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DEPARTMENT OF ELECTRONICS AND INSTRUMENTATION ENGINEERING

1907609 - PROCESS CONTROL LABORATORY

LAB MANUAL

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EVEN SEMESTER

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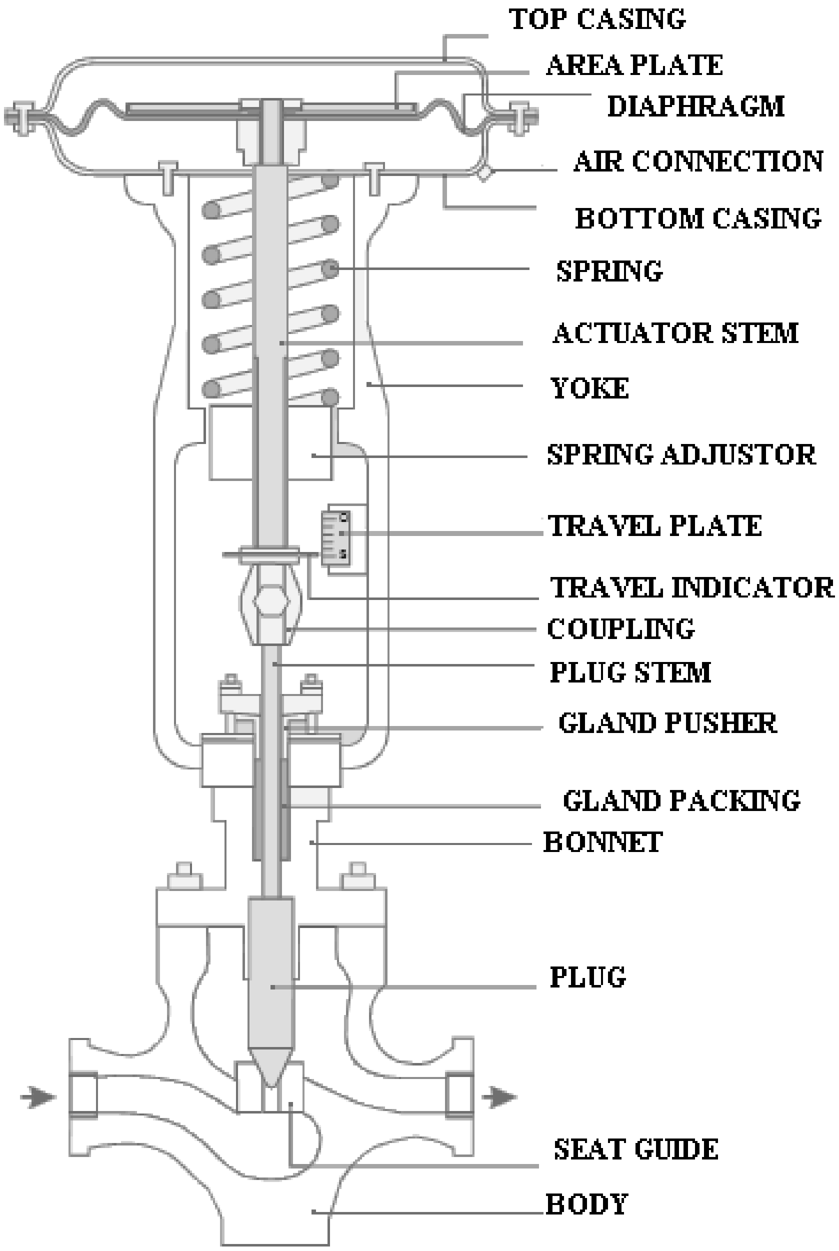


Control Valve (Air to Open)

The function of a control valve is to vary the flow of fluid through the value by means of a change of pressure to the valve top. The relation (or lift) is called the valve characteristic. There are three main types of valve characteristics. The types of valve characteristics can be defined in terms of the sensitivity of the valve, which is simply the fraction change in flow to the fractional change in stem position for fixed upstream and downstream pressures. Mathematically

Sensitivity = dm / dx

CHARACTERISTICS OF PNEUMATICALLY ACTUATED CONTROL VALVE (WITH AND WITHOUT POSITIONER)

Ex.No:1
Date:

AIM

To determine the flow – lift characteristics (Internet / Installed) of a control valve equipped with and without valve positioner.

EQUIPMENT

1. Control valve trainer (with position for varying ΔP across the valve) - 1 No

2. Flow meter - 1No

THEORY

Control valve

In most of the industrial process control systems control valve is the final control element. The control valve consists of two major components, namely, Actuator and valve. The actuator is made up of flexible diaphragm: spring and spring tension adjustments, plate, stem and lock nut housing. The valve is made up of body, plug, stem, and pressure tight connection.

In terms of valve characteristics, valve can be classified in to three types:

1. Linear.
2. Increasing sensitivity.
3. Decreasing sensitivity.

For the linear type valve characteristics, the sensitivity is constant and the characteristic curve is a straight line (e.g. linear valve). For increasing sensitivity type, the sensitivity increases with flow (e.g.) Equal percentage or logarithmic valve). In practice, the ideal characteristics for linear and equal percentage valves are only approximated by commercially available valves. These discrepancies cause no difficulty because the inherent characteristics are changed considerably when the valve is installed in a line having resistance to flow, a situation that usually prevails in practice.

VALVE POSITIONER

The valve positioner is an instrument working on force balance principle to position the control valve stem in accordance to a pneumatic signal received from a controller or manual loading station, regardless of packing box friction, actuator hysteresis or unbalanced forces on the valve plug. Thus the positioner ensures a reliable and accurate operation of control valve. The instrument signal is applied to the signal diaphragm. An increasing signal will drive the diaphragm and flapper-connecting stem to the right. The flapper- connecting stem will then open the supply flapper admitting supply pressure in to the output, which is connected to the actuator diaphragm. The exhaust flapper remains closed when the flapper-connecting stem is deflected to right. The effect of increasing signal is to increase the pressure in the actuator. This increased pressure in the actuator drives the valve stem downwards and rotates the positioned lever clockwise.

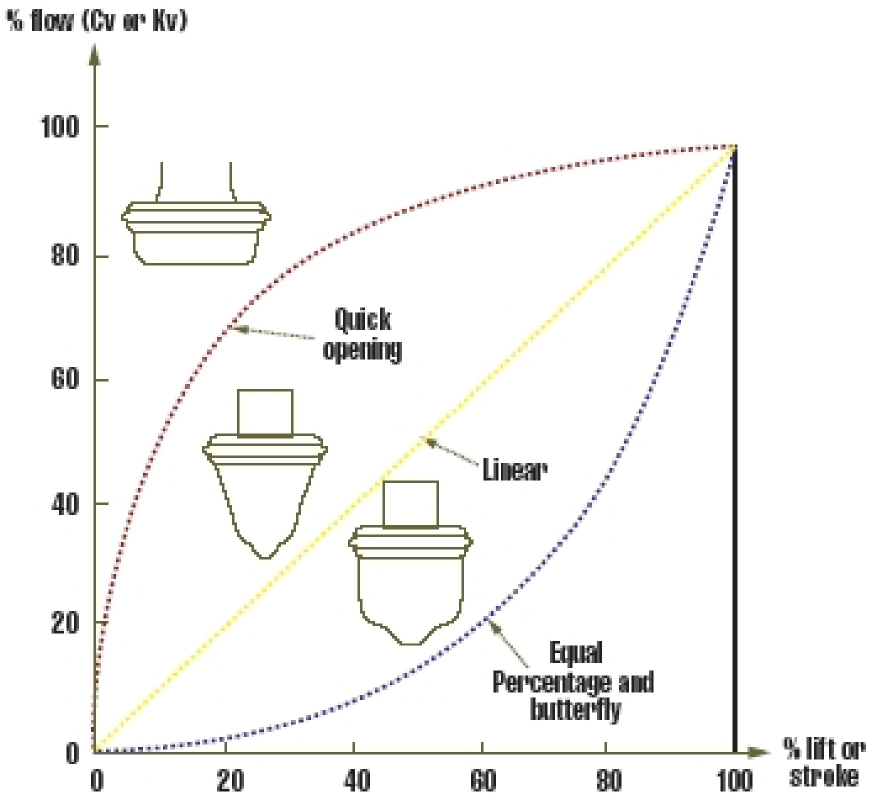
This clockwise rotation of the lever results in a compression of range spring through cam. When the valve stem reaches the position called for by the controller, the compression in the range spring will give a balance force resulting the closure of both the flapper. If the control signal is decreased the force exerted by the signal diaphragm will also decrease and the force from the range spring will push the flapper-connecting stem to the left, opening the exhaust flapper. This causes a decrease in actuator diaphragm pressure and allows the valve stem to move upward until a new force Balance is established.

Control valve (Linear) - Type: Pneumatic; Size: 1/2", Input: 3–15 psig, Air to open.

Control valve (equal %) - Type: Pneumatic; Size: 1/2", Input: 3–15 psig, Action: Air to close.

Control valve (quick opening) - Type: Pneumatic; Size: 1/2", Input: 3–15 psig, Air to open.

MODEL GRAPH

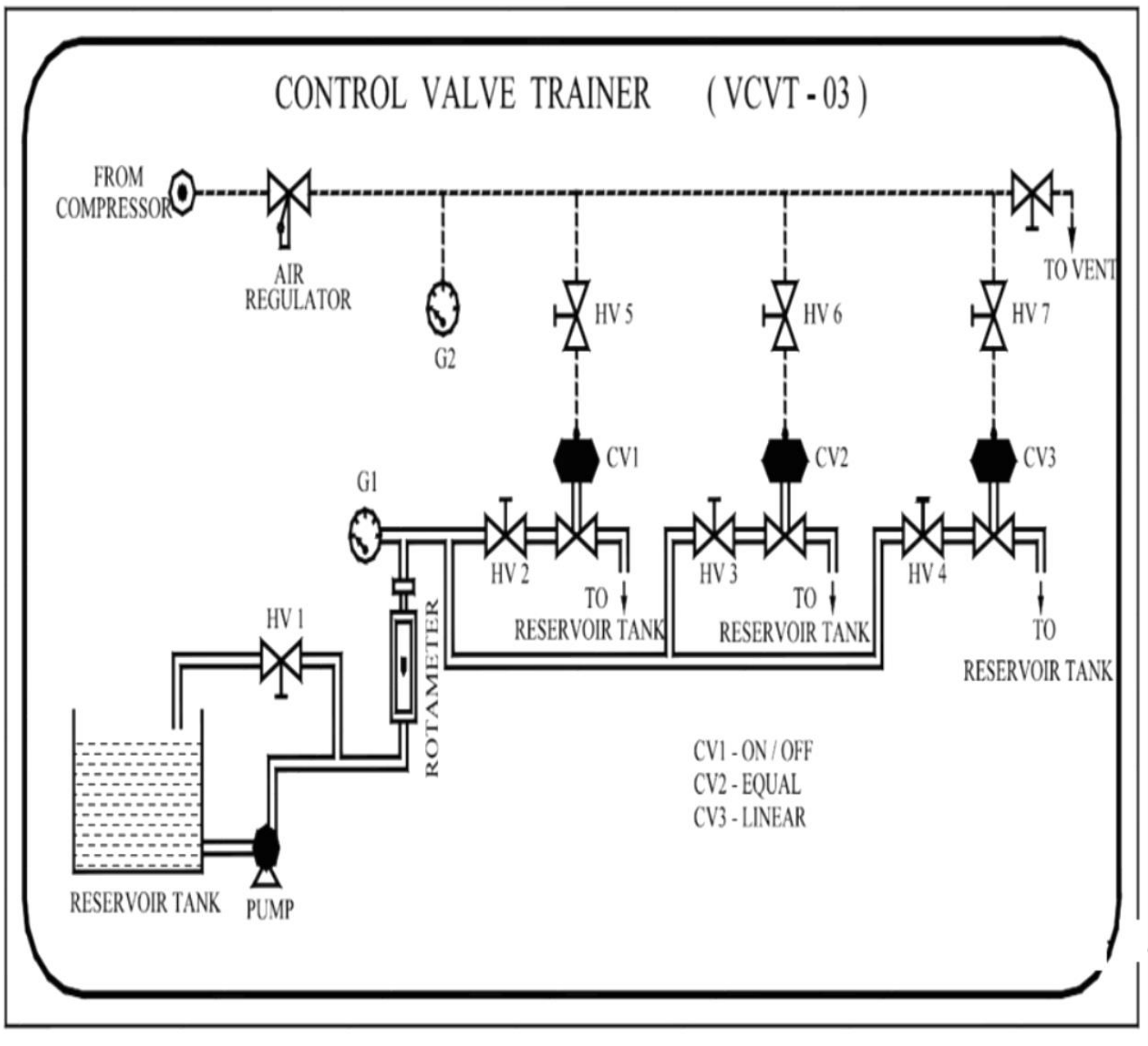


FRONT PANEL DESCRIPTION

Power ON/OFF switch	:	Switch ON/OFF the unit.
Pump ON	:	Switch ON/OFF the pump.
Pump Indicator	:	To indicate the pump power.
HV1	:	Bypass hand valve.
HV2	:	Inlet regulating valve for quick opening valve.
HV3	:	Inlet regulating valve for equal percentage valve.
HV4	:	Inlet regulating valve for linear valve.
HV5	:	Pressure supplying valve for quick opening valve.
HV6	:	Pressure supplying valve for equal percentage valve.
HV7	:	Pressure supplying valve for linear valve.
HV8	:	Vent valve

G1 : To measure the pressure drop across the control valve
G2 : To measure the actuator pressure
G3 : To measure the supply pressure for positioner
CV1 : Quick opening valve.
CV2 : Equal percentage valve.
CV3 : Linear valve

FRONT PANEL DIAGRAM



PROCEDURE:

- Before conducting the experiment, make sure that availability of water in reservoir tank. Fill
  clean and soft water in the reservoir
- Connect air supply pipe to regulator. Confirm there is no loose connection.
- Control valve positioned should be in “bypass” mode.
- Hand valve settings for linear control valve characteristics study; HV4(the regulating
  valve, which is provided at the inlet of control valve) and HV7 should be fully open.

  Regulating valves of other control valves should be fully closed.

- Initially, set the output pressure of air regulator to 15 Psi by varying the knob. Thelinear valve is fully open.
- Keep partially open the vent valve (HV8), when air regulator lifts to its maximumrange.
- Switch on the unit.
- Set the maximum flow in the rotameter by adjusting the bypass valve (HV1) and inletregulating valve (HV4).
- Maintain the pressure drop across the control valve in pressure gauge (G1)(e.g. 1/1.5/2Psi) remains constant varying the bypass valve (HV4). Note the pressure drop acrossthe valve at fully open (G1).
- Never disturb the hand valve (HV4), once it is adjusted for particular opening.
- Observe flow and inlet pressure variations. Note down the air regulator pressure (G2),rotameter flow, and stem position in control valve.
- Decrease the pressure in air regulator to 12 Psi, at same time, pressure across thecontrol valve slightly increases, adjust bypass valve (HV1) to maintain predefinedpressure in G1.
- Note the flow in rotameter and stem position in control valve, air regulator pressure.
- Slowly decrease/increase the air pressure regulator for achieving different stempositions till the valve is fully closed/open.
- Tabulate the rotameter flow, air regulator pressure and stem position.
- Plot the graph between rotameterflow in the y-axis and stem position in x-axis.

TABULATION

ΔPressure drop across control valve (Δp)=

Actuator pressure (Psi)	Stem position (%)	Rotameter flow (LPH)

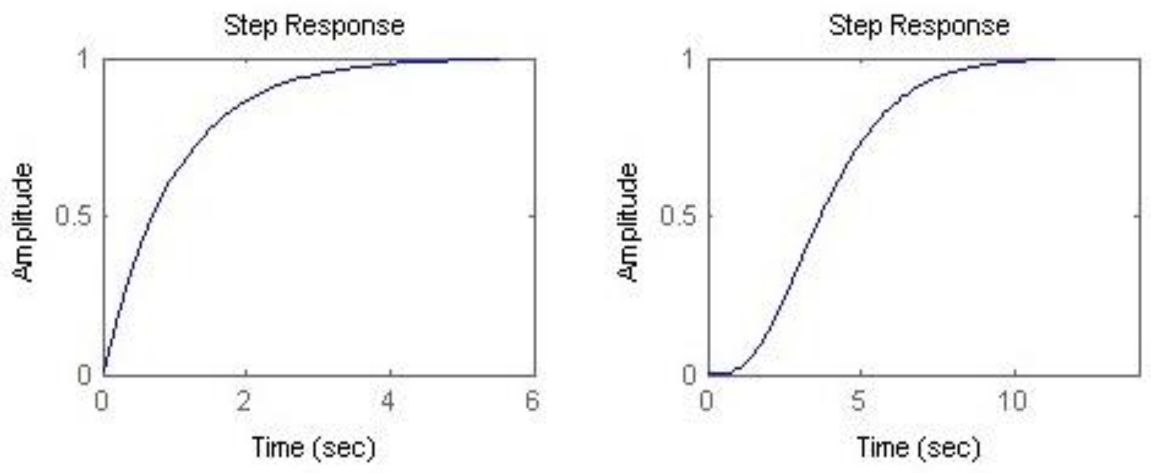
Calculate the control valve co-efficient from the table,

RESULT

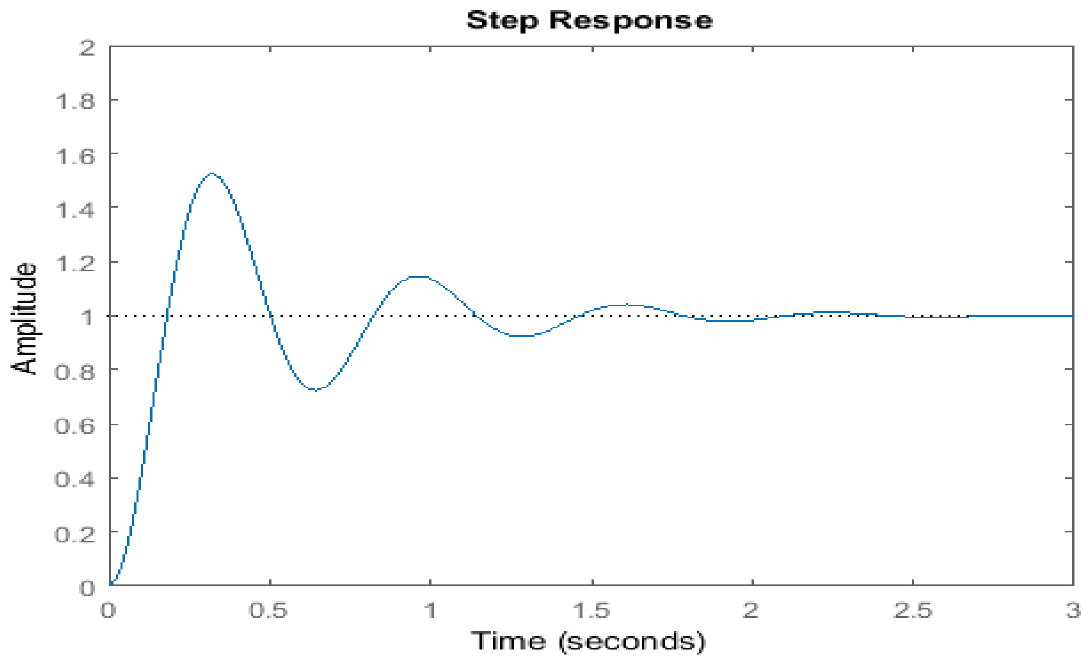
Thus, the characteristics of linear valve without positioner were studied.

MODEL GRAPH

FIRST ORDER SYSTEM (WITH AND WITHOUT DELAY)



SECOND ORDER SYSTEM (WITH AND WITHOUT DELAY)



DYNAMIC CHARACTERSITICS OF FIRST & SECOND ORDER SYSTEM WITH AND WITHOUT TRANSPORTATION LAG

Ex.No:2
Date:

AIM

To determine the dynamic characteristics of first order and second order system with and without transportation lag.

EQUIPMENT

1. Simulation kit

2. CRO

3. Patch Chords

4. PC with Matlab software

THEORY
FIRST ORDER SYSTEM

It is characterized by only one pole with or without a zero. In this case, consider only the pole and it is assumed that there is no more complex zeros available. Eg. For such transfer function are a pure integrator a single time constant (u) the pole is either at the origin or at the negative real axis.
The transfer function for a pure integrator is C(s) / R(s) = K/S

For step input R(s) = 1/s
$C(s) = K/S^2$
Taking Inverse Laplace Transform C(t) = kt
For a step input provided in the input the pure integrator gives the ramp response. The transfer function of a single time constant process is given
C(s) / R(s) = K/1+ts = 1/s X 1/1+ts
$C(t) = K(1-e^{-t/z})$

Here the time constant is defined as the time taken by C(t) to reach 63.3% of the final steady state value. In general, first order system with dead time is represented by the following transfer function
$C(s) / R(s) = K/s\ e^{-tds}$for pure integrator
$C(s) / R(s) = K\ e^{-tds}/ 1+ ts$ for single time constant process
Here td is the transportation lag or dead time.

SECOND ORDER SYSTEM

A second order system is represented in the standard form as
$C(s) = wn^2 / s^2 + 2zw_ns + w_n^2$
Z – damping ratio
W_n – undamped natural frequency

Depending on the value of "z" of the pole of the system may be repeated or complex conjucate.

a) **UNDERDAMPED SYSTEM (0 < z < 1)**

$C(t) = 1 – e^{-zwnt}\sqrt{1-z^2} \sin (wdt + \emptyset)$
Where, $wd = wn\sqrt{1-z^2}$
It is the natural frequency of damped oscillation.
$\emptyset = \tan^{-1}\sqrt{1-z^2} / z$

b) **CRITICAL DAMPED (z = 1)**

$C(t) = 1 – e^{-zwnt}$

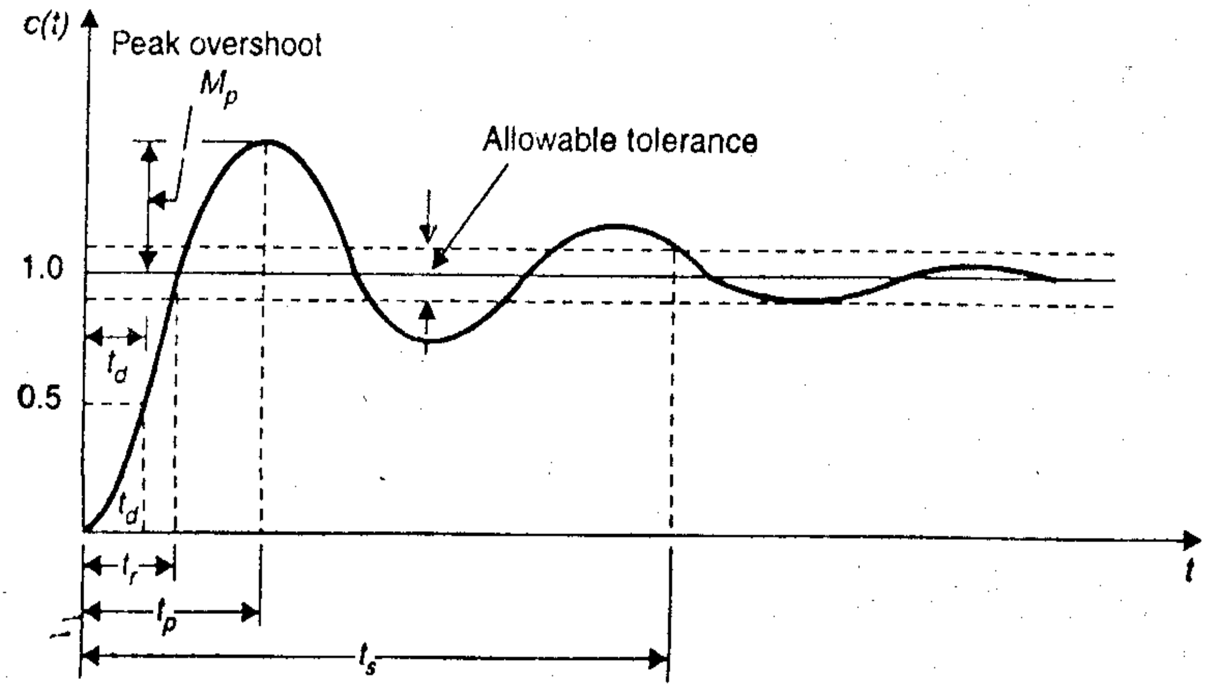
c) **OVERDAMPED SYSTEM (z > 1)**

$C(t) = 1 + w_n / 2 \sqrt{z^2-1} \{ e^{-zt}/ z – e^{-z2t}/ 2z \}$
Where, $z = z + \sqrt{z^2 + w_n}$
$z = z - \sqrt{z^2 + w_n}$
In general 2 nd order system with dead time is presented by

$C(s) = w_n^2e^{-Qds}/ s^2 + 2zw_ns + w_n^2$

PROCEDURE:

- Choose the input square wave of suitable frequency and amplitude say (30Hz, 2.5V)
- For the process of order 1, P is provided with a toggle.
- Provide the input supply as in step and analyses and second the response using a CRO or DSO
- Plot the graph.



