PERFORMANCE EVALUATION OF AN IMPROVED CLASSICAL CONTROL METHOD FOR SINGLE MASS PTP POSITIONING SYSTEM

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2021

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A report submitted

in partial fulfillment of the requirements for the degree of

Bachelor of Electrical Engineering with Honors

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

DECLARATION

I declare that this report entitle “PERFORMANCE EVALUATION OF AN IMPROVED CLASSICAL CONTROL METHOD FOR SINGLE MASS PTP POSITIONING SYSTEM” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Date : 5 July 2021

APPROVAL

I hereby declare that I have checked this report entitle “Performance Evaluation of an Improved Classical Control Method For Single Mass PTP Positioning System” and in my opinion, this thesis complies the partial fulfilment for awarding the award of the degree of Bachelor of Electrical Engineering with Honour.

Signature :

Supervisor Name : Norhaslinda binti Hasim.

Date : 6 July 2021

DEDICATIONS

It is my absolute appreciation and warmest gratitude that I devote this work to my beloved mother and father whose unwavering love, support and encouragement have enriched my soul and inspired me to pursue and complete this Final Year Project. I also devote this study to my friends who have helped me in the process. I do value everything that they did. I dedicate this work and leave special thanks to my supervisor, Madam Norhaslinda Binti Hasim, who is advising me in the entire process of completing this project.

ACKNOWLEDGEMENTS

I was in touch with many individuals, scholars, educators and professionals in the planning of this paper. They have contributed towards my understanding and thought. In particular, I wish to express my sincere appreciation to my main project supervisor, Madam Norhaslinda Binti Hasim, for encouragement, guidance critics and friendship. I am also very thankful to the Final Year Project coordinator in the Electrical Engineering department of the University Teknikal Malaysia Melaka (UTeM) for their guidance, advices and motivation. Without their continuing encouragement, the project may not have been the same as discussed here.

My fellow undergraduate friends should also be recognized for their support. Unfortunately, it is not possible to mention all of them in this limited area. I am grateful to all my family members who supported me and gave me a deep insight into the study.

ABSTRACT

This paper focuses on evaluating the efficiency contrast between the classical PID type controller and the improved fuzzy-PID controller method for a single mass PTP positioning system in term of the transient response. The PID controller is a system used for the industrial control of various process variables. However, these mechanisms also entail non-linear mechanism like friction and also saturation that occur in positioning system, which can induce slow motion and high overshoot percentage. In order to strictly limit the overshoot, we can achieve a great control result using a fuzzy-PID control. By using fuzzy-PID control, designers can realize lower productions costs, higher features and improved end product efficiency. The simulation system of PID and also the fuzzy-PID controller for the single-mass PTP positioning system is developed using the MATLAB/Simulink R2019b software. The result is to demonstrate that the fuzzy-PID control provides improved performance to different parameters, including time response, the settling time and the overshoot in contrast with the PID control system.

ABSTRAK

Kertas ini memberi tumpuan kepada menilai kecekapan berbeza antara pengawal jenis PID klasik dan kaedah pengawal "Fuzzy-PID" yang lebih baik untuk sistem kedudukan PTP jisim tunggal. Pengawal PID adalah sistem yang digunakan untuk kawalan perindustrian pelbagai pembolehubah proses. Walau bagaimanapun, mekanisme ini juga memerlukan mekanisme bukan linear seperti geseran dan juga ketepuan yang berlaku dalam sistem kedudukan, yang boleh mendorong gerakan perlahan dan "overshoot". Untuk mengehadkan "overshoot" dengan ketat, kita boleh mencapai hasil kawalan yang besar menggunakan kawalan "Fuzzy-PID". Dengan menggunakan kawalan "Fuzzy-PID", pereka dapat merealisasikan kos pengeluaran yang lebih rendah, ciri-ciri yang lebih tinggi dan kecekapan produk akhir yang lebih baik. Sistem simulasi PID dan juga pengawal "Fuzzy-PID" untuk sistem kedudukan PTP tunggal jisim dibangunkan menggunakan perisian MATLAB/Simulink R2019b. Hasilnya adalah untuk menunjukkan bahawa kawalan "Fuzzy-PID" memberikan prestasi yang lebih baik kepada parameter yang berbeza, termasuk tindak balas masa, kesilapan keadaan yang stabil dan "overshoot" berbeza dengan sistem kawalan PID.

