OPTIMIZATION OF PI CONTROLLER FOR LEVEL CONTROL OF WATER TANK SYSTEM

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A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Mechatronics and Automatic Control)

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AUGUST 2020

ACKNOWLEDGEMENT

Alhamdulillah. All praises to Allah for His all blessing in completing this master project. First and foremost, I would like to express my special appreciation to my supervisor, Ir. Dr. Shafishuhaza Sahlan, for her continuous supervision and guidance to help me throughout this master project journey. Not forgotten, my appreciation goes to all lecturers who have taught me throughout the master's program.

Sincere thanks to all my friends especially my classmates for their kindness and moral support during my study. Thanks for the friendship and memories. My gratitude also goes to my beloved family. Thanks for unconditional love and encouragement. Thank you very much.

ABSTRACT

The liquid level control is one of the most important parameter in most of industrial process such as in water treatment plant. The general control objective in water treatment system is to maintained a desired water level of the water tank when there is an inflow and outflow at the respective tank. Although the water tank system is considered as a simple plant from construction perspective, the control action faces with various challenges due to the complexity of the system which are influenced by nonlinear behavior and uncertainties. Inadequate control strategies to deal with the nonlinearities and uncertainties appearance will contribute to inaccurate levelling process. Proportional -Integral - Derivative (PID) controller is widely used as control algorithm in many process due to the simplicity and ease to use. However, conventional PID controller is not satisfactory to water level control system because it cannot perform better in nonlinear system as the controller parameters need to be tuned properly and continuously throughout the whole process. Therefore, this project proposes an optimized method to determine optimum PID control parameters for level control of water tank system using swarm optimization method. The solution is based on the idea that accurate selection of controller parameters in dealing with nonlinearities and uncertainties will contribute to high precision levelling process. The approach has several notable merits, namely rapid convergence, simplicity in determining algorithm parameters and finding the best optimal point. A comprehensive verification using simulation is carried out to determine the performance of the proposed method. From the simulation work, it is shows that swarm optimization method validates its ability to tune up controller parameters with high level of precision compared with manually adjustments of the controller parameters. The proposed method is shows it has better performance than manual tuning PID controller in terms of the time response.

ABSTRAK

Kebanyakan proses industri seperti di pusat rawatan air melibatkan kawalan aras cecair sebagai salah satu parameter yang penting. Secara asasnya, objektif kawalan di dalam sebuah sistem rawatan air adalah untuk mengekalakan aras air yang diperlukan khuusnya apabila melibatkan masukan dan keluaran air dalam sesuatu tangki. Walaupun secara dasarnya sistem tangki air dianggap ringkas dari perspektif struktur binaan, tindakan kawalan melibatkan pelbagai cabaran disebabkan oleh kesukaran sistem yang dipengaruhi oleh tindakan tidak linear dan perkara yang tidak dapat dijangka. Kelemahan strategi kawalan untuk mengatasi kesukaran ini akan mengakibatkan kepada proses kawalan air didalam tangi tidak jitu. *Proportional-Integral-Derivative* (PID) merupakan satu algoritma kawalan yang banyak digunakan dalam kebanyakan proses industri kerana strukturnya yang ringkas dan mudah digunakan. Namun, kawalan PID adakalanya tidak memadai dalam proses mengawal aras air kerana ia tidak dapat memberikan kawalan dengan baik dalam keadaan tidak linear memandangkan parameter-parameter kawalan perlu ditetapkan dengan berhati-hati secara berterusan. Oleh itu, projek ini mengetengahkan penggunaan satu kaedah untuk mengoptimumkan parameter kawalan PID untuk sistem tangki air dengan menggunakan *Particle Swarm Optimization* (PSO). Kaedah yang dicadangkan adalah berlandasan kepada idea ketepatan pemilihan parameter kawalan dalam sesuatu sistem akan menyumbang kepada kejituan dalam proses kawalan aras cecair. Kaedah yang dicadangkan memiliki kelebihan seperti konvergensi pantas, penggunaan algoritma yang ringkas dan mudah dan berkebolehan mencari titik optimum yang terbaik. Verifikasi menggunakan platform simulasi telah dilaksanakan untuk memnetukan kebolehan kaedah yang dicadangkan. Hasil simulasi mendapati kaedah yang dicadangkan membuktikan ia mampu menetukan parameter kawalan dengan baik berbanding dengan kaedah penetuan parameter kawalan secara manual dalam analisis tindakbalas masa.