RESULT

Thus, the responseof first order and second order system with and without transportation lag was obtained and the dynamic characteristics were studied.

CLOSED LOOP RESPONSE OF FLOW CONTROL LOOP

Ex.No: 3
Date:

AIM:

To obtain the closed loop response of flow control loop for servo and regulator Operation.

EQUIPMENT:

1. Flow process station with all accessories - 1 No
2. Analog / Digital PID controller - 1 No
3. Recorder - 1 No

THEORY:

Flow process controller is used to perform the control action on flow process. A Differential pressure transmitter is used to measure the flow of the fluid through orifice plate. Pump discharges the water from reservoir tank and give it to control valve. Computer acts as an error detector and controller. According to the error signal, that it develops a control signal.

This control signal is given to I/P Converter that operates the control valve. It controls the flow of the fluid in pipeline by varying stem position of the control valve. By pass line is provided to avoid the pump overloading. Data Acquisition card(Data Acquisition System) having ADC and DAC, section so that it acts an effective link between the process plant and the controller.

The level sensing element is a metal probe which is inserted vertically into the medium from the top of the tank. If the tank is a conductor it is used as a ground reference. In insulated tanks the probe is enclosed by a concentric electrode to serve as capacitance change.

When the tank is empty, the probe and inner wall of the tank are separated by air space. As the level of the medium increases the capacitance between the insulated probe and the tank wall increases. The change in capacitance is sensed and converted into a current signal in the range of 4-20 mA for transmission.

The I/P convertor is also called the electro pneumatic convertor, is used where a4 to 20 mA signal current is to be converted to 3-15 psi pressure signal. Essentially the convertor needs two inputs, viz. a fixed 20 psi air at its air inlet and a variable 4 to 20mA at its current input. It consists of 3 basic parts:

- Pick up system
- Convertor
- Pneumatic relay

The pickup system consists of a voice coil situated in the air gap of permanent magnet. The convertor consists of a nozzle, the restrictor and the baffle plate on the beam, which is mounted on low friction fulcrum. The pneumatic relay consists of a diaphragm, a valve seat, a needle, and a capillary tube.

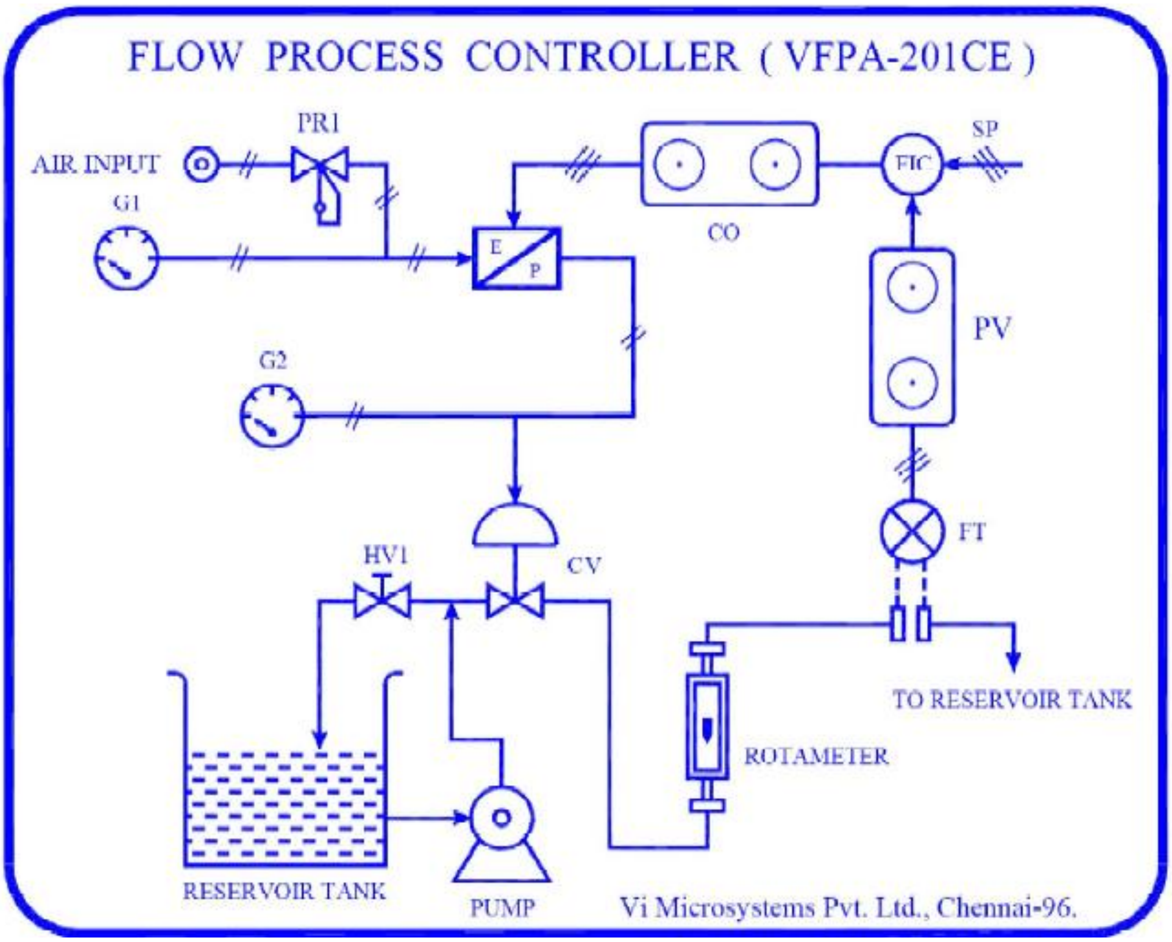
EXERCISE: 1

Closed – loop connection is made in the flow process station.

PROCESS DESCRIPTION:

The block diagram and schematic diagram for Closed – loop connection is made in the flow process station as shown in fig. given below.

FRONT PANEL DIAGRAM



FRONT PANEL DESCRIPTION

Power ON/OFF Switch - It is used to switch ON/OFF the unit.
Pump Speed regulator - It is used to vary the speed of the pump.
G1 - It is used to indicate output pressure of air regulator.
G2 - It is used to indicate the I/P converter output.
PV - Test points for flow transmitter output (4-20mA).
CO - Test points for Controller output (4-20mA)

EXERCISE: 2

The flow controller (P+I) is tuned using any one of the tuning techniques.

PROCEDURE:

i. Ensure the availability of Air & Water.
ii. Interface the PC with process and Data Acquisition System.
iii. Maintain Gauge (G1) pressure at 20 Psi by using air regulator knob.
iv. Position the Hand valve HV1 in partially open position.
v. Patch CO & PV terminals through Patch chords.
vi. Switch ON the Data Acquisition System with PC.
vii. Invoke Process Control Software.
viii. Using PI control mode to met the desired flow

EXERCISE: 3

The response of the control loop is obtained for changes in the set point.

PROCEDURE:

i. Procedure for exercise-1 is repeated upto viii.
ii. By changing the various set point, the response for corresponding set point plotted.

PI Controller Set Point---------- Kp----- Ki---------

Time in Sec	Controller output in percentage	Process variable (lph)

EXERCISE: 4

The response of the control loop is obtained for changes in the load variable.

PROCEDURE:

i. Procedure for exercise-1 is repeated up to viii.
ii. By varying HV1 (Disturbance), the response for corresponding disturbance plotted.

PI Controller Set Point---------- Kp----- Ki---------

Time in Sec	Controller output in percentage	Process variable (lph)

EXERCISE: 5

The Exercise 3 and 4 are repeated for different controller modes and settings.

RESULT:

Thus the closed loop response of flow process for Servo and Regulator operation was obtained.

TUNING OF PID CONTROLLER FORMATHEMATICALLY DESCRIBED PROCESS

Ex.No: 4
Date:

AIM

To study of various controller tunings using MATLAB software.

APPARATUS REQUIRED

MATLABSoftware,PC

THEORY

Controller tuning is the process of determining the controller parameters which produce the desired output. Controller tuning allows for optimization of a process and minimizes the error between the variable of the process and its set point.

Types of controller tuning methods include the trial and error method, and process reaction curve methods. The most common classical controller tuning methods are the Ziegler-Nichols and Cohen-Coon methods. These methods are often used when the mathematical model of the system is not available. The Ziegler-Nichols method can be used for both **closed** and **open loop systems**, while Cohen-Coon is typically used for open loop systems.

I) TRIAL AND ERROR METHOD

The trial and error tuning method is based on guess-and-check. In this method, the proportional action is the main control, while the integral and derivative actions refine it. The controller gain, K_c, is adjusted with the integral and derivative actions held at a minimum, until a desired output is obtained.

II) PROCESS REACTION CURVE

In this method, the variables being measured are those of a system that is already in place. A disturbance is introduced into the system and data can then be obtained from this curve. First the system is allowed to reach steady state, and then a disturbance, X_o, is introduced to it. The percentage of disturbance to the system can be introduced by a change in either the set point or process variable.

III) ZIEGLER-NICHOLS METHOD

Ziegler and Nichols devised two empirical methods for obtaining controller parameters. Their methods were used for non-first order plus dead time situations, and involved intense manual calculations.

Ziegler-Nichols closed-loop tuning method

The Ziegler-Nichols closed-loop tuning method allows one to use the ultimate gain value, K_u, and the ultimate period of oscillation, P_u, to calculate K_c . It is a simple method of tuning PID controllers and can be refined to give better approximations of the controller.

To find the values of these parameters, and to calculate the tuning constants, use the following procedure:

Closed Loop (Feedback Loop)

1. Remove integral and derivative action. Set integral time (T_i) to a largest value and set the derivative controller (T_d) to zero.
2. Create a small disturbance in the loop by changing the set point. Adjust the proportional, increasing and/or decreasing, the gain until the oscillations have constant amplitude.
3. Record the gain value (K_u) and period of oscillation (P_u).
4. Plug these values into the Ziegler-Nichols closed loop equations and determine the necessary settings for the controller. Closed-Loop Calculations of K_c, T_i, T_d

Ziegler-Nichols open-loop tuning method or process reaction method

This method remains a popular technique for tuning controllers that use proportional, integral, and derivative actions. The Ziegler-Nichols open-loop method is also referred to as a process reaction method, because it tests the open-loop reaction of the process to a change in the control variable output. This basic test requires that the response of the system be recorded, preferably by a plotter or computer. Once certain process response values are found, they can be plugged into the Ziegler-Nichols equation with specific multiplier constants for the gains of a controller with either P, PI, or PID actions.

IV) COHEN-COON METHOD

The Cohen-Coon method of controller tuning corrects the slow, steady-state response given by the Ziegler-Nichols method when there is a large dead time (process delay) relative to the open loop time constant; a large process delay is necessary to make this method practical because otherwise unreasonably large controller gains will be predicted. This method is only used for first-order models with time delay, due to the fact that the controller does not instantaneously respond to the disturbance (the step disturbance is progressive instead of instantaneous).

The Cohen-Coon method is classified as an 'offline' method for tuning, meaning that a step change can be introduced to the input once it is at steady-state. Then the output can be measured based on the time constant and the time delay and this response can be used to evaluate the initial control parameters.

V) Other Methods

There are other common methods that are used, but they can be complicated and aren't considered classical methods.

a. INTERNAL MODEL CONTROL

The Internal Model Control (IMC) method was developed with robustness in mind. The Ziegler-Nichols open loop and Cohen-Coon methods give large controller gain and short integral time, which isn't conducive to chemical engineering applications. The IMC method relates to closed-loop control and doesn't have overshooting or oscillatory behavior. The IMC methods however are very complicated for systems with first order dead time.

b. AUTO TUNE VARIATION

The auto-tune variation (ATV) technique is also a closed loop method and it is used to determine two important system constants (P_u and K_u for example). These values can be determined without disturbing the system and tuning values for PID are obtained from these. The ATV method will only work on systems that have significant dead time or the ultimate period, P_u, will be equal to the sampling period.

PROCEDURE

Type the program using matlab software in matlabeditor .

Given transfer function

Gp(S) = 5/(14s^3 +78S^2+11S+1)

Gp(S) = 6/(48s^3 +44S^2+12S+1)

TUNING METHOD:

ZIEGLER NICHOLS OPEN AND CLOSE LOOP

```
n=[5]

d=[1478 11 1]

y=tf(n,d)

[gm,pm,wpc,wgc] = margin(y)

gm =
```

12.05

pm =

31.4

ω pc =
0.25

ωgc =

0.88

From the program we got the above values, using the formulas we find the P,I and D values.

gm=ku

P=ku/1.7

FOR P CONTROLLER=12.05

Pu=2 x3.14(pi) / ω pc

ω pc =0.25

Pu = 25.12

FOR I CONTROLLER = Pu/8 = 3.14

FOR D CONTROL = Pu/2= 12.56

```
n=[6]

d=[48 44 12 1]

y=tf(n,d)

[gm,pm,wpc,wgc] = margin(y)

gm =
    1.6667
```

pm =

17.7247

ω pc =
0.5000

ωgc =

0.3906

From the program we got the above values, using the formulas we find the P,I and D values.

gm=ku

P=ku/1.7

FOR P CONTROLLER=0.97

Pu=2 x3.14(pi) / ω pc

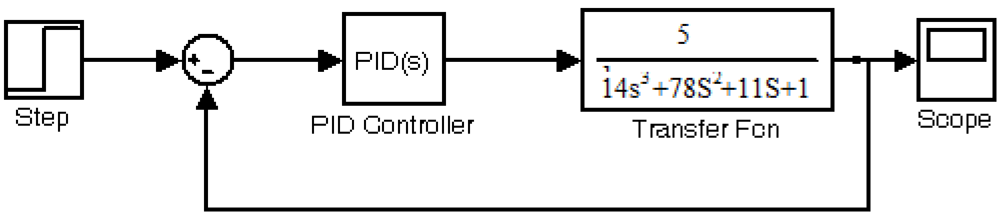
ω pc =0.5

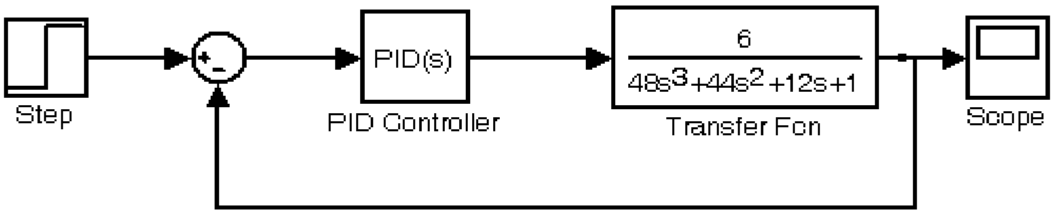
Pu = 12.36

FOR I CONTROLLER = Pu/8 = 1.545

FOR D CONTROL = Pu/2= 6.18

For closed loop Response apply the values in MATLAB SIMULINK.



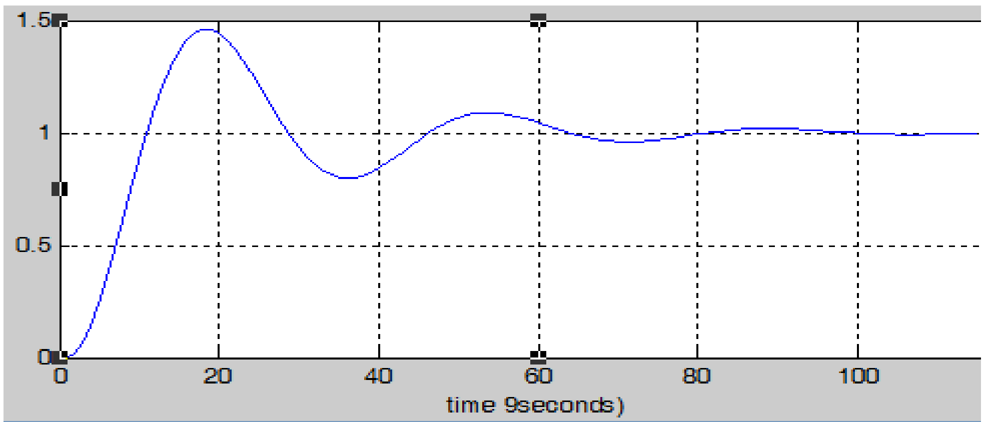


Now the controller parameters are calculated using the table below,

	Kp	Ti	Td
P	Ku/2		
PI	Ku/2.2	Pu/1.2	
PID	Ku/1.7	Pu/2	Pu/8

Now using the PID values again implement the Simulink Model to get the response of Ziegler Nichols Closed Loop responses.

Output Response



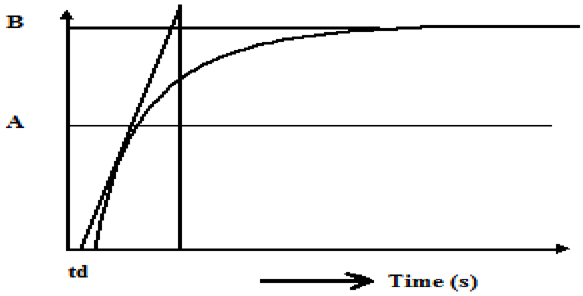
ii) <u>CLOSE LOOP RESPONSE OF I ORDER SYSTEM WITH DELAY USING COHEN COON TUNNING METHOD IN MATLAB CODING:</u>

Gp (s) = $\frac{2}{10s+1}e^{-2s}$

PROCEDURE

1. Write a coding or simulink for a open loop I order process and observe the response.
2. Draw a tangent line in the graph.
3. Find k,τ,td from a graph.
4. After that find the controller values using k,τ,td in cohen coon tuning method.
5. Then we write a coding for a close loop system.
6. Observe the close loop response of P, PI and PID controllers.

OPEN LOOP RESPONSE

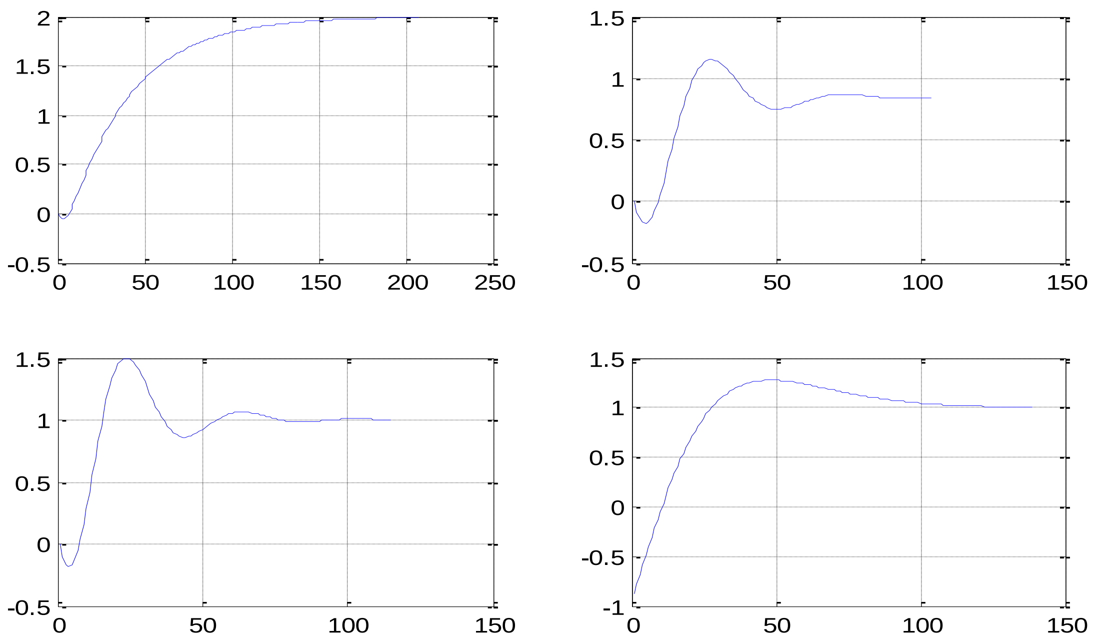


K=B/A
τ = B/Slope
Slope= opposite / adjacent
td=Delay Time

```
n=[2]

d=[10 1]

[n1,d1]=pade(2,1)

n2=conv(n,n1)

d2=conv(d,d1)

t=[0:0.5:25]

y=step(tf(n2,d2))

subplot(2,2,1)

plot(y)

kp=2.67
```

```
[n3,d3]=cloop(kp*n2,d2)

y1=step(tf(n3,d3))
subplot(2,2,2)
plot(y1)
kp=2.56
n4=[6.96 1]
d4=[6.96 0]
[n5,d5]=cloop(kp*conv(n2,n4),conv(d2,d4))
y2=step(tf(n5,d5))
subplot(2,2,3)
plot(y2)
kp=3.33
n6=[3.18 4.547 1]
d6=[0 4.547 0]
[n7,d7]=cloop(kp*conv(n2,n6),conv(d2,d6))
y3=step(tf(n7,d7))
subplot(2,2,4)
plot(y3)
```

CLOSED LOOP RESPONSE



RESULT :

Thus the different tuning methods were studied using MATLAB software.

CLOSED LOOP RESPONSE OF LEVEL CONTROL LOOP

Ex No: 5 (a)
Date:

LEVEL CONTROL IN PROCESS CONTROL TRAINING PLANT

AIM

To obtain the closed loop response of level control loop for servo and regulator operation.

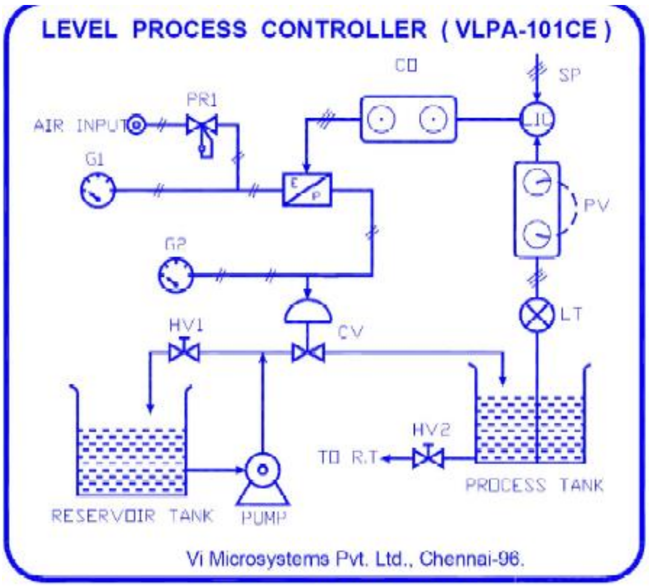
APPARATUS REQUIRED

1. Level Process Analyser
2. Data Acquisition System.
3. PC with Process Control software.
4. Patch chords.

EXERCISE: 1

Closed loop connection is made in the level process station.

FRONT PANEL DIAGRAM



FRONT PANEL DESCRIPTION

Power ON/OFF Switch - It is used to switch ON/OFF the unit.
Pump Speed regulator - It is used to vary the speed of the pump.
G1 - It is used to indicate output pressure of air regulator.
G2 - It is used to indicate the I/P converter output.
PV - Test points for Level transmitter output (4 - 20mA).

EXERCISE: 2 & 3

The level controller (P+I) is tuned using any one of the tuning techniques
The response of the control loop is obtained for changes in the set point.

PROCEDURE

* Ensure the availability of Air & Water.
* Interface the PC with process and Data Acquisition System.
* Maintain Gauge (G1) pressure at 20 Psi by using air regulator knob.
* Position the Hand valve HV1 in partially open position.
* Patch CO & PV terminals through Patch chords.
* Switch ON the Data Acquisition System with PC.
* Invoke Process Control Software.

i. In PC select **“Start →Menu → All Programs** → Process Control**”**
The following window will be appeared,
CO - Test points for Controller output (4 - 20mA).
ii. Select the “file>>Start” menu. The menu will be shown below,

- The port setting window will open Select the **COM port number, Baud rate (38400)** and keep the
- remaining boxes as it is and click **OK** button
- The **Port opened successfully** window will appear. Then click **OK** button.
- To select the appropriate control and set the parameters like **Set point, Kp, Ki &Kd**values
- Switch ON the pump and vary the speed control knob.
- Enter the parameters and observe the responses.
- Switch OFF the pump.
- Save the response and conclude the behavior of Level process.
- Load the file and analysis the graph

PI Controller Set Point---------- Kp----- Ki---------

Time in Sec	Controller output in percentage	Process variable

RESULT

Thus, the performance of PI controller on Level process was studied.

