MONITORING AND CONTROLLING A PROCESS USING OVERRIDE CONTROLLER & ANTI WINDUP

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FINAL PROJECT REPORT

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CERTIFICATION OF APPROVAL

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Approved:

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Dr. Nordin Bin Saad
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

June 2009

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Nur Syukriyah Asriyah Bt Abdul Jalil

ABSTRACT

The project involves the design and analysis and implementation of controller for industrial process plant. The objectives of the project are to design an override controller and anti windup for the control of pressure in a Gaseous Pilot Plant via real-time using Matlab/Simulink.. The Gaseous Pilot Plant in the Plant Process Laboratory, Universiti Teknologi PETRONAS is chosen as the case study. Specifically, the focus is on the monitoring and controlling the pressure of the gas medium in the Gaseous Pilot Plant. The PID and Override controllers operate based on the characteristic and properties of the process. The response of the pressure can be controlled and monitored in real-time during the experimentation process. These involved an extensive study to understand the process plant operation and obtaining its parameters for use in the PID controller have been conducted. Modeling and simulation involves the Matlab/Simulink modeling and the PID controller design. The external feedback is implemented to reduce the anti windup. The results indicate that the override control and anti-windup can be achieved for PI control. In the case for PID, the responses are too fast, while very slow performance for the P control.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

P	Proportional
I	Integral
D	Derivative
PID	Proportional, Integral and Derivative
Z-N	Ziegler- Nichols

CHAPTER 1
INTRODUCTION

1.1 Background of study

One of the main issues in a plant is on controlling and monitoring the pressure of a process. This project attempts to answer several issues related to the computer control of a plant. In this project a Gaseous Pilot Plant has been selected as the case study. The Gaseous Pilot Plant involves variables such as flow, pressure, level and temperature. The variables need to be set according to the process involved in the plant. The focus of this project is on the controlling and monitoring of the pressure in a gaseous pilot plant. The pressure should be maintained at its desired value when the disturbances occur. Also, in some processes the pressure has to response when there are changes in the desired value. Notably, there are seven control objectives in an industrial plant and they are the safety, smooth operation, product quality, equipment protection, environment protection, product quality, profit optimization and operation monitoring. The PID controller will be designed as the pressure controller. It is a feedback controller in which the output is the error between user-defined set point and measured process variable. Each element of the PID controller refers to a particular action taken on the error. The control actions will affect the control loop performance.

The immense majority of the controllers used in industry are still of the PID type. Most feedback loops are controlled by this algorithm or its minor variations. PID controllers have become the bread and butter of control engineering practice for a long time and have been implemented in many different forms, as stand-alone regulators or as a part of DDC packages or hierarchical distributed control systems. The derivative action is frequently switched off for the simple reason that it is difficult to tune properly.

This situation has renewed interest of control researchers and practitioners in PID control. Despite using the PID control, override control method also will be used in this project. Override method control is used to take control of an output from one loop to allow a more important loop to manipulate the output. Override method is more to enhance the safety of the equipment and the process itself. Override control or constraint control is a powerful yet simple control strategy generally used as

(1) A protective strategy to maintain process variable within the limits that must be enforced to ensure the safety of personnel and equipment, and product quality.
(2) An optimization strategy that permits smooth transition between controllers to obtain maximum benefits.[1]

Override control is a form of multivariable control in which a manipulated variable can be set at any time by one of a number of different controller variables. When a controller with integral action (PI or PID) sees an error signal for a long period of time, it integrates the error until it reaches a maximum (usually 0%). This is called anti windup. A sustained error signal can occur for a number of reasons, but use of override control is one major cause. If the main controller has integral action, it will wind up when the override controller has control of the valve. And if the override controller is a PI controller, it will wind up when the normal controller is setting the valve. So this anti windup problem must recognize and solved.

Reset windup causes very poor control performance. It is because of the changes in controller operation, the controller is again able to adjust the final element and achieve zero offset. The anti windup has caused a very large positive value of the error occurred for a long time. To reduce the integral term, the error must be negative for a very long time. Therefore, the controllers maintain the final element at the limit for a long time simply reduces the improper "wound-up" value of the integral mode.

This accomplished in a number of different ways, depending on the controller hardware and software used. In pneumatic controllers, anti windup can be prevented by using external anti feedback (feeding back the signal of the control valve to the anti chamber of the controller instead of the controller output).

This lets the controller integrate the error when its output is going to the valve, but breaks the integration loop when the override controller is setting the valve. Similar strategies are used in analogue electronics. In computer control systems, the integration action is turned off when the controller does not have control of the valve.

1.2 Problem Statement

The controlling system in the industrial process plant can be done manually by the operators or automatically by the computer control. The control strategy is based on the decision of many aspects that includes the performance requirements of the process designs in Gaseous Pilot Plant involves the measurement of the process variable, final control element characteristic, control structure in Matlab/Simulink and also control calculation for the best performance. All disturbances need to be considered and analyzed to prevent them from disturbing the control loop. In this project, the requirements are that a pressure and flow controller will be developed and response based on the requirement either from the operator or the process itself. The controller should perform well between the operation range and at the desired set point despite of the disturbances. The stability of the system is also taken into consideration. The windup that will occur during the process will be eliminated or reduce using the anti-windup technique.

1.3 Objectives & Scope of study

In particular, this study will be on monitoring and simulating control of a pressure vessel in a gas plant. Basically, the one loop pressure plant consists of a main vessel, a pressure transmitter, a controller, and a control valve. The main objectives of this project are

- To control and maintain the pressure in the vessel using the override method.
- To design the PID controller to control the pressure at the Gaseous Pilot Plant
- The controller should be able to response to give the best performance in the control loop. The system must be stable within the process range and plant requirement.
- To enhance the safety of the equipment and process by controlling and maintain the pressure.

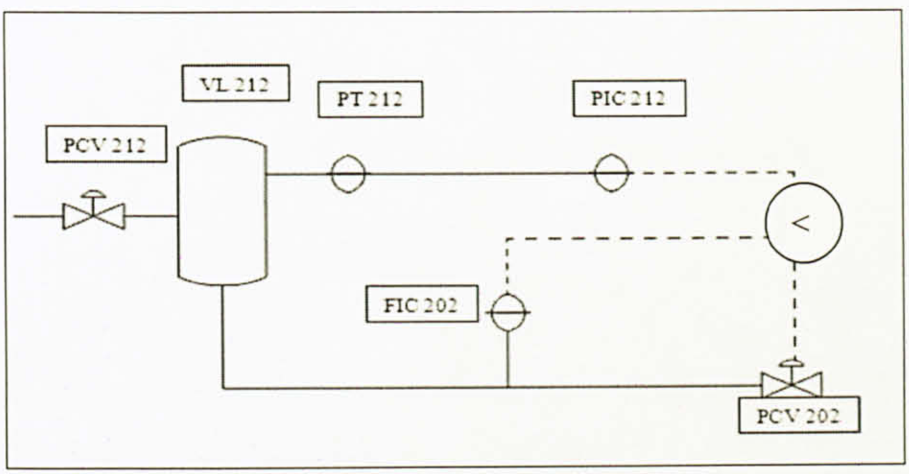


Figure 1: Block Diagram of the Process

CHAPTER 2
LITERATURE REVIEW

A proportional–integral–derivative controller (PID controller) is a generic control loop feedback mechanism widely used in industrial control systems. A PID controller attempts to correct the error between a measured process variable and a desired set point by calculating and then outputting a corrective action that can adjust the process accordingly.

The PID controller calculation (algorithm) involves three separate parameters; the Proportional, the Integral and Derivative values. The Proportional value determines the reaction to the current error, the Integral determines the reaction based on the sum of recent errors and the Derivative determines the reaction to the rate at which the error has been changing. The weighted sum of these three actions is used to adjust the process via a control element such as the position of a control valve or the power supply of a heating element.

By "tuning" the three constants in the PID controller algorithm, the controller can provide control action designed for specific process requirements. The response of the controller can be described in terms of the responsiveness of the controller to an error, the degree to which the controller overshoots the set point and the degree of system oscillation. Note that the use of the PID algorithm for control does not guarantee optimal control of the system or system stability

Override control is used to take control of an output from one loop to allow a more important loop to manipulate the output. The outputs from two or more controllers are combined in a high or low selector. The output from the selector is the highest or lowest individual controller output. The selector is shown in the diagram by the < or > symbol.

Many chemical processes have constraint placed on the operating variables such as: reactor temperature cannot exceed a specified value or pressure drop must be kept below a maximum limit etc. Under normal operating conditions these variables may not be at or near the constraints. However, the presence of disturbances can cause the variables to approach or even violate the bounds placed on them.

Override or constraint control is used to prevent such constraint violations. The idea is to activate a controller when the constraint is approached and then use this controller to keep the variables at the constraint. When the conditions change so that the process no longer needs to operate at the constraint, the controller should become inactive.

The topic of anti-windup has been studied over a long period of time by many authors, and the most popular techniques are described in [1, 2 and 3]. To avoid windup, it is obviously desirable to limit the integral portion so that its contribution never exceeds the amount needed for the controller output to reach limit. This limiting is called "anti-reset windup" (AW). In the case of auto – manual mode switching, the method that aims to minimize the jump at the plant input is referred to as the bumpless transfer (BT). The AW techniques are aimed at reducing the undesirable windup effect (large overshoot and settling time). A common way to handle this problem is to take into consideration the plant input limitation and to add extra feedback compensation (that feeds back discrepancy between controller output and pant input to the integral term) at the stage of control implementation. This scheme is referred to as the linear feedback AW algorithm.

