UNIVERSITI PUTRA MALAYSIA

POSITION CONTROL STRATEGIES OF DC SERVO MOTOR

ERNY AZNIDA ALWI

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By

ERNY AZNIDA ALWI

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DEDICATION

To MY BeLoVeD FaMiLY,
HuBBY aND auNY

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Master of Science

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June 2003

Chairman: Samsul Bahari Mohd Noor, Ph.D.

Faculty: Engineering

Direct Current (DC) servo motor is mainly studied for its speed and position control. This study however, concentrated only on the position control part. The technology of position control of DC servo motor has evolved considerably over the past few years. To date, various types of DC servo motor position control scheme have been developed. To name some, there are microcontroller-based control, PC based control, adaptive control and optimal control.

In this study, a simulation and a real time implementation of DC servo motor position control are presented. The types of controller designed and tested are the proportional integral derivative (PID) controller and the adaptive controller. PID control scheme is chosen mainly because of its simplicity advantage while the adaptive scheme is chosen due to its ability to adapt.

With some modification and adaptation, these two designed schemes have been interfaced via MATLAB Real Time Toolbox to a servo trainer as the plant for real time implementation. This toolbox contains a library of blocks with real time input and output support. Following the design part, the modeling and simulation part are done. The mathematical design or model of the controller then has been simulated in MATLAB before being interfaced to the real plant. The PID and adaptive controller have been successfully implemented to the plant with satisfactory results. Analysis has been done to compare the performance of the two controllers from the simulation and real time results.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

STRATEGI KAWALAN KEDUDUKAN MOTOR SERVO ARUS TERUS

Oleh

ERNY AZNIDA ALWI

Jun 2003

Pengerusi: **Samsul Bahari Mohd Noor, Ph.D.**

Fakulti: **Kejuruteraan**

Kajian berkenaan motor servo arus terus (DC) kebiasaannya tertumpu kepada kawalan kelajuan dan kedudukannya. Walaubagaimanapun, dalam kajian ini, hanya kawalan kedudukan sahaja akan diberi tumpuan. Teknologi kawalan kedudukan motor arus terus telah berkembang pesat sejak beberapa tahun kebelakangan ini. Sehingga ke hari ini, pelbagai jenis sistem kawalan kedudukan motor arus terus telah dibangunkan. Di antaranya, kawalan berasaskan pengawal mikro, kawalan berasaskan komputer, kawalan adaptasi dan kawalan optimal.

Dalam kajian ini, simulasi dan implementasi masa nyata dibentangkan. Jenis pengawal yang direkabentuk dan diuji adalah pengawal terbitan kamiran perkadaran (PID) dan pengawal adaptasi. Skima pengawal PID dipilih disebabkan kelebihannya yang mudah manakala pengawal adaptasi dipilih kerana kebolehannya untuk menyesuaikan diri.

Dengan sedikit pengubahsuaian dan penyesuaian, kedua-dua sistem yang telah direkabentuk disambungkan ke *servo trainer* yang merupakan loji untuk implementasi masa nyata melalui antaramuka *MATLAB Real Time Toolbox*. Perisian ini mengandungi himpunan blok-blok dengan masukan dan keluaran masa sebenar. Selepas rekabentuk, permodelan dan simulasi dilakukan. Rekabentuk matematik atau model pengawal kemudiannya disimulasikan di dalam MATLAB sebelum diantaramukakan dengan loji sebenar. Pengawal PID dan adaptasi telah berjaya diimplementasikan ke loji dengan keputusan yang memuaskan. Analisa ke atas keputusan simulasi dan masa nyata dijalankan untuk membandingkan prestasi kedua-dua pengawal.

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TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

LIST OF ABBREVIATIONS

$\hat{\theta}(t)$	Parameter estimates
λ	Forgetting factor
θ	Output shaft position (°)
ω	Shaft velocity / speed (rpm)
φ	State vector
$\varepsilon(t)$	Prediction error
b	Friction coefficient of rotating component
DC	Direct current
hp	Horse power
k_θ	Angle sensor gain (volts/rev)
k_ω	Velocity sensor gain (volt.sec/rev)
K(t)	Weighting factor vector
K_d	Derivative gain
K_i	Integral gain
k_i	Motor sensor gain (rev/sec.volt)
k_l, k_l'	Gain constant of load
k_m, k_m'	Motor constant
K_p	Proportional gain
LQ	Linear quadratic
L	Motor armature inductance (H)
P(t)	Covariance matrix

PI	Proportional-integral
PID	Proportional-integral-derivative
R	Motor armature resistance (Ω)
rev	Revolution
RLS	Recursive least square
rpm	Rotation per minute
T	Time constant (sec)
v	Input drive voltage (volts)
v	Motor drive amplifier voltage (volts)
v_l	Load control voltage (volts)
VSC	Variable structure control
y_θ	Position output (volts)
y_ω	Velocity output (volts)

CHAPTER 1

INTRODUCTION

1.1 Importance of Servo Position Control

The rapid development of electronics world has not left the area of motor control deserted. The initiation of motors has brought about profound changes in everyday life for over a century. At present, there are numerous system topologies for motor control depending on the motor type and application as to be discussed in the following chapter. Servo motors have replaced traditional gears, belts, and pulleys, thereby eliminating the wear and failure problems associated with the use of these older technologies. These servo motors are used in applications that require position and speed or torque control, and these range from robotics and semiconductor equipment to packaging, food and beverage, and printing. Use of servo motors in factory machines and equipment are helping to improve productivity in a wide array of processes.

