PID AND STATE-FEEDBACK CONTROLLER DESIGN BY USING MATLAB

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MEI 2008

"I hereby declared that I had read through
this report and found that it has complete the partial
fulfillment for awarding the degree of
Bachelor in Electrical Engineering (Control, Instrument and Automation)"

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Faculty of Engineering Electrical
Technical University Malaysia Malacca

MAY 2008

"Hereby, I declare that this project is
a result of my own research idea except for works
that has been cited clearly in the reference."

Signature : Radhi
Name : AHMAD KHAIRUL RADHI KAMARUZAMAN
Date : 7^{TH} MAY 2008

TO MY BELOVED PARENTS
FOR THEIR STRENGTH, MOTIVATION AND
WILL POWER ARE INCREDIBLE INSPIRATION
TO ME EACH AND EVERYDAY

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ABSTRACT

In PID controller design, designers used trial and error method to obtain the optimum result. However, this method needs more time and higher mathematics computation. Matlab with Control Toolbox helps them to see response of the system, in many combinations and input variety. This software is very helpful to determine which controller should choose, to get the simplest and best control system.

The objectives of this project are to design PID and State-feedback controller by using matlab. The project is undertaken in the following stages. The design of PID controller and finally compare the results with the state-feedback controller using matlab/simulink as its platform. Through this comparison, it can be shown that the PID gives better performance as compared to the state-feedback controller.

ABSTRAK

Dalam reka bentuk sistem kontrol PID, pereka menggunakan kaedah percubaan dan ralat untuk mendapatkan hasil yang optima. Bagaimanapun kaedah ini memakan masa yang banyak dan memerlukan sistem matematik pengiraan tinggi. dengan adanya peti alat daripada matlab, dapat membantu mereka untuk melihat respon sistem itu, dalam gabungan yang banyak dan input yang pelbagai.. Perisian ini sangat berguna untuk menentukan pengawal yang harus dipilih, untuk mendapatkan sistem kawalan yang paling mudah dan terbaik.

Projek ini bertujuan untuk mereka pengawal PID dan pengawal suap balik keadaan dengan menggunakan MATLAB. Kajian projek ini telah dibahagikan kepada beberapa peringkat berikut. Mereka pengawal bagi PID dan akhirnya membuat perbandingan dari sudut keputusan simulasi dengan pengawal suapbalik keadaan dengan menggunakan MATLAB/Simulink sebagai pelantar. Melalui perbandingan ini, pengawal PID telah dapat memberikan prestasi yang lebih baik berbanding dengan pengawal suapbalik keadaan.

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Chapter 1

INTRODUCTION

1.1 Overview

Educating students in the subject of engineering controls has traditionally has been limited to analysis by theory and simulation. Students learn control theory by modeling plants and design controllers with root locus method, bode plots, and nyquist plots.

This project is to design PID and State-Feedback controller by using MATLAB. The project consists of one main part which is software. Couple tank (CTS-001) as a system and PID and state-feedback as the controller for the couple-tank. This project relies upon to the m-file that runs on the MATLAB.

Besides the aim of this project is to develop PID and State-Feedback controller and to compare and investigate the trend of control technology development to stabilize an inherently unstable system especially in process industry.

1.2 Objective Project

The main purpose of this project is to design and compare PID and State-Feedback controller by using MATLAB. Besides other objectives for this project are;

I. To study & investigate PID controller
II. To study and investigate state-feedback controller
III. To design a PID controller base on Couple tank systems

1.3 Scope of Project

This project is based on couple tank (CTS-001). There are three scopes of project. First scope is focus on PID and State-Feedback controller. This is very important to make sure the main objective of this project is achieved. Second scope is related to software MATLAB which is design the controller for the system. Last scope by focusing to the result of MATLAB and compare both of the system to fulfill this project becomes the success project development. This project is based on coupled-tank system.

