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PERFORMANCE COMPARISON OF SELF-TUNING PID CONTROLLER FOR CONTROLLING THE SPEED OF A DC MOTOR

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2018

DECLARATION

I declare that this dissertation entitled "Performance Comparison of Self Tuning PID Controller for Controlling the Speed of a DC Motor" is the result of my own research except as cited in the references. The dissertation has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	....
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Date	:	7/9/2018

APPROVAL

I hereby declare that I have read this dissertation, and, in my opinion, this dissertation is sufficient in terms of scope and quality for the award of Master of Electrical Engineering (Industrial Power).

Signature	:	....
Supervisor Name	:	DR. Nurul Ain Binti Mohd Said
Date	:	7/9/2018

DEDICATION

To my father

For earning an honest living for us and for supporting and encouraging me to believe

In myself

To my mother

A strong and gentle soul who taught me to trust in Allah, believe in hard work and that

So much could be done with little

To my brothers and sisters

I am really grateful to my family

The reason of what I become today

Thanks for your great support and continuous care.

ABSTRACT

DC motors are widely used in industrial applications, such as electric trains, robot manipulators and home appliances where speed and position control of the motor are required. The DC motors have high primary torque that makes it suitable in many applications. Moreover, the DC motors have the advantage of implementing in a wide range of operating speed, such as above or below the rated speed. In addition, the control system of the DC motor is simple, flexible and low cost when compared to other types of motors. In industrial applications the speed control system that able to give a fast response with a minimum overshoot, lower steady state error, shorter settling time and faster rising time are essential. The speed control of the DC motor is fed through a buck-converter. The buck converter will regulate the desired output voltage level and maintain the speed of the DC motor constant. Any change in torque does not affect the speed of the motor. Therefore, in this thesis, the DC motor speed control by using three different types of controller are being analyzed and developed. The controller gains are obtained based on conventional PID, self-tuning fuzzy logic and self-tuning genetic algorithm (GA) controller. The performance evaluation of the system is developed based on the MATLAB/Simulink. Results are investigated considering the system running with no load and half load at 500 and 1000 rpm. The results demonstrate that the proposed GA tuned PID provides improved performance as compared to PID controller and fuzzy logic tuned PID controller in terms of time specification such as 0% overshoot, shorter settling time, faster rise time and zero steady state error.

ABSTRAK

Motor DC digunakan secara meluas dalam industri antaranya seperti kereta api elektrik, manipulator robot dan peralatan elektrik di mana kawalan kelajuan dan kedudukan enjin dikehendaki. Motor DC mempunyai kilasan utama yang tinggi yang menjadikan ia sesuai dalam kebanyakan aplikasi. Tambahan pula, ia mempunyai kelebihan untuk mendapatkan pelbagai kelajuan operasi di atas atau di bawah kelajuan maximum. Di samping itu, ciri-ciri sistem kawalan adalah mudah, fleksibel dan kos rendah apabila dibandingkan dengan AC motor dan lain-lain jenis motor. Sistem kawalan yang boleh memberi tindak-balas yang cepat untuk mengekalkan kelajuan motor DC pada nilai yang diingini dengan lajakan minima, ralat kadaran yang minima, masa pengenapan yang minima dan masa peningkatan yang pantas adalah amat penting dalam aplikasi industri. Oleh itu, dalam tesis ini, kawalan kelajuan motor DC yang menggunakan tiga jenis pengawal yang berbeza dianalisis dan dibangunkan. Nilai parameter pengawal diperolehi berdasarkan konvensional PID, penalaan fuzzy logik dan penalaan pengawal GA. Penilaian prestasi untuk system dibangunkan berdasarkan MATLAB/Simulink. Keputusan disiasat dengan mengambilkira sistem yang berkelajuan dengan tiada beban dan separuh beban pada 500 dan 1000 rpm. Keputusan menunjukkan bahawa GA yang ditala menggunakan kawalan PID menghasilkan prestasi yang lebih baik berbanding dengan pengawal PID dan fuzzy logik yang ditala menggunakan pengawal PID dari segi spesifikasi masa seperti 0% lajakan dan sifar dalam ralat keadaan mantap.

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LIST OF ABBREVIATIONS

DC	Direct current
V_b	Armature voltage
R_a	Armature resistance
L_a	Armature inductance
K_b	Damping friction of the mechanical system
K_a	Back electromotive force constant
J	Moment of inertia of the rotor
T	Torque of motor
w	Angular velocity
e.m.f	Electro Motive Force
PID	Proportional Integral Derivative
K_P	Proportional gain
K_I	Integral gain
K_D	Derivative gain
FLC	Fuzzy Logic Controller
STFLC	Fuzzy logic Self-Tuning of PID Controller
MF	Membership Function

LIST OF ABBREVIATIONS

GA	Genetic Algorithm
NL	Negative Large
NS	Negative Small
ZE	Zero
PS	Positive Small
PL	Positive Large
PVS	Positive Very Small
PMS	Positive Medium Small
PM	Positive Medium
PML	Proportional Integral Derivative
PVL	Positive Very Large
PWM	Pulse With Modulation

CHAPTER 1

INTRODUCTION

1.1 General Overview

Electric motors such as DC motors is used in a wide variety of applications, on of it is as a source of mechanical motor energy for industrial wheel and productivity. Not only that the DC motors, can be used in a wide range of speed, either above or below the rated speed. Moreover, the DC motor has high primary torque that makes it suitable in many applications (Rashid, 2004). The used of the DC motors can be found in Cement kilns, Robots, cars and all applications that needs variable speed with high installation accuracy (Chan,1987). Hence, the need to build a staid control system for the DC motor speed control is necessary.

