ANALYSIS AND SIMULATION OF CONVERTER-FED DC MOTOR DRIVE BY USING MATLAB

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KOTA KINABALU

2006

PUMS 99:1

UNIVERSITI MALAYSIA SABAH

JUDUL: ANALYSIS AND SIMULATION OF CONVERTER-FED DC MOTOR DRIVE BY USING MATLAB

IJAZAH: SARJANA MUDA KEJURUTERAAN ELEKTRIK & ELEKTRONIK

SESI PENGAJIAN: 2002/2003 – 2005/2006

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ACKNOWLEDGEMENT

I would like to convey my most gratitude to my supervisor Prof. Dr. Neelakantan Prabhakaran, school of Engineering and Information Technology (SEIT), Electrical and Electronic Engineering, University Malaysia Sabah (UMS) for his immensely incisive and constructive guidance in all stages of the project work, and providing the priceless knowledge and ideas as well as the facilities in completing this project. His timely encouragement and advices helped in improvising the quality and thus, greatly facilitating the shaping of this dissertation.

Deepest appreciation to my parents for their encouragement, patience, financial support and valuable advices in the process of developing this dissertation.

Last but not least, affectionate thanks to my course mates and friends for their priceless helps and knowledge sharing.

ABSTRAK

Kajian perbandingan tentang gelung terbuka dan tertutup bagi fungsi pemindahan motor dc dan gambarajah blok,pengawal PI, ciri-ciri kelajuan tork dan simulasi MATLAB bagi tiga fasa ac-dc *thyristor* penukar-suap pacuan motor dc dibentangkan. Simulasi penukar-suap pacuan motor dc dikaji dengan lebih mendalam, menggunakan SimPowerSystems dalam MATLAB Simulink kerana memberikan pencapaian yang lebih baik berbanding dengan pengaturcaraan perisian yang lain. Pengawal *Proportional plus integral (PI)* direka untuk mengurangkan ralat pada sistem dan memperbaiki respon dinamik. Pemalar K_P dan K_I dalam pengawal PI boleh ditukar untuk mendapatkan pencapaian yang memuaskan. Projek ini membuat perbandingan pelbagai kajian dalam mereka penukar-suap pacuan motor dc dengan dan tanpa menggunakan sistem suap-balik dan simulasi pacuan pada bebanan dan kelajuan asal yang berlainan. Dengan peningkatan pemalar K_P dan K_I lebih cenderung untuk mengurangkan ralat pada sistem dan memperbaiki masa untuk mencapai suatu tahap yang malar. Namun begitu, K_P dan K_I yang tinggi akan memburukkan lagi kestabilan tindakbalas sementara bagi sistem tersebut. Pengawal yang baik akan menukar balik kelajuan motor kepada nilai asal apabila berlaku perubahan pada beban tork. Penukar yang dicadangkan telah direka dan diuji dalam makmal menggunakan rangsangan berasingan motor dc. Keputusan eksperimen yang diperolehi mampu menyokong teori dan keputusan simulasi yang telah dibuat.

ABSTRACT

A comparative study of open loop and closed loop dc motor transfer function and block diagram, PI controller, speed – torque characteristics and MATLAB simulation of three phase ac-dc thyristor converter-fed dc motor drive is presented. The simulation of converter-fed dc motor drive is studied in detailed, employing the SimPowerSystems in MATLAB Simulink because it has been found to offer better overall performance among other programming software. A Proportional plus Integral (PI) controller is design to reduce the system errors and improve the dynamics responses. The constant K_P and K_I in PI controller can be changed to meet the acceptable performance. This project compares a various study in designing the converter-fed dc motor drive with and without system feedback and simulates drive under different loading and speed references. By increasing the constant K_P and K_I tends to reduce the systems errors and improve the overshoot and settling time. However, large K_P and K_I will worsen the transients' stability. A good controller will change back the motor speed to the normal value due to the change of load torque. The proposed converter is designed, constructed and tested in the lab using the separately excited dc motor. The experimental results are shown to be in good agreement with the simulated results.

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LIST OF SYMBOLS

α	Delay angle
Φ	Flux density
$\int$	Integration
Ω	Ohm
ω	Speed
τ	Torque
B	Viscous frictional torque
E_a/E_g	Back e.m.f voltage
e(t)	Signal error
f_s	Frequency
H_c	Current loop transducer gain
I_a^*	Reference armature current
I_a	Armature Current
I_f	Field current
J	Moment of inertia
K_b	Induced e.m.f constant
K_c	Current controller gain
K_I	Integral gain
K_m	Motor constant gain
K_P	Proportional gain
K_r	Converter gain

K_s	Speed controller gain
K_t	Torque constant
K_v	Voltage constant
K_ω	Speed feedback gain
L_a	Armature Inductance
L_f	Field Inductance
P	Power
P_a	Armature Power
R_a	Armature Resistance
R_f	Field Resistance
T_c	Current controller delay time
T_e	Electrical torque
T_i	Integral time
T_l	Load torque
T_m	Mechanical torque
T_r	Delay time of converter
T_s	Speed controller delay time
T_ω	Time constant
u(t)	Output variable
U_x	Actual voltage
V_a	Armature voltage
V_{ac}	Reference synchronization voltage
V_c	Current controller output voltage

V_{cn}	Control voltage
V_f	Field Voltage
W	Setpoint
w_{mr}^*	Speed feedback
w_r	Rated speed
w_r^*	Reference speed
X	Actual value

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Converter-fed dc motor drives are extensively used in special heavy duty application like draglines, electric trains, and steal mills where sudden change of speed or rotation is required. They are used for these applications because their speed and torque can be easily being varied without suffering in the efficiency of the machine.

