LABORATORY MANUAL

of

AEL411 PROCESS CONTROL LAB (S7)

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

COLLEGE OF ENGINEERING TRIVANDRUM

DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

COLLEGE OF ENGINEERING TRIVANDRUM

CERTIFICATE

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AEL411	PROCESS CONTROL LAB	CATEGORY	L	T	P	CREDIT
		PCC	0	0	3	2

Preamble

This course aims students to achieve the following skills

- Ability to control basic physical processes using both simple and complex control schemes
- Experimentally verify a variety of process controls using computerized control
- Realization of process control schemes using various simulation software

Prerequisite

AET304 PROCESS DYNAMICS & CONTROL

(i) Course Outcomes: The student will be able to

CO1	Analyze and study the responses of various combinations of P, I, D controls for controlling basic processes like level, temperature, etc.
CO2	Tune controllers for processes using different methods
CO3	Analyze the performance of complex controls- cascade, feed forward and ratio
CO4	Implement process controls using computerized control
CO5	Acquire familiarity with usage of simulation tools for mathematical computation, processing and virtual instrumentation for process control applications

(ii) <u>CO-PO/PSO matrix showing level of correlation (1-Low, 2-Medium, and 3-high)</u>

Course: AEL411 Process Control Lab															
Course Outcome Designation	**CO-PO/PSO matrix showing level of correlation (1-Low, 2-Medium, and 3-High)**														
	PO - 1	**PO - 2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**	**PO-7**	**PO-8**	**PO-9**	**PO-10**	**PO-11**	**PO-12**	**PSO-1**	**PSO-2**	**PSO-3**
AEL411/ CO1	3	3	3	3		3	2	3	3		3	3	3		
AEL411/ CO2	3	3	3	3	3	3	2	3	3		3	3	3		
AEL411/ CO3	3	3	3	3		3	2	3			3	3	3		
AEL411/ CO4	3	3	3	3	3	3	2	3	3		3	3	3		
AEL411/ CO5	3	3	3	3	3	3	2	3			3	3	3		

Assessment

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	75	75	2.5 hours

Continuous Internal Evaluation Pattern:

Attendance : 15 marks
Continuous Assessment : 30 marks
Internal Test (Immediately before the second series test) : 30 marks

End Semester Examination Pattern: The following guidelines should be followed regarding award of marks

(a) Preliminary work : 15 Marks
(b) Implementing the work/ Conducting the experiment : 10 Marks
(c) Performance, result and inference (usage of equipment and troubleshooting) : 25 Marks
(d) Viva voce : 20 marks
(e) Record : 5 Marks

PROCESS CONTROL LAB

14	Study of virtual instrumentation and data logging	76	CO5

EXPERIMENT NO. 1
ON-OFF CONTROLLER WITH AND WITHOUT NEUTRAL ZONE-TEMPERATURE CONTROL

Aim

To design and set up ON-OFF controller with and without neutral zone for the following specifications.

1. Design and test an ON-OFF controller for a heater, for a set point of 150°C.
2. Design an ON-OFF controller with neutral zone to control the temperature of water between 80°C and 100°C

Apparatus Required

Temperature controller.

Theory

An ON-OFF controller is the simplest form of a temperature control device. The output from the device is either on or off, with no state in between. An ON-OFF controller switches the output only when the temperature is below the set point, and off when the temperature is above the set point. The temperature keeps cycling continuously between these two stages. In cases where this cycling occurred rapidly, to prevent damage to contactors and valves, an on ON-OFF differential or 'hysteresis', is added to the controller operations. The temperature exceeds set point by a certain amount before the output will turn off or on again because of hysteresis. ON-OFF differential prevents the output from 'chattering' or making fast, continuous switching if the cycling above and below the set point occurs very rapidly.

ON-OFF control is usually used where a precise control is not necessary, in systems which cannot handle the energy of turning on and off frequently. Systems where the mass of the system is so great that temperature change extremely slowly, a temperature alarm, etc. can use ON-OFF controller. One special type of ON-OFF control used for alarm is a limit controller. This controller uses latching relay, which must be manually reset and is used to shut down a process when a temperature is reached.

