

Carrying out an open-loop step response on the process trainer pt326



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INTRODUCTION:

The control systems are based up on the behaviour of the dynamics systems and it is also a branch of the engineering and mathematical model of the process. The desired output of the system is called as reference. A controller is device which observes and outcome the changes in the output that are affected by the input variables. And it is also used to operate the input variables to a system to achieve the desired result on the output of the system. It is very simple and flexible to solve using the mathematical model. In control system design, we have a concept of feedback control system. The main concept of this feedback loop is to control the system performance and it is a negative feedback because the sensed value is subtracted from the desired value to produce the error signal which is amplified by the controller. To avoid the problem of the open-loop control system, the control system initiated the feedback loop. Where as in closed loop system, the control system uses the feedback to control the output of the process.

One of the most widely used controllers in the design of continuous data control system is the PID controller, where PID stands for the proportional plus integral and derivative control. The PID controller is mostly used in the feedback control design. The controller is used for the operation of the error signal to produce the control signal.

Proportional (P) control:

This is the one type of action performed and used in the PID controllers is the proportional control. It is the simplest form of continuous control system that can be used in the closed loop system. Proportional control is used to minimize the fluctuation in the process, but it does not allow to bring back to <https://assignbuster.com/carrying-out-an-open-loop-step-response-on-the-process-trainer-pt326/>

the required set point. P-only controller provides the faster response than other controllers. The system first allows the P-only controller in order to get the system a few seconds/minutes faster. The main advantage of the P-only controller is the faster response time, it produces the deviation from the set point and this deviation is called offset.

Mathematical Equations:

P-only controller linearly correlates the controller output (actuating signal) to the error (difference between measured signal and set point). In the mathematical form, the p-controller is given below

$$Y(t) = K_c e(t) + b$$

Where

$Y(t)$ = controller output

K_c = controller gain

$e(t)$ = error

b = bias

In the above equation the controller gain and bias are constant to each controller. The controller gain is the change in the controller output per change in the controller input. Bias is simply a controller output, when the error is zero. In the PID controller, when the signals are transmitted then the controller gain relates the changes in the output voltage to the changes in the input voltage. Thus, the gain ultimately changes in the input and output

properties. If the controller output changes more than the input, K_c is greater than one.

If the change in the input is greater than the controller output, K_c is less than one. Ideally, K_c is equal to infinity then the error will be reduced to zero. Exact equalities cannot be achieved in the control logic. In this, the error will be allowed up to a certain range of the system.

Integral (I) Control:

This is another type of action performed in the PID controllers is the integral control. Integral control is the second form of feedback control system. It is obtained used to remove the deviations that may exist. Thus the system moves to the steady state and original settings. A positive error will cause the signal to be increased and whereas a negative error will cause the signal to be decreased the system. However, I-only controller is much slower in response time than the P-controller. Thus, the slower response time will be reduced by combining with another form such as P or PD controller. It is often used to measure the required variables to remain within a narrow range and also require a fine tuning control.

Mathematical Equations

I-controller correlates the controller output to the integral of error. The integral of error is taken with respect to time within a specified interval. In the mathematical form, the I-controller equation can be represented as

Where

$C(t)$ = controller output

T_i = integral time

$e(t)$ = error

$c(t_0)$ = controller output before integration.

Derivative (D) Control:

This is another type of action performed in the PID controllers is the derivative control. I-control and D-control are a form of a feed forward control. D-control anticipates the process conditions by analyzing the change in error. Its main function is to minimize the change in error, thus keeping the system in a consistent setting. The main benefits of the D-controller is to resist change in system, the most important of these being is oscillations.

PI-controllers:

PI-controller is a combination of both proportional plus integral controller. This is the feedback controller which drives the process/plant to be controlled with sum of error and also the integral of that value. In PID controllers, we have not yet used the D-controller ($D = k_d = 0$). The basic block diagram of the PI controller is shown below,

The controller output for the above closed loop system is

Where

\hat{e} is the error of actual measured value from the desired set point.

$\hat{e} = SP - PV$.

The main advantage of the PI controller; the integral terms in the PI controller causes the steady state error to be zero for a ramp input. The main disadvantages of using with the PI controller is the phase lag. This means that the phase margin decreases.

Required Apparatus:

The report of this experiment is carried out on the Feedback Process Trainer, PT326. The design of the control system consist of a computer , A/D and D/A converters, and a printer used to provide the copies of the response system. The networked PCs used to obtain the system design using the nyquist simulation method employing the design and simulation program CODAS.

