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Supervisor’s Name : .....

Date : .....

**DISTURBANCE REJECTION ANALYSIS FOR WASTEWATER  
TREATMENT PLANT**

**BRIYATHARSINI A/P RAMU**

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

**Faculty of Electrical Engineering**

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**2017**

I declare that this report entitled “Disturbance Rejection Analysis for Wastewater Treatment Plant” 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 candidature of any other degree.

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To my beloved mother and father

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## ABSTRACT

Wastewater Treatment Plant is an important system need to be implemented nowadays as the level of water pollution is at peak because of different kind of activities. Efficiency and performance of a plant always need to be excellent so that the effluent discharging from the plant is meeting the quality requirement of contaminant free water. Thus implementing a good controller that can control the system performance is necessary for best performance. In this project a Proportional Integral Derivative (PID) controller which commonly used in industries is used as feedback controller. There are two kind of PID controllers used which are Davison and Penttinen-Koivo. Feedback controllers will affect the output response before eliminating the error. Thus for prevention and better performances purpose, an observer is integrated with PID controller to reject the disturbance present in the plant before the output performance become undesirable. The closed loop performance of both Davison and Penttinen-Koivo with observer was analysed to compare the performance. It can be observed that Penttinen-Koivo controller with the observer shows better results in rejecting the high level of oscillation as well as the overshoot that exist in the plant compared to Davison controller with observer. With the observer, the injected constant value which act as disturbance can be rejected and the system able to be tracked back to the desired condition.

## ABSTRAK

Loji Rawatan Air Sisa adalah satu sistem penting yang perlu dilaksanakan pada masa kini kerana tahap pencemaran air berada di puncak oleh sebab pelbagai jenis aktiviti. Kecekapan dan prestasi tumbuhan sentiasa perlu menjadi sangat baik supaya efluen yang dikeluarkan dari kilang memenuhi keperluan kualiti air simpan. Oleh itu, melaksanakan pengawal yang baik yang dapat mengawal prestasi sistem diperlukan untuk prestasi terbaik. Dalam projek ini, pengawal Proportional Integral Derivatif (PID) yang digunakan secara berleluasa dalam industri digunakan sebagai pengawal maklum balas. Terdapat dua jenis pengawal PID yang digunakan iaitu Davison dan Penttinen-Koivo. Pengawal maklum balas akan mempengaruhi tindak balas output sebelum menghapuskan ralat. Oleh itu untuk tujuan pencegahan dan pencapaian yang lebih baik, pengawal berasaskan Observer diintegrasikan dengan pengawal PID untuk menolak gangguan yang dikenali di dalam loji terlebih dahulu sebelum mengganggu prestasi output. Prestasi kedua-duanya pengawal Davison dan Penttinen-Koivo dengan observer dianalisis untuk membandingkan kecekapannya. Ia dapat diperhatikan bahawa pengawal Penttinen-Koivo dengan observer menunjukkan hasil yang lebih baik dalam menolak tahap ayunan tinggi serta overshoot yang ada pada sistem berbanding dengan pengawal Davison dengan observer. Dengan observer, nilai tetap yang disuntik dalam system sebagai gangguan boleh ditolak dan sistem dapat dikesan kembali ke keadaan yang diinginkan.

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## LIST OF ABBREVIATION

MIMO	-	Multivariable Input Multivariable Output
SISO	-	Single Input Single Output
PI	-	Proportional Derivative
PD	-	Proportional Integral
PID	-	Proportional Integral Derivative
MPID	-	Multivariable Proportional Integral Derivative
DO	-	Disturbance Observer
DOBC	-	Disturbance Observer Based Control
NDOBC	-	Nonlinear Disturbance Observer Based Control
ESO	-	Extended State Observer
SMC	-	Sliding Mode Control
MPC	-	Model Predictive Control
ADRC	-	Active Disturbance Rejection Control
WWTP	-	Wastewater Treatment Plant
TD	-	Tracking Differentiator
LADRC	-	Linear Active Disturbance Rejection Control
TDF	-	Two-Degree of-Freedom
IMC	-	Internal Model Control
LQR	-	Linear Quadratic Regulator
GPC	-	General Predictive Control
LMI	-	linear matrix inequality
AHV	-	Air-breathing Hypersonic Vehicle
ENMPC	-	Explicit Nonlinear Model Predictive Control
D	-	Dilution rate
W	-	Air flow rate
RGA	-	Relative Gain Analysis
ANN	-	Artificial Neural Network
DMC	-	Dynamic Matrix Control
QDMC	-	Quadratic Dynamic Matrix Control
NLMPC	-	Non Linear Model Predictive Control

