Universiti Teknikal Malaysia Melaka

Faculty of Electrical Engineering

COMPARISON OF LINEAR AND INTELLIGENT CONTROL FOR A NONLINEAR ELECTRO-HYDRAULIC ACTUATOR SYSTEMS

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Bachelor of Electrical Engineering (Control, Instrumentation and Automation)

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APPROVAL

I hereby declare that I have read this report "comparison of linear and intelligent control for a nonlinear electro-hydraulic actuator systems" and found that it has complied the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrumentation and Automation).

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Date	:………………………….….

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in fulfillment of the requirements for the degree of Electrical Engineering (Control, Instrumentation and Automation)

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2017

DECLARATION

I declare that this report entitled "Comparison of linear and intelligent control for a nonlinear electro-hydraulic actuator systems" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature :……………………….

Name : Saeed Mohammed

Date : ………………………….

DEDICATION

To my beloved mother and father

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Firstly, I am grateful that Dr. Rozaimi Bin Ghazali is my supervisor for my Final Year Project 1. His guidance throughout the period of the final year project is very appreciated. His patience, motivation, and knowledge guide me to the right track of conducting this project. His guidance and corrections on writing the report have helped me a lot in term of writing a good and qualified technical report. Also, I would like to thank my panels Dr. Azrita Binti Alias and Pn. Nur Asmiza Binti Selamat.

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ABSTRACT

Electro-hydraulic actuator systems perform a necessary role in industrial applications. The nonlinear electro-hydraulic actuator suffers from nonlinearities and time varying characteristics such as high speed, fast stop and the start of the hydraulic cylinder. The nonlinear properties challenging the position of the nonlinear electro-hydraulic actuator. In this report, development of linear and intelligent control techniques will be designed such as linear PID control, intelligent fuzzy logic control and hybrid fuzzy-PID control that can be used to control the tracking position of nonlinear electro-hydraulic actuator systems. Firstly, the mathematical model of electro-hydraulic systems will be represented using MATLAB and Simulink. Through simulation in MATLAB and Simulink, the appropriate procedure to tune PID parameters and fuzzy rules will be conducted. The fuzzy controller also will be utilized to tune the gain parameters which are (K_p, K_i and K_d) of the PID controller. The performance parameters such as the system steady-state error, overshoot and settling time are different control techniques will be assessed. Through the mathematical model of the process, the tuning method for PID, Fuzzy and Fuzzy-PID controllers will be conducted with considerations that should be made for that system. The linear and intelligent controllers have been evaluated using various tracking trajectories. It shows that hybrid Fuzzy-PID performs better as compared to PID and Fuzzy controllers. About 20% improvement of the tracking error has been obtained using the Fuzzy-PID controller. As conclusion integration between linear and nonlinear controllers will produce significant improvement for tracking performance particularly in nonlinear electro-hydraulic actuator systems.

ABSTRAK

Sistem penggerak elektro-hidraulik mempunyai peranan yang penting di dalam aplikasi industri. Penggerak elektro-hidraulik yang bersifat tidak linear telah terdedah kepada ciri-ciri ketaklinearan dan berubah berdasarkan masa seperti kelajuan yang tinggi kadar berhenti yang segera, dan pada permulaan silinder hidraulik. Ciri-ciri tak linear ini telah manambah cabaran dalam menentukan kedudukan penggerak elektro-hidraulik. Dalam laporan ini, pembangunan teknik-teknik kawalan linear dan kawalan pintar akan direka seperti kawalan linear PID, kawalan logic kabur pintar. Pada awalnya, model matematik untuk sistem elektro-hidraulik akan dipersembahkan dengan menggunakan perisian MATLAB dan Simulink. Melalui simulasi dalam MATLAB dan Simulink, prosedur yang sesuai untuk penalaan parameter PID dan 'Fuzzy Logic' akan dijalankan. Pengawal fuzzy juga akan digunakan untuk menala parameter-parameter pengawal PID termasuk (K_p, $K_i$dan K_d). prestasi untuk parameter-parameter ini seperti kesilapan ralat sistem, terlajak dan masa penetapan untuk teknik penalaan yang berbeza akan dinilai. Melalui proses model matematik, teknik penalaan bagi PID, Fuzzy Logic dan Fuzzy-PID akan dijalankan dengan pertimbangan yang perlu dibuat untuk sistem tersebut. Pengawal linear dan pengawal bijak telah dinilai dengan menggunakan pelbagai jenis penjejakan trajektori. Ia menunjukkan bahawa hibrid Fuzzy-PID memberi prestasi yang lebih baik berbanding dengan pengawal PID dan Fuzzy. Peningkatan sekitar 20% peningkatan ralat dari segi penjejakan trajektori telah diperolehi dengan menggunakan pengawal Fuzzy-PID. kesimpulannya, gabungan di antara pengawal linear dan bukan linear akan menghasilkan peningkatan yang ketara untuk prestasi penjejakan terutamanya dalam sistem penggerak electro-hidraulik yang tak linear.

