Performance Comparison of WCT-03N Water Level Control Trainer System

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***Abstract*— This project is focused on the comparative analysis of the two different controller applied to the WCT-03N water level control trainer system in terms of the process dynamic performances. The controllers in use for comparison are proportional and proportional plus integral control. On top of that, the best tuning method is selected between Ziegler-Nichols and Cohen-Coon for both controllers. The dynamic performance is analyzed in terms of percent overshoot and settling time. The result revealed that WCT-03N water level control trainer gives best performance when proportional-only controller that tuned using Ziegler-Nichols is used in the system.**

Keywords; proportional, proportional plus integral, dynamic process performance, tuning, water level control

I. Introduction

Generally, water level control systems that have a regulated exit flow stream do not naturally settle at steady-state operating level and can be remarkably challenging to control. Hence, many researches had been conducted to study and improve the system [1]–[13].

Amongst, PID controller is the most commonly used controller for the process because of the possibility of making PID controllers with automatic tuning, automatic generation of gain and continuous adaption [2]–[11]. Furthermore, it is well understood by many operational, technical and maintenance personnel [7][8].

The main objective of this project is to determine the best process dynamic performance of WCT-03N water level control trainer system. The project is focused on the comparative analysis of two different controllers in term of the process control system performance criteria such as percent overshoot and settling time. In addition, two different tuning methods are used for comparison.

II. System Description

Figure 1 shows a photograph of WCT-03N Water Level Control system which located at DCS laboratory, UiTM Shah Alam. The system can be operated via either local, SCADA or DCS modes. The process plant system is equipped with the pressure regulator and pumps. The pressure regulator operational voltage output 0-10Vdc is proportional to the fluid level inside the tank. This process plant is used to measure the water level in the main tank (T-03).

Figure 2 shows the schematic diagram for water level control system. The water level is measured and controlled in the main tank with maximum capacity of 500mmH2O. The measurement is taken using differential pressure transmitter that attached to the main tank. As shown in Figure 2, water from a sump tank (T-01) enters the main tank using a pump (PCV-01). The controller is used to control the rate of the water delivered by the pump so that the water level is within the desired target.

Figure 1. WCT-03N water level trainer system

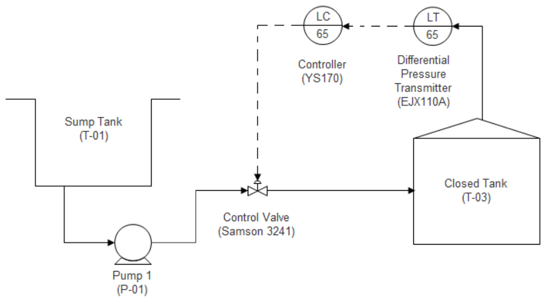

Figure 2. Schematic diagram of water level system

III. METHODOLOGY

In this work, the process model is determined using an open loop test. The three main process parameters are obtained using a graphical method.

The model is then used to tune the controller parameters. In this work, Ziegler-Nichols and Cohen-Coon tuning methods are used for the controller parameter adjustment. The simulation work is done using Matlab Smulink updated version. Figure 3 and Figure 4 show the simulated diagram used for P-only and PI controller respectively.

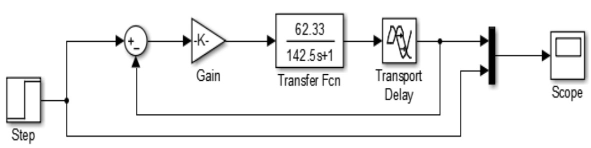

Figure 3. Simulation diagram for P-only controller

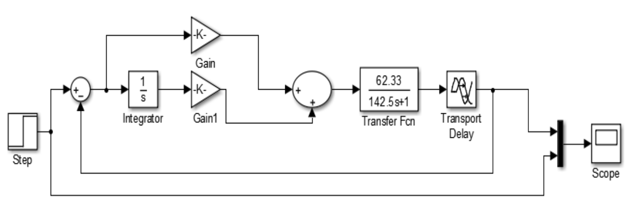

Figure 4. Simulation diagram for PI controller

The simulated response is observed. The best tuning is selected in which, then the simulated response is compared with the actual response from the process plant.

The best controller type with the best parameter adjustment is chosen by comparing the process dynamic performance in terms of settling time and percent overshoot. Normally, the process dynamic performance is best described as follows [11], [12]:

- Reduce in settling time
- Minimum percent overshoot

.The flow chart for the methodology is as shown in Figure 5.

