IMPROVED PERFORMANCE DC MOTOR CONTROL

USING A UNIPOLAR SWITCHING SCHEME

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Bachelor of Electrical Engineering

June 2012

“ I hereby declare that I have read through this report entitle “Improved Performance of DC Motor Control Using a Unipolar Switching Scheme” and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Power Electronic and Drive)”

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This report is submitted in partial fulfillment of requirements for the degree of

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I declare that this report entitle *"Improved Performance of DC Motor Control Using a Unipolar Switching Scheme*" 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.

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Date : 25 June 2012

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ABSTRACT

This report presents the improvement performance of DC motor drive in terms of torque ripple, dynamic control and switching frequency. These motor drive is very essential for industrial applications. To improve performance of motor drive, precise control for some variable such as current (or torque), speed and position are necessary. The overall system is simulated using Matlab where the different switching techniques operation, output current and voltage are presented. The performance of three control switching technique which are bipolar-hysteresis, bipolar-triangular and unipolar-triangular are analyzed and discussed. Each switching technique for controlling the armature current (or torque) of DC machine was implemented using ezdsp F28335, with sampling period at 50us. The improvements of unipolar switching technique (i.e. minimization of torque ripple and provide constant switching frequency) compared the other switching techniques can be verified through simulation and experimentation.

ABSTRAK

Laporan ini membentangkan peningkatan prestasi pemacu motor AT dari segi riak tork, kawalan dinamik dan frekuensi pensuisan. Motor pemacu ini sangat penting untuk diaplikasikan dalam industri. Untuk meningkatkan prestasi pemacu motor kawalan tepat untuk beberapa pembolehubah seperti arus (atau tork), kelajuan dan kedudukan adalah perlu. Keseluruhan sistem disimulasikan menggunakan Matlab di mana teknik pensuisan yang berbeza, output arus dan voltan telah dibentangkan. Prestasi tiga kaedah pensuisan iaitu dwikutub-arus histerisis, dwikutub-segitiga dan ekakutub-segitiga juga telah dianalisis dan dibincangkan. Setiap teknik pensuisan untuk mengawal arus angker (atau tork) mesin DC telah dilaksanakan dengan menggunakan ezdsp F28335, dengan tempoh persempelan 50us. Peningkatan teknik pensuisan unipolar (meminimumkan riak tork dan menyediakan frekuensi pensuisan malar) berbanding teknik pensuisan yang lain boleh ditunjukkan melalui simulasi dan eksperimen.

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LIST OF ABBREVIATION

PWM	-	Pulse Width Modulation
DC	-	Direct Current
ezdsp	-	Digital Signal Processor from Texas Instrument
IGBT	-	Insulated Gate Bipolar Transistor
CPLD	-	Complex Programmable Logic Devised
MOSFET	-	Metal-oxide Semiconductor Field Effect Transistor
DSP	-	Digital Signal Processor
I/O	-	Input and Output
Hz	-	Frequency unit in Hertz
V_{dc}	-	Voltage DC Source
I_a	-	Armature current
k_t	-	Torque constant
$\emptyset_f$	-	Field flux
k_e	-	Voltage constant
ω_m	-	Mechanical Speed
P_e	-	Electrical power

P_m	-	Mechanical power
μs	-	Micro Second
Ω	-	Unit for resistance (OHM)
H	-	Unit for inductance (Henry)

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The purpose of this project to improved DC motor drive performance in terms of torque ripple, dynamic control and switching frequency by using unipolar switching scheme. This motor drives very essential for industrial engineering application. To improve performance of motor drive, precise controls current are necessary. To control precision of this variable, the feedback control has been used. The proper PI controlled had been designed to obtain zero steady-state error and good dynamic responses to achieve a good performance of motor drives. With the proper design of PI controller, it is expected that the system is less sensitive to disturbances and changes is the system parameters. The result of using some switching schemes of full bridge DC-DC converter has been compared to analyze DC motor drive performance. The torque control to observe the torque ripple reduction using unipolar switching scheme of DC motor drives is used and simulated using Matlab-Simulink. Unipolar voltage switching is also referred to as doubled PWM switching where the switches in each inverter leg are controlled independently of the other leg. The unipolar voltage switching results in a better output voltage waveform and in a better frequency response since the effective switching frequency of the output voltage waveform is doubled and the ripple will be reduced.

1.1.1 Background of DC Motor

Direct current (DC) motors have various characteristics and are used extensively in variable-speed drives. Many industrial applications use DC Motor because the speed and torque relationship can be varied. DC Motor provides excellent control of speed for acceleration and deceleration [1]. The power supply of a DC Motor connect directly to the field of the motor which allows for precise voltage control, and is necessary for speed and torque control applications. However the performances of DC motor control systems are reduced by the effect of DC motor variable torque but the control system of a DC motor will increase the electric current in a DC motor to maintain a desirable speed when the DC motor receives the variable torque or disturbance torque[2].