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CHAPTER 1

INTRODUCTION

1.1 Motivation

The actuator system is a device that makes mechanical movement by changing different types of energy to mechanical energy. The actuator produces the force that comes from several sources pneumatic pressure, hydraulic pressure and motive force. The actuators classified depend on the type of supply. The hydraulic actuator is the one type of actuator system used as a drive or transmission system that utilizes pressurized hydraulic fluid supply to actuate hydraulic machinery. For electro-hydraulic actuator required hydraulic fluid supply, control valve and cylinder. The hydraulic system used in many application such as power systems, braking systems and cranes[2].

The hydraulic actuator is widely used in industry and important equipment because it can produce large torques, capable of high power and good positioning with fast motion. The hydraulic circuit can transmit large force and is easy to control. Low power input is converted into a movement to control a high-power hydraulic actuator. The hydraulic control used in a wide number of application such as ships and electromagnetic, manufacturing system, flight simulation and paper machines[3].

The nonlinear electro-hydraulic systems suffer from nonlinearities and time varying characteristics such as high speed, fast stop and start of the hydraulic cylinder that produced by flow and pressure and effect on dynamic behaviors. The nonlinear properties causing a backlash in the control valve, actuator friction, distinction in fluid volume that make the system models and controller designs more complex [4].

The nonlinear properties that produced by pressure and flow rate of the electro-hydraulic system are looking for a suitable controller to achieve success performance. There are many controllers used as a feedback to improve the behavior and nonlinearities of the nonlinear electro-hydraulic actuator system. That feedback controller or controller design employed to dealing with nonlinear electro-hydraulic actuator systems over the past decades including intelligent control, linear control and nonlinear control [5].

1.2 Problem Statement

The furthermost a suitable modeling of the system could be controlled by developed a control strategy. The difference between the output response and the actual system must be close that means the system stable. The model and parameters (K_p, K_i and K_d) are unknown by applying the mathematical model to overcome those limitations. The nonlinear electro-hydraulic actuator model needs to evaluate in non-linear models, intelligent models and linear models. The nonlinear electro-hydraulic system suffers from uncertainties, nonlinearities, disturbances and time-varying. Therefore, a prepare control strategy needs to be designed to increase the robustness and stability of the system[6].

To increase robustness and stability of nonlinear electro-hydraulic actuator system by utilizing controller design to enhance the position following of the nonlinear electro-hydraulic system. The PID, Fuzzy and Fuzzy-PID controllers will develop the nonlinearities behavior of nonlinear electro-hydraulic actuator systems. The mathematical model of nonlinear electro-hydraulic systems is approximated using MATLAB and Simulink. The Fuzzy rules is the suitable method to tune the parameters gain (K_p, K_i and K_d) of the PID controller through simulation in MATLAB and Simulink.

1.3 Objective

The objectives of this project are: -

i. To develop the mathematical model of a nonlinear electro-hydraulic actuator systems.
ii. To design linear and intelligent controllers that are capable to achieve the tracking position of the nonlinear electro-hydraulic actuator.
iii. To evaluate the performance of the developed linear and intelligent controllers in terms of transient response, steady state error and RMS values.

1.4 Scope of Work

The scope of this project will be focused on improving the tracking position of the electro-hydraulic actuator by using controller design. This project will be done based on two parts, the first part of a mathematical model for electro-hydraulic actuators will be identified by determining the mathematical model for each component of the nonlinear electro-hydraulic system then approximate by using MATLAB and Simulink. The second part, simulation by using a Fuzzy logic, PID and Fuzzy-PID controllers of system modules to make the output value equal or near to the desired value and control the single ended cylinder of the nonlinear electro-hydraulic actuator system. Also, the parameters (K_p, K_i and K_d) will be improved and Fuzzy logic methods are highlighted to choose the best method that can tune the PID controller recursively to improve the nonlinearities characteristic of the actuator and make the system more stable. Analyse the electro-hydraulic actuator behavior such as rise time, settling time, overshoot and steady-state error by adjusting the gain of the controller. MATLAB and Simulink are chosen as the platform to design and simulate the mathematical model and the proposed controller.

