EI6612 - PROCESS CONTROL LABORATORY

EI6612 - PROCESS CONTROL LABORATORY

COURSE OUTCOMES:

Course Outcome	Statement
CO1	Model and Analyze the various systems using MATLAB.
CO2	Apply the different PID controller tuning methods on various bench mark processes.
CO3	Analyze the installed and inherent characteristics of control valve with and without positioner..
CO4	Demonstrate the PID implementation issues using MATLAB.
CO5	Design and implement PID controller for multi loop systems.
CO6	Design and implement PID controller for multi variable systems.

CO - PO MAPPING :

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	-	-	-	3	-	-	-	-	-	-	-	3	3	-
CO2	3	3	3	-	3	-	-	-	-	-	-	-	3	3	-
CO3	3	3	-	-	3	-	-	-	-	-	-	-	3	3	-
CO4	3	-	-	-	3	-	-	-	-	-	-	-	3	3	-
CO5	3	3	3	3	3	-	-	-	-	-	-	-	3	3	-
CO6	3	3	3	3	3	-	-	-	-	-	-	-	3	3	-
AVG	3	3	3	3	3	-	-	-	-	-	-	-	3	3	-

3 - Substantially **2 - Moderate** **1 - Slightly**

PANIMALAR ENGINEERING COLLEGE

Bangalore Trunk Road, Nasarathpet,Poonamallee,Chennai600 123

DEPARTMENT OF ELECTRONICS & INSTRUMENTATION ENGINEERING

BONAFIDE CERTIFICATE

This is a certified that the bonafide observation book of Mr. / Ms. ______________________

Register No.________________ submitted for the Practical Sessions in ________________

___________________ during the year 2018-2019.

Signature of the Lab-in-charge

INDEX

SYLLABUS

EI6612 PROCESS CONTROL LABORATORY

OBJECTIVES:

To experimentally verify the process control concepts on the selected process control loops.

LIST OF EXPERIMENTS:

1. Study of Process Control Training Plant and Compact Flow Control Unit.
2. Characteristics of Pneumatically Actuated Control Valve (with and without Positioner).
3. Level Control and Pressure Control in Process Control Training Plant.
4. Design of ON/OFF Controller for the Temperature Process.
5. PID Implementation Issues.
6. Tuning of PID Controller for mathematically described processes.
7. PID Enhancements (Cascade and Feed-forward Control Schemes).
8. Design and Implementation of Multi-loop PI Controller on the Three-tank system.
9. Analysis of Multi-input Multi-output system (Four-tank System).
10. Study of AC and DC drives.
11. Study of pH Control Test Rig.
12. Auto-tuning of PID Controller

TOTAL : 45 PERIODS

OUTCOMES:

- Ability to understand and analyse process control engineering problems.

Ex No: 1	**CLOSED LOOP RESPONSE OF FLOW CONTROL LOOP**
DATE:	

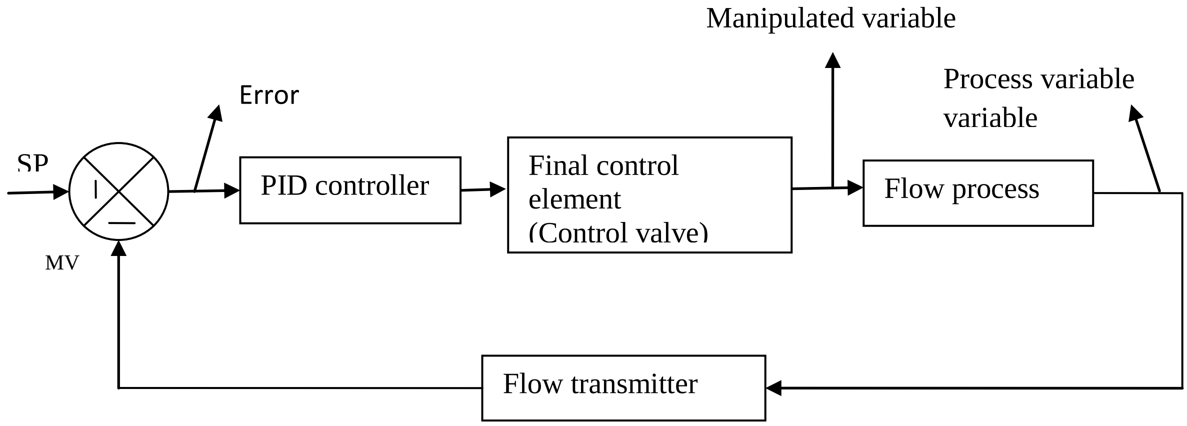
AIM

To obtain the closed loop response of Flow control loop for Servo and Regulator operation using any tuning techniques.

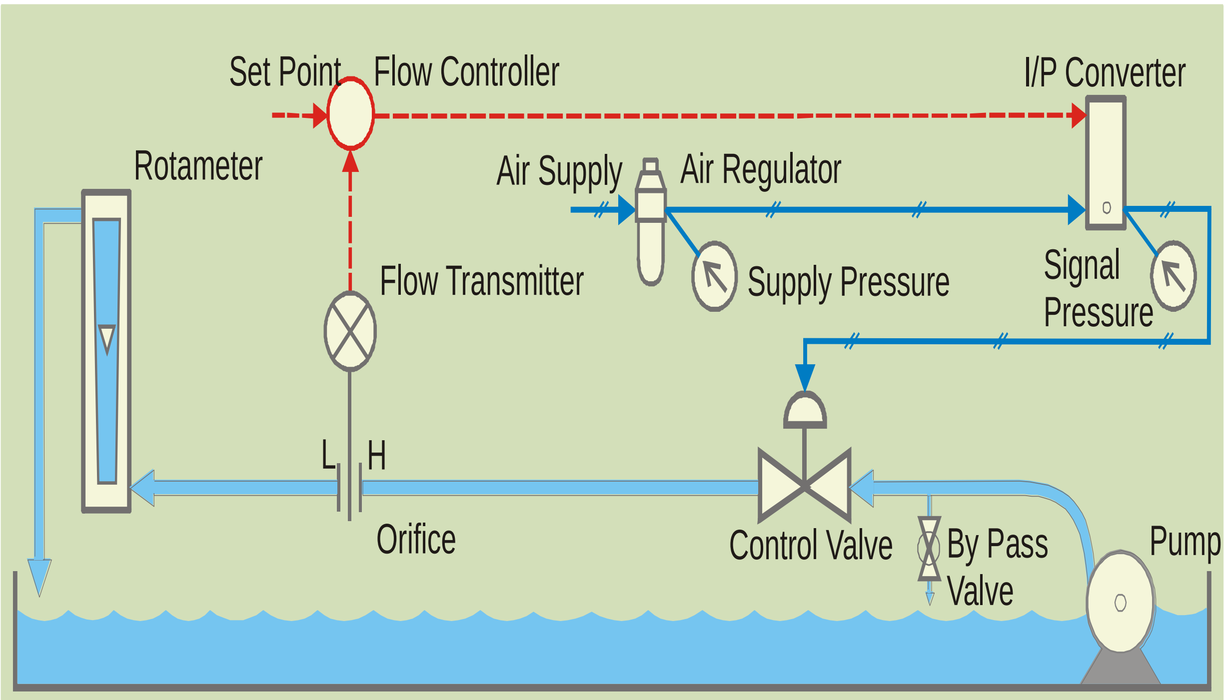
APPARATUS REQUIRED

1. Flow process set up
2. Computer with Printer

BLOCK DIAGRAM



EXPERIMENTAL SET UP



DESCRIPTION

Flow control trainer is designed for understanding the basic principles of flow control. The process setup consists of supply water tank fitted with pump for water circulation. A DP transmitter is used for flow sensing which measures differential pressure across orifice meter. The process parameter (flow) is controlled by microprocessor based digital indicating controller which manipulates pneumatic control valve through I/P converter. The control valve is fitted in water flow line.

These units along with necessary piping are fitted on support housing designed for tabletop mounting.The controller can be connected to computer through USB port for monitoring the process in SCADA mode.

In automatic controlled process the parameter to be controlled is measured and compared with the set point by process controller. The difference between the measured signal and the set point is error. The controller performs on-line calculations based on error and other setting parameters and generates an output signal. The output signal drives the final control elements like control valve or a damper to control the process to the set point.

Sensor : DP Transmitter .Type- Capacitance , two wire, Range 0–200 mm, Output 4–20 mA Make Yokogawa

Controller: Digital indicating controller with Ethernet communication Make Yokogawa, model UT35

FCE : Type Pneumatic, Size 1/4", Input 3–15 psig, Air to close, Characteristic Linear, Make Pneucon

1. TUNING OF CONTROLLER (CLOSED LOOP METHOD)

THEORY

This method is recommended by Ziegler and Nichols. This method is also called as ultimate gain method. The term ultimate was attached to this method because its use requires the determination of the ultimate proportional band and ultimate period. The ultimate proportional band, (PBu) is the minimum allowable value of proportional band (for a controller with only proportional mode) for which the system continuously oscillates at constant amplitude. The ultimate period, (Tu) is the period of response with the proportional band set to its ultimate value. To determine the ultimate proportional band and ultimate period the proportional band of the controller (with all integral and derivative action turned off) is gradually reduced until the process cycles continuously.

The process is placed in the closed loop with a proportional controller. The Proportional band is decreased until the process goes to continuous oscillations. The corresponding value of proportional band is called as ultimate proportional band PBu and the period of oscillation is called the ultimate period Tu.

The PID controller parameters are selected from the following table:

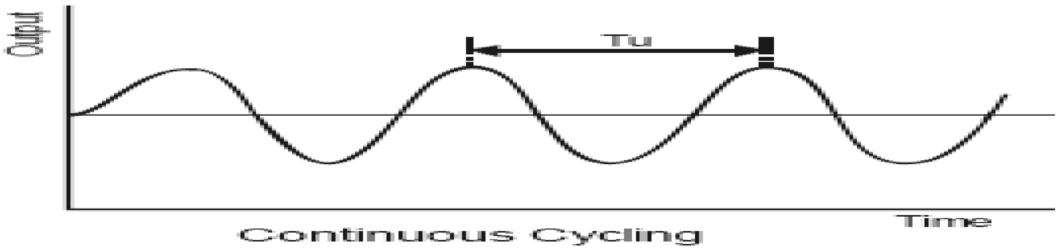
Mode	Proportional	Integral	Derivative
P	2 PBu	-	-
P+I	2.2 PBu	Tu/1.2	-
P+I+D	1.65 PBu	0.5 Tu	Tu/8.0

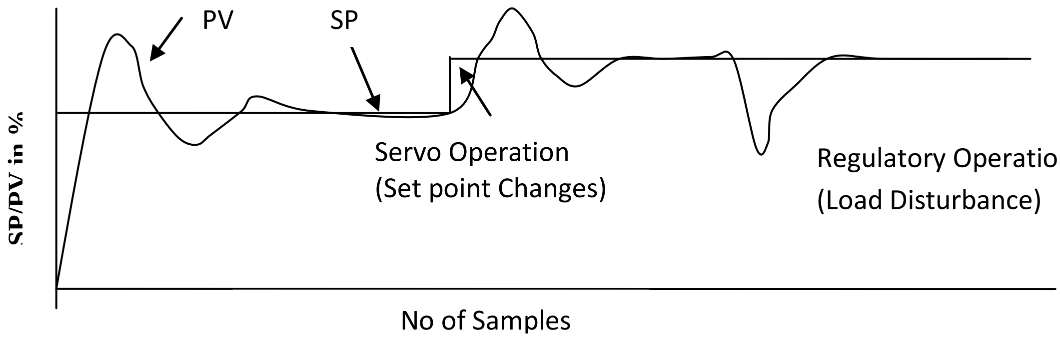
PROCEDURE

1. Start up the set up.
2. Double click the apex procedure exe file in the desktop.
3. One Window will open. Then select the product (i.e.) level control trainer (313)A.
4. Then select the controller (UT 321E) and port COM 5.
5. Select closed loop option and select P controller only
6. Set the proportional band value to maximum(say 100%) set the controller to manual mode and adjust the output so that the process value reaches to 70%
7. Switch the controller to auto mode and decrease the proportional band and apply the step change to set point and observe the process response
8. Repeat the above procedure and find the value of proportional band for which the system under goes continuous oscillation
9. Record the ultimate proportional band and ultimate period from the response
10. Calculate the PID values from the table
11. Select the PID controller and apply the parameter values obtained from the above steps observe the response of the process.

MODEL GRAPH

Response Curve to find Ultimate Gain & Period for continuous oscillations method





2. TUNING OF CONTROLLER (OPEN LOOP METHOD)

PROCEDURE

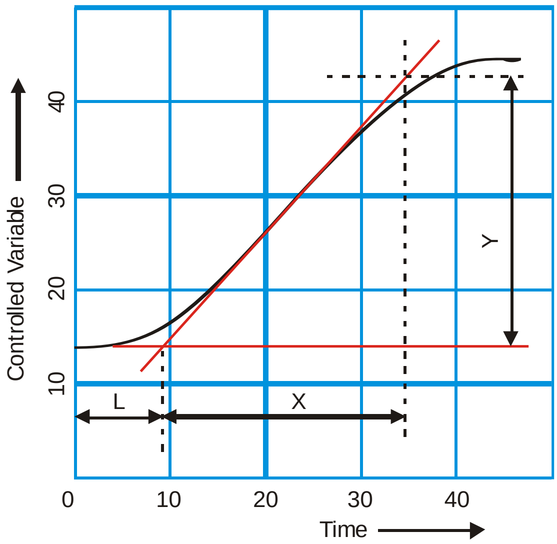
1 Start up the set up.
2 Double click the apex procedure in the desktop.
3 One Window will open. Then select the product (i.e.) flow control trainer(312)A.
4 Then select the controller (UT 321E) and port COM 4.

5 Select **Process Reaction** option for control from software. (Click on “Change Expt.” Button, click on “Change”, Click on “Process Reaction” button.)
6 Adjust controller output, so that the process value is maintained at 70%.
7 Start data logging.
8 Apply a 20 - 30 % change to controller output. (Open the control valve) Record the step response. Wait for the steady state.
9 Stop data logging.
10 Plot the step response (Process reaction curve) from stored data. Find out the value of slope at the point of inflection and time lag.
11 Calculate P I D settings for different modes.
12 Select **close loop.** Set the PID values obtained from the calculations. Apply the step change & observe the response of the system. Allow the system to reach steady state.

Open loop method (Process reaction curve method)

In open loop method the process is assumed to be model of first order. The step response i.e. process reaction curve, allows to obtain the approximate values of P, I and D parameters. With the feedback loop open, a step response is applied to manipulated variable and the values of P, I and D are estimated.

Model graph: **Open loop response for input step change (Process reaction curve)**



Where Slope R: Slope of line drawn tangent to the point of inflection.

$$R = \frac{\%ChangeinVariable}{time(\min)} = \frac{Y}{X}$$

Dead time L: Time between the step change and the point where tangent line crosses the initial value of the controlled variable (in min.)

ΔP = Step change applied in %

Using these parameters, the empirical equations are used to predict the controller settings for a decay ratio of 1/4.

For P, PI and PID controller the parameters are calculated as follows.

Mode	Proportional band (in %)	Integral time (in minutes)	Derivative time (in minutes)
P	100RL/ΔP	-	-
P+I	110RL/ΔP	L/0.3	-
P+I+D	83RL/ΔP	L/0.5	0.5L

Observations

- Step change to the system ΔP = Initial output - Final output of the controller.
- Plot the graph of process value Vs Time on a graph paper.
- From process reaction curve:
    - Slope of the process reaction curve R =
    - Time lag L=
- Calculate P, PI, and PID setting from above values.

Observe the closed loop response of the system for different PID settings.

RESULT

Thus the closed loop response of flow process for Servo and Regulator operation was obtained using process reaction curve tuning method.

Ex No: 2	**CLOSED LOOP RESPONSE OF LEVEL CONTROL LOOP**
DATE:	

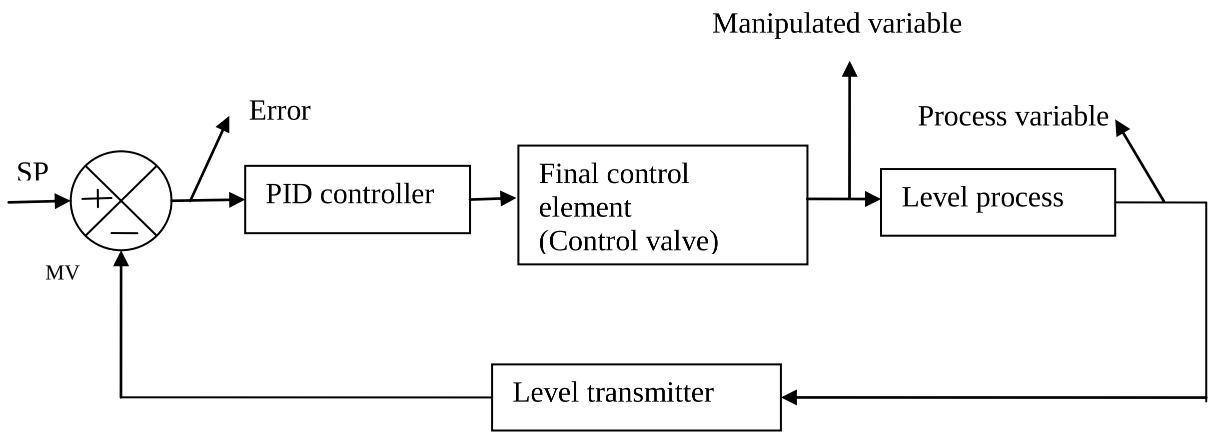
AIM

To obtain the closed loop response of Level control loop for Servo and Regulator operation using any one tuning techniques.

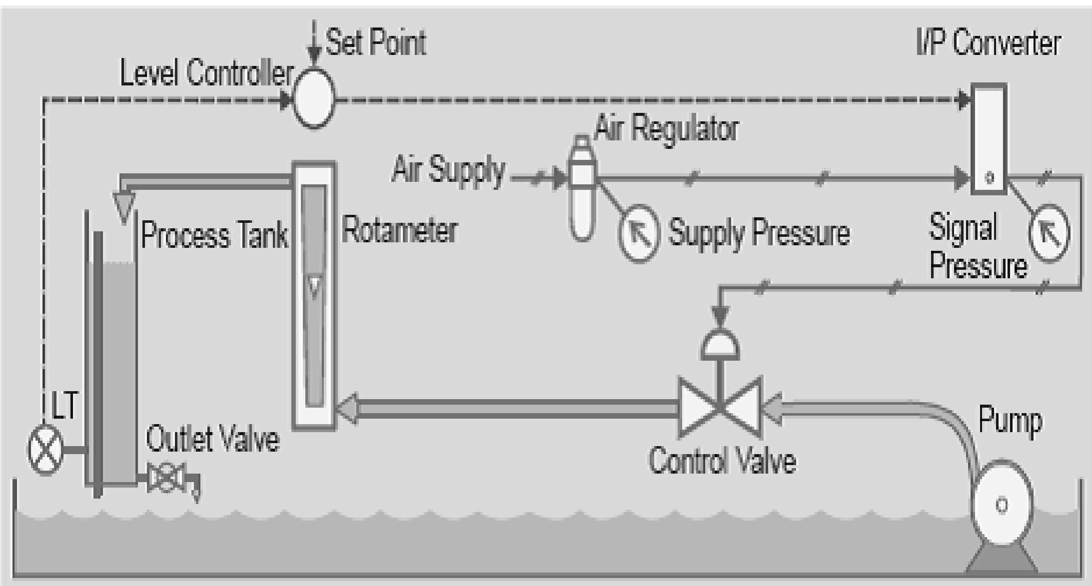
APPARATUS REQUIRED

1. Level process set up
2. Computer with Printer

BLOCK DIAGRAM



EXPERIMENTAL SET UP



DESCRIPTION

Level control trainer is designed for understanding the basic principles of level control. The process setup consists of supply water tank fitted with pump for water circulation. The level transmitter used for level sensing is fitted on transparent process tank. The process parameter (level) is controlled by microprocessor based digital indicating controller which manipulates pneumatic control valve through I/P converter. A pneumatic control valve adjusts the water flow in to the tank. These units along with necessary piping are fitted on support housing designed for tabletop mounting.The controller can be connected to computer through USB port for monitoring the process in SCADA mode.

Sensor : Level Transmitter,Type Two wire, Range 0–5 bar, Output 4–20 mA, Make Wika
Controller: Digital indicating controller with Ethernet communication Make Yokogawa, model UT35
FCE : Type Pneumatic, Size 1/4", Input 3–15 psig, Air to close, Characteristic Linear, Make Pneucon

2. TUNING OF CONTROLLER (CLOSED LOOP METHOD)

THEORY

This method is recommended by Ziegler and Nichols. This method is also called as ultimate gain method. The term ultimate was attached to this method because its use requires the determination of the ultimate proportional band and ultimate period. The ultimate proportional band, (PBu) is the minimum allowable value of proportional band (for a controller with only proportional mode) for which the system continuously oscillates at constant amplitude. The ultimate period, (Tu) is the period of response with the proportional band set to its ultimate value. To determine the ultimate proportional band and ultimate period the proportional band of the controller (with all integral and derivative action turned off) is gradually reduced until the process cycles continuously.

The process is placed in the closed loop with a proportional controller. The Proportional band is decreased until the process goes to continuous oscillations. The corresponding value of proportional band is called as ultimate proportional band PBu and the period of oscillation is called the ultimate period Tu.

The PID controller parameters are selected from the following table:

Mode	Proportional	Integral	Derivative
P	2 PBu	-	-
P+I	2.2 PBu	Tu/1.2	-
P+I+D	1.65 PBu	0.5 Tu	Tu/8.0

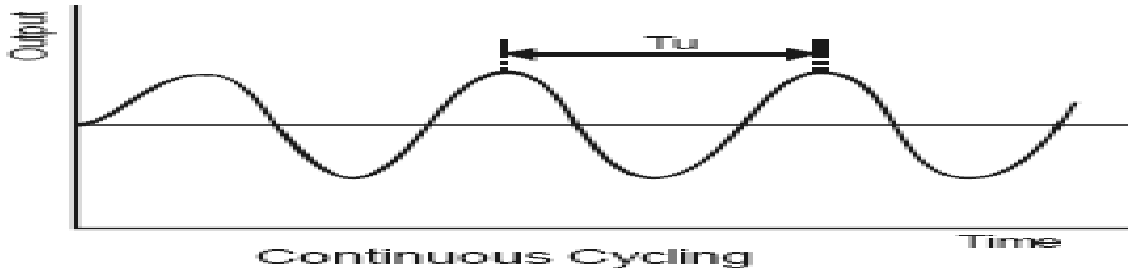
PROCEDURE

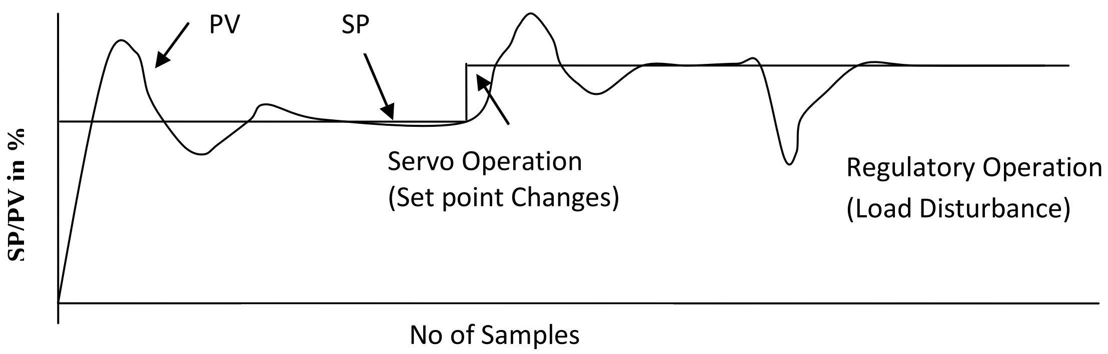
1. Start up the set up.
2. Double click the apex procedure exe file in the desktop.
3. One Window will open. Then select the product (i.e.) level control trainer (313)A.

4. Then select the controller (UT 321E) and port COM 5.
5. Select closed loop option and select P controller only
6. Set the proportional band value to maximum(say 100%) set the controller to manual mode and adjust the output so that the process value reaches to 70%
7. Switch the controller to auto mode and decrease the proportional band and apply the step change to set point and observe the process response
8. Repeat the above procedure and find the value of proportional band for which the system under goes continuous oscillation
9. Record the ultimate proportional band and ultimate period from the response
10. Calculate the PID values from the table
11. Select the PID controller and apply the parameter values obtained from the above steps observe the response of the process.

MODEL GRAPH

Response Curve to find Ultimate Gain & Period for continuous oscillations method





RESULT

Thus the closed loop response of level process for Servo and Regulator operation was obtained using process reaction curve & continuous oscillation tuning method.

Ex No: 3	**CLOSED LOOP RESPONSE OF PRESSURE CONTROL LOOP**
DATE:	

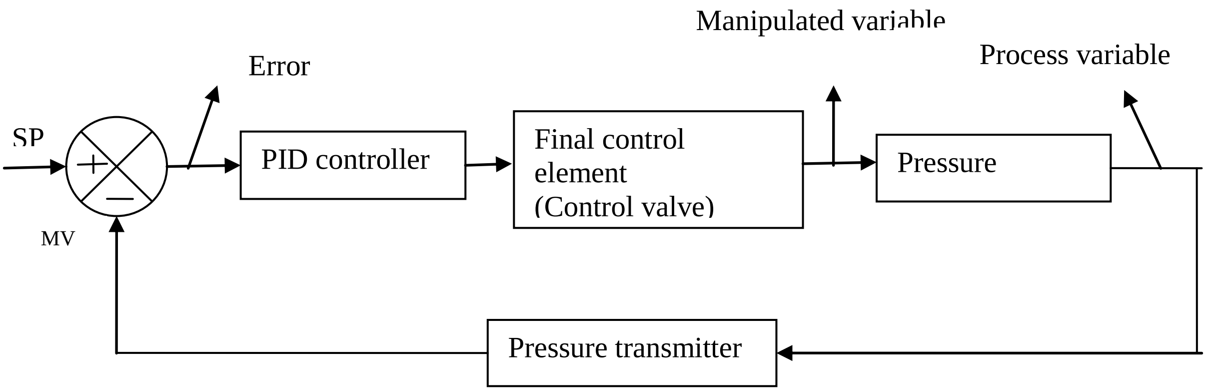
AIM

To obtain the closed loop response of Pressure control loop for Servo and Regulator operation. using any one tuning techniques.

