" I hereby declare that I have read through this report entitle "*Design a PID Controller for An Activated Sludge Process* and found it has comply the partial the fulfilment for awarding the degree of *Bachelor of Electrical Engineering (Control, Instrumentation and Automation)*"

Signature : .....

Supervisor's Name : **MDM EZREEN FARINA BINTI SHAIR**

Date : **19 JUNE 2013**

DESIGN A PID CONTROLLER FOR AN ACTIVATED SLUDGE PROCESS

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A report submitted in partial fulfilment of the requirements for the degree of Bachelor of Electrical Engineering

Faculty of Electrical Engineering
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2013

I declare that this report entitle "*Design a PID Controller for An Activated Sludge Process*" is the result of my own research except as cited in references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Student's Name : **MUHAMAD AFIQ BIN BACHOK**

Date : **19 JUNE 2013**

Dedicated to my beloved family especially my father and mother,
lecturer and friends

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Thanks.

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ABSTRACT

Activated sludge process is a process of aerobic wastewater treatment. This process is used to reduce the amount of dissolved organic matter from the wastewater by using the microorganism in aeration tank. The water that has been produced after the process can be used again without effecting or damaging the environment to avoid pollution. The main objective of this project is to design the PID controller for the plant to control the substrate concentration and dissolved oxygen concentration contained in the water. Besides that, the performance of the controller also will be analysed to make the process of the system better. This project covered the design of the PID controller based on the non-linear equation obtained from the online system. The result will be analysed and the controller will be redesign to meet the specification of the performance. The non-linear equation must obtain first from the online system. Then the equation will go through linearization process to get the linear equation before design the controller. The controller design process will be repeated based on the performance result of the controller. The performance that has been considered was settling time, percent overshoot and steady-state error.

ABSTRAK

Proses enapcemar diaktifkan adalah satu proses rawatan air sisa aerobik. Proses ini digunakan untuk mengurangkan jumlah bahan organik terlarut daripada air sisa dengan menggunakan mikroorganisma di dalam tangki pengudaraan. Air yang telah dihasilkan selepas proses boleh digunakan semula tanpa melaksanakan atau merosakkan alam sekitar bagi mengelakkan pencemaran. Objektif utama projek ini adalah untuk merekabentuk pengawal PID untuk kilang untuk mengawal kepekatan substrat dan kepekatan oksigen terlarut yang terkandung di dalam air. Selain itu, prestasi pengawal juga akan dianalisis untuk membuat proses sistem yang lebih baik. Projek ini meliputi reka bentuk pengawal PID berdasarkan persamaan bukan linear yang diperolehi daripada sistem dalam talian. Hasilnya akan dianalisis dan pengawal akan mereka bentuk semula untuk memenuhi spesifikasi prestasi. Persamaan bukan linear mesti mendapatkan pertama dari sistem dalam talian. Maka persamaan akan melalui proses linear untuk mendapatkan persamaan linear sebelum reka bentuk pengawal. Proses reka bentuk pengawal akan berulang berdasarkan keputusan prestasi pengawal. Prestasi yang telah dianggap telah menyelesaikan masa, peratus terlajak dan kesilapan mantap.

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CHAPTER 1

INTRODUCTION

1.1 Background of the project

Waterwaste treatment process is a process to treat mass of raw materials in waterwaste. However, it was very difficult to make the plant treat the wastewater and make the effluent quality reach the standards that have been set. This case occurred because of the advance models that need to add more steps of process operation. When more steps are added, it will produce more disturbances to the plant system. Because of that, the controller is needed to overcome this problem. The qualities have shown improvement after automation was introduced which consist of sensing elements and control loops. This project focuses on biological treatment of wastewater by using the activated sludge process. It specifically controls the dissolve oxygen concentration in the wastewater at aeration tank. Controller was design to control the process of the plant to make it behave like the desired one. The mathematical model of the plant is needed before the control design. In this project, the linearization approach has been used to get the transfer function. The PID controller is a simple controller that can be used to control the activated sludge process.

1.2 Problem Statement

Activated sludge process is a process to reduce the amount of dissolved organic matter from the wastewater by using the microorganism in aeration tank. It will decompose the dissolved organic before it is released to the open environment. The problem was without the controller, the effluent quality will not reach the specification needed before it disposed to the environment. It also consumes more power consumptions. If more steps are added to the system process which means that add up of the aeration tank and clarifier tank, more motor will be needed in order to supply the oxygen to the tank. It will consume more power to run the process. For more advance model of the waterwaste treatment process, usually involves more steps of process and it will make the process become more complex. This will result in more disturbances to the process.

