IMPLEMENTATION OF PID CONTROLLER USING PSO AND HARMONY SEARCH ALGORITHM FOR DC MOTOR SPEED CONTROL SYSTEM

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Dedicated to my dearest dad and mum who supported me all the time and my friends who always by my side.

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ABSTRACT

Nowadays the DC motor is common used in industrial application. However, the performance of DC motor without any controller is unstable due to high overshoot, rise time, settling time and steady-state error. Therefore, the PID controller will be implemented into the DC motor system to solve those problems. This project focused on the tuning method for the parameter of PID controller such as PSO algorithm and Harmony Search Algorithm. These algorithms will help to obtain the optimization value of PID parameters. Therefore, the optimization value of PID parameters can decrease the maximum overshoot, shorter rise time, settling time and the steady-state error. This improvement will cause the performance of the DC motor more stable and function well.

ABSTRACT

Pada masa kini DC motor yang biasa digunakan dalam aplikasi industri. Prestasi untuk DC motor tanpa pengawal seperti PID adalah tidak stabil kerana terlajak, masa peningkatan, masa penetapan dan ralat keadaan mantap amat tinggi. Dengan itu, pengawal PID akan dilaksanakan dalam sistem DC motor untuk menyelesaikan masalah tersebut. Projek ini memberi tumpuan dalam PSO algorithm dan Harmony Search Algorithm yang boleh mencari parameter untuk pengawal PID. Oleh itu, nilai PID parameter yang mengoptimumkan boleh mengurangkan terlajak maksimum, masa penaikatan, masa menetap dan ralat keadaan mantap. Peningkatan ini akan menyebabkan prestasi DC motor menjadi lebih stabil dan berfungsi dengan lebih baik.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Overview

Majority of the industries uses DC motor for their industrial used compare to AC motor based on few characteristics. The main reason using DC motor because DC motor can provide the speed control and stability. This is the main reason why majority of the industry machines will use DC motor to adjust their machine speed for their application like the conveyor belt so that it can improve the performance of their industry applications. Although DC motor is much stable than AC motor, they found that there have some unstable performance by DC motor in early state. The overshoot and undershoot will occur after started run the DC motor. This situation will decrease the accuracy and performance for the industry applications. Beside than overshoot problem, high rise time,Tr ,settling time,Ts and state-state error will also decrease the performance of the system. Therefore, the PID controller will be implemented to DC motor to solve those problems for improve the performance of the system. The PSO and Harmony Search Algorithm will apply in PID controller for tuning the PID parameters to get a better values for proportional gain, Kp , integral gain,Ki and derivative gain, Kd.

1.2 Problem Statement

1. Unknown plant or mathematical model of the system.
2. Undesired output response of the DC motor which used as adjustable or variables speed applications.

1.3 Objectives

1. To determine the mathematic model of the DC motor using system identification approach based on Real-Time workshop.
2. To design a PID controller for the purpose of controlling the speed of DC motor.
3. To apply PSO and Harmony Search Algorithm in PID controller for the purpose of tuning the PID parameters
4. To make a comparison and justification based on the controller performances obtained from the simulation.

1.4 Scope of Work

This project mainly focus on software design in Matlab / Simulink for overcome the problems like overshoot, high rise time ,t_r high settling time ,t_s and high steady state error ,%e. Therefore, the design of this system consists of the PID controller and the transfer function of the DC motor that obtained from the real experiment (ELECTRO-MECHANICAL Engineering Control System (EMECS)) and system identification approach .The common method for tuning the parameters of PID controller is Ziegler-Nichols method but this project will use good gain method to tune the parameters and the performance for both methods will be compared. Besides that, computation technique like PSO and Harmony Search Algorithm will be used to optimize the PID controller. This project focuses on the PSO and Harmony Search Algorithm and the output response for these 2 algorithms will be compared and justified.

