CONTROL OF DC MOTOR USING PROPORTIONAL INTEGRAL (PI) CONTROLLER

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18 NOVEMBER 2005

"I hereby declare that I have read this project report and in my opinion this project report is sufficient in terms of scope and quality for the award of Degree of Bachelor in Electrical Engineering (Industry Power)"

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Date : 18 NOVEMBER 2005

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This Project Report Is Submitted In Partial Fulfilment of Requirements for the Degree of Bachelor in Electrical Engineering (Industry Power)

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"I hereby declare that this project report is the result of my own work and all sources of references have been clearly acknowledged."

Signature : ....

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Date : NOVEMBER 2005

To my beloved mother, father, sister and family

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ABSTRACT

The used of DC motor these recent years has been increased due to the human needs that been applied to the robotic, machine and others. In this project, the classical technique control which is PI controller has been studied for servo application to drive the system or loads to control speed and torque. The objectives of this project are to obtain good performances of the DC drive which are minimum of overshoot and less sensitive to the parameters variations. Also, this controller has a good dynamic response such as to provide fast transient response and has a minimum overshoot. To design this controller, the cascade control structure has been applied. In this thesis, the torque and speed control is been discussed. In the first stage, the PI controller is designed to get the proper value of PI controllers with Linear Theory Analysis. Then the PI values of the torque and speed will be evaluated under a large signal analysis. The implementation of hardware for torque control, there are several main components that had been used such as, Integrated circuit (IC) analogue, comparator, triangular waveform generator, current transducer, gate drivers, DC-DC converter and others. The hardware of torque control of DC motor has been tested to ensure the practical experimental results, satisfied with the simulation results.

ABSTRAK

Penggunaan motor berarus terus beberapa tahun kebelakangan ini semakin meningkat selaras dengan keperluan manusia yang mana diaplikasikan pada robot, mesin dan sebagainya. Dalam projek ini, teknik kawalan klasik iaitu pengawal PI telah dikaji untuk aplikasi servo, untuk memacu system atau beban bagi mengawal halaju dan arus. Objektif projek ini adalah mendapatkan prestasi yang baik bagi motor berarus terus di mana dengan lajakan terlampau minimum kurang sensitif kepada kepelbagaian parameter. Juga, pengawal ini mempunyai sambutan dinamik yang baik seperti memberikan sambutan fana yang cepat dan lajakan terlampau yang minimum. Untuk mereka bentuk pengawal ini, struktur kawalan '*cascade*' digunakan. Dalam tesis ini, pengawalan arus dan halaju dibincangkan. Pada peringkat pertama, pengawal PI direka bentuk untuk mendapatkan nilai pengawal-pengawal PI yang sesuai dengan Analisis Teori Linear. Selepas itu, nilai-nilai PI bagi arus dan halaju akan dinilai di bawah analisis pengisyarat besar. Pelaksanaan kepada perkakasan untuk pengawal arus, ada beberapa komponen utama yang telah digunakan seperti analog IC, pembeza, penjana gelombang segitiga, pengubah arus, pemacu, penukar DC-DC, dan lain-lain. Perkakasan pengawal arus bagi DC motor diuji untuk memastikan keputusan eksperimen secara praktikal, adalah memuaskan dengan keputusan simulasi.

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DC	-	Direct current
AC	-	Alternated current
PI	-	Proportional-Integral
K_i	-	Integral gain of PI controller
K_p	-	Proportional gain of PI controller
PID	-	Proportional-Integral Derivative
PD	-	Proportional Derivative
PPU	-	Power-processing unit
IC	-	Integrated circuit
Op-Amp	-	Operational amplifier
Φ_f	-	Field flux
T	-	Electromagnetic torque
k_t	-	Torque constant
i_a	-	Armature current
i_{ref}	-	Current reference
ω_m	-	Speed (rad/s)
e_a	-	Back emf
k_e	-	Back emf constant
P_e	-	Electrical power
P_m	-	Mechanical power
U_a	-	Armature voltage
R_a	-	Armature resistance
T_L	-	Load torque
J	-	Total moment inersia

B	-	Vicious friction
V_c	-	Control signal
V_{tri}	-	Triangular voltage
V_d	-	DC voltage
f_s	-	Switching frequency
PWM	-	Pulse Width Modulation
MOSFET	-	Metal-oxide-semiconductor field effect transistors
$R_{ds(on)}$	-	Resistance across the MOSFET (drain to the source) when Switch is turn on
J_1	-	Nominal inertia coefficient

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CHAPTER 1

INTRODUCTION

1.1 Background of DC Motor

DC motor has been widely used nowadays and historically in DC drive applications. It's been very popular drives for speed and position control application. Otherwise, this drives also low in cost and ease of control. 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 sectors, factory automation, and not forgotten our daily life, the motor accuracy and effectiveness have to be improved [1].