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LIST OF SYMBOLS AND ABBREVIATIONS

PTP	-	Point To Point
PID	-	Proportional Integral Derivatives
vs	-	versus
FLC	-	Fuzzy Logic Control
MATLAB	-	Matrix laboratory
DC	-	Direct Current
EMF	-	Electromagnetic force
Ea	-	armature terminal voltage
Kc	-	proportional constant
PI	-	Proportional Integral
Fig.	-	Figure
e(t)	-	error
τ_I	-	Integral time constant
τ_D	-	Derivative time constant
u(t)	-	Output of the classical PID controller
Co.	-	Company
PD	-	Proportional Derivative
I	-	Integral
PI	-	Proportional Integral
et al.	-	and others
Eq.	-	equation
n	-	Refer time
TS	-	Sampling time
e(n)	-	error
$\Delta e(n)$	-	Error shift
$\Delta^2 e(n)$	-	Error change rate

$\sum e(n)$	-	Error sum
y(n)	-	Feedback response signal
$y_{sp}(n)$	-	Desired response
etc.	-	And the other things
$e_s(t)$	-	Back electromotive force of the motor
L_a	-	Armature inductance
R_s	-	Armature resistance
K_s	-	Back-emf constant
K_t	-	Torque constant
B	-	Viscous-friction coefficient
J	-	Total load inertia
P	-	Proportional
s	-	seconds
Kp	-	Proportional gain
Ki	-	Integral gain
Kd	-	Derivative gain
Tr	-	Rise time
ms	-	milliseconds
%	-	percentage
Ts	-	Settling time
=	-	equal
NB	-	Negative Big
NM	-	Negative Medium
NS	-	Negative Small
ZO	-	Zero
PS	-	Positive Small
PM	-	Positive Medium
PB	-	Positive Big
e	-	error
de	-	Change in error
EMECS	-	Electric-Mechanical Engineering Control System

CHAPTER 1
INTRODUCTION

1.1 Background

In this age of globalization, the single-mass point to point (PTP) positioning control system is gradually spreading over the world with various controller concepts. The single-mass positioning control is critical for precision control system applications. The positioning controller's objective is to put the signal showing the needed angle and move the mass to the appropriate location. However, it is still difficult to preserve the accuracy of positioning using the classic control method.

DC motors were chosen for this project because they are often utilized in sectors requiring speed and position control, such as robotics and household appliances. Because dc motors come in a wide range of shapes and sizes, creating dc motor applications is straightforward and versatile. It also has a high level of dependability and a low cost. [1]

To lessen load effects, several types of conventional control systems have been designed, including Proportional-Integral (PI), Proportional-Integral-Derivative (PID), optimum, adaptive, and robust controllers. Despite the fact that each technique has advantages and limitations in terms of practical implementation, most controllers must still be constructed utilizing the plant's requirements and precise structure. Increased control performance will be wasted if this is not done, when load effects occur. As a result, this project develops a control mechanism to mitigate the effects of heavy and/or uneven loads. [2]

In control systems, fuzzy logic is utilized as an alternative for conventional control theory in the design of many nonlinear plants where accurate mathematical modeling is difficult or impossible [3].

The fundamental advantage of fuzzy logic over conventional control systems is that no mathematical modeling is required for controller design. The control rules are mostly based on the control engineer's knowledge of system behavior and experience. Fuzzy logic controllers do not require as complicated mathematical calculations as classical controllers, hence their implementation does not required extremely fast computers.

In this project, MATLAB/Simulink R2019b is used as a platform to design the Fuzzy-PID logic controller. A simulation of a PID controller is also included in this thesis. In this project, the efficiency in terms of the transient response of the PID controller will be examined and compared to the improved PID controller, Fuzzy-PID, for the DC motor positioning system.