CHAPTER 2

LITERATURE REVIEW

2.1 DC Motor System

According to Jalilvand, A. Kimiyaghalam, A. Ashouri, H. Kord (2011), the design of block diagram for DC motor in the Simulink software will based on the transfer function that obtain from the Figure 2.1.

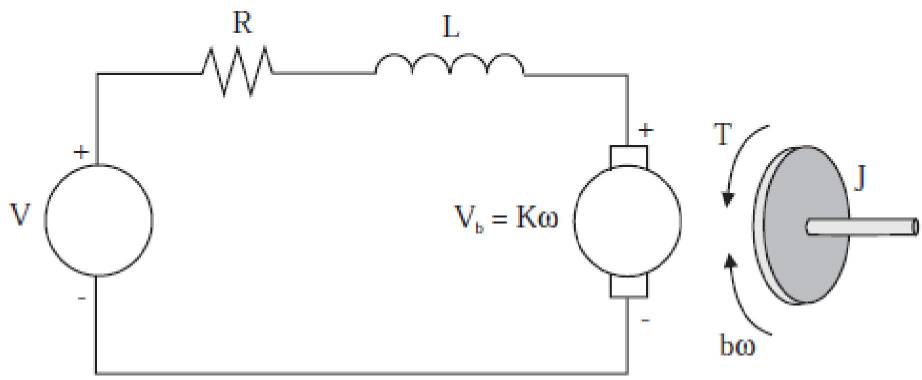

Figure 2.1: Schematic representation of DC motor

Using the Newton's law combine with the Kirchhoff's law,

$$J\frac{d^2\theta}{dt^2} + b\frac{d\theta}{dt} = Ki \quad (2.1)$$

$$L\frac{di}{dt} + Ri = V - K\frac{d\theta}{dt} \quad (2.2)$$

Using the laplace transform for equation (2.1) and (2.2),

$$Js^2\,\theta(s) + bs\,\theta(s) = KI(s) \tag{2.3}$$

$$LsI(s) + RI(s) = V(s) - Ks\,\theta(s) \tag{2.4}$$

From the equation (2.4)

$$I(s) = \frac{V(s) - Ks\theta(s)}{R + Ls} \tag{2.5}$$

Hence substitute equation (2.5) into (2.3)

$$Js^2\,\theta(s) + bs\,\theta(s) = K\,\frac{V(s) - Ks\theta(s)}{R + Ls} \tag{2.6}$$

Therefore the transfer function will be

$$\frac{\theta(s)}{V(s)} = \frac{K}{s[(R+Ls)(Js+b)+K^2\,]} \tag{2.7}$$

The block diagram for DC motor will construct as Figure 2.2 by using the transfer function that obtained from the schematic representation of DC motor.

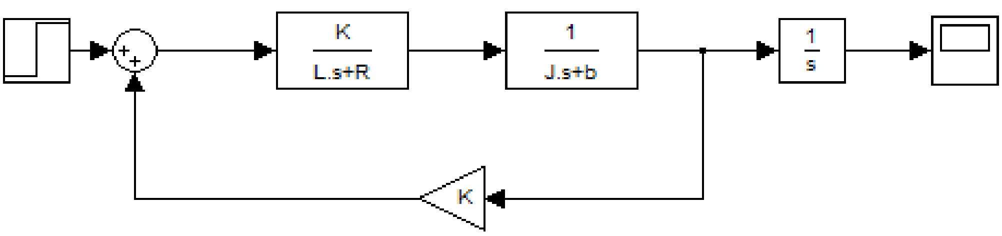

Figure 2 : Block diagram for DC motor

2.2 PID Controller

The purpose of implement PID controller into the system is to improve the dynamic response and reduce the steady-state error. The Figure 2.3 show how to implement the PID controller into the system in Simulink. There is a lot of other journal that research on the topic of PID controller and the comparison with other controller to observe the performance of the DC motor.