CHAPTER 3
METHODOLOGY

A revision on the process control area gave a better understanding of the pressure control in the Gaseous Pilot Plant. The research on the PID controller has also been conducted. The research covers on the characteristic of the PID, function and effect of each controller elements. Initially, a simple model of PID controller has been developed using the Matlab/Simulink, in order to familiarize with the software. This stage helps the author to have a better understanding and knowledge about this project.

The second stage is on parameters identification. In this stage the process model is developed using the empirical method. This method ensures that proper data is generated through careful experimentation design and execution. The procedures make the best use of the data by diagnosing and verifying results from the initial model parameters calculations. The process model is calculated and the initial value of the PID controller is determined by the Ziegler – Nichols. These methods involved the open loop and closed loop analysis. We will get value for ultimate gain, Ku and ultimate period, Pu.

The third stage is finding the transfer function of the pressure and flow that will be used in this experiment. The value of ultimate gain and ultimate period will be used to obtain the transfer function which will be used to simulate the controller. Three step tuning will be developing during this stage. The first step will determine the feedback process model by fundamental modeling or empirical model, using either process reaction curve or statistical identification method. Second stage, the initial tuning constant values will be determined and the last step for this stage is test of the closed-loop control system and fine tuning if necessary.

The fourth stage is on simulation. The computer simulation stage involves the design of the override method, PID controllers, block diagram arrangement and simulating the system. The system is developed in the Matlab/Simulink and also in LabVIEW for the monitoring purpose. The block diagram consists of the input and output block of the process variables, PID controller block, digital driver that connect the software to hardware, scopes and other related control system blocks. The system is simulated using the initial values of the PID controller from the previous stage. The responses are compared and the best parameter is determined.

The final stage is the plant experimentation. The parameters of the PID controller are used for the online real-time tuning. During the online tuning the other process value is set to constant values to get the best tuning result. The PID controller and the fuzzy logic controller with the best parameters are tested online to ensure the system is stable during running. The performance check is done to evaluate the performance of the PID controller.

3.1 Flowchart

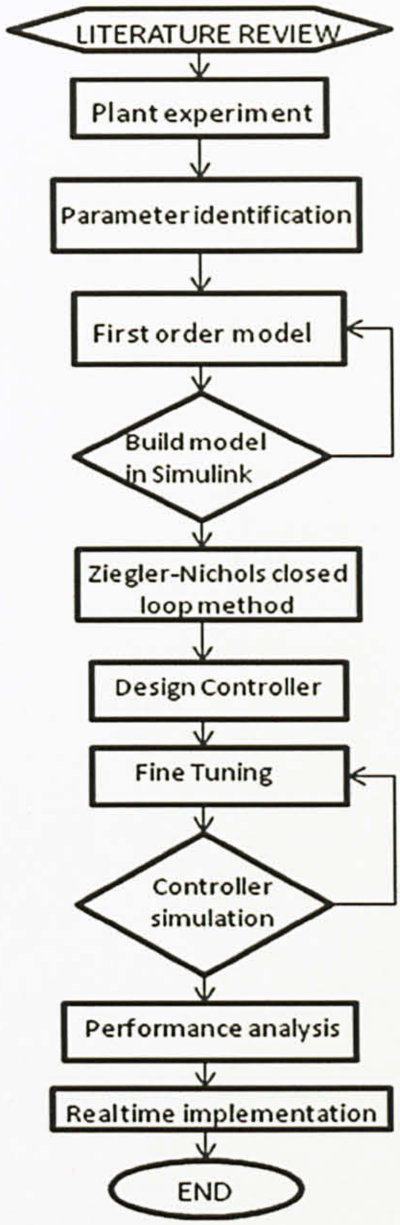


Figure 2: Flowchart

3.2 Tools

Matlab/Simulink software

Matlab/simulink is the powerful software to for modeling, simulating and analyzing dynamical systems. In this project, it is use to design, tune, test and simulate the PID controller. The control block diagram is constructed in the Simulink.

LabVIEW Application

LabVIEW application is one of the real time monitoring system. In this project, it is used to monitor the process during the experiment. In the LabView, the process variables that have to be monitored can be specified and represent in the graphic. The LabView is connected to the Gaseous Pilot Plant by the xPC target and can run simultaneously with the Matlab/Simulink application.

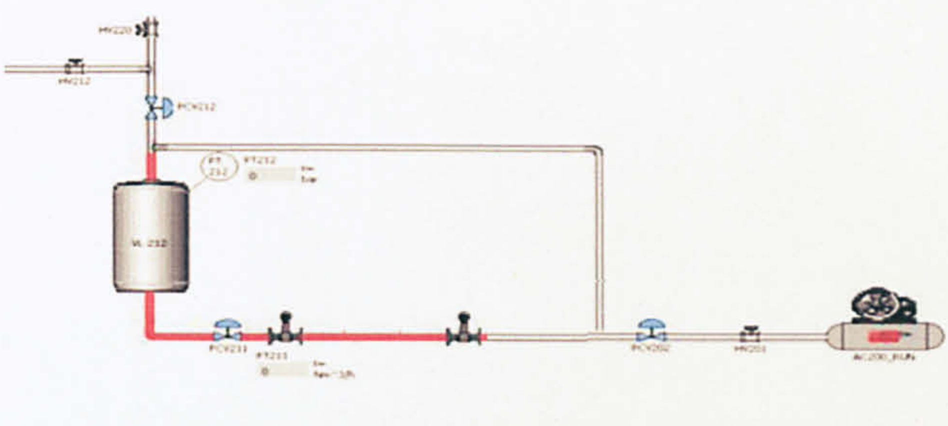


Figure 3:LabView Block diagram for Realtime Monitoring

Gaseous Pilot Plant is the process plant that been used as the case study. The pilot plant is situated in the Plant Process Laboratory at Block 23, Universiti Teknologi PETRONAS. The gaseous pilot plant used in this project consists of real equipments and components which can be found any industrial process plant such as valve, transmitters, controller and others instruments.

xPC target industrial PC

xPC target industrial PC acts as server and interface system to connect the Simulink model and Gaseous Pilot Plant. The xPC target is connected to the gaseous Pilot Plant by the Local Area Network, 100 Mbps. The signal from Simulink model is to write to the server via xPC target scope block. The xPC target root automatically creates the scope on the target when the target application is downloaded to the target PC. For this project, the target is UTP workstation 2. The workstation consists of the computer with XP operating system and uninterruptible power supply.

3.3 Loop Tuning

3.3.1 Ziegler-Nichols Closed Loop

Ziegler-Nichols Method is straightforward. Firstly, set the controller to P mode only. Then, the gain of the controller (Kc) will be set to small value. Observe the response of the controlled variable when make a small set point. The response would be sluggish if the Kc is low. To obtain the good response, increase the Kc by a factor of two and make another small change in the setpoint. Remain increasing Kc (by a factor of two) until the response become oscillatory. Finally, adjust the Kc value until a response is obtained that produces continuous oscillations. This is known as the ultimate gain (Ku) and the period of the oscillations (Pu). The control laws setting are obtained from the following table.

Controller	**Proportional time, Kp**	**Integral time, Ti**	**Derivative time, Td**
P	Ku/2	-	-
PI	Ku/2.2	Pu/1.2	-
PID	Ku/1.7	Pu/2	Pu/8

Table 1: Ziegler-Nichols Closed Loop Method

3.3.2 Ziegler-Nichols Open Loop

This method is for determining the tuning constants for a controller by testing the process variables response to change in the control variable output in an open loop system.

Controller	**Proportional time, Kp**	**Integral time, Ti**	**Derivative time, Td**
P	$\frac{\tau}{Kp\theta}$	-	-
PI	$\frac{0.9\tau}{Kp\theta}$	$\frac{\theta}{0.3}$	-

PID	$\frac{4\tau}{3Kp\theta}$	$\frac{\theta}{0.5}$	0.5θ

Table 2: Ziegler- Nichols Open Loop Tuning Method

3.3.3 Cohen Coon Method.

Cohen-Coon method depends upon the identification of a suitable process model. Cohen-Coon recommended the following settings to give responses having ¼ decay ratios, minimum offset and other favorable properties. The Cohen-Coon methods have modified the Ziegler-Nichols open loop tuning rules. The Cohen-Coon tuning parameters are given in Table 3.

Controller	**Proportional time, Kp**	**Integral time, Ti**	**Derivative time, Td**
P	$\frac{1}{Kp}\frac{\tau}{\theta}\left(1+\frac{\theta}{3\tau}\right)$	-	-
PI	$\frac{1}{Kp}\frac{\tau}{\theta}\left(\frac{9}{10}+\frac{\theta}{12\tau}\right)$	$\theta\frac{30+3(\theta/\tau)}{9+20(\theta/\tau)}$	-
PID	$\frac{1}{Kp}\frac{\tau}{\theta}\left(\frac{4}{3}+\frac{\theta}{4\tau}\right)$	$\theta\frac{32+6(\theta/\tau)}{18+8(\theta/\tau)}$	$\theta\frac{4}{11+2(\theta/\tau)}$

Table 3 : Cohen Coon Tuning Method

3.3.4 Choosing Tuning Method

Choosing a Tuning Method		
Method	**Advantages**	**Disadvantages**
Manual Tuning	No math required. Online method	Requires experienced personnel
Ziegler- Nichols	Proven method. Online method	Process upset, some trial-and-error, very aggressive tuning
Cohen-coon	Good process models	Some math. Offline method. Only good for first-order processes.