EXERCISE: 4

The response of the control loop is obtained for changes in the load variable.

PROCEDURE

By applying disturbance using corresponding control valve

PI Controller Set Point---------- Kp----- Ki---------

Time in Sec	Controller output in percentage	Process variable

EXERCISE: 5

The step 3 and step 4 are repeated for different controller modes and settings.

Ex No: 5 (b)
Date:

PRESSURE CONTROL IN PROCESS CONTROL TRAINING PLANT

AIM

To obtain the closed loop response of pressure control loop for servo and regulator operation.

APPARATUS REQUIRED

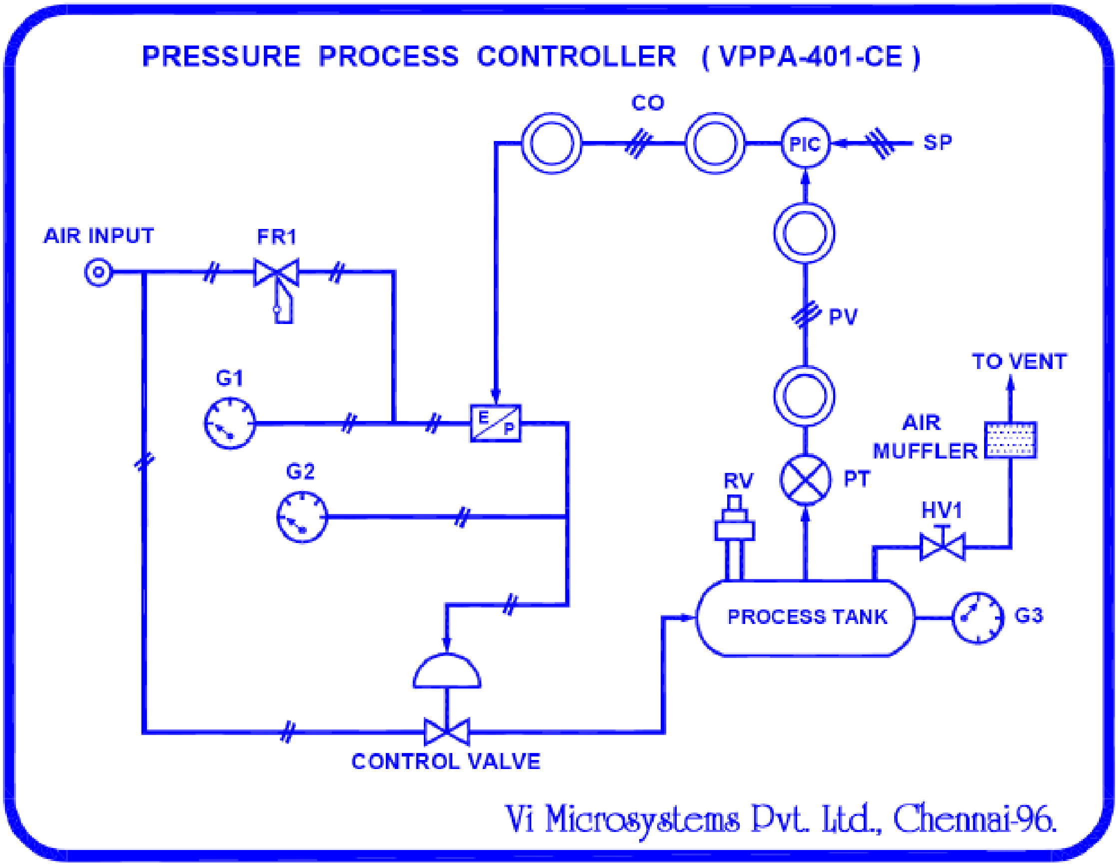
1. Pressure Process Analyser.
2. Data Acquisition System.
3. PC with Process Control software.
4. Patch chords.

THEORY

EXERCISE: 1

Closed loop connection is made in the pressure process station.

FRONT PANEL DIAGRAM



FRONT PANEL DESCRIPTION
Power ON/OFF Switch - It is used to switch ON/OFF the unit.
Pump Speed regulator - It is used to vary the speed of the pump.
G1 - It is used to indicate output pressure of air regulator.
G2 - It is used to indicate the I/P converter output.
PV - Test points for pressure transmitter output (4 - 20mA).
CO - Test points for Controller output (4 - 20mA).

EXERCISE: 2 & 3

The level controller (P+I) is tuned using any one of the tuning techniques
The response of the control loop is obtained for changes in the set

PROCEDURE
* Ensure the availability of Air.
* Interface the PC with process and Data Acquisition System.
* Maintain Gauge (G1) pressure at 20 Psi by using air regulator knob.
* Position the Hand valve HV1 in partially open position.
* Patch CO & PV terminals through Patch chords.
* Switch ON the Data Acquisition System with PC.
* Invoke Process Control Software.

Precautions:

1. Check the air inlet pressure to the process station as 100 – 150 psi.
2. Check whether the I/P converter inlet pressure is 20 psi.
3. Let hand valves HV2, HV4 and HV6 be fully closed position.
4. Keep the hand valves HV1 and HV3 connected tank 1 slightly opened.
5. Keep the outlet valve HV5 of tank 1 slightly opened.
6. Check whether there is any leakage in air path.
7. Switch off the mains before making the connections.

PI Controller Set Point---------- Kp----- Ki---------

Time in Sec	Controller output in percentage	Process variable

EXERCISE:4

The response of the control loop is obtained for changes in the load variable.

PROCEDURE

By applying disturbance using corresponding control valve

PI Controller Set Point---------- Kp----- Ki---------

Time in Sec	Controller output in percentage	Process variable

RESULT

Thus the closed loop response of pressure process for Servo and Regulator operation was obtained.

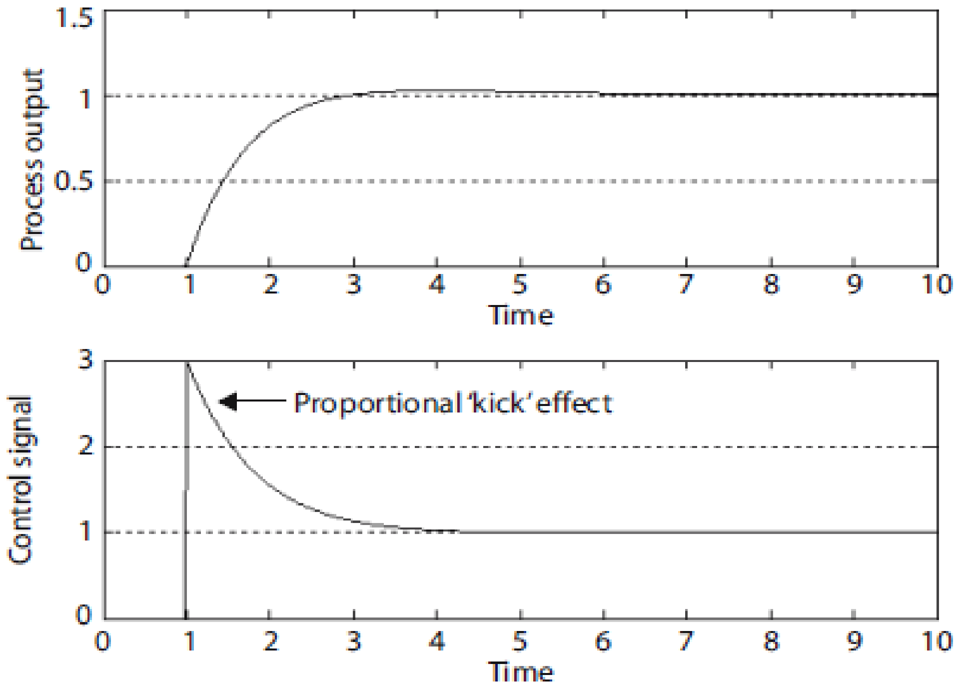


Figure 1.16 Process output and control signals showing proportional kick effects due to unit step change in reference signal at $t = 1$.

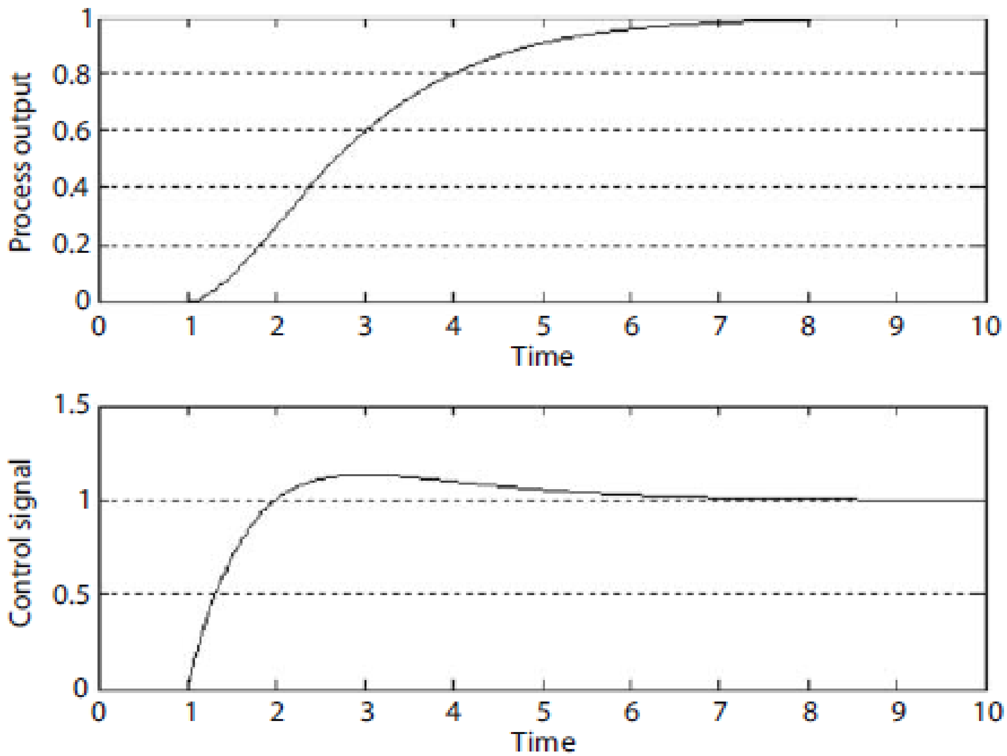


Figure 1.18 Typical output and control signals for the restructured PI controller (removing proportionalkick).

PID IMPLEMENTATION ISSUES

Ex.No 6
Date:

AIM

To obtain the response of integral windup, anti integral windup, proportional kick, anti proportional kick, derivative kick, anti derivative kick controllers using MATLAB software.

APPARATUS REQUIRED

PC with MATLAB Software.

THEORY

Industrial PID control usually comes in a packaged form, and before attempting a tuning exercise, it isinvaluable to understand *how* the PID controller has been implemented. This usually means a detailedexamination of the manufacturer’s User Manual, and possibly a meeting and discussion with thecontroller manufacturer’s personnel. Even then, many of the manufacturer’s innovations in PID controlmay remain commercially sensitive, since for a number of the problems arising in industrialPIDcontrolmanufacturers have introduced customized features, and details of these may not be available tothe user or installer. However, there are several common problems in the implementation of the terms ofthe PID controller and it is useful to examine general solutions and terminology even if specific industrialdetails are not available. Table 1.6 shows some common process control problems and the appropriatePID implementation solution.Toperformwell with the industrial process problems of Table 1.6, the parallel PID controller requiresmodification. In this section, detailed consideration is given to the bandwidth-limited derivative term,proportional and derivative kick, anti-windup circuit design and reverse acting control.

Table 1.6 Process control problems and implementing the PID controller.

Process control problem	PID controller solution
Measurement noise Significant measurement noise on process variable in the feedback loop. Noise amplified by the pure derivative term.	Noise signals look like high frequency signals Replace the pure derivative term by a bandwidth limited derivative term. This prevents measurement noise amplification.
Proportional and derivative kick P- and D-terms used in the forward path Step references causing rapid changes and spikes in the control signal. Control signals are causing problems or outages with the actuator unit.	Move the proportional and derivative terms into feedback path. This leads to the different forms of PID controllers which are found in industrial applications.

Nonlinear effects in industrial processes Saturation characteristics present in actuators. Leads to integral windup and causes excessive overshoot. Excessive process overshoots lead to plant trips as process variables move out of range.	Use anti-windup circuits in the integral term of the PID controller. These circuits are often present and used without the installer being aware of their use.
Negative process gain A positive step change produces a wholly negative response. Negative feedback with such a process gives a closed-loop unstable process.	Use the option of a reverse acting PID controller structure.

Proportional Kick

The Problem

Proportional kick is the term given to the observed effect of the proportional term in the usual parallel PIDstructure on rapid changes in the reference signal.Recall first the parallel PI controller structure as shown in Figure 1.15.

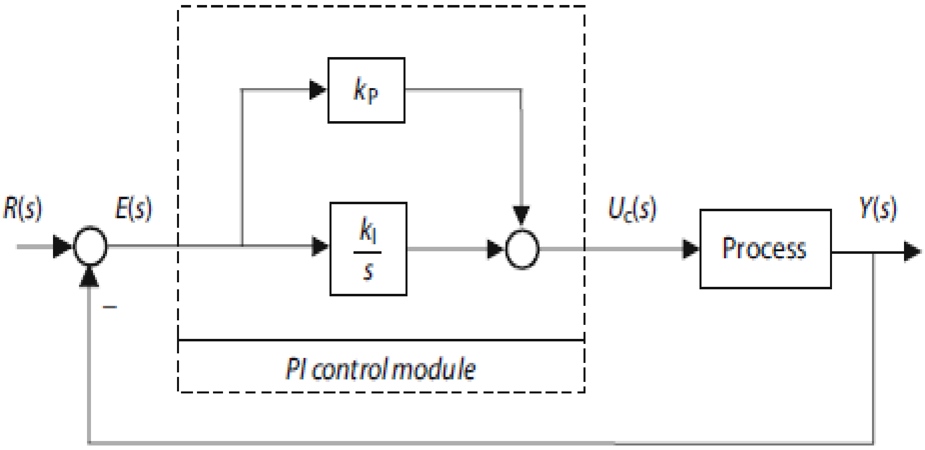


Figure 1.15 Parallel PI control structure.

Using Figure 1.15, if the process is under control and the outputs of the system are steady then the error signal $E(s) = R(s) - Y(s)$will be close to zero.Consider now the effect of a step change in the reference input $R(s)$.This will cause an immediate step change in $E(s)$ and the controller will pass this step change directly into the controller output $U_c(s)$ via the proportional term $k_P E(s)$. In these circumstances, the actuator unit will experience a rapidly changing command signal that could be detrimental to the operation of the unit; the actuator will receive a proportional *kick*. A typical sharp spike-like change in the control signal is seen in Figure 1.16, which shows output and control signals for thisproportional kick problem

The Remedy

The remedy for proportional kick is simply to restructure the PI controller, moving the proportional term into the feedback path, as shown in Figure 1.17.

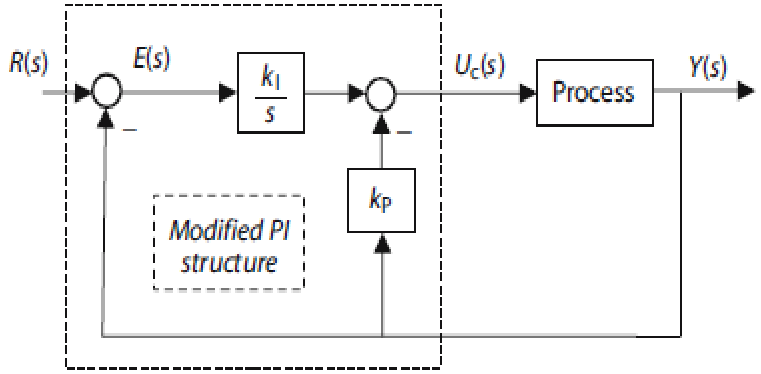


Figure 1.17 Restructured PI controller removing proportional kick effects.

The step response and control signal for this modified PI structure typically look like those of Figure 1.18. The spike on the control signal has been removed and the control signal is no longer an aggressive- looking signal.Meanwhile, the process output signal is now a little slower.

The equation for the restructured form of the PI controller is

$$U_c(s)=\left[\frac{k_I}{s}\right]E(s)-[k_P]Y(s)$$

This structure shows the integral (I) term to be on the setpoint error signal and the proportional (P)term to be on the measured output or process variable signal. This has lead to the industrial terminology where this structure is called I–P,meaning I on error and P on process variable. Clearly, a new set of PID controllers is possible by restructuring the controller in this way.

Derivative Kick

The Problem

Derivative kick is very similar to proportional kick (Section 1.3.2). Figure 1.19 shows a parallel ID–Pcontrol system. This structure is read as “integral (I) and derivative (D) on error and proportional (P)on process variable”. The derivative term is also the modified derivative term from Section 1.3.1. Thuswith this particular form of three-term controller, the proportional (P) on process variable has eliminatedproportional kick and the presence of the modified derivative term has reduced high-frequencynoise amplification.

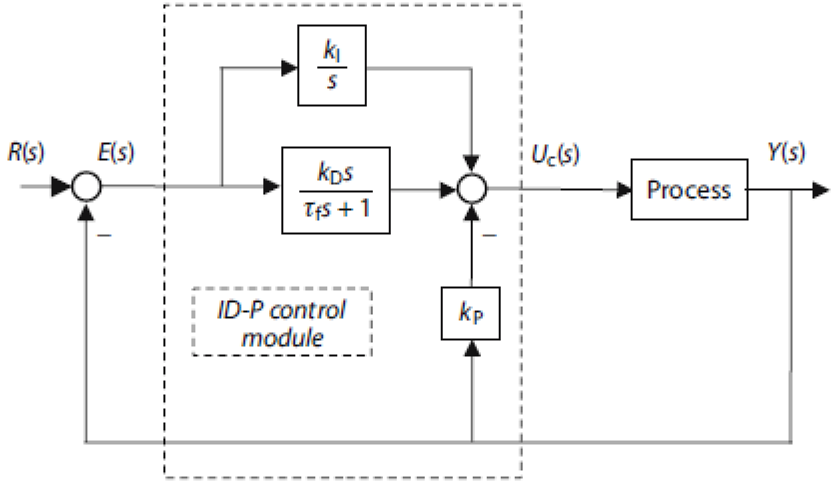


Figure 1.19 Three-term ID–P control system, with modified derivative term.

The equation for the ID-P control action is

$$U_c(s) = \left[\frac{k_I}{s} + \frac{k_D s}{(\tau_f s + 1)}\right] E(s) - [k_P]Y(s)$$

If the output of the process is under control and steady then the setpoint error signal $E(s) = R(s) - Y(s)$ will be close to zero.A subsequent step change in the reference signal $R(s)$ will cause an immediate stepchange in the error signal $E(s)$. Since the proportional term of the controller operates on the processoutput,proportionalkickwill not occur in the control signal; however,the output of the derivative term

$$\frac{k_D s}{(\tau_f s + 1)} E(s)$$

must be considered. Differentiating a step change will produce an impulse-like spike in the control signal and this is termed derivative kick. Figure 1.20 shows typical output and control signals for this problem.Note the very sharp spike-like change in the control signal.This control signal could be driving a motor or a valve actuator device, and the kick could create serious problems for any electroniccircuitry used in the device.

The Remedy

If the derivative term is repositioned so that the reference signal is not differentiated, then derivativekick is prevented. The ID–P controller transfer function is

$$U_c(s) = \left[\frac{k_I}{s} + \frac{k_D s}{(\tau_f s + 1)}\right] E(s) - [k_P]Y(s)$$

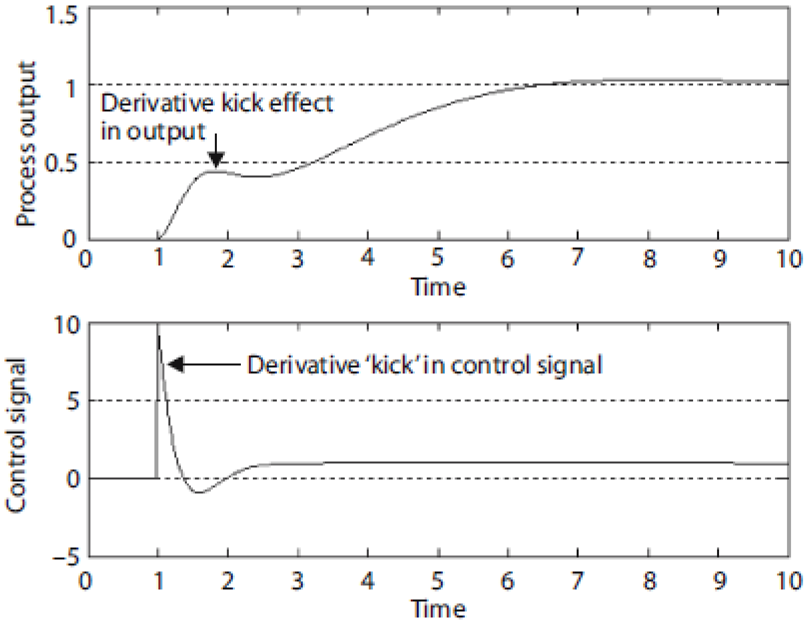


Figure 1.20 Output and control signals showing derivative kick in the control signal (unit step changein reference at $t = 1$).
and hence removing the operation of the derivative term on the reference gives

$$U_c(s) = \left[\frac{k_I}{s}\right]E(s) - \left[k_P + \frac{k_D s}{(\tau_f s + 1)}\right]Y(s)$$

This new I-PD controller is shown in Figure 1.21. In this case, the I-PD terminology denotes Integral term on error and Proportional and Derivative terms on process variable or measured output.

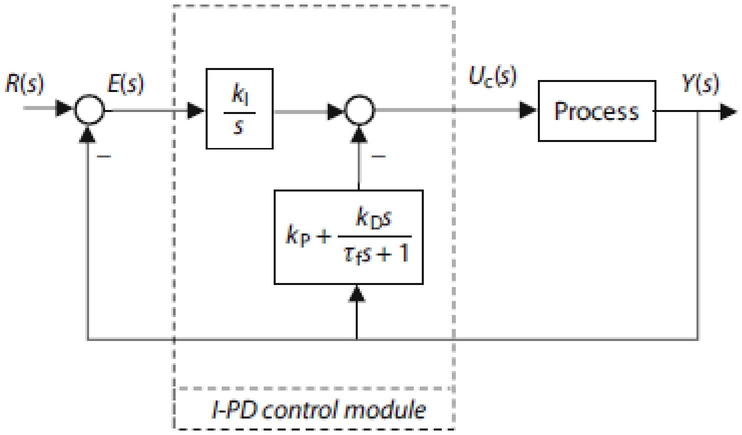


Figure 1.21 Three-term I-PD control for preventing derivative kick (and proportional kick).

Typical step response and control signals for themodified I-PD control structure are shown in Figure 1.22. In the figure, it can be seen that the spike on the control signal due to derivative kick has been removed and that no proportional kick is present either.

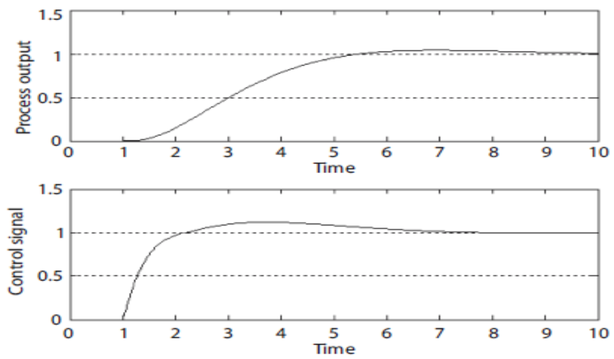


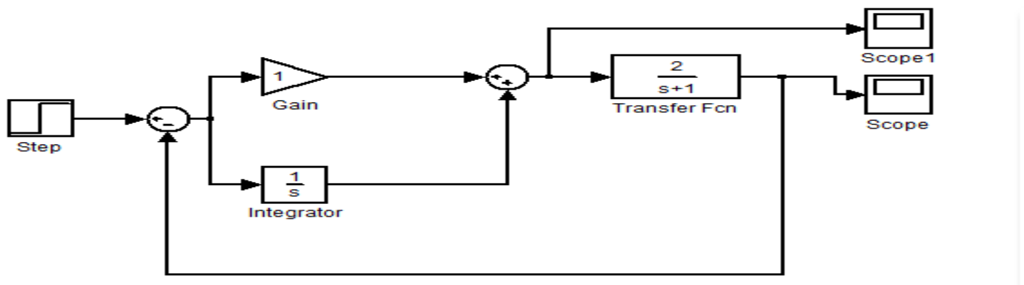
Figure 1.22 Typical output and control signals for the three-term I-PD controller showing that derivativekick has been removed.

