IMPLEMENTATION OF TORQUE HYSTERESIS CONTROLLER (THC) FOR BLDC MOTOR UTILIZING DSPACE 1104

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" I hereby declare that I have read through this report entitle "*Implementation of Torque Hysteresis Controller (THC) for BLDC Motor Utilizing DSpace 1104*" and found that it complies the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering"

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

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2018

I declare that this report entitle "*Implementation of Torque Hysteresis Controller (THC) for BLDC Motor Utilizing DSpace 1104*" 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 : NURFARAH BINTI ROSMAN

Date : .....

DEDICATION

To my beloved mother and father

My beloved siblings

My supervisor and lecturers

My fellow friends

For their moral support and encourangement 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 family for their moral support and encouragement in completing this project.

ABSTRACT

This project presents the implementation of Torque Hysteresis Controller of BLDC Motor (BLDC) drive using a dSPACE 1104. 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 favourable 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 demanding motor to complete a better drives system. 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. A mathematical modeling which is created using Matlab 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. The model is described briefly to give a better understanding on the whole system. Finally, the simulation and are shown to validate the performance of THC of BLDC motor with improvements of the problem highlighted.

ABSTRAK

Projek ini membentangkan pelaksanaan Pengawal Hysteresis Torque BLDC Motor (BLDC) dengan menggunakan dSPACE 1104. Motor BLDC terkenal dan telah digunakan secara meluas di kawasan perindustrian kerana keupayaan kelajuan tinggi dan ketumpatan kuasa. Pergantungan elektronik jauh lebih menguntungkan berbanding dengan kaedah konvensional, dimana penggunaan berus dan komutator akan lusuh mengikut masa. Walau bagaimanapun, pengawal tepat diperlukan untuk mengawal suis sebelum proses penggantian. Sepanjang tahun yang lalu, kaedah Kawalan Tork Hysteresis (THC) untuk pemacu motor induksi menerima banyak perhatian daripada penyelidik dan industri pemacu motor. THC BLDC menggabungkan kaedah kawalan mudah dan motor untuk melengkapkan sistem pemacu 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. Mengikut projek yang pernah dijalankan sebelum ini iaitu Kawalan Voltan bagi motor BLDC, kaedah ini menyumbang arus yang sangat tinggi semasa permulaan. Pemodelan matematik yang dibuat menggunakan simulasi Matlab pada pemacu motor untuk Brushless DC Motor dibentangkan bersama model lengkap sistem THC untuk BLDC menggunakan blok Simulink. Model digambarkan secara ringkas untuk memberi pemahaman yang lebih baik ke seluruh sistem. 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
DC	DIRECT CURRENT
AC	ALTERNATING CURRENT
THC	TORQUE HYSTERESIS CONTROLLER
DTC	DIRECT TORQUE CONTROL
IGBT	INSULATED GATE BIPOLAR TRANSISTOR
VSI	VOLTAGE SOURCE INVERTER
CSI	CURRENT SOURCE INVERTER
DSC	DIRECT SELF CONTROL
PMSM	PERMANENT MAGNET SYNCHRONOUS MOTOR
GTO	GATE TURN OFF
ADC	ANALOG DIGITAL CONVERTER
FPGA	FIELD PROGRAMMABLE GATE ARRAY
EMF	ELECTROMOTIVE FORCE

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Conventional dc motors are highly efficient and their characteristic makes it reliable for use in many applications. However, the only drawback is that it uses commutator and brushes that require frequent maintenance and cannot be performed at dirty and explosive environment and at very high speed operating conditions. Maintenance-free motor can be developed by replacing the functions of commutator and brushes by solid-state switches, and these types of motors are now known as brushless dc motors. Brushless dc (BLDC) motors are, in fact, a type of permanent magnet synchronous motors (PMSM). It is driven by dc voltage, and the current commutation are done by solid-state switches.