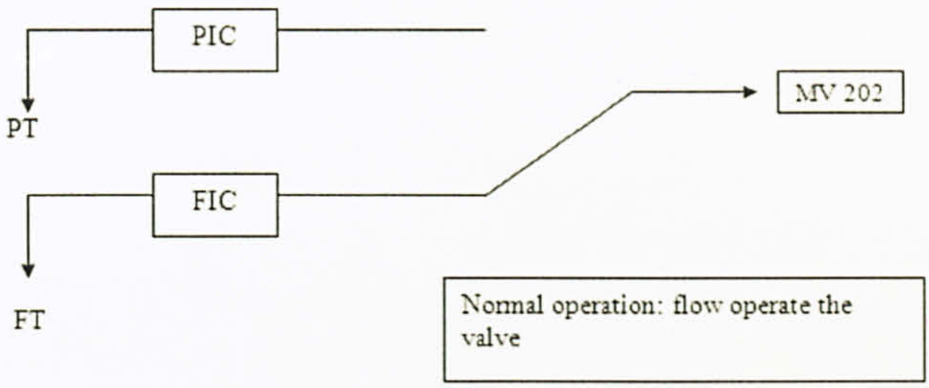
Table 4 : Tuning Method Advantages and Disadvantages

From the table above, the Ziegler-Nichols tuning method been selected for this project. This is because of the response of the P, PI and PID value is better from the Cohen Coon method. The PID value for both tuning method being test in the simulation and the result been discussed in Chapter 4.

CHAPTER 4
RESULT AND DISCUSSION

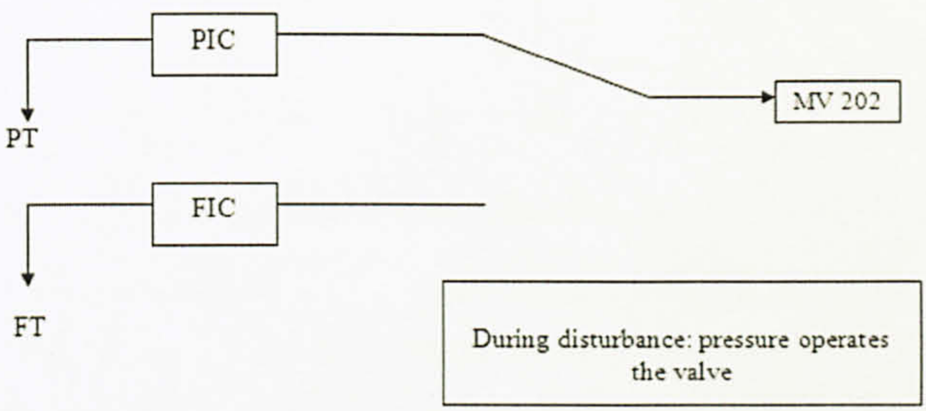
4.1 Result

The override method is more on switching model. The pressure in the vessel 212 must be maintained above a minimum pressure. The flow of the gas is controlled by FIC-202. During the normal operation, the flow will operate the valve and the pressure controller will be inactive. When the pressure fall below its set point, the pressure controller will operate the valve and the flow controller will be inactive. If FIC is no longer active when the pressure drop is no longer at the set point, this implies that the integral term in the controller equation will keep on accumulating (anti windup). When the disturbance is no longer present, the flow will have to go below its set point before FIC will recover from its wound position. To prevent anti windup, each controller is provided with another feedback input which is used by the controller to see if it is selected (active) or not. If it is not selected the controller turns off the integral action thus preventing unnecessary accumulation of error in its output.



Normal Operation: Above minimum set point 5 barg

Figure 4: Override method (Normal operation)



During disturbances: Below set point 5 barg

Figure 5: Override method (during disturbance)

Gaseous Pilot Plant - Air Flow Process Overall

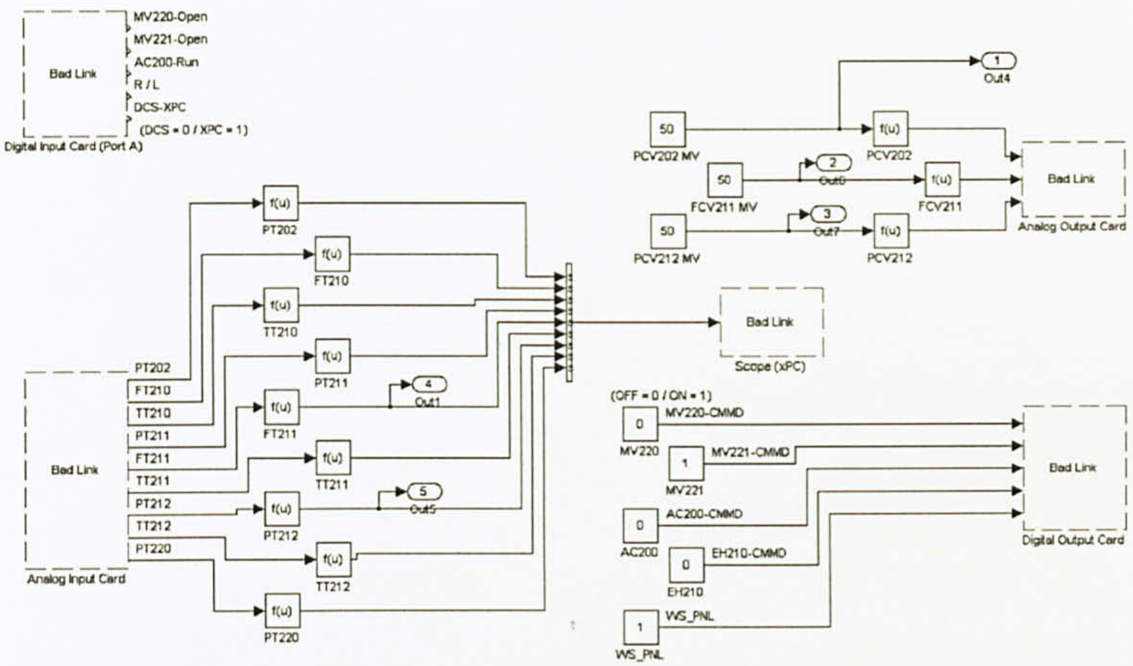


Figure 6: Schematic Diagram of Air Flow Process Overall

The method suggested in [7] is used to yield the plant transfer function to be used for flow and pressure controller analysis. The empirical model of the flow and pressure model is developed based on process reaction curve of the pilot plant. The purpose of process reaction curve is to identify the dynamic model which will be used on the first-order with dead time model. For this loop, the manipulated variable is PCV 202 and the disturbance is PCV 212.

There are 4 parameters that need to be determined, which are:

- Changing PCV 202, take the reading of FT 211

- Changing PCV 212, take the reading of FT 211
- Changing PCV 202, take the reading of PT 212
- Changing PCV 212, take the reading of PT 212

Figure 6 demonstrates the process reaction curve obtained from plant experiment is a first order with dead time response. The input step change is 20% valve opening. From the process reaction curve, transfer function of first order with dead time will be obtained. Hence, the general first order plus dead time model transfer function is,

$$\boxed{\frac{Y(s)}{X(s)} = \frac{K_p e^{-\theta s}}{\tau s + 1}}$$

Transfer function 1 (TF 1) = PCV 202 → PT212

Transfer function 2 (TF 2) = PCV 202 → FT211

Transfer function 3 (TF 3) = PCV 212 → PT 212

Transfer function 4 (TF 4) = PCV 212 → FT211

For the overall

PCV 202 = transfer function of FT 211 + transfer function of PT212

PCV 212 = transfer function of FT 211 + transfer function of PT212

4.2 Process model with transfer function

4.2.1 FT211 vs PCV212

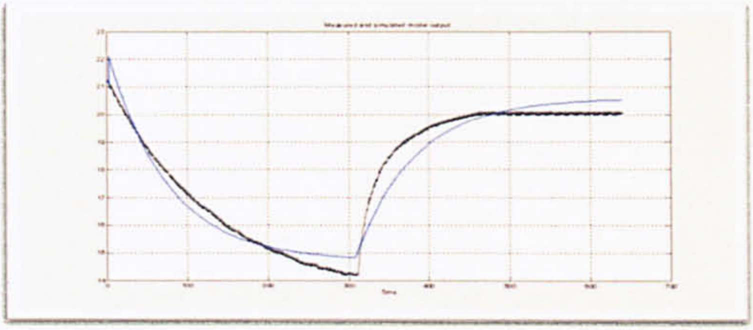


Figure 7: Process Reaction Curve for FT211 vs PCV 212

Transfer Function:

$$\frac{Kp\ e\text{-}\theta s}{\tau s+1} = \frac{1.29419\ e^{-84}}{73.682s+1}$$

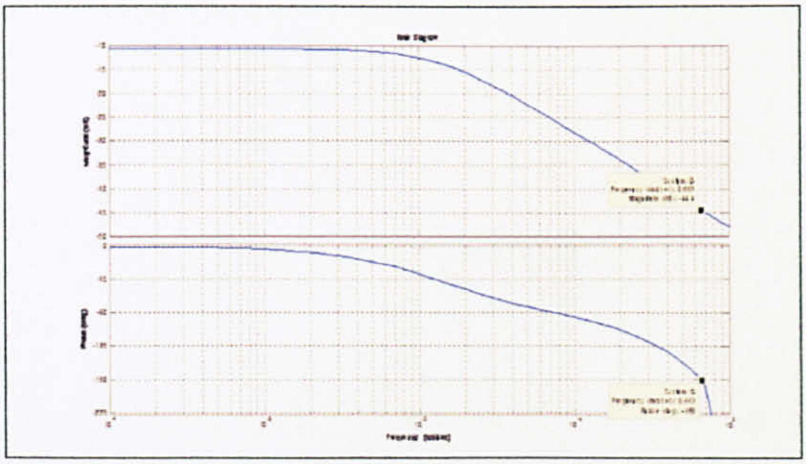


Figure 8 : Bode Plot for FT211 vs PCV212

From the bode plot

Ku= 186.2087, Pu=8.423

PID value

Controller	Proportional time, Kc	Integral time, Ti	Derivative time, Td
P	93.10	-	-
PI	84.64	7.02	-
PID	109.53	4.2115	1.052875