When a controller operates in discontinuous mode around a set point (for example turning an air conditioner ON above a certain room temperature and turn OFF below that temperature) there can be frequent undesirable oscillations between on and off (sometimes referred to as 'chatter'), when the variable is close to the set point. To solve this problem a neutral zone (as shown in Fig.1.1), can be implemented between two set points (high and low) with the controller taking no action as long as the temperature is in the neutral zone.

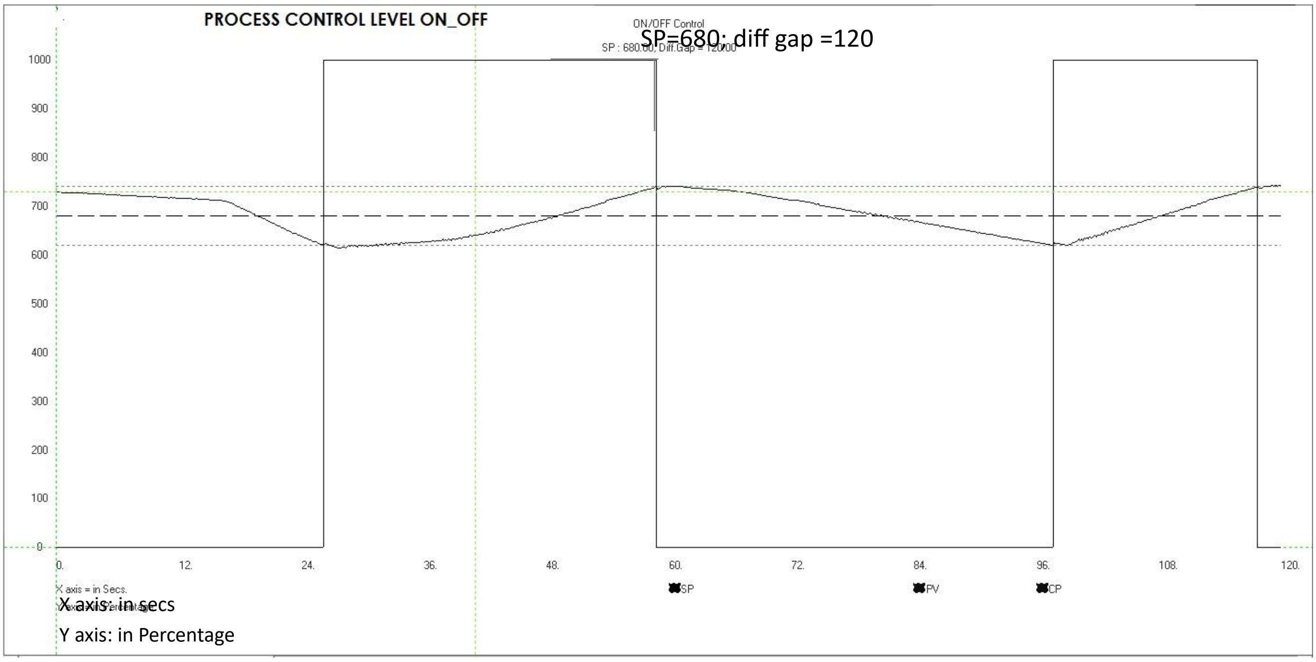

Fig. 1.1 ON-OFF control graph

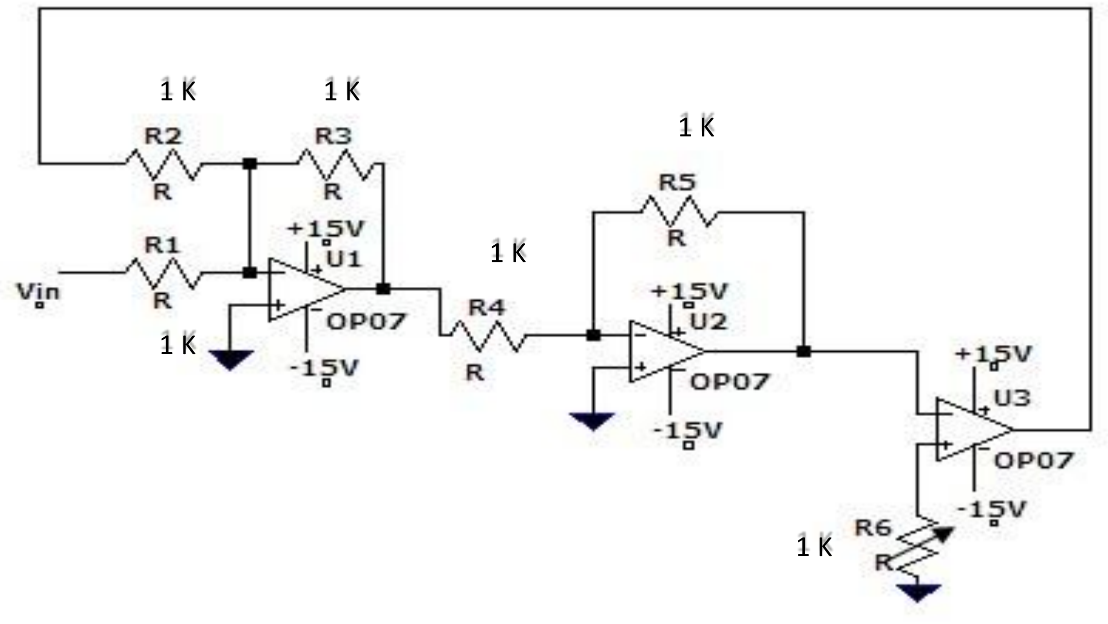

Fig. 1.2 ON-OFF Controller without neutral zone

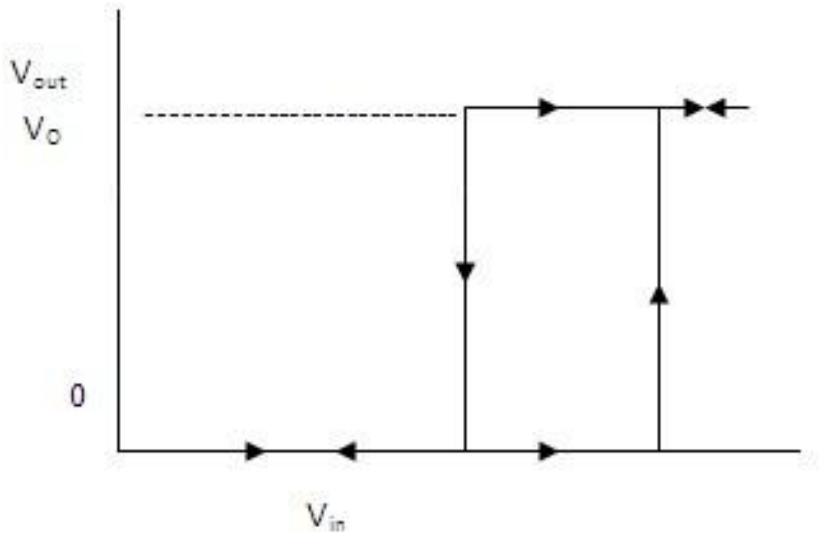

Fig. 1.3 Hysteresis curve of ON- OFF Control

ON-OFF controller without neutral zone

Select Pt100 as the sensing element. Pt100 has 100Ω at 0°C and a temperature coefficient, α of .0036 Ω/°C. Select the lower fixed resistance as 150 Ω and the other as RTD measured value. For setting bridge performance, the upper arms are selected approximately 10 times as lower arms. The voltage across 154 Ω is applied as the reference voltage to a comparator. The RTD voltage is applied at the non -inverting terminal. When the temperature just exceeds 150°C, output of the comparator switches to positive saturation. This will turn on the transistor as the normally closed terminals of relay are used, the heater turns off when the transistor switches on. When the temperature falls below 150°C, the output of the comparator switches to negative saturation and the heater is turned on again.