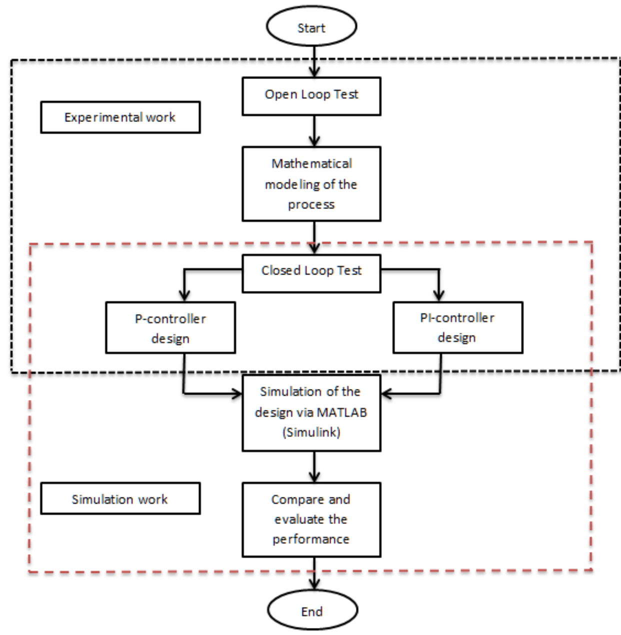

Figure 5. Methodology

IV. PROCESS MODEL

Fundamentally, the first order plus dead time model is as shown in (1) where Tp is the process constant time and Kp is the process gain.

$$G(s) = \frac{K_p e^{-t_o s}}{\tau_p s + 1} \quad (1)$$

In this work, the process parameters are obtained using two-point method. This method is an analytical method that used by measure the reaction graph as shown in Figure 6.

$$K_p = \frac{y_{final} - y_{initial}}{u_{final} - u_{initial}} = \frac{\Delta y}{\Delta u} \quad (2)$$

$$\tau_p = \frac{3}{2}(t_! - t_2) \quad (3)$$

$$t_0 = t_2 - \tau_p \quad (4)$$

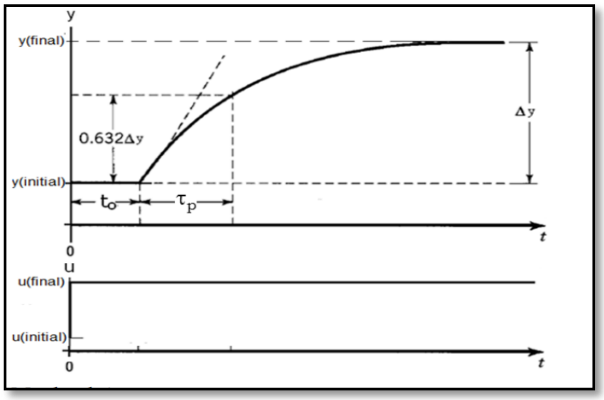

Figure 6. Estimation of process response using two point method [12]

V. PID TUNING

A. Ziegler-Nichols's Method

Several tuning rules had been derived for PID controller [12]. The most popular and widely used tuning method in the industry is Ziegler-Nichols rule [14]. In this tuning method, the controller gains can be calculated using Table I.

TABLE I. ZIEGLER-NICHOLS TUNING RULE

Controller Type	**Proportional Gain (K_C)**	**Integral Time (T_I)**	**Derivative Time (T_D)**
P-Only	$\frac{1}{K_p}\left(\frac{\tau_p}{t_o}\right)$	-	-
PI	$\frac{0.9}{K_p}\left(\frac{\tau_p}{t_o}\right)$	$3.33t_o$	-
PID	$\frac{1.2}{K_p}\left(\frac{\tau_p}{t_o}\right)$	$2t_o$	$0.5t_o$

B. Cohen-Coon Method

The Cohen-Coon tuning rule is as shown in Table II. The Cohen-Coon tuning rules work well on processes where the dead time is less than two times the length of the time constant [12].

TABLE II. COHEN-COON TUNING RULE

Controller Type	**Proportional Gain (K_C)**	**Integral Time (T_I)**	**Derivative Time (T_D)**
P-Only	$\frac{1}{K_p}\left(\frac{\tau_p}{t_o}\right)\left(1+\frac{t_o}{3\tau_p}\right)$	-	-
PI	$\frac{1}{K_p}\left(\frac{\tau_p}{t_o}\right)\left(0.9+\frac{t_o}{12\tau_p}\right)$	$t_o\frac{30+\frac{3t_o}{\tau_p}}{9+\frac{20t_o}{\tau_p}}$	-
PID	$\frac{1}{K_p}\left(\frac{\tau_p}{t_o}\right)\left(1.33+\frac{t_o}{4\tau_p}\right)$	$t_o\frac{32+\frac{6t_o}{\tau_p}}{13+\frac{8t_o}{\tau_p}}$	$t_o\frac{4}{11+\frac{2t_o}{\tau_p}}$

VI. RESULT & DISCUSSION

The open loop response for water level control system is as shown in Figure 7.