Table 5: PID value for FT211 vs PCV 212 Z-N Closed Loop Tuning

Controller	Proportional time, Kc	Integral time, Ti	Derivative time, Td
P	67.78	-	-
PI	61.002	27.72	-
PID	81.3358	16.8	4.2

Table 6: PID value PT212 vs PCV 212 using Cohen Coon Tuning Method

4.2.2 *PT212 vs PCV212*

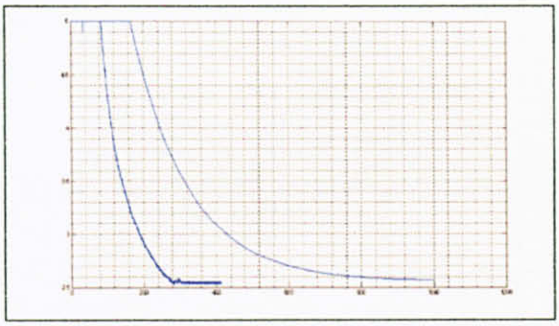


Figure 9: Process Reaction Curve for PT212 vs PCV212

Transfer function

$$\frac{Kpe^{-\theta s}}{\tau s+1} = \frac{-0.1225\ e^{-8.4}}{15.52s+1}$$

Bode plot diagram

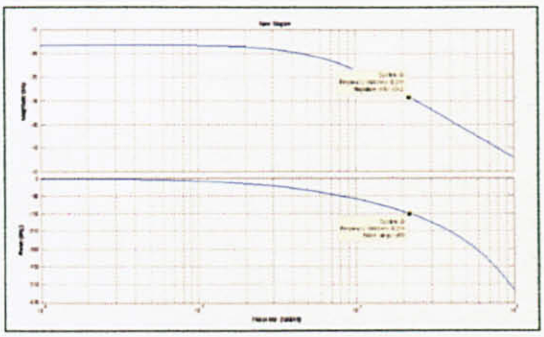


Figure 10: Bode Plot for PT212 vs PCV 212

From the bode plot

Ku= 28.84, Pu=28.69

Controller	Proportional Time, Kc	Integral time, Ti	Derivative time,Td
P	14.42	-	-
PI	13.11	23.90	-
PID	16.96	14.345	3.58625

Table 7: PID value for PT212 vs PCV212 Z-N Closed Loop Tuning

Controller	Proportional Time, Kc	Integral time, Ti	Derivative time,Td
P	-9.6359	-	-
PI	-4.1754	13.3998	-
PID	-6.4883	17.085	2.7809

Table 8: PID value for PT212 vs PCV 212 using Cohen-Coon Tuning Method

4.2.3 *FT211 VS PCV 202*

Using the data from the lab, the actual process reaction curve (PRC) is shown as below

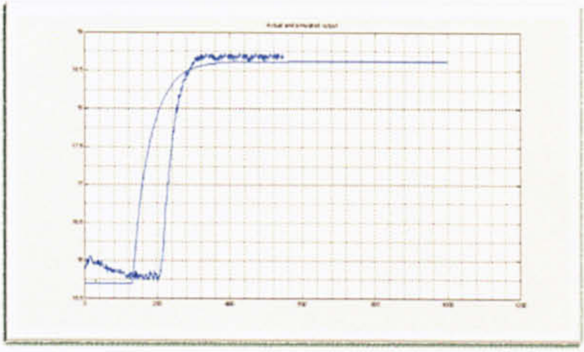


Figure 11: Process reaction curve for FT211 vs PCV 202

Transfer function that obtained from the PRC above is,

$$\frac{Kpe^{-\theta s}}{\tau s+1} = \frac{-1.46\,e^{2.9}}{4.87s+1}$$

After getting the transfer function, using the Z-N closed method (bode plot method)

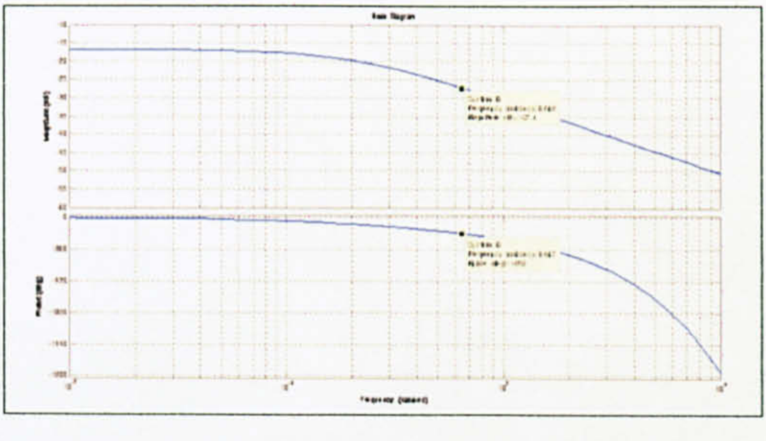


Figure 12: Bode plot for FT211 vs PCV202

From the bode plot

Ku = 22.65, Pu = 9.711

Controller	Proportional time, Kc	Integral time, Ti	Derivative time, Td
P	11.325	-	-
PI	10.295	8.0925	-
PID	13.32	4.8555	1.214

Table 9: PID value for FT211 vs PCV 202 using Z-N Closed Loop Tuning

Controller	Proportional time, Kc	Integral time, Ti	Derivative time, Td
P	-1.4718	-	-
PI	-1.0519	4.408	-
PID	-1.7050	5.8074	0.9515

Table 10 : PID value for FT211 vs PCV 202 using Cohen-Coon Loop Tuning

4.2.4 PT 212 vs PCV 202

Using the data from the lab, the actual process reaction curve (PRC) is shown as below

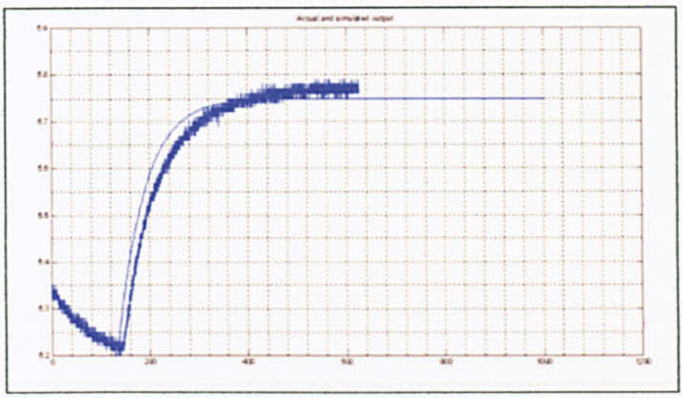


Figure 13: Process Reaction Curve for PT212 vs PCV 202

Transfer function that obtained from the PRC above is,

$$\frac{Kpe^{-\theta s}}{\tau s+1} = \frac{2.75\ e^{-3.25}}{5.5+1}$$

After getting the transfer function, using the Z-N closed method (bode plot method)

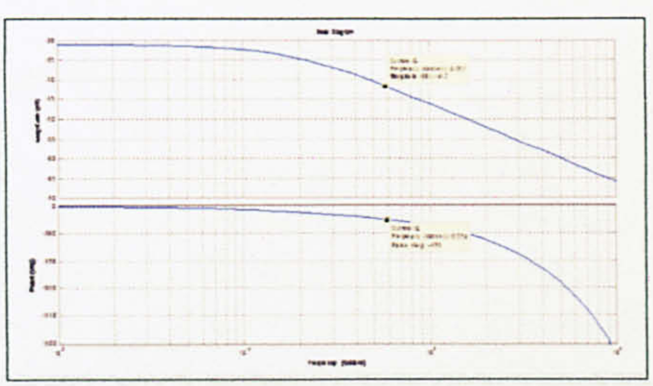


Figure 14: Bode plot for PT212 vs PCV 202

From the bode plot

Ku = 121.62, Pu = 10.76

Controller	Proportional time, Kc	Integral time, Ti	Derivative time, Td
P	60.81	-	-
PI	55.28	8.967	-
PID	71.54	5.38	1.345

Table 11 : PID value for PT212 vs PCV 202 using Z-N Closed Loop Tuning

Controller	Proportional time, Kc	Integral time, Ti	Derivative time, Td
P	0.81023	-	-
PI	0.6425	4.776	-
PID	1.003	6.51668	1.0672

Table 12 : PID value for PT212 vs PCV 202 using Cohen-Coon Loop Tuning

4.3 Performance analysis for each loop

From the PID value that obtain using the Ziegler-Nichols Closed Loop method, the performance analysis and fine tuning will be done to analyse and determine the best controller for each transfer function. This shown in figure 15. After obtain the suitable value of PID, the transfer function for each manipulated variable and disturbance will gathered in one loop to determine the PID value that suitable when the transfer function been added. Both of this performance analysis PID block shown in the Figure 16 below.