BLDC motor has advantages of longer lifespan, faster torque response and capability of high speeds drive in comparison with DC motor. BLDC motor implements the basic operating principles of DC motor operation but with a difference by placing the permanent magnet in the rotor and coils in the stator. The coil windings are electrically separate from each other, which allow it to be turn on and off in a sequence that creates a rotating magnetic field. The rotor position needs to be determined so that excitation of the stator field always leads the permanent magnet field to produce torque. The commutation instants are determined by the rotor position, and the position of the rotor is detected either by position sensors or by sensorless techniques. The signals from Hall Effect sensors that usually used in BLDC motor need to be decoded to determine the shaft and energize the appropriate stator windings.

The power electronic converter is necessary to operate the BLDC machine. The converter is three phases DC to AC converter, and it consists of six solid-state semiconductor switches. Mosfets and IGBT are the most common types of switches used. In lower power application, mosfets are preferred over IGBT. The power electronic inverter must be capable

of applying positive, negative and zero voltage across the motor phase terminals. Each drive phase consists of one motor terminal driven high, one motor terminal driven low, and one motor terminal floating.

1.2 Motivation

DC motors were known for their efficiency and reliable characteristics that are suitable for many applications. Unlike AC motors, DC motors able to operate at a fixed speed for a fixed voltage. Yet, one of the conventional DC motors is Brushed DC motor have many drawbacks on its mechanical compartments. It requires both brushed and commutator for its operation where its limit the capabilities of the motor. Thus, the BLDC motor is proposed to overcome the drawbacks of conventional dc machines.

From the reviewed methodology of the controlling mechanism, it is showed that the conventional method needs many improvements in order to improve the speed control performance of the BLDC machines to its fullest. Based on the previous control algorithm which is the Voltage Controlled of BLDC motor, the main problem of that method is high current during start-up and the current measurement cannot be controlled. Thus, the Torque Hysteresis Controller of BLDC motor is introduce due to its advantages to overcome the problem on previous work.

1.3 Problem Statement

In the last two decade, several variations of BLDC drives have been proposed and one of them is a Voltage Controlled of BLDC motor. However, this existing works have their constraint that need to be overcome. The main problem for Voltage Controlled of BLDC motor is it produce very large current during start-up since it does not provide current limitation. If a large demand is being injected which means increase the speed, the torque will become larger due to no current control obtained. Plus, they have no current loop since no current sensor is being used. This is because their feedback is based on Hall Effect Sensor only.

1.4 Objective

The aims of this project are:

1. To limit the current by established current control loop.
2. To operate the proposed THC in BLDC motor.
3. To verify the effectiveness of proposed THC drives through simulation and experimental results.

1.5 Scope of Project

This project are mainly focuses on study of Torque Hysteresis Controller strategy for BLDC motor. Other than that, the THC of BLDC motor will be implemented using Dspace 1104. Last but not least, the focus is on the construction of the hardware for THC of BLDC motor.

1.6 Report Outlines

First and foremost, this report consists of 5 chapters that starts with Chapter 1 and contains the brief explanation about the proposed technique in the project background and motivation which is the implementation of Torque Hysteresis Controller (THC) for BLDC motor utilizing DSpace 1104. The problem statement is being stated in this chapter and supported by the objective and scope of project. This is the most important part to ensure the vision of the project is clearly understood.

The Chapter 2 presents the literature review which relates with the previous existing works.

Next, for Chapter 3, the methodology of the project was clearly described. This is to ensure that the process of conducting the project are in the right track and follow the sequence.

After that, the Chapter 4 shows the discussion in overall results of the simulation using Simulink in MATLAB software regarding the comparison in details between previous existing

work which is the Voltage Controlled of BLDC motor and the proposed technique which is the Torque Hysteresis Controller of BLDC motor. The results obtained will indicates whether the proposed technique has meets the desired output of the proposed control scheme or not.