1.3 Objective of the project

The main objective of this project is as follows:

1. To study the basic operation of wastewater treatment flow process.
2. To obtain a mathematical model using linearization approach.
3. To design the PID controller for substrate and dissolved oxygen in an activated sludge process.
4. To analyze the performance of the PID controller for an activated sludge process for various tuning method.

1.4 Scope of the project

1) Wastewater treatment process is a process to reduce the amount of dissolved organic matter from wastewater by using microorganism in aeration tank. This project just focuses on the substrate and dissolved oxygen concentration in the sludge process.

2) The transfer function of the plant model should be obtained in order to design the controller for the plant process. The transfer function will be obtained by using linearization approach.

3) The controller that has been design is to control the amount of substrate and dissolved oxygen contained in the waste water. In this project, the controller that has been considered was only PID controller.

1.5 Thesis Outline

In Chapter 1, it will discuss on the project background, problem statement, objective, scope of the project and also the summary of work. In Chapter 2, it will focus more to the literature review of analysis of the articles, journal, and other sources that relates to the project to gain more knowledge that can help in the project.

In Chapter 3, it will cover the methodology of the project which explains how the project was run and method that have been used to solve the problem. It includes the plant definition, linearization, plant modelling and also PID controller design. In Chapter 4, it will show the result of the experiment that has been held during the project.

In Chapter 5, it discusses the analysis that has been made and also discussions that have been done based from the result that was obtained from Chapter 4. While in Chapter 6 which is the last chapter, project recommendation and conclusion have been made to summarize the project based on the result and discussion that have been come out from the previous chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discusses the literature review on the wastewater treatment process, activated sludge process and also designing the PID controller based on past journals and conference paper. The knowledge gained was used to provide ideas about the project background and to assist in the research.

2.2 Wastewater Treatment Process

Wastewater is a water that the quality in it was affected by any biochemical during the process of industries or other process that make the quality of the water become low and not safe for human. Wastewater treatment process is a process to remove the biochemical or a substance in the water to make sure that the water was safe and can be reused again. Basically, there are three stages in the wastewater treatment which is primary treatment, secondary treatment, and tertiary treatment.

2.2.1 Primary Treatment

Before the wastewater go through the primary stage treatment, there is a pre-treatment which is the process is to remove raw things that can be collected easily such as branches, trash, and etc before it damaged the pump that collect the wastewater to the treatment plant. In the primary stage treatment, sewage flows through large tanks, commonly called "pre-settling basins", "primary sedimentation tanks" or "primary clarifiers"[8]. In this stage, basically the particles like oil will be skimmed and will be floating at the surface of the wastewater. The primary stage treatment tank is usually equipped with the mechanicals that will continuously feed the sludge to the base of the tank where it was pumped to the sludge treatment facilities.

2.2.2 Secondary Treatment

Secondary stage treatment is a process where the biochemical in the wastewater is being degraded to make the treated water safe to the environment. It was placed in the aerobic tank and go through to the aerobic process. To make the process become more effective, it was add up the microorganism that will help the decomposition process. The bacteria will decomposed the sludge and it will produced floc that can be removed by filtering. This process will reduced the biochemical level contain in the water.

2.2.3 Tertiary Treatment

The tertiary treatment is a process to improve the quality of the effluent that come from the secondary treatment process. This process usually placed at the last of the treatment process which is before the effluent was discharged to the open environment.

2.3 Activated Sludge Process

Activated sludge process is a biological process which involves the microorganisms that are mainly bacteria where it will mineralize the organic matter in mass of raw water [1], [5]. The bacterium needs constant energy to grow and support their life activities. There are different types of bacteria that needs different energy source. Dissolved oxygen is an important material to support the bacteria activities. It was crucial to maintain dissolved oxygen concentration in the wastewater tank treatment to make the bacteria be more active [1], [2]. The constructions of the wastewater treatment basically have 2 parts of process which is aerated tank and settler tank [1], [6]. The settler is re-circulated to the aerated tank in order to maintain the biological population in the plant system [1].

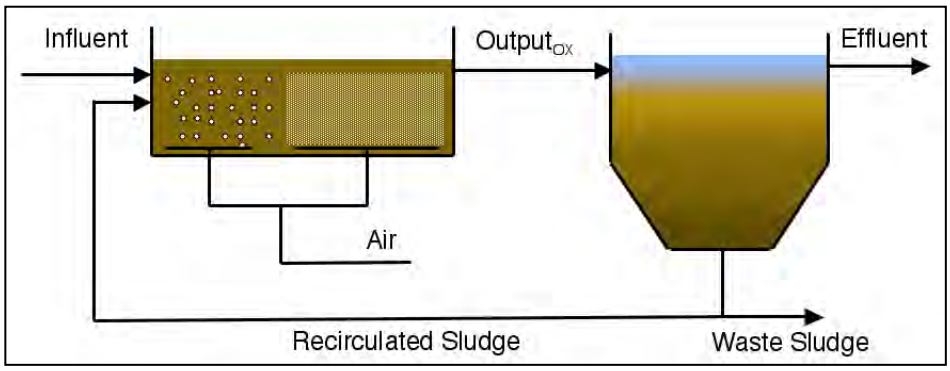

Figure 2.1: Simple configuration for the activated sludge process [1].