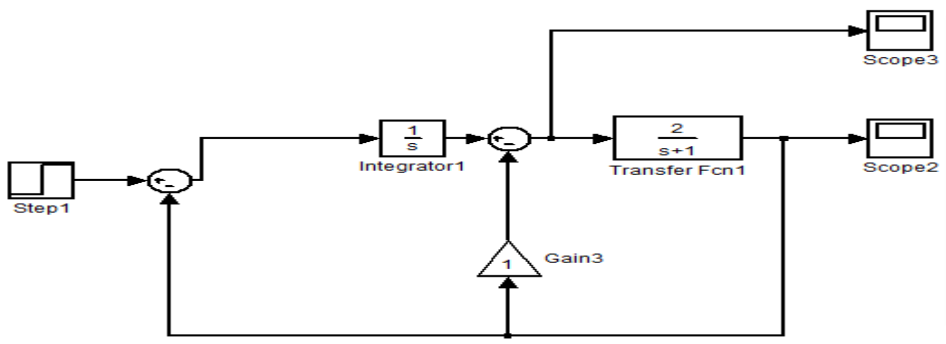
Integral windup in PID controller: Integral windup refers to the situation in a PID controller where a large change in setpoint occurs (say a positive change) and the integral terms accumulates a significant error during the rise (windup), thus overshooting and continuing to increase as this accumulated error is unwound (offset by errors in the other direction). The specific problem is the excess overshooting.This problem can be addressed by:

- Initializing the controller integral to a desired value.
- Increasing the set point in a suitable ramp.
- Disabling the integral function until the to-be-controlled process variable (PV) has entered the controllable region.
- Limiting the time period over which the integral error is calculated.
- Preventing the integral term from accumulating above or below pre-determined bounds.

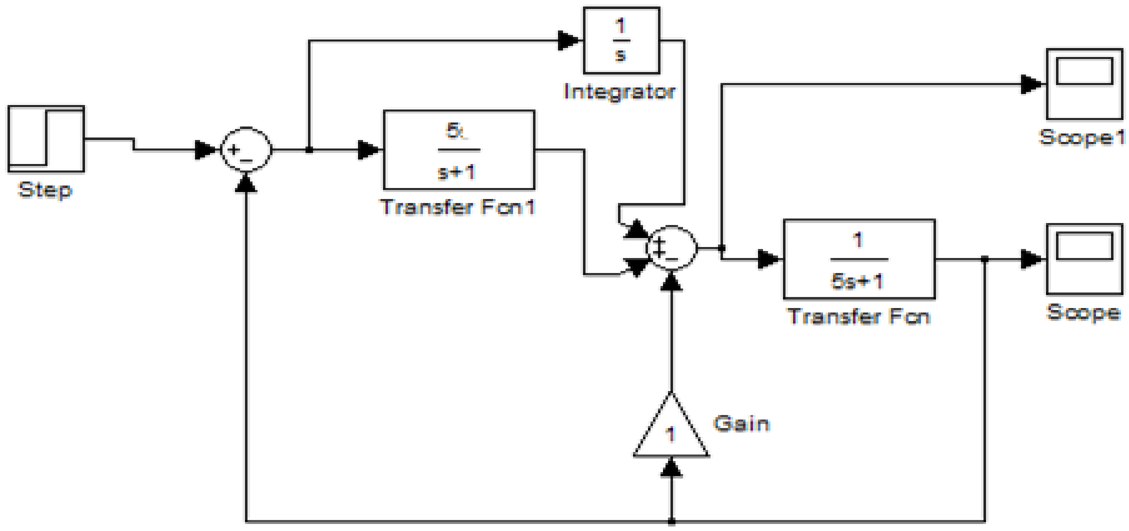
PROCEDURE

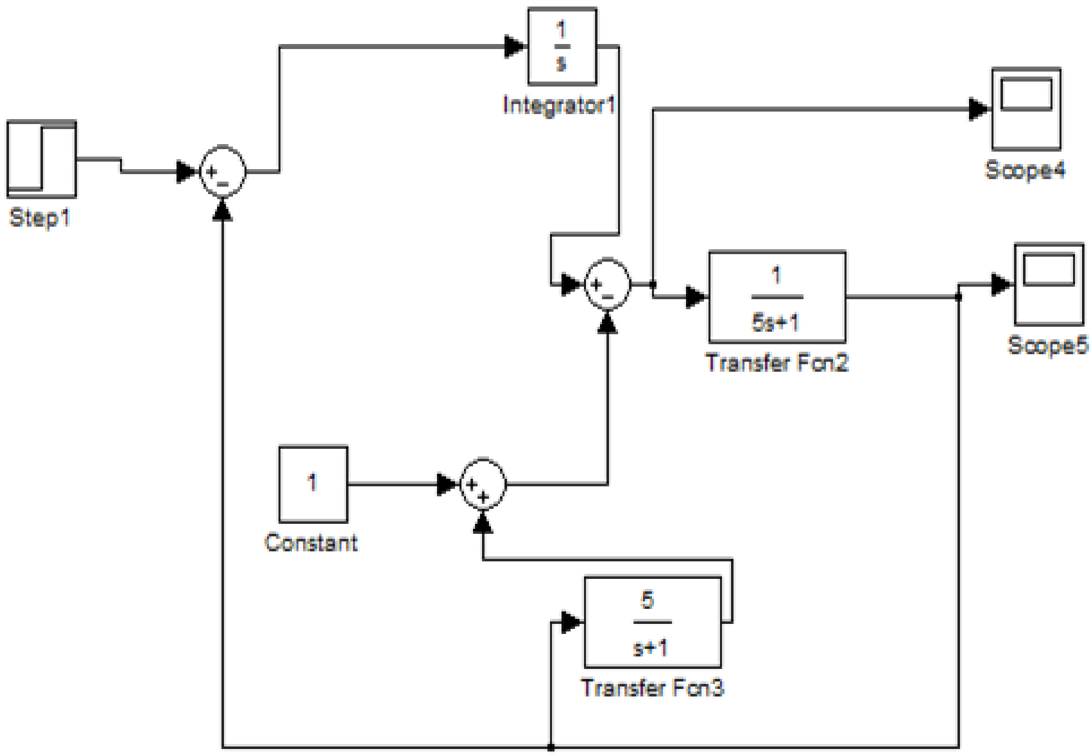
PROPORTIONAL KICK & ANTI PROPORTIONAL KICK STRUCTURE





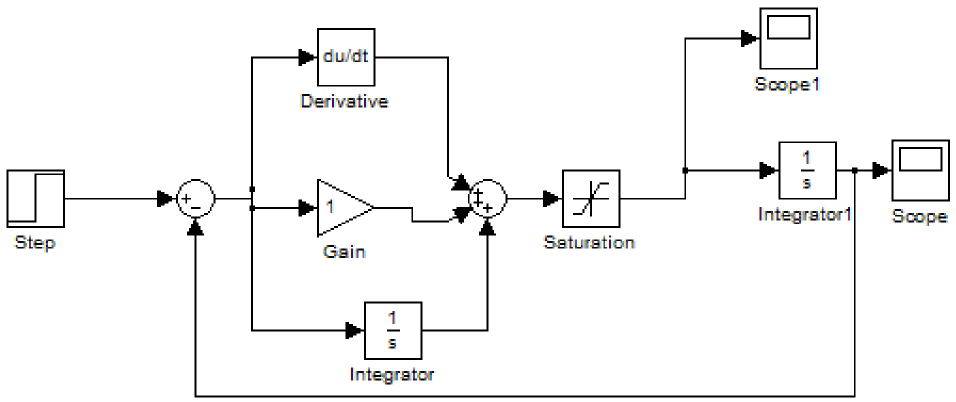
DERIVATIVE KICK &ANTI DERIVATIVE KICK STRUCTURE



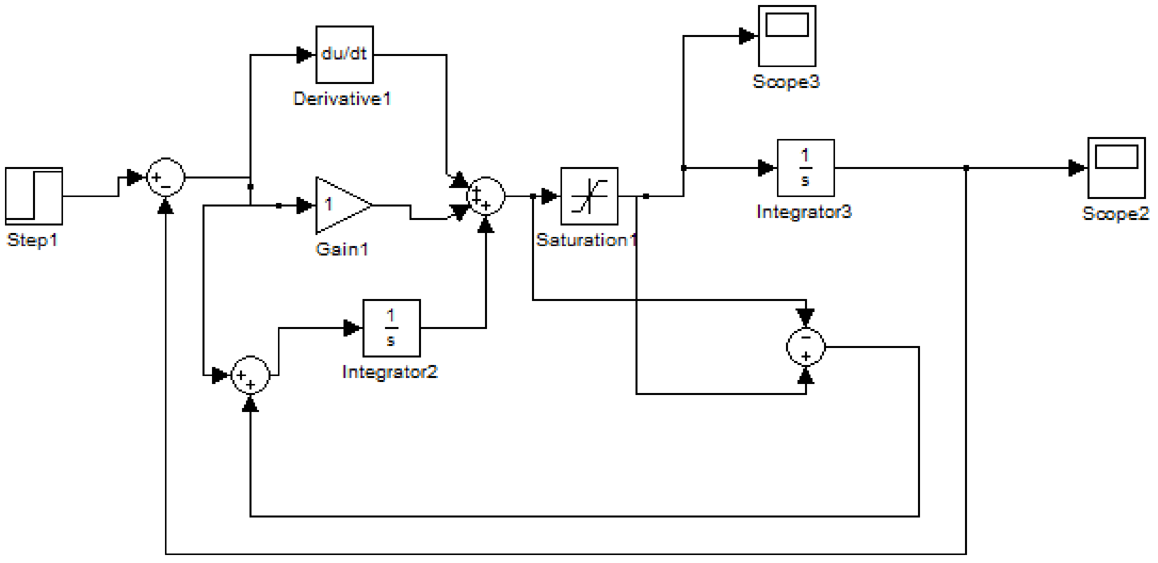


INTEGRAL WINDUP AND ANTIWINDUP STRUCTURE

INTEGRAL WINDUP



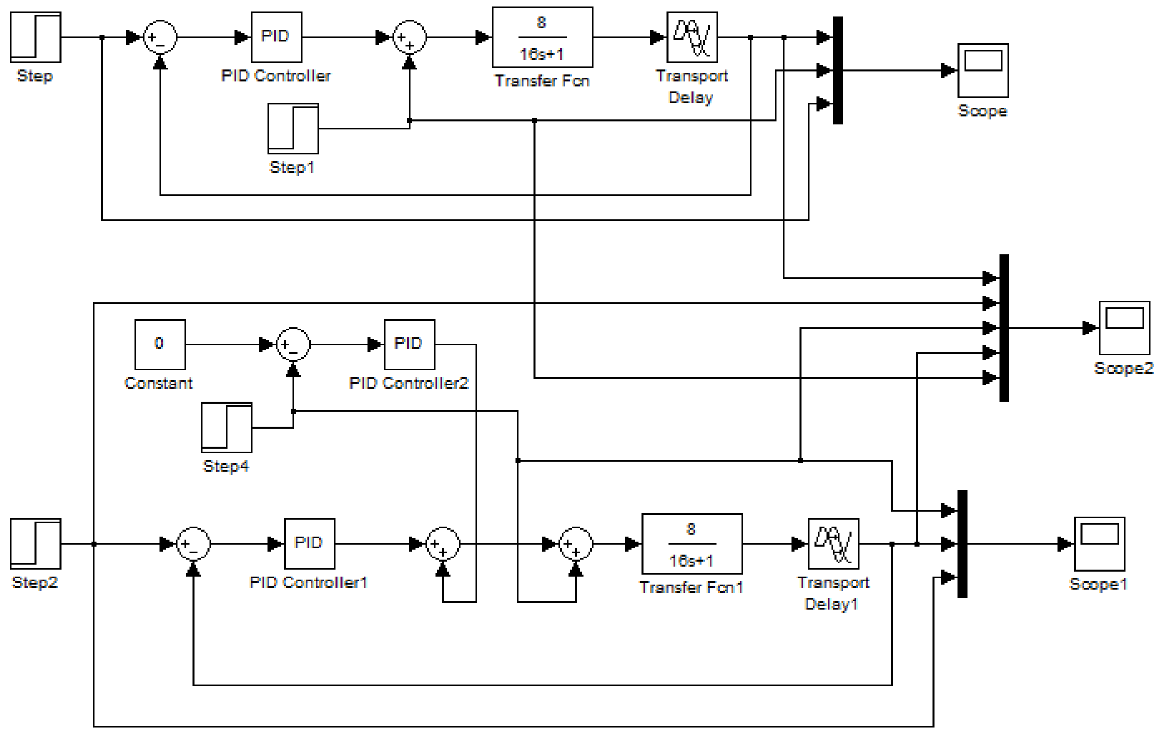
ANTI WINDUP

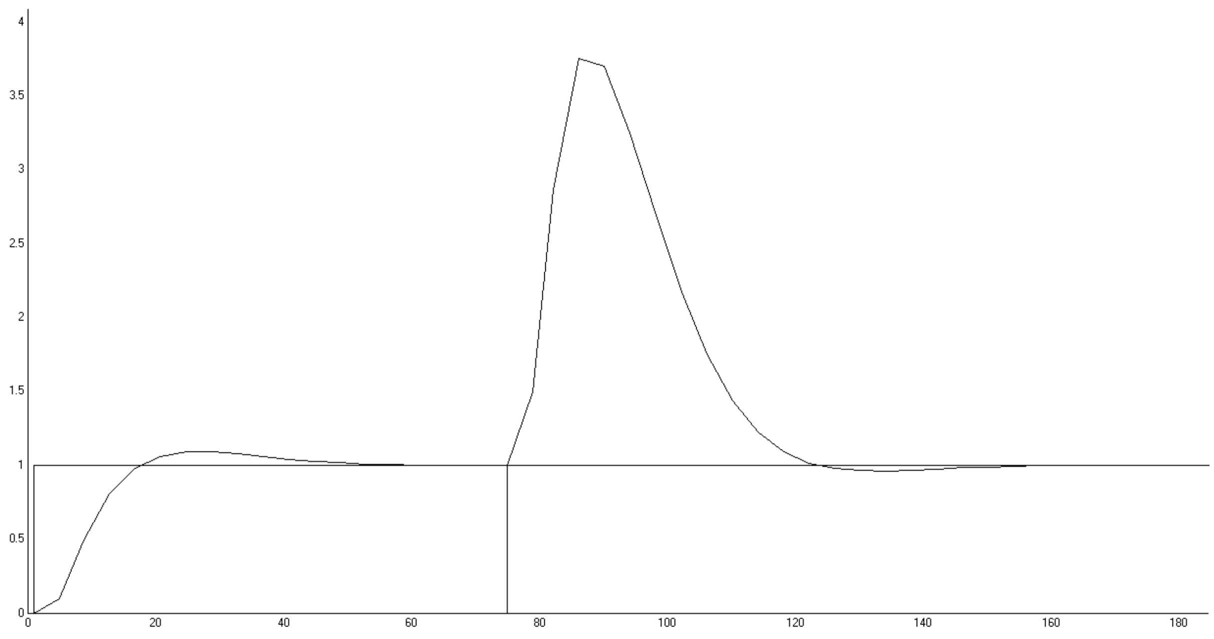


RESULT

Thus the response of integral windup, anti-integral windup, proportional kick, anti-proportional kick, derivative kick, anti-derivative kick action was studied using MATLAB software.

Designing a Single Loop Control System with a PI Controller





PID ENHANCEMENTS (CASCADE AND FEED-FORWARDCONTROL SCHEMES)

Ex.No: 7

Date:

AIM

To study the perform Feed Forward Control System and Cascade Control System using MATLAB software.

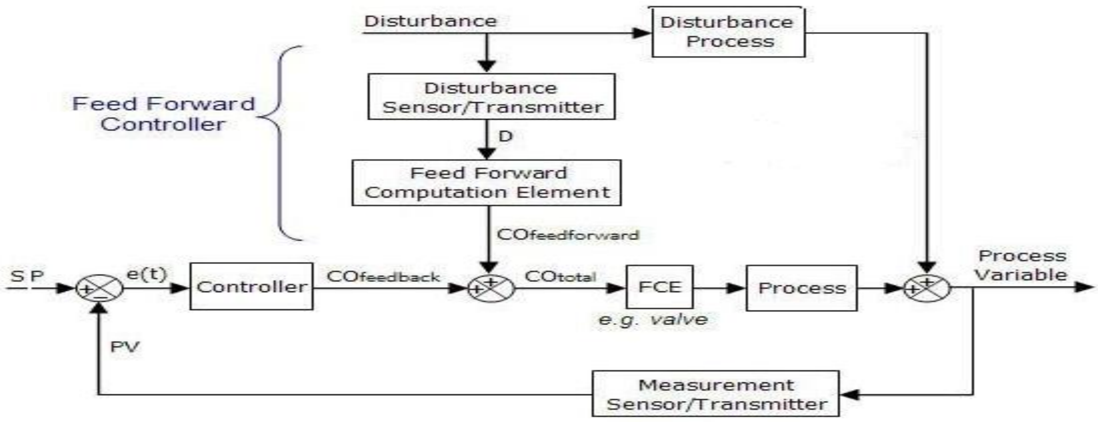
APPARATUS REQUIRED:

1. Matlab software
2. Printer

THEORY

FEED FORWARD CONTROL

A feed forward control law is used to compensate for the effect that measured disturbance variable's may have on the controlled variable. The basic idea is to measure a disturbance directly and take control action to eliminate its impact on the process output. How well the scheme will work depends on the accuracy of the process and disturbance models used to describe the system dynamics.



Feed forward control actually offers the potential for perfect control. However, because of Plant Model Mismatch (PMM) and unmeasured / unknown disturbances this is rarely achieved in practice. Consequently, feed forward control is normally used in conjunction with feedback control. The feedback controller is used to compensate for any model errors, unmeasured disturbances etc. and ensure offset free control.

Feed forward control is always used along with feedback control because a feedback control system is required to track set point changes and to suppress unmeasured disturbances that are always present in any real process.

Feed forward control is distinctly different from open loop control and teleoperator systems. Feed forward control requires a mathematical model of the plant (process and/or machine being controlled) and the plant's relationship to any inputs or feedback the system might receive. Neither open loop control nor teleoperator systems require the sophistication of a mathematical model of the physical system or plant being controlled. Control based on operator input without integral processing and interpretation through a mathematical model of the system is a teleoperator system and is not considered feed forward control.

PROCEDURE

Feed Forward System

1. Draw a simulink program for a given transfer functions for feed forward controlsystem.
2. Find kp, Ti, Td values using auto tuning techniques.
3. Observe the responses for with and without feed forwardsystem.

CASCADE CONTROL

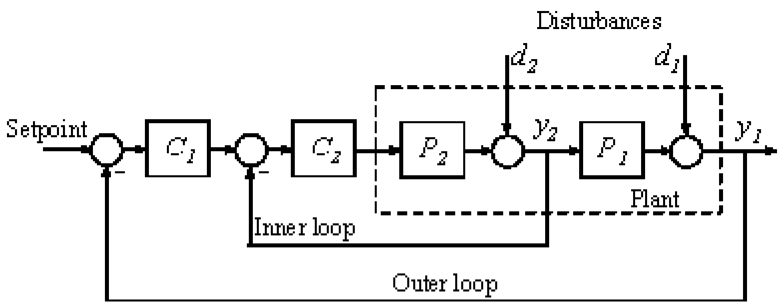
A cascade control configuration can be used in cases where there are one manipulated variable and more than one measurement. It is clear that with a single manipulation only one output can be controlled. Therefore the performance of single feedback control is improved by changing it into cascade control which consists of two loops.

1) Primary loop
2) Secondary loop

In cascade control disturbances arising within the secondary loop are corrected by the secondary controller before they can affect the value of the primary controlled output. That is the closed loop response of the primary loop is influenced by the dynamics of the secondary loop.

BLOCK DIAGRAM

Cascade control is mainly used to achieve fast rejection of disturbance before it propagates to the other parts of the plant. The simplest cascade control system involves two control loops (inner and outer) as shown in the block diagram below.

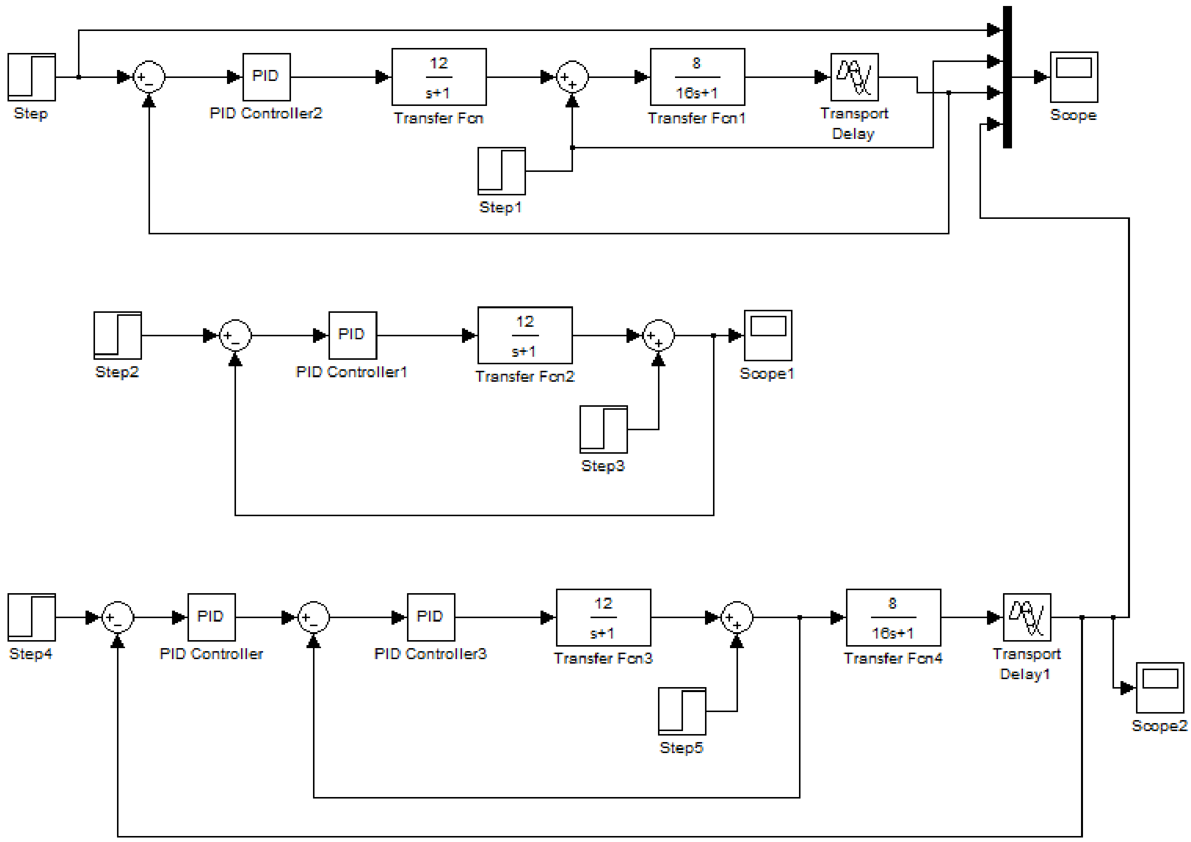


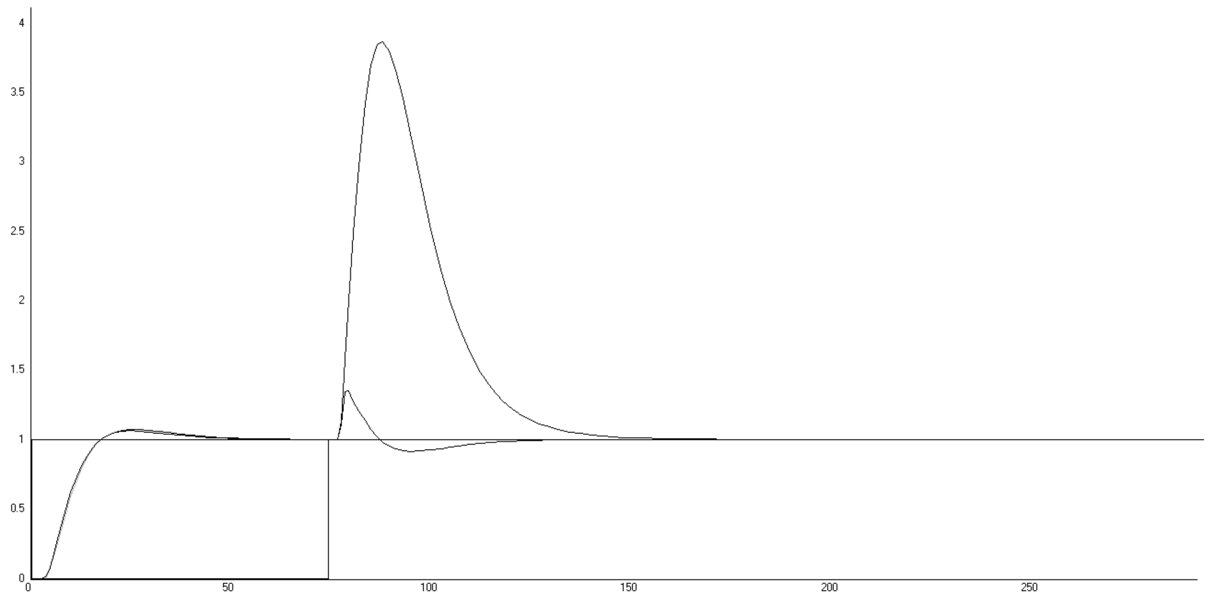
Controller **C1** in the outer loop is the primary controller that regulates the primary controlled variable **y1** by setting the set-point of the inner loop.

