DC MOTOR SPEED AND POSITION CONTROL USING ANALOG PID CONTROLLER

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MAY 2008

"I hereby declared that I have read through this report and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Control Instrumentation & Automation)"

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Supervisor's Name : **SYED NAJIB BIN SYED SALIM**

Date : 7/5/08

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"I hereby declared that this report is a result of my own work except for the excerpts that have been cited clearly in the references"

Signature : .....

Name : **AHMAD ISMAIL BIN MAN**

Date : **7 MAY 2008**

Dedicated, in thankful appreciation for support, encouragement
and understandings to my beloved mother, father, brothers and sisters.

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All praise and glory is to Allah Almighty who taught man through the pen. And, peace and blessing of Allah be on His last messenger, Muhammad S.A.W, who brought the absolute truth and wisdom to mankind.

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ABSTRACT

Hence, many concepts of control system are abstract and difficult to fully comprehend, by most of the students whose study in engineering. The opportunity to study and design controllers of an actual laboratory process is a valuable experience that can reinforce important concepts and make learning process more effective and interesting. This project addresses real-time DC motor speed and position control for learning purpose using operational amplifier as an analog PID controller. A PID controller is designed using MATLAB as a simulation tool to determine a set of coefficients that meet the performance requirement of dc motor. The controller coefficients are then transfer to the hardware configuration that implements the PID controller. The graphical user interfaces (GUI) is developed using Microsoft Visual Basic 6.0 to plot and monitor the system response in real time. It will greatly help the student to visualize the performance of control system.

ABSTRAK

Konsep sistem kawalan adalah abstrak dan sukar untuk difahami sepenuhnya. Peluang untuk mengkaji dan merekabentuk alat kawalan untuk satu proses makmal adalah satu pengalaman berharga yang boleh mengukuhkan konsep-konsep penting serta menjadikan proses pembelajaran lebih efektif dan menarik. Kawalan kelajuan dan kedudukan motor dc adalah untuk menyediakan aplikasi masa nyata dalam sistem kawalan dengan menggunakan Op-amp sebagai alat pengawal PID. Pengawal PID dibangunkan melalui Matlab sebagai alat simulasi untuk mendapatkan pekali-pekali bagi memenuhi spesifikasi motor dc. Pekali-pekali ini kemudianya diterjemahkan dalam bentuk perkakasan untuk membagunkan pengawal PID. Pengantara muka pengguna kemudiannya dibangunkan menggunakan perisian Microsoft Visual Basic 6.0 untuk memplot dan mengawasi respon sistem dalam keadaan nyata. Ini akan membantu pelajar untuk melihat prestasi sistem kawalan dengan lebih mudah.

CONTENT

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LIST OF FIGURE

LIST OF ABBREVIATIONS

AC	Alternating Current
ADC	Analog To Digital Converter
C	capacitor
DAQ	Data Acquisition System
DC	Direct Current
Dm	Damping Ration of mechanical system
Emf	Electromagnetic Force
FPGA	Field Programmable Gate Array
FPAA	Field Programmable Analog Array
GUI	Graphical User Interface
Jm	Moment Inertia
K	Gain
L	inductor
LTI	Linear Time Invariant System
PC	Personnel Computer
PID	Proportional- Integral-Derivative
PV	Process Variable
PWM	Pulse Width Modulated
Rltool	Root Locus Tool
R	Resistance
SP	Set Point
Ts	Settling time
Tp	Peak time
VSD	Variable Speed Drives
% Os	Percent Overshoot

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CHAPTER I

INTRODUCTION

The "DC Motor Speed and Position Control Using Analog PID Controller" project is designed to develop the firmware for educational and learning purposes. This equipment is very versatile, and in fact it is able to give the student understanding the concept of control systems. While the project incorporates both these parts, the desired output from the system will be visible and much clearer when displayed through GUI. This chapter will discuss about general background of the project, its concept, objectives, scope of project and problem statement.

1.1 BACKGROUND OF THE PROJECT

A control system is an integrated set of elements that can be use to maintain a process variable at a desired output or within a desired range of set-point (SP). The control system monitors a process variable (PV) or set-point, and then makes some action to maintain the desired system parameter [15]. Control systems are important part in industrial and also for education field. There are two common classes of control systems, with many variations and combinations: logic or sequential controls, and feedback or linear controls [16].

Many of the concepts of the controller are abstract and difficult to fully comprehend. The continuous improvement and research to improve the process and operand of control system is a challenge to researchers and system developers. Advanced technology in electronic field currently makes control system more complicated. This situation will inconvenience more students to understand the

concept and application in control system. In a few years, various applications have been developed to increase teaching and learning quality in control system.

In its role of preparing the future workforce, a critical aspect of engineering education is to provide students with the skills and knowledge required to be successful in industry as well as appealing from a recruiting perspective. In this project, the classical technique of control system by using analog PID controllers will be implemented in. The aim of this project is to help student to understand the characteristic of PID controller particularly in theory and its application.