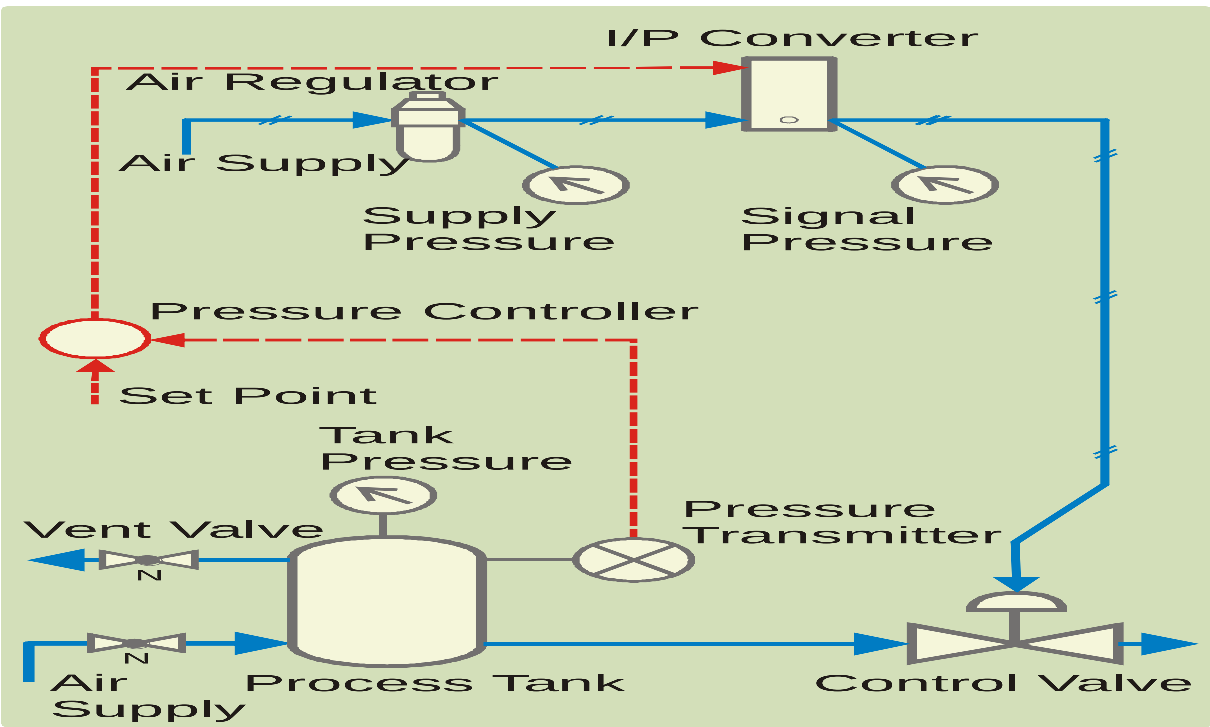
APPARATUS REQUIRED

1. Pressure process set up
2. Computer with Printer

BLOCK DIAGRAM



EXPERIMENTAL SET UP



DESCRIPTION

Pressure control trainer is designed for understanding the basic principles of pressure control. The process set up consists of pressure vessel fitted with pneumatic control valve. Pressure transmitter is used for pressure sensing. The process parameter (Pressure) is controlled by microprocessor based digital indicating controller which manipulates pneumatic control valve fitted at outlet of pressure tank outlet through I/P converter. These units along with necessary piping are fitted on support housing designed for tabletop mounting. The controller can be connected to computer through USB port for monitoring the process in SCADA mode.

Sensor : Level Transmitter,Type Two wire, Range 0–5 bar, Output 4–20 mA, Make Wika
Controller: Digital indicating controller with Ethernet communication Make Yokogawa, model UT35
FCE : Type Pneumatic, Size 1/4", Input 3–15 psig, Air to close, Characteristic Linear, Make Pneucon

PROCEDURE

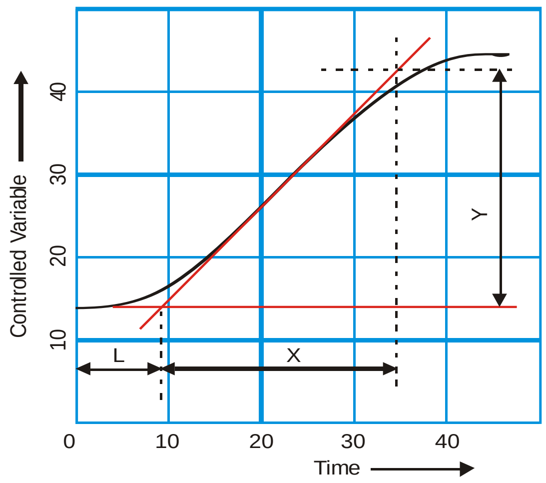
- Start up the set up.
- Double click the apex procedure exe file in the desktop.
- One Window will open. Then select the product (i.e.) Pressure control trainer (314)A.
- Then select the controller (UT 321E) and port COM 3.
- Select **Process Reaction** option for control from software. (Click on “Change Expt.” Button, click on “Change”, Click on “Process Reaction” button.)
- Adjust controller output, so that the process value is maintained at 50%.
- Start data logging.
- With the controller still in manual mode impose a step change apply a 20 - 30 % change to controller output. (Open the control valve) Record the step response. Wait for the steady state.
- Stop data logging.
- Plot the step response (Process reaction curve) from stored data. Find out the value of slope at the point of inflection and time lag.
- Calculate P I D settings for different modes.
- Select **PID Mode** option for control from software. (Click on “Change Expt.” Button, click on “Change”, Click on “PID Mode” button.) Switch on the controller to manual mode and Keep the set point to 50%. Adjust output value so as to match the process value to set point.

- Set the PID values obtained from the calculations. Switch on the controller to Auto mode. Apply the step change & observe the response of the system. Allow the system to reach steady state.

Open loop method (Process reaction curve method)

In open loop method the process is assumed to be model of first order. The step response i.e. process reaction curve, allows to obtain the approximate values of P, I and D parameters. With the feedback loop open, a step response is applied to manipulated variable and the values of P, I and D are estimated.

Model graph: Open loop response for input step change(Process Reaction curve)



Where,

Slope R: Slope of line drawn tangent to the point of inflection,

$$R = \frac{\%ChangeinVariable}{time(\mathrm{min})} = \frac{Y}{X}$$

Dead time L: Time between the step change and the point where tangent line crosses the initial value of the controlled variable (in min.)

ΔP = Step change applied in %

Using these parameters, the empirical equations are used to predict the controller settings for a decay ratio of 1/4.

For P, PI and PID controller the parameters are calculated as follows.

Mode	Proportional band (in %)	Integral time (in Min)	Derivative time (in Min)
P	100RL/ΔP	-	-
P+I	110RL/ΔP	L/0.3	-
P+I+D	83RL/ΔP	L/0.5	0.5L

OBSERVATIONS

(Refer Theory process control for formulae.)

- Step change to the system P = Initial output- Final output of the controller.
- Plot the graph of process value Vs Time on a graph paper.
- From process reaction curve:
    - Slope of the process reaction curve R =
    - Time lag L=
- Calculate P, PI, PID setting from above values.
- Observe response of the system for different PID settings.

THEORY

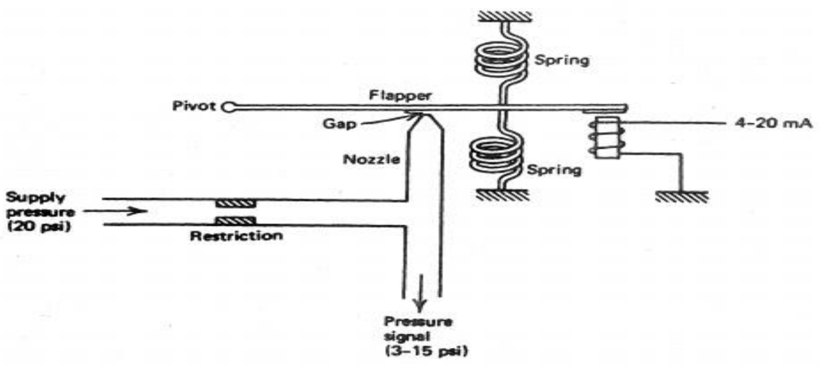
Measurement of pressure is of considerable importance in process industries. Most of these pressures range from a little below atmosphere to hundreds of atmospheres. Another important aspect of pressure measurement is the measurement of very low pressure or what is known as vacuum with the advancement of scientific research and industrial application of the results, pressure as low as 10^{-6}mm of mercury is often required to be measured in some systems. Measurement of pressure, therefore, consists of two parts that of pressure and vacuum the force exerted by the fluid per unit area of the wall of the container is called the absolute pressure where as the gauge pressure is the difference between the absolute and the local atmospheric pressure, and when gauge pressure is negative, it is known as vacuum. There are three different types are in practice

1. Bourdon Tubes or Pressure springs.
2. Bellows, elements
3. Diaphragms

Bellows, elements and diaphragm gauges are suitable up to about 3 to 6 mPa. Bourdon tubes have very high ranges.

I/P Converter: The current to pressure converter, are simply I/P Converter is an important element in process control. Often, when we want to use the low-level electric current signal to do work, it is easier to let the work to be done by pneumatic signal.

I/P CONVERTER



The I/P converter gives us a linear way of translating the 4 to 20 mA current in to a 3 to 15 psi signal. There are many designs for the converters, but the basic principle almost always involves the use of nozzle/flapper system. Figure illustrates a simple way to construct such a converter. Notice that the current through a coil produces a force that will tend to pull the flopper down and close of the gap. A high current produces a high pressure so that the device is direct acting.

TUNING OF CONTROLLER (CLOSED LOOP METHOD)

THEORY

This method is recommended by Ziegler and Nichols. This method is also called as ultimate gain method. The term ultimate was attached to this method because its use requires the determination of the ultimate proportional band and ultimate period. The ultimate proportional band, (PBu) is the minimum allowable value of proportional band (for a controller with only proportional mode) for which the system continuously oscillates at constant amplitude. The ultimate period, (Tu) is the period of response with the proportional band set to its ultimate value. To determine the ultimate proportional band and ultimate period the proportional band of the controller (with all integral and derivative action turned off) is gradually reduced until the process cycles continuously.

The process is placed in the closed loop with a proportional controller. The Proportional band is decreased until the process goes to continuous oscillations. The corresponding value of proportional band is called as ultimate proportional band PBu and the period of oscillation is called the ultimate period Tu.

The PID controller parameters are selected from the following table:

Mode	Proportional	Integral	Derivative
P	2 PBu	-	-
P+I	2.2 PBu	Tu/1.2	-
P+I+D	1.65 PBu	0.5 Tu	Tu/8.0

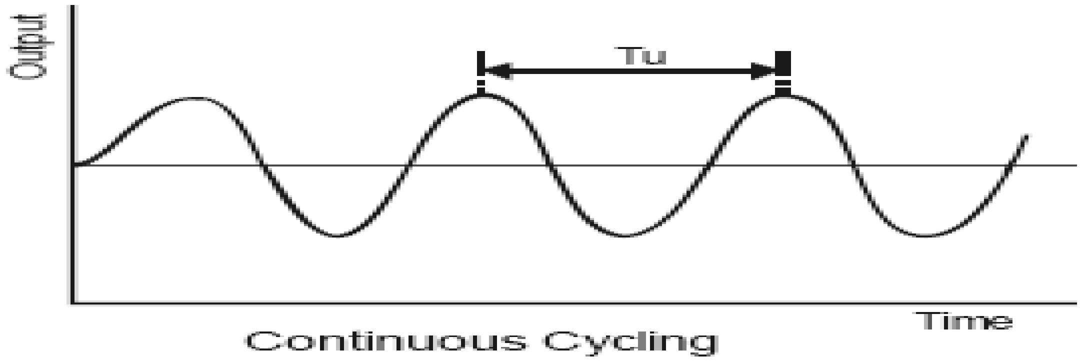
PROCEDURE

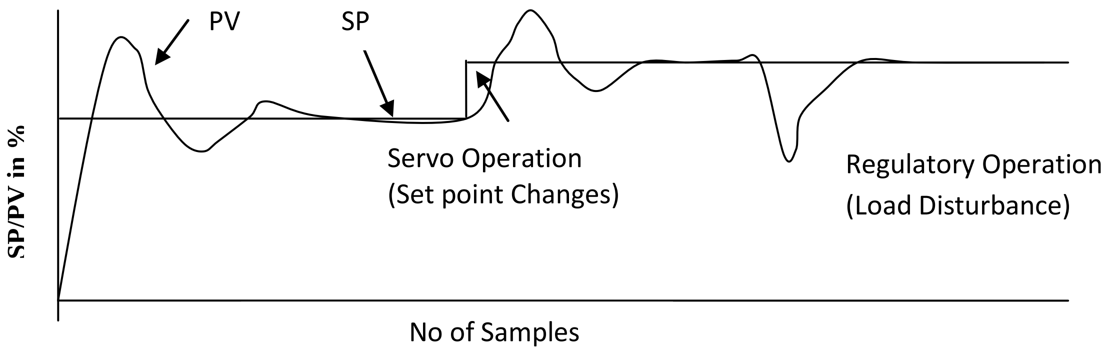
1. Start up the set up.
2. Double click the apex procedure in the desktop.
3. One Window will open. Then select the product (i.e.) level control trainer (313)A.
4. Then select the controller (UT 321E) and port COM 5.
5. Select closed loop option and select P controller only
6. Set the proportional band value to maximum(say 100%) set the controller to manual mode and adjust the output so that the process value reaches to 70%
7. Switch the controller to auto mode and decrease the proportional band and apply the step change to set point and observe the process response

8. Repeat the above procedure and find the value of proportional band for which the system under goes continuous oscillation
9. Record the ultimate proportional band and ultimate period from the response
10. Calculate the PID values from the table
11. Select the PID controller and apply the parameter values obtained from the above steps observe the response of the process.

MODEL GRAPH

Response Curve to find Ultimate Gain & Period for continuous oscillations method





RESULT

Thus the closed loop response of pressure process for Servo and Regulator operation was obtained using process reaction curve tuning method.

Ex No: 4	CHARACTERISTICS OF CONTROL VALVE WITH AND WITH OUT POSITIONER
DATE:	

AIM

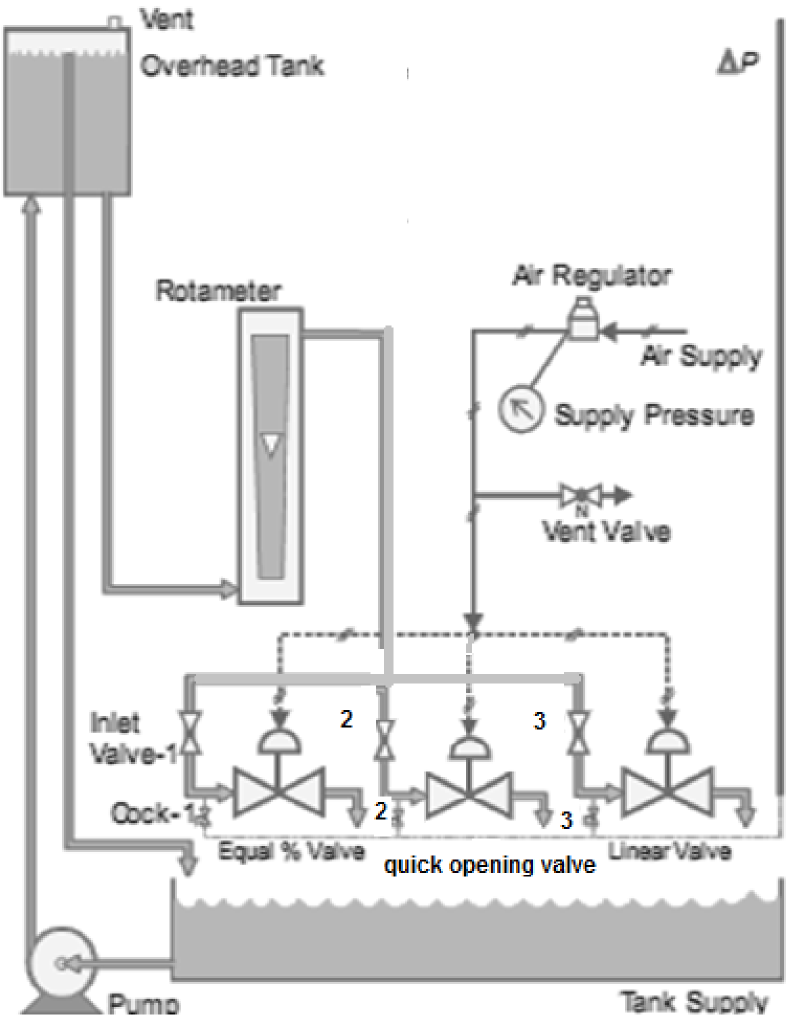
To determine the Flow-Lift characteristics of

1. Equal% valve without positioner
2. Quick opening valve without positioner
3. Linear valve with and without positioner.

APPARATUS REQUIRED

1. Control Valve Trainer set up.
2. Air compressor.

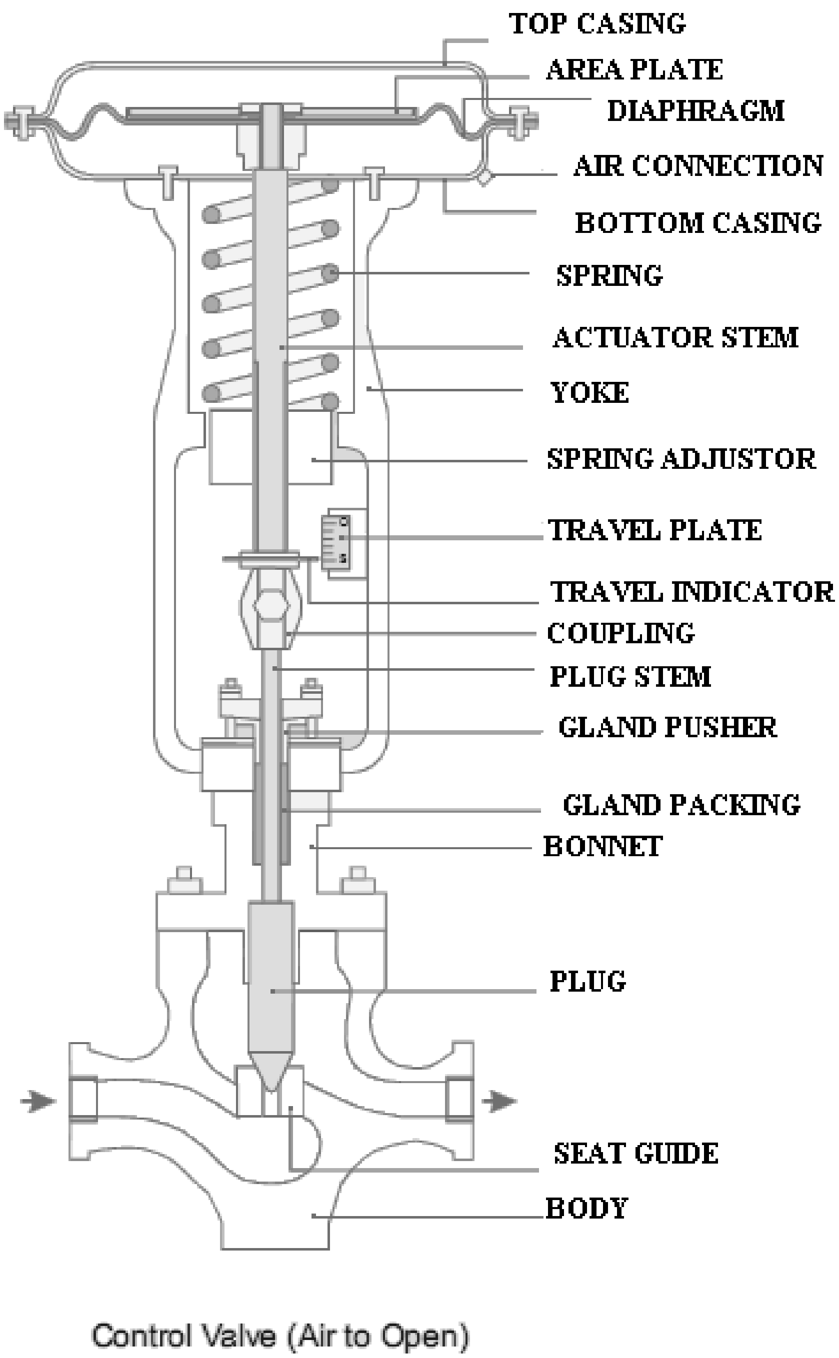
EXPERIMENTAL SET UP



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.



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

$$\text{Sensitivity} = dm / dx$$

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.

PROCEDURE

1. STUDY OF INSTALLED CHARACTERISTICS

1. Start up the set up. Open the flow regulating valve of the control valve to be studied (linear/Equal%/quick opening). Open the respective hose cock for pressure indication. (Close the flow regulating valves and hose cocks of other control valves.)
2. Ensure that pressure regulator outlet is connected to the valve actuator of the control valve under study. Keep the control valve fully open by adjusting air regulator.
3. Adjust regulating valve and set the flow rate. (Set 400 LPH flow for linear/equal % valve or 600 LPH for quick opening valve).
4. Slowly increase or decrease air pressure by adjusting the regulator and close the control valve in steps of 2 mm in stem position (Note the lift).
5. Note the pressure drop of control valve at full open condition and also corresponding flow rates.
6. Repeat the above step and take readings at each 2 mm stem travel till the valve is fully closed.

2. STUDY OF INHERENT CHARACTERISTICS

1. Start up the set up. Open the flow regulating valve of the control valve to be studied (linear/Equal%/quick opening). Open the respective hose cock for pressure indication. (Close the flow regulating valves and hose cocks of other control valves.)
2. Ensure that pressure regulator outlet is connected to the valve actuator of the control valve under study. Keep the control valve fully open by adjusting air regulator.
3. Adjust regulating valve and set the flow rate. (Set 400 LPH flow for linear/equal % valve or 600 LPH for quick opening valve).
4. Slowly increase or decrease air pressure by adjusting the regulator and close the control valve in steps of 2 mm in stem position.
5. Note the lift corresponding flow rates.
6. Repeat the above step and take readings at each 2 mm stem travel till the valve is fully closed.

TABULATION

INSTALLED CHARCTERISTICS FOR EQUAL PERCENTAGE CONTROL VALVE

S.No.	Lift (in mm)	Flow (LPH)	Pressure drop Δp (mm of H_2O)	Value coefficient (CV

INSTALLED CHARCTERISTICS FOR LINEAR CONTROL VALVE WITH POSITIONER

S.No	Lift (in mm)	Flow (LPH)	Pressure drop Δp (mm of H_2O)	Value coefficient (CV)

INSTALLED CHARCTERISTICS FOR LINEAR CONTROL VALVE WITH OUT POSITIONER

S.No	Lift (in mm)	Flow (LPH)	Pressure drop Δp (mm of H_2O)	Value coefficient (CV)

INSTALLED CHARCTERISTICS FOR QUICK OPENING CONTROL VALVE

S.No	Lift (in mm)	Flow (LPH)	Pressure drop Δp (mm of H_2O)	Value coefficient (CV)

INHERENT CHARACTERISTICS FOR EQUAL PERCENTAGE CONTROL VALVE

S.No.	Lift (in mm)	Flow (LPH)

INHERENT CHARCTERISTICS FOR LINEAR CONTROL VALVE WITH POSITIONER

S.No.	Lift (in mm)	Flow (LPH)

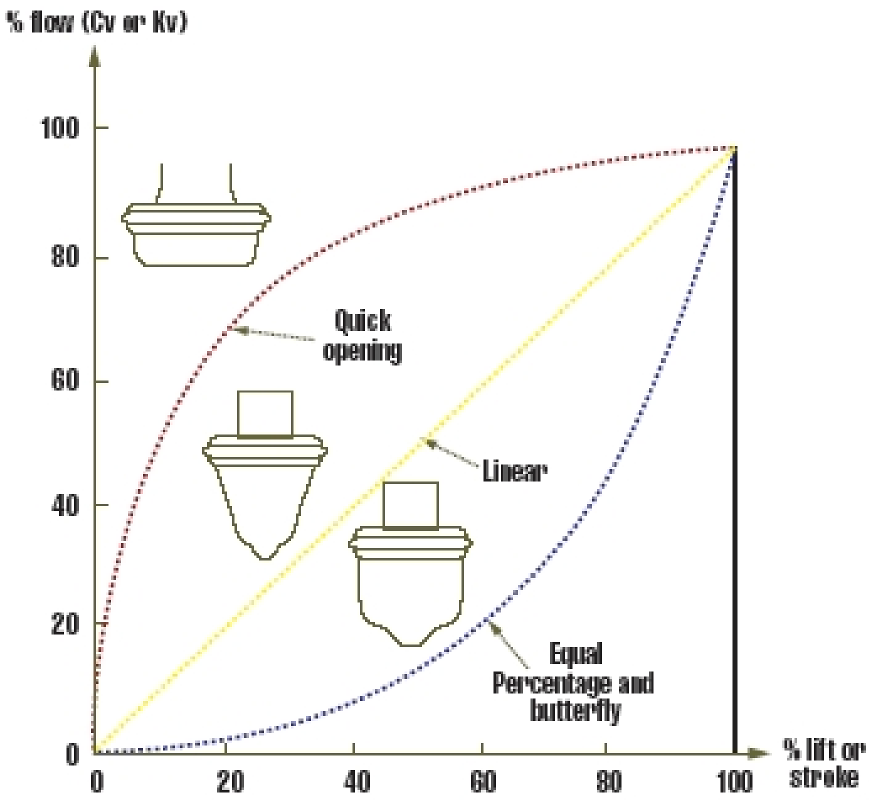
INHERENT CHARCTERISTICS FOR LINEAR CONTROL VALVE WITH OUT POSITIONER

S.No.	Lift (in mm)	Flow (LPH)

INHERENT CHARCTERISTICS FOR QUICK OPENING CONTROL VALVE

S.No.	Lift (in mm)	Flow (LPH)

MODEL GRAPH



CALCULATION

$C_V = 1.16 * Q * \sqrt{(G/\Delta P)}$

Where,

Q = Flow (m^3 /h) = Q in LPH/1000

ΔP = Pressure drop across valve (bar) = ΔP in mm of H_2O* 1.013/(10.33*10^3)

G = Specific Gravity = 1 for water

RESULT

Thus the flow lift characteristics of control valves equipped with and without positioner were studied.