From the Figure 2.3, air will be supply to the aeration tank in order to make the bacteria to be active and can decompose the wastewater completely and make the effluent reach the quality that needed [1], [2], [3], and [5]. The dissolved oxygen must constantly supplied to provides the bacteria with energy to decomposed the sludge [1].

2.3.1 The component and the flow process of activated sludge process

In the conventional activated sludge process, there have several components that needed. It was consist of two tanks which is aeration tank and clarifier tank or settling tank. The construction of the component was shown in Figure 2.3.1.

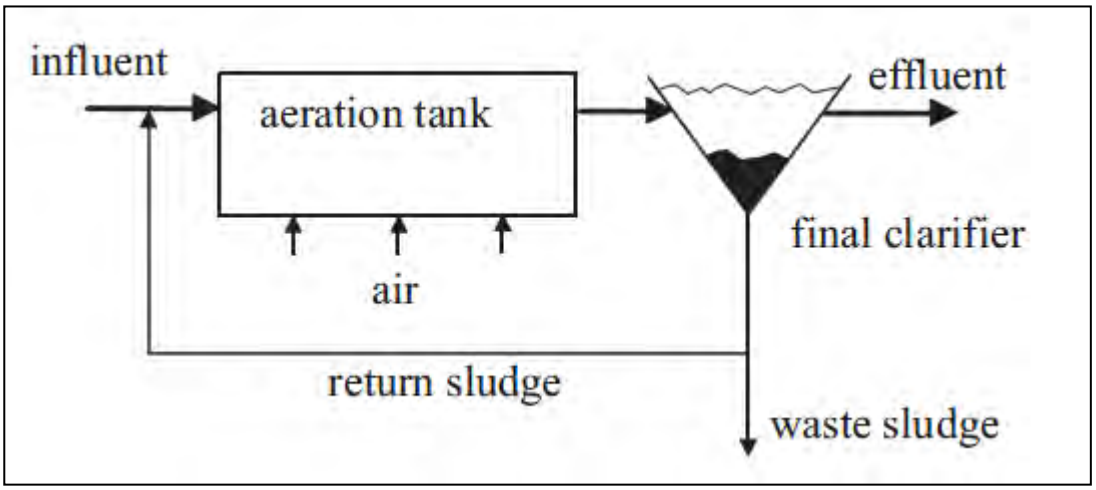

Figure 2.2: Flow scheme of conventional activated sludge plant [2]

The influent will be pumped to the aeration tank for the decomposition process. In the aeration tank, it has bacteria that help in the decomposition process to make sure that this process was running effectively. At the same time, the air will blow up into the aeration tank to supply the oxygen to the bacteria so that the bacteria will be more active to do the decomposition process. The dissolve oxygen concentration in the aeration tank was important to make sure that the bacteria didn't die. During the decomposition process, the biochemical like biomass, substrate, and dissolved oxygen was produced [2].

From the aeration tank, the mixed liquor goes to the clarifier tank to allow gravitation separation of particles which the substances with higher weight will be drowned to the bottom of the tank [2]. In this tank also, there is return sludge where the sludge was pumped back to the aeration tank to reprocess. There it will produce another biochemical which is recycle biomass.

2.3.2 Bioprocess Modelling

In the modelling process of bioprocess, there are several parameters that were considered which is biomass, substrate, dissolve oxygen, and recycle biomass. These four types of biochemical were the main substances that influence the treatment process. In additional of the process, there are also other parameters that need to be considered during the process.

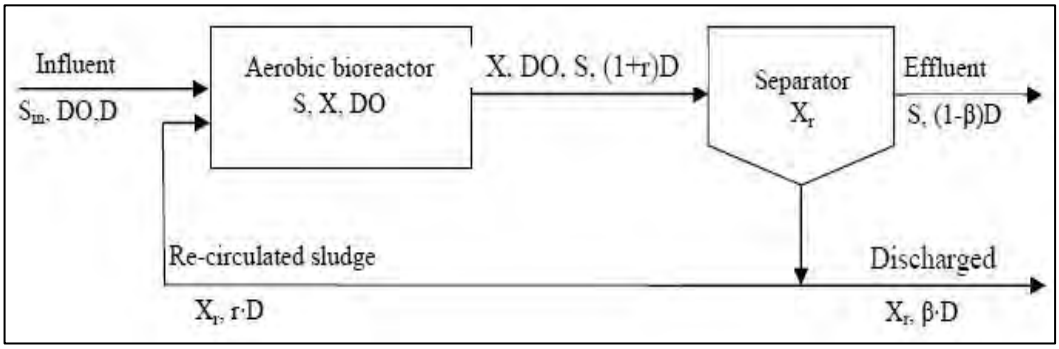

Figure 2.3: Activated Sludge Process Structure [10]

