IMPLEMENTATION OF TORQUE HYSTERESIS CONTROLLER (THC) FOR BRUSHLESS DIRECT CURRENT (BLDC) MOTOR

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A report submitted in partial fulfilment of the requirements for the degree of Bachelor of Electrical Engineering with Honours

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"I hereby declare that I have read through this report entitle "Implementation of Torque Hysteresis Controller (THC) for Brushless Direct Current (BLDC) Motor" and found that it complies the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering with Honours"

Signature : .....

Supervisor's Name : Dr. Auzani Bin Jidin

Date : 21/6/2019

I declare that this report entitles "*Implementation of Torque Hysteresis Controller (THC) for Brushless Direct Current (BLDC) Motor*" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : NABILAH 'AISYAH BINTI MANSOR

Date : 21/6/2019

DEDICATIONS

To my beloved mother and father

My beloved husband and daughter

My beloved siblings

My beloved supervisor and lecturers

My fellow friends

For their moral support and encouragement through my journey of education

ACKNOWLEDGEMENT

First and foremost, I would like to express my gratitude to the Almighty Allah SWT for His willing in giving me the strength to complete my Final Year Project 1.

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Last but not least, thanks to my husband, my daughter and my both side of family for their moral support and encouragement in completing this project.

ABSTRACT

This project is about the implementation of Torque Hysteresis Controller of Brushless Direct Current (BLDC) Motor. BLDC motor is well-known and has been widely used in the industrial area due to its high speed and power density capabilities. Electronic commutation is by far more favorable compared to the conventional method, which uses brushes and commutators, that wear and tear by time. However, a precise controller is required in order to control the switches prior to commutation process. Over the past years, Torque Hysteresis Controller (THC) method for induction motor drives received lots of attention from researchers, and motor drive industries. THC of BLDC combines a simple control method and a demanded from BLDC motor to complete a better performance. THC method is known to have a simple structure without having complex calculations thus offers a fast response and a good dynamic performance. The previous work which is the Voltage Controlled of BLDC motor contributes a very high current during the start-up. Furthermore, the conventional implementation gives large ripple with uncontrollable in the restricted bandwidth of hysteresis. A mathematical modeling which is created using Matlab/Simulik simulation on the motor drive for Brushless DC Motor is presented along with a complete model of the THC system for BLDC motor using Simulink Block. Finally, the simulation and are shown to validate the performance of THC of BLDC motor with improvements of the problem highlighted.

ABSTRAK

Projek ini adalah mengenai pelaksanaan Pengawal Hysteresis Torque Brushless Direct Current (BLDC) motor. Motor BLDC terkenal dan telah digunakan secara meluas di kawasan perindustrian kerana keupayaan berkempen dan kelajuan tinggi. Pergantungan elektronik jauh lebih menguntungkan berbanding dengan kaedah konvensional, yang menggunakan berus dan komutator, yang memakai dan lusuh mengikut masa. Walau bagaimanapun, pengawal tepat diperlukan untuk mengawal suis sebelum proses penggantian. Sepanjang tahun yang lalu, kaedah Pengawalan Torque Hysteresis (THC) untuk pemacu motor induksi menerima banyak perhatian daripada penyelidik, dan industri memandu motor. THC BLDC menggabungkan kaedah kawalan mudah dan menuntut dari motor BLDC untuk menyelesaikan prestasi yang lebih baik. Kaedah THC diketahui mempunyai struktur mudah tanpa pengiraan yang kompleks dengan itu menawarkan tindak balas yang cepat dan prestasi dinamik yang baik. Kerja sebelumnya yang Pengalawan Voltan motor BLDC menyumbang arus yang sangat tinggi semasa permulaan. Selain itu, pelaksanaan konvensional memberikan riak besar dengan tak terkawal dalam jalur lebar hysteresis yang terhad. Pemodelan matematik yang dicipta menggunakan Matlab / Simulik simulasi pada pemacu motor untuk Brushless DC Motor dibentangkan bersama model lengkap sistem THC untuk BLDC menggunakan blok Simulink. Akhir sekali, simulasi dan ditunjukkan untuk mengesahkan prestasi THC motor BLDC dengan penambahbaikan masalah yang diketengahkan.