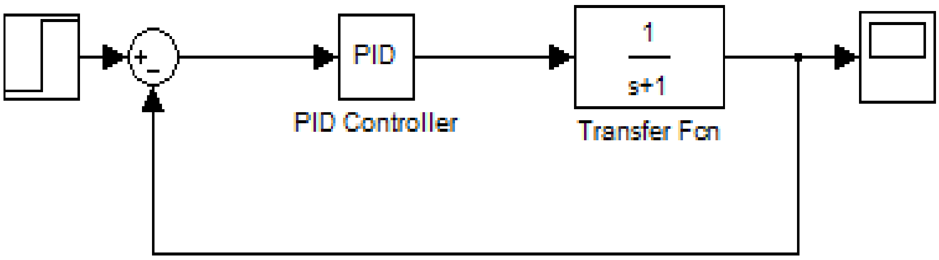

Figure 2.3 : Close loop system with PID controller

2.2.1 Speed Control of DC Motor Using Genetic Algorithm Based PID Controller

Megha Jaiswal and Mohna Phadnis(2013) designed the block diagram for the DC motor with and without the genetic algorithm based PID controller. The purpose for this research is to do a comparison of output response of DC motor between the system with genetic algorithm and system without the genetic algorithm. The transfer function for the DC motor in this research is $\frac{0.5}{0.0077s^2+0.09007s+0.25018}$ that obtained from the model of the DC motor. The block diagram of the DC motor system will be constructed based on this transfer function. The output response for the system without using the genetic algorithm has these problems such as high overshoot, rise time, settling time and steady-state error. The performance of DC motor will become not stable and accurate due to these problems.

After that, PID controller block diagram is inserted into system and then simulate the circuit to observe the output response. The output response with and without the genetic algorithm will be compared. Hence, the output response for the system with the genetic algorithm shows that it will eliminate the maximum overshoot problem. Besides that, it also reduces the rise time and settling time for the whole system. The steady-state error for the system with and without the genetic algorithm is almost zero percentage. Therefore, system with the genetic algorithm is much better performance for the system without the genetic algorithm due to overall characteristics.

2.2.2 Simulation of Optimal Speed Control for a DC Motor Using Conventional PID Controller and Fuzzy Logic Controller

Ritu Soni, DBV Singh, Pramod Pandey and Priyanka Sharma (2013) research about the comparison between the fuzzy logic controller and PID controller for speed control of DC motor. DC motor is the best choice for speed and position control in industrial applications. PID controller or the Fuzzy logic controller will normally implement with the DC motor to improve the performance and stability of the motor. Ziegler-Nichols frequency response and hand-tuning method will be used for tuning the parameter of the controller. These two methods can obtain the perfect output response but it requires a long period for tuning the parameters.

Figure 2.4 and Figure 2.5 show the block diagram for the PID controller and fuzzy logic controller respectively in Simulink. Hence, the simulation result for both controllers can be observed respectively. The simulation result for the PID controller shows the high maximum overshoot, settling time and the steady-state error while the performance of the fuzzy logic controller shows zero maximum overshoot. Hence, the fuzzy logic controller will eliminate the overshoot problem. Besides that, system with fuzzy logic controller shows the lower settling time and rise time compare with the system with PID controller. The result for both output response show that the system is stable due to zero steady-state error from the simulation result. In conclusion, the performance of system with fuzzy logic controller is much better than system with PID controller due to overall characteristics. Therefore, Fuzzy logic controller is more suitable to implement into the DC motor system.