DC motor is one machines devised to convert electrical power into mechanical power. Permanent magnet (PM) direct current converts electrical energy into mechanical power. It is becoming more popular in many control systems because of high power density, large torque to inertia ratio, small and high efficiency [3]. It is probably the most commonly used DC Motors, but there are also use coils to make permanent magnetic field, movement of magnetic field is achieved by switching current between coils within the motor which is called commutation. PM motors are usually physically smaller in overall size and lighter for a given power rating [1]. Furthermore, since the motor's field, created by the permanent magnet, is constant, the relationship between torque and speed is very linear. A Permanent Magnet motor can provide relatively high torque at low speeds and permanent magnet field provides some inherent self-braking when power to the motor is shutoff[4].

DC Motor has been widely used in DC drive application. Because of their simplicity, reliability, ease to control and favorable cost have long been backbone of industrial engineering application [1]. DC Motor drives have been used for speed and position control application. In the past few years, the use of ac motor servo drives in these applications is increasing. But in application where an extremely low maintenance is not required, with low initial cost and excellent drive performance DC drives continue to be used in this application. This drives usually been implicated in application of printer, robots, scanner and others. In conjunction with the highly demand for the drives in so many field of works and needs especially in engineering sector, factory automation and our daily life, the motor accuracy and effectiveness have to be improved [1].

1.1.2 Proportional Integral (PI) Controller

PI Controller (proportional integral controller) is a feedback controller which drives the plant to be controlled with a weighted sum of the error (difference between the output and desired set point) and the integral of that value[10]. Motion control system often utilizes a proportional integral (PI) controller. Which is the P controller in the position loop and PI Controller in the speed and torque loop are often adequate. PI controller consist Kp and Ki where Kp is proportional-controller gain and Ki is the integral-controller gain [8]. It implemented in this transfer function to obtain zero steady-state error and good dynamic responses such as fast transient responses with minimum overshoot and make the system less sensitive to disturbances and changes in the system parameters.

1.1.3 Cascade Control Structure

The cascade control structure is commonly used for DC Motor because of this flexibility. It consists of inner torque loop and outer speed loop. The cascade control requires that the bandwidth (speed of response) increase towards the inner loop, with the torque loop being the fastest and the position loop being the slowest [8].

1.1.4 Switch-Mode Converters in Electric drives

The power electronic converters are used to obtain an adjustable DC voltage applied to the armature of a DC motor. There are basically two types of converter normally employed in DC drive which is controlled rectifier and switch mode converter. To develop the model of power electronic converters will depend on the application of the model. The model for a switching device used to analyze or switching losses is different from a model develop used to study the fundamental behaviour of a converter containing that particular switching device [11].

1.2 PROJECT OBJECTIVE

The objectives of this project are:

1. To improved DC motor drive performance in terms of torque ripple, dynamic control and switching frequency by using unipolar switching scheme.
2. To developed the DC motor drive using ezdsp F28335.

1.3 SCOPE

- To compare dc motor drive performance, i.e. torque ripple and switching frequency for some switching scheme (bipolar-hysteresis based controller, bipolar-triangular based controller and unipolar-triangular based controller) of full bridge DC-DC converter.
- To verify the DC motor drives using a unipolar switching scheme can provide a constant switching frequency and minimization of torque ripple through simulation and experimental results.

1.4 PROBLEM STATEMENT

Based on the figure 1.1 below:

- Overcurrent condition during starts-up when application of large DC voltage to the DC motor that contains resistive and inductive load.
- Torque as well as current cannot be controlled and predictable when variation of load torque is subjected to the DC motor control system.

To solve the problem, a torque control loop with bipolar-hysteresis control for full bridge DC-DC converter of DC motor drive can be used as shown in figure 1.2. However, the another problem raises namely larger torque ripple and variable switching frequency due to the bipolar switching scheme and hysteresis employed in the DC drive system.

