MODELING AND PRESSURE CONTROL SYSTEM FOR AIR PLANT

By

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FINAL PROJECT REPORT

Submitted to the Department of Electrical & Electronic Engineering
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronic Engineering)

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CERTIFICATION OF APPROVAL

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Approved:

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September 2013

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.

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Annamyrat Sapbaev

ABSTRACT

This paper present about Modeling and Controlling linear process. Currently linear process is highly important for plant operation optimization.

Modeling of the plant could be said is one of the major part of the plant, where the behavior and control tuning parameters could be dependent on it. Some problems that are met in modeling could be unpredictable behavior of the model, thus causing the tuning parameters inaccurate value, which may cause undesired output at the end. Another reason could be lack of experiment on obtained plant model.

Empirical and Statistical modeling is the technique that has been used throughout the paper. Since the Process Reaction Curve method is known as simple and reliable method to be used, obtained parameters have been compared to other parameters that have been obtained several times from the same process plant. Obtained model has been analyzed step by step, to make sure that model parameters are valid to be used.

ACKNOWLEDGEMENTS

I want to express my gratitude to all people who has been surrounding and supporting me throughout this project. I want to give my special gratitude to Ir. Dr Idris Ismail, who has been supervising me with his knowledge and experience which he has obtained from industry. Another person whom I would like to thank is Mr Azhar, the lab technician of Plant Process Lab. He is another great person who gave me advice how to handle with my real process problems, which actually helped me to overcome the constraints that I was facing.

Last but not the least, I would like to thank Universiti Teknologi PETRONAS for giving me such opportunity where I could obtain knowledge and develop my skills, which would help me a lot in my future career and life.

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INTRODUCTION

1.1 Background of study

In Control and Automation engineering field it is desired to construct the system that would be able to function under multi variable conditions and wide range of operations. The nonlinear systems control in the usage of, for ex: pH neutralization developed by input-output linearizing system controller. With the help of this method comparison of adaptive, and non-adaptive nonlinear controllers to the PI controller , the nonlinear controllers provide best tracking and tuning performance compared to PI controller. In the area of pH neutralization the nonlinear control gives best result in the range of buffering conditions.

There are three types of modeling, those are: Mathematical modeling, Empirical modeling, and Experimental modeling .For the sake of our experiment we will concentrate on Empirical modeling. The main function of Empirical modeling is controlling the process at its operational time, which is divided into two sub modeling methods:

- Reaction Curve method modeling
- Statistical method modeling

The Process Reaction Curve (PRC) method is the method of testing the process system by applying the change to its independent variable like set point. The moment when the system is operating at its stability and constant operational time, the change at the set point (not more than 20%), is applied. The respond of the dependent variable which are including dead, delay and rise times are producing the curve/slope, until it becomes constant/stable. As the curve has produced, parameters like dead, delay, rise time and other parameters can be calculated and observed. This method is known as simple and reliable methods in modeling so far.

The Statistical modeling method is basically for modeling the process. Modeling the process, and monitoring at full potential. This method takes a close monitoring and controlling and detailed parts of the process which may cause any damage to the process. Detected variations can be corrected for better process, which is the main objective of Statistical modeling method.

The modeling of the process is one of the crucial parts of the plant. It is important to get correct parameters, since the parameters obtained will decide the dynamic behavior of the plant. The model parameters are obtained in different techniques, like Mathematical, Empirical or Experimental techniques could be used to get the plant model. Since the Empirical modeling is one of the reliable techniques to be used, the parameters obtained with the help of Process Reaction Curve (PRC) Method I and Method II are used. As mentioned earlier the Empirical modeling method containing Cohen Coon, Ziegler-Nichols. With the help of this modeling method we can obtain the parameters required for analyzing and observing the plant behavior.

The control of the loop of the process is very sensitive part of the plant, since the process would not always meet the desired output, if poor controller tuning is applied. Controller of the plant is located just before the final element and process model in the plant loop. The main objective of the controller is to testify the error value difference of the process variable and achieved the desired set point. PID consists of three algorithms, Proportion (P), Integration (I) and Derivation (D). This algorithm has big role in maintaining the fast and stable response of the output, since each of those algorithm is responsible for calculating the error, which is coming from the output as a feedback loop back to controller.

Proportion algorithm, is accumulation of present error and produces proportional output value to it. Integration is dealing with accumulation of past errors and Derivative is future error based on current change. The PID controller is known as one of the best controller throughout the history of controllers. The tuning parameters can be tuned to desired value and responsiveness for the set point oscillation, overshoots and in minimization of error.

1.2 Problem Statement

Solving the control problems on-line could reduce the control constraints. Obtaining a good model of Linear Model Control highly important since they are facing some lagging and some improvement in real time application. Throughout this paper we mostly concentrate on two things.

- Modeling of desired system
- Control over the desired model

Modeling of the control system are divided into three methods. First is Experimental, second is Mathematical, and the third is Empirical modeling method. For our project we would concentrate more on Empirical modeling method, where it has two Modeling sub methods. Those are: Process Reaction Curve method, and Statistical method of modeling.

Control of the, would mostly concentrated on the application of PID controllers, and mainly tuning the system's gain.

1.3 Objective and scope of study

The objective of the study is obtaining a model of control system which would minimize the overshoot, obtain the faster settling time, and increase the response of the system at the output[1]. The modeling system optimization requires to be experimented and obtained in real time[2].

The objectives of the paper are:

- Obtaining a good model for linear process.
- Applying that model to solve non convergence optimization problem in real time system.

Obtaining good PID controller would smoothen the step response of the system and help us to get the desired output, so the most concentration will be on application of PID under different conditions (e.g. closed loop PID, PI or PD)

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

As mentioned before modeling is obtained in several ways. The Empirical and Statistical modeling methods are highly used throughout the experiment and analysis of it. Empirical model is having two techniques of tuning, which are obtained under PRC[3]. The reason why this tuning technique is highly used is that, it is visual and graphical method. Moreover this method is simplest and most used method[4].

Cohen Coon and Ziegler-Nichols are obtained from perfect step change (usually a unit input) in the input. Before the parameter calculations are done. It is advised to make sure on the certain criteria in the input. There are criteria for the step change in the input, in order to get valid output, such that: step input should be large enough to overcome the disturbance, but not too large to harm the process. Another important thing is that, the output signal-to-noise ratio should be greater or equal to 5. The PRC parameters cannot be calculated unless it reaches the steady-state output after step input is applied and it should last for $\theta + 4\tau$ [5].

In order to determine that the output is not effect of disturbance, the input change applied before is changed back to it's initial position. If the output is coming to its initial position then the PRC is known as valid and could be proceeded with further steps. If no, then the experiment should be repeated, because it is known as long term disturbance. As the above criteria are fulfilled, either technique could be used to obtain the parameters of the model.