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LIST OF ABBREVIATIONS

BLDC	BRUSHLESS DIRECT CURRENT
BDC	BRUSHED DIRECT CURRENT
DC	DIRECT CURRENT
AC	ALTERNATING CURRENT
IC	INTERGRATED CIRCUIT
THC	TORQUE HYSTERESIS CONTROLLER
IGBT	INSULATED GATE BIPOLAR TRANSISTOR
MOSFET	METAL–OXIDE–SEMICONDUCTOR FIELD-EFFECT TRANSISTOR
VSI	VOLTAGE SOURCE INVERTER
PMSM	PERMANENT MAGNET SYCHRONOUS MOTOR
EMF	ELECTROMOTIVE FORCE
PCB	PRINTED CIRCUIT BOARD

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Conventional Direct Current motors are exceptionally effective and their trademark makes it reliable for use in numerous applications. In any case, there are some disadvantages in this motor since it's using a commutator and brushes which needs maintenance frequently and besides it's can't be performed at dirty and hazardous condition also in faster working conditions [8]. Thus, machine with maintenance free can be created by replacing the elements of commutator and brushes by strong state switches, and these sorts of engines are currently known as Brushless Direct Current Motors (BLDC). In fact, (BLDC) is a type of permanent magnet synchronous motors (PMSM). The current commutation is done by solid-state switches and it's supplied by DC voltage.

BLDC Motor has an advantages such as fast torque response besides capable in high speeds drive compared with DC Motor for longer lifespan [6]. Placement of coils in the stator and permanent magnet in the rotor are the basic operating principles of DC motor operation used in BLDC motor. Winding of coils are electrically separated from each other, where creates a rotating magnetic field by allowing it turn on and off in a sequence. The position of rotor needs to be determined, as so the stator fields' excitation always leads to produce a torque by permanent magnet field. Rotor position which later

determine the commutation instants and it is also detected either by sensor less techniques or position of sensors BLDC Motor need to be decoded by the signal from the Hall Effect Sensor then can determine the shaft and energize the appropriate windings of stator [5].

Operation of BLDC motor necessary needs the power electronic converter. BLDC motor consists of three phases DC to AC converter with a six solid-state semiconductor switches. The most common used type of switches was MOSFET and IGBT. In low power applications, MOSFET is preferable compared to IGBT. Positive, negative and zero voltage should be applied by the power electronic inverter to the terminals phase of motor. Each phase contains of high, low and floating terminals.

1.2 Motivation

As known in many applications, Direct Current (DC) motors proven in their efficiency and reliable characteristics besides it can be operated at fixed speed in a fixed voltage compared with an AC motors. Furthermore, conventional DC motors such as Brushed DC motor (BDC) have many disadvantages especially on their mechanical parts. Brush and commutator needed in order to operate BDC motor which later limit it capability. Therefore, to overcome the problem, BLDC motor is proposed. In the view of controlling mechanism, BLDC motors has a good speed control compared to conventional methods. One of the control method named Voltage Controlled of BLDC motor. The main problem by using Voltage Controlled method for BLDC motor is the uncontrollable in measurement of current during start-up. Thus, the Torque Hysteresis Controller (THC) of BLDC motor is introduced due to its advantages to overcome the problem on previous work.

1.3 Problem Statement

The basic control method for BLDC motor is Voltage Controlled method. But somehow this method having some drawbacks which need to overcome for a better performance on BLDC motor. The main problem is this method has a poor torque and current dynamic control where its produce inrush current during start-up besides it also doesn't provide a current limitation in this method. The torque and speed increases whenever there is a large demand given due to no current control. In this method, there is no current sensor been used and hall effect sensor signal; is the only feedback that they have been used to run the method. Besides, with conventional method of THC, the torque and current ripple become larger and uncontrollable.

1.4 Objective

The purposes of this project are to:

1. To produce excellent torque dynamic control using hysteresis controllers for BLDC Motor.

2. To develop/implement of Torque Hysteresis Controller (THC) of BLDC Motor using Analogue Integrated Circuit (ICs).

3. To evaluate the improvements, i.e. excellent torque/current using Analogue ICs through simulation/experiment results.

1.5 Scope of Research

This project mainly focuses on:

1. Understand the behavior and operation of BLDC Motor.
    - At this stage, it is necessary to know the construction of BLDC Motor and the mathematical modelling of BLDC Motor.

2. Study various control techniques of BLDC Motor.
    - Various techniques that need to study such as Voltage Controlled, Direct Torque Current (DTC) and Torque Hysteresis Controller (THC).
    - Understand THC operation for BLDC Motor.

3. Develop simulation model of THC for BLDC Motor
    - Develop simulation model by using Matlab/Simulink for Voltage Controlled and Digital Implementation of THC.
    - Develop simulation model for proposed method which is fully using Analogue ICs by using Matlab/Simulink.

4. Implement the hardware system for THC of BLDC Motor
    - Identify the components/devices which are suitable for this research.
    - Design Printed Circuit Board (PCB) Layout by using Orcad Pspice.