Ex No: 5	OPERATION OF ON-OFF CONTROLLED THERMAL PROCESS
DATE:	

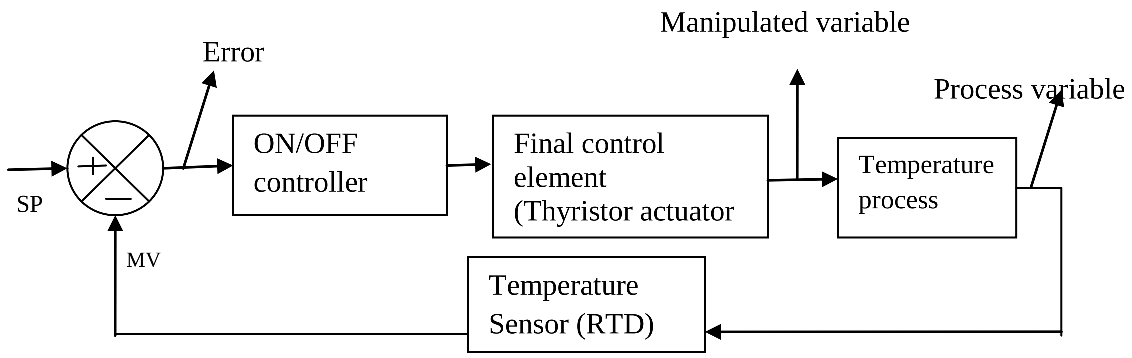
AIM

To obtain the operation of on-off controlled thermal process for Servo and Regulator operation.

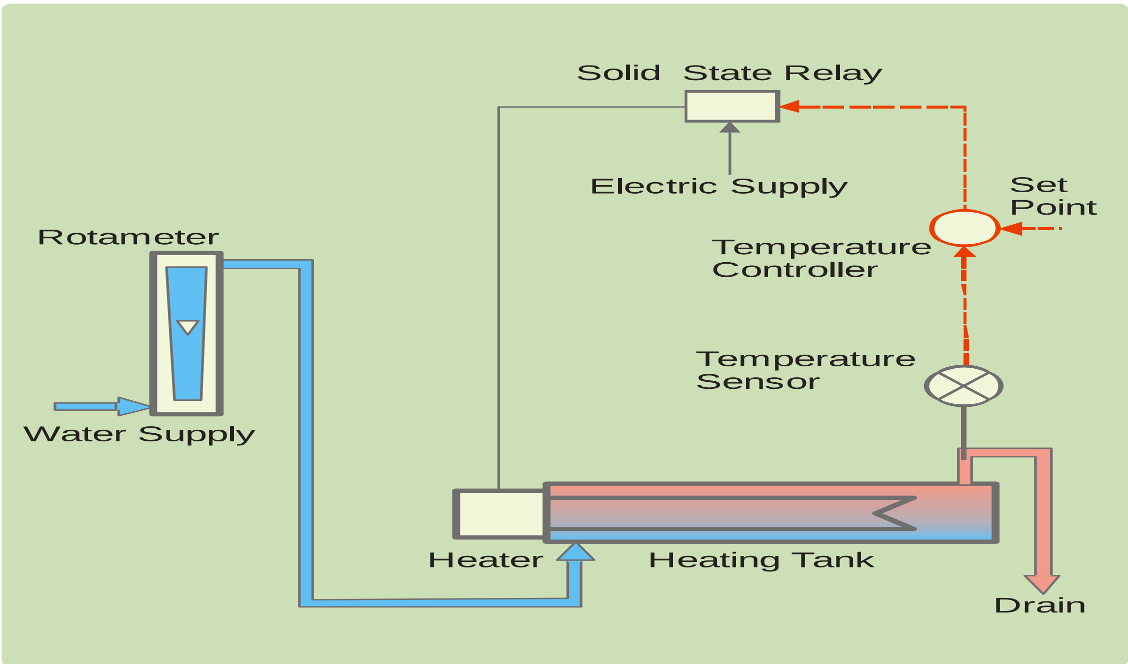
APPARATUS REQUIRED

1. Temperature process set up
2. Computer with Printer

BLOCK DIAGRAM



EXPERIMENTAL SET UP



DESCRIPTION

Temperature control trainer is designed for understanding the basic temperature control principles. The process setup consists of heating tank fitted with SSR controlled heater for on-line heating of the water. The flow of water can be manipulated and measured by rotameter. Temperature sensor (RTD) is used for temperature sensing. The process parameter (Temperature) is controlled by microprocessor based digital indicating controller which manipulates heat input to the process. These units along with necessary piping and fitting are mounted on support frame designed for tabletop mounting.

The controller can be connected to computer through USB port for monitoring the process in SCADA mode.

Study of on/off controller

PROCEDURE

- Start up the set up and adjust flow rate @40 LPH.
- Double click the apex procedure exe file in the desktop.
- One Window will open. Then select the product (i.e.) Temperature control trainer(311)A.
- Then select the controller (UT 321E) and port COM 1.
- Start the set up and Select **On-Off Mode** Experiment (click on "Change Expt." Button, click on "Change", Click on "On-Off Mode" button.)
- Change Hysteresis value to 1 %.(Range 0.1-10%)
- Change the values of the set point and observe the On-Off control operation.

THEORY

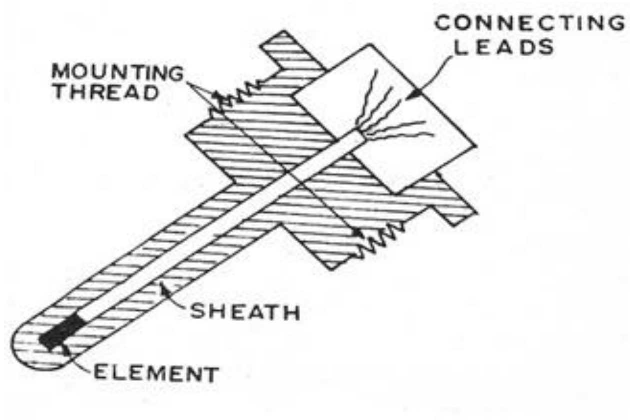
The resistance of a conductor changes with the change of temperature. This property is used for measurement of temperature and such a transducer is called resistance thermometer and falls in the category of electrical resistance transducers. The variation of resistance R with temperature T can be represented by the

$R = R_o (1 + \alpha_1 T + \alpha_2 T^2 + \ldots\ldots\ + \alpha_n T^n + \ldots\ldots)$

Where, R_o is the resistance at zero temperature, $\alpha_1, \alpha_2, \alpha_3 \ldots\ldots \alpha$ are constants.

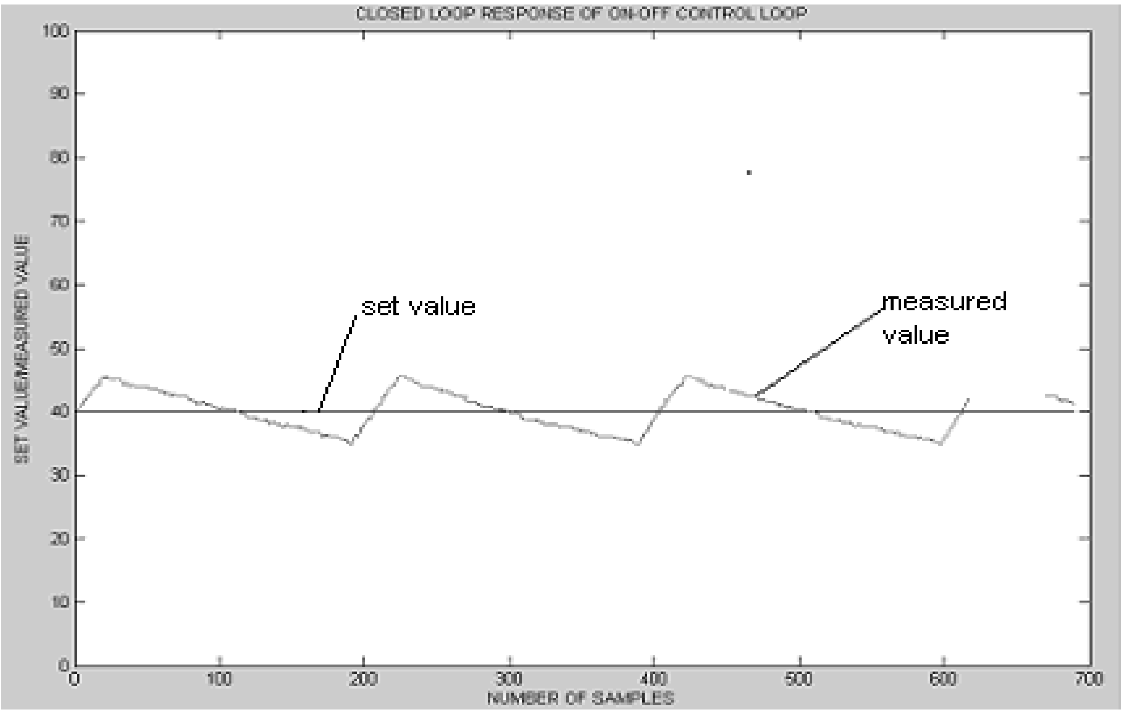
The conductor material used in these thermometers should be such that change in temperature must be as large as possible and the resistance of the material should have a continuous and stable relationship with temperature. Metal most commonly used are platinum copper, nickel and tungsten. Platinum resistance thermometer is shown in the below.

RESISTANCE TEMPERATURE DETECTOR



MODEL GRAPH

.



RESULT

Thus the operation of on-off controlled thermal process for Servo and Regulator operation was studied.

Ex No: 6	PID ENHANCEMENTS
DATE:	

AIM

To study the performance enhancement of PID using Feed Forward Control System and Cascade Control System.

APPARATUS REQUIRED

1. Process set up
2. Computer with Printer

FEED FORWARD CONTROL

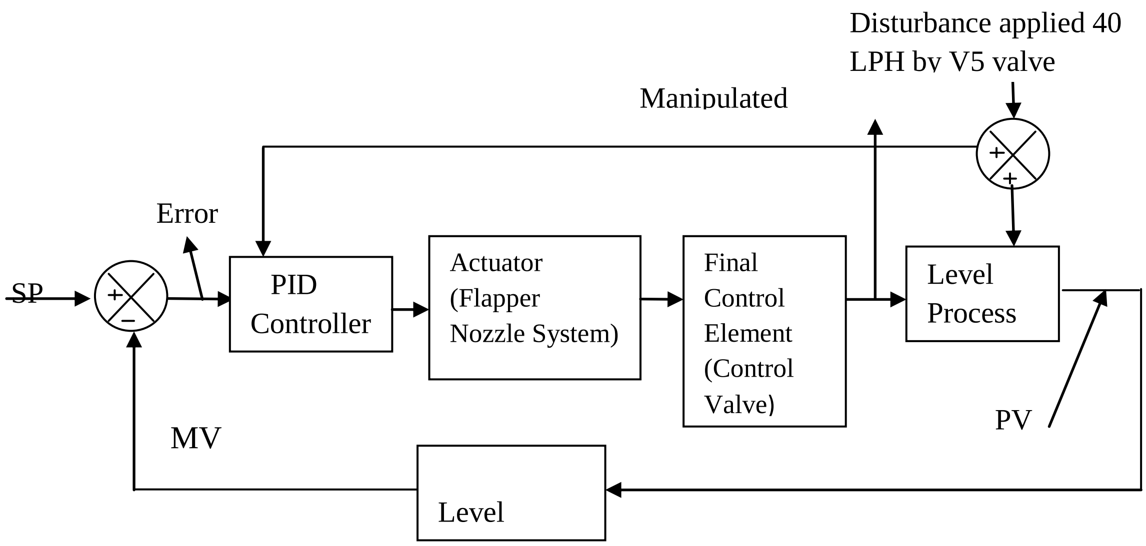
A feed forward control law is used to compensate for the effect that measured disturbance variable’s may have on the controlled variable. The basic idea is to measure a disturbance directly and take control action to eliminate its impact on the process output. How well the scheme will work depends on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

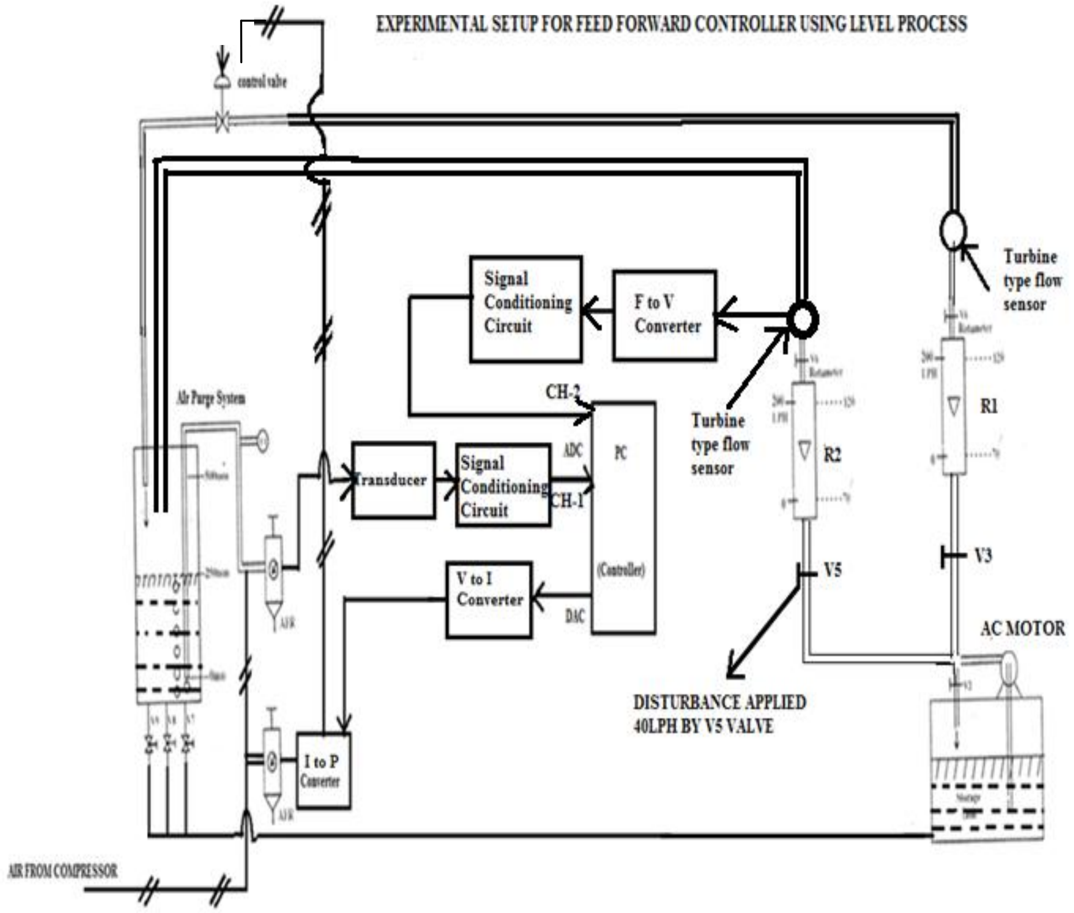
Feed forward control actually offers the potential for perfect control. However, because of Plant Model Mismatch (PMM) and unmeasured / unknown disturbances this is rarely achieved in practice. Consequently, feed forward control is normally used in conjunction with feedback control. The feedback controller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

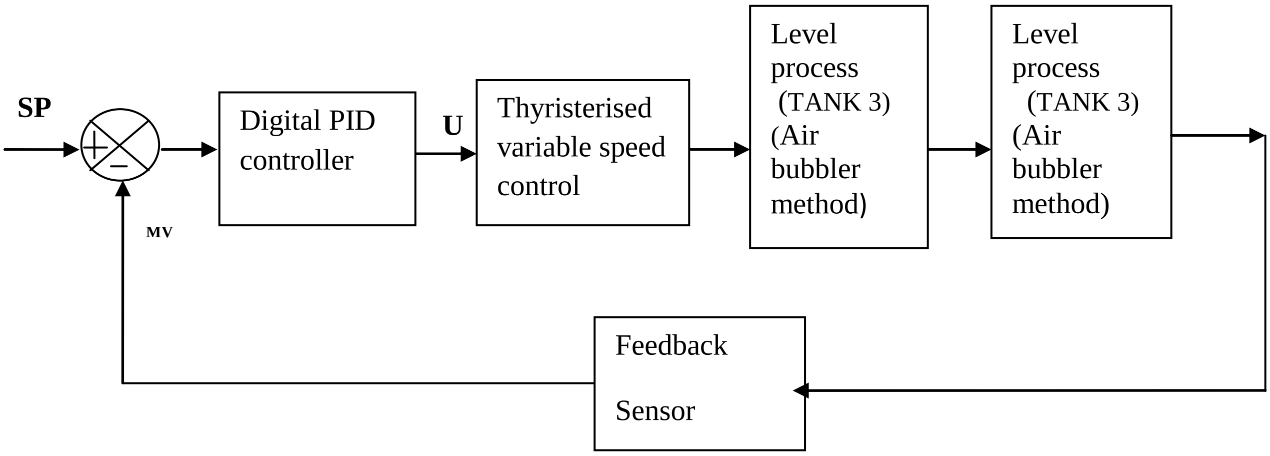
Feed forward control is distinctly different from open loop control and teleoperator systems. Feed forward control requires a mathematical model of the plant (process and/or machine being controlled) and the plant's relationship to any inputs or feedback the system might receive. Neither open loop control 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.

BLOCK DIAGRAM & EXPERIMENTAL SET UP

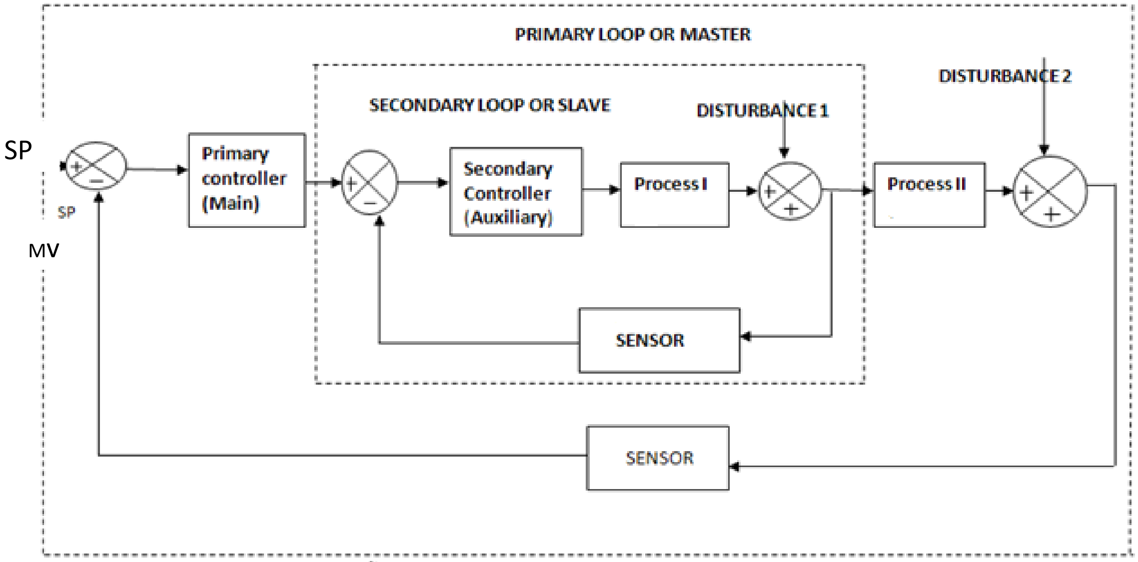




BLOCK DIAGRAM FOR WITHOUT CASCADE CONTROL LOOP



CASCADE CONTROL SYSTEM USING LEVEL PROCESS

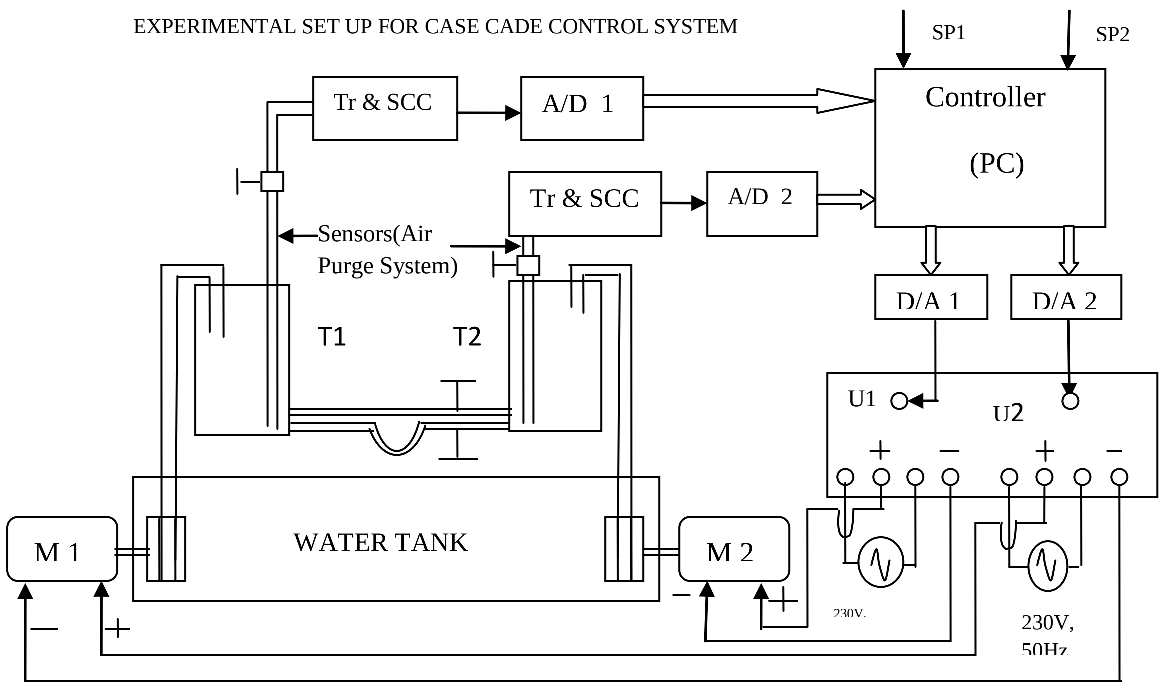


A cascade control configuration can be used in cases where there are one manipulated variable and more than one measurement. It is clear that with a single manipulation only one output can be controlled. Therefore the performance of single feedback control is improved by changing it into cascade control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

EXPERIMENTAL SET UP



SCC :Signal Conditioning Tr:Transduser T1-T2:Tank.M1-M2:Motor

WIRING SEQUENCE

TYPE	WIRING SEQUENCE	VALVE POSITION	CONTROLLER SETTINGS
FEED FORWARD	EMT 8 L2 (12) to Motor +ve. EMT 8 N2 (13) to Motor -ve. Signal Conditioning Panel 16 to CH (CHANNEL) 1. Signal Conditioning Panel 14 to CH (CHANNEL) 2. CIP (6) to CIP (9). CIP I O/P (10) to +ve of I to P Converter. CIP (20) to -ve of I to P Converter.	V1 Open, V2 Closed, V3 adjust to 200 LPH, V5 Closed, V7 Open, V8 Closed, V9 Closed.	**MAIN PID SETTING:** PB = 30%, Ti = 64000sec, Td = 0sec, Ts = 1sec, Kd =10, O/P lower Limit = 0%, O/P upper limit = 100% & Reverse action. Select Channel 1 for Measure Variable, Se source for set value from PANEL, Ratio Factor=1, SET VALUE = 50% Select Feed forward, Select Fn-1 Function GF6(s), Gain (k) =1, T=10, Fn-2Function skip, Fn-3Function skip, Fn-4Function skip.

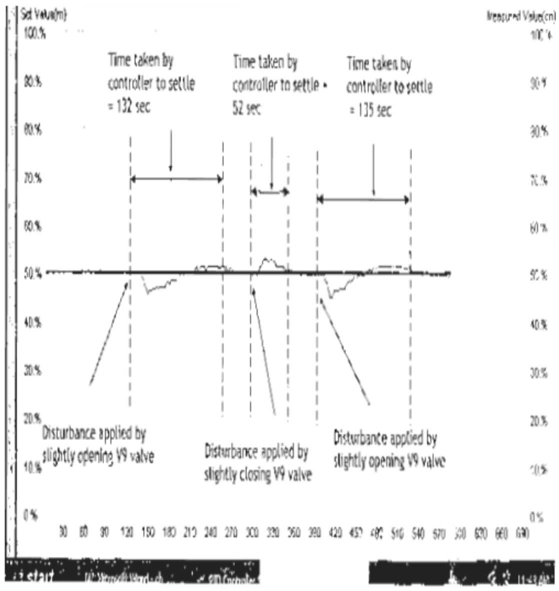
PROCEDURE

In setting windows select channel 1 for MV, source for set value from panel, unit =%, ratio factor=1. In main pid window select Ts=1, Kd=10, o/p lower limit = 0 %, o/p upper limit =100%, reverse action. & Rest of the setting are deselected. Set valves position according to table 3.1.Now we will try the system with PI controller with following parameters. Set following parameters.

