ANALYSIS OF THE PERFORMANCE OF PI CONTROLLER FOR MULTIVARIABLE PLANT

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DEDICATION

Dedicated to my dearest family who supported me all the time and my friends who always by my side.

ABSTRACT

The wastewater treatment plant (WWTP) is one of the multivariable plants and classified as a complex system due to its nonlinear dynamics, large uncertainty in the disturbance inputs and multivariable structure. A precise control in biological processes for all the operating conditions is necessary in order to guarantee adequate biological conditions for microorganisms to oxidize the organic materials. The project is aimed to develop a nonlinear PI controller to control substrate (S) and dissolve oxygen (DO) concentration level. However, difficulties come in handling the interactions between different loops that are usually required for an iterative cycle that typically create the changes in parameters, therefore the optimal treated water is challenging to be obtained. To overcome the manual trial and error method is by implementing PSO technique; hence a suitable nonlinear gain function can be achieved with minimal parameterization tuning. It is found that with proper tuning of nonlinear PI controller gain using the PSO algorithm, the tracking response of substrate level and dissolve oxygen is well improved.

ABSTRAK

Loji rawatan air kumbahan (WWTP) adalah salah satu daripada sistem multi-ubah dan diklasifikasikan sebagai sistem yang kompleks disebabkan oleh dinamiknya yang tidak linear, kebarangkalian yang besar dalam input gangguan dan strukturnya pelbagai pembolehubah. Pengawalan yang tepat dalam proses biologi untuk semua keadaan operasi diperlukan bagi menjamin keadaan biologi untuk mikroorganisma adalah mencukupi untuk mengoksida bahan organik. Projek ini bertujuan untuk menghasilkan pengawal PI bukan linear untuk mengawal tahap kepekatan Substrat (S) dan Larutan Oksigen (DO). Walau bagaimanapun, terdapat kesukaran dalam mengendalikan interaksi kitaran berbeza yang biasanya diperlukan oleh kitaran berulang yang menyebabkan perubahan parameter, oleh itu untuk memperoleh air yang dirawat adalah mencabar. Untuk mengatasi kaedah percubaan dan kesalahan manual adalah dengan melaksanakan teknik PSO; oleh itu fungsi keuntungan tak linear yang sesuai dapat dicapai dengan pengoptimuman dalam penala parameter pengawal PI. Didapati bahawa dengan penalaan yang betul pengawal PI bukan linear menggunakan algoritma PSO, tindakbalas pengesanan aras substrat dan larutan oksigen diperbaiki dengan baik.

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LIST OF SYMBOLS AND ABBREVIATIONS

WWTP	:	Wastewater Treatment Plant
ASP	:	Activated Sludge Process
PI	:	Proportional Integral
PID	:	Proportional Integral Derivatives
Non-PI	:	Nonlinear Proportional Integral
PSO	:	Particle Swarm Optimization
WAS	:	Waste Activated Sludge
S	:	Substrate
DO	:	Dissolve Oxygen
MIMO	:	Multi-Input-Multi-Output
SISO	:	Single-Input-Single-Output
ISE	:	Integral Square Error
IAE	:	Integral Absolute Error
ITAE	:	Integral of Absolute Error
ITSE	:	Integral of Absolute Square Error

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CHAPTER 1

INTRODUCTION

This chapter present a brief introduction about the project. First, the background of the project is elaborated and is followed by the problem statement, the objectives of the project. Based on the problem statement and objective, the scope or limitation of the project is identified. Finally, the organization of the report is explained.

1.1 Background of Study

Water is one of the most important natural resources for all life live on Earth. The provision and water quality invariably and continuously have played an important part in determining not only wherever people will live, as well as their quality of life.

A large portion of industrial systems are nonlinear multivariable dynamics with input-output interactions. Wastewater Treatment Plant (WWTP) is one of the multivariable plant which is a process of contaminants removal from wastewater and household waste material, both runoffs (effluents), domestic, industrial and institutional. The physical, chemical, and biological processes are included in the plant to remove all the waste contaminants. The major constituents of wastewater are suspended solids, organic matter and pathogens. The objective is to supply an environmentally safe fluid waste stream or treated effluent and a solid waste or treated sludge that suitable for usage or disposal. The wastewater treatment is not only necessary for our own health nevertheless, in addition, to protect the environment and our surroundings clean and safe [1].

WWTPs are known with large nonlinear systems subject due to its significant perturbations in flow and load, together in the composition of the wastewater [2]. In any case, these multivariable plant need to be continuously operated, meeting stricter and stricter regulations. Various control strategies are proposed within the literature however their analysis and comparison, either sensible or supported simulation are troublesome might be difficult to solve the problems. This can be large because of the variability and fluctuation of the influent, to the biochemical complexness and biological phenomena and to the massive range of time constants which is from a few minutes to many days, due to the lack of standard analysis criteria among other things, which is region-specific effluent needs or other requirements and cost levels.