2.2 Ziegler-Nichols and Cohen Coon

Cohen Coon and Ziegler-Nichols are both getting the parameters from the dynamics of the plant, caused by the step change. The difference of either method could be identified from optimization of parameters[6]. The Cohen Coon method is using the 63 and 28 percent of the output proportion of time. This technique is developed in early 1960's and involving simple calculations. While the Ziegler-Nichols is more direct and simple, but however differs with optimization slope of PRC. Ziegler-Nichols first developed method, but however this method is not that accurate, since in optimization of parameters with maximum slope may show not accurate value, especially when there are high disturbance, like noise during the process.

2.3 Statistical modeling

Statistical modeling method provides more general approach and which is not limited to first order dead time. This method does not require perfect step input, or reaching steady-state at the end of experiment, and a large amount of perturbation could be within the possibility of calculation of this method. However this method is involving more calculation, compared to Empirical method. In this method, we should formulate a first order dead time equation in order to get the regression be evaluated.

PID controller has been developed in 1940's, since then it has become the most practiced algorithm in process industry [7]. The PID algorithm is commonly used in Single-Input Single-Output systems, where controlled variable is adjusted with one manipulated variable. As mentioned before, the PID parameters are obtained from process dynamics, and every tuning parameter can be calculated. Every parameter exerting a different effect on the dynamics of process.

As proportion part of algorithm is correction proportional to error accumulated.The proportion will calculate and try to decrease the error that was obtained from from the output and coming back through the feedback loop. But proportional mode has a disadvantage that, this mode has no effect on control variable on offset, since the offset can be decreased through the set point from which the control variable is deviated.

The integral mode is interoperated in terms of time like other modes with accumulated errors of pas[8]t. The integral gain has a great effect on decreasing the rise time, and increasing the overshoot. However gain has an effect on increasing the settling time, eliminating the steady-state error.

The derivative mode is known as “predictive” mode, since the derivative term predicts the behavior of the system and stabilizes it as well as improves the settling time[9]. However this mode has no effect on steady-state error, and has a small change on rise time.

CHAPTER 3

METHODOLOGY

3.1 Research Methodology

Linear controller could be said excellent controller when it comes for the control over the wide range. But for closed loop system change (e.g. temperature change) in set point, it is found that nonlinear system behavior is more linear compared to linear control which is full of overshoots and oscillations [9]. The linear controller results to oscillation and overshoots, which results to deviation from the set point, while nonlinear controller gives effective attenuation of disturbance [10].

By bearing in mind all this information that has been retrieved from other research papers. Let's look at conventional model (system) with the clear image of PID. The model is conventional closed loop system with PID controller.

As you may find from the modeling shown below, the modeling of the system includes the variable input, where first it goes into PID controller (the PID is tuned according to our desire), after which it goes into plant model for required parameters. The processed values will come

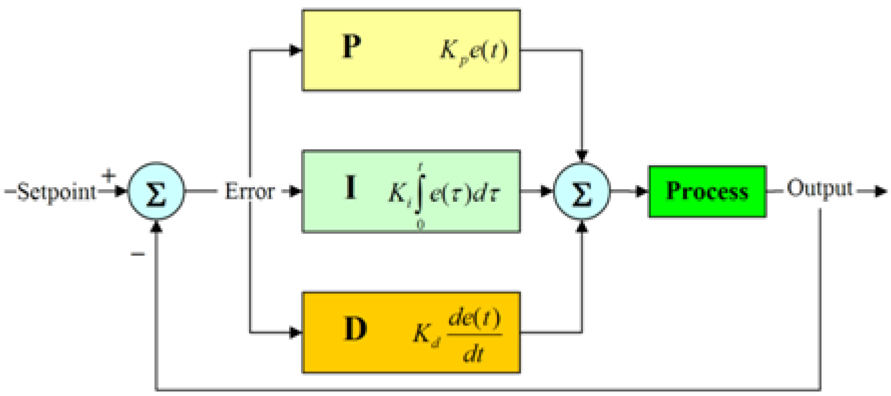

Figure 1 PID modeling

up from the variable output Y. The error signal (e) will be sent back through the feedback and be processed via controller to the output. The error will be compared/referred to its input variable (u) to improve the performance.

The tuning parameters of the PID controller are K_p, K_i and K_d. The desired signal output can be manipulated by tuning those gain parameters.

The PID controller is defined with the next formula:

$$u(t) = MV(t) = K_p e(t) + K_i \int_0^t e(\tau)d\tau + K_d \frac{d}{dt} e(t) \qquad \text{Eq (1)}$$

Where:

Table 1 Equation parameters.

u	Input variable
MV	Manipulated Variable
K_p	Proportional gain
K_i	Integral gain
K_d	Derivative gain
e	Error
τ	Variable of Integration

Since the effect of gain parameters are differing from each other, it is important to tune them, so that the best output is obtained. As well as design of modeling of the closed loop system could be benefited from the gain behavior. The gain behaviors are tuned and observed in MATLAB SIMULINK.

The MATLAB SIMULINK is preferred software to construct the modeling of the closed loop continuous system, the gain variables can be input and edited (if needed), according to the effects they (gain parameters) each perform behavior at the output. Since each gain of the process parameter has different effect on the system, they can be tuned and manipulated as you want them at the output.

3.2 An Empirical model construction procedure

The modeling method can be said that, it is designed for process control, known as empirical modeling. The models which are developed using this method are using the dynamic relationship of variables which are input and output. In making the model, especially in empirical modeling the small change is applied, the resulting dynamics, determines the model. This kind model identification and development using the empirical modeling is found to be useful for many design process control, and for its implementation.

Empirical model building consists of six parts shown in the figure below. This procedure makes sure that designing and execution would generate appropriate data. The figure also shows that prior knowledge, and iteration required which are shown with red arrows. At the end of the procedure the satisfactory model could be obtained if not, the procedure could be repeated, as further experimentation is required. For the modeling steps to be more understandable, a brief explanation is given below.