Controller **C2** in the inner loop is the secondary controller that rejects disturbance **d2** locally before it propagates to **P1**. For a cascade control system to function properly, the inner loop must respond much faster than the outer loop.

In this example, you will design a single loop control system with a PI controller and a cascade control system with two PI controllers. The responses of the two control systems are compared for both reference tracking and disturbance rejection.

MATLAB SIMULINK PROGRAM FOR CASCADE CONTROL SYSTEM



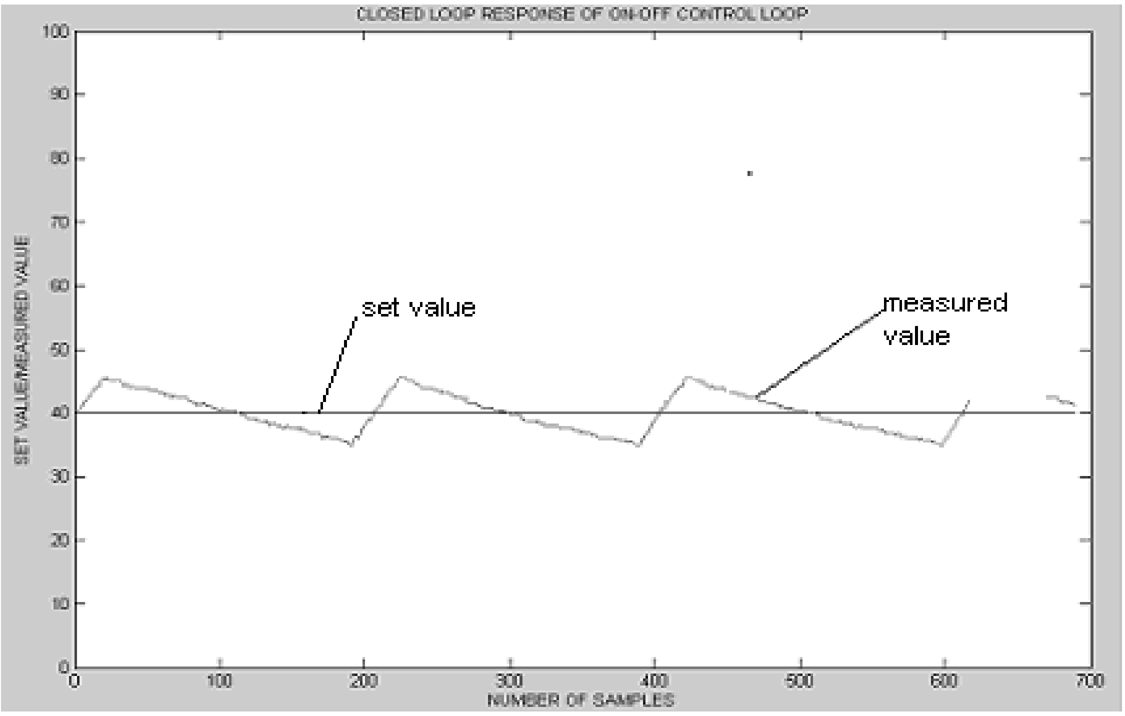


Result:

Thus the feedforward and cascade control system was implemented using Matlab software.

MODEL GRAPH

.



Tabular Column:

S.No	Time in sec	Temperature in ^{0}C

OPERATION OF ON-OFF CONTROLLED THERMAL PROCESS

Ex.No: 8
Date:

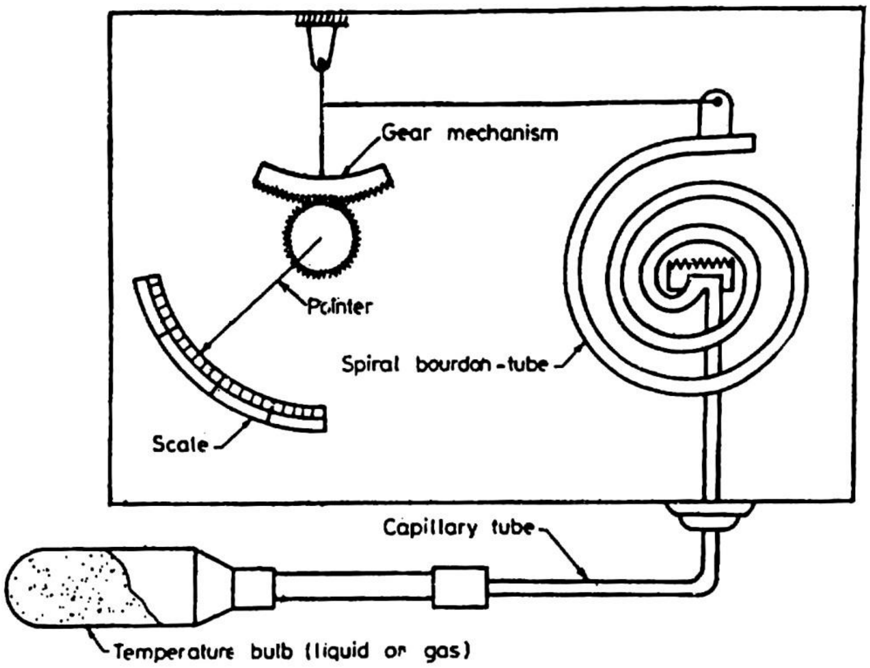
AIM

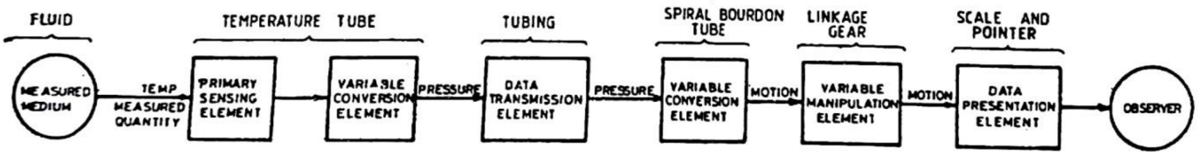
To obtain the operation of on-off controlled thermal process using filled in system thermometer.

APPARATUS REQUIRED

1. Temperature process set up
2. stop watch

EXPERIMENTAL SET UP





Filled-system thermometer

DESCRIPTION

The temperature is converted in to a mechanical motion caused by pressure or expansion, and this is measured. The instruments working with this principal are much simpler ones. The thermal system of a filled system thermometer comprises the thermometer bulb, an expansion element, such as a Bourdon tube, diaphragm, capsule or bellows and a capillary tube connecting the bulb and the expansion element.

Study of on/off controller

PROCEDURE

1. Switch ON the trainer.
2. Adjust the required set temperature in standard temperature controller.
3. Put the sensors both the filled system thermometer temperature response bulb as well as standard temperature controller thermocouple in to the furnace.
4. The digital display of temperature controller shows the furnace temperature.The corresponding temperature is also displayed in the filled system thermometer temperature dial.

RESULT

Thus the operation of on-off controlled thermal process using filled in system thermometer was studied.

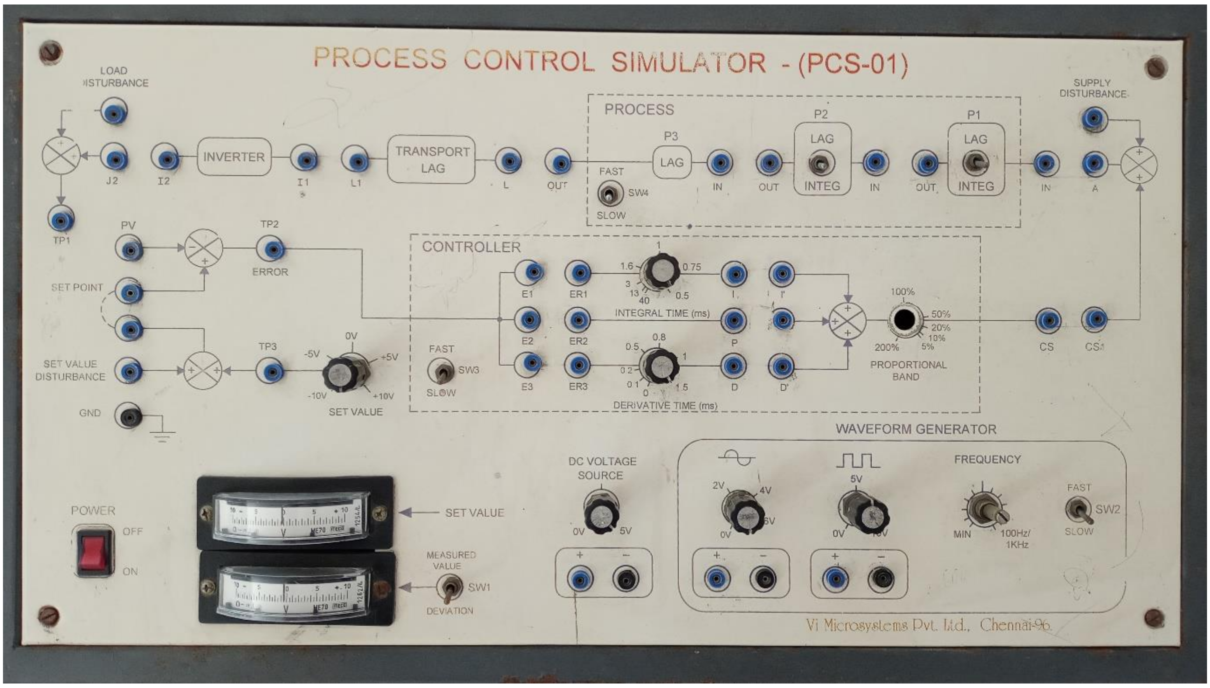


Fig. Experimental Setup

TABULATION

P CONTROLLER

Propotional Band	Rise Time (ms)	Peak Time (ms)	Peak Overshoot (V)	Settling Time (ms)	Offset (V)

DYNAMIC CHARACTERSITICS OF PROPOTIONAL PLUS INTEGRAL PLUS DERIVATIVE CONTROLLER

Ex.No:9
Date:

AIM

To determine the dynamic characteristics of Proportional plus Integral plus Derivative controller.

EQUIPMENT

1. Simulation kit
2. CROs
3. Patch chords

THEORY

Proportional control mode :

In this control mode, a smooth, linear relationship exists between the controller output and the error.

For each value of error input, the controller gives out unique controller output in one-to-one correspondence.

Proportional band :

The range of error to cover the 0% to 100% controller output is called the proportional band, because the one-to-one correspondence exists only for errors in this range. The Proportional mode can be expressed by

$$P = Pe_p$$

$$P = K_p e_p + p_0$$

where

K_p = proportional gain between error and controller output (% per %)

P_0 = controller output with no error (%)

PI CONTROLLER

Propotional Band	Rise Time (ms)	Peak Time (ms)	Peak Overshoot (V)	Settling Time (ms)

PID CONTROLLER

Propotional Band	Rise Time (ms)	Peak Time (ms)	Peak Overshoot (V)	Settling Time (ms)

Characteristics of proportional mode :

1. If the error, e_p is zero, then the controller output p = (K_p x 0) + P_0ρ a constant $P_{0.}$
2. For every 1% of error, a correction of K_p percent is added or subtracted from P_0, depending on the sign of the error.
3. There is a band of error about zero of magnitude PB within which the output is not saturated at 0% or 100%

Integral - control mode :

This mode is otherwise called as reset mode as the offset error in proportional mode can be reset to zero. In the proportional mode, offset error occurs because the controller cannot adapt to changing loads (external conditions). The zero error output is a fixed value. The problem is eliminated by the integral mode as the controller adapts to changing loads (external conditions) by changing the zero - zero output.

Integral action is provided by summing the error overtime, multiplying that sum by a gain, and adding the result to the present controller output. If the error becomes positive or negative for an extended period of time, the integral action will begin to accumulate and make changes to the controller output.

The integral mode is represented by the equation,

$$p(t) = KI \int_0^t e_p \, dt + p(o)$$

$$\frac{dp}{dt} = K_I e_p$$

.

Derivative - control mode :

Derivative controller is otherwise called as rate controller or anticipating controller.

The derivative mode is represented by the equation.

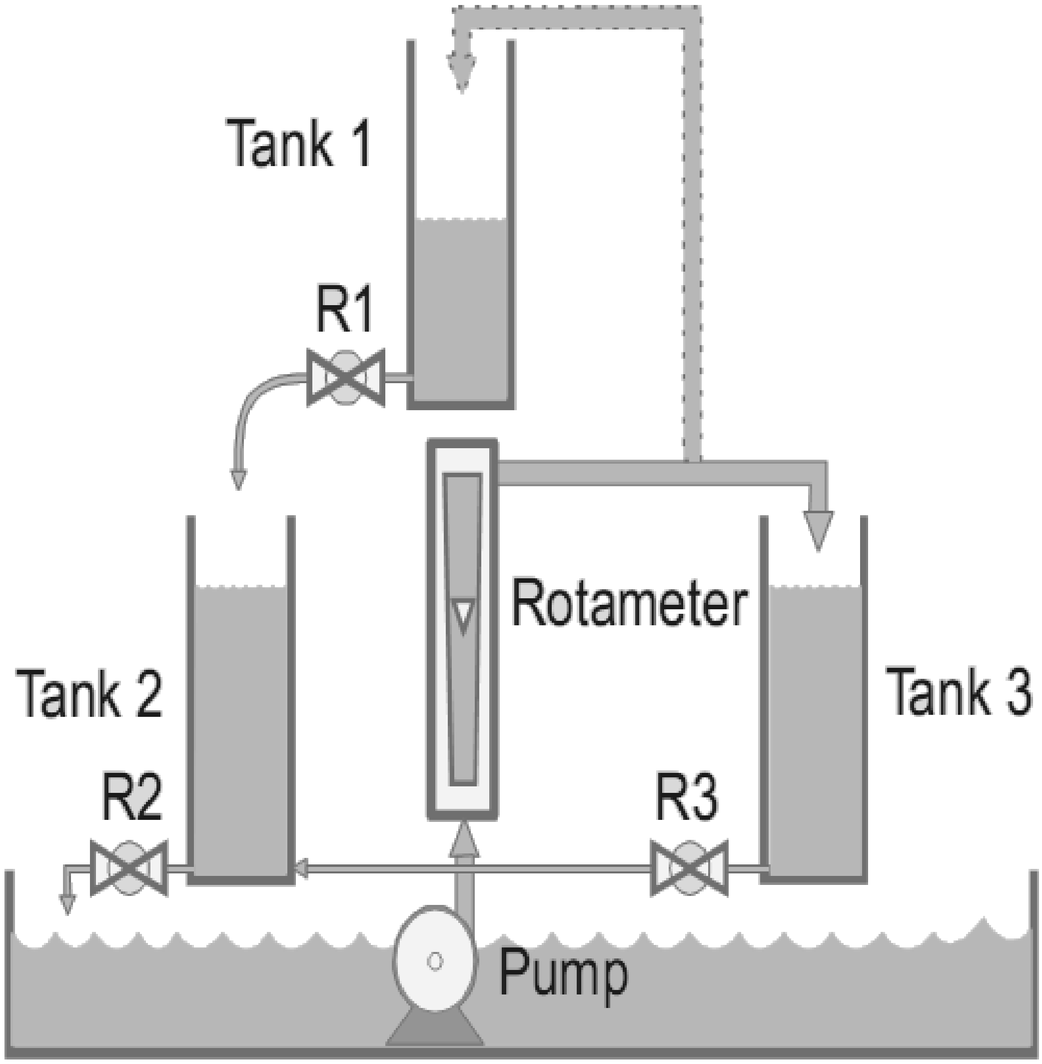
$$p(t) = K_D \frac{de_p}{dt}$$

where K_D= Derivative gain

RESULT

Thus, the dynamic characteristics of Proportional plus Integral plus Derivative controller were studied.

EXPERIMENTAL SET UP (NON INTERACTING SYSTEM):



OPERATION OF NON-INTERACTING SYSTEMS

Ex.No 10 (a)
Date:

AIM:

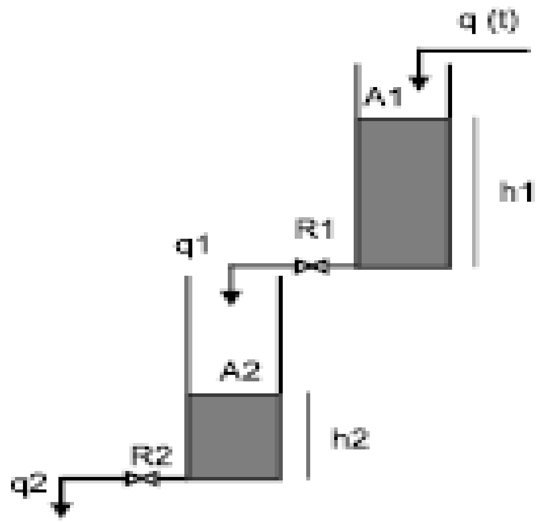
To study the operation of Non Interacting System and find its transfer function.

APPARATUS REQUIRED:

1. Non Interacting system set up.
2. Stop Watch.

THEORY:

Consider the two tank system shown in experimental setup. The outlet flow from $tank_1$ discharges directly into the atmosphere before spilling into $tank_2$ through valve R_1. The flow through R_1 depends only on h_1 (head or level in $tank_1$) the variation in h_2 (head or level in $tank_2$) does not affect the transient response occurring in $tank_1$. This type of system is referred as non interacting system.



Assuming the liquid to of constant density and the tanks having uniform cross sectional area and the flow resistances to be linear, the energy mass balance equations can be written as follows,

The mass balance equation of tank1 is

$(q - q_1) = A_1(dh_1/dt)$ --------------- (1)

The mass balance equation of tank2 is

$(q - q_1) = A_2(dh_2/dt)$ --------------- (2)

The flow head relationships for the two linear resistances are given by the expressions,

$q_1 = h_1/R_1$ ------------------------ (3)

$q_2 = h_2/R_2$ ------------------------ (4)

Combining the equations (1) & (3) we get the transfer function for $tank_1$ as,

$Q_1(s)/Q(s) = 1/\tau_1 s+1$

Where,

$Q_1 = q_1 - q_1 s$

$Q = q - qs$

And $\tau_1 = R_1 * A_1$

Combining the equations (2) & (4) we get transfer function for $tank_2$ is,

$H_2(s)/Q_1(s) = R_2/ \tau_1 s +1$

Where,

$H_2 = h_2 - h_2 s$

$\tau_2 = R_2 * A_2$

The overall transfer function of non interacting system is,

$H_2(s)/Q(s) = R_2/(\tau_2 s+1) (\tau_1 s+1)$

Where,

q=inflow to $tank_1$ in LPH
A_1=area of $tank_1$
h_1=output variable head of $tank_1$
R_1=resistance of valve in the outlet of $tank_1$
q_1=inflow to tank1 in LPH
A_2=area of $tank_2$
h_2=output variable head of $tank_2$
R_2=resistance of valve in the head of $tank_2$
q_2=outflow of $tank_2$ in LPH
τ_1&τ_2 =time constants of tank1, 2 respectively

VALVE POSITIONS:

1. Input valve of $tank_1$ fully open
2. Valve between tanks 1&2 partially open
3. Output valve of $tank_2$ partially open
4. All other valves closed

PROCEDURE:

1. Switch on the pump
2. Set the flow rate of liquid at desired flow rate(say 50LPH)by adjusting the rotameter and wait till the level reaches a steady state in both the two tanks.
3. Record the initial flow rate and initial steady state levels in both tanks.

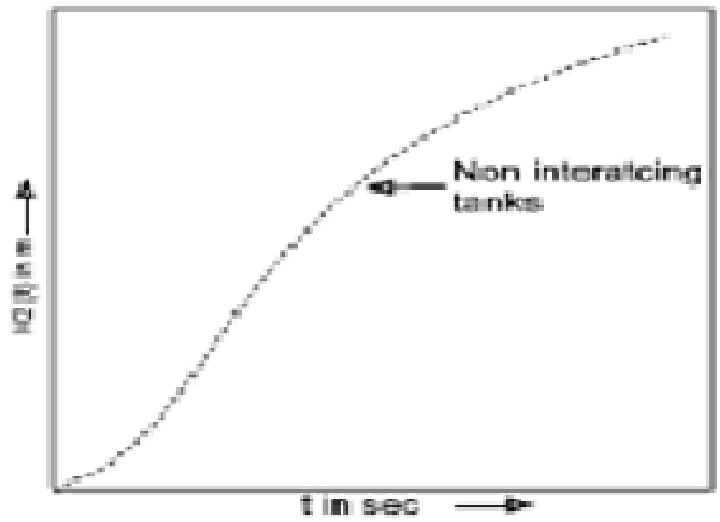
4. Once the level or reaches a steady state give a small step change in flow rate and note down the heads h_1&h_2 of tanks1&2 till tanks reach another steady state.
5. Note down the final steady state of head in both the tanks.
6. Find out the overall transfer function by finding τ_1,τ_2, R_1, R_2 & A_1,A_2.

TABULATION AND OBSERVATION:

Diameter of tanks (d_1 in mm) = 92 mm
Diameter of tanks (d_2 in mm) = 92 mm
Initial flow rate (LPH) =
Initial steady state level of $tank_1$ (mm) =
Initial steady state level of $tank_2$ (mm) =
Final flow rate (LPH) =
Final steady state level of $tank_1$ (mm) =
Final steady state level of $tank_2$ (mm) =

S.No	Time (t) sec	Height of $tank_1$(h_1) mm	Height of $tank_1$(h_2) mm

MODEL GRAPH:



CALCULATION:

Area of tank (A_1) = $\pi/4(d_1)^2$ in m^2
Area of tank (A_2) = $\pi/4(d_2)^2$ in m^2

$R_1 = dH_1/dQ$ = (Final steady state level of $tank_1$) - (Initial steady state level of $tank_1$)
(Final flow Rate - Initial flow rate)/3600

$R_2 = dH_2/dQ$ = (Final steady state level of $tank_2$)-(Initial steady state level of $tank_2$)
(Final flow Rate-Initial flow rate)/3600

$\tau_1=A_1*R_1$
$\tau_2=A_2*R_2$

Transfer function of $tank_1$
$Q_1(s)/Q(s)=1/\tau_1 s+1$
Transfer function of $tank_2$
$H_2(s)/Q(s)=R_2/\tau_1 s+1$
Over all transfer function of non interaction system
$H_2(s)/Q(s)=R_2/(\tau_1 s+1)*(\tau_2 s+1)$

RESULT:

Thus the response of the non interacting system was studied and transfer function was found.

