THE SIMULATION OF THE DIRECT TORQUE CONTROL OF PERMANENT MAGNET SYNCHRONOUS MOTOR.

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To my beloved husband, mother and family,

for their encouragement, blessing and inspiration……..

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ABSTRACT

The direct torque control theory has achieved great success in the control of induction motor. Many attempts have been made to implement the idea of DTC of induction motor to PMSM since 1990's. The DTC is implemented by selecting the proper voltage vector according to the switching status of inverter which was determined by the error signals of reference flux linkage and torque with their measured real value acquired by calculating in the stationary reference frame by means of simply detecting the motor voltage or currents. Aiming at the DTC in PMSM Drives, this project explained the theoretical basis of the direct torque control (DTC) for PMSM firstly. Then explained the difference between the application of DTC to PMSM and to IM. Finally the Matlab/Simulink models were developed to examine the DTC for PMSM and IM. The simulation results is presented and explained in detail.

ABSTRAK

‘Direct Torque Control’ berjaya digunakan bagi mengawal Motor Aruhan . Oleh yang demikian berbagai usaha dilakukan oleh para penyelidik bagi menggunakan DTC mengawal Motor Segerak Magnet Kekal (PMSM) sejak tahun 1990. DTC mempunyai banyak kelebihan berbanding cara kawalan yang lain terutamanya FOC. Cara DTC ialah pada mulanya tork and fluks motor dianggarkan melalui voltan dan arus motor yang diukur. Tork dan fluks ini dibandingkan dengan tork dan fluks rujukan. Hasil perbezaannya dibandingkan dalam pembanding hysteresis dan seterusnya vektor voltan yang sesuai dipilih untuk dibekalkan kepada motor berdasarkan jadual penyuisan bagi penyongsang. Projek ini menggunakan cara kawalan DTC dalam mengawal PMSM. Pada mulanya teori PMSM dan DTC dibincang dan diterangkan dengan jelas. Kemudian model-model simulink dibina bagi tujuan simulasi. Simulasi dilakukan dengan menggunakan applikasi Matlab Simulink. Simulasi dilaksanakan dan hasil simulasi dibentang dan dibincangjan.

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LIST OF SYMBOLS

L_d	-	d-axis self inductance
L_q	-	q- axis self inductance
i_d	-	d-axis current
V_d	-	d-axis voltage
i_q	-	q- axis current
V_q	-	q- axis voltage
J	-	inertia
B	-	friction
L	-	Self inductance
ψs	-	Stator flux linkage
ψf	-	Field flux linkage
τ	-	output Torque hysteresis
ϕ	-	output flux hysteresis
δ	-	load angle
Va,Vb,Vc	-	Three Phase Voltage
Rs	-	rotor resistance
P	-	pairs of pole
Te	-	develop torque
ω_r	-	rotor electrical speed
ω_m	-	rotor mechanical speed.
ν_{dc}	-	DC Voltage
Sa,Sb,Sc	-	switching states

LIST OF ABBREVIATIONS

DTC	Direct Torque Control
PMSM	Permanent magnet Synchronous Motor
IM	Induction Motor
VSI	Voltage Source Inverter
FOC	Field Oriented Control
VSV	Voltage Space Vector

CHAPTER 1

INTRODUCTION

1.1 Introduction

Permanent magnet synchronous motors (PMSM) are widely used in low and mid power applications such as computer peripheral equipments, robotics, adjustable speed drives and electric vehicles.

The growth in the market of PMSM motor drives has demanded the need of simulation tool capable of handling motor drive simulations. Simulations have helped the process of developing new systems including motor drives, by reducing cost and time. Simulation tools have the capabilities of performing dynamic simulations of motor drives in a visual environment so as to facilitate the development of new systems.

In this work, the simulation of a direct torque control of PMSM is developed using Simulink. The Direct Torque Control is one of the high performance control strategies for AC machine. The DTC scheme has been realized successfully in the Induction Motor drives. The aim of the project is to study the implementation of the Direct Torque Control (DTC) in Permanent Magnet Synchronous Motor (PMSM).

1.2 Objectives

The objectives of the project are:

i) To stimulate the Direct Torque Control (DTC) of Permanent Magnet Synchronous Motor (PMSM) and Induction Motor (IM).

ii) To compare the performance of the DTC of Permanent Magnet Synchronous Motor (PMSM) and Induction Motor.

1.3 Scope of project

The scope of work for this project:

i) PMSM with saliency is considered.

ii) Simulation is performed using MATLAB Simulink.

iii) The performance of DTC in PMSM and IM are discussed based on the simulation results.

1.4 Research Methodology

The research work is undertaken in the following stages:

i) Studied the application of MATLAB simulink.

ii) Studied the theoretical basis of the direct torque control (DTC) for Permanent Magnet Synchronous Motor (PMSM) drives and Induction Motors.

iii) Simulation of DTC of PMSM and IM is performed using Simulink.

iv) Analyzed the simulation results.

1.5 Literature Review

The original concept of DTC was proposed by Takahashi and Noguchi in 1986 for application in Induction Motors. Their idea was to control the stator flux linkage and the torque directly , not via controlling the stator current. This was accomplished by controlling the power switches directly using the outputs of hysteresis comparators for the torque and the modulus of the stator flux linkage and selecting an appropriate voltage vector from a predefined switching table. The table was called the ‘optimum switching table”. The measurement of the rotor angle was not used.

A same kind of control was proposed by Depenbrock (1987). At first, Takahashi and Noguchi did not give any name to their new control principle. In a later paper by Takahasi and Ohmori (1987) the control system was named the direct torque control, DTC. Depenbrock called his control method Direct Self Control, DSC. Tiitenen et al discussed the first industrial application of the DTC. After that , the number of papers on the DTC has grown tremendously on different aspects of the DTC for asynchronous motors. In recent years there has been interest to apply the DTC to permanent magnet synchronous motors.

L.Zhong et al discussed the implementation of DTC in PMSM Drives. In 1998, Rahman et al proposed a DTC scheme for a wide speed range operation of an interior PMSM drive. The proposed scheme possess some attractive features compared to the conventional current-controlled drives like field oriented control (FOC). Later on, Tang et al proposed a DTC control schemes for the IPM featuring almost fixed switching frequency.

In 2002, Rahman et al, proposed a completely sensorless DTC control for an IPM drive, which uses a new speed estimator from the stator flux linkage vector and the torque angle. To reduce the torque ripples, Sun et al proposed a fuzzy logic algorithm to refine the selection of the voltage vectors. Today, the DTC has become an accepted control method beside the field oriented control.

1.6 Structure and Layout of Thesis

The purpose of this thesis is to present a simulation of a direct torque controlled of permanent magnet synchronous motor and compared the performance with IM. The simulation is carried out by using Matlab Simulink. The thesis is organized into six chapter:

Chapter 1 gives the introduction to project, stating its objectives, scope of work, research methodology and overview.

Chapter 2 introduces to permanent magnet synchronous motor and the equation related to PMSM such as the voltage, stator flux linkage and torque.

Chapter 3 presents some common control techniques used for control of Permanent Magnet Synchronous Motors (PMSM).

Chapter 4 present and analyzed the implementation of the Direct Torque Control in PMSM drives.

Chapter 5 explain the simulink block of DTC of PMSM and Induction motor and also discuss the results obtained from the simulation

Chapter 6 gives the summary of this project and present the recommendation for future work to improve the performance of the DTC of PMSM.