Last but not least, Chapter 5 explains the conclusion of the research project whether it achieves the desired objective and able to solve the problem stated or not. As for that, some of the recommendation for a better control scheme are also being proposed in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In open loop control system, the deviation in output direct current (DC) voltage have a problem commonly when the load is variable. However, this problem can be solved when a closed loop control is used as it will get a fixed output. In the close loop control, the current signal is matched with the reference current to decline the error in output so that the desired output can be obtained. [1]

2.2 Construction of Brushless DC Motor

Brushless Direct Current (BLDC) motor is the synchronous motor with combination of two conventional motor which is the installation for the stall torque capability of a conventional brush-type direct current (DC) motor and the high speed operation capability associated with an alternating current (AC) induction or reluctance motor drives.

The brushless DC drive system has better performances than the brushed DC drive system. The absence of brush gear and commutator increase the operation speed rather than conventional DC machines which leads to reductions in weight and volume. The elimination of commutator segments precludes the problem of segment oxidation. The lack of brushes eliminates certain types of radio frequency interference. The use of permanent magnet rotor leads to the elimination of rotor copper losses which improves the thermal characteristics. The development of high energy permanent magnet materials allows the rotor diameter to be smaller compared to a conventional brush-type motor. This yields lower rotor inertia and faster the acceleration [2].

An induction motor has an excellent properties for high speed. However, they have relatively low power factor and efficiency when operates at lower speed due to the heavy weight and thus, it becomes costly. Unlike induction motor, synchronous motor such as BLDC motor is particularly compatible for low speed drives since its efficiency is high. Although it is more complex to build, their weight and cost are often less than induction motor with equal power and speed. A synchronous motor can improve the power factor of a plant while carrying its rated load. Plus, its starting torque is greater than an induction motor due to the high resistance of the squirrel-cage winding without affecting the speed and efficiency at synchronous speed [3].

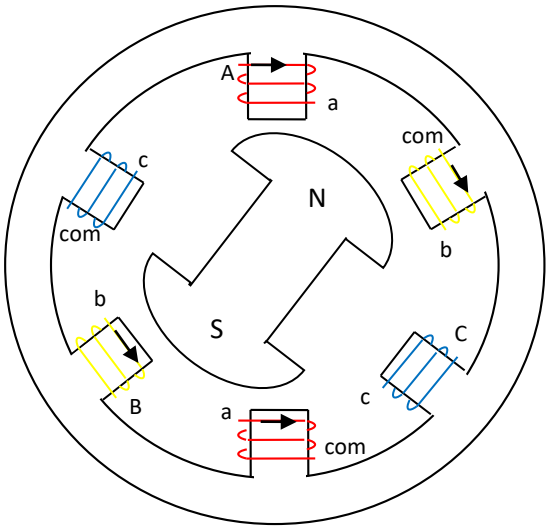

Figure 2.2: Construction of BLDC Motor.

2.3 Operation of Brushless DC Motor with Hall Effect Sensor

The recent trend has been used the brushless dc motor in order to make the operation more reliable, more efficient and less noisy. If the same power output is being applied, this type of motor are lighter compared to Brushed DC motor as the brushes in conventional DC motors wear out over time and sometimes leads to spark. This is the main reason Brush DC motors are not compatible to be used for operations that demand longer lifespan and reliability.

An electronic controller is used to determine which and when the stator coils to be energized so that the rotor will get a continuous rotation. A sensor determines the position of

the rotor and the controller decides which coils to be energized. In this case, a Hall Effect sensor is mostly used for the motor. The rotor of the BLDC motor is the permanent magnet and the stators are winded with coils. When a DC power supply is being applied to the coil, the coil will energized and magnetized. Thus, it becomes an electromagnet. The operation of the BLDC is based on the simple force interaction between the permanent magnet and the electromagnet. For this condition, when the coil A is energized, its opposite poles on the rotor and stator will attracted to each other. Since the rotor now nears to coil A, then coil B is energized. When the rotor is near to coil B, coil C is energized. After that, coil A is energized with the opposite polarity and this process is repeated along with the continuous rotation of the rotor.