This project describes laboratory equipment for teaching purposes that can relate the theory with the real application. The implementation involves the construction of firmware that can realize this application. This effort provides an opportunity for the student to increase the quality of learning process during lectures and lab session.

1.2 THE CONCEPT OF SYSTEM

Overall concepts of this project can be illustrated as shown in Figure 1.1. The output response from plant will directly connect to personal computer via DAQ to show the response of the systems. In this part, analog signal from plant will convert to digital signal and transfer to personal computer to plot and analyze the response during operation.

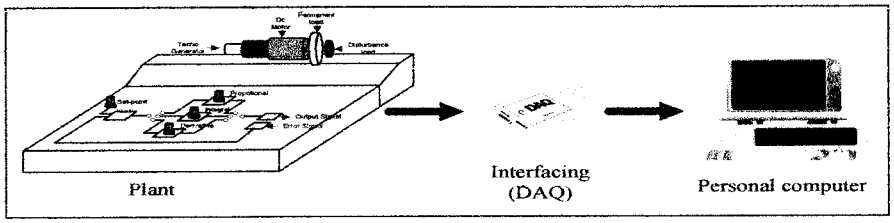

Figure 1.1: Concept of project

Figure 1.2 shows the block diagram of the systems. In this systems the set-point are electric voltage that can adjusted to change the variable condition of the

plant. During operation the PID controller will attempt to correct the error and improve the transient response between a measured process variable (output) and a desired set-point by calculating and then outputting a corrective action that can change the process accordingly.

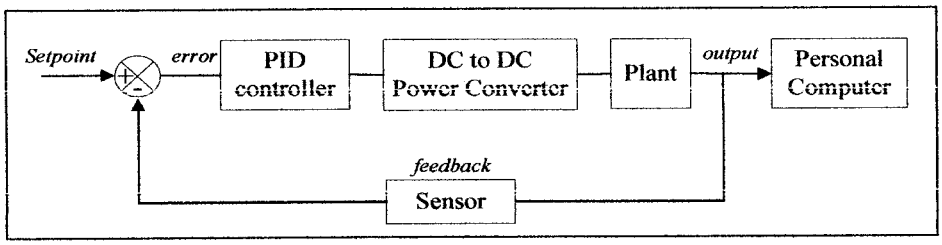

Figure 1.2: The block diagram of a process-control loop

1.3 THE OBJECTIVES

The main objective of this project is to develop the controller for speed and position of dc motor using analog PID controllers that can be used as education training equipment. In order to understand the characteristic of the PID controller, this project will be built to enhance the teaching and learning quality in control system subject. Specific objectives of this project are:

i. To perform a modeling of dc motor
ii. To investigate the performance of open-loop and closed-loop systems by using simulink simulation
iii. To realize the operation of PID controller for dc motor speed and position control application.
iv. To develop the analog controller including proportional-Integral (PI), Proportional-Derivative (PD) controllers and PID.
v. To investigate the effect of output response according to a variety of controller, load and input.
vi. To display the output response of the system in computer by using Microsoft visual basic.

vii. To provide valuable hands-on experience in order to support the theory learned in classroom lectures.

1.4 THE SCOPE OF THE PROJECT

The scope of this project is to present an innovative idea related to educational control system equipment for use in teaching and learning process. In order to present this invention, the project comprises of a circuit board corresponding to the block appearing on the block diagram of an automatic control system. This project having control circuit capable of being optionally combined and display through visual recognition in order to display the output response of the PID controllers. Figure 1.3 below shows the block diagram for scope of the project.

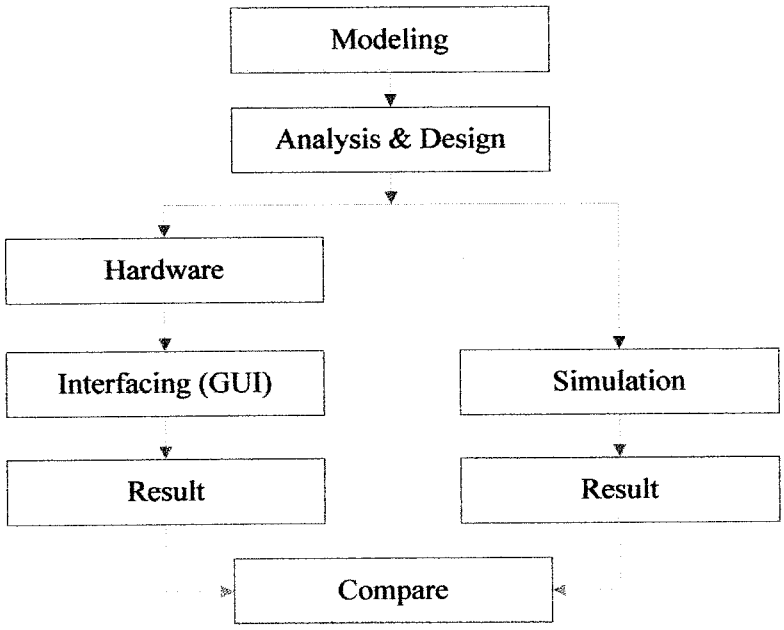

Figure 1.3 : Block diagram for the scope of the project

This project involved the construction of hardware and GUI that can figure out this application. The plant (DC Motor) is modeled and the dynamics parameter obtained will used to analyze and design the controller. By using Simulink this plant