DC motor systems are also used widely in various fields of technology. They are used in power plants to generate electrical power and in industrial occupancies to furnish the required mechanical motive power to drive mechanical machinery and control various industrial processes. Ranging from robotics manipulators to the disk drive of a computer, DC motor acts as one of the vital part. For both applications, the position control of the motor is the major part to be given attention. Efforts made on controlling the position of DC motor result in so many types of control scheme for the mentioned purpose. For instance, there are micro controller-based control, PC based control, adaptive control, optimal control, etc. Some of these control schemes will be explained and discussed briefly in this study. More detailed discussions will be centered upon the studied controllers, which are the PID and adaptive controllers.

1.2 Objectives

The main intention of this project is to implement the designed position control strategies of DC servo to the real plant, via newly introduced real time software, the MATLAB Real Time Toolbox. Among other objectives to be achieved through out the study are:

(i) To describe in detail how to develop the plant model, plus description on how to design the two types of controller, the PID and the adaptive controller by means of SIMULINK and by making use of MATLAB Real Time Toolbox.

(ii) To apply the developed or established control strategies to real DC servo motor based on simulation done in SIMULINK, MATLAB.

(iii) To analyze the stability and to compare the simulation performance of the two designed controllers of DC servo position.

(iv) To analyze the stability of adaptive control system, plus to compare the performance between adaptive controller and conventional PID controller in real time implementation.

1.3 Thesis Organization

This thesis describes the development of real time implementation of DC servo position control schemes. The first chapter introduces the background and the aim of this study. Subsequently, the second chapter reviews the present and past works on various means of position control of a DC motor. Previous research examples on related topic will be unleashed. It also includes brief descriptions of methods to be used in this study. The third chapter discusses the way and the flow of works towards realizing the project designs and simulations. Detailed explanation on designing the controller via SIMULINK also presented in this chapter. This includes the hardware configurations and software designs. The fourth chapter reveals the simulations and experimentations results obtained. Analysis and discussions upon the achieved results are featured in this chapter. Finally, the last chapter concludes the study with a few suggestions of future works, to further develop the design.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Various importance of position control in the industry and research fields has been explained in the first paragraph of the previous chapter. It is imperative for the user to understand the performance specification of different motor types when designing a product for position control. For position control systems, three major motor types are most commonly used: stepper motors; DC servo motors, in which the current-carrying windings move and the second field is stationary and usually comes from a permanent magnet; and brushless DC motors with a moving permanent magnet and stationary current-carrying windings [30].

Most motion control systems today make use of either stepper or DC servo motors. Both motor types offer precise positioning and speed control but they differ in a number of ways [30]. For DC motors, stator field is produced by either a field winding or by permanent magnets while rotor field is set up by passing current through a commutator and into the rotor assembly. Their rotational speed is dependant on the strength of the rotor field.

Whereas, the stepper motors are electromechanical actuators which convert digital inputs to analog motion. They are particularly well suited to applications where the controller signals appear as pulse train. Also, they are limited to about one horsepower and 2000 rpm, therefore limiting them in many applications [1]. Due to these reasons, the DC motor is found more suitable and has been chosen for this study.

To date, lots of other controller types [2,4,6] have been implemented for the same purpose, position control of motors. However this study differs in a way that it is realized using the Real Time Toolbox, which is a new tool applied for position control of DC servo. A couple of previous designs of various controllers for motor position control purpose will be featured further in section 2.2 of this chapter.

2.2 Position Controller Development for Different Types of Motor

Researchers designed different types of controllers to suit different types of motors. Despite the latest emphasis of the ever-evolving fuzzy logic control technology, the conventional controllers are not lagging in terms of efficiency and simplicity advantages. Many engineering problems demand automatic control in the presence of uncertainties and unforeseen large changes in system parameters and input signal. To obtain robustness to uncertainties, a lot of adaptive control approaches have been proposed in recent years. A few approaches of position control techniques done in previous researches [2,3,5] will be presented briefly in this section.

2.2.1 The Optimal Position Controller

Even though the designed techniques for the sliding mode are well established [8], it is not easy to shape the dynamics of the reaching phase. Some process may require an optimal performance. Hence to comply with this reason to be considered, the linear quadratic (LQ) method is an easy way to design the control law. This proposed method has the fully flexibility of shaping the dynamics of the closed loop system to meet the desired specification. An optimal controller has been designed via combining the classical state feedback control and variable structure control (VSC) and demonstrated on a synchronous reluctance motor to meet this purpose [2]. This new method fully matches the merits of the easy design of the linear quadratic method and the strong robustness of the variable structure control. This method has proven that the synchronous reluctance motor can be used in position control and the designed performance can be easily obtained regardless of the disturbance and uncertainty.

While Morris, et. al. [3] has addressed the problem of controlling a two flexible link manipulator system, and proposed a quadratic optimal control and a computed-torque controller as the solutions. The study initially explained the necessity for having an accurate static and dynamic model of the two flexible link manipulator, which properly represents the coupling and interaction between links. The functions to be fulfilled by the controller of a flexible manipulator system were to compensate for the static deflection of the flexible links under gravity forces and also to reduce both the magnitude and the time duration of link oscillations, which arise naturally out of its