However, even though this motor works, it has one drawback because only one coil is energized at a time. The two dead coils greatly reduce the output power of the motor. In order to overcome this problem, simply energize the coil behind the first coil when it is in the position that pulls the rotor so that it will push the rotor. For instance, the same polarity current is passed through the second coil. The combined effect produces more torque and output power from the motor. Plus, the combined force also make certain the BLDC motor consists of constant torque nature. As for that, two coils need to be energized separately but the process can be simplified by making a small modification to the stator coil. This process can be done by connecting one free end of the coils together. Therefore, when the power is applied between coils A and B, the current flow through the coil is like the separately energized state.

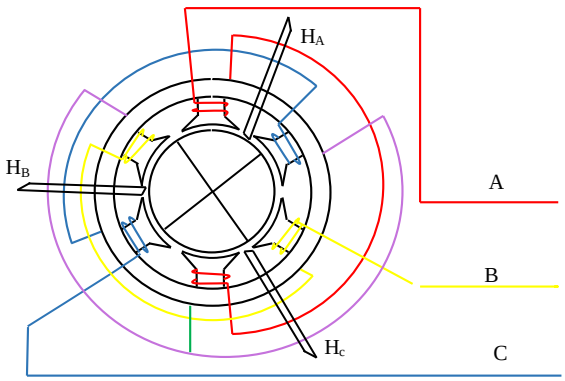

Figure 2.3: Cross-sectional of BLDC Motor with respect to Hall Effect Sensor.

2.4 Hall Effect Sensor in BLDC Motor

In most of the BLDC control applications, the Hall Effect Sensor is commonly used in order to determine the rotor position. These sensors are located in the motor housing and being offset from each other by 120º to make certain each sensor output is aligning with one of the electromagnetic circuit. The motor will rotates counter clockwise as there is a current pass through the motor windings. This flow of current will generates magnetic field in the stator which is North and South. Then, the rotor will rotates in order for the North pole in the rotor to align with the magnetic South generated in the stator. After that, the steps of rotation repeated with the same concept but different current flow [4]. The switching states to control the current flow through the motor and the relationship between the sensor output and the sector in which position of rotor is located are shown in Figure 2.4 (a) [5]. An inverter circuit connected to BLDC motor is shown in Figure 2.4(b). Each motor lead is connected to an upper and lower switching. The relation between the sector and the switching state are referred as the drive circuit firing which shown in Figure 2.4(a).