ON-OFF controller with neutral zone

In Fig.1.2, if the input voltage Vin from the sensor processing circuits output reaches a value V

DESIGN

1. ON-OFF controller without neutral zone

$R_{150} = R_0 (1+ \alpha T) = 100(1 + 0.0036 \times 150) = 154\Omega$ (select 150Ω)

Select upper arms as 1k Ω. At positive saturation, output of comparator = 15V Relay needs a current $= 12V/200\ \Omega = 60mA$

Select transistor with I_C more than 60 mA.
$I_b = I_c/\beta$ = 60mA/100= 0.6 mA.

$R_b = \frac{15-.7}{.0006} = 22k$

2. ON-OFF controller with neutral zone

For Pt100 RTD, $R_0 = 100\Omega$

$R_T = R_0(1 + \alpha T) = 100(1 + .0036 \times 100) = 136\Omega$

At 80°C the difference O/P of the bridge = .567-.454 =.113V

At 100°C the diff. O/P of bridge = $((5\times 136)/(1000 + 136)) - .454 = .144$V

Set the gain of the diff. amplifier, such that the voltage will be changing from 1.13V to 1.44V when the temperature changes from 80°C to 100°C

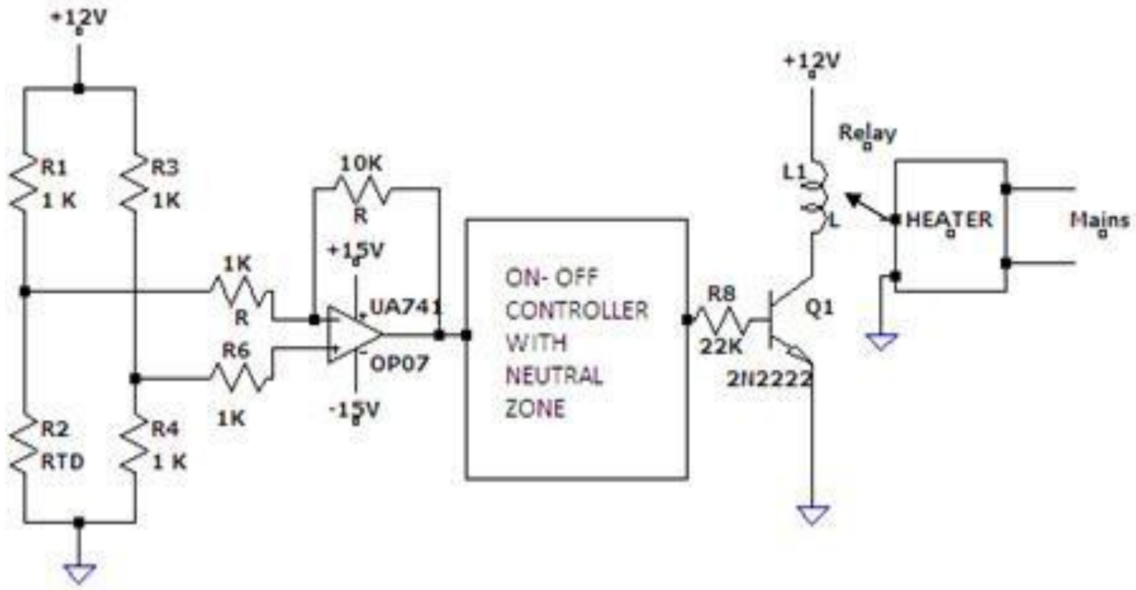

Fig. 1.4 ON-OFF Controller with neutral zone

Therefore, set Vsp = V_H 1.44 V by adjusting the pot 'p'. Put R of the inverter as 1K

$tV_1 = V_{SP} - (\frac{R1}{R2}) \times V_O = 1.13V$

$V_1 = 1.44 - \left(\frac{R1}{R2}\right)$ (V_{sat} of the comparator)

Take R1 & R2 which satisfies the above condition.

Procedure

Without neutral zone

- Place the overall system in the on-off mode.
- Give a value set point.
- Observe the process output Vs time.