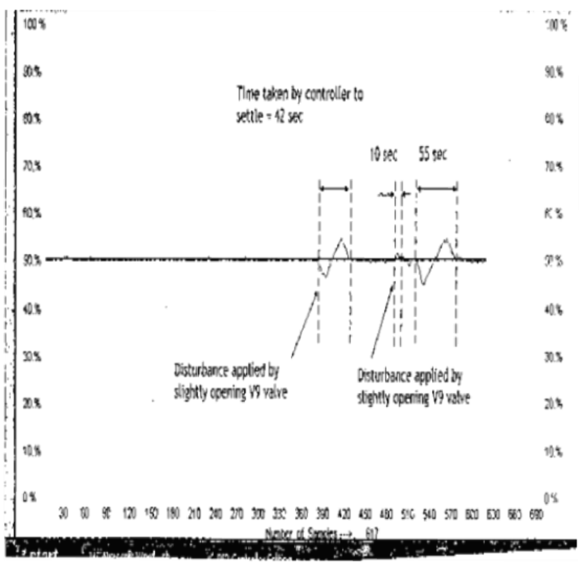
Pb = 50 %, Ti = 25 Sec, Td = 0 Sec

Therefore set Pb 50 %, Ti 25 Sec & Td 0-Sec. Observe the system performance for set point = 50 & graph of measured variable Vs set point. Let the process to settle at 50 set value. When process is settled then applies disturbance by closing or opening of drain valve V9 & again let the process to settle as shown on graph.The graph will be as shown in fig. below.

Conclusion: From the graph it is observed that the process take long time (132- sec) to settle after disturbance is applied.

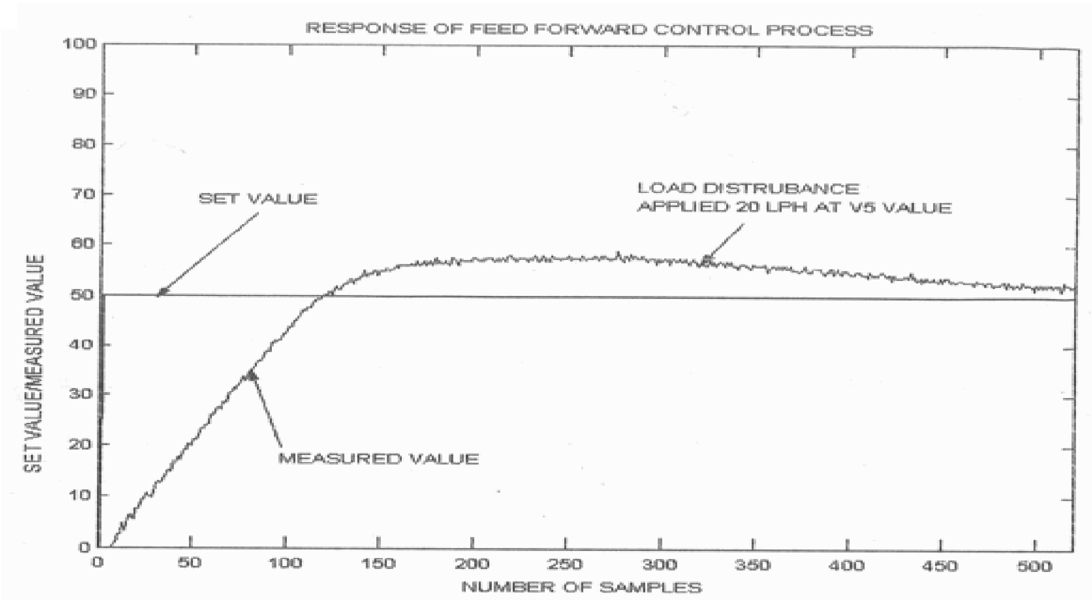


Response curve for without Casecade



Response curve for with Casecade

RESPONSE OF FEED FORWARD CONTROL



PROCEDURE FOR CASCADE CONTROL

In this cascade control loop the inner loop is control by auxiliary control and the outer control is controlled by main PID.

Main PID setting:

In setting windows select channel 1 for MV, source for set value from panel, unit =%, ratio factor=1. In main pid window select Ts=1, Kd=10, o/p lower limit = 0 %, o/p upper limit =100%, Forward action, PB = 50%, Ti=25 sec, Td=0, set value =50% 6t Rest of the setting are deselected.

Auxiliary PID setting:

In setting window of main PID select set Auxiliary PID, click on auxiliary PID button then auxiliary PID window will display on front monitor. Fill following parameters in that window.

Set PB=30%, Ti=15sec, Td=0, reverse action, o/p lower limit = 0 %, o/p upper limit =100% and press PID button main pid window will come. H's = I

Now press starts button of main PID and observed the graph of measured variable vs set point for 50 set value.

When process is settled then applies same disturbance as in without cascade experiments by closing or opening of drain valve V9 fit again let the process to settle as shown on graph. The graph will be as shown in fig. 3T34ii below.

PROCEDURE

1. Connections are made as per the wiring sequence.

2. First click on the START menu on your computer, and then select

   PROGRAMS

3. Then select PID CONTROLLER VERSION 10.7 and click on it.

4. After clicking on that, SETTINGS screen will appear.

5. Now enter the various values in their necessary columns.
6. Next Click on the feed forward controller and Enter
   the Various values in their necessary blocks.
7. After entering the values, now click on AUTO START.
8. Now after clicking on the GRAPH, we will be directed to the Graph Plotting page.
9. Click on GRAPH STOP and the select the PC BASED PID CONTROL.
10. Then select SET VALUE (rn) in the GRAPH1 LEFT, THICK and also select
    MEASURED VALUE (cn) in the GRAPH1 RIGHT 2, THIN.
11. Now click on GRAPH PLOT and note down the response of different controllers.

RESULT

Thus the feed forward control system was obtained and also the performance of a Cascade Control System was studied and compared with the conventional feedback system.

Ex No: 7	CLOSED LOOP RESPONSE OF MIMO THREE TANK SYSTEM
DATE:	

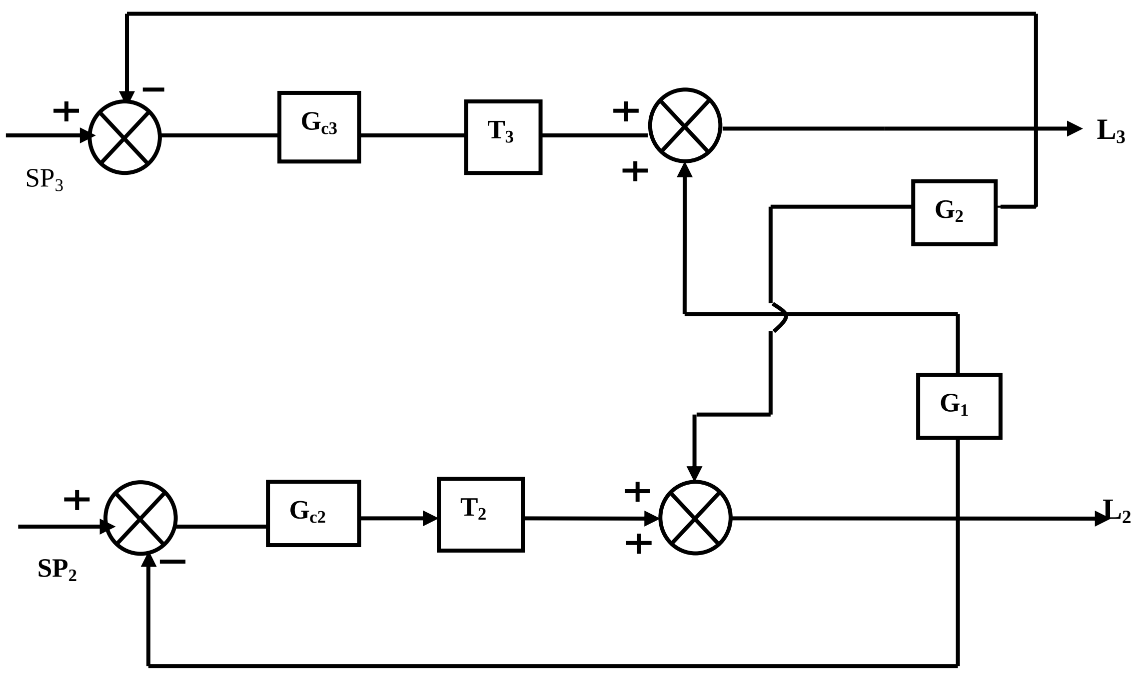
AIM

To obtain the Closed Loop response of MIMO three tank system.

APPARATUS REQUIRED

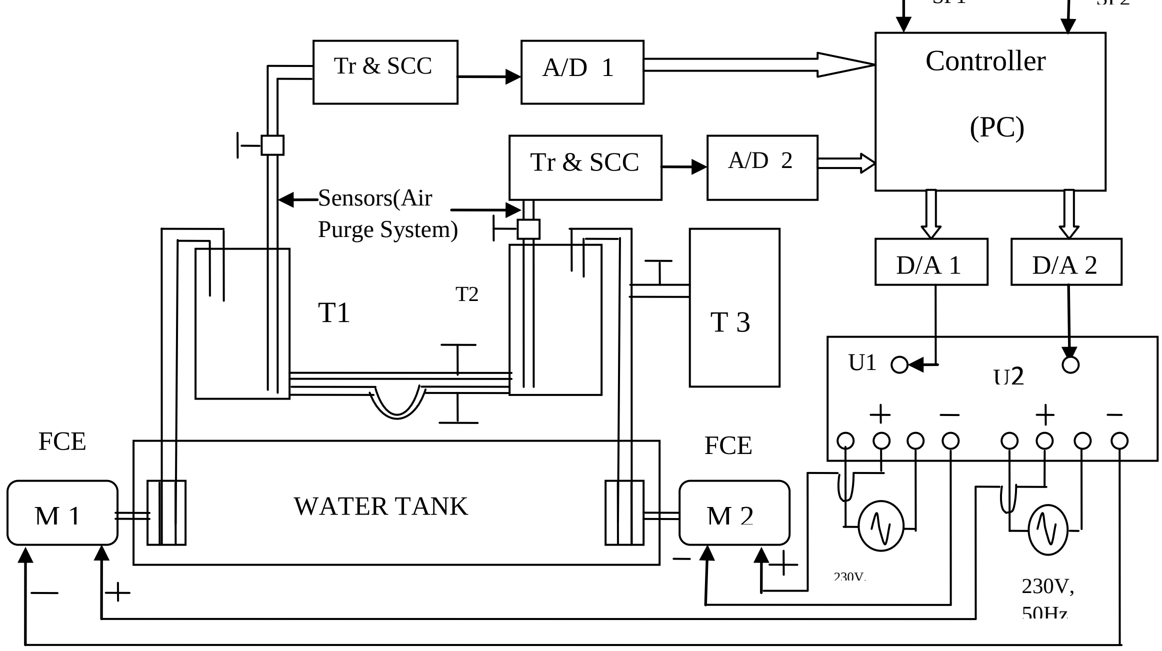
1. Three tank system
2. Computer with Printer
3. Patch Cords.

BLOCK DIAGRAM



EXPERIMENTAL SET UP

EXPERIMENTAL SET UP FOR THREE TANK MIMO SYSTEM



SCC :Signal Conditioning Tr:Transduser T1-T3:Tank.M1-M2:Motor

THEORY

MULTIPLE INPUT MULTIPLE OUTPUT SYSTEMS

In the case of single input single output (SISO) systems has a single manipulating variable to control single output variable. But in many cases, we have a number of inputs to control a number of outputs simultaneously, and the input-outputs are not decoupled. This will be evident if we consider a system, slightly modified system from that one shown in figure1.In the modified system, we have added another inlet flow line in tank2 shown in figure2.

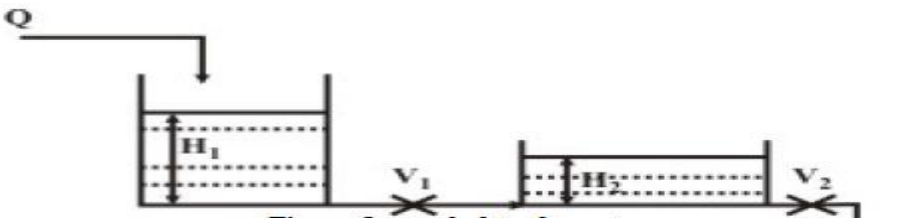


Figure 1 coupled tank system

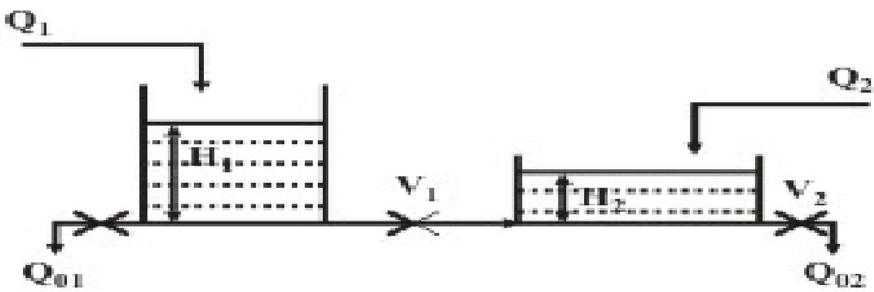


Figure 2 two input two output coupled tank system

If we consider the changes in inflow rates q_1 and q_2 are in inputs and the changes in the liquid levels of the two tanks h_1 and h_2 as the outputs, then the complete input-output behaviour can be modeled using the transfer function matrix, as shown below:

$$\begin{bmatrix} h_1(s) \\ h_2(s) \end{bmatrix} = \begin{bmatrix} G_{11}(s) & G_{12}(s) \\ G_{21}(s) & G_{22}(s) \end{bmatrix} \begin{bmatrix} q_1(s) \\ q_2(s) \end{bmatrix}$$

We define $G(s)$ as the transfer function matrix and

$$G(s) = \begin{bmatrix} G_{11}(s) & G_{12}(s) \\ G_{21}(s) & G_{22}(s) \end{bmatrix}$$

In general, if there are m inputs and p outputs, then the order of the transfer function matrix is p X m. The MIMO system can also be further classified depending on the number of inputs and outputs. If the number of inputs is more than the number of outputs ($m>p$), then the system is called an *overactuated system*. If the number of inputs is less than the number of outputs ($m<p$), then the system is an *underactuated system*; while they are equal then the system is *square* (implying the *G(s)* is a square matrix).

A Multi-input-multi-output nonlinear system can be described in its state variable form as:

$$\dot{x} = f(x,u)$$

$$y = g(x,u)$$

where x is the state vector, u is the input vector and y is the output vector. f and g are nonlinear functions of x and u.

The above nonlinear system can also be linearised over its operating point and can be described in the state-space form as:

$$\dot{x} = Ax + Bu$$

$$y = Cx + Du$$

where u is the input vector of dimension m; y is the output vector of dimension p and x is an n-dimensional vector representing the states. The transfer function matrix $G(s)$ can be obtained as:

$$G(s) = C(sI - A)^{-1} B + D$$

WIRING SEQUENCE

EMT 8 (L3) to EMT 9B (8)
EMT 8 (N3) to EMT 9B(7)
EMT 9 B (9) to PUMP2 +ve
EMT 9B (13) to PUMP2 –ve
EMT 9 A (9) to PUMP1 +ve
EMT 9A (13) to PUMP1 –ve
LEVEL O/P 1 (16 of EMT 9B) to CIP (CH-1)
EMT9B (16) to EMT9B (28)
EMT9B (3) to CIP (CH-3)
EMT9A (7) to EMT8 (12)
EMT9A (8) to EMT8 (13)

CIP (6) to EMTA1
LEVEL O/P 1 (16 of EMT 9A) to CIP (CH-2)

VALVE POSITION
V1Adjusted to 200 LPH on R1,
V2 open,
V3 open,
V4 Adjusted to 200 LPH on R2,
V5 open,
V6 open,
V7
V8 Partially open,
V9 Partially open,
V10 open,
V11 open,
V12 open,
V13 closed,
V14cosed,
V15 open,
V16 closed.

PROCEDURE
1. Open Double PID MATLAB software, First Double Click the Install batch file then Double Click the MATLAB Application file.

2. Click the Connect button a window will appear and ensuring connection is succeeded.

3. In PID 1 window, set PB= 45%,Ti=15,Td=0,Kd=10.output lower limit =0%,otput upper limit -100%,Action = Reverse, Set value =40%.

4. In PID 2 window, set PB= 45%,Ti=15,Td=0,Kd=10.output lower limit =0%,otput upper limit -100%,Action = Reverse, Set value =30%.

5. In configure window, For PID 1 SP= From Panel, PID MV =Ch0,PID 1 DAC =DAC 1 & PID 2 SP =From Panel, PID 2 MV =Ch 1,PID 2 DAV =DAC 2.

6. In graph setting 1.PID 1 SP, PID 1 MV, PID 2 SP, PID 2 MV.

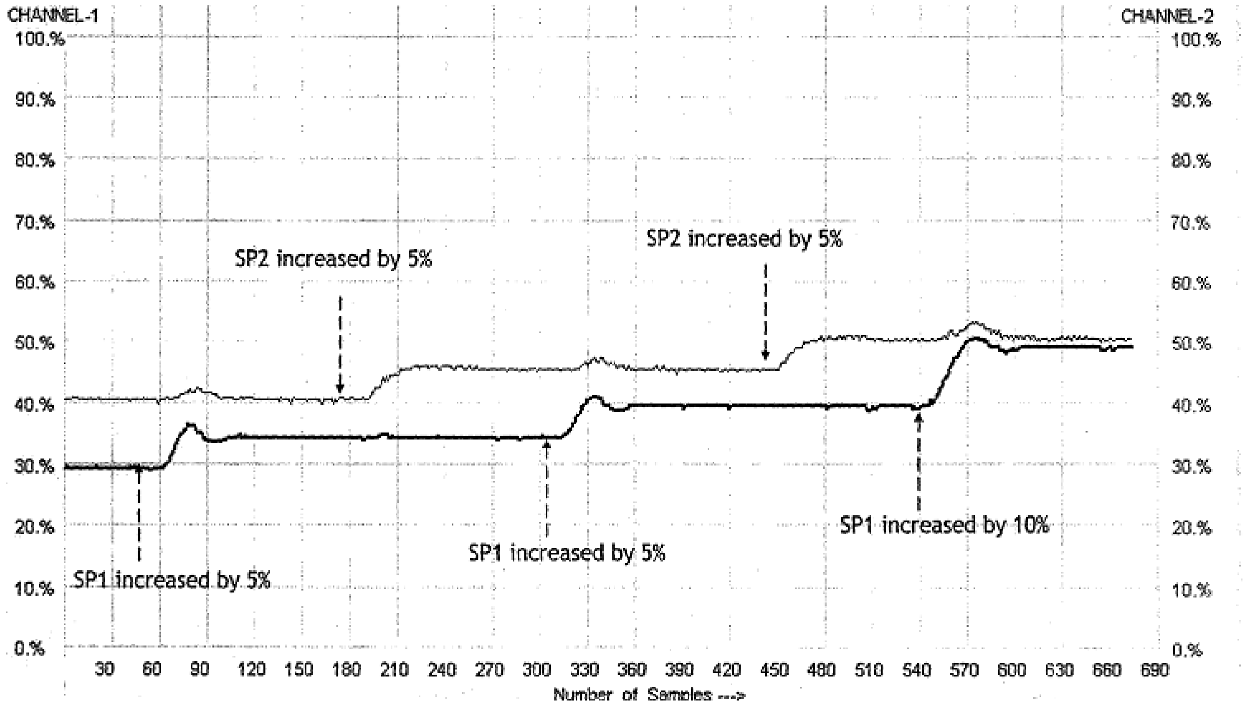
7. Keep Sampling Time Ts= 5 Sec.

8. Make SW 2 and SW3 Switch on EMT 8 Panels ON.

9. Observe the system response for set point change. Vary the set point on the panel from 30 % to 50% manually. But while changing the set point click Pause/Resume button to held online graph window and change Process parameter like SP if you want. Observe the graph of measured variable Vs set point.

10. After performing experiment click the stop button it will stop the entire process.

MODEL GRAPH



RESULT

Thus the response of three tank MIMO system was studied.

Ex No: 8	CLOSED LOOP RESPONSE OF MIMO FOUR TANK SYSTEM
DATE:	

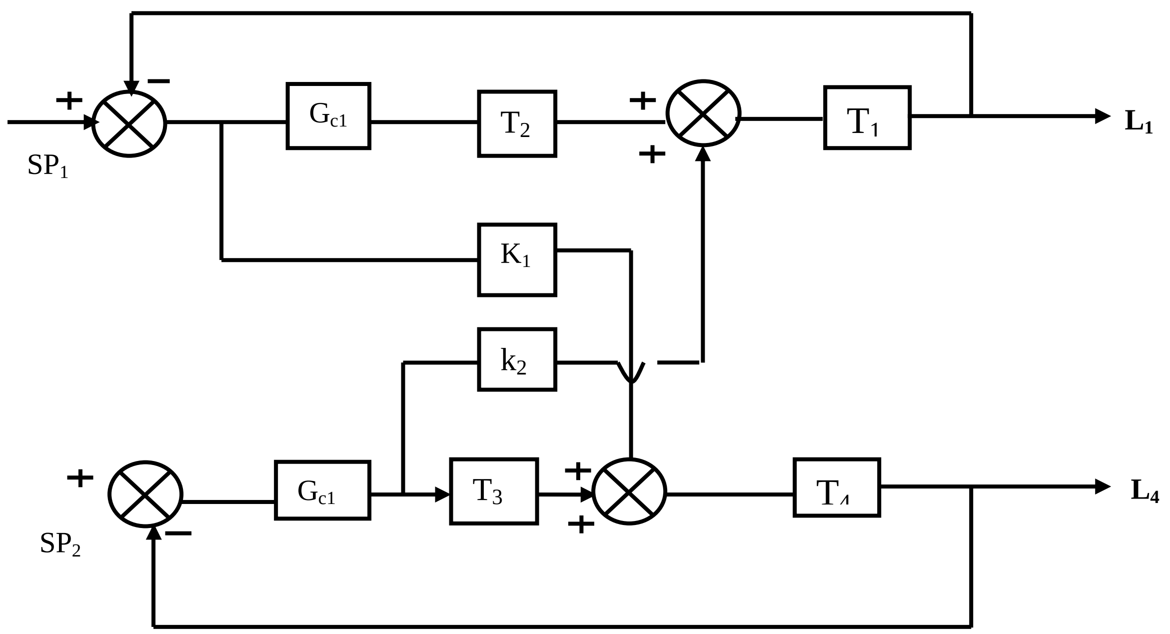
AIM

To obtain the Closed Loop response of MIMO four tank system.

APPARATUS REQUIRED

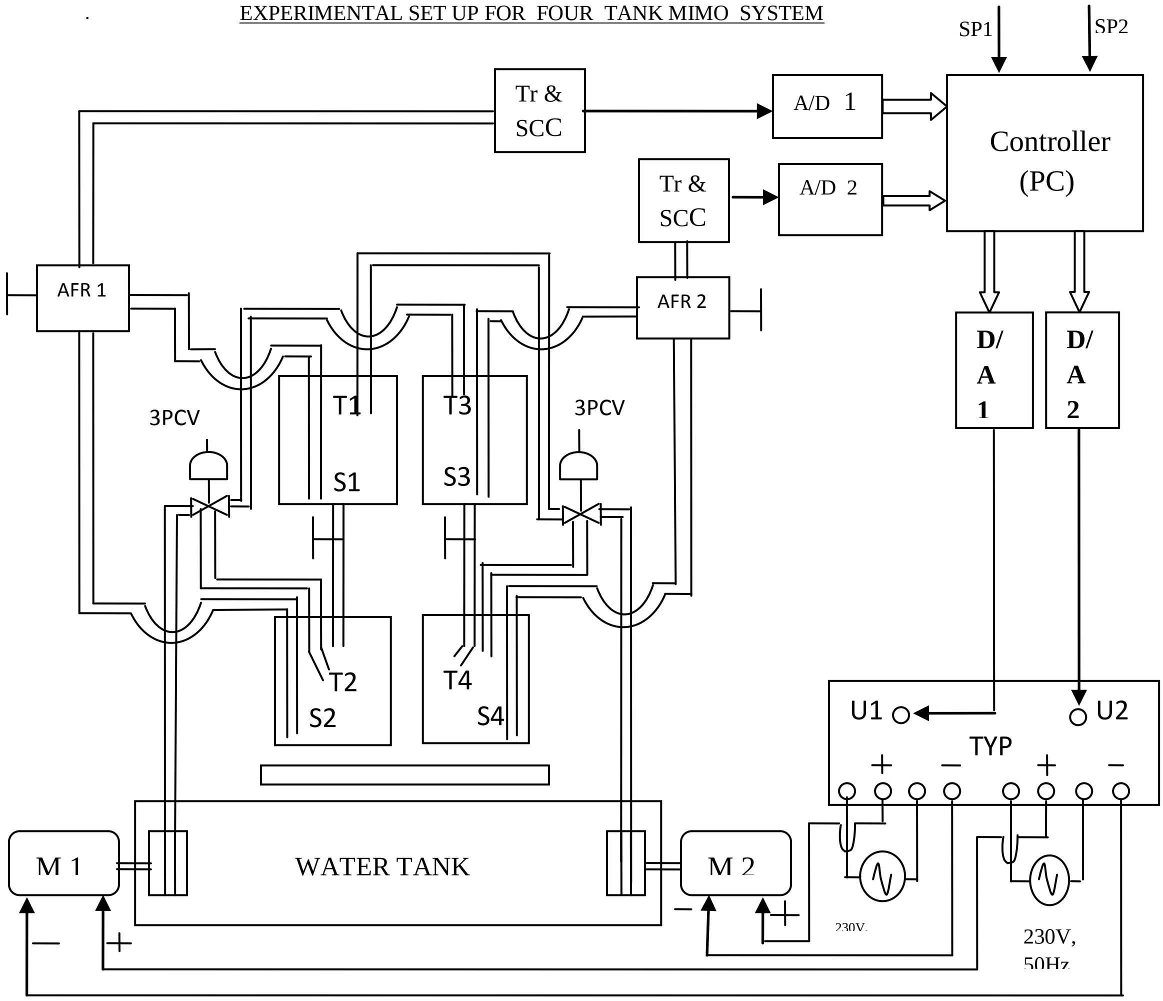
1. Four tank system
2. Computer with Printer
3. Patch Cords.