5. Evaluate the improvements of the proposed method.
    - Evaluate comparison between torque/current of digital and analogue ICs.

1.6 Research Methodology

First and foremost, the behavior and operation of BLDC Motor needs to understand to ensure the research to run smoothly. Besides, understanding about the construction of BLDC Motor which consists of Stator, Rotor and Hall Effect Sensor and mathematical modelling of BLDC Motor that will used in simulation in Matlab/Simulink are needed. Furthermore, various control technique of BLDC Motor such as Voltage Controlled and Torque Hysteresis Controller (THC) need to be studied. In this research, torque hysteresis controller (THC) is used and understanding about THC operation for BLDC Motor is more focused. Next, in this research, development of simulation model of THC for BLDC Motor by using Matlab/Simulink for digital and analogue implementation. After that, implement the hardware system by using THC for BLDC Motor. Before implement hardware system, the component or devices that are suitable in the research need to identify. Printed Circuit Board (PCB) Layout is designed using Orcad Pspice Software. Last but not least, evaluate the improvement of the proposed method which is Torque Hysteresis Controller (THC). Grant Chart which describe the research or activities on planning is given in Appendix A.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter is discussing about literature review so as to realize enough data which will be used to complete the analysis. All the data in this chapter are taken from thesis, books, journals, and any educational articles that are associated with the analysis topic and can be clearly cited. Information about THC of BLDC is also highlighted in order to identify the problem occur in the THC itself. Theoretical of magnetic force and basic principle operation of BLDC are explained well. This section reviews about simulation of method between the Voltage Controlled and Implementation of Basic THC for Brushless Dc Motor. Both methods are briefly explained and the problem of each method are mentioned.

2.2 Magnetic Force Theory

Invisible lines of magnetic force generate by magnetic poles flowing from North to South Pole as shown in Figure 1. When magnetic poles of opposite polarity face each other, they generate an attractive force, while like poles generate a repulsive force. [9]

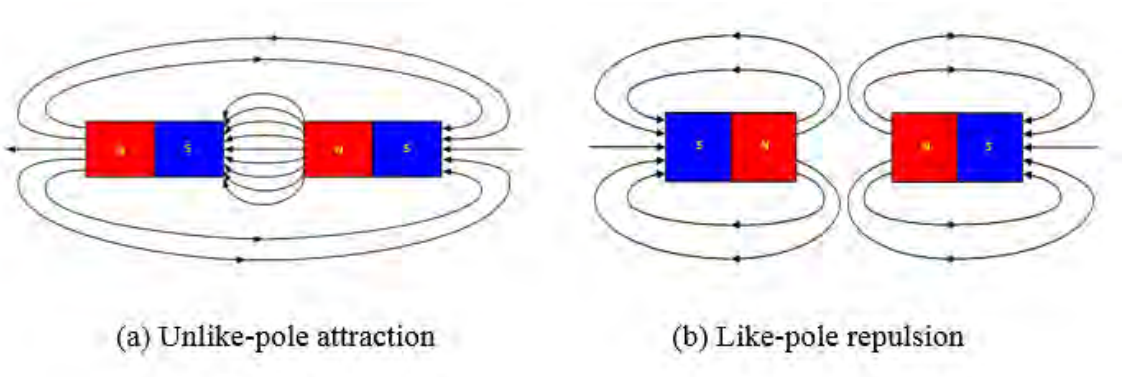

Figure 2.1: Magnetic Force

2.3 Principle Operation of BLDC Motor

This section is about principle operation of Brushless Direct Current (BLDC) Motor. Detailed explanation on construction of BLDC Motor which consist of Stator, Rotor and Hall Effect Sensor. Furthermore, operation of BLDC Motor with Hall Effect Sensor is also explained well in this section.

2.3.1 Construction of BLDC Motor

In order to make the operation more reliable or more efficient and less noisy, in recently trends has been use the brushless DC motor; they also lighter compare to brushes motor with the same power output. Basically, BLDC motors used to be high performance motors that also capable to produce large amount of torque with a vast speed range. Figure 2.2 shows structure of BLDC motor while Figure 2.3(a) and Figure 2.3(b) show the cross sectional view DC and BLDC motors. Both motors are commonly used nowadays that also share the same torque and speed performance curve characteristics.

Compare with brushed DC motor (BDC) system, the brushless DC motor (BLDC) system has a better performance. The present of brush gear and commutator in conventional DC machine reduce the speed operation rather than in BLDC, which leads increases in weight and volume. The advantage of permanent magnet rotor is leads to elimination of rotor copper losses which later improved the thermal characteristics. The diameter of rotor tends to become smaller compared to a conventional brushed motor, since there is a development of high energy permanent magnet. This also gives lower rotor inertia and faster the acceleration.