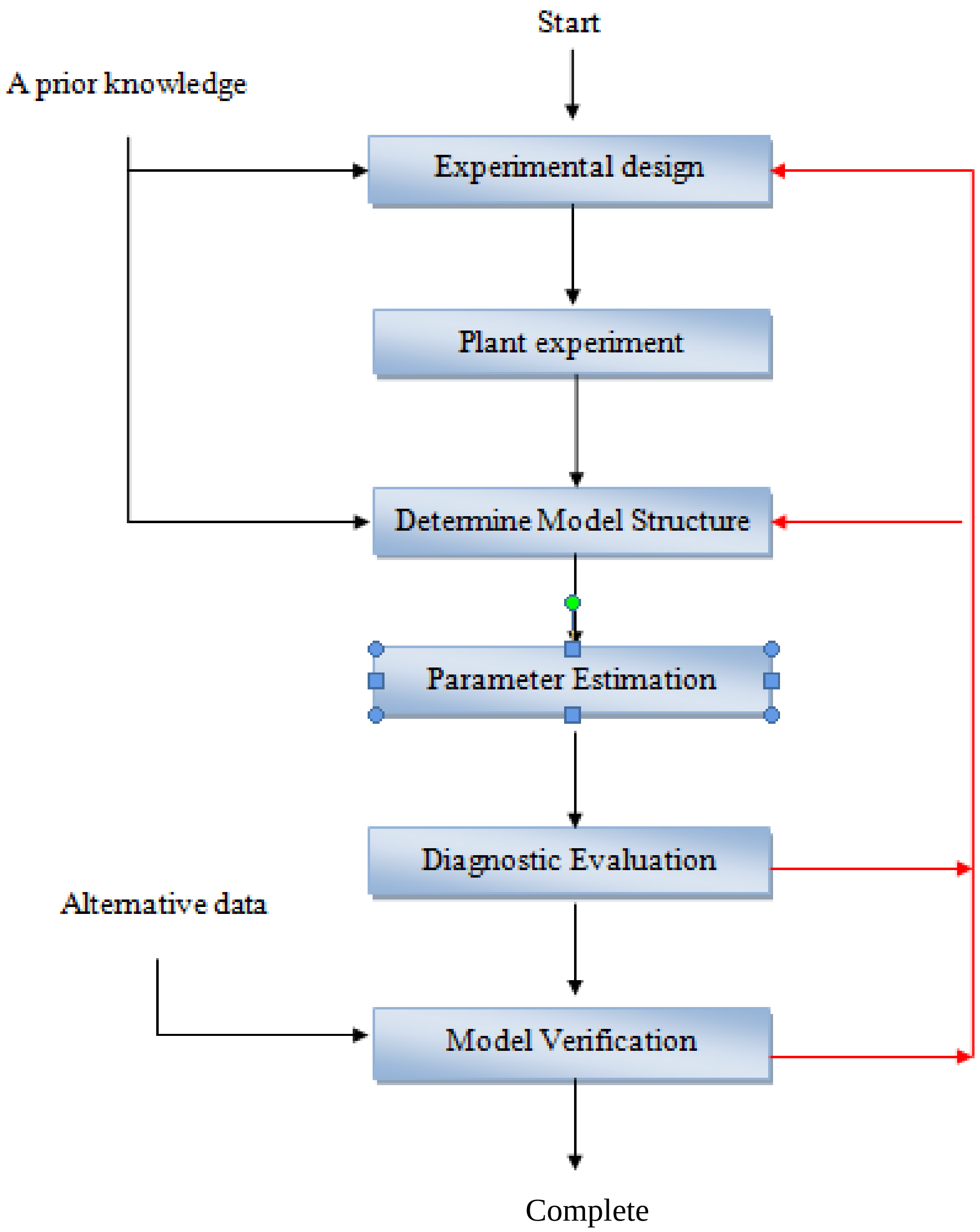

Figure 2 : Procedure for empirical transfer function model identification.

Experimental design:

In this part of the modeling, it is important to determine the right modeling, since it determines the shape and duration of the design. It also determines the condition of the process, based on which accuracy is judged.

Plant experiment:

The plant experiment should be held as close as possible to the plan. It is not possible to escape the plant variations overall, therefore the plant should be under monitoring during whole process of the experiment. A difference in the input set point, may crucially change the output expectation. It is advised to monitor with every possible measuring device wherever available.

Determine model structure:

Many methods are available to determine the model of the process. One of the methods used to determine the parameters of the model are obtained from the first and second order of transfer function. Typically the initial structure of the data is collected from prior knowledge, later on the model is improved with a number of experiment and the behavior is observed over and over.

Parameter estimation:

This is the step when the model structure is selected and as well as the data has been collected. With the help of two methods the model parameters are determined. Those methods are, graphical technique and the other one is statistical modeling method technique. These methods are able to provide model parameters like gain, time constant as well as dead time, like wise constructing first order transfer function is done.

Diagnostic evaluation:

At this step the model is basically diagnosed and the model evaluation is held according the parameters estimated earlier. The diagnostic evaluation may use two approaches: 1) measured data is compared with predicted data. 2) results are compared with assumptions with any estimation methods.

Verification

This step is similar to the diagnostic evaluation step, where the model is verified with predictions. But the only difference is that the model is compared to the parameters that are different from the diagnostic evaluation in order to be sure that simple degradation does not deviate the model accuracy. Two things are closely controlled in this step. 1) safe, smooth and profitable operation of the plant. 2) development of the plant for future improvement.

3.3 Plant experiment

The experiment has been conducted on Simple PID Pressure Control plant. The purpose of the experiment was measuring and obtaining the dynamic movement of the potential output based on PRC modeling methods, and obtained model should be able to be tuned for better performance. The output of the plant dynamics has been analyzed in two methods. Those are:

- Empirical modeling method, where it includes two techniques.

  Method I. Cohen Coon method

  Method II. Ziegler-Nichols method

- Statistical Model method.

3.3.1 Process Reaction Curve (PRC)

Method I Cohen Coon method, where it allows the correction of the slow steady-state response by the Ziegler-Nichols method. This method is advised to be used when there is large dead time or having any delay time, and it uses the graphical calculation. The values that are determined from the graph are input magnitude change, δ; steady-state change in the output, Δ; and the moment of time where the output reaches the 28 and 63 percent of its final value. Any random two values of the time, help to determine τ , and θ parameters. The times are selected where the response is changing rapidly, even though measurement, like noise are there. The parameters can be determined accurately (Smith, 1972). The mathematical expressions are:

$$Y(\theta + \tau) = \Delta(1 - e^{-1}) = 0.632\Delta \qquad \text{Eq(2)}$$

$$Y(\theta + \tau/3) = \Delta\left(1 - e^{-\left(\frac{1}{3}\right)}\right) = 0.283\Delta \qquad \text{Eq(3)}$$

The values of the time that reaches 28.3 and 63.2 percent of the output are used to calculate the model parameters, which are shown in the next equation.

$$t_{28\%} = \theta + \frac{\tau}{3} \qquad t_{63\%} = \theta + \tau \qquad \text{Eq(4)}$$

$$\tau = 1.5(t_{63\%} - t_{28\%}) \qquad \theta = t_{63\%} - \tau \qquad \text{Eq(5)}$$

Method II. was adapted from Ziegler and Nichols (1942). Ziegler–Nichols tuning method is done by making the Integral and Derivative parameters to zero and by increasing the Proportional gain until it reaches the maximum gain. This method also based on graphical calculation, where magnitude of the input change, δ ; output magnitude of the steady-state change, Δ; and slope of the output-versus-time plot, S can be measured from the obtained graph. The next relationship shows value of the plot to model parameters.The general model for the step input with $t \geq \theta$ will be:

$$Y'(t) = K_p\,\delta\left[1 - e^{-(t-\theta)/\tau}\right] \qquad \text{Eq(6)}$$

The slope can be determined for this response at $t \geq \theta$

$$\frac{dY\prime}{dt} = \frac{d}{dt}\left\{K_p\delta\ \left[1 - e^{-(t-\theta)/\tau}\right]\right\} = \frac{\Delta}{\tau}e^{-(t-\theta)/\tau} \qquad \text{Eq(7)}$$