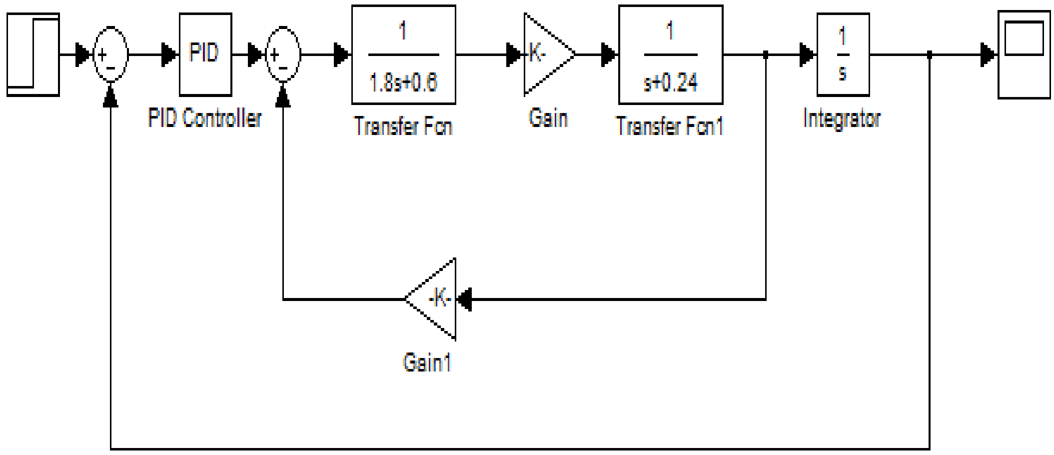

Figure 2.4: Block diagram for PID controller

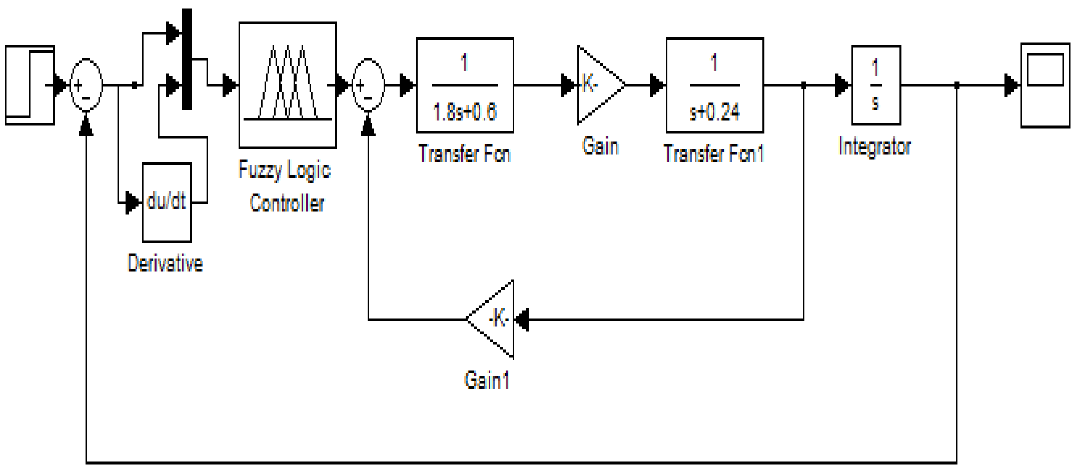

Figure 2.5: Block diagram for Fuzzy logic controller

2.2.3 Speed Control of DC Motor using PID Controller Based on Matlab

According to the Aditya Pratap Singh, Udit Narayan and Akash Verma (2013) , their research is designed the PID controller to control the speed response of the DC motor. Different value of PID parameters which is proportional gain, Kp integral gain, Ki and derivative gain, Kd will provide different effect to the performance of the DC motor. Table 2.1 show the effect of DC motor by using different values of Kd. Table 2.1 prove the value of rise time will increase but the value of maximum overshoot will decrease by increasing the value of Kd.

Table 2.1 : The effect by using different values of derivative gain

Kd	Rise time(sec)	Maximum Overshoot (%)	Steady-state Error	Peak Amplitude of Velocity (red/sec)
1	0.50	23.39	0	40
2	0.65	15.95	0	40
3	0.71	14.52	0	40
4	0.82	12.58	0	40

Hence, the values of Kp and Ki will be increased respectively to observe the effect to the performance of DC motor. From the observation of this research, increasing the value of Kp will cause the effect of decreasing the rise time and the steady-state error while increasing the value of Ki will cause the effect of eliminate the steady-state error and reducing the rise time. Therefore, different value of PID parameters will have the different effect to the performance of DC motor.

