SPEED CONTROL OF DC MOTORS

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To my dearest parents and family for their love and blessing.

To my dearly beloved wife, Fatimah Mohammad for her support and encouragement.

To my daughter, Nur Hadhirah Insyirah for making my life meaningful.

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ABSTRACT

The function of speed control in DC motors is very essential in the achievement of desirable outputs. DC motors are designed for use in industrial and commercial applications such as the pump and blowers, material handling, system and gear drives, and adjustable speed drives. Both the nonlinear and linear of DC motor mathematical model is derived and the system model also represented in the form of continuous state space equation. Four type of controllers namely Proportional-Integral-Derivative (PID) controller, state-feedback controller, fuzzy logic controller and fuzzy PID controller are considered for controlling the speed of dc motor by giving the step input signal. The system is simulated using MATLAB/SIMULINK software. The system responses under the four different controllers are also analysed and discussed in term of their performances.

ABSTRAK

Fungsi kawalan kelajuan motor arus terus adalah sangat penting dalam mencapai objektif yang diingini. Motor arus terus direka untuk digunakan dalam aplikasi industri dan komersial seperti pam dan peniup, pengendalian bahan, sistem dan pemacu gear, dan laras kelajuan memandu. Kedua-dua linear dan ketidaklinearan untuk model matematik motor arus terus diterbitkan dan model sistem ini juga diwakili dalam bentuk persamaan keadaan berterusan. Empat jenis pengawal iaitu pengawal *Proportional-Integral-Derivative* (PID), pengawal suap balik keadaan, pengawal fuzzy dan pengawal fuzzy PID telah dipertimbangkan untuk mengawal kelajuan motor arus mengikut isyarat masukan yang ditetapkan. Pengawal tersebut disimulasi dengan menggunakan perisian MATLAB / SIMULINK. Tindakbalas sistem di bawah empat pengawal yang berbeza juga dianalisa dan dibincangkan dari segi prestasi.

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LIST OF SYMBOLS

Kp	-	Proportional gain
Ki	-	Integral gain
Kd	-	Derivative gain
T_L	-	Torque load
T_f	-	Friction load
F_c		Coulumb friction coefficient
x	-	Position of the cart
θ	-	Angle of the pendulum with respect to vertical axis
T_m	-	motor torque
i	-	armature current
K_t	-	constant factor
e_t	-	back emf
$\dot{\theta}$	-	rotational speed
K_e	-	electromotive force constant
K_m	-	motor constant
L_m	-	Armature inductance
R_m	-	Armature resistance
V	-	Input Voltage
$d\theta/dt$	-	Rotating speed
J	-	Moment of Inertia of the Rotor
b	-	Damping ratio of the mechanical system

T_S	-	Settling time
T_r	-	Rise time
ζ	-	damping ratio
ω_n	-	natural frequency
A	-	System matrix
B	-	Input matrix
C	-	Output matrix
K_f	-	Forward path gain
A_{cl}	-	Close loop system matrix
B_{cl}	-	Close loop input matrix
$\Delta e(t)$	-	Change of error
e(t)	-	error
u(t)	-	change of voltage

LIST OF ABBREVIATIONS

PID	-	Proportional, Integral and Derivative
DC	-	Direct Current
FIS	-	Fuzzy Inference System
OS	-	Overshoot
NB	-	Negative Big
NM	-	Negative Meddle
NS	-	Negative Small
ZO	-	Zero
PS	-	Positive Small
PM	-	Positive Middle
PB	-	Positive Big
emf	-	Electromotive field

CHAPTER 1

INTRODUCTION

1.1 Project Background

DC motors are designed for use in industrial and commercial applications such as the pump and blowers, material handling, system and gear drives, and adjustable speed drives. These motors are used to give rotary speed and position to a various electromechanical system. The purpose of developing a control system is to enable stable control since it has parameters tuning difficulties, non-linear, poor stability and imprecise control.

The whole system is needed to be modeled first by using a state space equation. It has been found that this system results a non linear model. From this nonlinear model, the linearization process has to be done to simplify the model. After the linearized model has been acquired, the next task to do is to control the DC motor according to the required specifications.

In this project, the main task is to control the speed of the DC motor. If the speed is equal to the reference signal, it can be concluded that the designed controller is successful in controlling the speed of the system become stable. There are four types of controllers considered namely, PID controller, state-feedback controller, fuzzy controller and another one is fuzzy PID controller.

The performance of the controllers in controlling the speed of DC motor system is evaluated via computer simulation using MATLAB/SIMULINK platform.

1.2 Objective of the project

The objectives of this project are as follows:

(i) To formulate the complete mathematical model and state-space representation of the DC Motor.

(ii) To design PID controllers for the DC Motor as a benchmarking controller.