Explanation of PT326:

According to the industrial situation, the PT326 process trainer model is commonly used. This situation appears when the temperature control is required in the presence of transport delay and transfer lags.

In this PT 326 process trainer, the trainer involves air that is strained from the atmosphere through a centrifugal blower and it is heated and passed over the heater through duct before it is being heated. The objective of the control is to sustain the temperature of the air at the required level. The temperature control can be achieved by varying the electrical power supplied to the heater grid. By using the bead thermistor which is placed in the flow at any three position along the duct, the air temperature may be sensed. The process trainer introduces the transport delay in the system which is located between the thermistor and heat coil. By setting the opening of the throttle, the mass flow of the air can be adjusted through the

duct. The temperature sensors can be placed at any three of the position in the duct, so that these sensors can acts as a detector. The variation in the resistance of the temperature sensor is converted to the voltage variation through the bridge circuit and is available at terminal Y. The output of the temperature sensor can be used as feedback for connecting the terminal X and Y.

The required temperature can be indicated by adjusting the knob label " set value". In additionally, the set value can change the step by using the command throwing the switch as " internal". An external reference input can also be provided using the label as " external". The difference between reference input set value and feedback signal is availabel at terminal ' B' and can be supplied to the heater power supply so that the gain can be adjusted by using the " prportional band". To select a continuous control, the signal at A can be send directly to the heater power supply by using the switch ' s'. The switch ' s' can be alternatively used as on-off controller as well as it is used to select the " two step control". This on-off control command reponds to the maximum heater power when on and for the zero heater power it is off. The hysteresis is an on-off controller which can be adjusted by the knob label as " overlap". The maximum heater supply can be adjusted using the knob label as " max heater power".

The process may be seen to comprise a simple blower in which air is drawn from the atmosphere, blown past a heater grid and along a tube having a provision for several temperature to pick up. The purpose of the control system is to maintain the temperature of the air flowing in the tubeat some

required set point. The output of the process is a temperature which is measured by the use of the thermistor bead transducer and bridge circuit.

Procedure:

In the set of experiments of the PT326 process trainer, a personal computer acts as a controller. Three controllers are going to be investigated,

- a) Proportional control
- b) Integral control
- c) Proportional plus integral control.

The final experiment make use of the analytical control system to show how the control theory can be used to calculate the behaviour of the control system.

- a) Proportional control:

Using the computer program go into the controller setting menu. Set the controller to be a proportional only type i. e set the $k_p = 0.1$, $k_i = 0$, $k_d = 0$.

On the process trainer, adjust the throttle to 250 and place the sensor in the position away from the heater. Vary the proportional gain and plot the graph of the steady state error against the proportional gain. Choose the value of gain we think for the best response and obtain the screen dump to get a copy from the printer. Finally, indicate on graph the onset of instability.

- b) Integral control:

Using the computer program go into the controller setting menu. Set the controller to be a integral only i. e set the $k_p = 0$, $k_i = 0.1$, $k_d = 0$. On the process trainer leave the throttle at 250 and keep the sensor in the position away from the heater. Vary the integral gain and plot a graph of steady state error against the integral gain. Choose a value of gain that gives the best response of the system and obtain the screen dump. Finally, indicate on the graph the onset of instability.

c) Proportional-plus-Integral control:

Using the computer program go into the controller setting menu. Set the controller to be proportional-plus-integral type i. e set the $k_p = 0.1$, $k_i = 0.1$, $k_d = 0$. On the process trainer leave the throttle at 250, and keep the sensor in the position away from the heater. Vary the proportional and integral gains until we get the best response from the system and obtain the screen dump.

d) Open-loop step response:

Using the computer program PRESS 'o' this will put the system under the open loop control. The programme will then automatically carry out an open loop step response. Obtain a screen dump for the open loop step response.

From the loop step response it is possible to calculate the transfer function of the process trainer.

The transfer function has the form:

Where K is the open loop D. C gain of the system and T_d is the pure time delay present in the system and T_p is the time constant for the system. It is possible to measure these values directly from the open loop step response.

The steady state error for the control system can be derived as :

$$\text{Steady state error} = V/(1+k_p k)$$

e) After obtaining the open loop step response values like K , T_p , T_d , e and R from the graph.