1.2 Motivation

Many attempts to develop the process of high positioning efficiency have proven expensive. Essentially, PTP positioning systems are expected to have fast response time and high accuracy. However, these controller also include non-linearities like saturation and friction, which can induce slow motion as well as high percentage of overshoot. PID controller are most commonly used in functional control due to their basic form, ease of understanding and design. However this classic controller has a hard time maintaining the fastest response without overshooting. Therefore in order to prevent certain occurrences, a low cost controller that satisfies the specifications is designed.

Figure below shows a comparison of PID and Fuzzy-PID simulation graphical result [4] which shows that Fuzzy-PID presented better performances compared to PID controller.

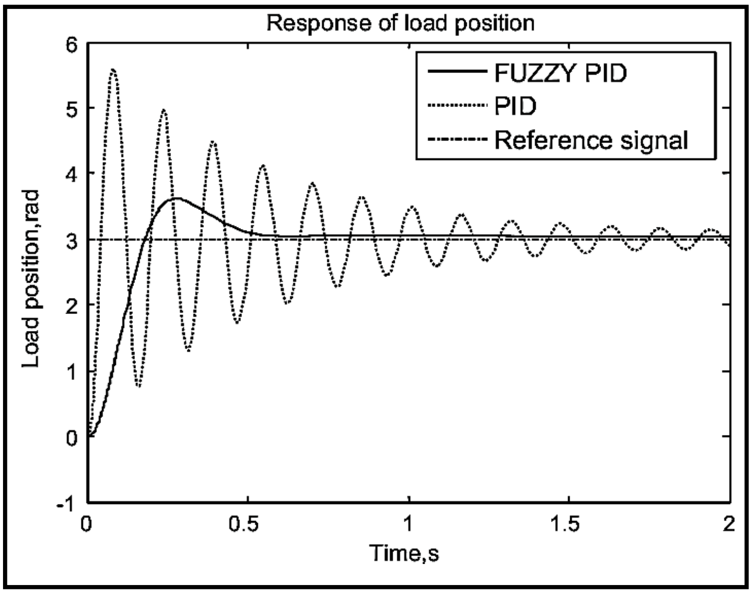

Figure 1.1: PID versus Fuzzy-PID graphical simulation result [4]

The fuzzy-PID controller outperforms the conventional PID controller, as demonstrated in Figure 1.1. The Fuzzy-PID controller dampens the oscillations noticeably and responds quickly.

1.3 Problem statements

The aim of the motor positioning controller is to recognize the signal of the desired angle and move the motor to that position [5]. Nowadays, most DC machines use the classical controller such as PID to control the positioning mechanism of the engine since it is easier to understand, inexpensive and easy to design. PID controllers can work quite well, but they are not adaptable enough to accommodate the various possibilities that may arise. When the load changes, this is tempting since the original controller will often be unable to maintain the desired performance and will need to be re-designed for the new system circumstances. An attempt to regulate a system using classical control theory, a mathematical model for the process, and knowledge of the system variables' evolution are necessary to complete the control loops. Both prerequisites are normally difficult to meet: Sometimes this is due to the complexity of the process or a lack of comprehension of it, and other times it is due to an insufficient technical level obtained at the time.

Classical controller, while used on their own, may provide unsatisfactory transient response performances. Therefore, PID type controller is converted to a fuzzy-PID type controller to improve the positioning DC motor control system.

Zadeh's (Zadeh, 1968) pioneering work on expert knowledge that may be successfully applied to the management of systems with unanticipated, nonlinear dynamics is acknowledged. He developed fuzzy control theory to address the inadequacies of conventional controllers. With simple solutions, fuzzy systems can manage complicated, nonlinear, and sometimes theoretically intangible dynamic circumstances. Fuzzy logic incorporates expert-based language control concepts into automated control systems that employ human-like yet systematic characteristics [6]. The use of fuzzy-PID controller increases the quality factor. However, the implementation necessitates expertise, and the reaction time is slightly slower than that of a typical controller.