3.3.2 Statistical Model

The Statistical model identification method is providing more flexible approach compared to Process Reaction Curve methods. The graphical methods were facing some limitations: first order with dead time model and a perfect step input. Statistical approach uses all data and is not just limited with few points in the response. For the particular method, the regression method has been applied, where the transfer function has been converted to algebraic model, and the current value of the output is related to the previous value of input and output. The statistical identification method and fitting model of simple structure has been used to obtain the algebraic equation. The first order with a dead time could be written in time domain as follows:

$$\tau \frac{dY'}{dt} + Y'(t) = K_p X'(t-\theta) \qquad \text{Eq(8)}$$

The prime here indicates the deviation from the initial steady state value. The above differential equation can be integrated from t_i to $t_i + \Delta t$, where $X'(t)$ assumed constant. The dead time is represented by a real number as a sum of sample delays. The next equation describes it clearly.

$$Y'_{i+1} = e^{-\Delta t/\tau} Y'_i + K_p\left(1 - e^{-\Delta t/\tau}\right) X'_{i-\Gamma} \qquad \text{Eq(9)}$$

This equation could also be simplified as:

$$Y'_{i+1} = aY'_i + bX'_{i-\Gamma} \qquad \text{Eq(10)}$$

The remaining parameters left to be determined are a, b, and Γ , which provide sufficient data for the model. K_p, τ, and θ parameters can be calculated.

In linear regression method it is possible to predict the output at any time of the output. Then the equation above would be written as:

$$(Y'_{i+1})_p = a(Y'_i)_m + b(X'_{i-\Gamma})_m \qquad \text{Eq(11)}$$

In the above equation m denotes as measured value, and p denotes as predicted output. The model parameters a and b would give accurate prediction at the output for every time, so that parameters of a and b , $(Y'_{i+1})_m$ and $(Y'_{i+1})_p$ are as close as possible

3.4 Results and Discussions

Method I : Cohen Coon tuning method.

The obtained/calculated values from the experiment are listed in table below.

Table 2 Measured parameters for Cohen Coon tuning method

Measurement	**Value**
Change in, MV	10%
Change in output, PV	2.67
MAX Slop, S	0.037 bar/sec
Apparent dead time, θ	4 sec
Calculation	**Value**
Steady state process gain, K_p	0.267
Apparent time constant,τ	72 sec
Fraction dead time, R	0.056

	K_C	T_I	T_D
P	$\left(\frac{P}{NL}\right) * \left(1 + \left(\frac{R}{3}\right)\right)$		
PI	$\left(\frac{P}{NL}\right) * \left(0.9 + \left(\frac{R}{12}\right)\right)$	$L * \frac{30 + 3R}{9 + 20R}$	
PID	$\left(\frac{P}{NL}\right) * \left(1.33 + \left(\frac{R}{4}\right)\right)$	$L * \frac{30 + 3R}{9 + 20R}$	$4L/(11 + 2R)$

Table 3 Equations for obtaining PID parameters

After getting the parameters from the experiment, transfer function has been obtained from the experimental parameters, and the PID parameter has been calculated. The transfer function of the model has been obtained by substituting into next formula. This equation is applicable for both methods.

$$\frac{Y(s)}{X(s)} = \frac{K_{p}\, e^{-\theta s}}{\tau s+1} \qquad \text{Eq(12)}$$

The tuning parameter has been obtained by using Cohen Coon method formulas, which are shown at the table below.

Table 4 PID parameters of Cohen Coon method

Control Modes	K_C	T_I	T_D
P	68	-	-
P + I	60	11.9	-
P + I + D	90	9.618	1.44

Potential model has been constructed on MATLAB SIMULINK, and a calculated value of transfer function, and tuning parameter of the controller has been applied to the model.

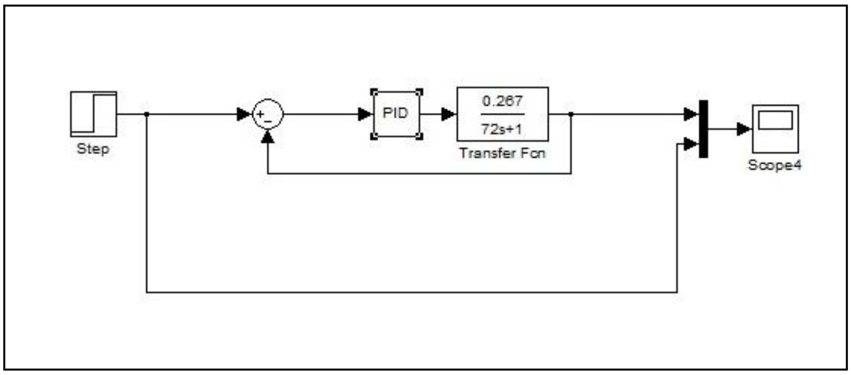

Figure 3 Cohen Coon modeling

Output response of step input:

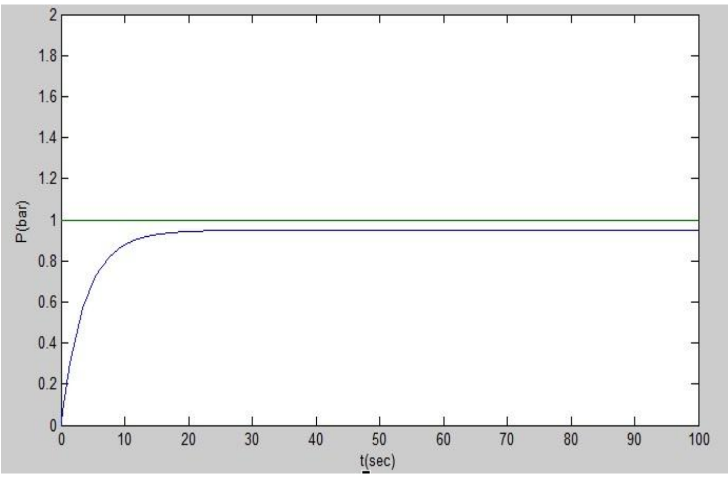

Figure 4 P=68 parameter output for Cohen Coon

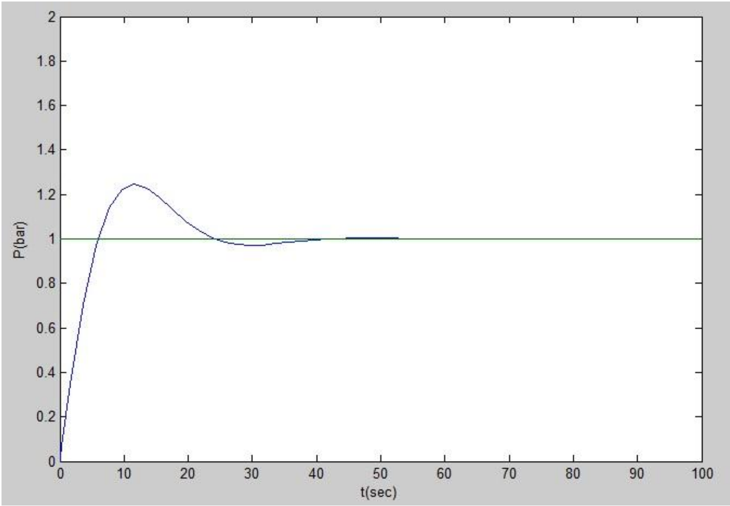

Figure 5 P=60,I=11.9 parameter output for Cohen Coon

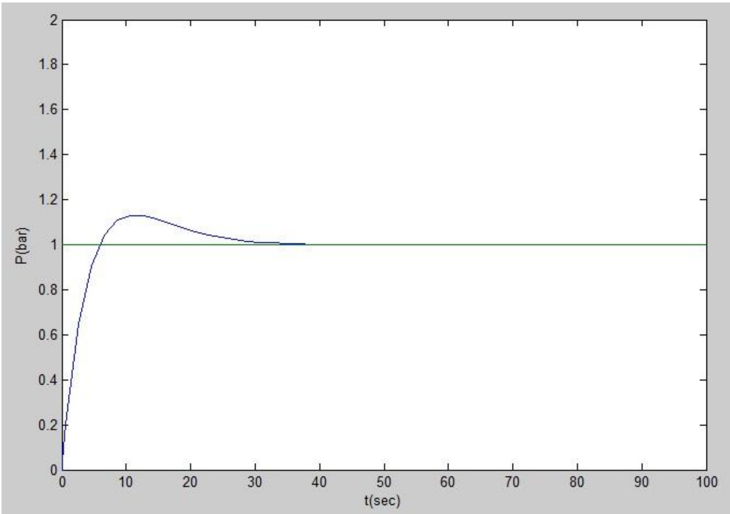

Figure 6 P=90,I=9.618,D=1.44 parameter output for Cohen Coon

Method II : Ziegler-Nichols tuning method.

The parameters that have been calculated are shown in the next table.

Table 5 Measured parameters for Ziegler-Nichols tuning method

Measurement	**Value**
Ultimate Gain, K_u	16
Calculation	**Value**
Ultimate Time, P_u	18 sec

Measurement	**Value**
Change in MV	10%
Change in output PV	2.67
MAX Slop, S	0.037 bar/sec
Apparent dead time, θ	9.33 sec
Calculation	**Value**
Steady state process gain, K_p	2.4
Apparent time constant, τ	31.5 sec
Fraction dead time, R	0.3

PID parameter calculation formulas are shown in table below. The PID parameters are calculated once the Ku and Pu are calculated.

Table 6 Formulas for obtaining PID parameters

	K_C	T_I	T_D
P	$\frac{K_u}{2}$		
PI	$\frac{K_u}{2.2}$	$\frac{P_u}{1.2}$	
PID	$\frac{K_u}{1.7}$	$\frac{P_u}{2}$	$\frac{P_u}{8}$

The PID parameters are calculate and obtained by using the formulas, which are shown in table 6.

Table 7 PID parameters of Ziegler-Nichols method

Control Modes	K_C	T_I	T_D
P	8	-	-
P + I	7.2	15	-
P + I + D	9.6	9	2.25

The MATLAB SIMULINK modeling:

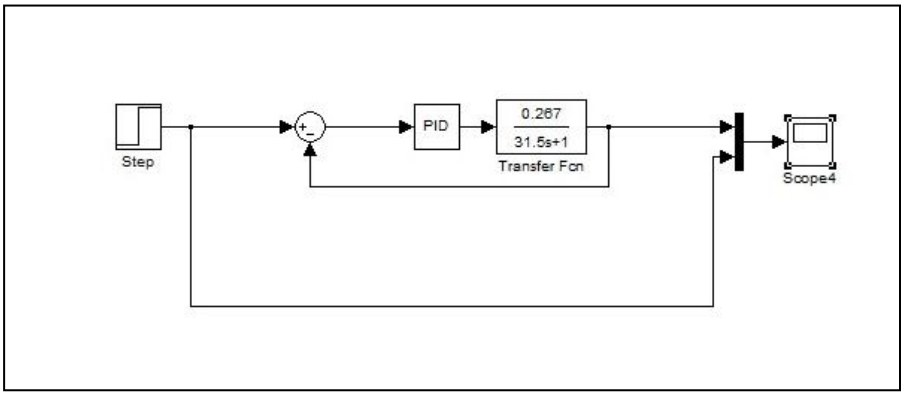

Figure 7 Ziegler-Nichols modeling

Output response of the step input:

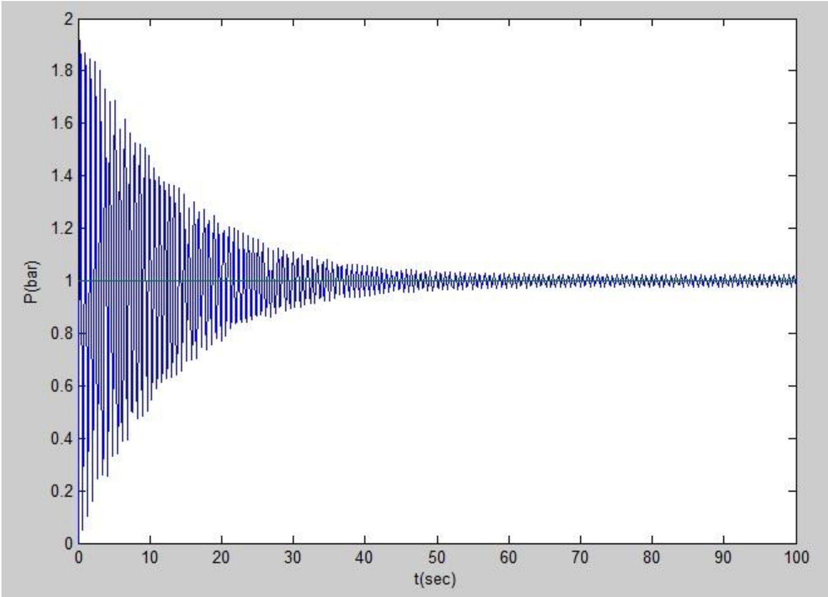

Figure 8 P=8 parameter output for Ziegler Nichols

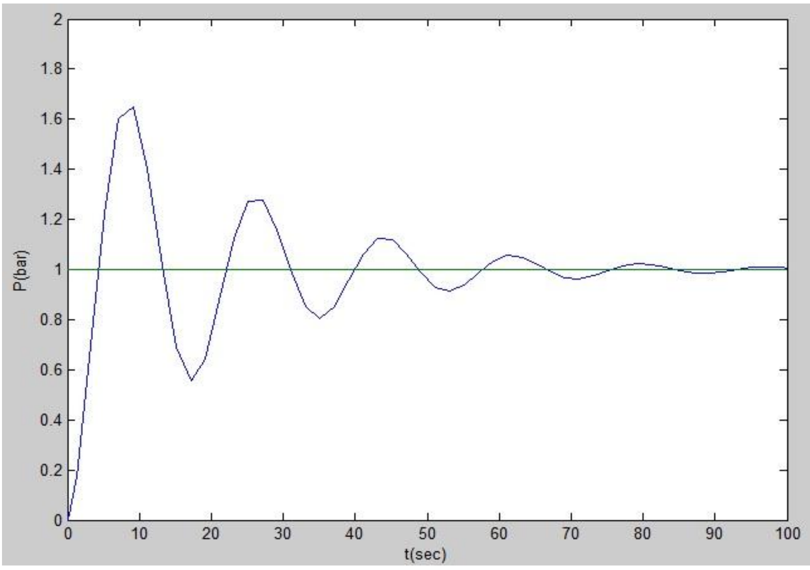

Figure 9 P=7.2,I=15 parameter output for Ziegler Nichols

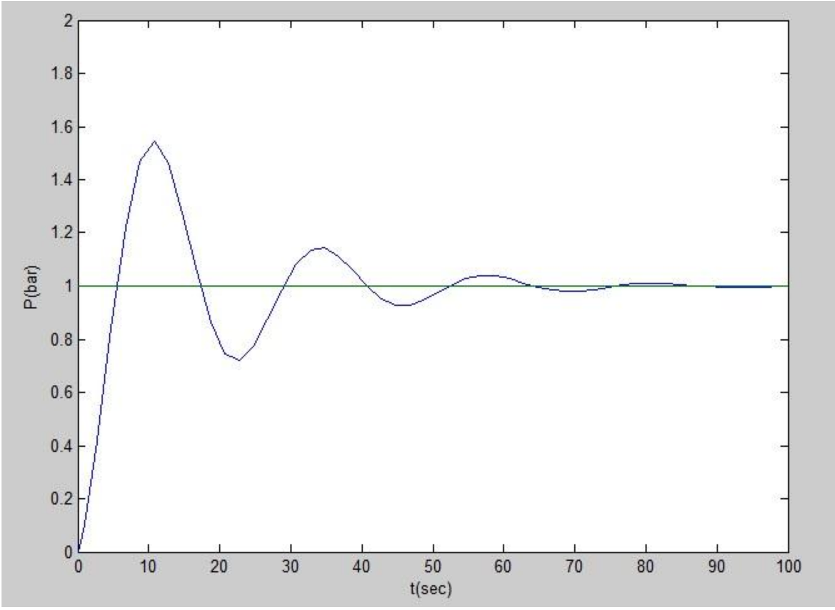

Figure 10 P=9.6,I=9,D=2.25 parameter output for Ziegler Nichols

Statistical Model

For calculation of Statistical modeling the basic parameters has been adopted from the Process Reaction Curve method.

Basic parameters:

Table 8 Measured parameters for Cohen Coon tuning method

Measurement	**Value**
Change in, MV	10%
Change in output, PV	2.67
MAX Slop, S	0.037 bar/sec
Apparent dead time, θ	4 sec
Calculation	**Value**
Steady state process gain, K_p	0.267
Apparent time constant,τ	72 sec

Statistical model parameters:

Table 9 Statistical model parameters

Calculation	**Value**
Δt	$2\ sec$
$a = e^{-\Delta t/\tau}$	0.973
$b = K_p\ \left(1 - e^{-\Delta t/\tau}\right)$	0.0073
$\Gamma = \theta/\Delta t$	2

Tabulation of data

Time T	Input x	Output y	Sample i	Output Y'_{i+1}	Output Y'_i	Input X'_{i-2}	Predicted Y'_{i+1}	Predicted - Measured
0	5	0.62	1	-	-	-	-	-
2	5	0.62	2	-	-	-	-	-
4	5	0.62	3	-	-	-	-	-
6	15	0.62	4	-	-	-	-	-
8	15	0.62	5	0	0	0	0	-
10	15	0.62	6	0.01	0	10	0	-
12	15	0.63	7	0.02	0.01	10	0.0827	0.0627
14	15	0.64	8	0.03	0.02	10	0.0924	0.0624
16	15	0.65	9	0.04	0.03	10	0.1021	0.0621
18	15	0.66	10	0.06	0.04	10	0.1118	0.0518
20	15	0.68	11	0.07	0.06	10	0.1312	0.0612
22	15	0.69	12	0.12	0.07	10	0.1409	0.0209
24	15	0.74	13	0.24	0.12	10	0.1894	-0.0506
26	15	0.86	14	0.41	0.24	10	0.3058	-0.1042
28	15	1.03	15	0.63	0.41	10	0.4707	-0.1593
30	15	1.25	16	0.74	0.63	10	0.6841	-0.0559
32	15	1.36	17	0.83	0.74	10	0.7908	-0.0392
34	15	1.45	18	0.89	0.83	10	0.8781	-0.0119
36	15	1.51	19	0.89	0.89	10	0.9363	0.0463
38	15	1.51	20	0.89	0.89	10	0.9363	0.0463
40	15	1.61	21	0.89	0.99	10	1.0333	0.1433
42	15	1.61	22	1.1	0.99	10	1.0333	-0.0667
44	15	1.72	23	1.1	1.1	10	1.14	0.04
46	15	1.72	24	1.33	1.1	10	1.14	-0.19
48	15	1.95	25	1.49	1.33	10	1.3631	-0.1269
50	15	2.11	26	1.81	1.49	10	1.5183	-0.2917
52	15	2.43	27	1.88	1.81	10	1.8287	-0.0513
54	15	2.5	28	2.08	1.88	10	1.8966	-0.1834
56	15	2.7	29	2.17	2.08	10	2.0906	-0.0794
58	15	2.79	30	2.2	2.17	10	2.1779	-0.0221
60	15	2.82	31	2.46	2.2	10	2.207	-0.253
62	15	3.08	32	2.46	2.46	10	2.4592	-0.0008
64	15	3.08	33	2.49	2.46	10	2.4592	-0.0308
66	15	3.11	34	2.49	2.49	10	2.4883	-0.0017
68	15	3.11	35	2.42	2.49	10	2.4883	0.0683
70	15	3.04	36	2.42	2.42	10	2.4204	0.0004
72	15	3.04	37	2.35	2.42	10	2.4204	0.0704
74	15	2.97	38	2.35	2.35	10	2.3525	0.0025
76	15	2.97	39	2.33	2.35	10	2.3525	0.0225
78	15	2.95	40	-	2.33	10	2.3331	-

The following is the table containing the measured data from the experiment. The table consist of two different parts namely the data in original formatting as collected in the experiment performed at Plant #1, which is PID pressure control plant, and data in restructured format for regression model fitting, first-order-with-dead-time model with dead time of two sample periods.

The regression plot:

Figure 11 Regression plot

3.5 Comparison between Open loop and Closed loop system.

The further investigation was geld in order to see the difference and effect of controller over the model without controller.

The figure below demonstrates the open loop model without controller. By running the experiment without controller we can observe how good is our model, or what is the potential effect of controller to the model obtained.