2.2.4 Real Time DC Motor Speed Control using PID Controller in LabVIEW

Pratap Vikhe, Neelam Punjabi and Chandrakant Kadu(2014) developed the design for the PID controller in DC motor in purpose to control the speed of the motor in LabView. This design will apply to the hardware called Arduino Uno Board for low cost data acquisition board. The speed of the DC motor will sense by the tachometer that is a sensor to measure the revolution of the DC motor. The block diagram of closed-loop system for this system will design and simulate. It will connect with Arduino so that it can check the result taken from the tachometer in Arduino and the output response from Simulink is same or not. PID controller will make the speed of DC motor to become desired speed if the result taken from Arduino and Simulink is not the same.

2.2.5 DC Motor Speed Control : A Case between PID Controller and Fuzzy Logic Controller

Research of Philip A. Adewuyi(2013) is to make the comparison between the performance of Fuzzy logic controller and PID controller by using the block diagram in Simulink. The transfer function that used in this research is $\frac{K}{(Js+b)(Ls+R)+K^2}$. Then, this transfer function will simulate in Simulink to observe the output response without any controller. In the result, the output response shows the rise time, settling time and the steady-state error is quite high. Therefore, PID controller and Fuzzy logic controller will be implemented to solve these problems.

The problem for using the PID controller is the unknown value for the proportional gain Kp, integral gain Ki and derivative gain Kd. Therefore, few methods such as trail and error method and Ziegler-Nichols method will use for tuning the parameter of the controller. Trial and error method will not consider because this method is waste time and might damage the DC motor. Hence, Ziegler-Nichols method will be the best choice for tuning the PID parameter.

The comparison output response between PID and the Fuzzy logic controller will observe and analyze. The output response of PID controller shows that the performance of the DC motor is much better than Fuzzy logic controller. The rise time , settling time and steady-state error for the PID controller is smaller than the Fuzzy logic controller from the output response. The speed response for PID controller is 10 times improvement compare with the uncontrolled system.

Therefore, PID controller will more suitable to implement into the DC motor compare with Fuzzy logic controller although Fuzzy logic controller did not require any tuning method.

2.2.6 Performance Based Comparison Between Various Z-N Tuning PID And Fuzzy Logic Controller In Position Control System of DC Motor

G.SUDHA and DR.R.ANITA (2012) developed the design to make the comparison between the output response of the Fuzzy logic controller and the PID controller. The purpose of this research is to check which controllers can provide better performance of the DC motor. The transfer function of DC motor for this research is $\frac{1.28}{0.00013919s^3+0.0000007648s^2+0.0002468s}$. The output response of the DC motor by using this transfer function will cause the performance of system is unstable. Therefore, others controller such as PID controller and Fuzzy logic controller will be implemented to improve the performance of the DC motor.

There is few methods will be used for tuning the PID parameters Kp, Ki and Kd such as trial and error method, Ziegler Nichols method , Ziegler-Nichols open-loop point of inflection (POI) PID tuning method and the tuning based on stability margins method (SM). The Ziegler-Nichols open-loop point of inflection (POI) PID tuning method and the tuning based on stability margins method will more consider compare which other methods because the output response for these 2 methods will give the performance of the DC motor more stable. Fuzzy based PID controller is also another tuning method for PID controller. Table 2.2 show the performance of DC motor by using different tuning method. The Fuzzy logic controller tuning method has a better performance compare with other tuning method due to shorter settling time, peak time , final value and maximum overshoot. Therefore, Fuzzy logic controller tuning method is the better tuning method to provide a better performance of DC motor although there is a higher raise time than the Ziegler-Nichols open-loop point of inflection method.