CHAPTER 2

LITERATURE REVIEW

In this chapter, the theory, and basic principles of linear, nonlinear, and intelligent control is presented. Besides that, the basic concept of the nonlinear electro-hydraulic actuator with the review of previous related works is included in this chapter.

2.1 Introduction

In the world of technology, the nonlinear electro-hydraulic actuator has been researched for quite a long time by many researchers. The aims are basically to improve the controller that is used to solve many problems for nonlinear electro-hydraulic actuator system in fluid power technology. This advanced research will help enhance the position following of the system[7].

The nonlinear electro-hydraulic actuator is a device uses fluid to generate energy and to drive hydraulic machine. The advantage such as high force rendered nonlinear electro-hydraulic actuator system to be widely implemented in industrial applications and it can maintain high loading capabilities for a longer period and the hydraulic cylinder has nonlinear properties high speed that challenging the position tracking. To develop the nonlinear properties by applying feedback control to the system that capable of improving the position tracking of the nonlinear electro-hydraulic actuator system.

The control system is utilized to adjust the behavior of a system so it behaves on in a particularly desirable method over time. The control system contains several characteristic stabilities when the system is stable should be fast as a possible response, rise time and the error of the system must be zero, that is mean the error of the reference output and the output of the system should be close. The system divided into two categories open loop and closed loop systems. In the closed loop system, the stability achieved by measurements and making an adjustment to the system. The close loop in control system consists of the desired value or reference value, the controller (PI, PD, PID and fuzzy logic), the process and plant (actuator system) and the feedback or measured output (sensor). The Figure 2.1 shows the structure of closed loop system[8][9].

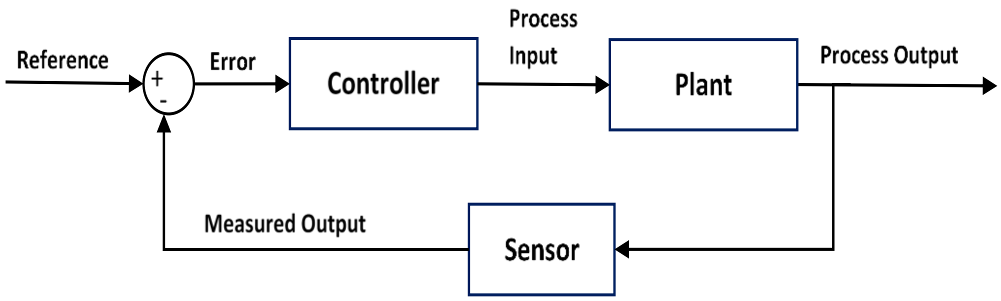

Figure 2.1: The structure of closed loop system

The sensor measures the output value to identify the error value and then subtracted with input value (desired value). This error value flows to the controller to adjustment and produces the process input then do some calculation and modify it to get the new process output.

2.2 Linear Control

Linear control is a controller design used widely to the system in the industrial application that deals with superposition principle. The linear differential equations apply to the system when the output values proportional to the input values. Types of classes system have parameters that do not change with time (linear time invariant). This way of controller design used in a nonlinear electro-hydraulic actuator to achieve the best performance [10][11]. By utilized several controllers P, PD, PI, PID and linear quadratic regulator (LQR). This type of control widely used in industries because easy to implement and grow the specific plant.

The PID controller is the of the one most common close-loop linear controller utilized in industries. PID control is one of the oldest and classical control used to for nonlinear electro-hydraulic actuator. The PID controller utilize a three mean performance types proportional, integral and behaved as single mode and the derivative is seldom used on it is own in control systems[11]. The PID utilized to develop the overshoot, transient response, steady state error and fast rise time. Due to the various advantage of the PID controller is widely used for industrial applications in the nonlinear electro-hydraulic actuator [12]. The PID calculate the desired actuator output by computing proportional, integral, and derivative the combining those three parameters to get a stable output [13], [1]. It provides excellent control behavior of nonlinear electro-hydraulic actuator system by obtaining the gain value of P, I and D. Figure 2.2 shows the structure of a PID controller[8].