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LIST OF ABBREVIATIONS

PID	-	Proportional Integral Derivative
PSO	-	Particle Swarm Optimization
FLC	-	Fuzzy Logic Controller
Tr	-	Rise time
Ts	-	Settling time
Ess	-	Steady state error
OS	-	Overshoot
IAE	-	Integral Absolute Error
ISE	-	Integral Square Error
ITAE	-	Integral of Time with Absolute Error

CHAPTER 1

INTRODUCTION

1.1 Introduction

Water treatment is a process to purify and treating raw water from natural sources such as lake, river or stream to get acceptable range for specific end user. The purified water is desirable for drinking water purpose, irrigation in agriculture sector, industrial water purpose, medical purpose and all types of domestic purpose. A water treatment plant comprises four major stages namely coagulation, sedimentation, filtration and disinfection. Along the stages, water will be transferred from one stage to another stage and get treated and purified through mechanical process, chemical process and biological process.

Level control is essential in water treatment process as the process of treating the water involve the usage of water pump for water transference and water storage in all stages. The operation of pump is directly affected by the respective water volume in each tank which can be measured through transducer. During operation, the water pump need to continuously run to ensure sufficient amount of water could be delivered to consumer. The water pump can be damaged if the pump is alternately run and stop. Thus, it is necessary for water treatment plant to have a proper monitoring and controller to ensure the production requirement is met as well as provide safe operations to personnel and equipment. Apart from that, efficient water treatment process could contribute to improvement of plant operation quality, optimized energy usage and improve the plant productivity.

1.2 Problem Background

Generally, most water utilities are considering the optimization method of their plants operation to minimize the expenditures and to reach water quality specifications and regulations. The aim can be achieved by implementing appropriate process control and automation. Water level control is an important process parameter that need to be maintained at the desired level. However, there are many difficulties in controlling water level system. In some situation, system could operate under unstable condition such as operating below or above the set point. Thus, water level control is often encountered as a complex system with nonlinearities and uncertainties. The nonlinearities and uncertainties in the system could occurs due to several causes such as modelling errors, interruption during the process, noise in the measuring device and water turbulence. Improper action for dealing with the nonlinearities and uncertainties could leads to the unsatisfactory response and stability. Therefore, designing a control algorithm in water level control system is necessary to reach greater system performance.

1.3 Problem Statement

Control system performance is directly affected by proper selection of controller parameter. Inaccurate tuning of the parameter could lead the system becomes unstable and possess poor performance characteristics for nonlinear system. Conventional Proportional Integral Derivative (PID) control is one of the best controller to be implemented. However, it is highly dependent on precise mathematical model of the process and tuning the optimal control parameter for PID control in nonlinearity condition of liquid level system is very difficult. One of the most commonly method used in determining the PID controller is trial and error method, but this method may take a longer time and quite difficult to obtain the suitable parameters (Djalal *et al.*, 2015). Therefore, an optimization algorithm is proposed to assist tuning process to ensure liquid level process system could achieve greater system performance.

1.4 Research Goal

This project will be conducted by integrating advantages offered by PID controller and optimization method. The proposed evolutionary algorithm will determine optimum PID controller parameters and thus enhancing water level control performance at various operating points.

1.5 Research Objectives

Several objectives have been identified to ensure the project's aim is achievable. The objectives are:

1. To develop a suitable model for automated liquid level process system.
2. To develop an PI and optimized PI controller for automated liquid level process system.
3. To perform a comparative study between PI and optimized PI in order to determine the best controller performance for automated liquid level process system.

1.6 Research Scopes

This project will be conducted based on the laboratory scale water treatment system and focusing on the water level controller only. Throughout the work, water level system is denoted by automated liquid level process system. The mathematical model of the liquid level system is formulated based on the prototype in the laboratory and will be used as the reference model for this project. Then, the controllers design and performance analysis will be carried out in simulation platform by using MATLAB and Simulink. The proposed optimizing method to be used in this project is Particle Swarm Optimization (PSO) algorithm.

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