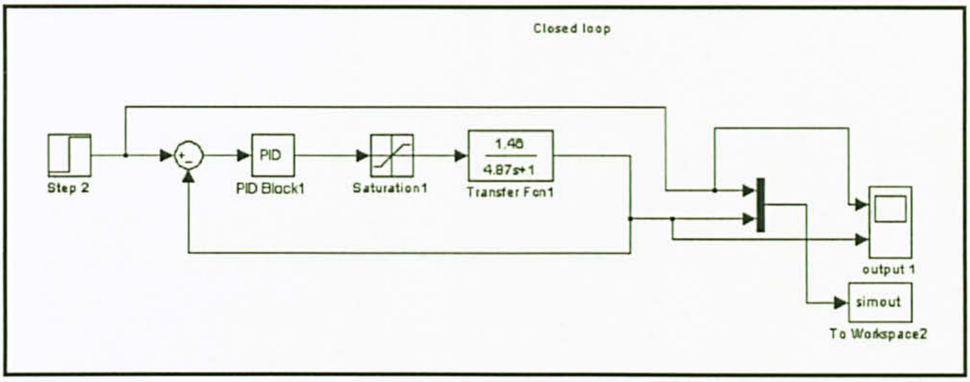


Figure 15: PID Block for Performance Analysis

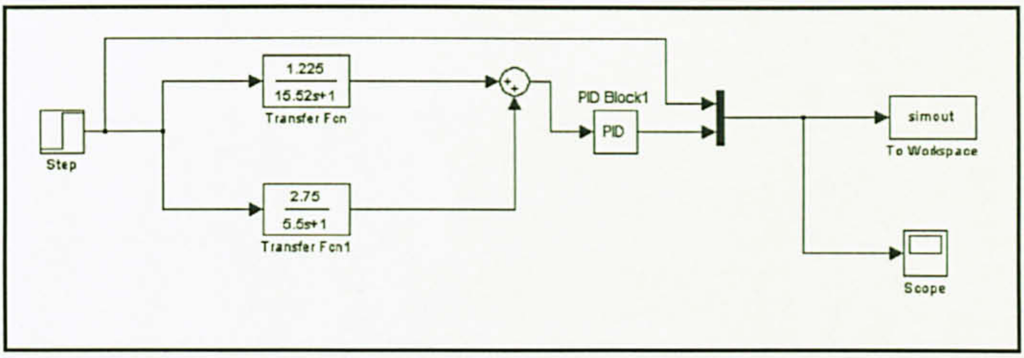
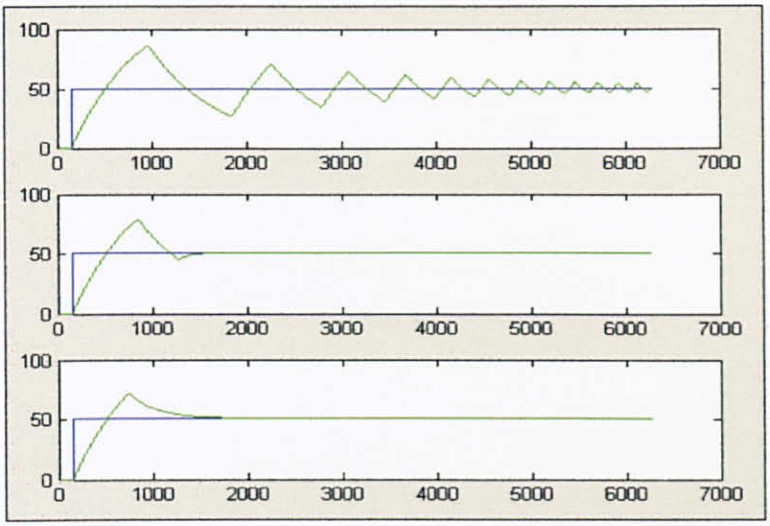


Figure 16 : PID Block for two transfer function

4.3.1 FT 211 vs PCV 212

$$\text{Transfer function} = \frac{1.29419\, e^{-8.4}}{73.682s+1}$$

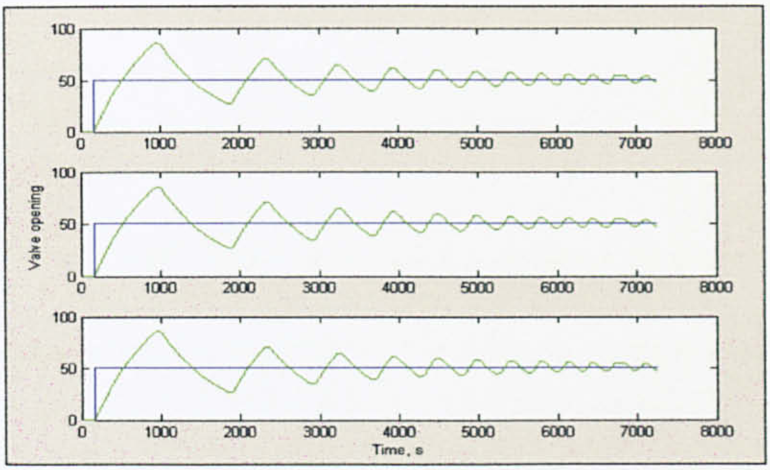


P = 93.10

P = 84.64
I = 7.02

P = 109.53
I = 4.2115
D = 1.052875

Figure 17: Performance Analysis for PID tuning using Z-N closed loop



P = 0.09144

P = 0.08012
I = 22.595

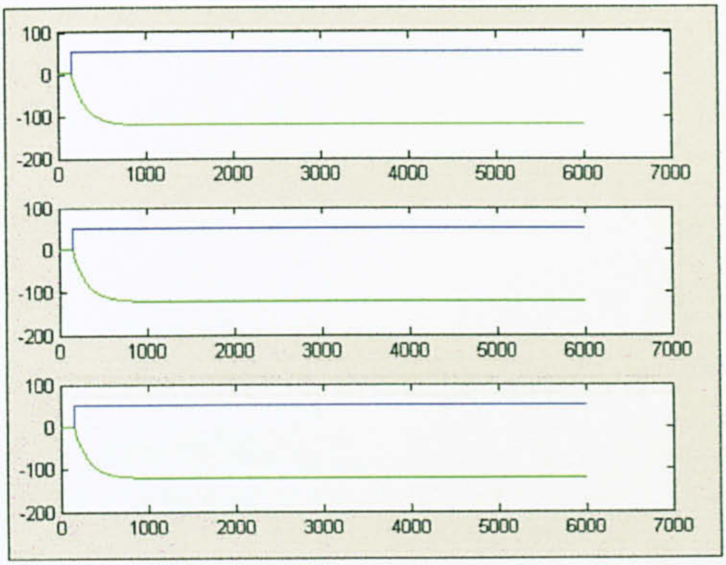
P = 0.11998
I = 19.7344
D = 2.9925

Figure 18: Performance analysis for PID tuning using Cohen Coon Method

For the Figure above, Z-N Closed Loop method is more suitable for getting the PID value based on the performance shown. The Cohen Coon method is not suitable because the settling time is larger. For a good controller, the settling time should be smaller. The PI controller of Z-N show the best performance and been chosen for FT211 vs PCV 212 controller.

4.3.2 PT212 vs PCV212

$$\text{Transfer function} = \frac{-0.1225\, e^{-8.4}}{15.52s+1}$$

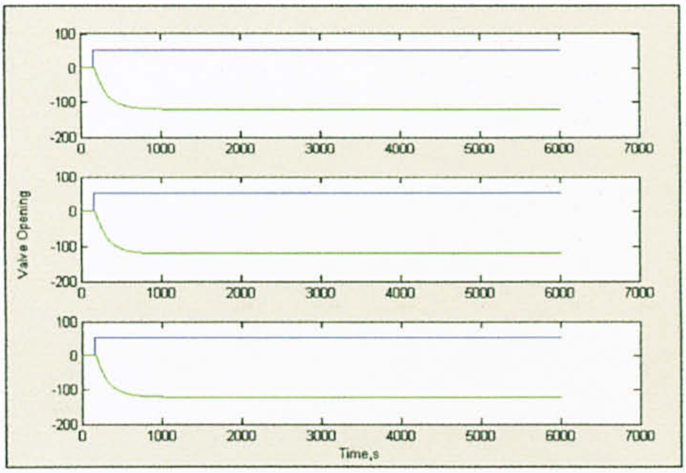


P = 14.42

P = 13.11
I = 23.90

P = 16.96
I = 14.345
D = 3.58625

Figure 19: Performance Analysis for PID tuning using Z-N Closed Loop



P = -9.6359

P = -4.1754
I = 13.3998

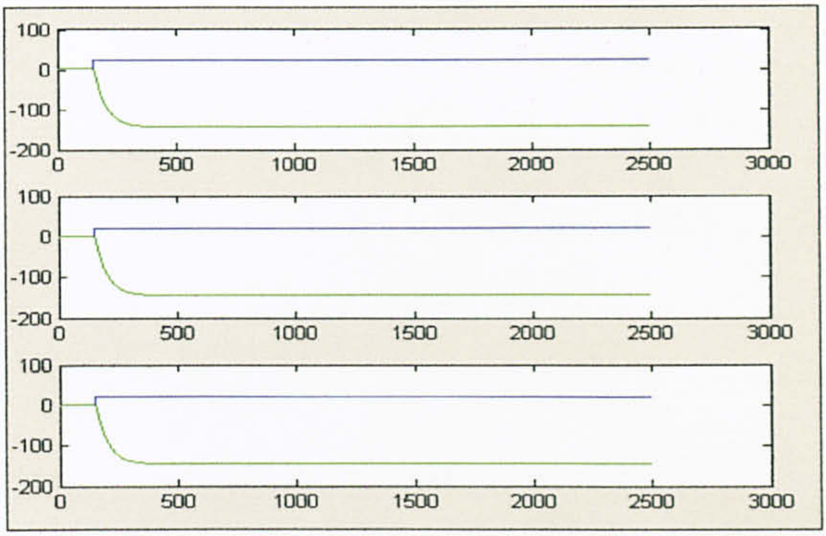
P = -6.4883
I = 17.085
D = 2.7809

Figure 20: Performance analysis for PID tuning using Cohen Coon Method

For this controller, again we choose the Z-N closed method to get the PID value. It is because of the suitability of the controller for good performance. The PI controller of Z-N closed loop been chosen for PT 212 vs PCV 212.