BLOCK DIAGRAM



EXPERIMENTAL SET UP

EXPERIMENTAL SET UP FOR FOUR TANK MIMO SYSTEM



SCC :Signal Conditioning Tr:Transduser T1-T4:Tank.M1-M2:Motor

TYP:Thyristor Actuator Panel, S1-S4 :Sensor 3PCV:Three Port Control Valve

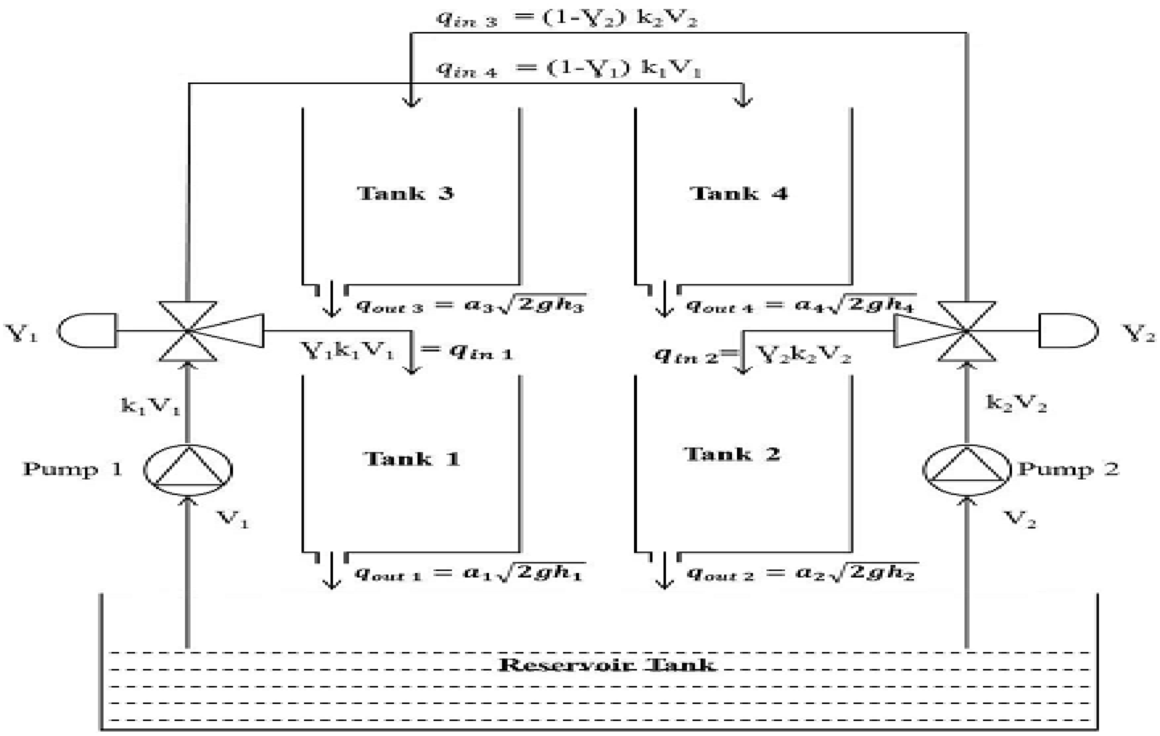
THEORY

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.

QUADRUPLE TANK PROCESS



WIRING SEQUENCE

EMT 8 (L2) to EMT 9A (7)
EMT 8 (N2) to EMT 9A(8)
EMT 9A9 PUMP1 +ve
EMT 9A 13 PUMP1 –ve
EMT 8(L3) TO EMT 9 (B7)
EMT 8 (N2) TO EMT 9 (B8)
EMT 9B(9)TO PUMP2 +ve
EMT 9B(13) TO PUMP2 –ve
LEVEL O/P 1 (16 of EMT 9A) to CIP –II (CH-0)
LEVEL O/P 2 (16 of EMT 9B) to CIP –II (CH-1)

CIP-II (6) to EMT(9) A1
CIP-II (5) to EMT 9B1
V/I (14) to V/I (9)
V/I (10) to I/P 1 +ve
I/P 1 –ve to GND
CIP II(14) to CIP II (9)
CIP II (10) to I/P 2 +ve
I /P 2 (-ve) to GND
LEVEL O/P 1 (16 of EMT 9A) to DPM (6)
LEVEL O/P 2 (16 of EMT 9B) to DPM (8)
DPM(9) to GND(4 of EMT-9A)
(Keep sensor selection switch on EMT8 panel at **level** position).

VALVE POSITION

V1 open,
V2 open,
V3 Adjusted to 200 LPH on R1,
V4 open,,
V5 Partially open,
V6 open,
V7 Partially open,
V8 open,
V9 open,
V10 Adjusted to 200 LPH on R1,
V11 open,
V12 closed.

PROCEDURE

1. Open Double PID MATLAB software, First Double Click the Install batch file then Double Click the MATLAB Application file.

2. Click the Connect button a window will appear and ensuring connection is succeeded.

3. Now in main Window. Select PID 1 tab set PB= 40%, Ts=1,Ti=10,Td=1.5,Kd=10.output lower limit =50%,otput upper limit -100%,Action = Reverse, Set value =50%.

4. In PID 2 window, Set PB= 40%,Ti=10, Ts=1,Td=1.5,Kd=10,output lower limit =50%,output upper limit -100%,Action = Reverse, Set value =30%.

5. In configure window, For PID 1 SP= From Panel, PID MV =Ch0, PID 1 DAC =DAC 1 & PID 2 SP =From Panel, PID 2 MV =Ch 1,PId 2 DAV =DAC 2.

6. In graph setting 1.PID 1 SP PID 1 MV 3.PID 2 SP 4 PID 2 MV

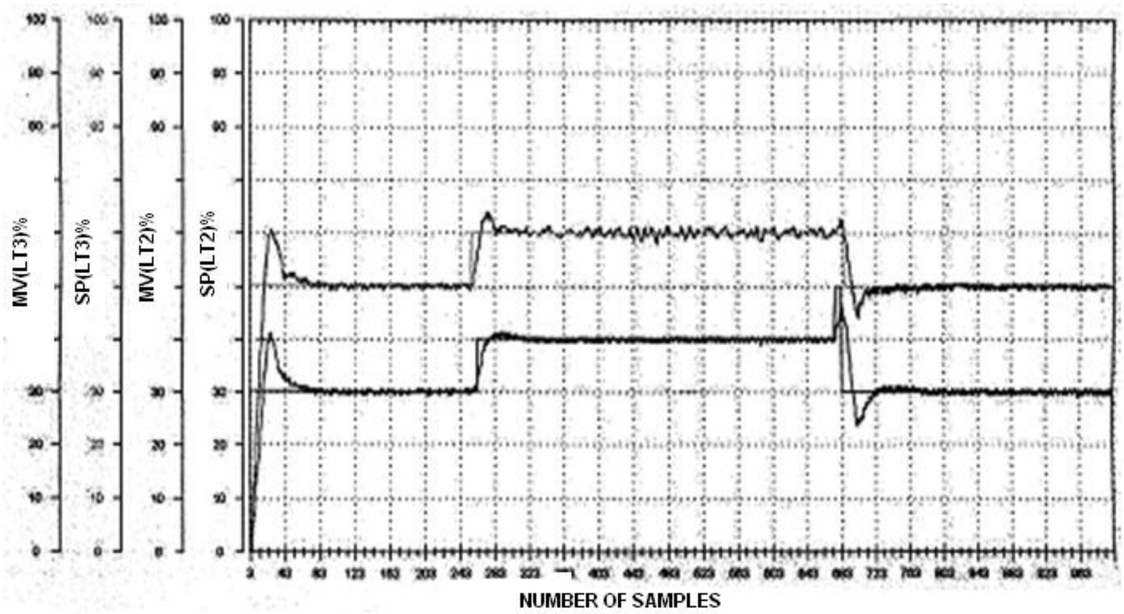
7. Make SW 2 and SW3 Switch on EMT 8 Panels ON.

8. To start PID controller click Start button, it will start plotting graph in figure windows.

9. Observe the system response for set point change. Vary the set point on the panel from 30 % to 50% manually. But while changing the set point click Pause/Resume button to held online graph window and change Process parameter like SP if you want. Observe the graph of measured variable Vs set point.

10. After performing experiment click the stop button it will stop the entire process.

MODEL GRAPH



RESULT

Thus the response of MIMO four tank systems was studied.

Ex No: 9	STUDY OF AC DRIVES
DATE:	

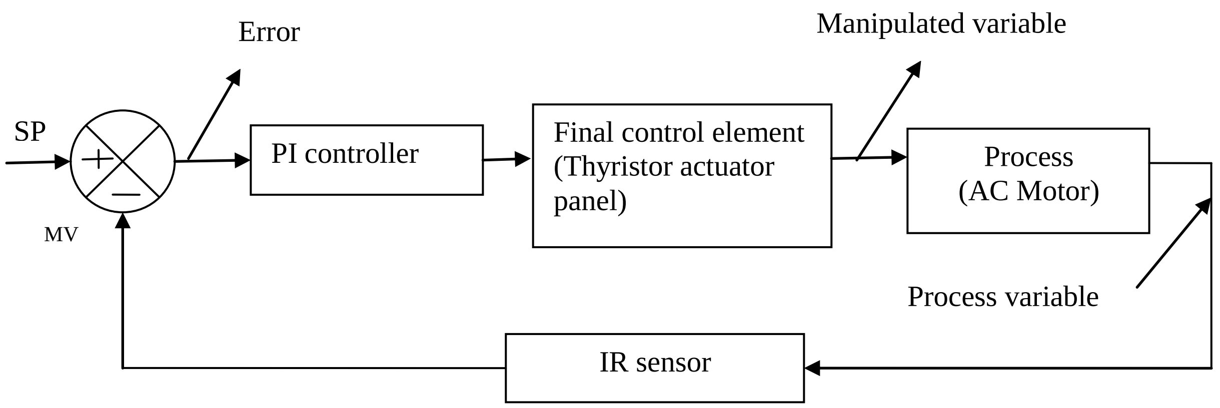
AIM

To study the closed loop response of AC Motor.

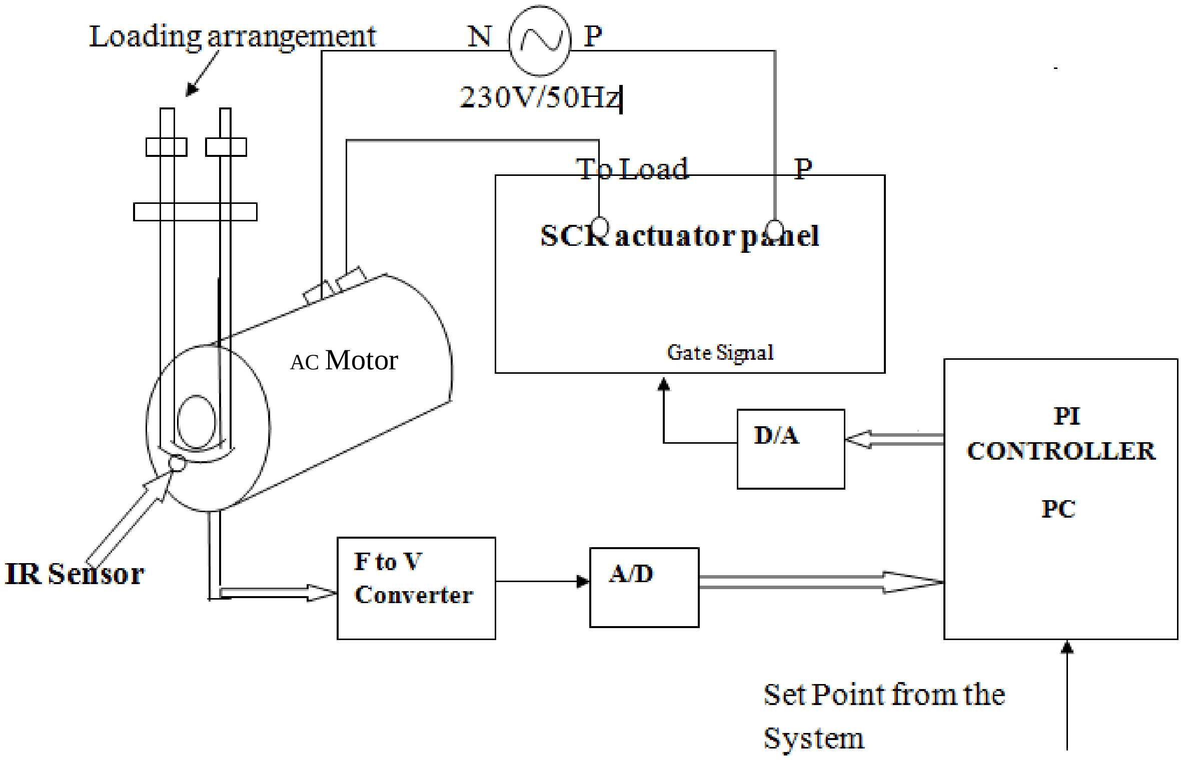
APPARATUS REQUIRED

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

BLOCK DIAGRAM



EXPERIMENTAL SET UP



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.

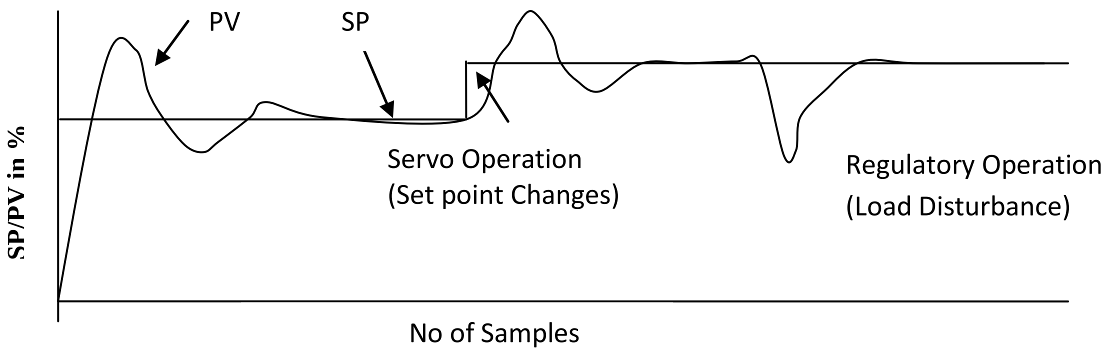
6. Click the configure settings make sure SP from Panel, MV = CH0, DAC = DAC 1
7. Click the Graph Settings Select PID 1 - SP(Black) , MV- CHO(Red) then click the OK Button
8. Then if you click the Start Button the Response window will open.
9. Observe the response.

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.

MODEL GRAPH



RESULT

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

Ex No: 10	STUDY OF DC DRIVES
DATE:	

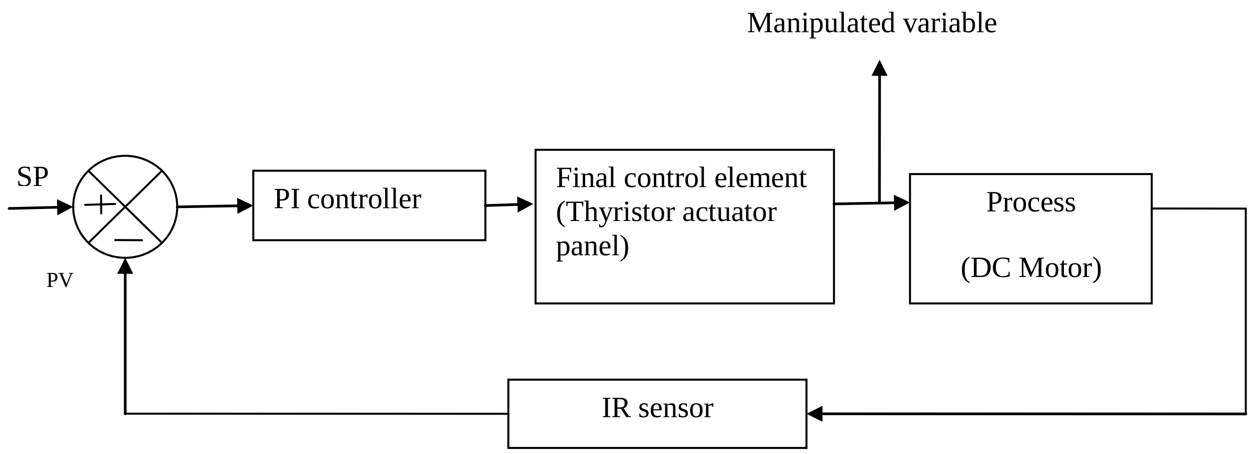
AIM

To study the closed loop response of DC Motor.

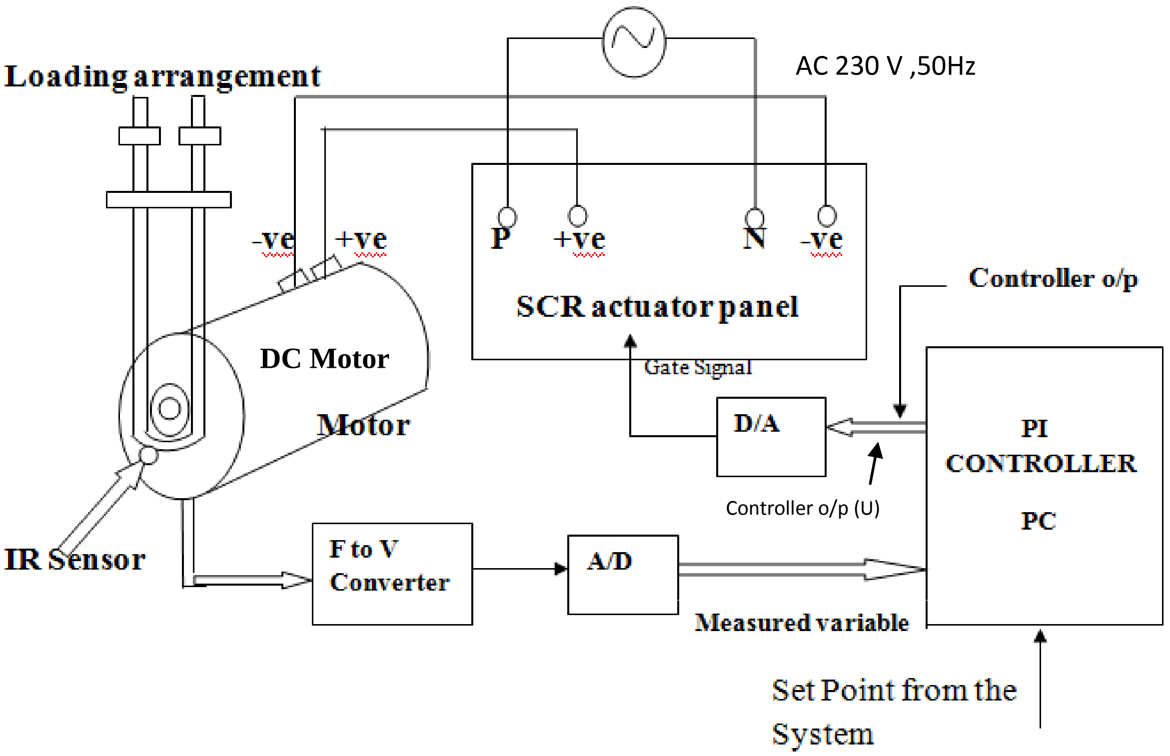
APPARATUS REQUIRED

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

BLOCK DIAGRAM



EXPERIMENTAL SET UP

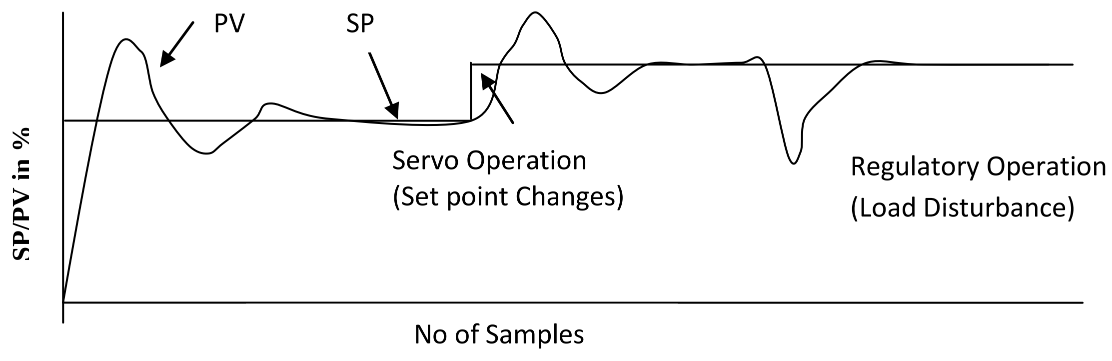


THEORY

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

MODEL GRAPH



RESULT

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

Ex No: 11	**PID IMPLEMENTATION ISSUES**
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 is invaluable to understand *how* the PID controller has been implemented. This usually means a detailed examination of the manufacturer's User Manual, and possibly a meeting and discussion with the controller manufacturer's personnel. Even then, many of the manufacturer's innovations in PID control may remain commercially sensitive, since for a number of the problems arising in industrial PID control manufacturers have introduced customized features, and details of these may not be available to the user or installer. However, there are several common problems in the implementation of the terms of the PID controller and it is useful to examine general solutions and terminology even if specific industrial details are not available. Table 1.6 shows some common process control problems and the appropriate PID implementation solution. To perform well with the industrial process problems of Table 1.6, the parallel PID controller requires modification. 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.

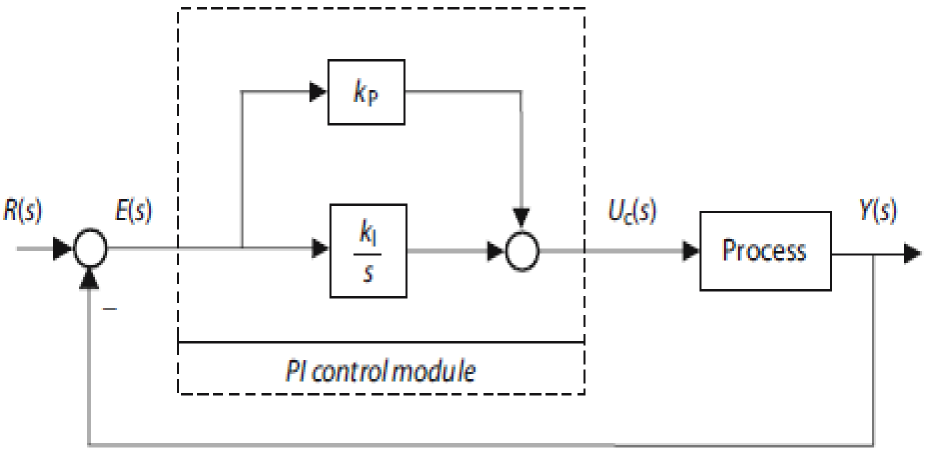


Figure 1.15 Parallel PI control structure.

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 $Uc(s)$ 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 this proportional kick problem

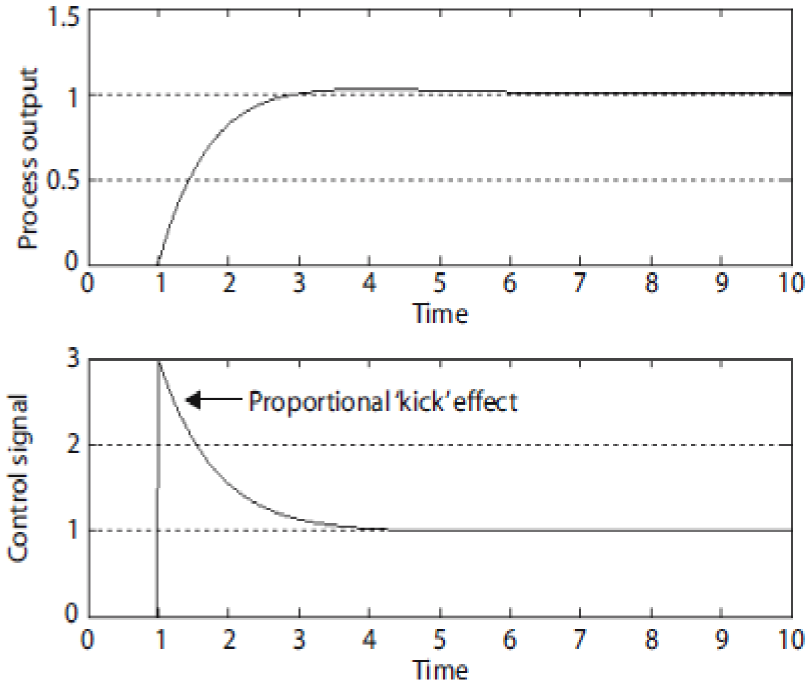


Figure 1.16 Process output and control signals showing proportional kick effects due to unit step change in reference signal at $t = 1$.

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.