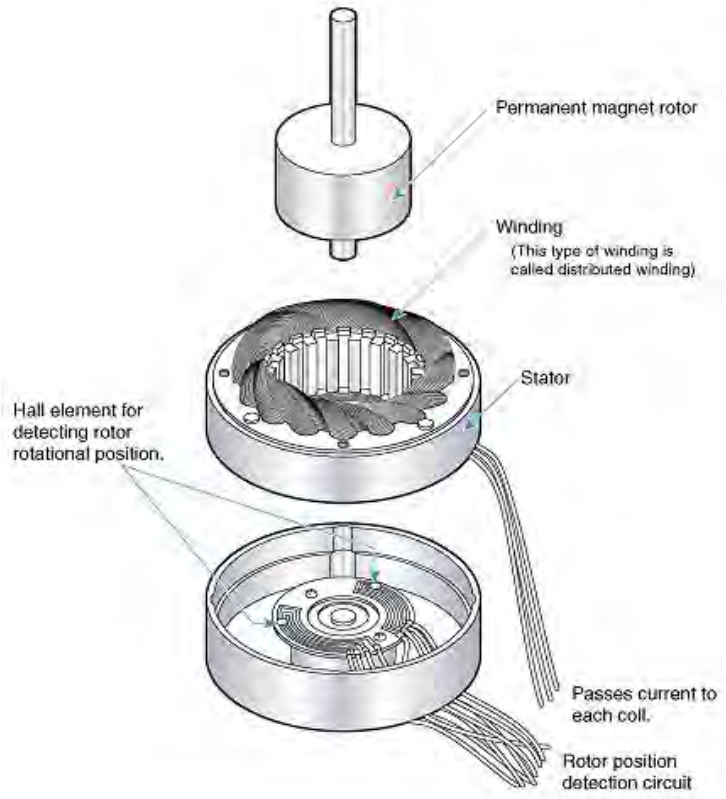

Figure 2.2: Structure of Brushless DC Motor [10]

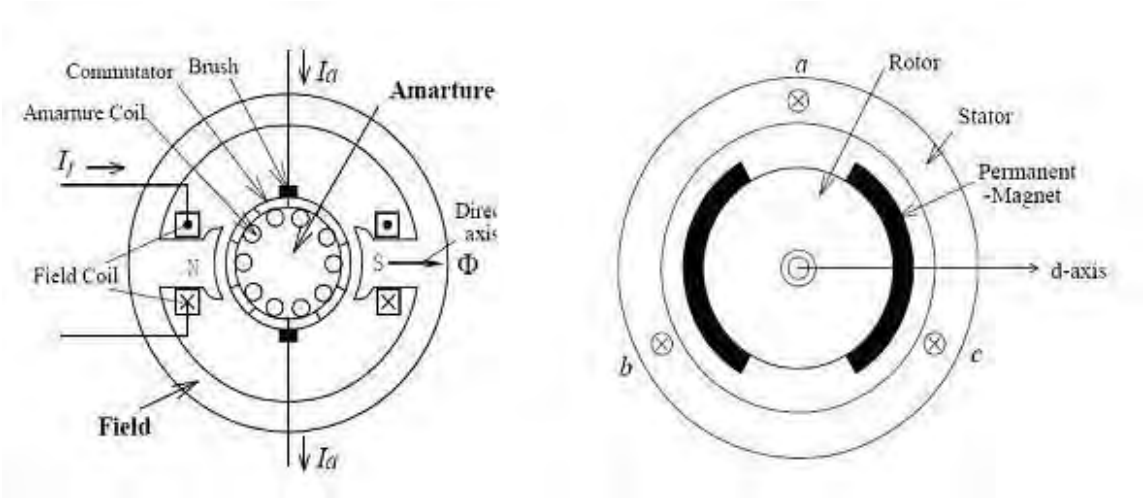

Figure 2.3: Cross Sectional View of Motors

An induction motor has a good property for high speed applications. But, they have low efficiency and power factor when operates at low speed just because of the heavy weight. Furthermore, the construction of it become costly. Different with synchronous motor such as BLDC motor has a better performance for low speed drives since the efficiency of BLDC is higher. Even though the construction of BLDC is more complex, lower weight and cost compared to induction motor gives equal power and speed. The power factor of a plant can be improved by using a synchronous motor together its rated load. Synchronous motor starting torque is larger than an induction motor due to the high resistance of the squirrel-cage winding but not affected the speed and efficiency at synchronous speed. Brushless DC motors usually consist of three main parts which are a Stator, a Rotor and Hall Sensors.