The speed of dc motors changes due to the changes of load torque. To maintain a constant speed, the armature voltage should be varied continuously by varying the delay angle of ac-dc converters. Most industrial drives operate as closed-loop feedback systems because it has the advantages of improved accuracy, fast dynamics response, and reduced effects of load disturbances and system nonlinearities.

Proportional feedback control can reduce error responses to disturbances; however, it still allows a non-zero steady-state error. When the controller includes a term proportional to the integral of the error, then the steady state error can be eliminated. Here the control signal is a linear combination of the error and the time integral of the error. All the proportional gain K_P and integral gain K_I are adjustable.

This project proposed a design and simulation of converter-fed dc motor drive by using MATLAB package. The physical modeling and simulation of the converter-fed using MATLAB M-file, Simulink and SimPowerSystems are presented in Chapter 4, 5 and 6. Experimental results for this study also discussed and compared to the simulated responses.

1.2 OBJECTIVES OF THE PROJECT

Direct current (dc) motors have variable characteristics and are used extensively in variable-speed drives. Dc motors can provide a high starting torque and it is also possible to obtain speed control over a wide range with good dynamics response.

The ac-dc converters also known as controlled rectifiers are generally used for the speed control of dc motors. Controlled rectifier provides a variable dc output voltage from a fixed ac voltage. The three-phase thyristor converter is usually used as ac-dc converter.

In the dc motor operation, the speed is changing due to the change in the load torque applied. When the torque is increased, the speed of the motor is decreases due to the voltage drop in the armature resistance. To maintain the constant speed of the motor, the armature voltage should be varied continuously by varying the alpha angle of a ac-dc converters. Thus, the controller must be added to control the alpha angle. The objectives of this project are:

- To develop the transfer function of the dc motor with and without feedback

- To design controller with a speed feedback (closed loop feedback) using PI controller and simulate the drive under different loading and reference speed.
- To conduct experiments to verify results with the simulated responses.

1.3 PROJECT APPROACH

1.3.1 Data Collection and Literature Survey

All the data were collected from the journals of IEEE columns, other trusted websites, and reference books from University Malaysia Sabah (UMS) library. There were several books on DC Motors, Power Electronics and Feedback dynamic control systems, but none pertaining to simulation of dc motors in MATLAB (SimPowerSystems).

1.3.2 Through Supervisor and lecturers Guidance

Supervisor gives the ideas of doing this project by understanding the MATLAB demos and does the tutorial in MATLAB help. Mr. Kenneth and Dr. G Sainarayan conduct the MATLAB simulation workshop to help students understand better in MATLAB.

1.4 ORGANIZATION OF THE PROJECT

The project organized into 7 chapters and brief content of each chapter is as follows:

In chapter 2, a review on separately excited dc motor characteristic and its basic equation are presented. The converted fed open loop and closed loop also being discussed. And, some studies of proportional plus integral controller that using this project.

In chapter 3, the methodologies that have been carried out in this project will be discussed. These include the development of transfer function and block diagram of dc motor.

Chapter 4 will cover the simulation of open loop and closed loop dc motor using the MATLAB M-file. These simulations compare the effect changing the gains of proportional integral (PI) controller to the system.

Chapter 5 is a simulation of dc motor block diagram with and without feedback by using Simulink. The same motor ratings in the previous chapter are used.

In chapter 6, a different loading, speed references and controller gains are used in the simulation using the SimPowerSystems. The controller is design to maintain the constant speed with the changing of the load torque. Effects on speed characteristics of a constant and changing load torque at a specified time are also being discussed.

Chapter 7 is the experimental results that constructed to verify the simulated responses. However, the speed characteristics of the converter-fed dc motor drive could not be observed due to the limited apparatus in the lab.

Chapter 8 is the concluding remarks on the developed module and suggestions for future research are given.

1.4 SUMMARY

MATLAB simulink have been proven to be effective and it is applied in many fields such as engineering, physical sciences, and economics and is gaining recognition in medicine, biomedical science, and finance. Working with MATLAB simulink helps most engineers in designing products and do research. Development of MATLAB modeling and simulation is proposed. Research problem and research methodology are also discussed in this project.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Dc motors have been in service for more than a century. Their fortune has changed a great deal since the introduction of the induction motor. There were several reasons for the continued popularity of dc motor. One was that dc power systems are still common in cars, trucks, and aircrafts. Another application for dc motor is a situation in which wide variation in speed are needed while retaining high efficiency (Stephen J. Chapman, 2005). There are five types of dc motors currently available such as follow:

- Separately excited dc motor
- Shunt dc motor
- Series dc motor
- Permanent magnet dc motor
- Compounded dc motor

Among these type of motors, the majority of industrial variable – speed drives have been designed for permanent magnet and separately excited dc motors (A.T.Alexandridis.et.al,1998).

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