Place the values of K , T_p and T_d in MATLAB simulink. To simulate the plant only in open loop in CODAS. Compare the time response with the actual plant open-loop response.

f) Introduce the controller into the simulation and in frequency domain, adjust proportional gain to give the gain margin of 2 i. e., Nyquist plot (controller plus plant, open-loop) cuts the real axis at -0.5. observe the corresponding time response(controller plus plant, closed loop in time domain).

g) Following the Nyquist method (f), introduce an integral control term and observe the time response.

h) Keeping the proportional plus integral control established in (g), adjust the overall gain(k) to give gain margin of 4, 2, 1.333, 1 and 0.8 (corresponding to the Nyquist plot cutting the real axis at -0.25, -0.5, -0.75, -1.0 and -1.25 respectively). Comparing the corresponding time responses on the same graph.

i) Now, changing the overall gain back to 1 and substituting the proportional and integral gains as calculated using the (i) ziegler-Nichols and (ii) cohen and coon formulas. And comparing the time responses for the three methods (Nyquist, Ziegler-Nicholos and cohen and coon) on the same graph.

j) Moving back to the industrial trainer, and substituting the PI gains that where obtained using the Nyquist method and observe the closed loop response. And finding to get fine tune PI gain to improve the performance of the system.

MATLAB CODE (CODAS Program):

The diagram represents the open loop step response of the system is

The code for the plotting of the open loop step response of the sytem is

```
hold on
```

```
xlabel(' Time')
```

```
ylabel(' Input (red), Output (green)')
```

```
title(' System response to a step input')
```

```
plot(t, x,'r')
```

```
plot(t, y,'g')
```

```
grid on
```

The code for the plotting of the closed loop step response of the system is

```
hold on
```

```
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```

```
axis([0. 0 10. 0 -10. 0 2900. 0])
```

```
xlabel(' Time')
```

```
ylabel(' Desired Output (blue), Actual Outputs')
```

```
title(' System responses to a step input')
```

```
plot(t, x,'k')
```

```
plot(t, y,'b')
```

```
grid on
```

The code for the nyquist process trainer in the nyquist plot for the closed loop response of the system is

```
% Plant :  $G_p(s) = K \cdot \exp(-T_d \cdot s) / (1 + T_p \cdot s)$ 
```

```
%
```

```
K= 1. 266; % DC Gain
```

```
Td= 0. 35; % Time Delay
```

```
Tp= 0. 729; % Time Constant
```

```
%
```

```
num_p= K;
```

```
den_p=[Tp 1];
```

```
disp(' Plant Transfer Function : ')
```

```
plant_tf= tf(num_p, den_p,'InputDelay', Td)
```

```
%
```

```
% Compensator:  $G_c(s) = K_m \cdot (K_p + (K_i/s) + K_d \cdot s) = K_m \cdot (K_d \cdot s^2 + K_p \cdot s + K_i) / s$ 
```

```
%
```

```
disp(' Km :')
```

```
%Km= 1. 0
```

```
Km= 2. 0/(2)
```

```
%Km= 1. 0 % Multiplier
```

```
Kp= 2. 1397; % Proportional Gain
```

```
Ki= 0. 857; % Integral Gain
```

```
Kd= 0. 0; % Derivative Gain
```

```
%
```

```
num_c= Km*[Kd Kp Ki];
```

```
den_c=[1 0];
```

```
disp(' Compensator Transfer Function : ')
```

```
comp_tf= tf(num_c, den_c)
```

```
%
```

```
OL_tf= comp_tf*plant_tf
```

```
%
```

```
%Gain and Phase Margins
```

```
%
```

```
[Gm, Pm, Wcg, Wcp]= margin(OL_tf);
```

```
disp(' Gain Margin: '); Gm
```

```
disp(' Phase Margin: '); Pm
```

```
%
```

```
% Nyquist plot of OL TF for 0. 2
```

```
%
```

```
%hold on
```

```
%axes_ranges=[-1. 5 0. 5 -2. 0 0. 5];
```

```
%nyquist(OL_tf,{0. 2, 25. 0})
```

```
%axis(axes_ranges)
```

```
%title(' Nyquist plot of  $G_c(s)G_p(s) = K_m \cdot ((K_d \cdot s^2 + K_p \cdot s + K_i) / s) \cdot ((K \cdot \exp(-T_d \cdot s) / (1 + T_p \cdot s)))$ ')
```

The code for the closed loop step response of the system is,