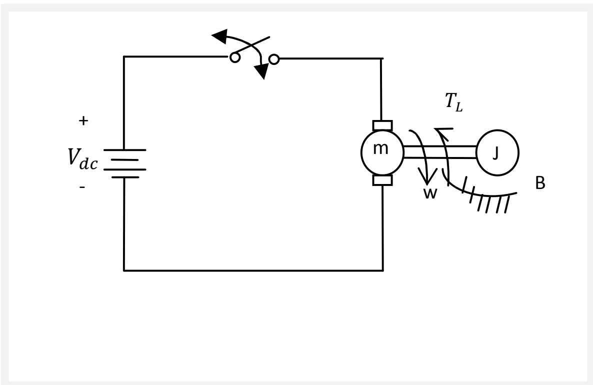

Figure 1.1 : DC Motor Equivalent Circuit

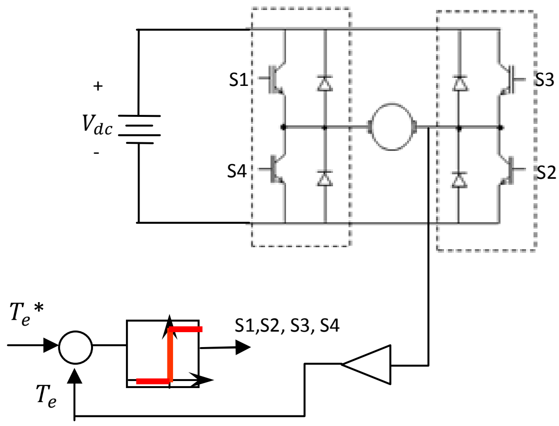

Figure 1.2 : Full Bridge DC-DC Converter

CHAPTER 2

LITERATURE REVIEW

2.1 Mathematical Modelling of DC Motor

In many engineering application, such as robotics and industry automation, require precise control of speed and position. The feedback control drive in figure 2.1 will be discussed in this chapter. This feedback control system consists of a power -processing unit (PPU), a motor and a mechanical load [8]. The torque and speed of the output variables are sensed and are feedback to be compared with the desired (reference) value. To control the power- processing unit to minimize or eliminate this error, the error between the reference and the actual values are amplified.

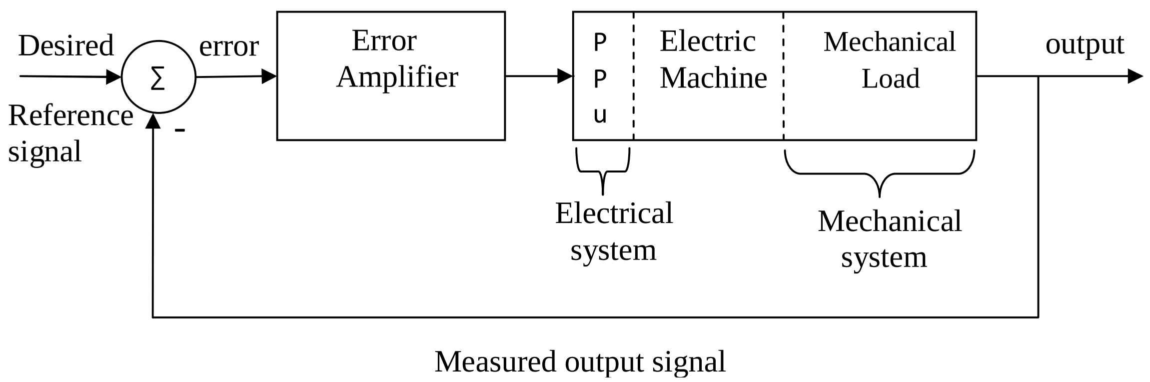

Figure 2.1 : Feedback Control Drive

In a DC motor, permanent magnets on the stator produce a constant field flux $\emptyset_f$ as shown in Figure 2.2. The electromagnet torque T is produced by the interaction of the field flux, $\emptyset_f$ and the armature current, i_a. The current and the torque are proportional to each other.

The mechanical equation:

$$T = k_t \emptyset_f i_a \tag{2.2}$$

wherek_t is the torque constant of the motor.

In the armature circuit, a back emf is produced by the rotation of armature conductors at a speed ω_m in the presence of a field flux $\emptyset_f$

The electrical equation:

$$e_a = k_e \emptyset_f \omega_m \tag{2.3}$$

wherek_e is a voltage constant of the motor.

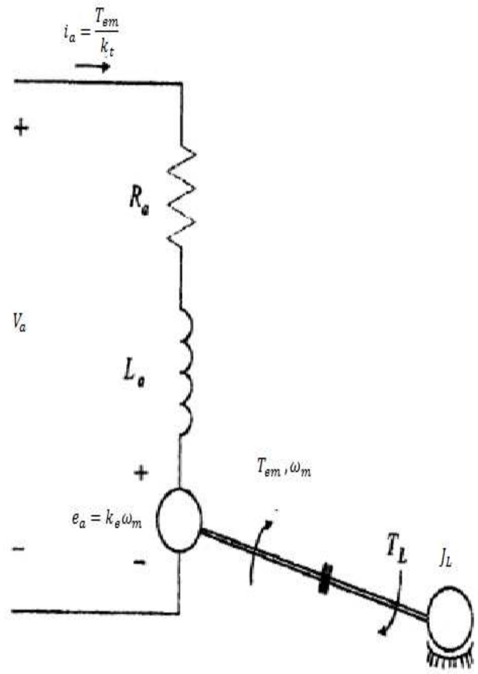

Figure 2.2 : Equivalent circuit of DC motor