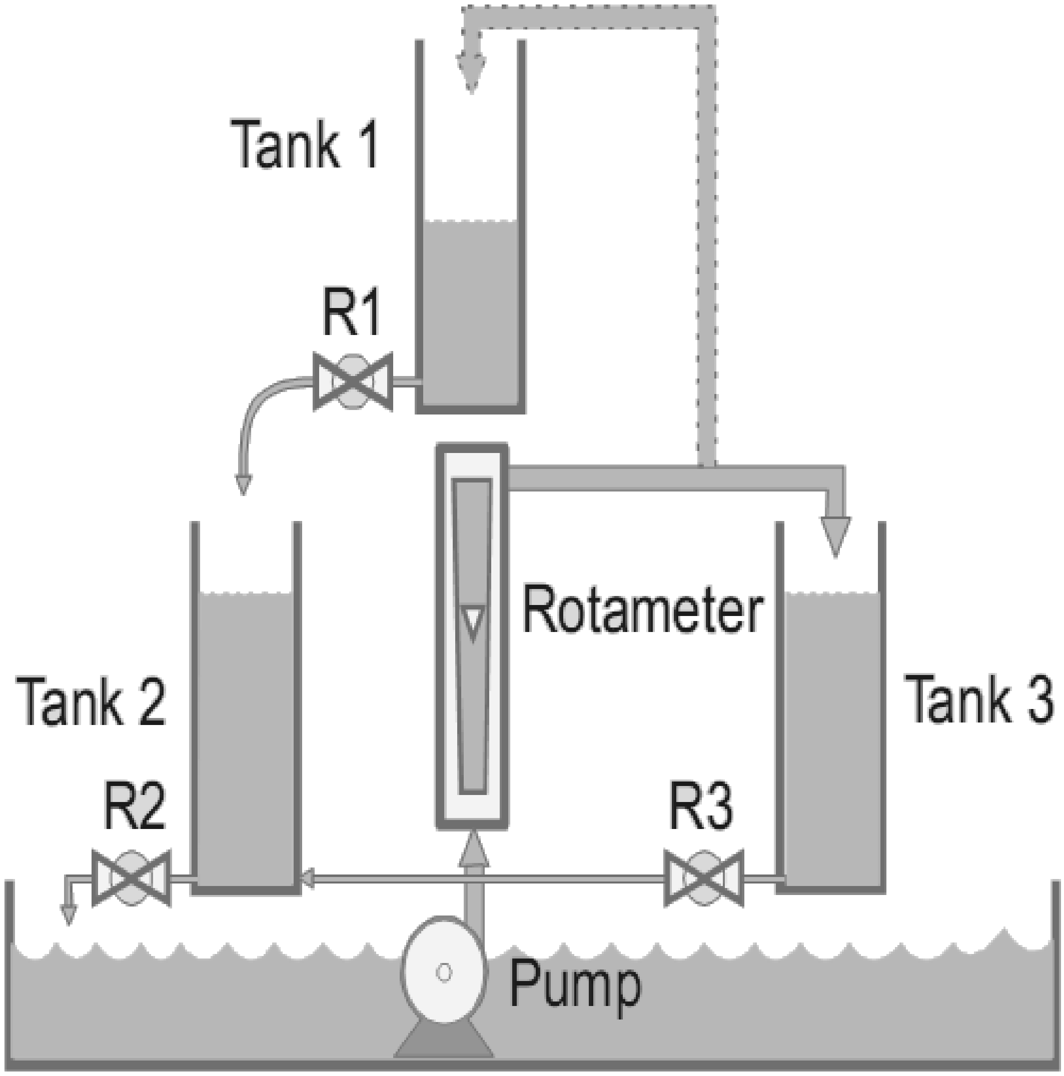
OPERATION OF INTERACTING SYSTEM

Ex.No 10 (b)
Date:

AIM:
To study the operation of Interacting System and find its transfer function.

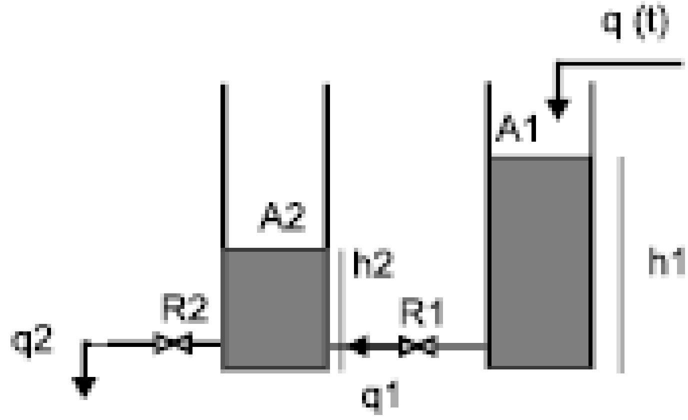
APPARATUS REQUIRED:
1. Interacting system set up.
2. Stop Watch.

EXPERIMENTAL SET UP (INTERACTING SYSTEM):



THEORY:

The term interacting is referred as loading. To understand the effect of interacting, a two tank system is considered in which, the second tank is said to load the first tank.



The flow through R_1 depends on the difference between h_1&h_2. To obtain the transfer function of an interacting system, mass balance equation of the tank is written. The balances on tank1&2 are same the flow head relationship for $tank_1$ is,

$q_1 = (h_1 - h_2)/R_1$ ---------- (a)

The mass balance equation of $tank_1$ is

$(q_1 - q_1) = A_1(dh_1/dt)$ ---------- (1)

The mass balance equation of $tank_2$ is

$(q_1 - q_2) = A_2(dh_2/dt)$ ---------- (2)

The flow head relationships for the two linear resistances are given by the expressions,

$q_1 = h_1/R_1$---------------------- (3)

$q_2 = h_2/R_2$---------------------- (4)

At steady state, the flow equation is,

Qs - q1s = 0 ----------------------5

$Q_1s - q_2s = 0$ --------------------6

By solving all the above equations using Laplace transform, we get the transfer function,

$H_2(s)/Q(s) = R_2/\tau_1\tau_2 s^2 + (\tau_1+\tau_2+A_1R_2)s+1$

Where,
q=inflow to $tank_1$ in LPH
A_1=area of $tank_1$
h_1=output variable head of $tank_1$
R_1=resistance of valve in the outlet of $tank_1$
q_1=inflow to $tank_1$ in LPH
A_2=area of $tank_2$
h_2=output variable head of $tank_2$
R_2=resistance of valve in the head of $tank_2$
q_2=outflow of $tank_2$ in LPH
τ1 & τ2 =time constants of tank 1,2 respectively.

VALVE POSITIONS:

1. Input valve of $tank_1$ fully open
2. Valve between tanks 1&2 partially open
3. Output valve of $tank_2$ partially open
4. All other valves closed

PROCEDURE:

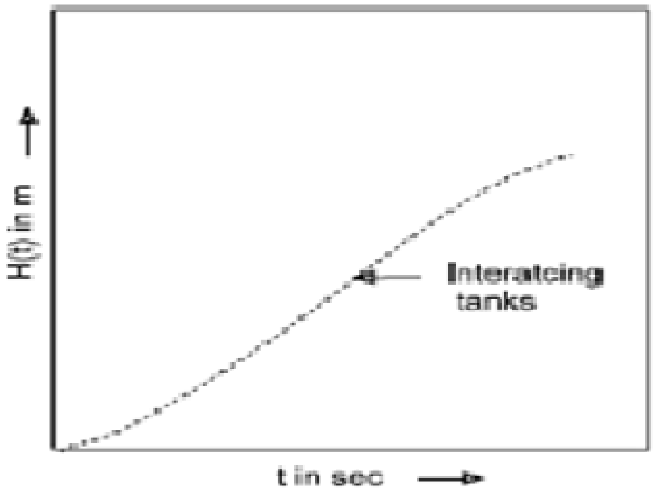
1. Switch on the pump
2. Set the flow rate of liquid at desired flow rate(say 50LPH)by adjusting the rotameter and wait till the level reaches a steady state in both the two tanks.
3. Record the initial flow rate and initial steady state levels in both tanks.
4. Once the level or reaches a steady state give a small step change in flow rate and note down the heads h_1&h_2 of tanks1&2 till tanks reach another steady state.
5. Note down the final steady state of head in both the tanks.
6. Find out the overall transfer function by finding τ_1,τ_2, R_1, R_2 & A_1,A_2.

TABULATION AND OBSERVATION:

Diameter of tanks ($d_1$in mm) = 92 mm
Diameter of tanks ($d_2$in mm) = 92 mm
Initial flow rate (LPH) =
Initial steady state level of $tank_1$ (mm) =
Initial steady state level of $tank_2$ (mm) =
Final flow rate (LPH) =
Final steady state level of $tank_1$ (mm) =
Final steady state level of $tank_2$ (mm) =

S.No	Time (t) sec	Height of $tank_1(h_1)$ mm	Height of $tank_1(h_2)$ mm

MODEL GRAPH:



CALCULATION:

Area of tank (A_1) = $\pi/4(d_1)^2$ in m^2
Area of tank (A_2) = $\pi/4(d_2)^2$ in m^2

R_1= dH_1/dQ = <u>(Final steady state level of tank$_1$) - (Initial steady state level of tank$_1$)</u>
(Final flow Rate - Initial flow rate)/3600

R_2 = dH_2/dQ = <u>(Final steady state level of tank$_2$) - (Initial steady state level of tank$_2$)</u>
(Final flow Rate - Initial flow rate)/3600

$\tau_1 = A_1*R_1$
$\tau_2 = A_2*R_2$
Transfer function of tank1 $Q_1(s)/Q(s) = 1/\tau_1 s+1$

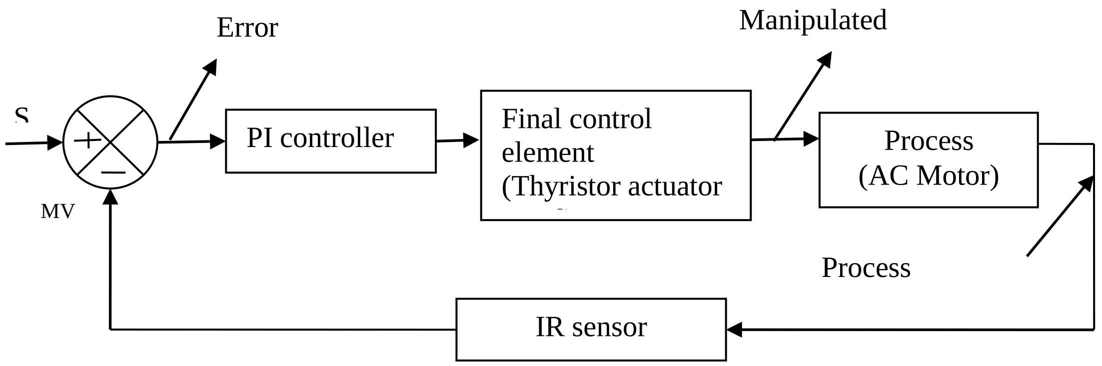
Find out the overall transfer function using the equation

$H_2(s)/Q(s) = R_2/\tau_1\tau_2 s^2+(\tau_1+\tau_2+A_1R_2)s+1$

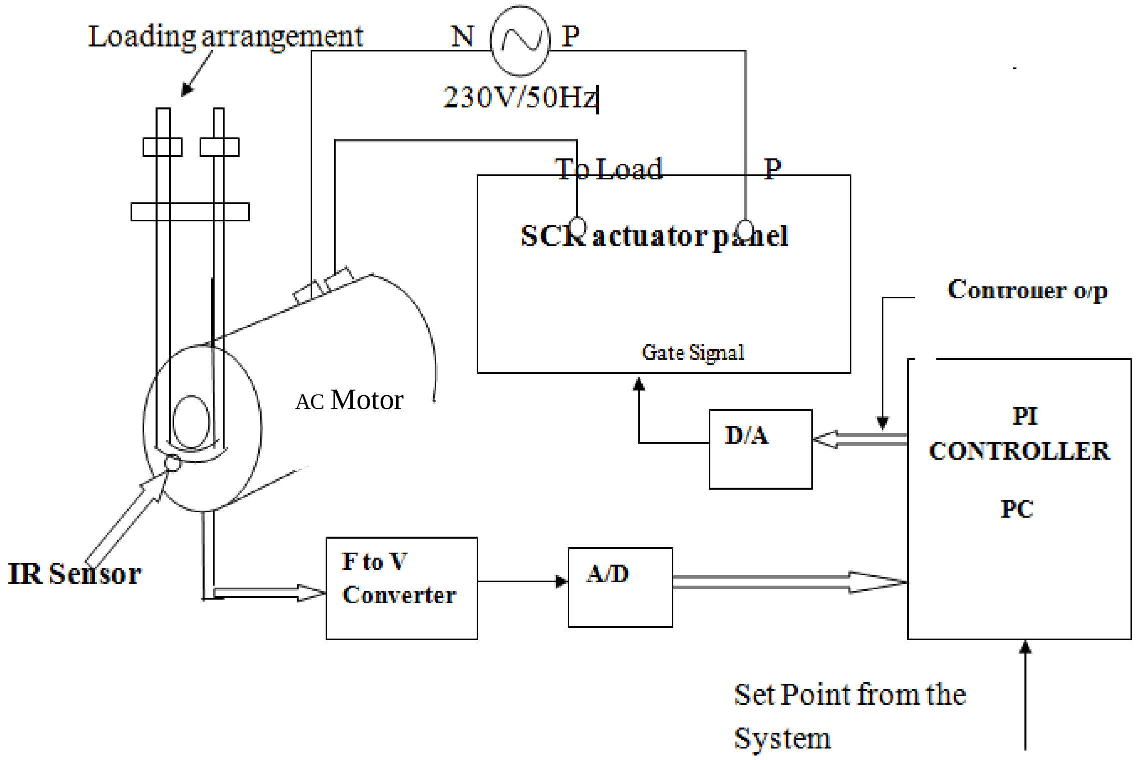
RESULT:

Thus the response of the interacting system was studied and transfer function was found.

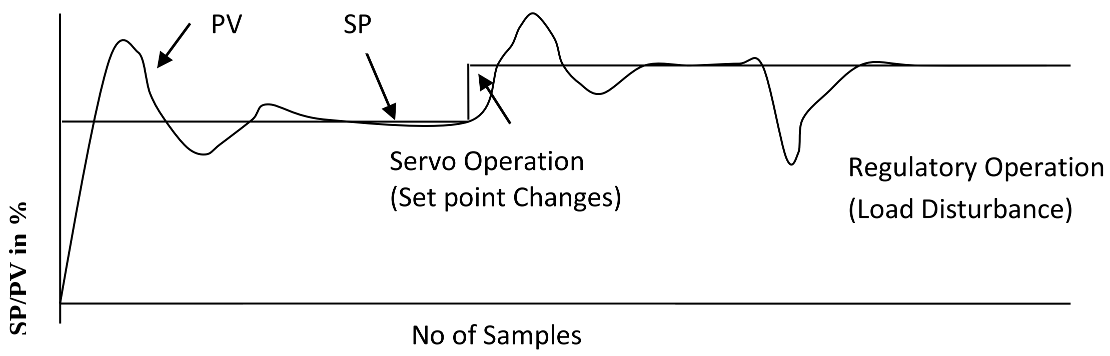
BLOCK DIAGRAM



EXPERIMENTAL SET UP



MODEL GRAPH



STUDY OF AC DRIVES

Ex.No:11 (a)
Date:

AIM

To study the closed loop response of AC Motor.

APPARATUS REQUIRED

1. AC Motor Speed Control Trainer
2. Computer with Printer
3. Patch Chords.

THEORY

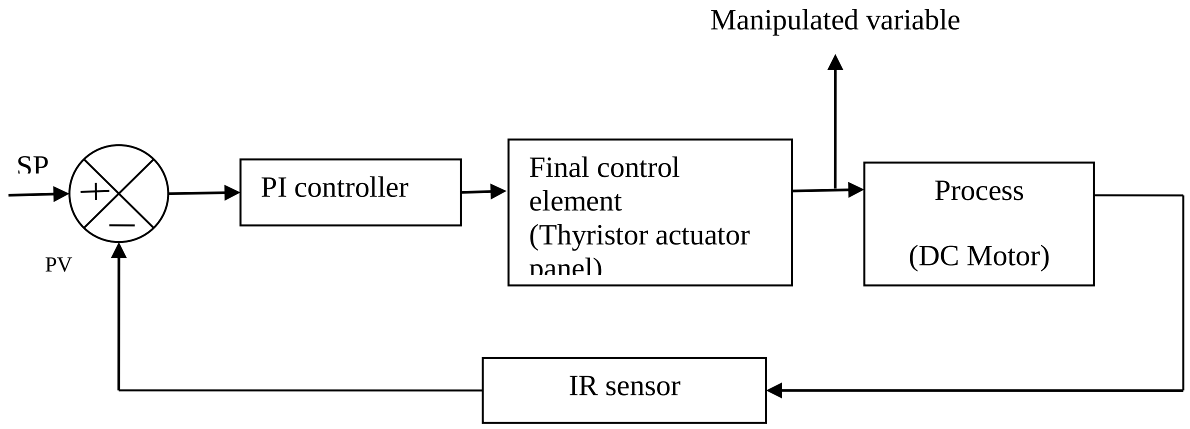
PROCEDURE

1. Open 4T double PID MATLAB application Folder.
2. Double click the install batch file.
3. Double click the double PID MATLAB application file.
4. First Click the Connection button .If you click the connection button pop up window will open which contain the connection succeed dialogue, then press ok button.
5. Then click check box of PID 1 ,after enter the Ti= ,PB= , Kd= ,Td= ,Ts= , Sepoint = ,output lower limit=0 ,output upper limit =100 and make sure PID action is Reverse.
6. Click the configure settings make sure SP from Panel, MV = CH0, DAC = DAC 1
7. Click the Graph Settings Select PID 1 - SP(Black) , MV- CHO(Red) then click the OK Button
8. Then if you click the Start Button the Response window will open.
9. Observe the response.
10 Change the different set point with the help of Pause and Resume button.
11 Again observe the response.
12. Apply the load disturbance with the help of the loading arrangement.
13. Again observe the response.

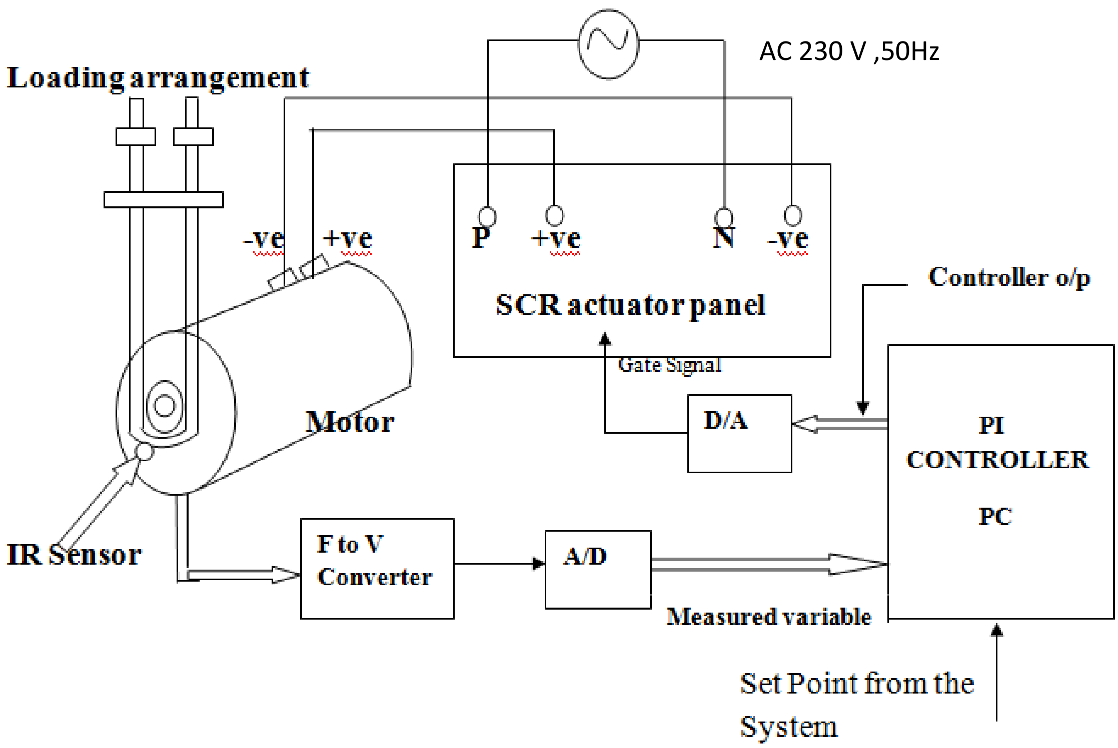
RESULT

Thus the closed loop response of ac motor using proportional integral controller was obtained.

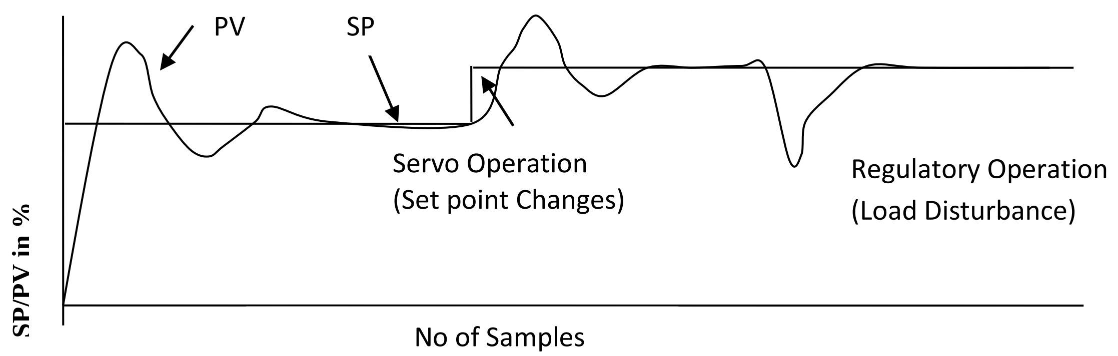
BLOCK DIAGRAM



EXPERIMENTAL SET UP



MODEL GRAPH



STUDY OF DC DRIVES

Ex.No:11 (b)
Date:

AIM

To study the closed loop response of DC Motor.