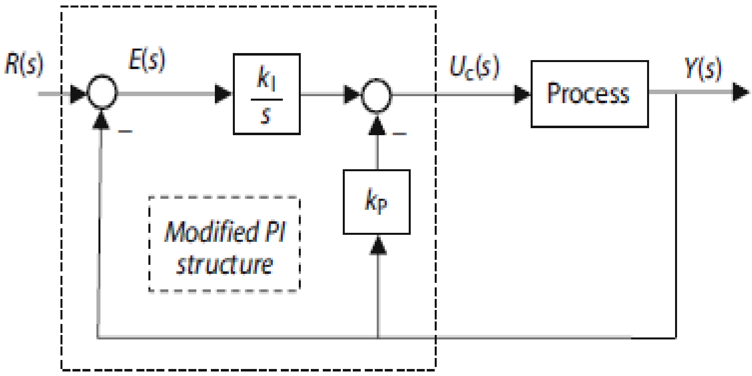


Figure 1.17 Restructured PI controller removing proportional kick effects.

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.

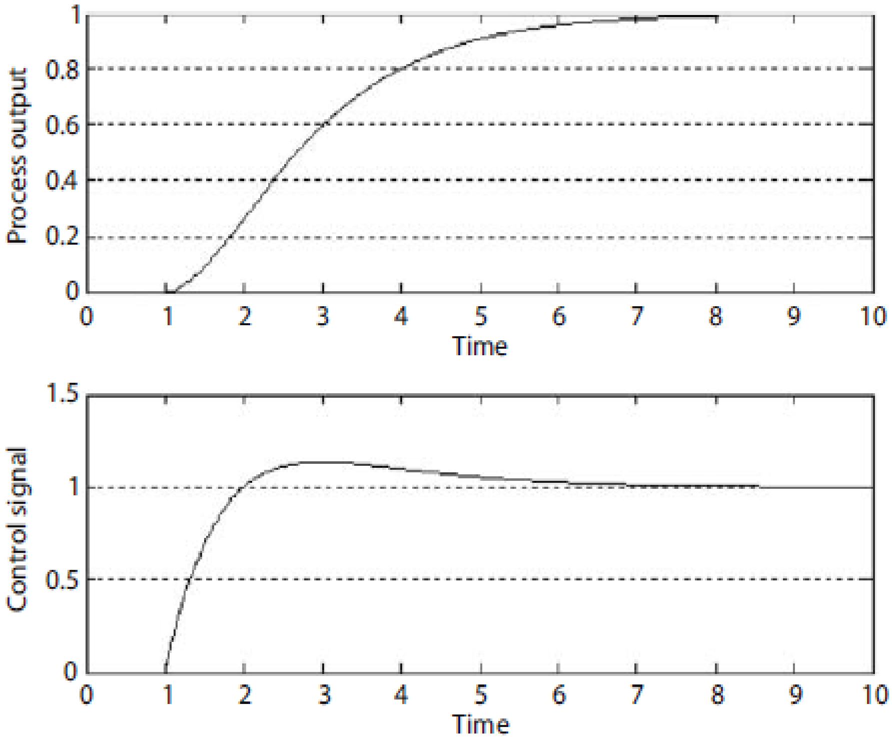


Figure 1.18 Typical output and control signals for the restructured PI controller (removing proportional kick).

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–P control 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. Thus with this particular form of three-term controller, the proportional (P) on process variable has eliminated proportional kick and the presence of the modified derivative term has reduced high-frequency noise amplification.

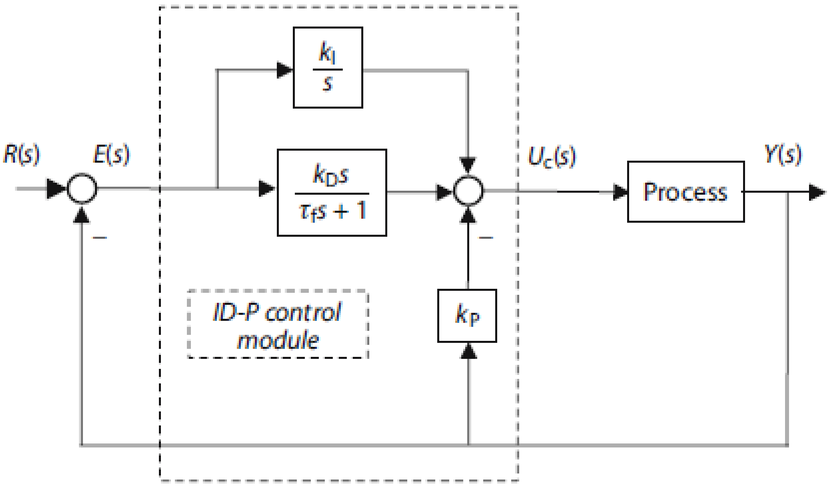


Figure 1.19 Three-term ID–P control system, with modified derivative term.

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 step change in the error signal $E(s)$. Since the proportional term of the controller operates on the process output,proportional kickwill 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 electronic circuitry used in the device.

The Remedy

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

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

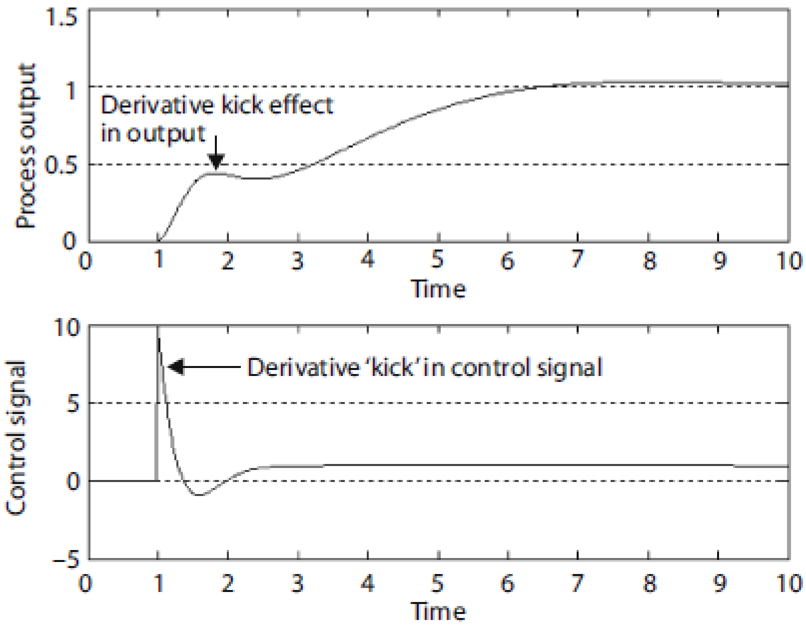


Figure 1.20 Output and control signals showing derivative kick in the control signal (unit step change in reference at $t = 1$).

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.

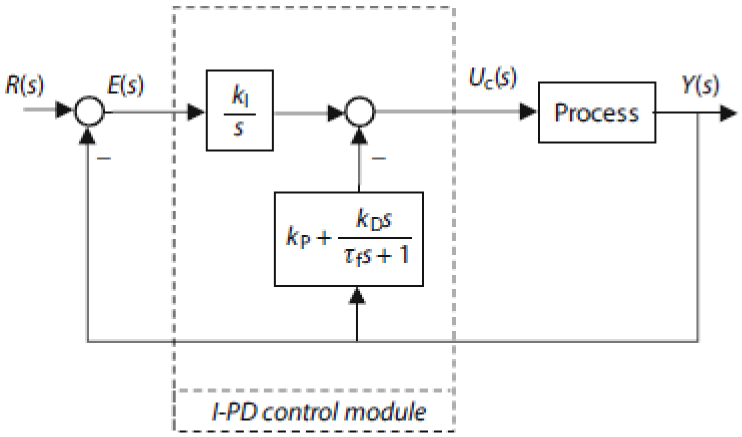


Figure 1.21 Three-term I-PD control for preventing derivative kick (and proportional kick).

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.

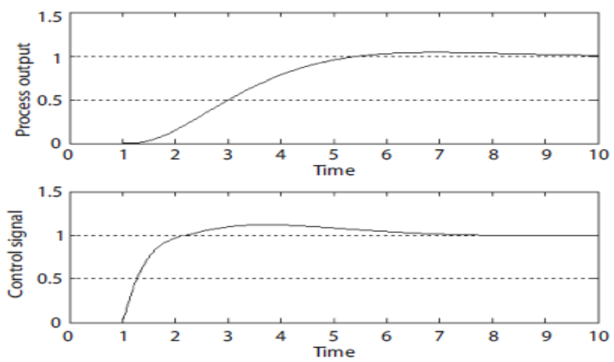


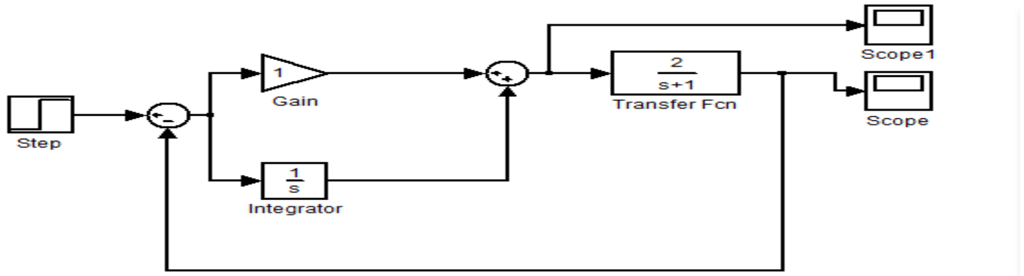
Figure 1.22 Typical output and control signals for the three-term I-PD controller showing that derivative kick has been removed.

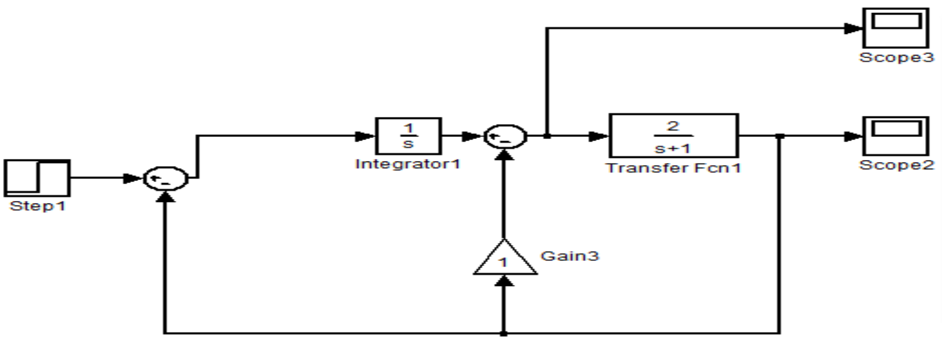
Integral windup in PID controller: Integral windup refers to the situation in a PID controller where a large change in set point occurs (say a positive change) and the integral terms accumulates a significant error during the rise (windup), thus overshooting and continuing to increase as this accumulated 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.

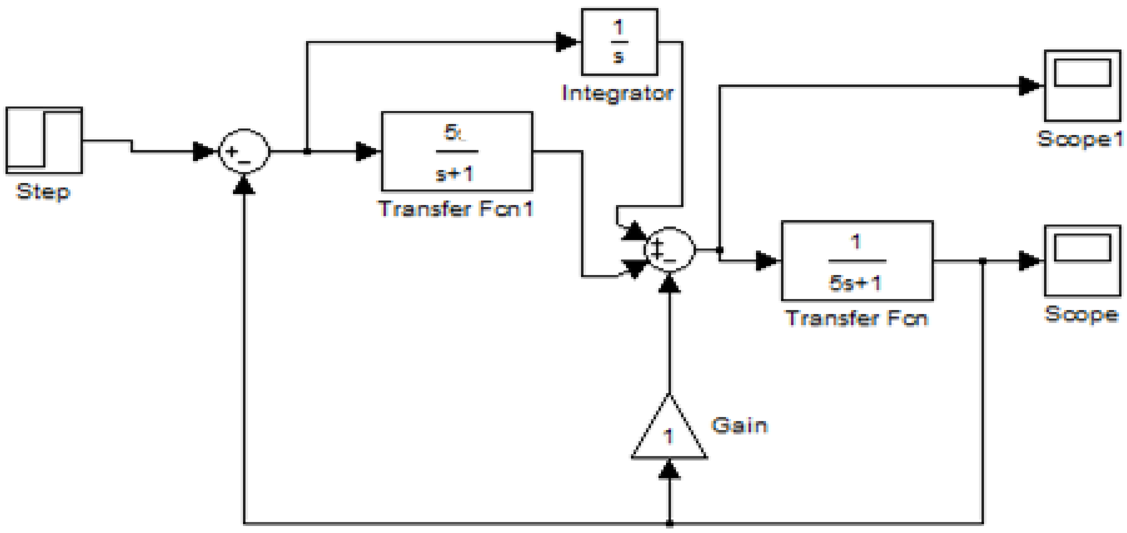
PROCEDURE

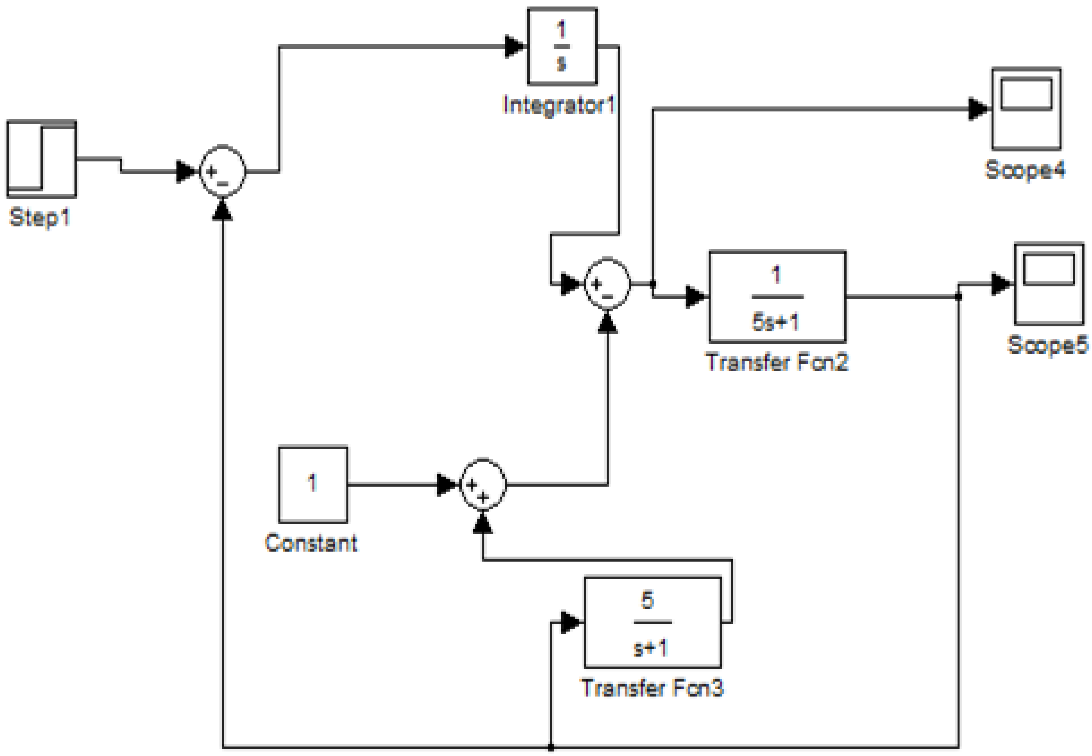
PROPORTIONAL KICK & ANTI PROPORTIONAL KICK STRUCTURE





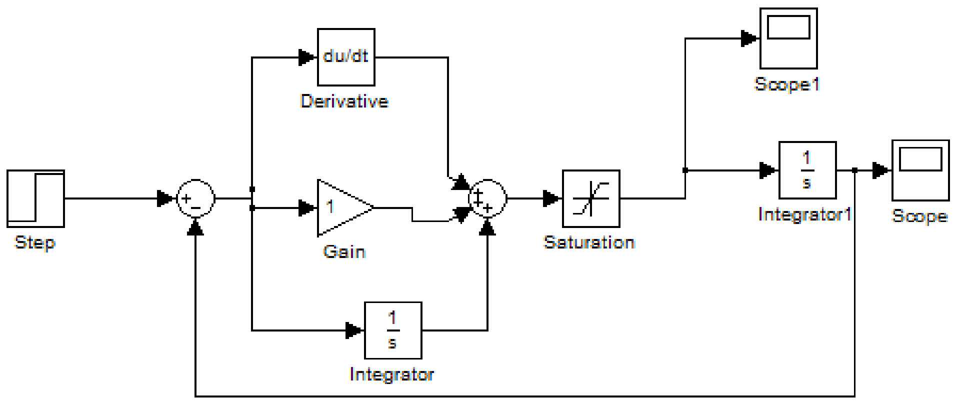
DERIVATIVE KICK &ANTI DERIVATIVE KICK STRUCTURE



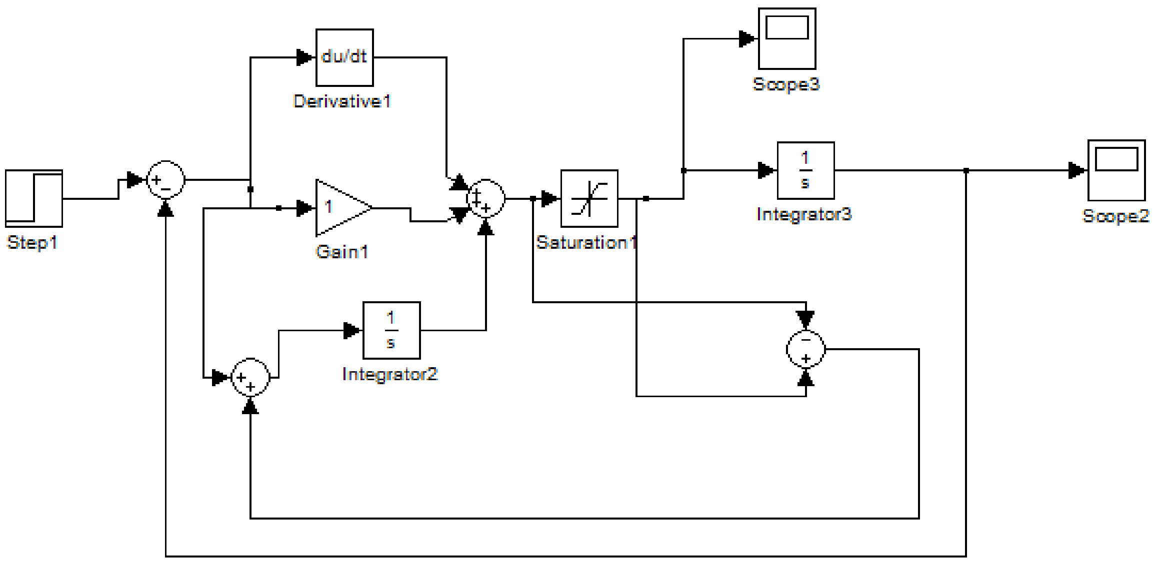


INTEGRAL WINDUP AND ANTIWINDUP STRUCTURE

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.

Ex No: 12	TUNING OF PID CONTROLLER FOR MATHEMATICALLY DESCRIBED PROCESS
DATE:	

AIM

To study of various controller tunings using MATLAB software.

APPARATUS REQUIRED

MATLAB Software,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 matlab editor .

1. ZIEGLER NICHOLS CLOSED LOOP TUNING:

Gp(S) = 6/(2S+1) (4S+1) (6S+1)

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

```
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

ω gc =

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

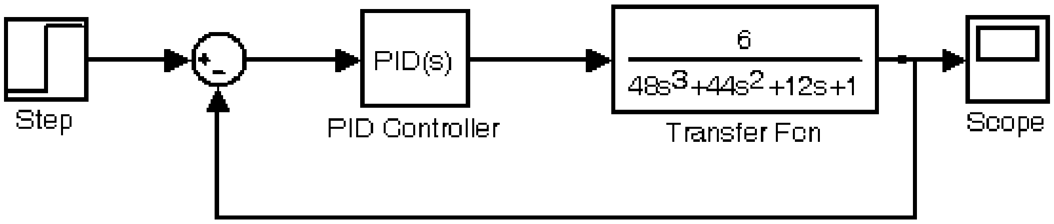
ω pc =0.5

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.



Pu = 2π/ ω pc
Therefore Pu = 12.36
Now the controller parameters are calculated using the table below,

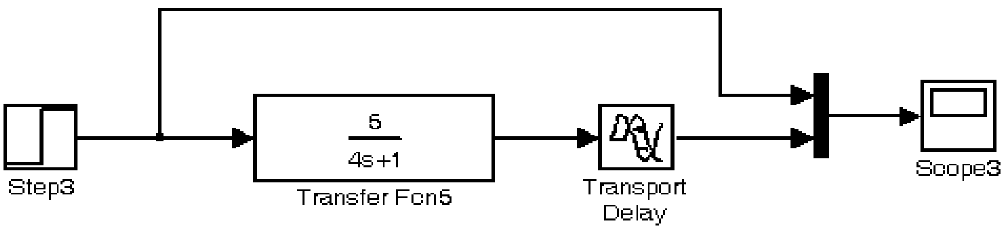
	Kp	Ti	Td
P	Ku/2		
PI	Ku/2.2	Pu/1.2	
PID	Ku/1.7	Pu/2	Pu/8

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

2. **COHEN COON TUNING:**

$G(s) = 5.e^{-1.55}/4S+1$

Draw the following Simulink model,



An "S" shaped curve is obtained.
From the curve, K = B (output at steady state)/A (input at steady state)

τ = B/S (Slope at point of inflection)
and Dead time is found out.
From the above values controller parameters are calculated from the formula

1. P

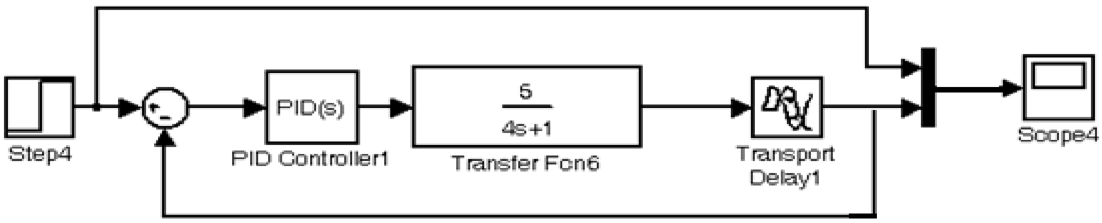
Kp = 1/K. τ/dead time. (1+dead time/3 τ)

2. PI

Kp = 1/K. τ/dead time.(0.9+dead time/12 τ)
Ti = dead time [(30+3.deadtime/ τ)/(9+20.deadtime/ τ)

3. PID

Kp = 1/K.τ/dead time. ((4/3)+(dead time/4τ))
Ti = dead time [(32+6deadtime/τ)/(13+8deadtime/ τ)]
Td = dead time[4/(11+2deadtime/ τ)
Now using these controller parameter values implement the Simulink model again and obtain the response of Cohen Coon tuning method.



Calculate, Kp = time constant + 0.5deadtime/K(λ+0.5deadtime) for λ = 1 and 2.
Also calculate Ti = time constant + 0.5deadtime and
Td = time constant * dead time/(2*time constant + dead time).
From the above Kp, Ki and Kd values are used in the Simulink model again for both λ values to obtain the response of system (transfer function) using Internal Model Control(IMC) tuning method.

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

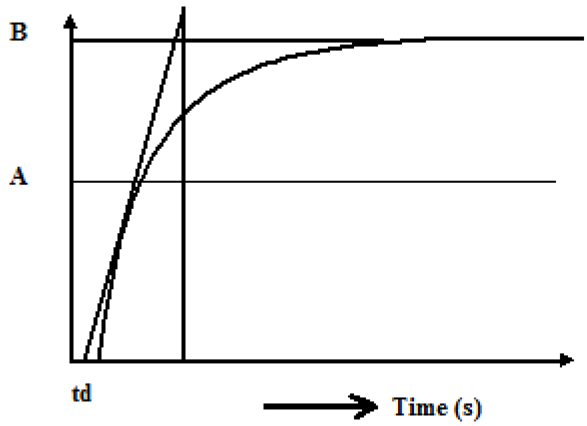
Gp (s) = $\frac{2}{10s+1}\, e^{-2s}$

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.

<u>Open loop response</u>

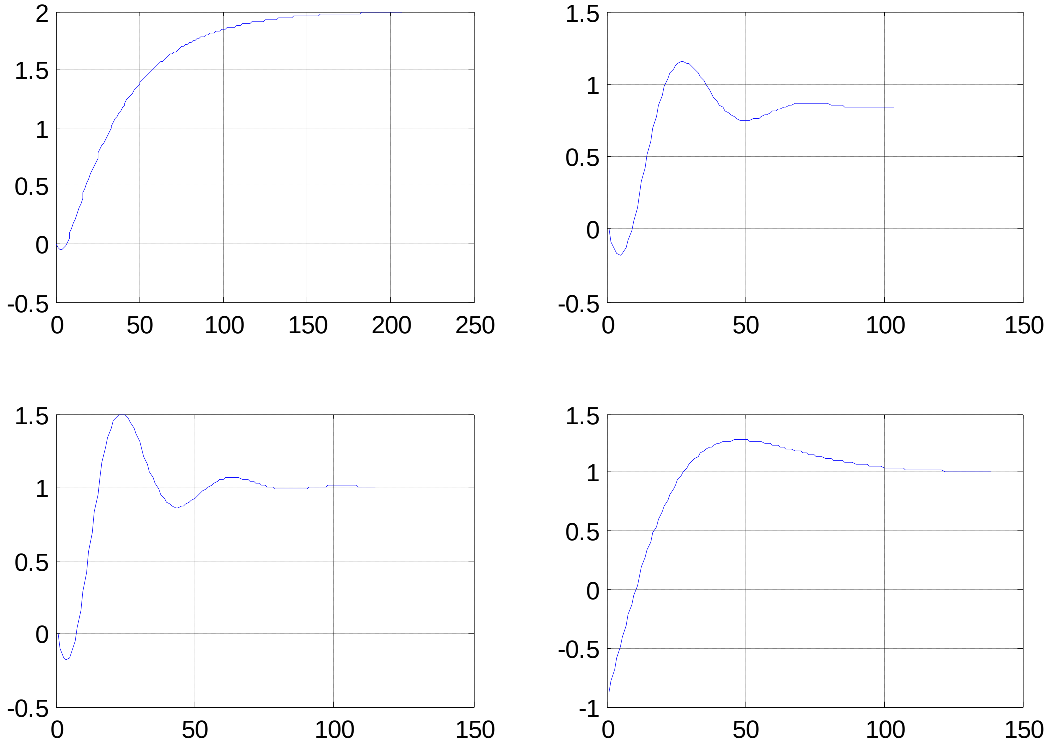


K=B/A
τ = B/Slope
Slope= opposite / adjacent
td=Delay Time