4.3.3 FT 211 vs PCV 202.

$$\text{Transfer function} = \frac{-\ 1.46\ e^{-2.9}}{4.87s + 1}$$

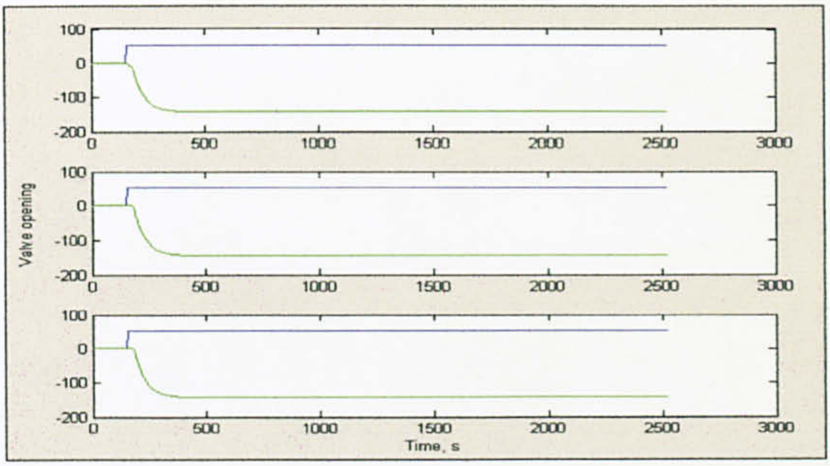


P = 11.325

P = 10.295
I = 18.0925

P = 13.32
I = 24.8555
D = 5.214

Figure 21: Performance analysis for PID tuning using Z-N closed loop



P = -1.4718

P = -1.0519
I = 4.408

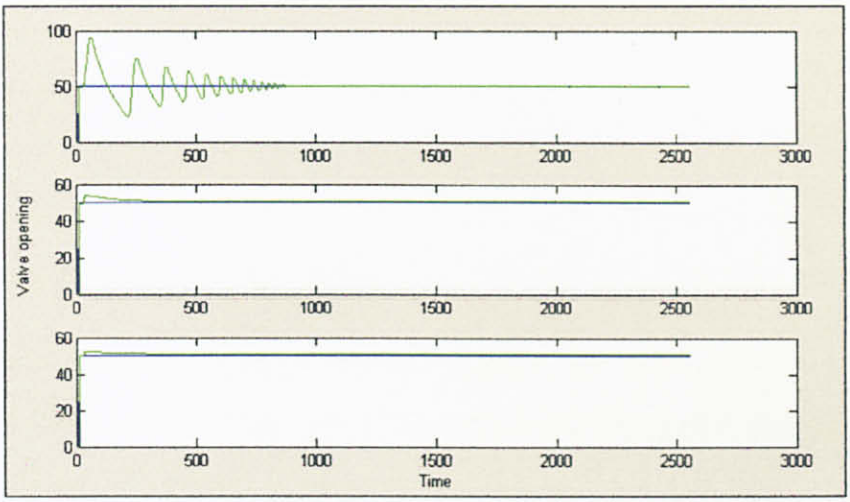
P = -1.7050
I = 5.8074
D = 0.9515

Figure 22: Performance analysis for PID tuning using Cohen Coon Method

For this controller, we choose the PI controller of Z-N closed method because of the suitability of the controller for good performance.

4.3.4 *PT 212 vs PCV 202*

$$\text{Transfer function} = \frac{2.75e^{-3.25}}{5.5s + 1}$$

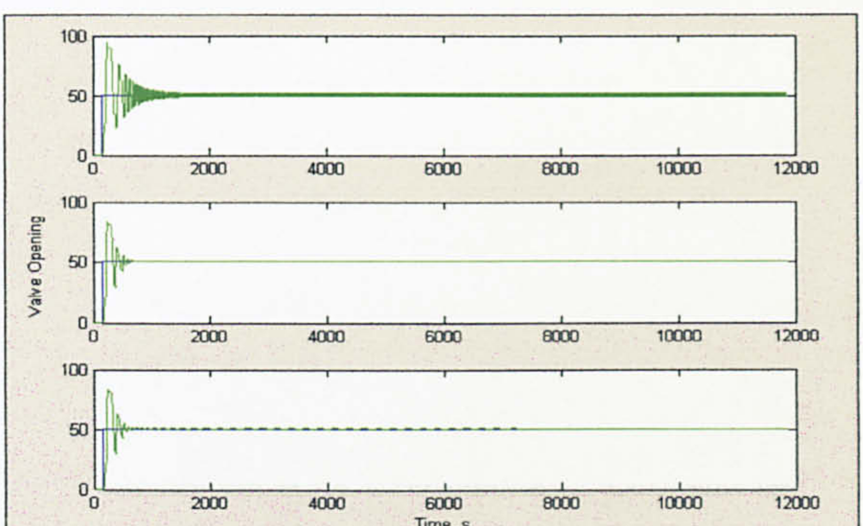


P = 60.81

P = 13.11
I = 23.90

P = 16.96
I = 14.345
D = 3.58625

Figure 23: Performance analysis for PID tuning using Z-N closed loop



P = 0.81023

P = 0.6425
I = 4.776

P = 1.003
I = 6.51668
D = 1.0672

Figure 24: Performance analysis for PID tuning Cohen Coon Method

For figure above, for P controller, both Z-N and Cohen Coon method get the response but the settling time is obviously different. P, PI and PID performance analysis for each Z-N and Cohen Coon method display the difference of their PID value. For this PT 212 vs PCV 202, PI controller of Z-N closed loop tuning been chosen for the override controller that will be design after all parameter been identify.

4.3.5 Override design

After obtain the suitable transfer function for each variable, the override controller method will be design using Simulink. Below is diagram for the override controller.

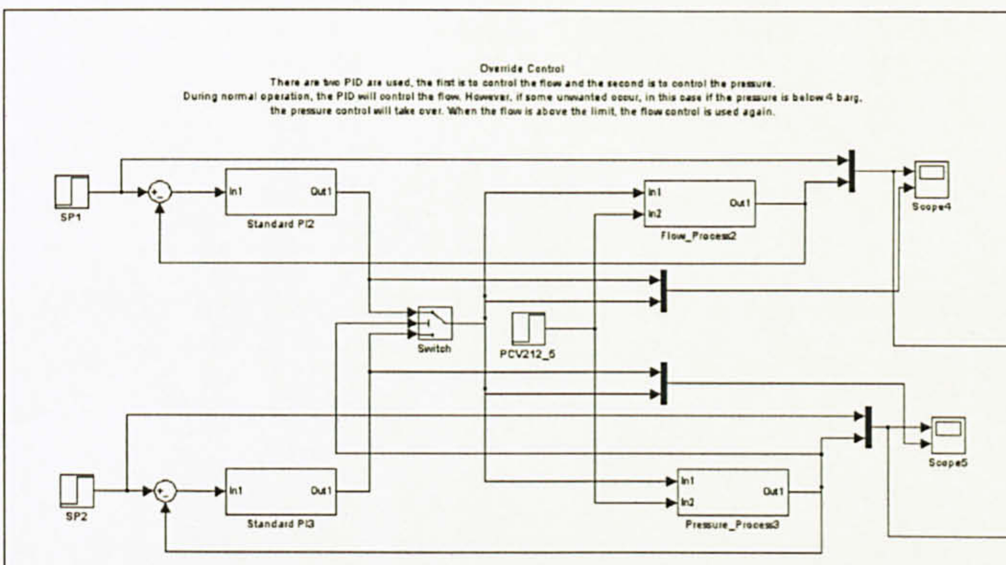


Figure 25: Basic Override Control Design

The next figure show the override controller design with and without anti wind up.