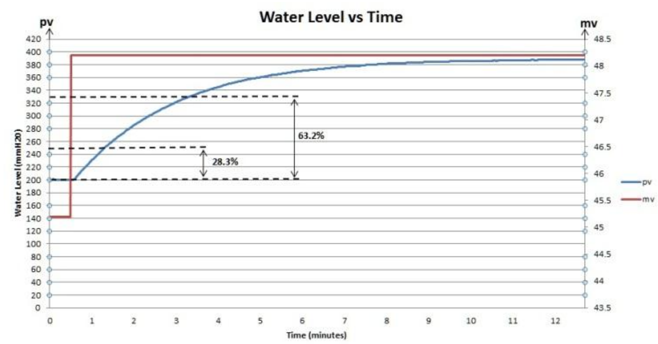

Figure 7. Open loop water level control response

From the response curve, the calculated process gain is 62.33, the time constant is 136.5 seconds and dead time is 34.5 seconds. This process is considered as FOPDT (first order plus dead time) as it holds some delay at the beginning of the process response.

A. Ziegler Nichols's Tuning

Table III and Table IV show the P-only controller parameters and the performance of the water level control system respectively.

TABLE III. P-ONLY CONTROLLER PARAMETER

Number of tuning	**Proportional Value (in PB)**
Before tuning	1666.7
1st tuning	833.33
2nd tuning	416.67
3rd tuning	111.64
4th tuning	83.7
5th tuning	65.8
6th tuning	55.8

TABLE IV. PROCESS PERFORMANCE USING P-ONLY CONTROLLER

Performance Criteria	**Simulated Response**	**Actual Response**
Percent Overshoot	6%	8%
Settling Time (sec)	330s	250s

From Table III, the best parameter of P that gives a reasonable response in terms of settling time and percent overshoot is equal to 65.8. This is depicted in Figure 8 and Figure 9.

Figure 8 shows the actual process performance when using P-only controller while Figure 9 shows the response for simulated P-only controller.

The small difference of percent overshoot between the simulated and actual response because the increasing of value of K_p. Increasing of K_p will reduce steady state error and after a certain limit it will only cause overshoot [14].

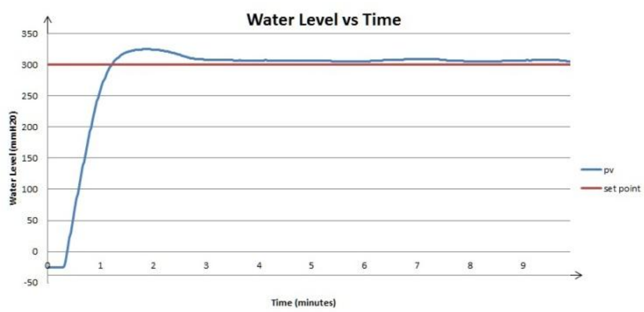

Figure 8. Actual performance using P-only controller

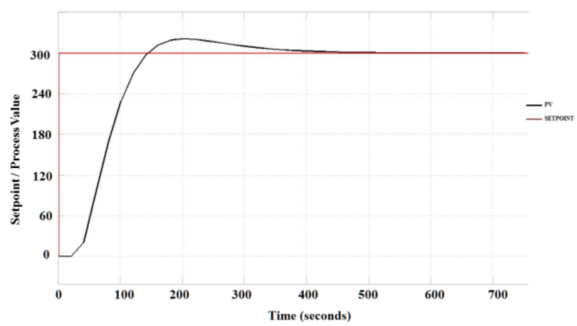

Figure 9. Simulated performance using P-only controller

Table V and Table VI show the PI controller parameters and the performance of the water level control system respectively.

TABLE V. PI CONTROLLER PARAMETERS

Number of tuning	Proportional gain (in PB)	Integral Time (in seconds)
1st tuning	65.8	1500
2nd tuning	65.8	1800
3rd tuning	65.8	2000
4th tuning	65.8	2100

TABLE VI. PROCESS PERFORMANCE USING PI CONTROLLER

Performance Criteria	Simulated Response	Actual Response
Percent Overshoot	34.5%	12.6%
Settling Time (sec)	282s	205s

It can be seen that, the best responses come when the value of integral time is equal to 2000s. This is as shown in Figure 10 and Figure 11. The response is improved in terms of settling time if the value of integral time is increased.