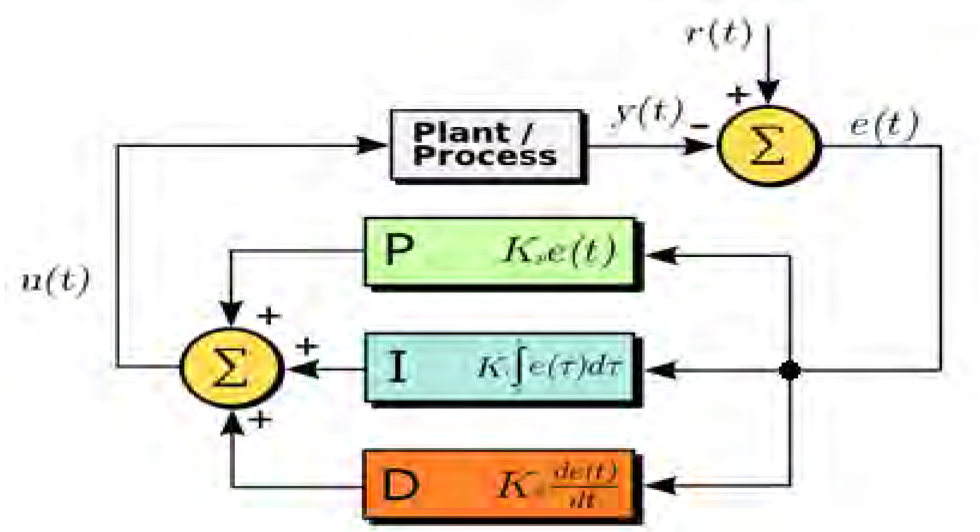

Figure 2.2: The process PID controller

The PID controller is used to illustrate the performance of the nonlinear electro-hydraulic actuator. To study the stability of the system, require the values of the parameters gain which are K_p, K_i and K_d. The changes of this parameter affect the transient response (rise time, settling time and overshoot) and steady-state error of the system [14].

2.3 Nonlinear Control

Nonlinear control is a field of control theory used when the system is time-variant and nonlinear. The nonlinear control widely used in many applications it deals with a wider type of systems that do not follow the superposition principle[12]. The mathematical techniques of nonlinear become more accurate that used to handle all the real-time systems. The nonlinear controller design used in many applications to achieve the perfect performance of the system and used to dealing with the nonlinear electro-hydraulic system. Nonlinear control includes several feedback controllers employ for trajectory tracking control of nonlinear electro-hydraulic actuator such as sliding mode control (SMC) [5].

The sliding mode control (SMC) is a common method in nonlinear control field used the discontinues control application to change dynamics of the nonlinear system. The sliding mode control is the most suitable approach to maintaining the stability of the controlling classes models that are subjected to external disturbances and parameters variation. Tracking error of the system needs to be minimized by using discrete and continues sliding mode control and trajectory tracking. The aim of SMC to control the nonlinear electro-hydraulic actuator (the plant) by using feedback loop that compares the desired value and the output value to make the system stable [15].

2.4 Intelligent Control

The intelligent control used to reduce a human who achieves and performs the control task or to get the solution of control problems. The intelligent control is a type of control techniques that employs various methods of artificial intelligence computing such as neural network, fuzzy logic and genetic algorithms [16]. The intelligent control is widely used in industrial application such as automation, manufacturing, communication, robotics, and traffic control. The intelligent control used to control and stabilize the performance of the actuator systems. The neural network is a mathematical representation or computer algorithm used to solve problems in almost all spheres of science and technology. Neural network includes two steps system identification and control. The artificial neural network is a network of neurons in a brain interconnected as a group of nodes each circle considered as artificial neurons and used the arrow to connected between the input and the output. The artificial neural network is utilized as a feed-forward in many applications to identify the dynamic model for the system such as nonlinear electro-hydraulic actuator [3][17].