One of biological wastewater treatment process is Activated Sludge process (ASP). The treatment that occur as pollutants are utilized as a food source by various different of microorganisms. It is a suspended growth process since the organisms are

suspended in the wastewater instead of connected to another medium as in biological rotating contactor or the filter trickling processes. Ahansazan *et al*. studied that Activated sludge is primarily removed the dissolved organic solids as well as settle-able and non-settle-able suspended solids which is a suspended growth secondary treatment process [3]. The activated sludge itself is included a degree of microorganisms and sludge particles that are naturally found in the raw or settled effluent. These organisms are cultivated in aeration tanks, wherever they are provided with soluble oxygen and food from the effluent. The "activated" term is came from the very fact that the particles are abundant with the microorganisms, fungi, and protozoa. Like in most alternative waste matter treatment plants, the preliminary treatment processes eliminate the coarse or heavy inorganic solids (grit) and other scraps, such as rags, and boards, once waste matter enters an activated sludge treatment facility. The ASP will treat either primary clarified. Effluent or raw wastewater straightaway from the preliminary treatment processes. As the wastewater is entered the aeration basin, the ASP microbes use the solids in the effluent. After the aeration basin, during the secondary clarifier, the effluent solids and microorganisms are separated from the water through gravity sinking. The settled solids and microorganisms are pumped back to the front of the aeration basin, whereas the processed water flows on to the following component.

The control strategies that are frequently applied in WWTP nowadays is the proportional-integral (PI). The reaching of control target is the contribution of every part of PI controller which the proportional part is potential to extend the response speed and control accuracy while the integration part is generally utilized in eliminating the steady-state error of the system. However, it comes in difficulties to attain high control performance in all operating conditions with a linear PI controller

due to completely different dynamic behaviors of the WWTP control parameters. The more returning task will continuously be required a fixed-gain PI controller, therefore, the controller generally has the potential to maintain a balance of DOs concentrations and nitrogen removal process throughout the set-point changes which are highly required. The adaptability and robustness of the controller such as self-tuning method, general predictive control, fuzzy logic, and neural network strategy are improvised with developing them with a lot of methods [4].

Optimization technique will be utilized in this study to obtain the parameter tuning of the PI controller with the developments of Artificial Intelligent (AI), a large number of intellectual algorithms have been proposed for PI/PID tuning purpose such as Ant Colony Optimization (ACO), Bee Algorithm, Genetic Algorithm (GA) and Particle Swarm Optimization (PSO). According to Kumar *et al.* the Particle Swarm Optimization (PSO) have enabled the PI controller to get an output which is robust and has faster response [5], which is then supported in study by [6], remarks that PSO-PI controller has exhibited relatively good performance with very less settling time, overshoot and transient oscillations.

The significance of this project is upon its completion, optimal control performance of the nonlinear plant (WWTP) can be identified thus the same method can be applied to other types of nonlinear plant (transportation, military, industrial, etc.). Based on the emerging issues, this project is also might contribute significant positive impact on the planet's scarce water resources by triggering brilliant scientific minds to develop adequate and a versatile process model of the wastewater treatment plant. Finally, this project is also considered as an effort in securing the optimal quality of treated water as either to be recycled or reused.

1.2 Problem Statement

The main goal for a wastewater treatment plant (WWTP) is to remove the suspended materials, organic substance, and phosphate from the water before discharging it to the recipient and obtained the best optimal treated water. The most effective technology available is applied to control the discharge of pollutants emphasized in a biological process, known as Activated Sludge Process (ASP). The microorganisms are oxidized the organic materials in the ASP and proceed with the next phase of treatment. Referring to A. Capodaglio, the issues of maintenance and poor quality of effluent are affected due to poor control approaches are the common problems in WWTP thus other multivariable plants also have the same problem due to many parameters to be controlled [7].

The comprise wastewater treatment technology that forging the control of these industrial plants is difficult due to the complexity of physical, chemical and biological processes. Previously, there have been many literature reviews of proposing numerous control strategies of WWTP with different goals such as Proportional Integral Derivative (PID). Although PID control strategies frequently been applied in WWTP [8]; most of the controller parameters adjustment is using a trial and error methods. However, a trial by manually and error method are regarding due to its tediousness and time-consuming. Difficulties come in handling the interactions between different loops that are usually asked for iterative cycle that make the parameters to be changed often. Hence, the optimal treated water is very challenging to be obtained. The idea to overcome manual trial and error method is by implementing PSO technique; hence a good nonlinear gain function can be achieved with minimal parameterization tuning [9].

1.3 Objectives

i. To develop control algorithm for optimal PI controller.

ii. To investigate the control performance of develop optimal PI controller to multivariable Wastewater Treatment Plant.

iii. To investigate the control performance of optimal nonlinear Wastewater Treatment Plant.

1.4 Scope of Project

This project uses optimal PI Controller. The optimization technique to be used is basic Particle Swarm Optimization (PSO). The control algorithm will be tested to the multivariable Wastewater Treatment Plant (WWTP). The results are based on the performance of nonlinear system and the output will be only observed and analyzed in the time domain. All of the simulation work will be performed using MATLAB/Simulink Software.

1.5 Organization of the Report

This report is divided into five chapters and organized as follows. For Chapter 1 is about introduction. This chapter provide readers an idea of the whole project, basic elements of the project, including the introduction of wastewater treatment plant overview, the significance of the project, problem statement, objectives, and scope or limitations of the projects.

In Chapter 2 which is Literature Review section, previous work and research that are related to this project are reviewed and studied. For example, previous works,