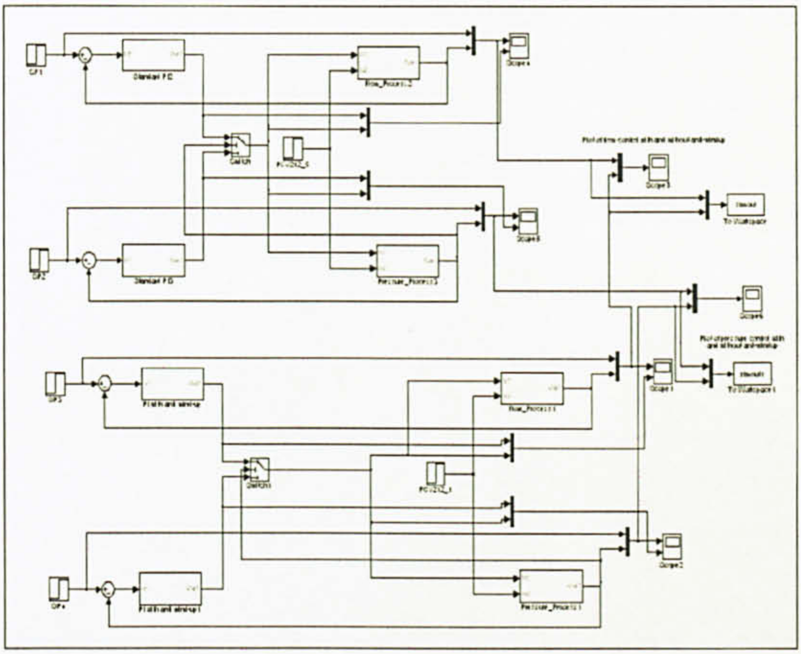


Figure 26: Override controller design with and without anti windup

Figure 25 show the detail of the PI controller design that been chosen from the performance analysis and been used in the override control design.

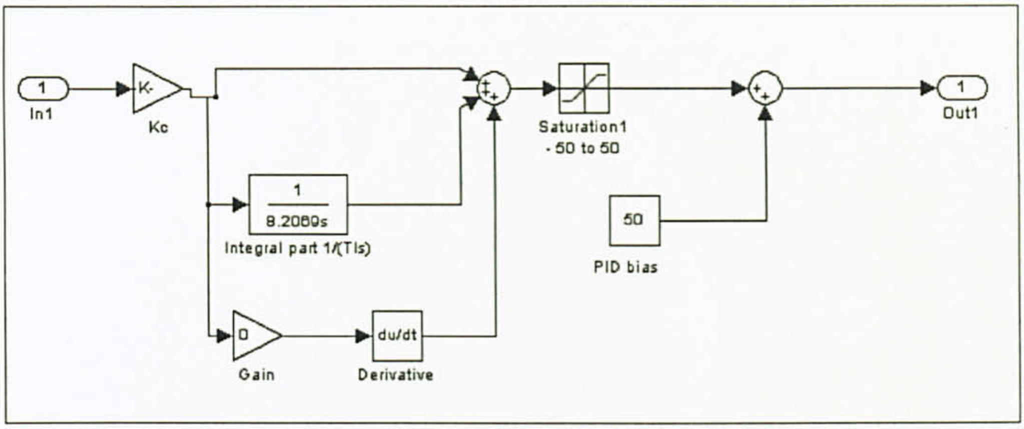


Figure 27: PI Controller for Override Control

For the override control, windup will occur. So the external feedback controller will be design to reduce the windup.

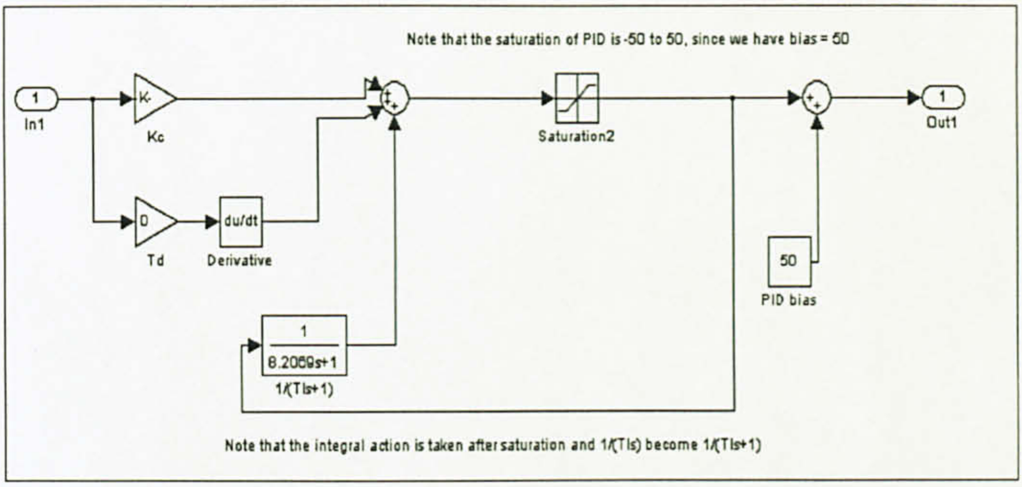


Figure 28: External Feedback Controller Design

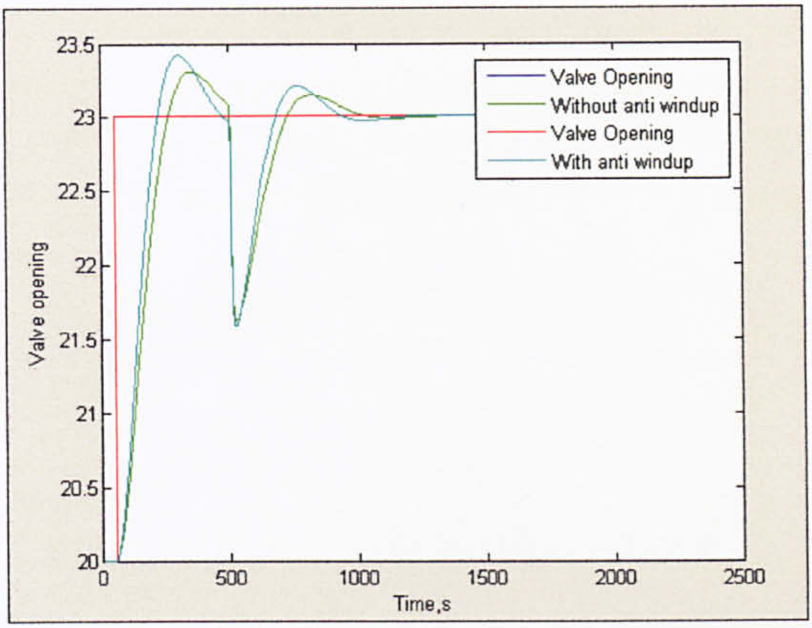


Figure 29: Simulation With and Without Anti Windup for Flow Controller

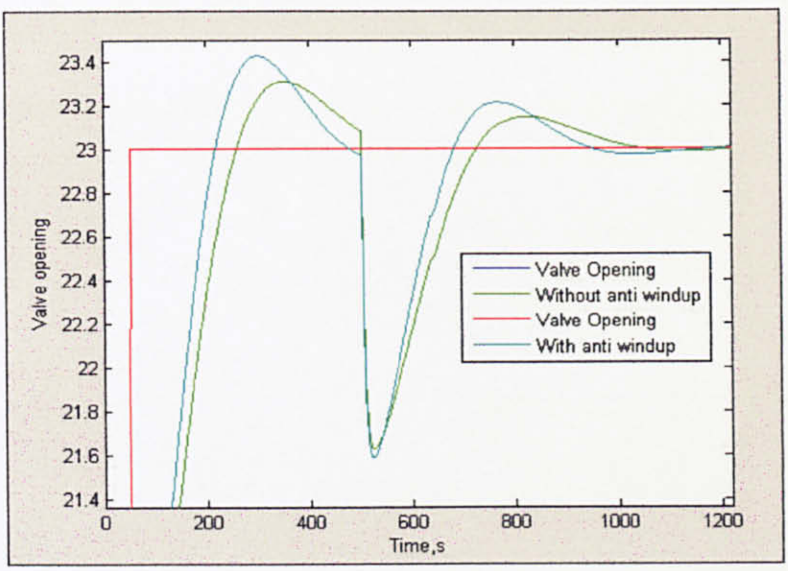


Figure 30: Simulation With and Without Anti Windup for Flow Controller

Figure 29 and 30 shows the simulation for flow controller with and without anti windup. The result been zoomed and the difference between using the external feedback can be clearly recognized in Figure 30. The external feedback reduce the windup that happen to occur when the controller switch from flow to pressure.