```
hold on
```

```
axis([0. 0 10. 0 -10. 0 3000. 0])
```

```
xlabel(' Time')
```

```
ylabel(' Desired Output (green), Actual Outputs')
```

```
title(' System responses to a step input')
```

```
plot(t, x,'k')
```

```
plot(t, y,'g')
```

```
grid on
```

Results:

Open-loop step response:

In order to bring the system to a steady state in open-loop condition: a step input M , is then applied and providing the system in a reasonably well modelled by the equation $G(s)$. The below diagram represents the step input for an open loop control system,

Now, using the computer program press ' o ' then this will put the system under open loop control. The program will then automatically carry out an open loop response. Obtain the screen dump of the open loop step response.

For the open loop step response it is possible to calculate the transfer function. The transfer function is of the form,

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From the above transfer function, we can calculate the value of gain(K), time constant of the system(T_p) and pure time delay present in the system(T_d) and from these values we can calculate directly the open loop step response.

The graph that obtained from the open loop step response is in the form of first order system but it is not really linear system and for the first order system the slope of the system cuts the curve in 63% of the system. But in first order system, to get a steady state value multiply the step size by D. C gain. When the step input is applied then the derivative of the output changes immediately. In this experiment for the open loop step response of the system, we have used the derivative controller also. The graph for the transfer function of open loop step response is shown below using the MATLAB code,

The code for the plotting of the open loop transfer function is,