We cannot avoid of getting a few problems while using this DC motor drives. The objective of this project is to discuss the design of motor-drives controllers as well implementing the hardware. With the proper design of feedback controller, it is expected the system less sensitive to disturbances and changes in the system parameters.

1.2 Proportional Integral (PI) Controller

PI controller consists of K_i and K_p gains. These controllers are placed at both speed and torque loop but with the different values. Gain K_p determines proportional gain of controller, while gain K_i determines the integral gain of controller [7][5]. It's also implemented in this transfer function to obtain zero steady state error, obtain a good dynamic response (i.e. fast transient responses with minimum overshoot), and make the system less sensitive to disturbances and changes in the system parameters.

PI controller is always been compared to PID and PD controller. PI controller is suited for dominant dead time (time constant > dead time) and to decrease the noise as in this task's objective and PID controller is suited for dominant time constant and no noise from the transmitter. D is used when the loop has low noise and to increase the stability. If the loop is very noisy, D will increase the noise in high frequency and make the output jittery. D is not used on a pure dead time process. It will make the loop unstable. As long as there is some amount of lag or first order time constant in the process, D can help. D term is most often used on temperature loops. Most temperature loops can make use of derivative because they are low noise, are not pure dead time, and usually have two or more lags. Of course, there are exceptions, but that is a good rule of thumb [7].

1.3 Cascade Control Structure

The cascade control structure is commonly used for DC motor. It is because its flexibility. The cascade control structure is consisting of inner torque loop and outer speed loop. This cascade structure requires that the bandwidth (speed of response) increase towards the inner loop, with the torque loop being the fastest and the speed loop being slower [1]. This will be designed with the Matlab simulink. The

Proportional Integral (PI) which is the controller is design to meet the objectives discussed above.

1.4 Project Objectives and Scope of Work

The objectives of this project are as follows:

i. To control the speed of DC motor using Proportional Integral (PI) controller.

ii. To obtain zero steady state error and a good dynamic response (i.e. fast transient responses with minimum overshoot).

iii. To design a proper feedback controller to make the system less sensitive to disturbances and changes in the system parameters.

Doing analysis and research on the project is the main things that had to be implemented first. On this purpose, all the information is collected from the sources such as, reference books, journals and from the internet (i.e. PI controller, cascade control structure, transfer function and DC motor). Besides all those references, the expertise of using MATLAB [6] is a must, in order to model the control of the DC drive system under small signal analysis and test the control design under large signal analysis that been specified to fulfil the objectives above.

Here are the steps to design the transfer function with good PI controller with the help of MATLAB based on Linear Control Theory:

i. Get the model of DC motor and the whole system using MATLAB software (PI controller, Mechanical load, DC-DC converter and etc).

ii. The whole system will be simulated with large signal analysis to evaluate the controller.

iii. Before the implementation of hardware, the simulink blocks have to be transfer to a circuit design using PESIM software. This is to make clear the hardware that will be used in the design.

iv. Then, the hardware is built up using IC analogue such as Op-Amp, comparator and precise generator waveform IC as the main components where these components has to be tested to make sure the accuracy of the result compared with the simulation result.

1.5 Project Organisation

The rest of the project's chapter are organised are as follows:

Chapter 2 reviews the basic of DC motor theory along with the model of DC motor and its equivalent transfer function or equations. This chapter also explain the four quadrant operation using DC-DC converter and on how the bipolar switching scheme operates.

Chapter 3 reviews the cascade control structure design with PI controller to control motor and mathematical formulation of the control system requirements. Designing PI controller with small signal analysis and evaluate the overall system with the large signal.

Chapter 4 describes the hardware implementing components that have been used. Setting up the components for current loop and follows by speed loop.

Chapter 5 comparing the simulation results with the experimental results. To shows that the objectives have been achieved for torque and speed.

Chapter 7 gives the conclusions and suggestions to the project.