APPARATUS REQUIRED

1. DC Motor Speed Control Trainer
2. Computer with Printer
3. Patch Chords.

THEORY

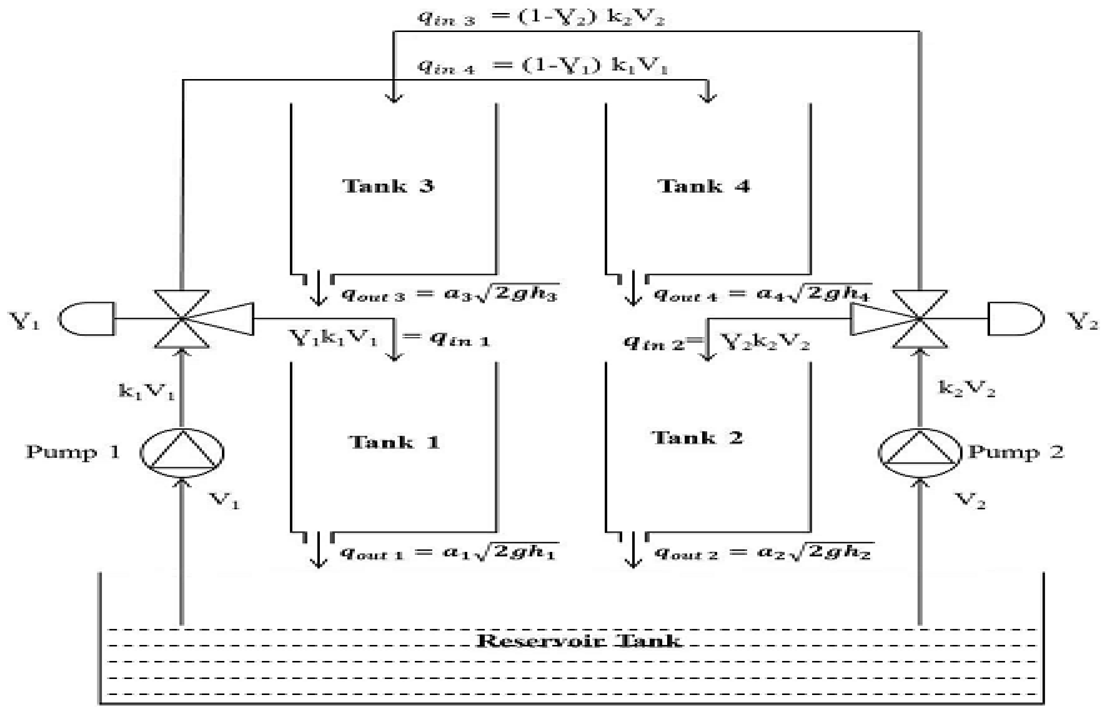
PROCEDURE

1. Open 4T double PID MATLAB application Folder.
2. Double click the install batch file.
3. Double click the double PID MATLAB application file.
4.First Click the Connection button .If you click the connection button pop up window will open which contain the connection succeed dialogue, then press ok button.
5.Then click check box of PID 1 ,after enter the Ti= ,PB= , Kd= ,Td= ,Ts= , Setpoint = , output lower limit=0 ,output upper limit =100 and make sure PID action is Reverse.
6. Click the configure settings make sure SP from Panel, MV = CH0, DAC = DAC 1
7. Click the Graph Settings Select PID 1 - SP(Black) , MV- CHO(Red) then click the OK Button
8. Then if you click the Start Button the Response window will open.
9. Observe the response.
10 Change the different set point with the help of Pause and Resume button.
11 Again observe the response.
12. Apply the load disturbance with the help of the loading arrangement.
13. Again observe the response

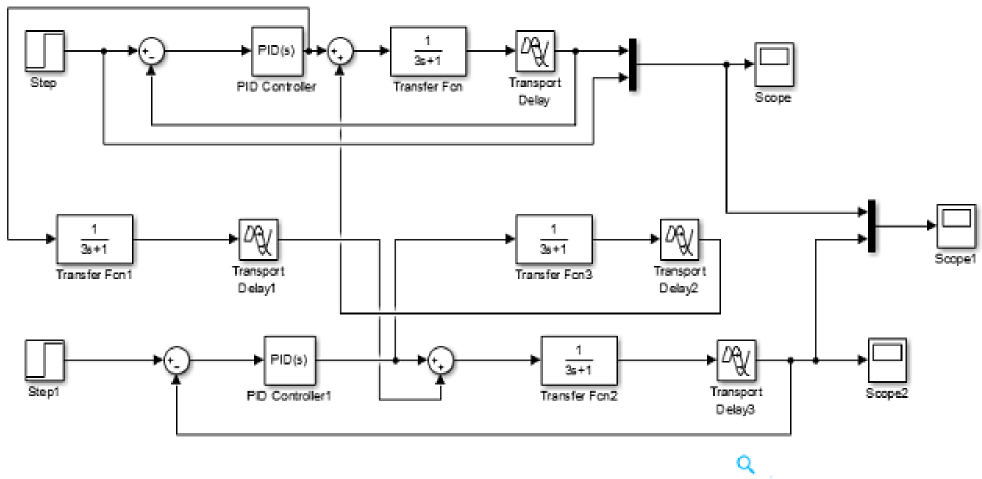
RESULT

Thus the closed loop response of AC Motor using proportional integral controller was obtained.

QUADRUPLE TANK PROCESS



Block diagram



DESIGN AND IMPLEMENTATION OF MULTILOOP PID CONTROLLER ON THE SIMULATED MODEL OF A TYPICAL INDUSTRIAL PROCESS

Ex.No: 12
Date:

AIM

To design and implemented MIMO system using MATLAB software.

APPARATUS REQUIRED

1. Matlab software
2. Printer

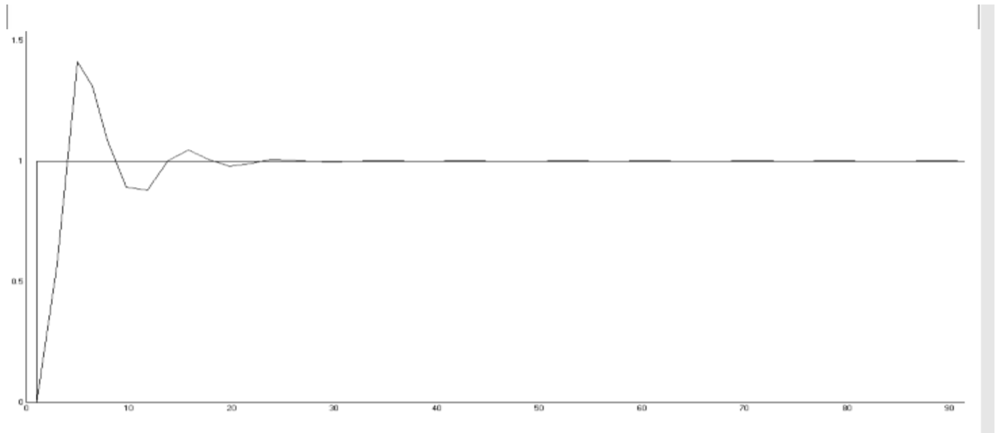
THEORY

The Quadruple tank is a laboratory process with four interconnected tanks and two pumps and two three port control valves as shown in figure. . The process inputs are u1 and u2 (input voltages to pumps, 0-180V) and the outputs are y1 and y2 (voltages from level measurement devices 0-2.5V). The target is to control the level of the lower two tanks with inlet flow rates.

The quadruple tank system is a multi input multi output system that could be used to analyze different control strategies. It is considered as a two double tank process. The setup consists of four interacting tanks, two pumps and two valves. Tank1 and tank4 are placed below tank 2 and tank3 to receive water flow by action of gravity when manual valves are kept open.

To accumulate the outgoing water from tank1 and tank4 a reservoir is present in the bottom. Every tank has a manual valve fitted to outlet. The action of pumps (centrifugal) 1 and 2 is to suck water from the reservoir and deliver it to tanks based on the control valve opening. The output of each pump is split into two using a three way control valve. Pump 1 is shared by tank1 and tank3, while pump 2 is shared by tank2 and tank 4. Thus each pump output goes to two tanks, one lower and another upper diagonal tank and the flow to these tanks are controlled by the position of the valve represented as γ. Due to gravitational force the lower tanks receive water from their corresponding upper tanks. The system aims at controlling the liquid levels in the lower tanks. The control valve positions give the ratio in which the output from the pump is divided between the upper and lower tanks.

Output response



Procedure:

1. Write a Simulink program for a given transfer function of MIMO system.

2. Tune the process for tank 1 and tank 2 using IMC tuning techniques to find PID values.

3.Change the setpoint and load disturbance for servo and regulator operation.

4.Observe the responses for tank 1 &2.

RESULT

Thus the MIMO system was implemented using MATLAB software.

ADDITIONAL EXPERIMENTS

SIMULATION OF LUMPED /DISTRIBUTED PARAMETER SYSTEM

Ex.No :13
Date:
AIM:

To simulate Lumped and Distributed Parameter system using MATLABsoftware.

APPARATUS REQUIRED:

1.MATLAB software

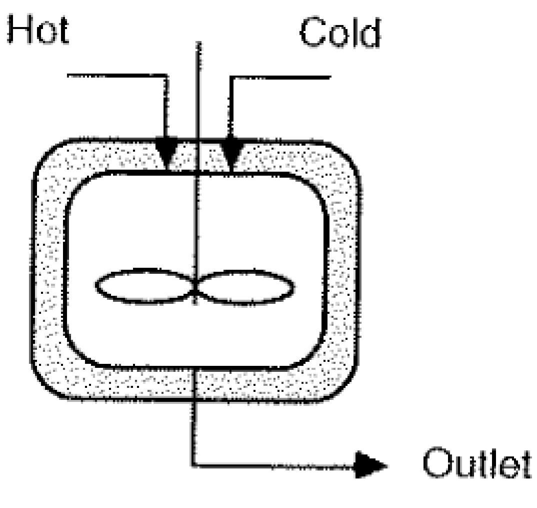
2.Printer

THEORY

Lumped Parameter System

Consider a perfectly insulated, well-stirred tank where a hot liquid stream at 60ºC is mixed with a cold liquid stream at 10ºC (Shown Figure below). The well mixed assumption means that the fluid temperature in the tank is uniform and equal to the temperature at the exit from the tank. This is an example of a lumped parameter system, since the temperature docs not vary with spatial position.

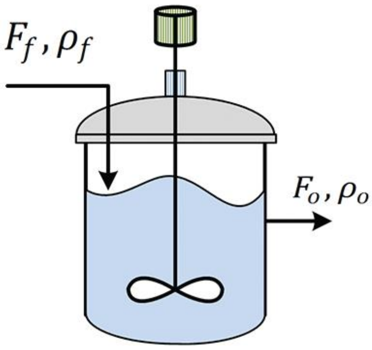
Models



Stirred tank.

Example Problem

A tank contains 3m^{3}of a solution consisting of 300 kg of sugar dissolved in water. Pure water is pumped into the tank at the rate of 15 L/s, and the mixture(kept uniform by stirring) is pumped out at the exact same rate. How long willit take for only 30 kg of sugar to remain in the tank?



Sugar concentration tank.

Solution

Assume an isothermal process and a perfect mixing tankAfter dividing both sides of the equation by ρ, the material balance equationis reduced to $(\rho_f = \rho_o = \rho)$.

$$\frac{dV}{dt} = F_f - F_o$$

The inlet and exit volumetric flow rates are equal; hence:

$$F_f = F_o = 15\ \text{L/s}$$

accordingly,

$$\frac{dV}{dt} = 0$$

The concentration of sugar in the tank is determined by component massbalance. The initial concentration of sugar in the tank is $c(0)$:

$$C(0) = \frac{300\,\text{kg}}{3000\,\text{L}} = 0.1\frac{\text{kg}}{\text{L}}$$

The final concentration is *cf*:

$$C(f) = \frac{30\,\text{kg}}{3000\,\text{L}} = 0.01\frac{\text{kg}}{\text{L}}$$

Component Balance

The component balance of sugar (*A*) equation:

$$\frac{d(VC_A)}{dt} = F_f C_f - F_o C_A$$

Since the feed stream contains fresh water, the feed concentration ofsugar (*A*) is zero; *cf*= 0:

$$\frac{d(VC_A)}{dt} = -F_o C_A$$

Differentiation of the left side of the equation can be done via productrule:

$$V\frac{d(C_A)}{dt} + C_A\frac{d(V)}{dt} = -F_o C_A$$

Since volume of the tank from the total mass balance is constant, theequation is reduced to:

$$V\frac{dC_A}{dt} = -F_o C_A$$

Divide both sides of the equation by *V*:

$$\frac{dC_A}{dt} = -\frac{F_o C_A}{V}$$

Rearranging and integrating both sides of the equation, we have:

$$\int_{C_{Ao}}^{C_A} \frac{dC_A}{C_A} = \frac{-F_o}{V} \int_0^t dt$$

Which leads to:

$$ln \frac{C_A}{C_{A0}} = \frac{-F_o}{V} t$$

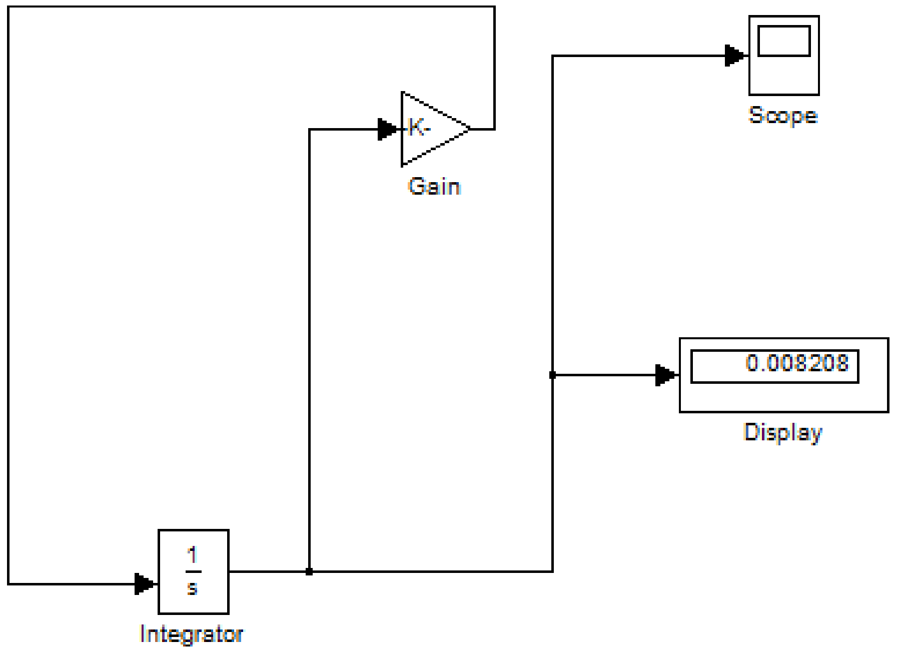
Substitute the values of known parameters in the integrated equation:

$$\ln \frac{0.01}{0.1} = \frac{-15}{3000} t$$

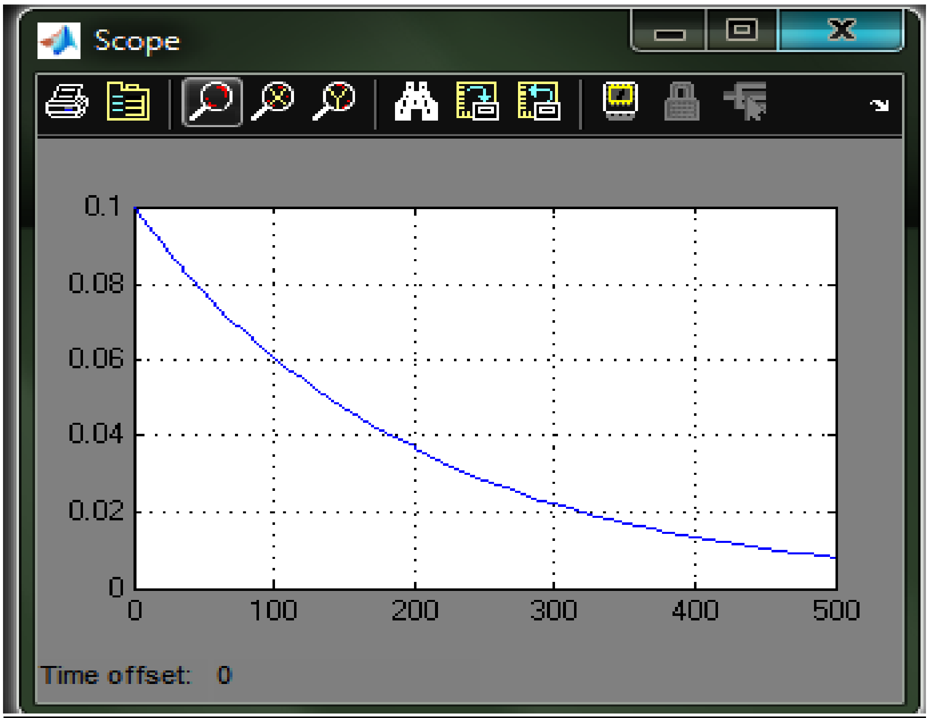
Solve for time (the time required to achieve the final concentration):
t = 460.517 s
The MATLAB/Simulink solution of the ODE is shown in Figure

$$\frac{dC_A}{dt} = -\frac{F_o C_A}{V} = -\frac{15\left(\frac{L}{s}\right)C_A}{3000\,\text{L}}$$

SIMULINK BLOCK DIAGRAM:



OUTPUT RESPONSE



PROCEDURE

1. Develop a Simulink program for a lumped &distributer parametersystem.
2. Observe the response for the same.

RESULT

Thus the lumped and distributed parameter system was implemented using MATLAB software.

MATHEMATICAL MODEL OF A TYPICAL INDUSTRIAL PROCESS USING NONPARAMETRIC IDENTIFICATION METHODS

Ex.No 14
Date:

AIM:

To simulate any industrial process using non parametric identification method using MATLAB software.

APPARATUS REQUIRED:

1.MATLAB software
2.Printer

THEORY

System Identification is the study of Modeling dynamic Systems from experimental data.

The System Identification Procedure

1. Collect Data. If possible choose the input signal such that the data has maximally informative.

2. Choose Model Structure. Use application knowledge and engineering intuition. Most important and most difficult step (don't estimate what you know already)

3. Choose Identification Approach. How would a good model look like?

4. Do. Choose best model in model structure (Optimization or estimation)

5. Model Validation. Is the model good enough for our purpose?

System Identification Methods

• Non-parametric Methods (SI).

The results are (only) curves, tables, etc. These methods are simple to apply. They give basic information about e.g. time delay, and time constants of the system.

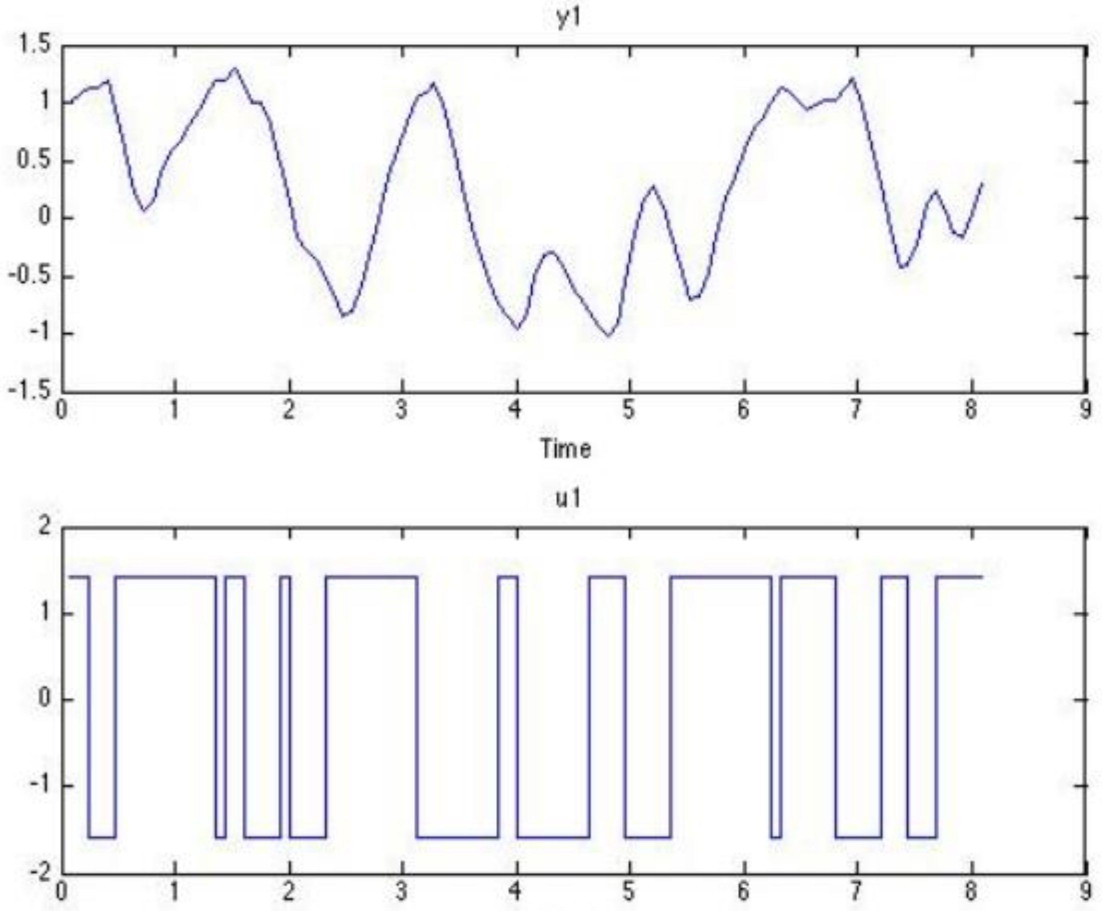
• Parametric Methods (SI)

The results are values of the parameters in the model. These may provide better accuracy (more information), but are often computationally more demanding.

PROCEDURE

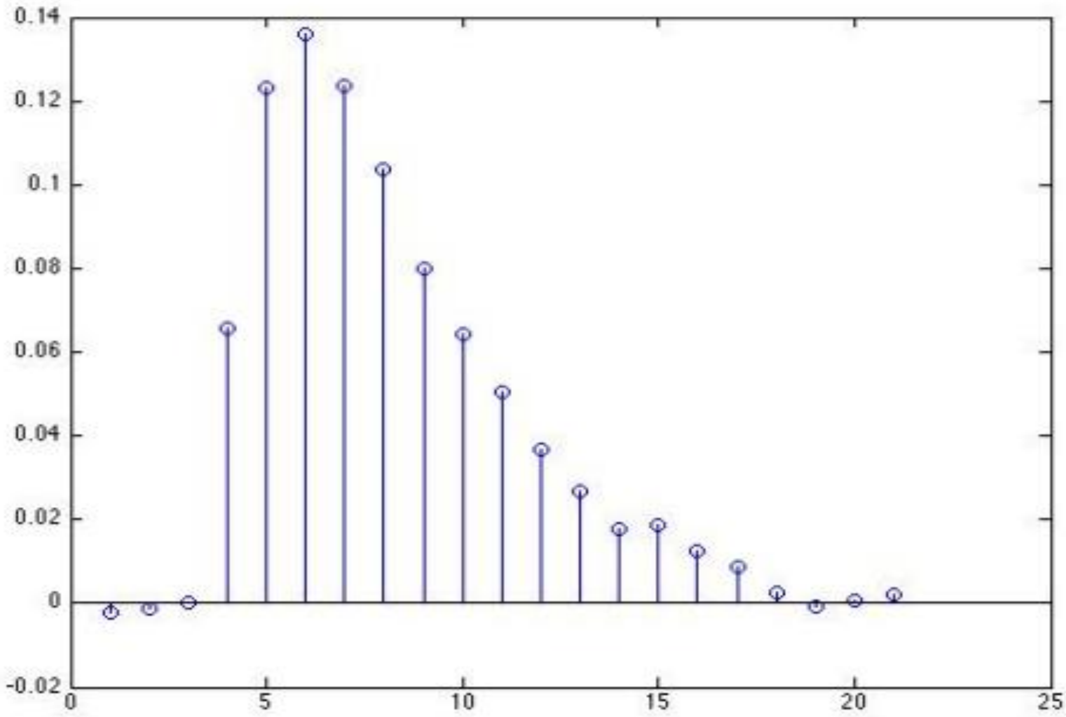
Identify a hairdryer: air is fanned through a tube and heated at the inlet. Input $u(t)$: power of the heating device. Output $y(t)$: air temperature.

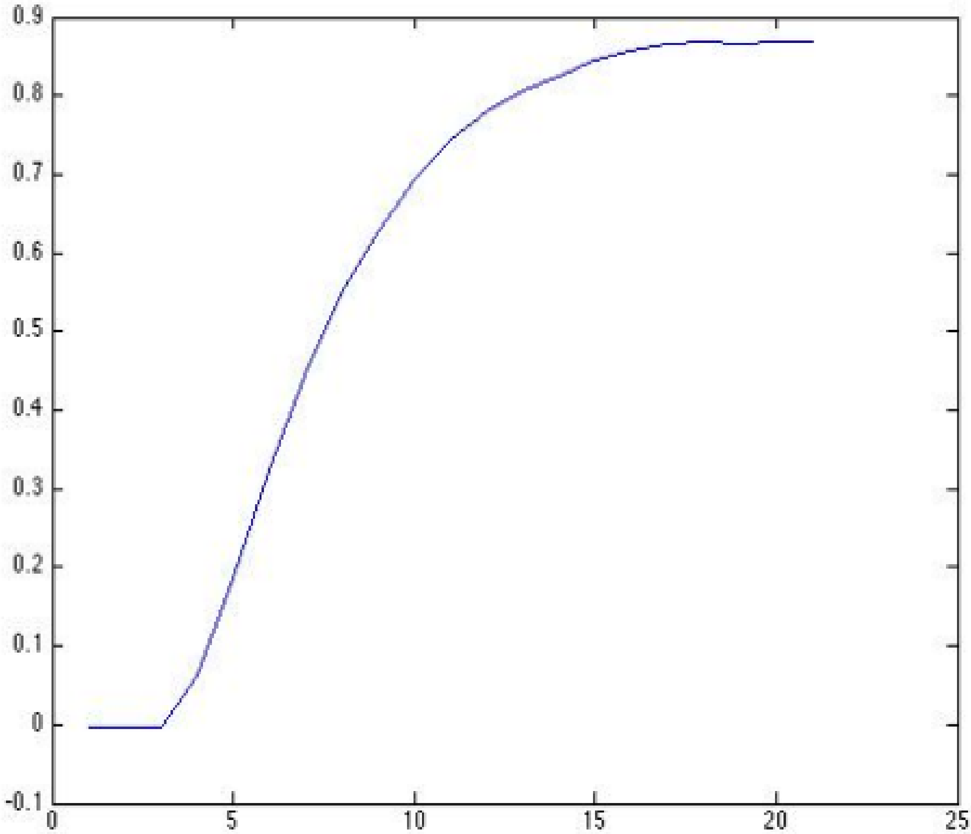
```
>> load dryer2
>> z2 = [y2(1:300) u2(1:300)];
>> idplot(z2, 200:300, 0.08)
```



Nonparametric Modeling

```
>> z2 = dtrend(z2);
>> ir = cra(z2);
>> stepr = cumsum(ir);
>> plot(stepr)
```


0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
0
5
10
15
20
25


0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
0
5
10
15
20
25

PROCEDURE

1. Draw a tangent line in the graph.
2. Find k,τ,td from a graph.from the values we get transfer function model.
3. After that find the controller values using k,τ,td in cohen coon tuning method.
4. Then we write a coding for a close loop system.
5. Observe the close loop response of P, PI and PID controllers.