With neutral zone

- Place the overall system in the on-off mode.
- Give the upper limit and lower limit of set point.
- Observe the process output versus time.

Result

ON-OFF controller, with and without neutral zone using a temperature controller was studied.

EXPERIMENT NO. 2

TEMPARATURE CONTROL USING P, PI, PD AND PID CONTROLLERS- STUDY OF OUTPUT RESPONSE

Aim

To study the performance of P, PI, PD and PID controllers in a temperature control system.

Apparatus required

Temperature Control System trainer kit

Theory

Fig 2.1 shows the block diagram of a closed loop control system. The function of the controller is to receive the measured output signal, which is to be compared with the set point to produce the actuating signal in such a way as to bring the output to the desired value. The input to the controller is the error signal which is the defined as the difference between the measured output signal and set point. The basic feedback controllers are explained below.

1. Proportional controller

Proportional controller produces a signal that is proportional to the error e(t). This action may be expressed as, $P(t) = K_C\, e(t) + P_S$, where P_S is controller bias signal which is a constant, K_c is gain, p(t) is output and e(t) is error. The P controller is described by K_C or equivalently by proportional band (PB), where $PB = 100/K_C$. P controller produces an oscillatory response with overshoot which always produces offset.

2. Proportional- Derivative controller

Proportional Derivative Controller is represented as Controller O/P, $P(t) = K_c\, e(t) + K_C \tau_d \frac{de(t)}{dt} + P_S$,

, where τ_d is the derivative time constant and 'e' and 'P' are functions of time. Here the response exhibits a smaller overshoot and smaller oscillations compared to P controller. The offset is also is less than that of P controller.

3. Proportional- Integral Controller

This mode of controller is represented as :

Controller O/P, $P(t) = K_c\, e(t) + \frac{K_C}{\tau_I} \int_0^t e(t)dt + P_S$, where τ_I is the integral time constant and 'e' and 'P' are functions of time. PI controller eliminates offset. The peak overshoot is same as that of P controller and the settling time is relatively large.

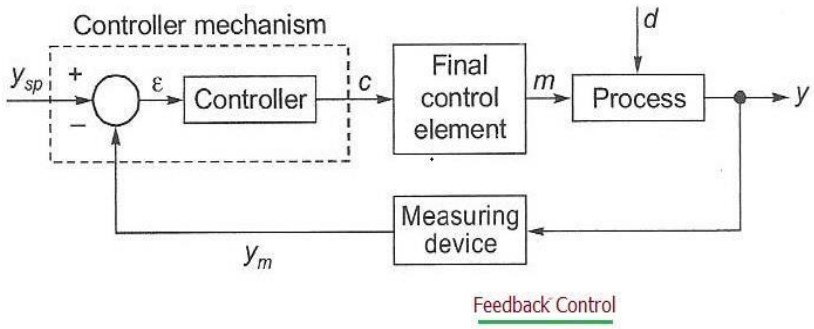

Fig. 2.1 Block Diagram of a closed loop control system

Note: For component specific problems refer Components' Manuals

Problems	Possible causes / remedies
Temperature does not rise	• Low electric supply voltage • Burnt heater coil. Replace the heater • Faulty Solid State Relay
No communication with computer	• Check communication settings for IP addresses of computer and controller. Default setting computer 192.168.1.2 and controller 192.168.1.11

Table 2.1 Troubleshooting

Product	Temperature control trainer
Product code	311A
Temperature sensor	Make Radix, Type Pt100, Sheath Dia.6mmX110mmL, SS316, Connection 1/4"BSP(M) adjustable compression fitting
Digital indicating controller	Make Yokogawa, Model UT35A-002-11-00 with Ethernet communication
Heating control (SSR)	Make Unison, Model UNI 701 PHT 24 25 420 (Back To Back SCR), Input 4-20 mA, O/P 230VAC with Heat sink, Rating: 25Amp. (765+89)
Heater	Type - 3.0 kw, 2 coil, industrial, Size - 1.25 " BSPx10 " L, Input 230VAC
Rotameter	Make Eureka, Model MG 10, Range 6 -60 lph, connection 1/4`` back, screwed, packing PTFE + Silicon