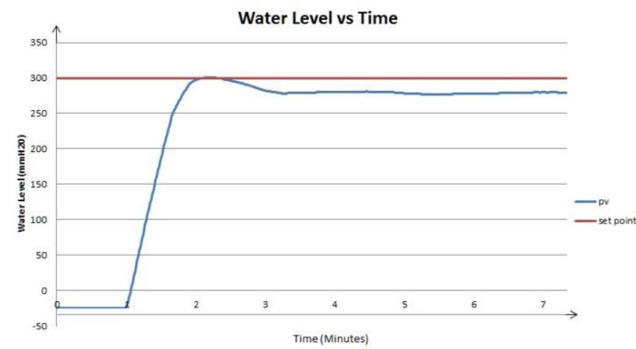

Figure 10. Actual process performance using PI controller

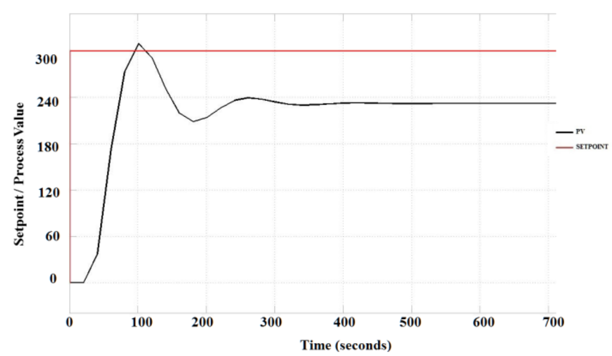

Figure 11. Simulated process performance using PI controller

The response for actual PI controller and simulated PI controller is as shown in Figure 10 and Figure 11 respectively.

The difference of percent overshoot between the simulated and actual response because the increasing of value of K_i.Integral control eliminates the steady state error. After a certain limit it will only cause overshoot [14].

B. *Cohen-Coon Tuning*

Table VII shows the best tuning parameters for P-only and PI controller when tuned using Cohen-Coon rule.

TABLE VII. BEST P-ONLY AND PI CONTROLLER PARAMETERS

Controller Mode	Value
P-only control	P = 0.0688
PI control	P = 0.585 I = 0.00078

TABLE VIII. PROCESS PERFORMANCE

Performance Criteria	Actual P-only Controller	Actual PI Controller
Percent Overshoot	46.6%	70.7%
Time Settling (sec)	388	580

The response for actual P-only and PI controller is as shown in Figure 12 and Figure 13 respectively.

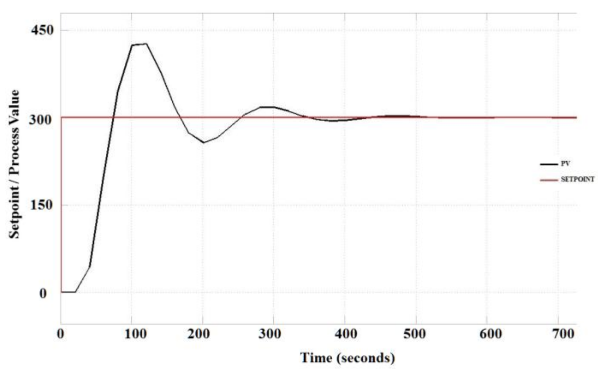

Figure 12. Actual process performance using P-only controller

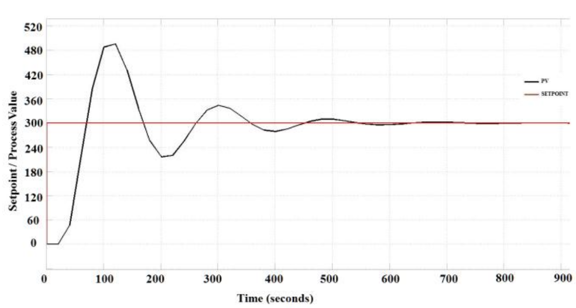

Figure 13. Actual process performance using PI controller

As shown in Table VIII, the percent overshoot of the P-only controller is lower than PI controller same as the settling time but the response is acceptable.

VII. CONCLUSION

In conclusion, it shows that the WCT-03N Water Level Control Trainer gives best performance when P-only controller is used than PI controller. It can be seen from the percent overshoot and time settling between the two controllers. It is also proved that, if the dead time divide by the time constant is less than 0.5, P-only controller is preferred over a PI controller [13].

Between the two tuning rule, Ziegler Nichols method gave better performance than Cohen-Coon method in terms of percent overshoot and settling time. Cohen-Coon tuning method is worked well since the Ziegler-Nichols only applicable when the dead time is less than ½ of time constant, while Cohen-Coon can tolerable until ¾ of time constant [14].

From the result between the simulated and experimental work, it can be concluded that there is not so much difference of percent overshoot and settling time. It can be done by following the right procedure, especially on the experimental works.

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