To demonstrate that the complex properties of the PID fuzzy type controller are faster and even more robust, a simulation by using the MATLAB/Simulink R2019b (Fuzzy Logic Toolbox) software are conducted and compared to the results of the PID controller.

1.4 Objectives

The goal of this project is to put to the test of an improved classical control approach for a single mass ptp positioning system by simulating a DC motor with PID and Fuzzy-PID controller systems for position control. The objectives of the project are as following:

1. To design a PID controller and Fuzzy-PID controller for a Single Mass PTP Positioning System.
2. To validate the controller designed experimentally and in simulation.
3. To analyze and investigate the transient performance of both controllers.

1.5 Scope of the project

The following are the project's scope:

- MATLAB/Simulink simulation of a DC motor controller
- Position control simulation utilizing a conventional controller and a Fuzzy-PID controller will vary from 0 to 360 degrees.
- Both controllers' peak overshoot and settling time were examined.

1.6 Report Outline

Chapter 1- Introduction

This project deals with the performance evaluation of the classical control method (PID) and the improved classical control method (Fuzzy-PID) for a single mass (DC motor) PTP positioning system.

Chapter 2- Literature Review

Reviewing hardware and software projects from internet books related to the project.

Chapter 3 – Methodology

Process and method used to carry out this project.

Chapter 4 – Expected Result and Discussion

The results obtained from the simulation are shown and explained after the simulation is carried out.

Chapter 5 – Conclusion and Recommendation

Conclude the whole process at the completion of the project.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

Precision positioning systems with electric motors, sensors and controls are commonly used in the industrial machinery applications for example manufacturing industry, semiconductors manufacturing systems, automotive robots as well as robotic system. PTP positioning system is a system that demands high precision with rapid speed, quick response including no or minimal overshoot as well as robust uncertainties of parameter. In the PTP implementations, the varies payload of parameter, and also some friction can end up contributing to performance instability. One of the most critical criteria for PTP positioning systems are thus the final precision and transition period, while transient response is known to be second essential aspect. The performance of the systems should be the same or close to its performance when the system is in a normal condition. A crucial aspect of maintaining the efficiency of positioning systems includes robustness.

PID controllers are the most common type of control systems used in the industry. However, they cannot be used in a wide range of even more complex cases, particularly where high positioning performance mechanisms with non-linearity are taken into consideration. A friction that induces a steady state error and/or restricts the cycles near the reference position is called non-linearity. [7].

Therefore, many type of enhanced PID controller is design to solve the problem. One of the upgraded PID type controllers is a Fuzzy-PID combination controller. They are designed to obtain more efficient response. Fuzzy-PID type controller approached is a better method of managing a high precision of single mass PTP positioning system. It can provide easy and efficient control, perform with fuzzy control robustness, better transient response and fast time response. FLC, a Fuzzy Logic Control has proved to be applicable in complicated non-linear and unclear developed systems for which classical control implementation is considered inefficient.

This paper described the evaluated comparison on the performance of classical control method namely PID controller and an improved classical control method for single mass PTP positioning system. The goal is to prove fuzzy logic makes the PID controller effective for the industrial process with differing degrees of non-linearity and variance in parameters. In Chapter 3, the analysis methodology and the simulation approach used will be describe. In Chapter 4, the results obtained is presented. In Chapter 5, the results and comparison findings will be discussed with those in the literature. In Chapter 6, research conclusions is stated and possible approach for future research is suggested.

2.2 Existing Model

According to Rozilawati et.al, the PID controller results in poor positioning and tracking performance for point-to-point positioning control of a one mass rotary system robustness. It results in significant overshoot during positioning performance and a significant error in tracking performance. (Rozilawati, 2014).