The mathematical model was created to solve the problem of the nonlinear equation. The mathematical model created is to improve the system by designing the controller. However the nonlinear equation must go through the linearization first before the controller design is done. The mathematical equation was show below.

$$\frac{dX(t)}{dt} = \mu(t)X(t) - D(t)(1+r)X(t) + rD(t)X_r(t) \quad (2.1)$$

$$\frac{dS(t)}{dt} = \frac{\mu(t)}{Y}X(t) - D(t)(1+r)S(t) + D(t)S_{in} \quad (2.2)$$

$$\frac{dD_o(t)}{dt} = -K_o\frac{\mu(t)}{Y}X(t) - D(t)(1+r)DO(t) + D(t)DO_{in} + \alpha W[DO_{max} - DO(t)] \quad (2.3)$$

$$\frac{dX_r(t)}{dt} = D(t)(1+r)X(t) - D(t)(\beta + r)X_r(t) \quad (2.4)$$

Where,

X (t) = biomass

S (t) = substrate

X_r (t) = recycle biomass

DO (t) = dissolved oxygen concentration

D (t) = dilution rate

r = ratio of recycle flow

β = ratio of waste flow

S_{in} = substrate in feed stream

DO_{in} = dissolved oxygen concentration in feed stream

μ = specific growth rate

Y = yield of the mass

K_0 = constant

DO_{max} = maximum dissolved oxygen concentration

αW = oxygen mass transfer coefficient

From the equation before, there is also the kinetic equation given by Olsson as follow [10]:

$$\mu(t) = \mu_{\max}\frac{S(t)}{Ks+S(t)}\frac{DO(t)}{Kc+DO(t)} \qquad (2.5)$$

This mathematical equation is important in order to determine the linear model for controller design purpose. The equation considered all the parameters that involved during the treatment process in order to make the controller that will be design could aware about any disturbances that maybe occur during the process.

2.4 PID Controller

PID controller is one of the controllers that are simple and easy to construct and analyze the performance [2]. In wastewater treatment, parameters were tuned once only at the beginning of the installation [5]. The actual control system design will consider the control structure, control algorithm(s) and tuning the controllers. Basically, the system of the plant will use closed-loop control system in order to reduce the disturbance and the sensitivity to parametric uncertainty [2]. The PID parameters that need to be determine were shown in the equation below where the value of Kp,Ki, and Kd is needed in order to design the controller.

$$C(s) = \left(K_P + K_I\frac{1}{s} + K_D s\right). \text{ [7]} \qquad (2.6)$$

2.4.1 Proportional Component (P)

P component will response only for the Error which is the difference between the set value and the final value of the operation. The equation for the P controller as shown below

$$G_c = K_p \text{ [7]} \quad \text{(2.7)}$$

As the proportional gain, K_p is increases, it will make the response become faster and the steady state error also will reduce but if the proportional gain is too large, the response will start to oscillate. If the gain is keep increasing, the response will become unstable [7].

2.4.2 Integral Component (I)

Integral component will remove the steady state error by integrating the error response by time. If the value of the integral component gain is too small, it will cause the overshoot, oscillation and the instability problem. The problem of the integral component can be overcome if it is combining with the proportional component [7]. The combination of the component called PI component and the equation is shown below.

$$Gc = Kp + \frac{Ki}{s} \quad \text{(2.8)}$$

The combination of this component will make the overshoot of the response becomes small and also it will reduce the steady state error if the used of the gain value is considerable suitable.

2.4.3 Derivative Component (D)

Derivative component basically will remove the overshoot and reduce oscillation. In other words, it will use small value of derivative gain because it is very sensitive to the noise. If the feedback of the response is too noisy, the system will become unstable. With the combination with the proportional component, it

will produce PD component which is, it will improved the transient response of the system [7]. The equation of the PD component is shown below.

$$Gc = Kp + Kds \quad \text{(2.9)}$$

2.4.4 PID Component

The PID component is the combination of the proportional, integral and derivative component where it helps each other to improve the system response. This will improve not only the steady state error but also the transient response which it will consider all the parameters in the plant and become a good controller. From the equation 2.6, it will be derive to the equation below.

$$Gc = \frac{Kds^2 + \mathrm{Kps} + \mathrm{Ki}}{s} \quad \text{(2.10)}$$