is simulated and the output response will compare to the actual output from hardware. The hardware of this project is divided into several blocks circuit to present the block diagram of the control systems which is: PID controller, servo amplifier, plant and feedback. The output response is collected by data acquisition card and transferred to PC to display the response. By using this technique the output response of the system is directly visualized through GUI to see the response of the system. The GUI for this project is developed by using Microsoft Visual Basic 6.0.

1.5 PROBLEM STATEMENT

PID Controller is the widest type of automatic control used in industry. Even though it has a relatively simple structure, there are many subtle variations in how it is applied in industry. This has probably resulted in confusion for lecturer and student, who are implementing and study the PID controller in control system.

PID controller is composite technology including electromechanical, electric and electronic and computer technology. Since many of the concepts of controller are abstract and difficult to fully comprehend, it is advantageous to learn and apply the PID controller effectively through empirical study.

In present the educational training equipment, the theoretical and real application should be related. Hence to address this problem, we will need more experience in control system source. Most of the problem is to present the PID controller in control system especially to transform theoretical in the form of a real time application.

Dc motor speed and position control using analog PID controller is a good application that can help students to understand the characteristic of the PID controller in control system. These equipments are a direct application that can visualize the theoretical in real time.

1.6 OUTLINE

As an outline, chapter one will discuss the background, concept, objectives, scope and problem statement. Chapter two covers the previous research of control system history, dc motor control technology and PID controller. The approach and method apply in this project are present in chapter three. The result from simulation and experiment present is discussed in chapter four. The conclusion and discussion will cover in last chapter.

CHAPTER II

LITERATURE REVIEW

In this chapter, a review of previous research projects that are related to this project will be discussed. The information of the control system, PID controller and dc motor control technique are also described in this chapter.

2.1 HISTORY OF CONTROL SYSTEM

Control systems are older than humanity. Numerous biological control systems were built into the earliest inhabitants of our planet [8]. Knowledge of the control system of the Hellenic period was preserved within the Islamic culture that was rediscovered in the west toward the end of the renaissance. New invention and application of hold principles began to appear during 18th century [6].

Speed control has been introduced since 17^{th} century. James Watt (1736-1819) was invented the flyball speed governor to control the speed of rotary engine governor. He was provided proportional speed control and hence exact control of speed at only one operating condition, it also can operate only over a small speed range [6]. In 1745 Edmund Lee was control the speed of windmill. He was increasing wind pitched blades further back, so that less area was available. As the wind increased, more blades were available [8]. William Siemens (1823-1883) substituted integral action for proportional action and hence produced "floating" controllers with no fix point [6].

The early years of the 20th century saw the rapid and widespread application of feedback control for voltage, current and frequency regulation such as motor speed and position control, temperature, pressure and flow in process industry. Elmer Sperry (1911) developed the automatic ship steering mechanism that incorporated PID controller and gain adjustment to compensate for the disturbances caused when the sea condition changed [6]. 1922 Nicholas Minorsky presents a clear analysis of the control involve in position control system and formulated a control law that we now refer to as three-term or PID controller [6].

2.2 DC MOTOR DRIVES TECHNOLOGY

DC Motor control has been used for variable speed and position applications for many decades and historically were the first choices for speed control applications requiring accurate speed control, controllable torque, reliability and simplicity [9]. The basic principle of a DC variable speed drive is that the speed of a separately excited DC motor is directly proportional to the voltage applied to the armature of the DC motor.

In 1891 Harry Ward Leonard was introduced The Ward Leonard motor control system [13]. The Ward-Leonard system comprises a fixed speed 3-phase AC induction motor driving a separately excited DC generator that, in turn, feeds a variable voltage to a shunt wound DC motor. So this is essentially a DC variable speed drive. In the case of the Ward-Leonard system, the output voltage of the DC generator, which is adjusted by controlling the field voltage, is used to control the speed of the DC motor as shown in Figure 2.1. This type of variable speed drive had good speed and torque characteristics and could achieve a speed range of 25:1. This method was commonly used for winder drives where torque control was important but it no longer commonly used because of the high cost of the 3 separate rotating machines. In addition, the system requires considerable maintenance to keep the brushes and commutators of the two DC machines in good condition. In modern DC drives, the motor-generator set has been replaced by a thyristor converter. The output DC voltage is controlled by adjusting the firing angle of the thyristors connected in a bridge configuration connected directly to the AC power supply.