Further, the literature research by Vineet et.al. fuzzy-PID controllers outperform conventional PID controllers (Vineet, 2011). In consonance with Adnan et.al. in his paper on the comparison between conventional PID, Adaptive PID and Sliding Mode Controller in designing the pitch control for aircraft, he stated that the performance of Sliding Mode Control and fuzzy-PID is comparably better to that of conventional PID. Also, in every industrial application, the Fuzzy Logic Controller allows for precise control of the water level when compared to conventional PID controller system (Bikas, 2016). Likewise, Tushar et.al. added despite the fact that conventional PID controllers provide decent performance, they have poor robustness and high exceeding. It is obvious that in case of few parameter changes of the plant led to decline of the performance of the conventional PID controller drastically. As a result, while tuning PID parameters is a good process to start, it is not enough to regulate process dynamics swimmingly (Tushar, 2014).

As stated in Sankalp paper on the stabilization of mobile inverted pendulum system, using conventional and Fuzzy-PID controller, Fuzzy-PID outperforms conventional pole placement techniques and trial and error methods. (Sankalp, 2016).

However, as stated by Fitri et. al. in his paper “Intelligent Control Method for Two-Mass Rotary Positioning Systems”, although the fuzzy-based technique outperforms the conventional technique in terms of positioning performance, the conventional technique is considerably simpler and more practical (Fitri, 2013).

2.3 DC Motor

The Direct Current (DC) motor is a typical actuator in control systems. It offers direct rotating motion and, when combined with wheels, drums, and cables, may create translational motion. DC Motors are easily found in a variety of portable appliances, cars as well as other types of the industrial equipment. The operation and construction of industrial DC motors depends on the different types of the motors. The simplest DC motors construction has the stator which generates the armature coil and a steady magnetic field, which is the component that are rotating. Armature is attached to a DC power source through a pair of comutator rings. Whenever the current flows passing the coil, it is induced by electromagnetic energy according to the Lorentz theorem, such that the coil continues to rotate. As the coil rotates, the comutator rings are connected to the opposite polarity of the power source. As a consequence, the electricity will always flow 'away' on the left side of the coil and on the right side the electricity will always flow ‘towards’. It means that the action of the torque is still in the similar direction during motion, so that coil continues rotating. The action of the torque is near zero once the coil is nearly perpendicular with the magnetic flux. As a result, if the DC motor were operated, an irregular rotation of the rotor will occur. In solving this problem, one more loop is added to the rotor, with separate couple of rotor comutator. By this setup, once the first loop is in an upright position, the subsequent loop would be attached to the power supply so that motor force would still be available in the system. In addition, rotation of the rotor, will be smoother when there are more such loops.

The armature loops are placed within the slots of highly permeable steel layers in a practical motor [8]. It would improve the magnetic flux interaction. The spring loaded comutator brushes maintain connection with source of power. The permanent magnetic stator pole is only used with a very small DC motors. Electromagnetic is commonly used. The electromagnetic field coil is powered from the similar DC source. The coil field can be connected to rotor coil in parallel or series. Two distinct types of DC motors; a shunt and series motors is the outcomes. The wound motor series type has a great torque starting, however the speed gradually decreases with load. A shunt motor is capable of operating at almost constant speed, independent of the motor load, however it has a low starting torque.

Unlike other electrical machines, DC motors has unique characteristics. A rotating loop in a magnetic field will produced an emf according to the principle of electromagnetic induction. The same case is also reasonable for the rotating armature loops. An internal Electro-Magnetic Field (EMF) that opposes the input voltage applied will be induced. The back EMF decreases the current of the armature by a significant amount. The back EMF is proportional to the speed of the rotor. At the start of the motor, the back of the EMF is much too small, making armature current very high, allowing the rotor could burn out. Proper starting mechanism for controlling the input voltage is therefore needed in larger DC motors. Another intriguing variations of the DC motor is a universal motor which are able to control both DC and AC power.

2.4 Physical System

2.4.1 Electro-Mechanical Engineering Control System (EMECS)

Electro-Mechanical Engineering Control System (EMECS) is used in this project as the DC Motor plant. EMECS is an electromechanical devices used in control engineering research and education. It is made up of modular mechanical and electrical gear that allows for the easy construction of a wide range of control experiments appropriate for various levels of teaching. It is also complex enough to be used as a platform for exploring a wide range of control-related issues, including system modelling, system identification, linear control, nonlinear control, optimum control,