Open loop model:

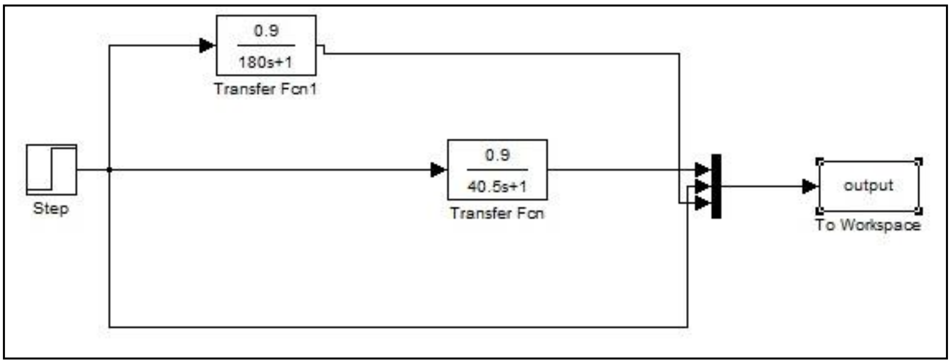

Figure 12 Model without controller

Model output without controller:

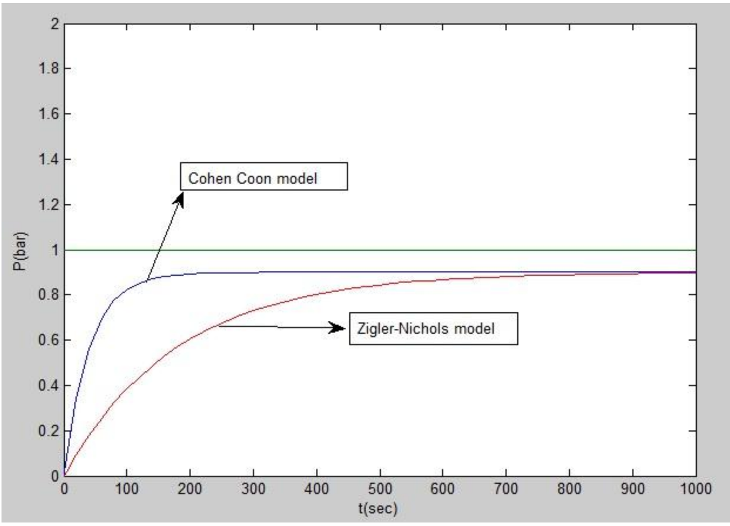

Figure 13 Cohen Coon and Ziegler-Nichols model output without controller

As we run Open Loop system model, we can see effect of controller from the output obtained. From the figure 13, we can say that the controller plays a major role in obtaining the output as close as possible to set point in very short time.

Besides the comparison of two model techniques shows us which one is more reliable and and shows the preferable output. For our case we see that Cohen Coon method has shown better performance compared to Ziegler-Nichols technique. This shows us that we could rely more on Cohen Coon method throughout our experiment.

Closed loop model:

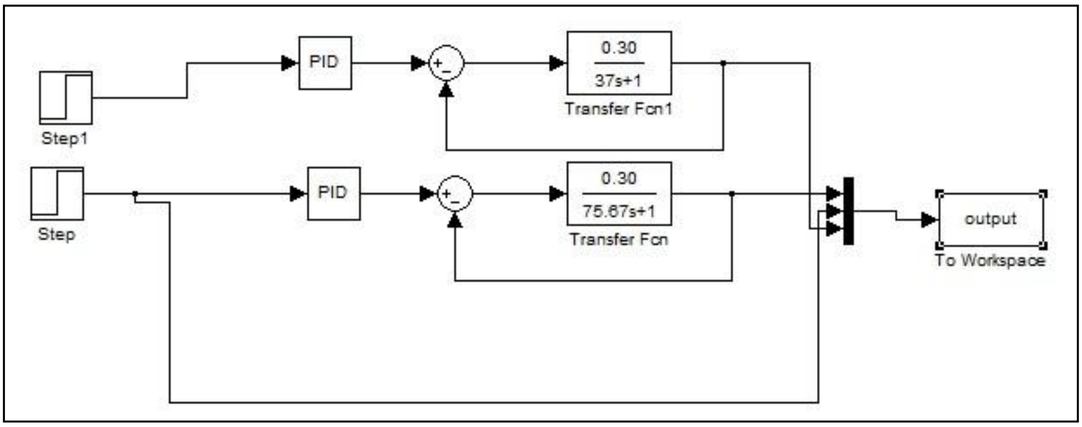

Figure 14 Model with controller

Model output with controller:

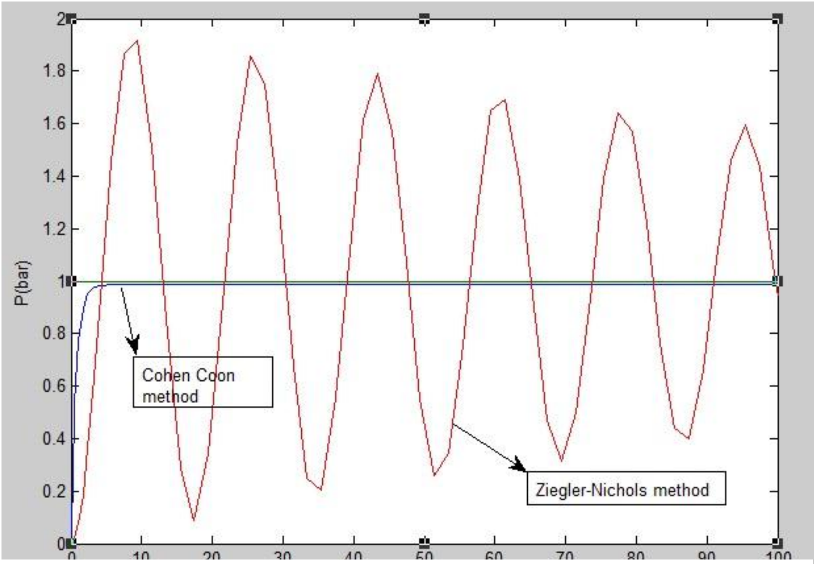

Figure 15 Cohen Coon and Ziegler Nichols model output with controller

The obtained graph above demonstrates the system with PID controller. We can see the clear difference of impact of the controller for potential system. The Cohen Coon tuning method shows way better performance compared to Ziegler-Nichols method. Even a model applied without controller shows quite acceptable performance, but not desirable.

3.6 Tuning

The parameters which was obtained from the open loop, was simulated on MATLAB SIMULINK in order to see the performance and evaluate the potential output. As it is seen from the table, initial obtained graph was simulated according to initial obtained parameters from the open loop, and the output of the two methods was compared.