```
hold on
```

```
xlabel(' Time')
```

```
ylabel(' Input (blue), Output (green)')
```

```
title(' System response to a step input')
```

```
plot(t, x,'b')
```

```
plot(t, y,'g')
```

```
grid on
```


The graph of the open loop transfer function is,

The results that were obtained from the MATLAB command by placing the $K= 1.266$, $T_p= 0.729$ and $T_d= 0.35$ for the plant transfer function of the open loop response is

Plant Transfer function:

1.266

$\exp(-0.35*s) * \text{-----}$

0.729 s + 1

$K_m :$

$K_m = 1.$

For the compensator transfer function:

Transfer function:

s

-

s

Transfer function:

1.266 s

$\exp(-0.35*s) * \text{-----}$

$$0.729 s^2 + s$$

Gain Margin:

$$Gm = 3.1090$$

Phase Margin:

$$Pm = 120.8216$$

Closed-loop step response:

In closed loop response of the system, the feedback of the system response will be obtained. In this closed loop step response, we are using the proportional closed loop and also the proportional integral with a gain margin.

We are taking the values of K_p , K_i and K_d and also a multiplier. The below diagram represents the closed loop response of the system,

In this we can setup the gain margin of 2 and taking the K_p and K_i , K_d values. By placing the values of K , T_p and T_d in the MATLAB code for closed loop in time domain and controller plus plant. In the nyquist process trainer, keeping the parameters initially K_p and K_i and by adjusting the proportional gain we can get the gain margin of 2. The results that were obtained from the closed loop transfer function is,

K_m :

$$K_m = 1$$

Compensator Transfer Function :

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Transfer function:

1. 555 s

s

Transfer function:

1. 968 s

$\exp(-0.35*s) * \text{-----}$

$0.729 s^2 + s$

Gain Margin:

Gm = 2.0000

Phase Margin:

Pm = 73.9152

In the Nyquist plot only, introduce the Ki control term and we need to observe the closed loop time response. The below figure shows the nyquist plot cuts the real axis at -0.5 with the use of proportional as well as integral.

Now, we need to calculate the system response of the step input with the help of proportional plus integral in order to get the proportional gain $K_p = 10\%$ and keeping the ki value as 1.2673 and execute it in nyquist plot.

Now, for the transfer function of $G(s)$ use the Ziegler-Nichols and Cohen methods to design the PI controllers for the transfer function obtained. To calculate the K_p and K_i values for the Ziegler-Nichols and Cohen-coon methods the following formulas is to be substitute.

a) Ziegler-Nichols PI gain is

$$K_p = 0.9 * M / (R * T_d) \quad M = 1000 \text{ is constant .}$$

$$= 0.9 * 1000 / (1201.7 * 0.35) \text{ [since the R and Td values can be obtained from the}$$

$$= 2.1398 \text{ open loop step response].}$$

$$K_i = 0.3 / T_d$$

$$= 0.3 / 0.35$$

$$= 0.857.$$

b) Cohen-Coon PI gain is

$$K_p = (T_p / K * T_d) * [0.9 + (T_d / (12 * T_p))]$$

$$= (0.729 / 1.266 * 0.35) * [0.9 + (0.35 / (12 * 0.729))]$$

$$= 1.6178$$

$$K_i = (9 + (20 * T_d / T_p)) / \{T_d [30 + (3 * T_d / T_p)]\}$$

$$= (9 + (20 * 0.35 / 0.729)) / \{0.35 [30 + (3 * 0.35 / 0.729)]\}$$

$$= 1.6904$$

The values of K, T_p and T_d are obtained from the open loop step response of the system.

The step response for the above method for (a) is given below

The results that were obtained from the MATLAB command for the transfer function of the closed loop system to get a gain margin of 2 is,

$$K_m = 1$$

Compensator Transfer Function :

Transfer function:

$$1.399s + 1.267$$

s

Transfer function:

$$1.771s + 1.604$$

$$\exp(-0.35s) * \text{-----}$$

$$0.729s^2 + s$$

Gain Margin:

$$G_m = 2.0000$$

Phase Margin:

$$Pm = 54.6789$$

Now, keeping those values of K_p , K_i which are obtained from the Ziegler-Nichols, Cohen-Coon and Nyquist methods of $G_m = 2$ in the Nyquist plot of the closed loop response. The following figure shows the three methods in the closed loop response of the nyquist plot with a gain margin of 2.

From the three methods, we have observe that the system is stable for the values of K_p , K_i and K_d .

The transfer function for the closed loop response of the system for both the Ziegler-Nichols and Cohen - coon methods are

Ziegler-Nichols:

$$K_m = 1$$

Compensator Transfer Function :

Transfer function:

$$2.14s + 0.857$$

s

Transfer function:

$$2.709s + 1.085$$

$$\exp(-0.35s) * \text{-----}$$

$$0.729 s^2 + s$$

Gain Margin:

$$Gm = 1.3966$$

Phase Margin:

$$Pm = 35.1637$$

Cohen and Coon:

Plant Transfer Function :

Transfer function:

$$1.266$$

$$\exp(-0.35s) * \text{-----}$$

$$0.729 s + 1$$

Km :

$$Km = 1$$

Compensator Transfer Function :

Transfer function:

$$1.618 s + 1.69$$

s

Transfer function:

$$2.048s + 2.14$$

$$\exp(-0.35s) * \text{-----}$$

$$0.729s^2 + s$$

Gain Margin:

$$Gm = 1.6924$$

Phase Margin:

$$Pm = 41.9646$$

Now we have to calculate the Kp and Ki for the different values of gain margin by placing the proportional plus integral in the system. Adjusting the overall gain with different values like 4, 2, 1.33, 1 and 0.8 and finding out the stable/unstable response of the system.

Consider the gain margin of 2 and place the values of Kp, Ki and Kd= 0 in the nyquist plot of the closed loop response of the system using the MATLAB code and taking the proportionl gain as 10% of that. The results that were obtained in MATLAB command for the gain margin of 2 is

Km :

$$K_m = 1$$

Compensator Transfer Function :

Transfer function:

$$1.399s + 1.267$$

s

Transfer function:

$$1.771s + 1.604$$

$$\exp(-0.35s) * \text{-----}$$

$$0.729s^2 + s$$

Gain Margin:

$$G_m = 2.0000$$

Phase Margin:

$$P_m = 54.6789$$

Consider the gain margin of 4 and place the values of K_p , K_i and $K_d = 0$ in the nyquist plot of the closed loop response of the system using the MATLAB code and taking the proportionl gain as 10% of that. The results that were obtained in MATLAB command for the gain margin of 4 is

Plant Transfer Function :

Transfer function:

1. 266

$\exp(-0.35*s) * \text{-----}$

$0.729 s + 1$

Km :

$Km = 0.5000$

Compensator Transfer Function :

Transfer function:

$0.6995 s + 0.6337$

s

Transfer function:

$0.8856 s + 0.8022$

$\exp(-0.35*s) * \text{-----}$

$0.729 s^2 + s$

Gain Margin:

$$G_m = 4.0000$$

Phase Margin:

$$P_m = 82.4786$$

Now, consider the gain margin of 1 and place the values of K_p , K_i and $K_d = 0$ in the nyquist plot of the closed loop response of the system using the MATLAB code and taking the proportionl gain as 10% of that. The results that were obtained in MATLAB command for the gain margin of 1 is

Plant Transfer Function :

Transfer function:

$$1.266$$

$$\exp(-0.35*s) * \text{-----}$$

$$0.729 s + 1$$

K_m :

$$K_m = 2$$

Compensator Transfer Function :

Transfer function:

$$2.798 s + 2.535$$

s

Transfer function:

$$3.542 s + 3.209$$

$$\exp(-0.35*s) * \text{-----}$$

$$0.729 s^2 + s$$

Gain Margin:

$$Gm = 1.0000$$

Phase Margin:

$$Pm = 3.3476e-004$$

Now, consider the gain margin of 1.33 and place the values of K_p , K_i and $K_d = 0$ in the nyquist plot of the closed loop response of the system using the MATLAB code and taking the proportional gain as 10% of that. The results that were obtained in MATLAB command for the gain margin of 1.33 is

Plant Transfer Function :

Transfer function:

$$1.266$$

$$\exp(-0.35*s) * \text{-----}$$

$$0.729 s + 1$$

Km :

$$K_m = 1.5000$$

Compensator Transfer Function :

Transfer function:

$$2.099s + 1.901$$

s

Transfer function:

$$2.657s + 2.407$$

$$\exp(-0.35s) * \text{-----}$$

$$0.729s^2 + s$$

Gain Margin:

$$G_m = 1.3333$$

Phase Margin:

$$P_m = 26.5904$$

Now, consider the gain margin of 0.8 and place the values of K_p , K_i and $K_d = 0$ in the nyquist plot of the closed loop response of the system using the

MATLAB code and taking the proportional gain as 10% of that. The results that were obtained in MATLAB command for the gain margin of 0.8 is

Plant Transfer Function :

Transfer function:

1.266

$\exp(-0.35*s) * \text{-----}$

0.729 s + 1

Km :

Km = 2.5000

Compensator Transfer Function :

Transfer function:

3.498 s + 3.168

s

Transfer function:

4.428 s + 4.011

$\exp(-0.35*s) * \text{-----}$

$$0.729s^2 + s$$

Gain Margin:

$$G_m = 0.8000$$

Phase Margin:

$$P_m = -25.7809$$

The below graph represents the nyquist response for the closed loop transfer function with different gain margins. The nyquist plots for the different gain margins cut the real axis at -0.25, -0.5, -0.75, -1.0 and -1.25 respectively.

For the gain margin of 0.8, the system is unstable because it exits more than the -1.0. And for the gain margin of 1, 2, 4 and 1.33, the system is stable. The table below shows the Kp and Ki values for different gain margins and also the two methods of the system.

Gain

margin Kp Ki

(Gm)

0. 0.

4.0 699 633

5 7

1. 1.

2

399 267

1.33 2. 1.

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099 901

1. 0 2. 2.
798 535

0. 8 3. 3.
498 168

1. 3966

(Ziegler

2. 0.
s- 14 857

Nichols

)

1. 2964

(Cohen 1. 1.

and 618 69

Coon)

Now we have find out the step response of the closed loop system for different values of gain margin. The figure shows the step response of the closed loop system for the gain margin of $G_m = 1.0$ and 0.8 .

The system is unstable for the gain margin of 0.8 because the response of the system moves over the range of intervals and it is a unsaturated system response for closed loop system.

After that changing the values of the gain margin 1.33, 2 and 4.0 then the closed loop response of the system is stable. The below figure shows the closed loop response for different gain margin.

The above graph shows that the closed loop step response for the different gain margin is stable.

Now observe the step response for the gain margin of 2 and also with the Gm of 1.3966 (Ziegler-Nichols) and with the gain margin of 1.2964 (Cohen and Coon) methods. Then the overall step response for the closed loop system is

The step response for the closed loop system is stable in these methods and with the gain margin of 2.

After observing all the gain margin and note down the K_p and K_i values from the closed loop step response of the system. And moving back to the process trainer, substitute those PI gains that has obtained in the system. Now observe the closed loop step response for the different PI gains to be stable. For the better performance of the system retune the PI gains.

Testing:

Open-loop step response:

On the process trainer, place the output sensor to give the largest time delay. Using the computer or controller and the program perform the operation on the open loop step responses on the system. Adjust the fan angle to between 30° and 40° to provide the satisfactory response.

PRESS ' P ' so that it loads in a dump screen routine and the output can appeared on the printer.

PRESS ' O ' produces an open-loop step response. And the size of the step is M and is obtained by the reference to the monitor.

Obtain the print so that the reaction curve taken place and determine the parameters of T_p , T_d and K . Since K is the gain.

Closed-loop step response:

For the transfer function, $G(s)$ use the ziegler-Nichols and Cohen and Coon methods to design the PI controllers for the transfer function obtained.