DO	- Dissolved Oxygen
S	- Substrate
RARFNN	- Rule Adaptive Recurrent Neural Network
BOD	- Biological Oxygen Demand
ASM1	- Activated Sludge Model no.1
DRGA	- Dynamic Relative Gain Array
R	- Resonant
SOC	- Self-Optimized Control
G1	- Substrate Concentration System
G2	- Dissolved Oxygen Concentration System
K1	- Controller Gain Value of G1
K2	- Controller Gain Value of G2
L1	- Observer Gain Value of G1
L2	- Observer Gain Value of G2

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## CHAPTER 1

### INTRODUCTION

In this chapter introduction of project, problem statement, objective, scope and project schedule will be discussed and presented. Basically, the description related to the project will be discussed here where the purpose of this project will be identified.

#### 1.1 Introduction of Project

Among the natural resources, water is the most essential element where it is an alternative word of life. As we all know, human being can live without food but life is impossible to continue without water because it is needed for all living organisms including human, food production and economic development. The problem in shortage of water had become severe in most of the country because of the drastic increase in number of population, development of country itself as well as pollution of water [1][2][3]. As speak about pollution of water, the quality of water influenced by human exercises and is declining because of the ascent of urbanization, populace development, mechanical creation, environmental change and different components. This water contamination is danger to both the earth and its populace [1]. An article stress out that progressing and developing country which has lesser capability to implement management of water quality causes the quality of water degradation [4]. Furthermore, another article recommend that this issue can only be handled by enforcing water resources policy [2][5]. Water pollution or quality of water can be upgraded by implementing wastewater treatment plant. This plant can be an effective way to cut down pollution and had been attract attention of most of the country [6]. Some country also suggest that enhancing the function and productivity of the treatment plant is an excellent method for water quality upgradation [7].

As mentioned above, water pollution issue faced by most of the nation worldwide. There are lots of research have been carried out regarding water pollution concerning severity of the problem. For instance, in Malaysia rivers are the main source of water resource and it has found that half of the rivers in Malaysia are polluted[8][9]. Apart from that, Nile River in Egypt which is the main source of fresh water become shortage of water because of human population explosion, urbanization as well as water pollution by organic materials[10]. Not only this issues, country such as China, Northern Brazil and Bangladesh also faces such impact toward their water source and their environment[1][11][12]. Thus, this shows that not only Malaysia but the country worldwide are lacking somewhere in taking care of their water resources and serious action should be taken before it is too late. To take such measures to enhance water quality, the factor that contribute to pollution should be studied. In most of the articles stated that industrialization, urbanization, dumping of domestic waste and oil released into the water source are the major reason for pollution to occur [1][2][11][12][13][14][15][16]. Moreover, a consolidation for mismanagement, apathy, low necessity with respect to administration agendas, absence of funds, poor open association and poor enforcement also extremely corrupts waterway [9].

Surely lots of thoughts would be going through about reasons of lots of concern directing towards quality of water. The world giving importance to the quality level of water because it might give huge bad impact towards mankind. In an articles stated that residents around the Huaihe River in China passed away in significantly higher proportion due to colon tumour than people miles stone away from the respected river which is very polluted by the factors listed above [11]. Besides, another research also pinpoint that excessive expel of oil into water because of technical and management defect, it endanger aquatic resources, human health, affecting crop production as well as destroy natural landscape [1][17]. Another journal mention that seventy percent of the people involved in this research were suffered from dangerous health issues such as skin infections, the runs, gastric ulcers or other gastric issues at the time that the exploration was occurring [1]. Contaminated drinking water could also affect human heart and kidney which might lead to dead [18].