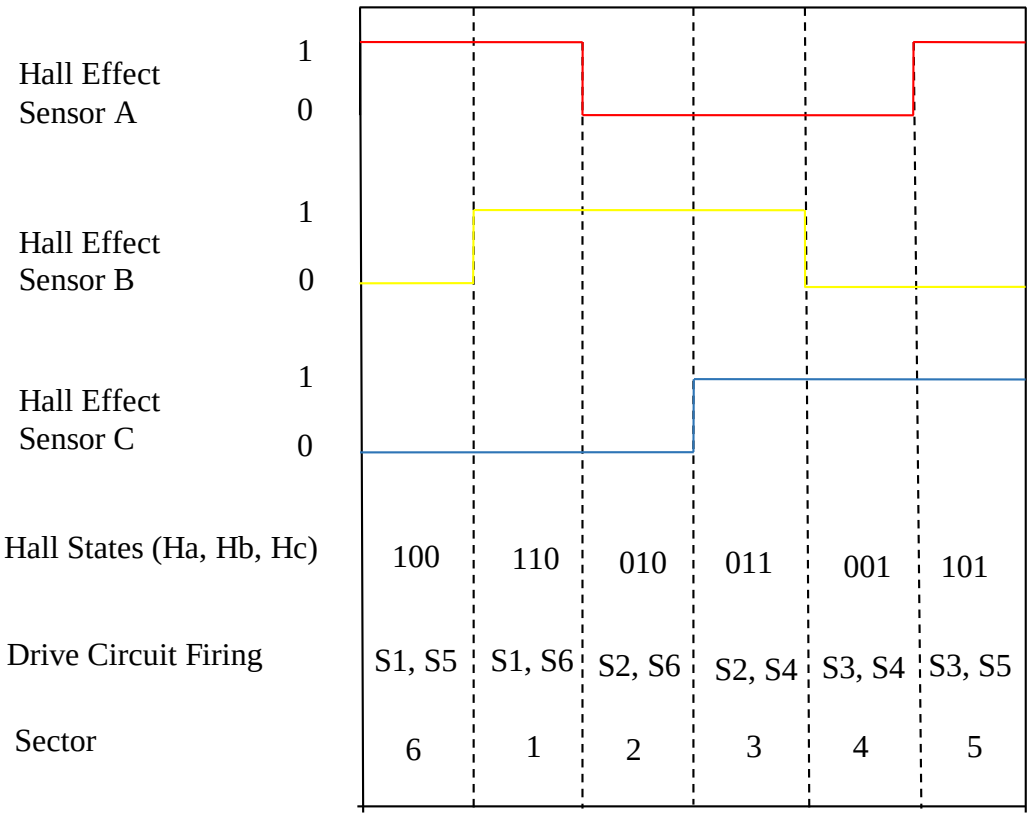

Figure 2.4(a): Output Graph of Hall Effect Sensor in BLDC Motor.

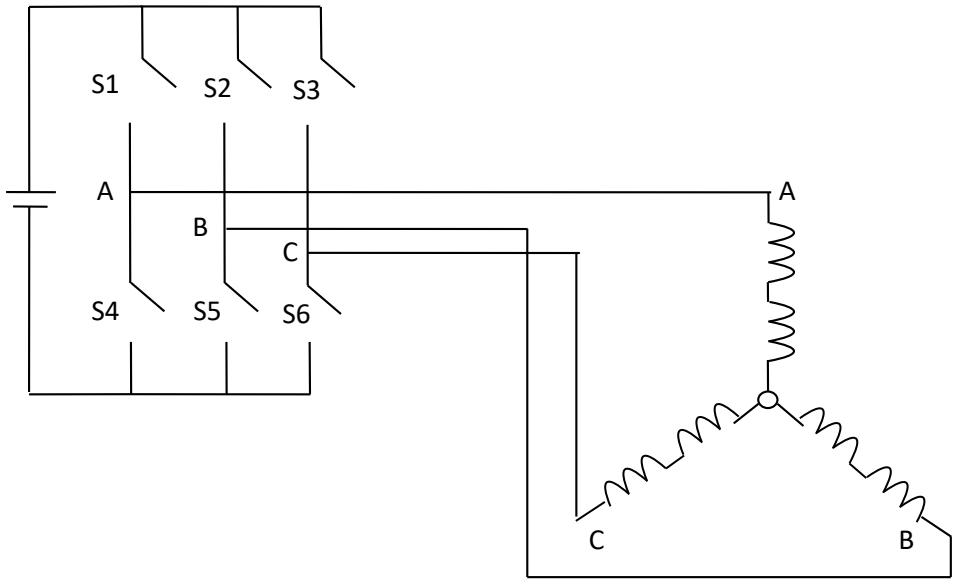

Figure 2.4(b): BLDC Motor Drive Circuit.

2.5 Related Previous Work

This section will be discussed about the schemes that is applicable for Brushless DC machine. The basic concepts and working operation for each method are being compared to get a better understanding on which controller is the most efficient to be used in controlling the BLDC motor.

2.5.1 Voltage Controlled of BLDC Motor

The concept for Voltage Controlled of BLDC motor strategy is the speed of BLDC motor is directly proportional to the voltage applied to the motor terminals [6]. As the voltage source is larger, the speed of the motor becomes faster. The main problem of this control strategy is it produces a very large current during start-up of the motor since it does not provide a current limitation due to no current sensor used. When a large demand is injected to the motor which caused the increasing of the speed, the torque produced is larger along with the larger current produced due to no current control. This is because their feedback is only based on the