```
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)
```

CLOSE LOOP RESPONSE



RESULT

Thus the different tuning methods were studied using MATLAB software.

Ex No: 13	AUTO TUNING OF PID CONTROLLER
DATE:	

AIM

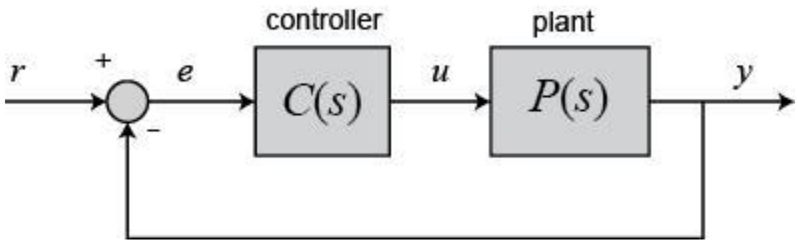
To study auto tuning of PID controller for a given process.

EQUIPMENT

1. Personal computer
2. MATLAB software

THEORY

In this tutorial, we will consider the following unity feedback system:



$$u(t) = K_p e(t) + K_i \int e(t)dt + K_p \frac{de}{dt}$$

The transfer function of a PID controller is found by taking the Laplace transform of Eq.(1).

$$K_p + \frac{K_i}{s} + K_d s = \frac{K_d s^2 + K_p s + K_i}{s} \quad \text{------ (1)}$$

K_p = Proportional gain, K_i = Integral gain, K_d = Derivative gain

We can define a PID controller in MATLAB using the transfer function directly, for example:

Kp = 1, Ki = 1;Kd = 1

s = tf ('s')

C = Kp + Ki/s + Kd*s

C = s^2 + s + 1
 - - - - - - - - - - -
 s

Continuous-time transfer function.

Alternatively, we may use MATLAB's PID controller object to generate an equivalent continuous-time controller as follows:

C = pid (Kp, Ki, Kd)

C=Kp + Ki * 1/s + Kd * s

with Kp = 1, Ki = 1, Kd = 1

Continuous-time PID controller in parallel form.

Let's convert the PID object to a transfer function to see that it yields the same result as above:

tf (C)

$$\text{Ans} = \frac{s^2 + s + 1}{1}$$

Continuous-time transfer function.

The Characteristics of P, I, and D Controllers,

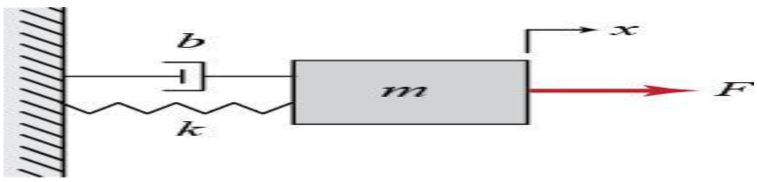
A proportional controller (K_p) will have the effect of reducing the rise time and will reduce but never eliminate the steady state error. An integral control (K_i) will have the effect of eliminating the steady state error for a constant or step input, but it may make the transient response slower. A derivative control (K_d) will have the effect of increasing the stability of the system, reducing the overshoot, and improving the transient response. The effects of each of controller parameters, K_p, K_d, and K_i on a closed- loop system are summarized in the table below.

CLOSE LOOP RESPONSE	RISE TIME	OVERSHOOT	SETTLING TIME	STEADY STATE ERROR
Kp	Decrease	Increase	Small Change	Decrease
Ki	Decrease	Increase	Increase	Eliminate
Kd	Small Change	Decrease	Decrease	No Change

Note that these correlations may not be exactly accurate, because , and are dependent on each other. In fact, changing one of these variables can change the effect of the other two. For this reason, the table Should only be used as a reference when you are determining the values for KP ,KI and KD .

<u>Example Problem</u>

Suppose we have a simple mass, spring, and damper problem.



The modeling equation of this system is
$M\ddot{x}$+b$\dot{x}$+kx=F
Taking the Laplace transform of the modeling equation, we get

$$Ms^2X(s) + bsX(s) + kX(s) = F(s)$$

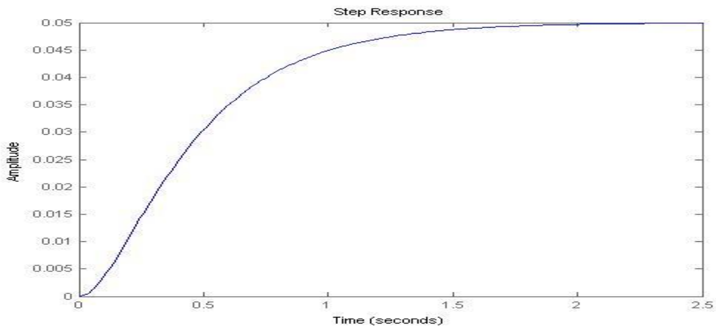
The transfer function between the displacement and the input then becomes

$$\frac{X(s)}{F(s)} = \frac{1}{Ms^2 + bs + k}$$

Let
M = 1kg , b = 10N s/m, k =20N/m ,F =1N
Plug these values into the above transfer function
The goal of this problem is to show you how each of, and contributes to obtain
Fast rise time
Minimum overshoot
No steady-state error
<u>Open Loop Step Response</u>

Let's first view the open loop step response. Create a new m-file and run the following code:

```
s = tf('s');

P = 1/(s^2 + 10*s + 20);

step(P)
```



The DC gain of the plant transfer function is 1/20, so 0.05 is the final value of the output to an unit step input. This corresponds to the steady-state error of 0.95, quite large indeed. Furthermore, the rise time is about one second, and the settling time is about 1.5 seconds. Let's design a controller that will reduce the rise time, reduce the settling time, and eliminate the steady-state error.

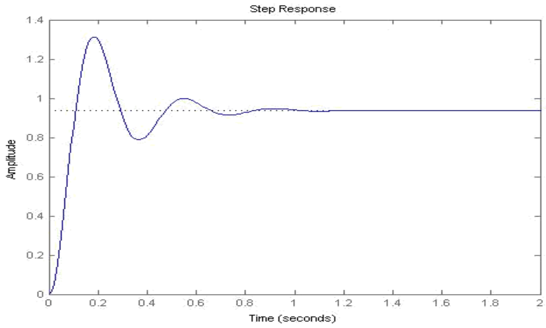
<u>PROPORTIONAL CONTROL</u>

From the table shown above, we see that the proportional controller (Kp) reduces the rise time, increases the overshoot, and reduces the steady- state error.
The closed-loop transfer function of the above system with a proportional controller is:

$$\frac{X(s)}{F(s)} = \frac{1}{s^2 + 10s + 20}$$

Let the proportional gain ( ) equal 300 and change the m-file to the following:

Kp = 300
C = pid(Kp)
T = feedback(C*P, 1)
t = 0:0.01:2
step (T,t)



P CONTROLLER ONLY

C=Kp = 300
T =300 / s^2 + 10 s + 320
Continuous-time transfer function.

The above plot shows that the proportional controller reduced both the rise time and the steady-state error, increased the overshoot, and decreased the settling time by small amount.

PROPORTIONAL-DERIVATIVE CONTROL

Now, let's take a look at a PD control. From the table shown above, we see that the derivative controller (Kd) reduces both the overshoot and the settling time. The closed-loop transfer function of the given system with a PD controller is:

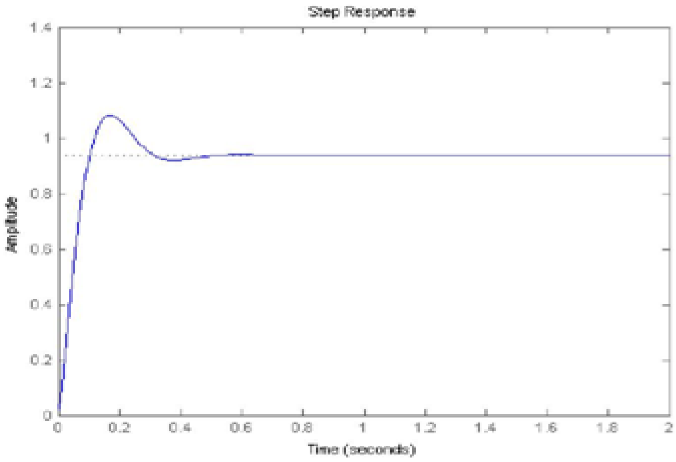
$$\frac{X(s)}{F(s)} = \frac{K_d s + K_p}{s^2 + (10 + K_d)s + (20 + K_p)}$$

Let equal 300 as before and let equal 10. Enter the following commands into an m-file and run it in the MATLAB command window.

Kp = 300
Kd = 10
C = pid(Kp,0,Kd)
T = feedback(C*P,1)
t = 0:0.01:2
step(T,t)
C=Kp + Kd * s
with Kp = 300, Kd = 10

Continuous-time PD controller in parallel form.

$$T = \frac{10S+300}{s^2 + 20 s + 320}$$



This plot shows that the derivative controller reduced both the overshoot and the settling time, and had a small effect on the rise time and the steady-state error.

PROPORTIONAL-INTEGRAL CONTROL

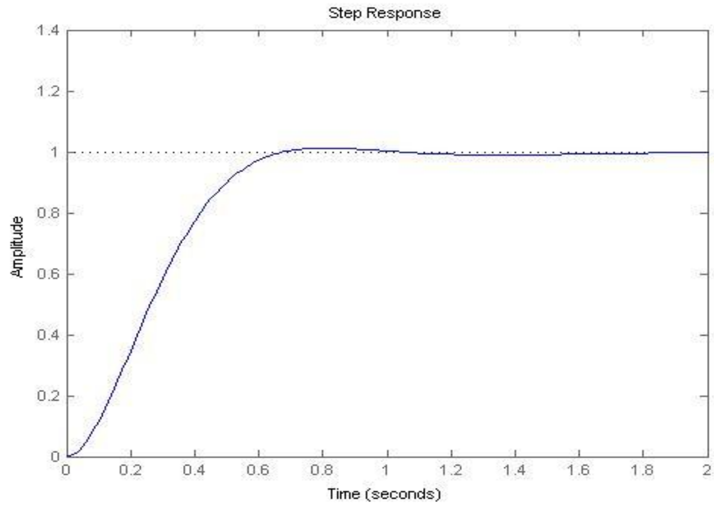
Before going into a PID control, let's take a look at a PI control. From the table, we see that an integral controller (Ki) decreases the rise time, increases both the overshoot and the settling time, and eliminates the steady-state error. For the given system, the closed-loop transfer function with a PI control is:

$$\frac{X(s)}{F(s)} = \frac{K_p s + K_i}{s^3 + 10s^2 + (20 + K_p s + K_i)}$$

Let's reduce the to 30, and let equal 70. Create an new m-file and enter the following commands.

```
Kp = 30
Ki = 70
C = pid(Kp,Ki)
T = feedback(C*P,1)
t = 0:0.01:2
step(T,t)
controller

C= Kp + Ki * 1/s
with Kp = 30, Ki = 70

Continuous-time PI controller in parallel form.

              30 s + 70
  T=  -----------------------------
       s^3 + 10 s^2 + 50 s + 70
```

Continuous-time transfer function.



Run this m-file in the MATLAB command window, and you should get the following plot. We have reduced the proportional gain (Kp) because the integral controller also reduces the rise time and increases the overshoot as the proportional controller does (double effect). The above response shows that the integral controller eliminated the steady state error.

<u>PROPORTIONAL-INTEGRAL-DERIVATIVE CONTROL</u>

Now, let's take a look at a PID controller. The closed loop transfer function of the given system with a PID controller is:

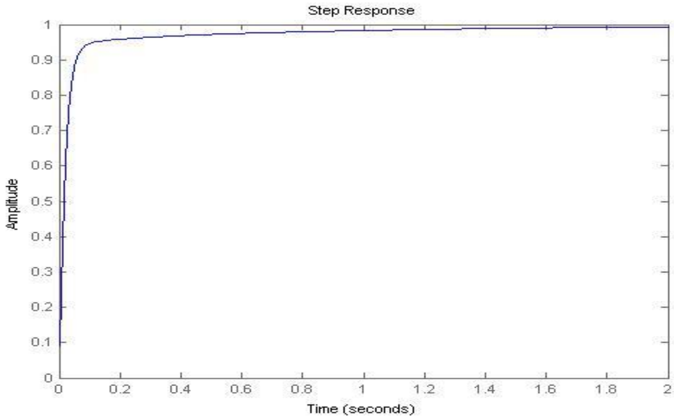
$$\frac{X(s)}{F(s)} = \frac{K_d s^2 + K_p s + K_i}{s^3 + (10 + K_d)s^2 + (20 + K_p)s + K_i}$$

After several trial and error runs, the gains = 350, = 300, and = 50 provided the desired response. To confirm, enter the following commands to an m-file and run it in the command window. You should get the following step response.

```
Kp = 350
Ki = 300
Kd = 50
C = pid(Kp,Ki,Kd)
T = feedback(C*P,1)
t = 0:0.01:2
step(T,t)
    C= Kp + Ki *1/s  + Kd * s
```

with Kp = 350, Ki = 300, Kd = 50

Continuous-time PID controller in parallel form



Now, we have obtained a closed-loop system with no overshoot, fast rise time, and no steady-state error.

General Tips for Designing a PID Controller

When you are designing a PID controller for a given system, follow the steps shown below to obtain a desired response.

1.Obtain an open-loop response and determine what needs to be improved
2.Add a proportional control to improve the rise time
3.Add a derivative control to improve the overshoot
4.Add an integral control to eliminate the steady-state error
5.Adjust each of Kp, Ki, and Kd until you obtain a desired overall response. You can always refer to the table shown in this "PID Tutorial" page to find out which controller controls what characteristics.

Lastly, please keep in mind that you do not need to implement all three controllers (proportional, derivative, and integral) into a single system, if not necessary. For example, if a PI controller gives a good enough response (like the above example), then you don't need to implement a derivative controller on the system. Keep the controller as simple as possible.

AUTOMATIC PID TUNING

MATLAB provides tools for automatically choosing optimal PID gains which makes the trial and error process described above unnecessary. You can access the tuning algorithm directly using pidtune or through a nice graphical user interface (GUI) using pidtool.

The MATLAB automated tuning algorithm chooses PID gains to balance performance (response time, bandwidth) and robustness (stability margins). By default the algorthm designs for a 60 degree phase margin.

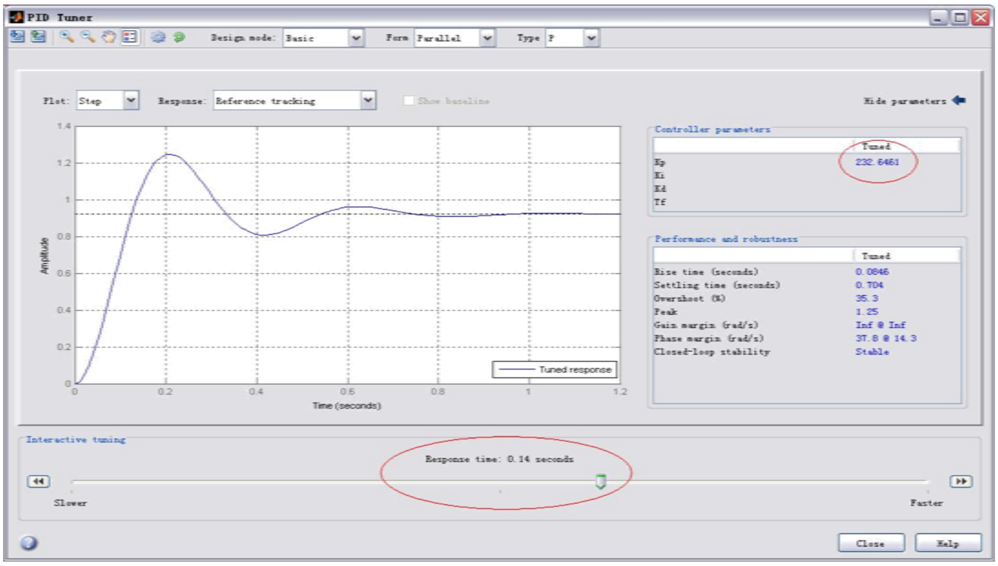
Let's explore these automated tools by first generating a proportional controller for the mass-spring-damper system by entering the following commands:

```
pidtool(P,'p')
```

The pidtool GUI window, like that shown below, should appear.

Notice that the step response shown is slower than the proportional controller we designed by hand. Now click on the Show Parameters button on the top right. As expected the proportional gain constant, Kp, is lower than the one we used, Kp = 94.85 < 300.

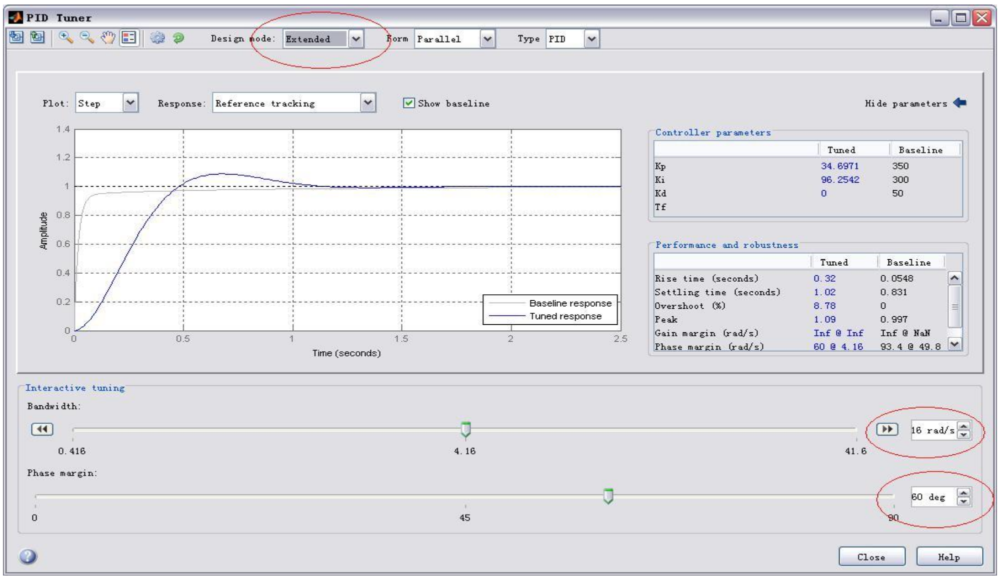
We can now interactively tune the controller parameters and immediately see the resulting response int he GUI window. Try dragging the resposne time slider to the right to 0.14s, as shown in the figure below. The response does indeeed speed up, and we can see Kp is now closer to the manual value. We can also see all the other performance and robustness parameters for the system. Note that the phase margin is 60 degrees, the default for pidtool and generally a good balance of robustness and performance.



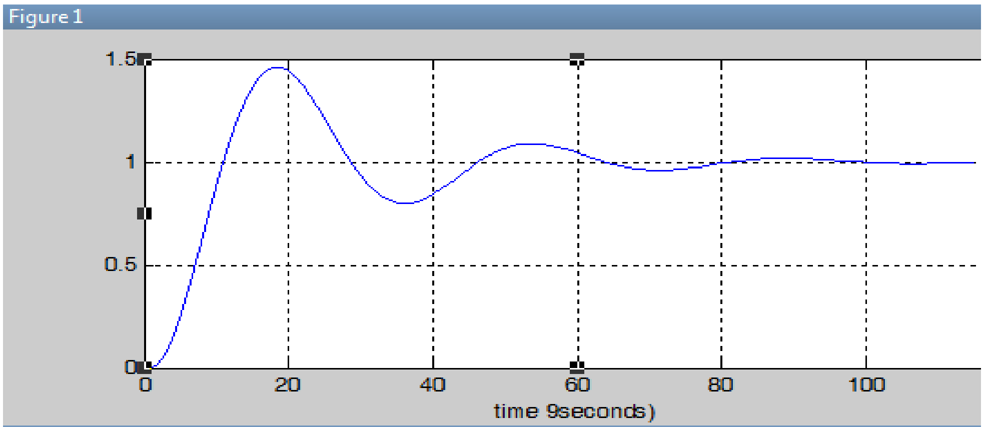
Now let's try designing a PID controller for our system. By specifying the previously designed or (baseline) controller, C, as the second parameter, pidtool will design another PID controller (instead of P or PI) and will compare the response of the system with the automated controller with that of the baseline.

pidtool(P,C)

We see in the output window that the automated controller responds slower and exhibits more overshoot than the baseline. Now choose the Design Mode: Extended option at the top, which reveals more tuning parameters.



Now type in Bandwidth: 32 rad/s and Phase Margin: 90 deg to generate a controller similar in performance to the baseline. Keep in mind that a higher bandwidth (0 dB crossover of the open-loop) results in a faster rise time, and a higher phase margin reduces the overshoot and improves the system stability.



RESULT

Thus the given process has tuned manually and auto tuning technique using Auto Tuning PID tool .

Ex No: 14	STUDY OF pH CONTROL TEST RIG
DATE:	

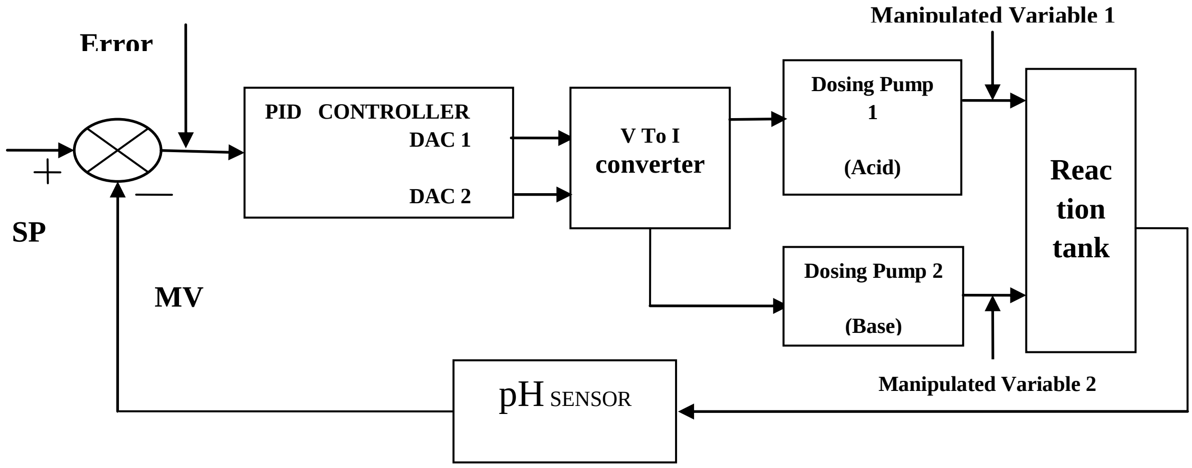
AIM

To obtain the closed loop response of pH measurement system.

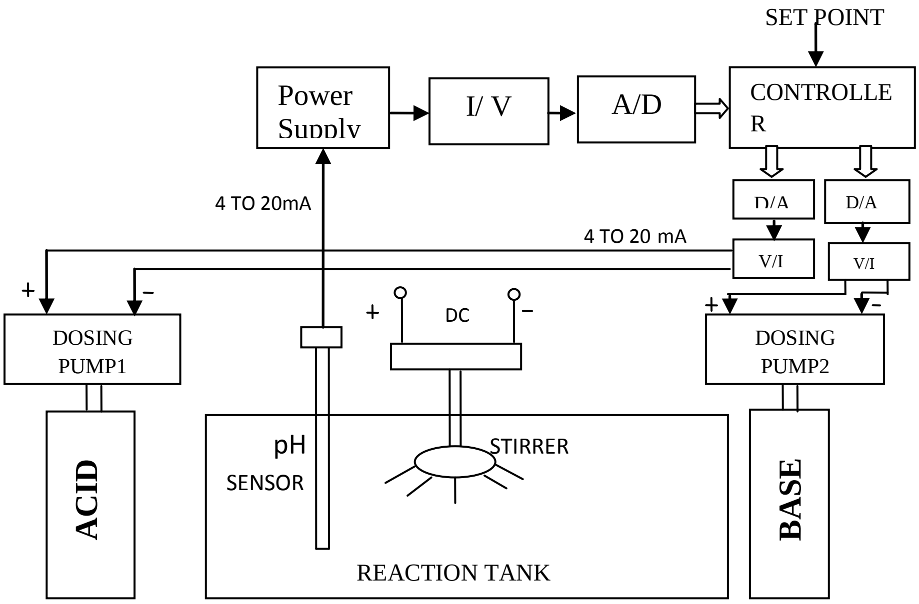
APPARATUS REQUIRED

1. pH trainer kit
2. Patch cords

BLOCK DIAGRAM



EXPERIMENTAL SETUP

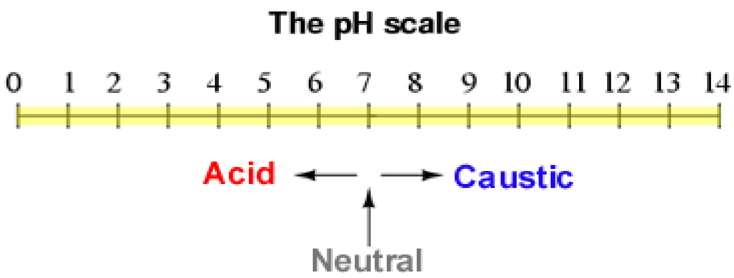


THEORY

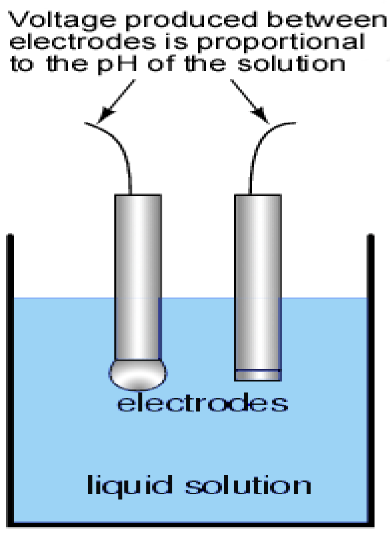
In the process world, pH is an important parameter to be measured and controlled. The pH of a solution indicates how acidic or basic (alkaline) it is. The pH term translates the values of the hydrogen ion concentration - which ordinarily ranges between about 1 and 10 x -14 gram-equivalents per liter - into numbers between 0 and 14.On the pH scale a very acidic solution has a low pH value such as 0, 1, or 2 (which corresponds to a large concentration of hydrogen ions; 10 x 0, 10 x -1, or 10 x -2 gram-equivalents per liter) while a very basic solution has a high pH value, such as 12, 13, or 14 which corresponds to a small number of hydrogen ions (10 x -12, 10 x -13, or 10 x -14gram-equivalents per liter).A neutral solution such as water has a pH of approximately 7.A pH measurement loop is made up of three components, the pH sensor, which includes a measuring electrode, a reference electrode, and a temperature sensor; a preamplifier; and an analyzer or transmitter. A pH measurement loop is essentially a battery where the positive terminal is the measuring electrode and the negative terminal is the reference electrode. The measuring electrode, which is sensitive to the hydrogen ion, develops a potential (voltage) directly related to the hydrogen ion concentration of the solution. The reference electrode provides a stable potential against which the measuring electrode can be compared.

When immersed in the solution, the reference electrode potential does not change with the changing hydrogen ion concentration. A solution in the reference electrode also makes contact with the sample solution and the measuring electrode through a junction, completing the circuit. Output of the measuring electrode changes with temperature (even though the process remains at a constant pH),so a temperature sensor is necessary to correct for this change in output. This is done in the analyzer or transmitter software. The pH sensor components are usually combined into one device called a combination pH electrode. The measuring electrode is usually glass and quite fragile. Recent developments have replaced the glass with more durable solid-state sensors. The preamplifiers a signal-conditioning device. It takes the high-impedance pH electrode signal and changes it into low impedance signal which the analyzer or transmitter can accept. The preamplifier also strengthens and stabilizes the signal, making it less susceptible to electrical noise.

A very important measurement in many liquid chemical processes(industrial, pharmaceutical, manufacturing, food production, etc.)is that of pH: the measurement of hydrogen ion concentration in a liquid solution. A solution with a low pH value is called an "acid, "while one with a high pH is called a "caustic." The common pH scale extends from 0 (strong acid) to 14 (strong caustic), with 7 in the middle representing pure water (neutral):



pH is defined as follows: the lower-case letter "p" in pH stands for the negative common (base ten) logarithm, while the upper-case letter "H" stands for the element hydrogen. Thus, pH is a logarithmic measurement of the number of moles of hydrogen ions (H+) per liter of solution. Incidentally, the "p" prefix is also used with other types of chemical measurements where a logarithmic scale is desired, pCO2(Carbon Dioxide) and pO2 (Oxygen) being two such examples. The logarithmic pH scale works like this: a solution with 10-12 moles of H+ ions per liter has a pH of 12; a solution with 10-3 moles of H+ ions per liter has a pH of 3. While very uncommon, there is such acting as an acid with a pH measurement below 0 and a caustic with a pH above 14. Such solutions, understandably, are quite concentrated and extremely reactive. While pH can be measured by color changes in certain chemical powders (the "litmus strip" being a familiar example from high school chemistry lasses), continuous process monitoring and control of pH requires a more sophisticated approach. The most common approach is the use of a specially-prepared electrode designed to allow hydrogen ions in the solution to migrate through a selective barrier, producing a measurable potential (voltage) difference proportional to the solutions.



The design and operational theory of pH electrodes is a very complex subject, explored only Briefly here. What is important to understand is that these two electrodes generate a voltage directly proportional to the pH of the solution. At a pH of 7 (neutral), the electrodes will produce0 volts between them. At a low pH (acid) a voltage will be developed of one polarity, and at a high pH (caustic) a voltage will be developed of the opposite polarity.

SPLIT CONTROL

Split control can be either MV based or error based ie error sign is needed to be detected. In split control either of two outputs (DACs) needs to be driven from PID while other DAC remains in OFF state depending upon selection of MV or error sign.

Example pH process has two dosing pumps one for acid solution and another for base solution. If you wish to increase pH towards 14 then base solution needs to be added. The upward movement of pH needs forward acting PID controller while downward movement of pH needs reverse acting PID control.

Inactive (Error) band is sometimes needed to prevent continuous shifting between the two PID outputs which appears as oscillatory behavior on MV graph. Once MV is within error band of SP then both outputs are kept of / to default values, thus stability.

GAIN SCHEDULER

Gain scheduler is needed to accounts for / compensate inherent non linearity either inherent in process or nature of sensor. In first case the process needs non linear actuator example equal percentage or quick opening, then you have to convert output of PID which is linear in to quick opening or equal percentage type curve by using gain scheduler before driving the output(DAC).

In second case the feedback sensor is non linear as in case of pH sensor which is very sensitive around 7 to 8 pH but as you move away, sensor becomes sluggish in response. In that case many times it is desirable to attenuate PID output(Un) when MV is around 7 -8 pH while you can choose to amplify Un as MV moves away say in the region around 12pH or 4pH.

PROCEDURE

1) Connect the test set up as per the wiring sequence as mention as per experiment, here Close loop control with digital PID setting describe as below.

2) Connect USB 10 module to your CIA/CIP card as well as PC via USB cable, then double click "Single PID Matlab" to run application in "Single PID Matlab Application" folder.

3) Press the 'CONNECT' button, "Connection succeeded" window will prompt then press 'OK', it also display in status line, if it fails to it display in status line "connection failed", then connection with the device has failed and try removing the USB cable and inserting again also press CONNECT button.

4) Now in main window PID tab set PB 20% , Ti = 10, Td = 2.5, Ts=2, Kd=lO, set value=30,. Set o/p lower =0% & upper =100, reverse action as shown in below window.

5) In Setting windows channel setting panel select set channel 0 for MV & SP From panel, Output on DAC 1.

6) Now in this setting window click on 'Gain scheduler' checkbox. Enter values in 'MV' row and in 'Ki' row as shown above.

7) Now click on 'Split control' checkbox, click on 'Error' and enter following values in as above. Press 'OK' button. Also press 'OK' button on setting window to save all setting.

8) Set valves position as VI slightly open, V2, V3 and V4 closed. Switch ON the entire pump supply.

9) In main window, Click on 'Graph setting' button open 'Graph setting' window, here set their parameter Graph 1- PID1 SP, Graph 2- PID1 MV to plot graph & rest of the setting are deselected. Press 'OK' button to close this window.

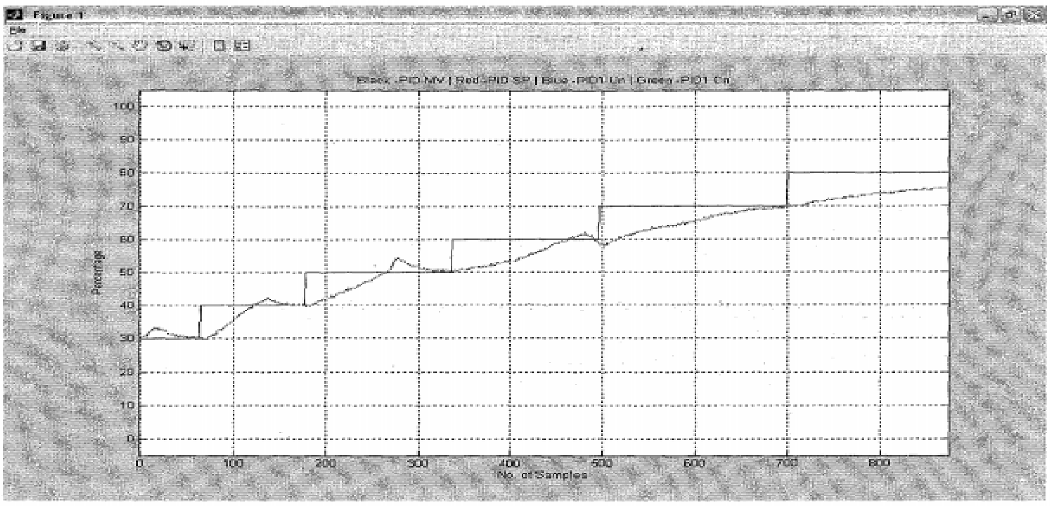
10)To Start PID controller click on 'Start' button, it will start plotting graph in figure window as shown end of section.

11) Observe the system response of the process for set point change. Vary the set point on the panel from 30 to 50 % manually. But while changing the set point click 'Pause/Resume' button to held online graph window & change Process parameter like 'SP' if you want. Observe the graph of measured variable Vs set point.

12) After performing experiment stop the pid controller 'Stop' button used for stop process with their graph plotting.

13) Press 'Save Graph' button to save plotted graph.

MODEL GRAPH



RESULT

Thus the closed loop response of pH control was obtained.

ADDITIONAL EXPERIMENTS

Ex No: 14	RESPONSE OF RATIO CONTROL
DATE:	

AIM

To obtain the closed loop response of ratio control system.

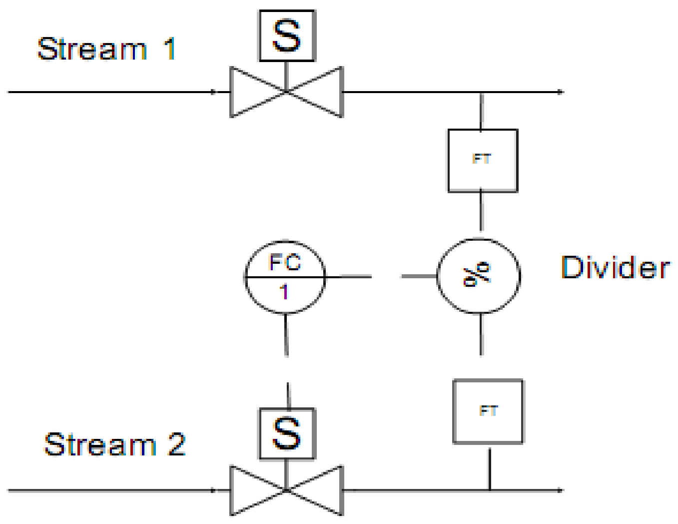
APPARATUS REQUIRED

1. Ratio control setup
2. Computer with printer
3. Patch cords.

THEORY

RATIO CONTROL

The objective of a ratio control scheme is to keep the ratio of two variables at a specified value. Thus, the ratio (R) of two variables (A and B), R = A / B is controlled rather than controlling the individual variables. Typical ratio control schemes include maintaining the reflux ratio for a distillation column, maintaining the stoichiometric ratio of reactants to a reactor and maintaining air/fuel ratio to a furnace.



The flow rate of the two streams is measured and their ratio calculated using a 'divider'. The output of the divider is sent to the ratio controller (which is actually a standard PI controller).

The controller compares the actual ratio with that of the desired ratio and computes any necessary change in the manipulated variable.

CONTROLLER	WIRING SEQUENCE	VALVE POSITION	CONTROLLER SETTINGS
RATIO	EMT 8 L2 (12) to Motor +ve. EMT 8 N2 (13) to Motor -ve. Signal Conditioning Panel 14 to CH (CHANNEL)0 . Thyristor actuator cum signal Conditioning Panel 14 to CH (CHANNEL) 1. CIP (6) to CIP (9). CIP I O/P (10) to +ve of I to P Converter. CIP (20) to -ve of I to P Converter.	V1 Open, V2 Closed, V3 adjust to 200 LPH, V5 Closed, V7 Open, V8 Open, V9 Open.	**MAIN PID SETTING** PB = 60%, Ti = 1sec, Td = 0.125sec, Ts = 0.1sec, Kd =10, O/P lower Limit = 0%, O/P upper limit = 100% & Reverse action. Select Channel 0 for Measure Variable, source for set value fro channel 1, Ratio Factor = 0.5.

PROCEDURE

1. Connections are made as per the wiring sequence.
2. First click on the START menu on your computer, and then select PROGRAMS
3. Then select PID CONTROLLER VERSION 10.7 and click on it.
4. After clicking on that, SETTINGS screen will appear.
5. Now enter the various values in their necessary columns.
6. Select the ratio factor
7. After entering the values, now click on AUTO START.
8. Take a graph of CHO and CH1 using matlab software.

RESULT

Thus the performance of a ratio control system was studied.

Ex No: 14	**RESPONSE OF INTERNAL MODEL CONTROL (IMC)**
DATE:	

AIM

To study about Internal Model Controller

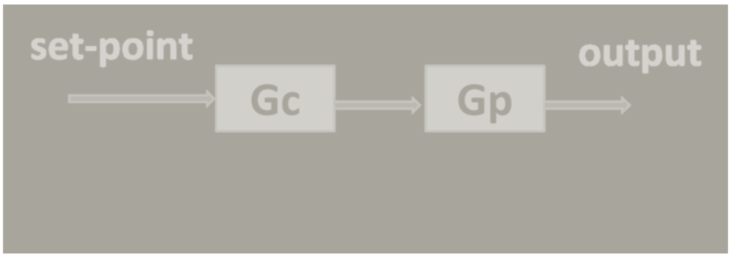
APPARATUS REQUIRED

PC with Matlab Software

THEORY

Internal Model Control (IMC) is a commonly used technique that provides a transparent mode for the design and tuning of various types of control. The ability of proportional-integral (PI) and proportional-integral-derivative (PID) controllers to meet most of the control objectives has led to their widespread acceptance in the control industry. The Internal Model Control (IMC)-based approach for controller design is one of them using IMC and its equivalent IMC based PID to be used in control applications in industries. It is because, for practical applications or an actual process in industries PID controller algorithm is simple and robust to handle the model inaccuracies and hence using IMC-PID tuning method a clear trade-off between closed-loop performance and robustness to model inaccuracies is achieved with a single tuning parameter.

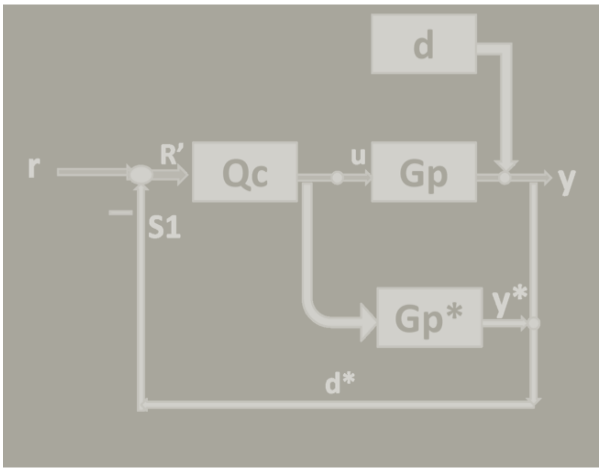
Also the IMC-PID controller allows good set-point tracking but sulky disturbance response especially for the process with a small time-delay/time-constant ratio. But, for many process control applications, disturbance rejection for the unstable processes is much more important than set point tracking. Hence, controller design that emphasizes disturbance rejection rather than set point tracking is an important design problem that has to be taken into consideration.



Open loop Control Strategy

Output = Gc . Gp . Set-point (multiplication of all three parameters)
Gc = controller of process
Gp = actual process or plant
Gp* = model of the actual process or plant.A controller Gc is used to control the process Gp. Suppose Gp* is the model of Gp then by setting:

Gc =inverse of Gp* (inverse of model of the actual process)
And if
Gp = Gp* (the model is the exact representation of the actual process)
Now it is clear that for these two conditions the output will always be equal to the set point.



IMC Basic Structure

IMC parameters

The various parameters used in the IMC basic structure shown above are as follows:
Qc= IMC controller
Gp= actual process or plant
Gp*= process or plant model
r= set point

R"= modified set point (corrects for model error and disturbances)
u= manipulated input (controller output)
d= disturbance
d*= estimated disturbance
y= measured process output
y*= process model output

Feedback signal:
d*= (Gp - Gp*)u +d
Signal to the controller:
R"= r- d*= r- (Gp - Gp*) u – d

Now we consider a limiting case

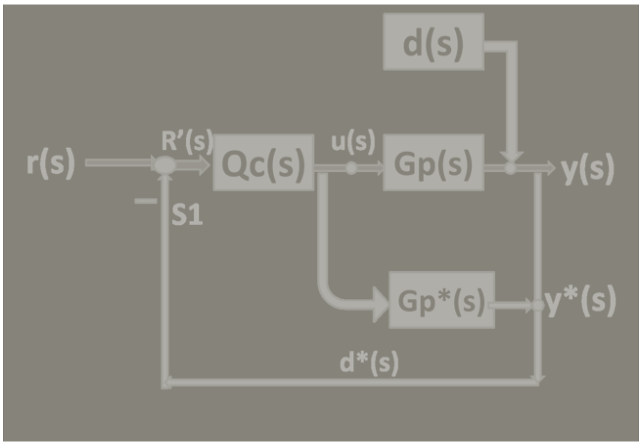
Perfect model with no disturbance:

We will say a model to be perfect if
Process model is same as actual process
i.e. **Gp = Gp***
no disturbance means
d = 0
Thus we get a relationship between the set point **r** and the output **y** as
y = Gp . Qc .r
This relationship is same for as we got for open loop system design. Thus if the controller Qc is stable and the process Gp is stable the closed loop system will be stable.

But in practical cases always the disturbances and the uncertainties do exist hence actual process or plant is always different from the model of the process.

IMC Strategy

As stated above that that actual process differs from the model of the process i.e. process model mismatch is common due to unknown disturbances entering into the system. Due to which open loop control system is difficult to implement so we require a control strategy through which we can achieve a perfect control. Thus the control strategy which we shall apply to achieve perfect control is known as INTERNAL MODEL CONTROL (IMC) strategy.



IMC Basic Structure

IMC parameters

The various parameters used in the IMC basic structure shown above are as follows:
Qc= IMC controller
Gp= actual process or plant
Gp*= process or plant model
r= set point
R‟= modified set point (corrects for model error and disturbances)
u= manipulated input (controller output)
d= disturbance
d*= estimated disturbance
y= measured process output
y*= process model output

Feedback signal:
d*= (Gp - Gp*)u +d
Signal to the controller:
R‟= r- d*= r- (Gp - Gp*) u – d

Now we consider a limiting case

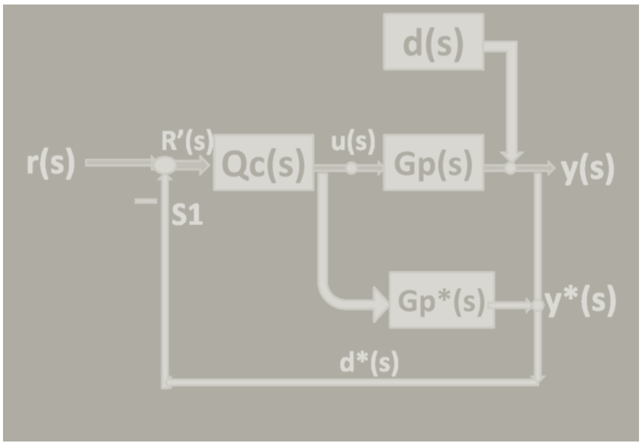
Perfect model with no disturbance:

We will say a model to be perfect if
Process model is same as actual process

i.e. **Gp = Gp***
no disturbance means
d = 0
Thus we get a relationship between the set point **r** and the output **y** as
y = Gp . Qc .r
This relationship is same for as we got for open loop system design. Thus if the controller Qc is stable and the process Gp is stable the closed loop system will be stable.
But in practical cases always the disturbances and the uncertainties do exist hence actual process or plant is always different from the model of the process.

IMC Strategy

As stated above that that actual process differs from the model of the process i.e. process model mismatch is common due to unknown disturbances entering into the system. Due to which open loop control system is difficult to implement so we require a control strategy through which we can achieve a perfect control. Thus the control strategy which we shall apply to achieve perfect control is known as INTERNAL MODEL CONTROL (IMC) strategy.



In the above figure, d(s) is the unknown disturbance affecting the system. The manipulated input u(s) is introduced to both the process and its model. The process output, y(s), is compared with the output of the model resulting in the signal d*(s). Hence the feedback signal send to the controller is
d*(s) = [Gp(s) – Gp*(s)].u(s) + d(s)

In case d(s) is zero then feedback signal will depend upon the difference between the actual process and its model.
If actual process is same as process model i.e **Gp(s) = Gp*(s)** then feedback signal **d*(s)** is equal to the unknown disturbance.
So for this case **d*(s)** may be regarded as information that is missing in the model signifies and can be therefore used to improve control for the process. This is done by sending an error signal to the controller.

The error signal **R'(s)** incorporates the model mismatch and the disturbances and helps to achieve the set-point by comparing these three parameters. It is send as control signal to the controller and is given by

R'(s) = r(s) – d*(s) (input to the controller)

And output of the controller is the manipulated input **u(s)**. It is send to both process and its model.

u(s) = R‟(s) . Gc(s) = [r(s) – d*(s)] Gc(s)

= [r(s) – {[Gp(s) – Gp*(s)].u(s) + d(s)}] . Gc(s)

u(s) = [[r(s) – d(s)] Gc(s)] / [1 + { Gp(s) – Gp*(s) } Gc(s)]

But

y(s) = Gp(s) . u(s) + d(s)

Hence, closed loop transfer function for IMC scheme is

y(s) = {Gc(s) . Gp(s) . r(s) + [1 – Gc(s) . Gp* (s)] . d(s)} / { 1 + [Gp(s) – Gp* (s)] Gc(s) }

Now if Gc(s) is equal to the inverse of the process model and if Gp(s) = Gp*(s) then perfect set point tracking and disturbance rejection can be achieved.

Also to improve the robustness of the system the effect of model mismatch should be minimized. Since mismatch between the actual process and the model usually occur at high frequency end of the systems frequency response, a low pass filter Gf(s) is usually added to attenuate the effects of process model mismatch.

Thus the internal model controller is usually designed as the inverse of the process model in series with the low pass filter i.e

Gimc(s) = Gc(s). Gf(s)

Where order of the filter is usually chosen so that the controller is proper and to prevent excessive differential control action. The resulting closed loop then becomes

y(s) = {Gimc(s) . Gp(s) . r(s) + [1 – Gimc(s) . Gp* (s)] . d(s)} / { 1 + [Gp(s) – Gp* (s)] Gimc(s) }

IMC design for 1st order system

Now we apply the above IMC design procedure for a first order system with a given process model.

Given process model for 1st order system : Gp*(s) = Kp*/[Tp*(s)+1]

Gp*(s) = Gp*(+)(s) . Gp*(-) (s) = 1 . Kp*/[Tp*(s)+1]

Qc*(s) = inv[Gp*(-) (s)] = [Tp*(s)+1] / Kp*

Qc(s) = Qc*(s). f(s) = [Tp*(s)+1] / [Kp*. (lem(s) + 1)]

f(s) = 1 / (lem. s + 1)

y(s) = Qc(s). Gp(s).r(s) = Gp*(+)(s) . f(s). r(s)

{PERFECT MODEL}

Output variable:

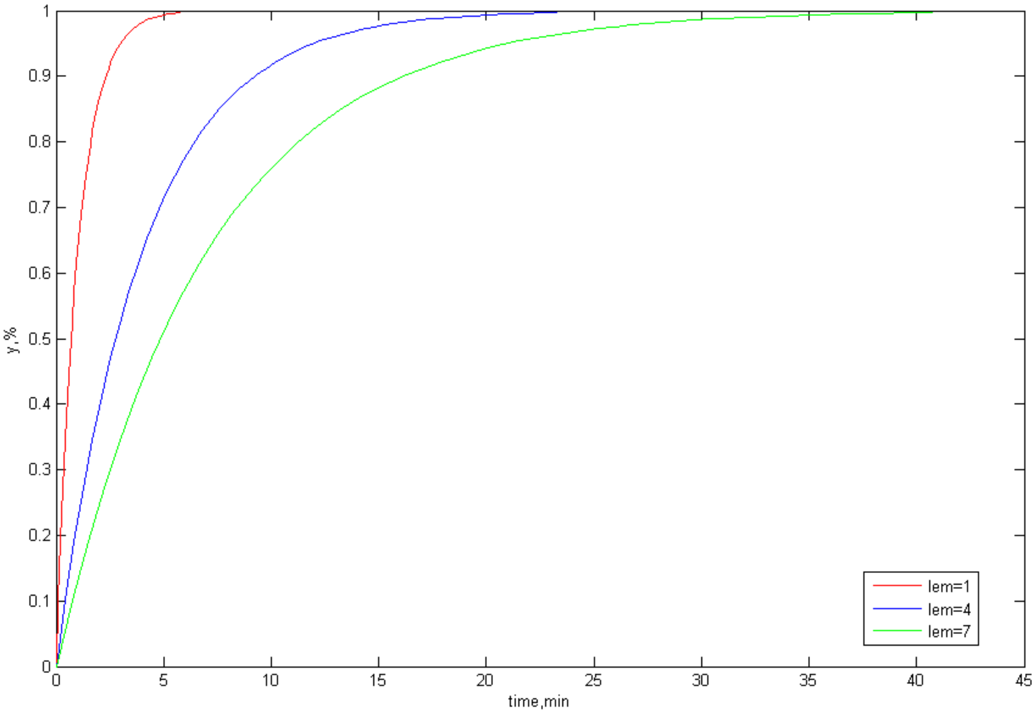
y(s) = r(s)/(lem. s +1)

Manipulated variable:

u(s) = Qc(s) . r(s) = [Tp*(s)+1].r(s)/ [Kp. (lem. s +1)

Simulation plot for IMC 1st order system

Output variable response



RESULT

Thus the IMC were Studied.

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 relationship 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 are 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.

.
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.

.

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.