(iii) To design a state feedback controller.

(iv) To design a controller using Fuzzy Logic Approach.

(v) To design a controller using Fuzzy PID Approach.

(vi) To compare the performance of the PID technique, state feedback, fuzzy logic and fuzzy PID controller via simulation results.

1.3 Scope of Works

The work undertaken in this project is limited to the following aspects:

(i). The complete mathematical model of the DC Motor speed controller.

(ii) Simulation work using MATLAB/SIMULINK as a platform to prove the effectiveness of the four designed controllers.

(iii) Comparative study between the PID, Fuzzy Controller, Fuzzy PID controller and state feedback technique will be done

1.4 Research Methodology

The research work undertaken in the following seven development stages:

(i) The development of linear mathematical model for DC motor.

(ii) The design of controller base on PID technique.

(iii) The design of state feedback Controller.

(iv) The design of Fuzzy logic controller.

(v) The design of Fuzzy PID controller.

(vi) Perform simulation using MATLAB/SIMULINK for PID, state feedback, Fuzzy Logic and Fuzzy PID Controller.

(vii) Comparative study of the controllers is done.

1.5 Literature review

The dynamics speed response of DC motors with Fuzzy controller. It was estimated and found that the speed can be controlled effectively. The analysis provides useful parameter and the information for effective use of proposed system. [6]

Three membership functions (center width narrow, center width constant and center width wide) of Fuzzy logic are used to check the speed error of DC motor. The best performance has been recorded when using center width wide Fuzzy Logic Controller.[7]

The fuzzy controller does not required a mathematical model of the process is shown. Rules could be adapted easily to achieve better response. The inputs could be either qualitative or quantitative since it has the fuzziness at its inputs and the rules can be derived from an expert or an operator who has experience of driving the process. [8]

The ability of the fuzzy logic control to adapt against the sensitiveness to variation of the reference speed attention discussed. The fuzzy logic speed controller of DC motor shows increases of optimal performance. The paper also highlights the disadvantage of the conventional control sensitiveness to inertia variation and sensitiveness to variation of the speed with drive system of DC motor. The fuzzy logic proposed to overcome such the problem. [9]

The DC motor speed regulating system with PID control is presented. The DC motor has parameters tuning difficulties, poor stability, and imprecise control. According to the controllers, the fuzzy PID controller was designed to make control system more stable, anti-interference ability stronger, overshoot smaller, response speed faster and robustness stronger. The structure chart of fuzzy PID control had been designed and simulated. Fuzzy rule of Kp, Ki and Kd are also been developed. [4]

The control performance between state-feedback controller with integral control and state feedback controller without integral control is compared. The controller is composed into two parts: the full state feedback with and without integral control with pole placement design via Bass and Gura's approach. The controller design for linear time-varying differential systems is generally a difficult problem, because of the fundamental problems related to the analysis of such systems. [12]

The state feedback theory and solving for Lyapunov equation step by step is shown. The effect of parameter variations and suppression of noise and disturbance can be reduced by a properly designed feedback system. In practice, the state feedback controller is used more widely. [10]

The full state feedback is a pole placement design technique proved by which the desired poles are selected at the start of the design process. The performance of the state feedback is not guaranteed and the forward gain is required to track set point changes. The theory and design procedure of full state feedback with forward gain performance are proposed. [11]

The nonlinear dynamic model of an actual DC motor including the nonlinear friction torque is established. The simplified friction model proposed in order to simplify applications and reproduced the real nonlinear friction of the motor. This model identified more accurate compared to the nonlinear friction proposed by Armstrong-helouvry B. *et al.* (1994). [13]

The classical cascade control architecture of DC motors compared where the state feedback control offers benefits in terms of design complexity, hardware realization and adaptivily. The approach of state space linear control of a DC motor presented successfully for compensation of Coulomb friction. [17]

1.6 Layout of Thesis

This thesis contains eight chapters. Chapter 2 contains a brief introduction of DC motor. The derivation of the mathematical model, which is a nonlinear model of the DC motor system, is also presented. The linear mathematical model of the system is derived and then transformed into the state space representations.

Chapter 3 discusses four type of controllers design namely PID controller using Ziegler-Nichols technique, state feedback controller via Lyapunov Equation, fuzzy Logic controller and fuzzy PID controller.

Chapter 4 presents the results of PID technique, state feedback, fuzzy logic and fuzzy PID controller. For every controller there will be graphs presented namely output of the speed DC motor. At the end of this chapter, the comparison between the PID technique, state feedback, fuzzy logic and fuzzy PID controller is done. The analysis and discussions about the results obtained in this chapter.

Chapter 5 concludes the work undertaken, suggestions for future work are also presented in this chapter.

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