K=B/A
τ = B/Slope
Slope= opposite / adjacent
td=Delay Time

RESULT

Thus the non parametric identification method used for hair dryer process was implemented in MATLAB software.

VIVA VOCE - Questions &answers

1. List any four objectives of process control.

Suppressing the influence of external disturbances, optimizing the performance and stability of the process, increasing the productivity, Cost effective.

2. Define process

Any system comprised of dynamic variables usually involved in manufacturing and production operations. Process is defined as an operation or series of operations performed on the material during which some materials are placed in more useful state.

3. What is manipulated variable?

It is a variable, which is altered by the automatic control equipment so as to keep the variable under control and make it conform to the desired value.

4. Define Controlled variable

It is the variable, which is to be maintained precisely at set value

5. What do you mean by self-regulation?

It is the tendency of the process to adopt a specific value of controlled variable for nominal load with no control operations.

6. Why do we need mathematical modeling of process?

To analyze the behavior of the process. The physical equipment of the chemical process we want to control has not been constructed. Consequently we cannot experiment to determine how the process reacts to various inputs and therefore we cannot design the appropriate control system. If the process equipment needs to be available for experimentation the procedure is costly. Therefore we need a simple description of how the process reacts to various inputs, and this is what the mathematical models can provide to the control designer.

7. Name different test inputs.

Step, Ramp, Impulse, Sinusoidal, Parabolic inputs

8. Name a process giving inverse response.

Drum boiler system, in which the flow rate of the cold feed water is increased by a step the total volume of the boiling water and consequently the liquid level will decrease for a short period and then it will start increasing.

9. Define interacting system and give an example.

When two level tanks are connected in series, the dynamic behaviour of one tank affects the other tank and vise versa.

10. A tank operating at 10ft head, 51pm outflow through a valve and has a cross section area of 10 sq ft. calculate the time constant.
T=RA, R=H/Q=10/(5X5.885X10-4)

11. Write any two characteristics of first order process modeling.
Smaller the value of time constant, the steeper the initial response of the system.
A first order lag process is self-regulating the ultimate value of the response equal to Kp (steady state gain of the process) for a unit step change in the input.

13. Distinguish between continuous process and batch process.
A process in which the materials or work flows more or less continuously through a plant apparatus while being treated is termed as continuous process. The problem of continuous process is due to load changes. (e.g.) storage vessel control.
A process in which the materials or work are stationary at one physical location while being treated is termed as batch process. (e.g.) furnace.

14. Explain the function of controller.
Determines the value of the controlled variable, compares the actual value to the desired value, determines the deviation and produces the counteraction necessary to maintain the smallest possible deviation between desired value and actual value.

15. What is the operation of the final control element?
Final control element is the mechanism, which alters the value of the manipulated variable in response to the output signal from the automatic control device.

16. Define Process control.
Controlling the process by measuring a variable representing the desired state of the product and automatically adjusting one of other variables of the process.

17. List the two types of process control.
Direct process control – Controlled variable directly indicates the performance of the process. Eg. Water heater system
Indirect Process control – Controlled variable indirectly indicates the performance of the process. Eg. Annealing

18. What is Servo operation and Regulator operation?
If the purpose of the control system is to make the process follow the changes in set point as quick as possible, then it is servo operation.

In many of the process control applications, the purpose of control system is to keep the output (controlled variable) almost constant in spite of changes in load. Mostly in continuous processes the set point remains constant for longer time. Such an operation is called regulator operation.

19. What is mathematical modeling?
Set of equations that characterize the process is termed as Mathematical Model. The activities leading to the construction of the model is called mathematical modeling.

20. Define a non-interacting system.
If the dynamic behaviour of one tank is affected by the other tank, and the reverse is not true, then it is called as non-interacting system. Eg. Two level tanks connected in parallel. Here the liquid heads are independent of each other.

22. Mention two drawbacks of derivative action.
(i) The output of controller is zero at constant error condition.
(ii) It will amplify the noise present in the error signal.

23. What are the steps involved to design a best controller?
Define appropriate performance criterion (ISE, IAE, ITATE).
Compute the value of the performance criterion using a P, PI, or PID controller with the best setting for the adjusted parameters Kp, Ti, Td.
Select controller, which gives the best value for the performance criterion.

24. Define proportional control mode
A controller mode in which the controller output is directly proportional to the error signal. $P=K_pe_p+P_0$ where, P-controller output, Kp - Proportional gain, e_p - Error in percent of variable range, P_0 – Controller output with no error (%).

25. Define proportional band.
The range of error to cover the 0% to 100% controller output is called the proportional band (PB) because the one-to-one correspondence exists only for errors in this range.

26. Write the relation ship between proportional band and proportional gain.
The reciprocal of gain expressed, as a percentage is called proportional band. PB=100/Kp.

27. Define offset.
It is the steady state deviation (error) resulting from a change in value of load variable.

28. Define error (deviation)?
It is the difference at any instant between the values of controlled variable and the set point. E = S.P - P.V

30. Why is the electronic controller preferred to pneumatic controller?
Electronic signals operate over great distance without time lags. Electronic signals can be made compatible with digital controllers. Electronic devices can be designed to be essentially maintenance free. Intrinsic safety techniques eliminate electrical hazards. Less expensive to install. More energy efficient. Due to the above said properties electronic controllers are preferred to pneumatic controller.

32. Write any two limitations of single speed floating control.
The present output depends on the time history of errors and such history is not known, the actual value of controller output floats at an undetermined value. If the deviation persists controller saturates at either 100% or 0% and remain there until an error drives it towards opposite extreme.

34. Why derivative mode of control is not recommended for a noisy process?
The series capacitor in the derivative controller will amplify the noise in the error signal.

35. Define integral windup?
The integral term of a P+I controller causes its output to continue changing as long as there is a non-zero error. Often the errors cannot be eliminated quickly, and given enough time this P+I mode produces larger and larger values for integral term, which in tern keeps increasing control action until it is saturated. This condition is called integral windup and occurs during manual operational changes like shutdown, changeover etc.

36. What are the two modes of controller?
Discontinuous and continuous modes are the two modes of controller.

37. Define Discontinuous mode of controller.
In discontinuous mode, the controller command initiates a discontinuous change in the controller parameter. Eg. Two position mode controller (ON-OFF), Multi position mode controller, single speed and multiple speed controller

38. Define Continuous mode of controller.
In continuous mode, smooth variation of the control parameter is possible.
Eg. Proportional, integral, Derivative and composite control modes

40. Define cycling.
Oscillations of error about zero is called cycling. This means the variable is cycling above and below the set point value.

41. Write Ziegler- Nicolas turning formulae.

Mode	Kp	Ti (Min)	Td (Min)
Proportional	Ku / 2	-	-
Proportional – Integral	Ku / 2.2	Pu / 1.2	-
Proportional – Integral – Derivative	Ku / 1.7	Pu / 2	Pu / 8

Where,
Ku – Ultimate gain, Pu – Ultimate period of sustained cycling.

42. Define controller turning.
Deciding what values to be used for the adjusted parameters of the controller is called controller turning.

43. What is reaction curve?
Controller is disconnected from the final control element. The process reaction curve is obtained by applying a step change, which actuates the final control element, and plotting the response of the output with respect to time.

44. What performance criterion should be used for the selection and turning of Controller?

1. Keep the maximum error as small as possible.
2. Achieve short settling time.
3. Minimize the integral of the errors until the process has settled to its desired set Point.

45. Define ultimate gain.
The maximum gain of the proportional controller at which the sustained oscillations occur is called ultimate gain (Ku).

46. What is ITAE and when to go for it?
ITAE means Integral Time Absolute Error. To suppress the errors that persist for long time, the ITAE critertion will tune the controllers better because the presence of large t amplifies the effect of even small errors in the value of the integral.

47. What are the parameters required to design a best controller?
Process Parameters (K, t), Controller parameters (Kp, Ti, Td), and performance creation (ISE, IAE, IATE)

48. Write the practical significance of the gain margin.

1. It constitutes a measure of how far the system is the brink of instability.
2. Higher the gain margin (above the value of one), the higher the safety factor we use for the controller turning.
3. Typically, a control designer synthesizes a feedback system with gain margin larger than 1.7. This means that amplitude ratio can increase 1.7 times above the design value before the system becomes unstable.

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49. Why is it necessary to choose controller settings that satisfy both gain margin and phase margin?

The gain margin and Phase margin are the safety factors, which is used for the design of a feedback system. Beyond the phase margin and gain margin the system goes to unstable position.

51. Name the time integral performance criteria measures.

1. Integral of the Square Error (ISE),
2. Integral of the Absolute value of Error (IAE),
3. Integral of Time weighted Absolute Error.

52. Define Integral Square Errors (ISE).

ISE = $\int e^2 (t)$ dt. Limit 0 to ∞

If we want to strongly suppress large errors, ISE is better than IAE because errors are squared and contribute more to the value of integral.

53. Define Integral Absolute Errors (IAE)

IAE = $\int |e^2 (t)|$ dt. Limit 0 to ∞.

If we want to suppress small errors, IAE is better than ISE because when we square small numbers, they even become smaller.

54. Define Integral of Time weighted Absolute Error (ITAE)

ITAE = $\int t\ e^2\ (t)$ dt. Limit 0 to ∞

To suppress errors that persist for long times, ITAE criterion will tune the controllers better because the presence of large t amplifies the effect of even small errors in value of integral.

55. Define One-quarter decay ratio.

It is a reasonable trade off between fast rise time and reasonable settling time.

56. Give the satisfactory control for gas liquid level process.

Proportional Control is the satisfactory control for liquid level process.

57. Give the satisfactory control for gas pressure process.

Proportional Control is the satisfactory control for liquid level process.

58. Give the satisfactory control for vapour pressure process.
PI Control is the satisfactory control for vapour pressure process having fast response.

59. Give the satisfactory control for temperature process.
PID Control is the satisfactory control for temperature process.

60. Give the satisfactory control for composition process.
PID Control is the satisfactory control for composition process.

61. Define ratio control.
Ratio control is a special type of feed forward control where two disturbances are measured and held in a constant ratio to each other.

62. Define cascade control.
In the scheme there will be two controllers namely primary controller and secondary controller. The output of the primary controller is used to adjust the set point of a secondary controller, which in turn sends a signal to the final control element. The process output is fed back to the primary controller and a signal from an intermediate stage of the process is fed back to the secondary controller.

63. When cascade control will give improved performance than conventional feedback control?
In conventional feedback control, variations in flow not dictated by the controller are caused by changes in pressure differential at the valve, which in turn result from changes in pressure of supply, changes in downstream pressure and so on. These changes are difficult to counteract since they must carry through the process before they are detected in the controller. Supply changes sometimes occur suddenly or over a wide range and deviation may become excessive before a new balance of conditions can be established. Such conditions are overcome by cascade control.

64. Explain the purpose of cascade control for heat exchangers?
In heat exchangers, the control objective is to keep the exit temperature of stream at a desired value. But the flow rate of the inlet stream creates the low disturbance throughout the process. The secondary loop is used to compensate the flow rate of the inlet stream.

65. What is mean by auctioneering control?
Auctioneering control configurations select among several similar measurements the one with the highest or lowest value and feed it to the

controller. Thus it is a selective controller, which possesses several measured outputs and one manipulated input.

66. Give any two types of selective control system.

1. Override control. 2. Auctioneering control.

67. What is limit switch?

In some cases it is necessary to change from the normal control action and attempt to prevent a process variable from exceeding an allowable upper or lower limit. This can be achieved by the use of special types of switches called limit switches.

68. Mention the types of limit switches.

1. High Selector Switch (HSS), 2. Low Selector Switch (LSS).

69. What is HSS?

High Selector Switch (HSS) is a limit switch, which is used whenever a process variable should not exceed an upper limit.

70. What is LSS?

Low Selector Switch (LSS) is a limit switch, employed to prevent a process variable from exceeding a lower limit.

71. What is override control?

During the normal operation of the plant or during its startup or shutdown it is possible that dangerous situations may arise which may lead to destruction of equipment and operating personnel. In such cases it is necessary to change from the normal control action and attempt to prevent a process variable from exceeding an allowable upper or lower limit. This can be achieved by the use of special type switches called limit switches (HSS and LSS). This type of protective control is called override control.

72. What is split-range control?

A single process output can be controlled by co-coordinating the actions of several manipulated variables all of which have same effect on the controlled output. Such systems are called split-range control systems.

73. Differentiate split-range control and selective control.

Split-range control system involves one measurement and more than one manipulated variables but selective control system involves one manipulated variables and several controlled outputs.

74. Why are fuel and air sent at a specified ratio into a combustion chamber?
To obtain the most efficient combustion.

75. What are decouplers?
The special element introduced in a system to cancel the interaction effects between the two loops and thus render two non-interacting control loops is called decouplers

76. When is inferential control used?
It is used in some cases where the controlled variable cannot be measured directly and the influence of the disturbance cannot be measured.

77. What are the advantages of feed forward controller?

1. Acts before the effect of disturbance has been felt by the process.
2. It is good for slow systems. (Multi capacity or with significant dead time)
3. It does not introduce instability in the closed loop response.

78. What are the disadvantages of feed forward controller?

1. Requires identification of all possible disturbances and their direct measurement
2. Cannot cope with unmeasured disturbances.
3. Sensitive to process parameter.

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79. What are the advantages of feedback controller?

1. It does not require identification and measurement of disturbance.
2. It is insensitive to modeling errors.
3. It is insensitive to parameter changes.

80. What are the disadvantages of feedback controller?

1. It is unsatisfactory for slow processes with significant dead time.
2. It may create instability in the closed loop response
3. It waits until the effect of the disturbances has been felt by the process before control action is taken.

81. What is flashing in control valve?
When the valve outlet pressure $P_{2\ is}$ less than or equal to the vapour pressure of the process liquid, some of the liquid flashes into vapour and stays in vapour phase as it enters the downstream piping. The specific volume increases as liquid changes to vapour.
The resulting high velocities can erode material.

82. When do you use a valve positioner?
If the diaphragm actuator does not supply sufficient force to position the valve accurately and overcome any opposition that flowing conditions create a positioner may be required.

83. Give two examples for electric actuators.
Motor, Solenoids.

84. What is the need of I/P converter in a control system?
In some process loop the controller is electronic and the final control element is pneumatic one. To interconnect these two we need a device that should linearly converts electric current in to gas pressure (4 – 20mA to 3 - 15psi). Such device is called I/P converter.

85.Why installed characteristics of a control valve are different from inherent characteristics?
Inherent characteristics are which the valve exhibits in the laboratory condition where the pressure drop is held constant. Installed or resultant characteristics are the relationship between flow and stroke when the valve is subjected to pressure conditions of the process.

86. Explain the function of pneumatic transmission lines.
Used to transmit the input signals into standard instrumentation pneumatic output signals (3 to 15 psi or 20 to 100 KPa).

88. What is meant by cavitation in control valve?
When a liquid enters a valve and the static pressure at the vena contracta drops to less than the fluid vapor pressure and the recovering to above fluid vapour pressure, this pressure recovery causes an implosion or collapse of the vapour bubbles formed at the vena contracta. This condition is called cavitation

89. What is “equal percentage” in the equal percentage valve?
A given percentage change in stem position produces an equivalent change in flow that is an equal percentage.

90. What are the types of control valve characteristics?
1. Inherent characteristics,
2. Installed characteristics.

92. What is “quick opening”(decreasing sensitivity type valve) control valve?
Small movement of the valve stem results in maximum possible flow rate through the valve.

93. What is "Linear" control valve?
This type of valve has a flow rate that varies linearly with the stem position.

94. Define Control Valve sizing.
The proper sizing of the control valve is important because of the effect on the operation of the automatic controller.
$Q = Cv.\sqrt{(\Delta p/Sg)}$
Q-Flow rate
Cv-Valve coefficient
Δp - pressure difference across valve.
Sg - Specific gravity of liquid.

95. Name any one final control element.
Control Valve.

96. What is the function of control valve in a flow control system?
The function of control valve in flow control system is to regulate the flow.

97. Name one application of electrical actuators.
Solenoid coil used to change gears.

98. Name the two types of plugs.
Single-seated and double-seated plug type control valves.

99. Define Range ability.
It is the ratio of maximum controllable flow to minimum controllable flow.
$R = Q_{max} / Q_{min}$

100. What is rotating shaft type control valves?
Control valves in which the restriction is accomplished by the rotation of a plug or vane may be called rotating shaft type.
1. Rotating-plug valves
2. Butterfly valves
3. Louvers.

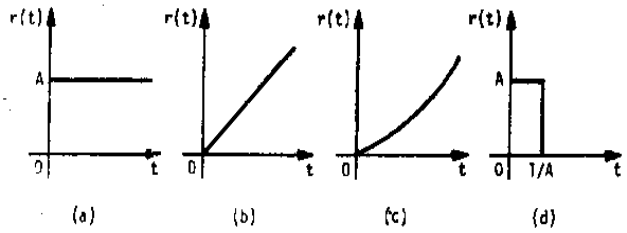
101. What is time – domain analysis?
If the response of a dynamic system to an input is expressed as a function of time it is time-domain analysis. It is possible to compute the time response of a system if the nature of input and the mathematical model of the system are known.

102. What are the components of time response in any system?
The time response of any system has two components: transient response and the steady-state response. Transient response is dependent upon the system

poles only and not on the type of input. It is therefore sufficient to analyze the transient response using a step input. The steady-state response depends on system dynamics and the input quantity. It is then examined using different test signals by final value theorem.

103. What are standard test signals? Give examples.
Usually, the input signals to control systems are not known fully ahead of time. For example, In a radar tracking system, the position and the speed of the target to be tracked may vary in a random fashion. It is therefore difficult to express the actual input signals mathematically by simple equations. The characteristics of actual input signals are a sudden shock, a sudden change, a constant velocity, and constant acceleration. The dynamic behavior of a system is therefore judged and compared under application of standard test signals – an impulse, a step, a constant velocity, and constant acceleration. Another standard signal of great importance is a sinusoidal signal.

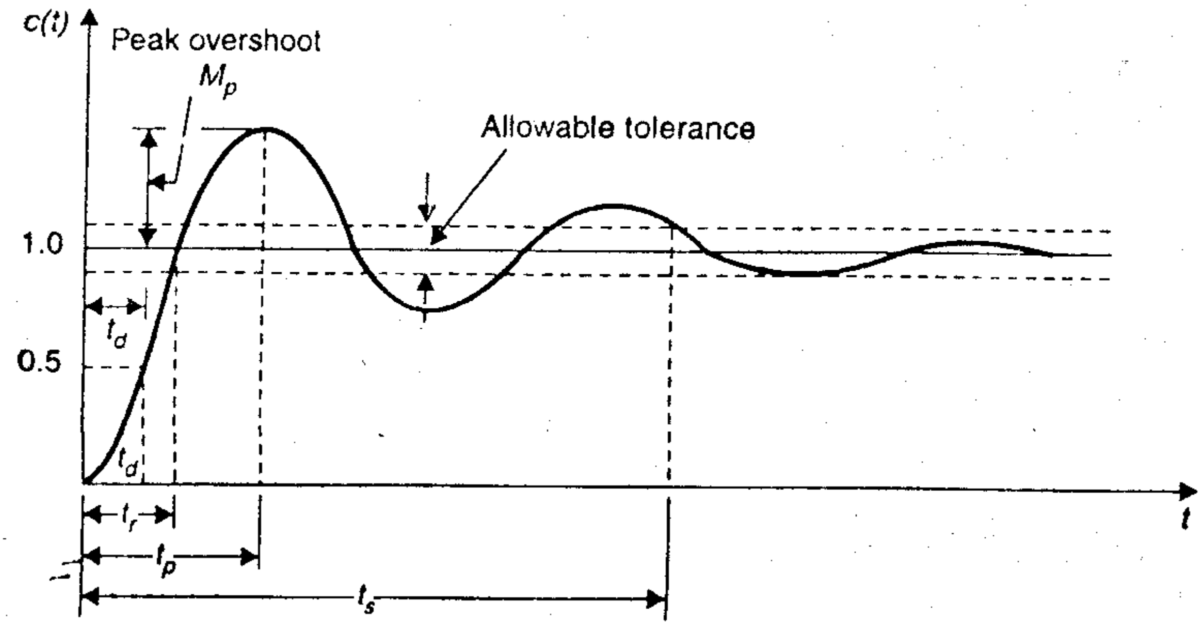
Standard test signals



a) Step signal: $r(t) = Au(t)$.
b) Ramp signal: $r(t) = At; \; t > 0$.
c) Parabolicsignal:
$r(t) = At^2/2; \; t > 0$.
d) Impulse signal: $r(t) = \delta(t)$.

104. What are the transient-response characteristics of a control system?
The transient-response characteristics of a control system to a unit step input, includes the following:

1. Delay time, t_d
2. Rise time, t_r
3. Peak time, t_p
4. Peak overshoot, M_p
5. Settling time, t_s
6. Steady-state error, e_{ss}



1. ***Delay time,*** t_d***:*** It is the time required for the response to reach 50% of the final value in first attempt.

2. ***Rise time,*** t_r***:*** It is the time required for the response to rise from 0 to 100% of the final value for the underdamped system.

3. ***Peak time,*** t_p***:*** It is the time required for the response to reach the peak of time response or the peak overshoot.

4. ***Settling time,*** t_s***:*** It is the time required for the response to reach and stay within a specified tolerance band (2% or 5%) of its final value.

5. ***Peak overshoot,*** M_p***:*** It is the normalized difference between the time response peak and the steady output and is defined as,

$$\%M_p = \frac{c(t_p) - c(\infty)}{c(\infty)} \times 100\%$$

6. ***Steady-state error,*** e_{ss}***:*** It indicates the error between the actual output and desired output as 't' tends to infinity.

$$e_{ss} = \lim_{t \to \infty} [r(t) - c(t)]$$

105. What is the advantage of state – space analysis?
1) It can be used on systems having more than one feedback loop,
2) It can be used on systems having multiple inputs and outputs,
3) It helps in finding out a set of feedback parameters that place the system poles at any desired location, if all the state variables are available for measurement (observable state variables).

106. State final value theorem.

Final value theorem is another useful control system property, where the steady-state time domain response is given by:

$$y(t \rightarrow \infty) = \lim_{s \rightarrow 0} s\ F(s)X(s).$$

The theorem states that the steady-state time domain step response can be obtained directly from the transfer function. For example, for a unit step input X(s) = 1/s, and transfer function
F(s) = 2/(s + 3), the steady-state time domain output value is,

$$y(t \rightarrow \infty) = \lim_{s \rightarrow 0} s \frac{2}{s+3}\frac{1}{s} = \frac{2}{3}.$$

The final value theorem forms the basis for static analysis of feedback control systems.

107. **Why is Control needed in any process?**

Chemical plants are intended to be operated under known and specified conditions. There are several reasons why this is so:

a) Safety:

Formal safety and environmental constraints must not be violated.

b) Operability:

Certain conditions are required by chemistry and physics for the desired reactions or other operations to take place. It must be possible for the plant to be arranged to achieve them.

c) Economic:

Plants are expensive and intended to make money. Final products must meet market requirements of purity, otherwise they will be un-saleable. Conversely the manufacture of an excessively pure product will involve unnecessary cost. A chemical plant might be thought of as a collection of tanks in which materials are heated, cooled and reacted, and of pipes through which they flow. Such a system will not, in general, naturally maintain itself in a state such that precisely the temperature required by a reaction is achieved, a pressure in excess of the safe limits of all vessels be avoided, or a flow rate just sufficient to achieve the economically optimum product composition arise.