The parameters counting conductivity, add up to broke up solids, temperature, saltiness, disintegrated oxygen, pH, turbidity, ammoniacal-nitrogen, organic oxygen request, chemical oxygen request and total suspended solid usually determines the quality of water [3][8][12][13][15][19]. The properties of water depend on the concentration and character of water constituent [20]. The Table 1.1 shows the water quality parameter standard index that water should have [1]:

Table 1.1 Standard Parameter for Good Water Quality

<b>Parameter</b>	<b>Standard</b>
<b>DO</b>	6 mg/L
<b>pH</b>	6.5-8.5
<b>Colour</b>	15 ptcu
<b>Turbidity</b>	10 NTU
<b>BOD</b>	0.2 mg/L
<b>Hardness</b>	200-500 mg/L
<b>TDS</b>	1000 mg/L
<b>CL-</b>	0.2 mg/L
<b>CO<sub>2</sub></b>	-
<b>COD</b>	4 mg/L

Pollution of water brings lots of disadvantages, so to maintain the above standard index for the respected parameter some measures need to be taken. Due to this, the government of people's Republic of China announced and released ten point of water pollution prevention and control action in April of 2015 [11]. In addition, further research made by Bangladesh inferences that epidemiological studies are crucial to determine impact that industries having on the environment and to warn the people who against the policy of environment. Banning poisonous chemicals and pollutant concentrations from industrial discharge into water source as well as implementation of legislation on safety precautions are also the best way to improve water quality [1][21]. Besides, in an article stated that wastewater treatment plant is also effective way to treat water [5].

Wastewater treatment plant (WWTP) is actually a plant where the wastewater from different sources such as industrial waste, domestic waste and plantation waste to be recycled, cleaned, purified and return back to the river with less contamination. In Malaysia, according to Indah Water Consortium, the preliminary, primary as well as secondary are the dominant treatment process [22]. In doing the wastewater treatment, in an article stated that Malaysia faces some constraints such as low sewerage tariff which unable to support the high operational and maintenance cost and do not have grease traps or do not maintain grease traps adequately. Apart from that sewage service collection by operators is not conducive as many Malaysians fail to realize the importance of this treatment system. Moreover, the risk factor of quality being compromised as the plant constructed by private developers and handed over to public operator [22]. Thus, it seems that full cost recuperation for sewage treatment is yet far way to be accomplished in Malaysia [16].

After all this facts and information it is clearly understandable that the sewage system should be enhanced for better water quality. For that, in this project disturbance rejection analysis need to done to wastewater treatment plant to minimize the error in the system and tract back according to the initial input of the WWTP.

## **1.2 Motivation**

Water as an important source of life is similar to human as crucial as cell to body. Many incident from different places around the world had occurred related to water. To start with, Malaysia faces the most serious issue where half of the rivers are polluted [9]. The issue of water quality degradation of surface water and rivers had become hot topic to be discussed [8]. To be more specific water quality index in progressing area such as Malacca, Alor Setar and Kota Baharu is in worst state because of pollution [13]. Moreover, in Egypt the Nile River provides 55.5 billion cubic metre of fresh water every year. Because of increase in human population, urbanization, water polluted by domestic waste and agricultural waste the people around the area faces shortage of water [10].

Apart from that, Burullus Lake, the second largest of northern lakes in Egypt also faces significant challenges where the diversity of fishes was decreased from 32 to 25 species as a direct effect of pollution. The lake act as dump site for drainage waters and discharging from agricultural areas. This causes the level of suspended solids to be very high and high pollution of organic and inorganic matter [20]. Traditional population had to leave their homes in the city of Barcarena, Northern Brazil because of industrial and port activities [12]. In addition, river pollution is also a serious issue discussed in Dhaka the capital city of Bangladesh [1]. Lastly, in an article it also stated that ground water and surface water recognized as being the most severely degraded natural resources in China and among most heavily polluted water resource in the world [11]. All this problems have become the motivation to enhance the management of polluted water or wastewater treatment. For that, efficient wastewater treatment plant is always necessary in order to purify the wastewater and minimize the effect on environment.