1.4 Problem statement

The control of liquid level in tanks and flow between tanks is a basic problem in the process industries. The process industries require liquids to be pumped, stored in tanks, and then pumped to another tanks. Many times the liquid will be processed by chemical or mixing treatment in the tanks, but always the level of fluid in the tanks must be controlled, and the flow between tanks must be regulated. Often the tanks are so coupled together that the levels interact and this must also controlled. Level and flow control in tanks are at the heart of all chemical engineering systems. But chemical engineering systems are also at the heart of our economics. Vital industries where liquid level and flow control are essential include:

- Petro-chemical industries.
- Paper making industries.
- Water treatment industries.

A common control problem in process industries is the control of fluid level in storage tanks, chemical blending and reaction vessels (Grega and Maciejczyk, 1994). The flow of liquid into and out of the tank must be regulated as to achieve a constant desired liquid level as fluid to be supply at a constant rate. Various factors are considered in designing the controllers such as set point tracking and load disturbance, reducing the effects of adverse conditions and uncertainty, behaviors in terms of time response (rise-time, overshoot and steady state error) and lastly engineering goals such as cost and reliability which is vital in industrial perspective.

Chapter 2

Literature review

2.1 Proportional control system

Proportional control is a simple and widely used method of control for many kinds of systems. Proportional controllers have these properties;

- The controller amplifies the error as shown in the block diagram below.
- So, the actuating signal (the input to G(s)) is proportional to the error.

Diagram 1.0; show the proportional control systems. In a proportional controller, steady state error tends to depend inversely upon the proportional gain, so if the gain is made larger the error goes down.

In this system, SSE is given by the expression

$SSE = 1/(1 + K_pG(0))$

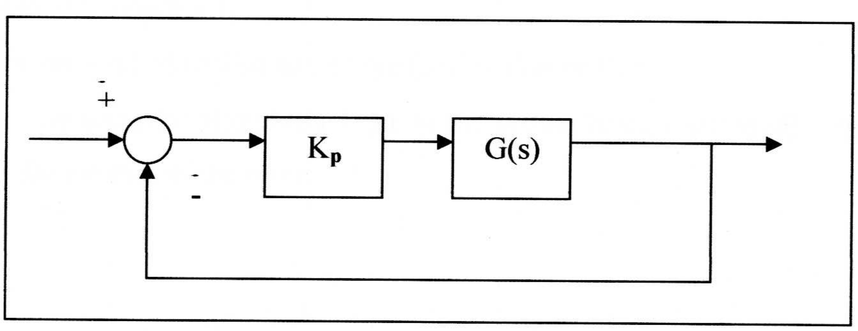

Diagram 1.0: Proportional control systems

As the proportional gain, K_p, is made larger, the SSE becomes smaller. As the DC loop gain, $K_pG(0)$, becomes large, the error approaches becoming inversely proportional to the proportional gain, K_p. This is true for most of the cases of interest, which are those with small SSE. Proportional control has a tendency to make a system faster.

A high proportional gain results in a large change in the output for a given change in the error. If the proportional gain is too high, the system can become unstable. In contrast, a small gain results in a small output response to a large input error, and a less responsive (or sensitive) controller. If the proportional gain is too low, the control action may be too small when responding to system disturbances.

In the absence of disturbances, pure proportional control will not settle at its target value, but will retain a steady state error that is a function of the proportional gain and the process gain. Despite the steady-state offset, both tuning theory and industrial practice indicate that it is the proportional term that should contribute the bulk of the output change.

2.2 Integral control system

An integral controller has one very good quality. Integral controllers have these properties:

- The controller integrates the error as shown in the block diagram of an example system diagram 1.1.
- The integral controller has a transfer function of K_i/s
- So, the actuating signal (the input to the system being controlled) is proportional to the integral of the error.

