

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

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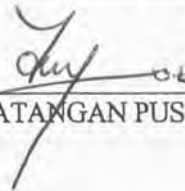
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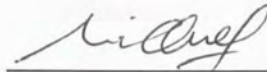
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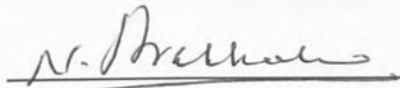
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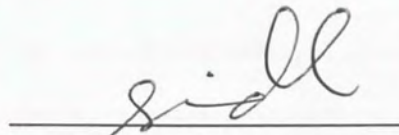


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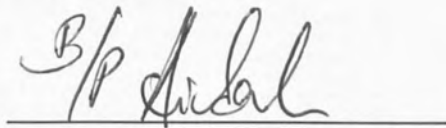
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## ABSTRAK

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

$\alpha$	Delay angle
$\Phi$	Flux density
$\int$	Integration
$\Omega$	Ohm
$\omega$	Speed
$\tau$	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
$K_w$	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
$T_w$	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 steel 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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