### **1.3 Problem Statement**

In this era of modernization, we can obviously say that pollution issues are increasing tremendously especially to water, air and land. This is because as discussed before the rate of industrialization, urbanization, dumping of domestic waste and oil released is also increased along with world development [1][2][11][12][13][14][15][16]. Inefficient wastewater treatment plant become one of the major reason to do this project [22]. An article release a statement that full cost recovery for sewage treatment is still a long way to be achieved in Malaysia [16]. Inefficient plant result in release of contaminated water into the environment. Contaminated water result in many health issues, destroy of aquatic living and many more [1][11][17]. In some cases when the effluent from a plant or company is filthy, respected bodies which related to regulation and enforcement of water quality can sue and take legal action toward the company or organization to cause pollution to the environment. This action will eventually causes problems to the respected company as it might involve handsome amount of money to be paid for the penalty. This consequences is surely an unwanted procedure by any company which might also lead to fractured image in industries. Since inefficient purifying plant might cost a lot to a company, it is wise to

enhance the plant for a better results. Hence, a better controller is obviously needed to avoid the consequences and come out with better performances [23].

In a plant, where it might be any kind of plant especially wastewater treatment plant, there will always be errors encountered. Errors means the difference in output from the plant to the desired set point. Although controller are designed to control the output value of the plant to the desired value, the plant always shows errors. This is because treatment of wastewater is a complicated process that is biological in nature and difficult to monitor and control. Treatment plant is also multivariable, non-linear and dynamic in nature [24]. Not only that, the continuous variation of wastewater flow which depend on the weather which changing seasonally, daily and hourly is another issue that distract and lead to disturbance. This influences the wastewater treatment plant to be extremely complicated in term of demonstrating and control purpose [25]. As a matter of fact general standards of control from industrial processes can be connected to wastewater treatment plant, but due to various and unique methods required, special control design always needed in that plant [25]. Thus, to detect error or compensate error suitable feedback controller installation is always needed.

As we know, feedback controller sense and read the output and calculates the error to be compensated by the controller. Normally this type of error occur due to the disturbance occur at the plant. The disturbance might be internal disturbance or external disturbance which can be from any kind of sources [47]. Using only feedback controller to the plant might be a huge drawback because as we know feedback controller detect the error only after it influence and affect the output of the plant. There is no prevention action could be taken to the plant to avoid the disturbance. However observer can detect and reject disturbance effectively said in an article [26]. Thus, this encourages to do the project so that the disturbance encountered eliminated at early stage and track back to the desired output performance.

Apart from that, a Multivariable Input Multivariable Output (MIMO) plant is denoted as having two or more variables which must be controlled and manipulated[27]. Few year back research studies regarding MIMO was not that popular because of the complexity due to complex interaction between the controller parameters and the system's variable and the lack of knowledge about it [28][29] and

at that time only Single Input Single Output (SISO) was investigated a lot. But recently MIMO has been a hot topic because obviously now plant influenced by multiple variables. In the case for wastewater treatment plant, MIMO plays an essential role as this plant affected by various variable depending on what we want to investigate. Moreover, there are so little investigation of MIMO on wastewater treatment plant. So this is also one of the reason to research on this topic.

As such, this project is all about implementing a controller which able to reject disturbance effectively in MIMO wastewater treatment plant. Not only compensate error from the internal system but also able to eliminate error caused by external source so that the effluent discharged is safe to be used.

#### **1.4 Objective**

This project will be carried on few objectives. Objectives have been set as a guideline to complete the project. Below are the following objectives;

- 1) To study and understand the theory and operation of wastewater treatment plant and disturbance rejection controller.
- 2) To design and analyse the performance of two types of controller which are Davison and Penttinen-Koivo in wastewater treatment plant.
- 3) To design and analyse the disturbance rejection ability as well as the ability of state variables estimation of observer in wastewater treatment plant system.

## 1.5 Scope

This project is about disturbance rejection analysis for wastewater treatment plant. Firstly, PID controller and observer were planned to be implemented in wastewater treatment plant. For that pole placement design method will be used to find the controller gain as well as the observer gain. Two linearize system of non-linear wastewater treatment plant will be used to implement the controller and observer design. The controller and observer gain values will be obtained using m-file in MATLAB Software. After that, Simulink block diagram will be designed for two types of PID controller with state observer design. The values obtained in the m-file simulation will be exported to Simulink block diagram to compare the performance of the Davison and Penttinen-Koivo controller. Not only that a disturbance will be injected to the system in term of constant values to evaluate the performance of observer design.