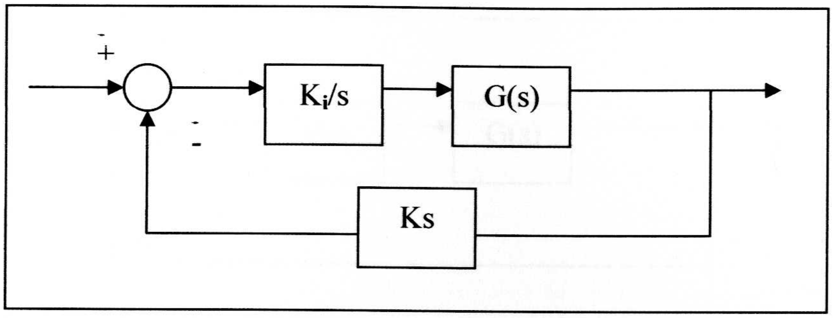

Diagram 1.1: Integral control systems

The integral term (when added to the proportional term) accelerates the movement of the process towards setpoint and eliminates the residual steady-state error that occurs with a proportional only controller. However, since the integral term is responding to accumulated errors from the past, it can cause the present value to **overshoot** the setpoint value (cross over the setpoint and then create a deviation in the other direction).

Finally, we should note that integral control changes the order of the system, so a second order system becomes a third order system when you use an integral controller. A proportional controller, on the other hand, does not increase the order of the system.

2.3 Derivative control system

An integral controller has one very good quality. Integral controllers have these properties:

- The controller integrates the error as shown in the block diagram of an example system diagram 1.2.
- The integral controller has a transfer function of sK_d

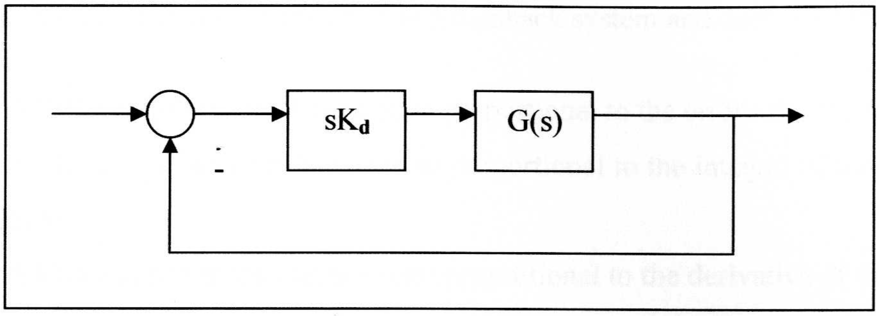

Diagram 1.2: Derivative control systems

The derivative term slows the rate of change of the controller output and this effect is most noticeable close to the controller setpoint. Hence, derivative control is used to reduce the magnitude of the overshoot produced by the integral component and improve the combined controller-process stability. However, differentiation of a signal amplifies noise and thus this term in the controller is highly sensitive to noise in the error term, and can cause a process to become unstable if the noise and the derivative gain are sufficiently large

2.4 Proportional, integral and derivative control system (PID)

PID controllers are a family of controllers. PID controllers are sold in large quantities and are often the solution of choice when a controller is needed to close the loop. The reason PID controllers are so popular is that using PID gives the designer a larger number of options and those options mean that there are more possibilities for changing the dynamics of the system in a way that helps the designer. In particular, starting with a proportional controller, and adding integral and derivative terms to the control the designer can take advantage of the following effects.

- An integral controller gives zero SSE for a step input.
- A derivative control terms often produces faster response.

A PID controller operates on the error in a feedback system and does the following:

- A PID controller calculates a term proportional to the error - the P term.
- A PID controller calculates a term proportional to the integral of the error - the I term.
- A PID controller calculates a term proportional to the derivative of the error - the D term.
- The three terms - the P, I and D terms, are added together to produce a control signal that is applied to the system being controlled.

You may need a PID controller in many situations, particularly in the following cases.

I. A proportional controller may not give SSE performance needed in a system.
II. An integral controller may give SSE performance, but slow a system down.
III. Adding a derivative term may help cure both of those problems.

Properties of PID Controllers

PID controllers can be viewed as three terms - a proportional term, and integral term and a derivative term - added together. PID controllers are also known as three-term controllers and three-mode controllers. Diagram 1.3 shows a block diagram of the PID control system.