entitle "**Direct torque control of induction motor drives**" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Power Electronics and drives)"

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Date : 26 JUNE 2012

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DEDICATION

Especially dedication is to my beloved mother Puan Che Rodiah Binti Che Ismail, my beloved father En Zuber Ahmadi Bin Hassan Hilmi, my sister and brothers beloved

For taking care of me and educating me all these while. Also thank for their continuous prayers until I became what I'm now.

Also for my family

Dr Auzani Bin Jidin

Thank you very much

And not forgetting to all my relatives

Especially Electrical Engineering (Power Electronics and Drives) batch 2009-2012

The success belongs to us all

May God bless all of us.....Amin

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ABSTRACT

Direct torque control (DTC) has gained popularity for induction motor control that requires high torque control performance due to its simplicity. This scheme does not require a frame transformer, knowledge of machine parameters, speed sensor and current controller, as opposed to the Field Oriented Control (FOC) which is another control scheme of induction machine. The prototype DTC drive offers several advantages such as robust control (less sensitivity to parameter variations), speed sensorless drive, inherent current control, fast instantaneous torque and flux control. The DTC algorithm (including estimations of flux and torque, hysteresis controllers, look-up table and etc) was performed using a low-cost Digital Signal Processor (DSP) controller board, i.e. eZdsp F28335. The algorithm of DTC was developed using IQ Math-MATLAB components as provided by Texas Instrument to optimize and minimize the digital computation in DSP. A decoupled control of torque and flux that provides fast dynamic control can be established in DTC, where in torque and flux are controlled using 3-level and 2-level hysteresis comparators, respectively. The output of comparators and flux sector information are used to index the look-up table, to select appropriate voltage vectors to control torque and flux, simultaneously. By modelling the DTC algorithm using IQ-math components, the sampling period of DSP computation can be minimized at 50 μs, that is much smaller than that obtained using Simulink component (about 100 μs). The feasibility and effectiveness of DTC implementation using ezDSP F28335 to provide fast instantaneous torque and flux control were verified through experimental results.

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ABSTRAK

Daya kilas langsung (DTC) telah mendapat populariti untuk mengawal motor aruhan yang memerlukan kawalan prestasi daya kilas yang tinggi disebabkan kelemahan yang dihadapinya. Teknik ini tidak memerlukan pengubah/bingkai, pengetahuan parameter mesin, penderia kelajuan dan pengawalan arus, rujukan bertentangan dengan kawalan orientasi medan yang merupakan satu lagi teknik kawalan mesin aruahan. Pemacu prototaip DTC menawarkan beberapa kelebihan seperti kawalan tahan lasak (kurang sensitif kepada perubahan parameter), pemacu tanpa penderia laju, kawalan arus semulajadi, kawalan cepat daya kilas ketika dan fluks ketika. Algoritma DTC (termasuk anggaran fluks and daya kilas, pengawal histerisis, jadual pemilihan dan sebagainya) dilakukan menggunakan pengawalan pemprosessan isyarat digital (DSP) yang berkos rendah, iaitu eZdsp F28335. Algoritma DTC dibangunkan menggunakan IQ-math Matlab komponen yang disediakan oleh Texas Instrumen untuk mengoptimunkan dan meminimumkan pengiraan digital DSP. Satu kawalan pemisah daya kilas dan fluks yang menyediakan kawalan pantas dinamik diwujudkan oleh DTC,di mana daya kilas dan fluks dikawal masing-masing pembanding histerisis 3 tahap dan 2 tahap. Keluaran pembanding tersebut dan maklumat sektor fluks digunakan untuk memilih vektor yang sesuai didalam jadual carian mengawal serentak kedua-dua daya kilas dan fluks. Dengan memodelkan algoritma DTC menggunakan komponen IQ-math, tempoh persempelan bagi pengiraan DSP boleh diminimakan kepada 50 μs, iaitu sangat kecil berbanding dengan yang dicapai menggunakan komponen Simulink (dianggarkan sekitar 100 μs). Keberkesanan dan kebolehan bagi melaksanakan DTC menggunakan ezdsp F28335 untuk menyediakan kawalan ketika daya kilas dan fluks yang cepat telah disahkan melalui keputusan ujikaji.