In variable speed applications, the close loop DC motor is practically in used. The control system works on a comparison between the reference speed and the instantaneous speed. The armature voltage is generated through a buck converter circuit to control the motor speed. In this thesis three types of control were studied to control the speed of DC motor.

1. Proportional Integral Differential controller (PID).

The PID controller is characterized by its durability and simple installation. Not only that, the PID controller can enhanced the transient and steady state of the control system by reducing the error to zero (e_{ss}=0). This PID controller normally found used in the industrial applications is largely due to its high efficiency. However, if the PID controller exposed to external disturbance the system will not function well (Johnson &Moradi, 2006).

2. Fuzzy logic Self -Tuning of PID Controller (STFLC).

The implementation of fuzzy logic in control application was firstly utilized by Assilian and Mamdani (Gil. et al, 2015). The components of Fuzzy Logic Controller (FLC) includes linguistic variables, rule sets and membership function. These three components can determine the control task to be accomplished. The FLC is built based on the fuzzy system which can be considered as approximately reasoning-based control method. The FLC does not need exact analytic modelling and is very close to human thoughts compared to the conventional logic control. The FLC can be represented as the implementation of human thinking-based system. Meaning that the FLC parameters such as membership functions, rules or scaling factors can be adjusted. The parameters adjusting process is faster in the real time in contrast of other methods, because the value of the elements gain is constant (Sharma & Palwalia, 2017).

3. Genetic Algorithm Self -Tuning PID Controller.

The GA can be defined as searching method that begins without any information about the proper solution and fully relies on the reactions obtained from its surrounding area and development operators (i.e. regeneration, crossover and mutation) to reach the optimum solution. The method averts minimum domestic and reaching to the closest optimum solutions, by commencing at various distinguished points. The GA has the capability of finding better performance and efficiency locations in complicated fields with no knowledge of the barriers related with higher dimensions. In this thesis, GA technique is utilized for the mentioned two aims:

1. To find the enhanced value of PID controller gains referred as K_P, K_I and K_D.
2. To minimize the error amount between existed high order and proposed minimized order systems.

1.2 Problem Statement

The DC motors can be found implemented in variable speed applications such as, cars and electric trains. Which the control system is subjected to disturbance. It is important that these disturbances do not drive the system to unstable conditions. The loss of the required speed or having overshoot and undershoot for the output waveform can be created by small disturbances in the system; such as load changes. Hence, the need to build a robust control system is needed. The control method that capable to obtain overshoot, lower steady state error, shorter settling time and faster rising time are essential and required in the applications.

Even though the PID controller is simple structure and normally found used in the literatures, it has the disadvantages of mainly depends on the plant behaviours (Thomas and Poongodi, 2009). The nonlinearity and instable open-loop system are the elements that contribute to the difficulties of the PID tuning process.

It is shown in the literatures that the existing PID tuning methods are not capable to provide satisfaction performance when the disturbance elements are present in the system. Therefore, to overcome the PID issues this research will propose a control method that capable to have minimum overshoot, lower steady state, shorter settling time and faster rising time even when the disturbance is added in the system (Swarup and Yamashiro, 2002).

1.3 Thesis Objectives

The aims to be accomplished in this thesis are as follow:

i. To design a DC motor speed control with traditional PID controller.

ii. To design a DC motor speed control with self-tuning FLC of PID controller.

iii. To design a DC motor speed control with self-tuning PID controller using Generic Algorithm.

iv. To perform performance comparison analysis the speed responses for the three algorithms relative to the overshoot, settling time, steady state error and rise time based on MATLAB/Simulink simulation of the DC motor.

1.4 Thesis Scopes

This thesis focused on the DC-DC buck converter that used DC motor as a load. The DC motor will be running at different values of speed and loads. Three methods are used in finding the controllers gain. Firstly, by utilizing the Ziegler Nichols method based on the PID controller. Second is by utilizing self-tuning FLC PID controller and the last one is by using the GA. The speed controller gain value that is obtained based on PID, FLC and GA methods will be analysed based on the rise time, settling time, overshoot and steady state error values. The MATLAB /Simulink is used to develop and analyse this research.

1.5 Layout

This thesis consists of six chapters: Chapter 1 presents an introduction to the principles of the study, the reasons and motivation and also discusses the objectives and outline methodologies of the study. Chapter 2 discusses the literature review. Chapter 3 theoretical backgrounds of DC motor, PID controller, fuzzy system, tuning PID by using FLC, GA and tuning PID by using GA. Chapter 4 presents the methodology and system control design of DC motor system, PID controller, tuning PID by using FLC and tuning PID by using GA. Chapter 5 presents the simulation results. Finally, Chapter 6 provides the conclusion and recommendation.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter presents the literature cited on the DC motors, PID controller, FLC self-tuning PID controller, and GA for self-tuning PID controller. The DC motors are deployed in wide range of application such as electric trains, robot manipulation and house gadgets. The mentioned applications particularly involved with speed and position control of the motor. The conventional PID controller are usually in used due to the basic constructions and intuitional understandable controlling methods. However, the PID controller has the drawback of dealing with disturbances.

In FLC is capable to deal with model non-linearities or disturbances. However, the FLC need to be designed utilizing commonly trial and error methods utilizing the IF, ELSE, THEN rule sets. These trial and error method is not accurate, therefor, limits performance of FLC in various control methods.

Additionally, GA is used for searching the global optimum solution in the control system. The development operation of GA is in accordance to the naturally selecting mechanism (Meza, et al. 2012). The GA implements chromosomes via three process: known as reproduction, crossover, and mutations. These processes able to obtain offspring for the second process. The superiority of GA free from derivation random optimizing and can be implemented in both continuously and discretely existed issues. In recent years, many researchers focusing on designing self-tuning PID utilizing GA to raise the abilities of PID controllers. Therefore, a comprehensive review will be provided in this chapter to