Table 10 Calculated parameters before tuning

Ziegler-Nichols				Cohen Coon			
	K_c	T_I	T_D		K_c	T_I	T_D
P	0.45	-	-	P	34.41	-	-
PI	0.405	56.25	-	PI	30.24	10.74	-
PID	0.53	33.75	8.44	PID	45.23	9.2	1.32

The output before tuning:

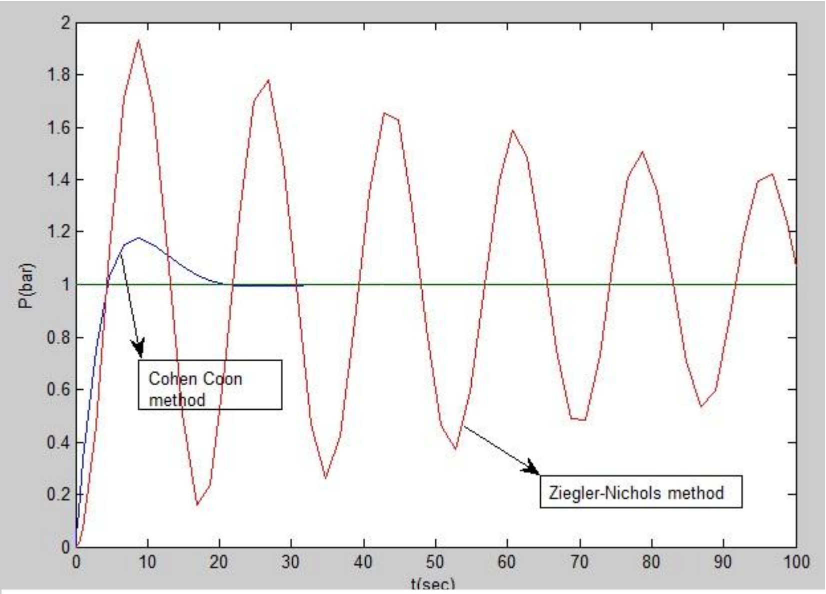

Figure 16 Output of the process before tuning

The output simulation of two methods has shown a quite good performance. Especially the Cohen Coon method has shown way more better output compared to Ziegler-Nichols method. But it is important to tune this parameters for way more better result.

Table 11 Controller parameters after tuning.

Ziegler-Nichols				Cohen Coon			
	K_c	T_I	T_D		K_c	T_I	T_D
P	31	-	-	P	20	-	-
PI	2	45	-	PI	10	6.7	-
PID	1.9	33.8	8.4	PID	12	7.5	1.4

Table above are the tuned parameters of the controller which was obtained from the lab. Before tuning the PID controller, the parameters have been obtained from the open loop. Latter on controller parameters was plugged in, into real plant controller for tuning purposes.

As it was experienced, tuned parameters are slightly different from the one that was obtained initially. P parameter was found out that it is way more different (large number) from the one that was obtained theoretically. Having offset in P parameter, it is not possible to make it better any more, since increasing the value would cause oscillation to the output.

PI and PID tuning parameter are somehow similar to the initial ones. Only a slight increase in P parameter would make the performance way better without any offset values and disturbances.

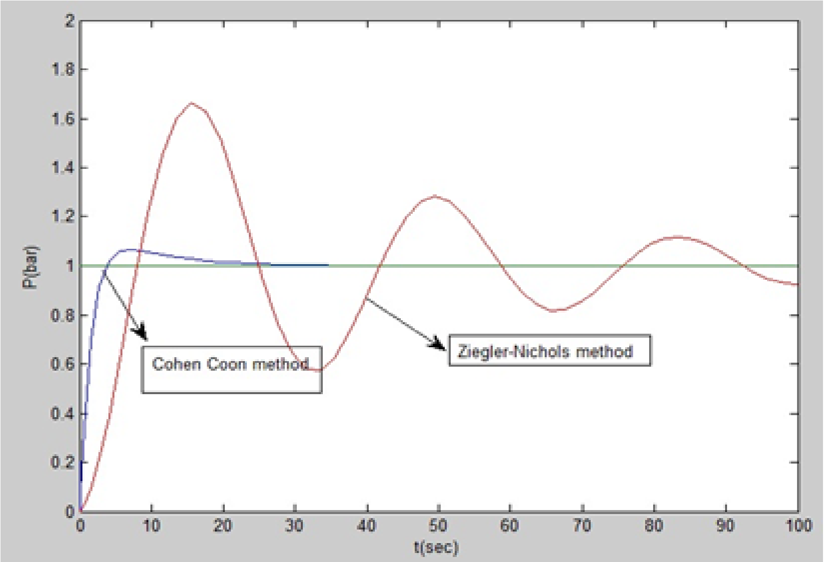

Figure 17 Output of the process after tuning

It is clear from the above picture that, after tuning the output has shown better performance. Both Ziegler-Nichols and Cohen Coon tuning methods are showing satisfying result after tuning.

3.7 Analysis

After obtaining the graph of two methods, the comparison of these two methods has been implemented for further knowledge.

Comparing based on the Actual Response and from Simulation:

PRC method 1:

In method 1, the response in the simulation part shows that P-only has slow response and can't reach the set point and this also showing in the actual graph of the experiment. In PI & PID the actual graph oscillatory response decreasing over time and this also shows in the simulation.

PRC method 2:

In method 2, the response in the simulation part portrays that P-only has oscillatory response which kept decreasing over time. This is also shown in the actual graph of experiment. In PI, the actual graph has small overshoot during the process and reaches steady state at a slower time. However, from simulation, it has large overshoot and reaches steady state at a shorter time. In PID the overshoot is much reduced and the settling time is shorter during experiment and simulation.

Comparing based on Simulation Results:

For method 1 by looking at Figure 4, 5, 6 we can say that P-only has slow response, but for PI parameter and PID parameter they have almost the same output behavior the only different is PID faster than PI.

For method 2, by looking at figure 8, 9, 10 P-only parameter highest overshoot and take long time to stabilize. For PI parameter and PID parameter has the same behavior but PID parameter is still faster than PI.

Statistical model:

From the plot of residuals between measured and predicted outputs, the data scattered shows some correlation. This correlation is expected since this simple model structure selected will not always give the best possible fit to the data set obtained from the experiment. Since the errors are only slightly correlated and small, the model structure and dead time are judged to be valid.

CONCLUSION

Modeling and Controlling the linear process has been studies and potential process problems has been analyzed. The approach of Empirical method technique has been chosen to give us further understanding and analyzing the process for better results.

As a simple experiment has been conducted on PID Pressure Control, the Reaction Curve, and Statistical modeling has been applied. Methods I and II has been used for better understanding the dynamic movement of the plant. Obtained parameters from the plant has been ran on the MATLAB SIMULINK. Simulated model parameters has shown that method I, which is Cohen Coon tuning method has shown better respond on the output of the step input. The statistical method has also shown the valid result for our obtained experimental result. The Statistical method is considered as more reliable since it is taking sample points from several places.

The idea of this experiment is running the parameters in MATLAB SIMULINK that has been obtained in real experiment, and observe the output of the system in simulation. By tuning the parameter and PID controller in simulation, we could obtain better results. These simulated results parameters could be applied back in real time plant experiment implementation for better dynamic output of the system.

RECOMMENDATION

I would like to give my recommendation on further improvement of this project. In order to improve the accuracy of the results obtained, it is advisable to do more research specifically using Statistical method. Since the Statistical modelling technique using more detailed and precise approach it is very useful in obtaining results in processes, which are having disturbance. With lesser interval of obtaining data points compared to Statistical method results in this paper, would make the obtained result more reliable and accurate to analyze, which will result in better performance when applied to real industrial plant.

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