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LIST OF SYMBOL

L_d	-	d-axis self inductance
L_q	-	q- axis self inductance
Lm	-	Mutual inductance
i_s	-	stator current
i_r	-	rotor current
r_r, r_s	-	Rotor and stator resistance
i_{sd}	-	d-axis current
V_{sd}	-	d-axis voltage
i_{sq}	-	q-axis current
V_{sq}	-	q-axis voltage
i_{sd}, i_{sq}	-	d and q components of the stator current in stationary reference frame
i_a, i_b	-	Current phase a and phase b
L	-	Self inductance
Ψ_{sd}, Ψ_{sq}	-	d and q components of stator flux reference frame
Ψ_r , Ψ_s	-	Stator and rotor flux linkage space vector in stationary reference frame
ψf	-	Field flux linkage
Ψ_{q1}		Flux threshold
T	-	Output Torque hysteresis
φ	-	Output flux hysteresis
δ	-	Load angle

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Va,Vb,Vc	-	Three Phase Voltage
Te	-	Electromagnetic torque
P	-	Pairs of pole
ω_r	-	Rotor electrical speed
v_{dc}	-	DC link voltage
Sa,Sb,Sc	-	Switching states
θsr	-	Angle between stator and rotor flux vectors
v_s	-	Voltage vector

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LIST OF ABBREVIATIONS

DTC	-	Direct Torque Control
IM	-	Induction Motor
VSI	-	Voltage Source Inverter
FOC	-	Field Oriented Control
DSC	-	Direct Self Control
AC	-	Alternating Current
DC	-	Direct current
DSP	-	Digital Signal Processor
IFO	-	Indirect Rotor Flux Orientation
ADC	-	Analog Digital Converter
DAC		Digital Analog Converter
CPLD	-	Complex programmable logic device
SVM	-	Space vector modulated
IGBT	-	Insulated gate bipolar transistor

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CHAPTER 1

INTRODUCTION

1.1 Background of project

Among types of AC machine, the induction machine is widely adopted in many industrial applications, for examples industrial blower, traction drives, spindle drives, stationary power tools and others. The induction machine is very economical, rugged and requires less maintenance.

In this project, direct torque control of the induction machine drive was developed using IQ-math block provided by Texas Instrument which are available in software Matlab (Version R2011b). The purpose of the project was to study the principle of DTC of induction machine, implement the Direct Torque Control algorithm using ezdsp F28335. The algorithm was programmed using IQ-math components.

A description of DTC drive will be presented and the operation of DTC will be verified to show its functionally via experimental results.

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1.2 Problem statement

Some challenges or problem need to be concerned in developing the AC motor control, as listed as below:

(i) It is required to avoid inrush current/overcurrent doing motor start-up or acceleration.

(ii) It is desirable to improve poor dynamic performance as resulted in the conventional system. i.e scalar method.

(iii) In many industrial drive systems, the motor can perform under 4-quadrant operations without any use or extra hardware to the drive system.

1.3 Objective

The main objectives of the project are as follows;

(i) To study the principle of DTC of induction machine which can offer fast torque dynamic performance, inherent current control (provide current limit) and allow 4-quadrant operations.

(ii) To develop a DTC drive for 3-phase induction machine using ezdsp F28335.

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1.4 Scope of project

The scopes of the project are listed as follows;

(i) To study the principle of DTC operation and the variations of DTC improvement through literature or technical papers.

(ii) To simulate and construct DTC algorithm using IQ-math component that can perform the executation time cycle at 50 μ s.

(iii) To realize DTC drive system using ezdsp F28335.

(iv) To verify the proper DTC operation via experimental results.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will discuss about the review of journal or technical report that related to the project. This chapter also covers the researchers related to the subject. This will provide a clearly understanding of the overall project. This chapter will discuss on overall theories and concept of the project.

2.2 Literature review of motor drives

In the past year DC motor was extensively used for many industrial applications due to its simplicity and offers superior torque and dynamic performance However, DC motor drive has many disadvantages such as high maintenance, expensive, and cannot operate at very high speed operations. The problem can be solved by replacing DC motor with induction motors which are much cheaper, less maintenance, and reliable. The advancement of induction motor control has gained much momentum as the technology of power electronic switching devices grow rapidly, which in turns excite the developments of the vector controlled that allows

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