The fuzzy logic control is a method of artificial intelligence designed to control something usually mechanical. The fuzzy logic used to develop the nonlinear electro-hydraulic system. The fuzzy logic consists of four components which are, the rule base, fuzzification, inference mechanism and defuzzification [18]. The fuzzy logic consists of two inputs go through the fuzzification. Finally, defuzzification converts the fuzzy output to signal send to the plant. This component is the structure of fuzzy logic control used to identify the reference input and transfer it to another form. The output consists of the signal send to control the actuator system. Figure 2.3 shows the fuzzy control system [1].

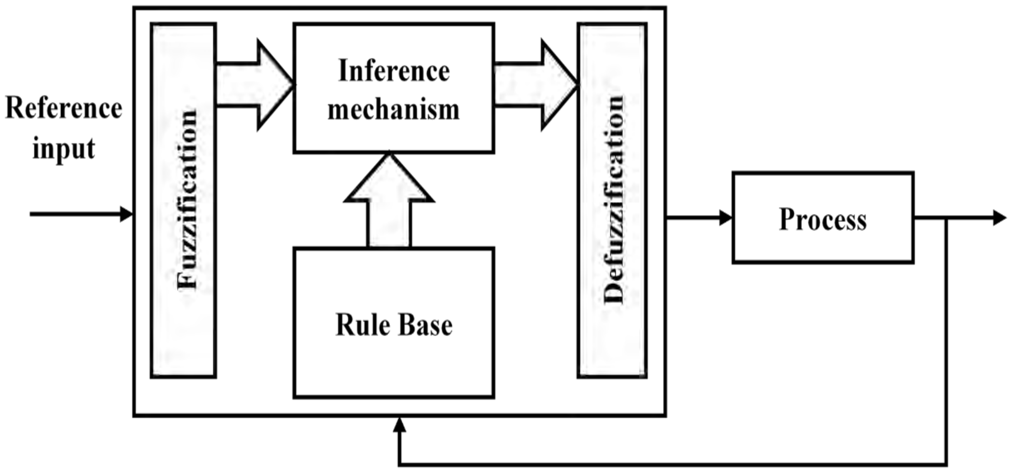

Figure 2.3: The Fuzzy logic control system

A Fuzzy controller is employed to control the system when the output value of the system is far away from the target value. There are two inputs for Fuzzy logic which including, the derivative of error $\frac{d_e(\mathrm{t})}{\mathrm{dt}}$ and the feedback error e(t) for the output connected to the plant (actuator). Fuzzy logic design to enhance the behavior of nonlinear electro-hydraulic actuator [12][19].

2.5 Review of Previous Related Works

There are several of design methods and different controller used to control the position of the nonlinear electro-hydraulic actuator system. Some of the previous related work is explained below:

In [13], the nonlinear electro-hydraulic actuator is used in industry related to some characteristic high speed, quick reversal possible, fast stop and the start of the cylinder. The nonlinear electro-hydraulic actuator has large torque into inertia ratio with increase result in the acceleration capability. The tracking position challenging by the nonlinear properties of the nonlinear electro-hydraulic cylinder. The self-tuning fuzzy PID controller is designed to control the tracking position variation of the nonlinear electro-hydraulic actuator. The self-tuning fuzzy designed to achieve the performance of the nonlinear electro-hydraulic system and tuning the PID. The mathematical model identifies by employing identification system.

In [10], this paper represented for a nonlinear electro-hydraulic actuator that suffered from external disturbances and physical uncertainties. In this paper, designed the PID controller to control the position following of the nonlinear electro-hydraulic system. The proportional, integral and derivative used as feedback controller to achieve the perfect performance of nonlinear electro-hydraulic actuator system in a wide rang of external disturbances and physical uncertainties by comparing the desired value and the output value to make the system closely that means the system is stable. By using the via a Q4 Quanser DSP card to implemented the PID controller in MATLAB.

The researchers in [3], they have completed research on the artificial neural network based PID controller to improve the tracking for a nonlinear electro-hydraulic servo system. The control scheme is developed for the artificial neural network based PID controller to achieve high precise tracking control of nonlinear electro-hydraulic systems. They used two controllers which are PID controller and cerebellar model articulation controller are structured in a parallel connection. The outputs summation of the controller proposed perfect system includes the tracking ability for nonlinear electro-hydraulic servo system. In order to achieve high stability of the system, The PID controller is utilized as a feedback. The neural network is supervised by the cerebellar model articulation controller (CMAC) as a feed-forward compensator to determine the