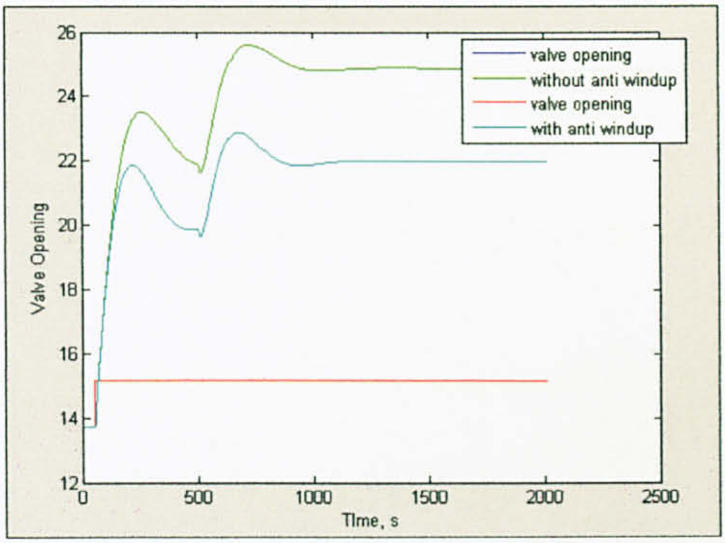


Figure 31: Simulation With and Without Anti Windup for Pressure Controller

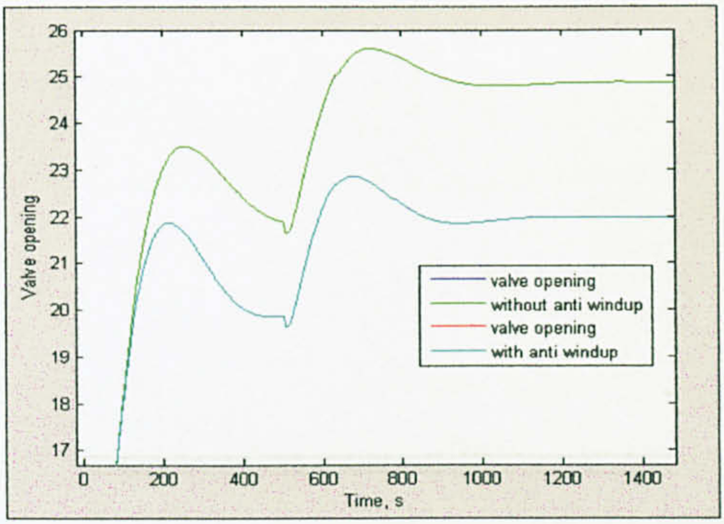


Figure 32: Simulation With and Without Anti Windup for Pressure Controller

Figure 31 and 32 shows the simulation for pressure controller with and without anti windup. The result been zoomed and the difference between using the external feedback can be clearly recognized in Figure 32. The external feedback successfully reduce the windup that happen to occur when the controller switch from flow to pressure.

4.4 Comparison

The figure below shows the comparison between using the anti windup and without using the anti windup.

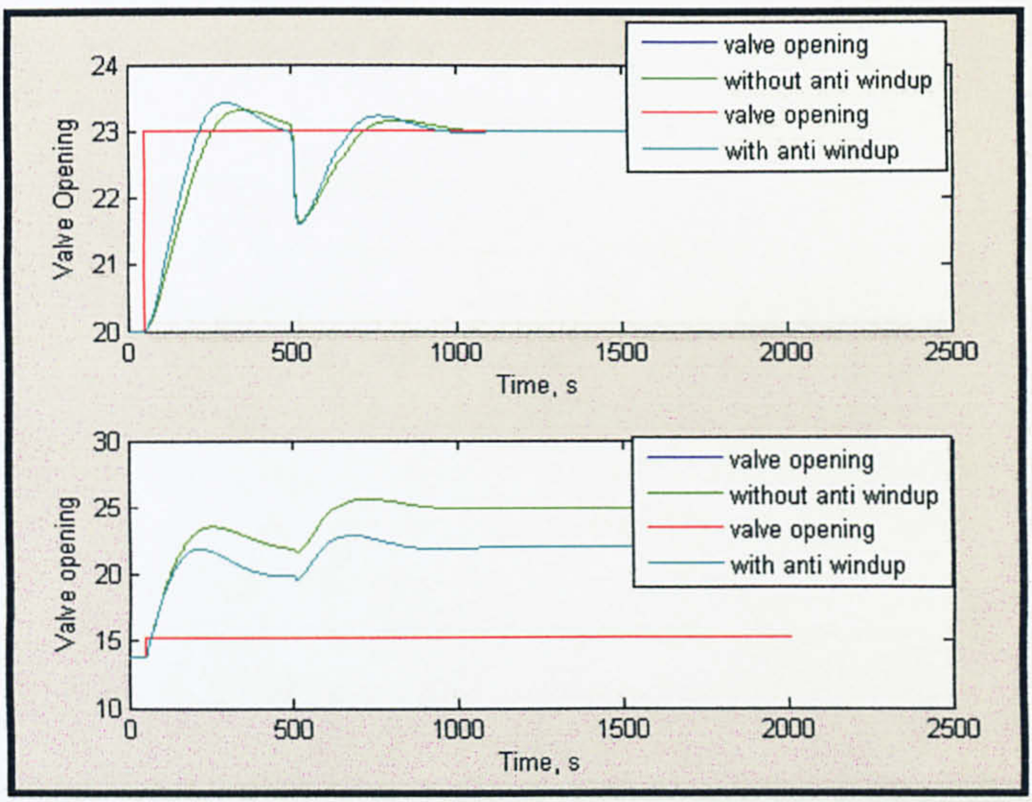


Figure 33: Comparison Between Anti Windup and Without Anti Windup.

Figure above shows the anti windup protection scheme. The external feedback PI controller is shown in Figure 28. The system behaves exactly like the standard algorithm when the limitation is not active, as demonstrated by the transfer function based on figure below. External feedback is successful in providing anti-windup. Figure 33 displays the closed-loop performance when an anti windup which is external feedback control scheme is used. The comparison against the performance without using anti windup is also shown clearly demonstrates the advantages of the anti windup control.

4.5 Discussion

From the process reaction curve obtained, first step to be done is, determine the feedback process model by fundamental modeling or empirical modeling, using either process reaction curve or statistical identification method.

(i) Research on the empirical model identification.

a. Empirical model should be analysis using the six procedures. This procedure should ensure the proper data is generated through careful experimental design and execution. The procedures also make the best use of the data thoroughly diagnosing and verifying results from the initial model parameter calculations.

b. At the completion of the 6 procedures, an adequate model will be determined.

c. Six procedures are experimental design, plant experiment, determine model structure, parameter estimation, diagnostic evaluation and model verification.

(ii) From the transfer function obtained from the measured and simulated output, the PID tuning based on stability obtained. For defining and provides a comprehensive of control performance that is flexible enough to represent most situations. There are goals that need to be aimed; Controlled-variable performance. The well-tuned controller should provide satisfactory performance for one or more measures of the behavior of the controlled variable.

a. Model error.
b. Manipulated-variable behavior.

There are 2 steps that need to be done for finding the relevant PID constant before designing the override controller. The steps are;

a. The initial value tuning constant values would be determined; typically the values would be determined from the general correlations.
b. The final step involves a test of the closed-loop control system and fine tuning if necessary.

(iii) After analyze the suitable transfer function for each variable, design the override controller using Simulink. Form the override controller, analyze the output and wind up occurred. For this project, the aim is to minimize the wind up.

The final stage is designing the override controller. The computer simulation stage involves the design of the override method, PID controller; block diagram arrangement and simulating the system. The system is developed in the Matlab/Simulink and also in LabVIEW for the monitoring purpose. After getting the output and analyzing the graph, wind up happen and this should be eliminate because it will affect the controller performance. Design anti anti-windup to prevent or minimize the probability of wind up from occurred.

The improper calculation can be prevented by many modifications to the standard PID algorithm that do not affect its good performance during normal circumstances. The modification that will be explained here is *external feedback* and is offered in many commercial analog and digital algorithms. The external feedback controller is shown in Figure 34. The external feedback is successful in providing anti windup.

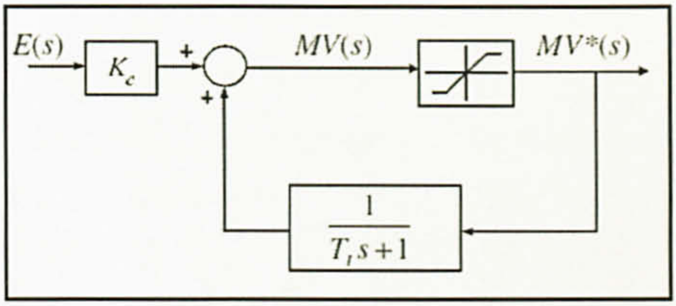


Figure 34: External feedback

CHAPTER 5
CONCLUSION

5.1 Conclusion

The override method and PI controller is chosen as the controller for the pressure control of the Gaseous Pilot Plant. Basically, it is a very common controller used in industrial control. Override method is used to control the safety of the equipment and process to maintain the pressure in the vessel. The concept of override method is to take control of an output from one loop to allow a more important loop to manipulate the output. There are three stages to complete this project. First, the research and literature review stage where useful information was gathered from research, reports and textbook. The information is very useful to gives better understanding of the project and for the project execution. The computer simulation using MATLAB/Simulink is conducted to obtain the PID controller parameters and to understand how the controller will perform. The data from plant experimentation is used for tuning, testing and performance check. The controller chosen for each flow and pressure for this override method is PI controller.

From the experiment done, when a controller with integral action (PI or PID) sees an error signal for a long phase of time, it integrates the error until it reaches a maximum scale or a minimum scale, and this is called anti windup. The use of override controller is one of major reason that causes a sustained error signal or windup. The anti windup can be prevented using external anti feedback (feeding back the signal of the control valve to the anti chamber of the controller instead of the controller output).

The external feedback successfully reduces the windup and this enhance to a better performance for the override controller. Anti windup should be included in every control algorithm that has integral mode, because limitations are encountered, perhaps occasionally, by essentially all control strategies due to large changes in operating conditions.

5.2 Recommendation for future work

The work presented in this report could still be improved as follow;

- It is worth to refine the method/ approach that can be later be implemented in real time.

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APPENDICES

External Feedback Equation

$$\frac{MV*(s)}{E(s)} = Kc\left(1 + \frac{1}{T_1 s + 1}\right)$$

$$MV*(s) = MV(s)$$

$$MV*(s) = \text{Constant}$$

$$MV(s) = KcE(s) + \frac{MV*(s)}{T_1 s + 1}$$