Table 2.2 Details of Equipment Used

4. Proportional- Integral- Derivative Controller

PID Controller is represented as Controller O/P, P(t) = $K_c\, e(t) + \frac{K_C}{\tau_I}\int_0^t e(t)dt + K_C\, \tau_d \frac{de(t)}{dt} + P_S$ where 'e' and 'P' are functions of $\tau_I$time. The response has lower overshoot and returns to set point more quickly.

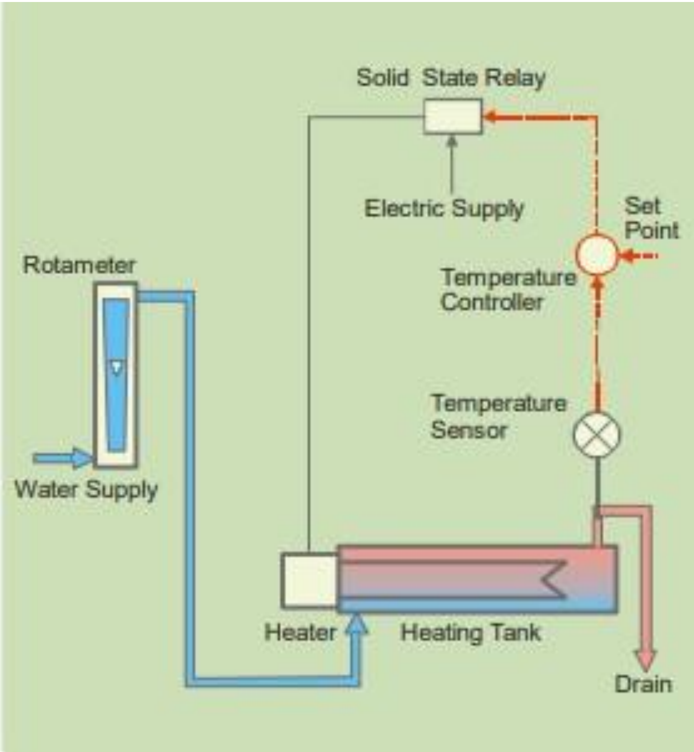

Fig. 2.2 Temperature Control of heating tank system diagram

Trainer Kit 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 Ethernet port for monitoring the process in SCADA mode.

Product	Temperature control trainer
Product code	311A
Type of control	SCADA
Control unit	Digital indicating controller with Ethernet communication
Communication	Ethernet
Temperature sensor	Type RTD, PT100
Heating control	Proportional power controller (SSR), Input 4-20 mA, Capacity 50 A.
Heater	Type Electrical 2 coil, Capacity 3 KW
Rotameter	6-60 LPH
Process tank	SS304, Capacity 0.5 lit, insulated
Overall dimensions	550Wx480Dx525H mm

Table 2.3 Specifications

Procedure

1. Study of open loop response (Manual Control)

- Switch on electric supply. Switch on Mains.
- Switch on the pump and adjust the bypass valve to set rotameter flow at 100 LPH.
- Switch on the compressed air source and adjust the air regulator to set supply air pressure at
- @ 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop.
- Select product Temperature Control Trainer (311A)
- Select Yokogawa (UT35A)
- Click Continue
- Click Connect
- Click on Select Experiment.
- Select Open Loop and click Start
- Decrease the controller output to 0%. Note down steady state process value.
- Apply the step change by 10% to controller output and wait for process value to reach the steady state value.
- Repeat the above step until the controller output reaches to maximum, i.e., 100% and for each change, note steady state process value.

Set the output of the controller to the noted value and at steady state, apply the load change to the process. Load change can be given by slightly varying the drain valve. Observe new steady state Process value.

Observations (Manual Mode)

Controller output (in %)	Process Value (%)

- From the above data, note the output required for maintaining the temperature at desired set points.

Observations (P Mode)

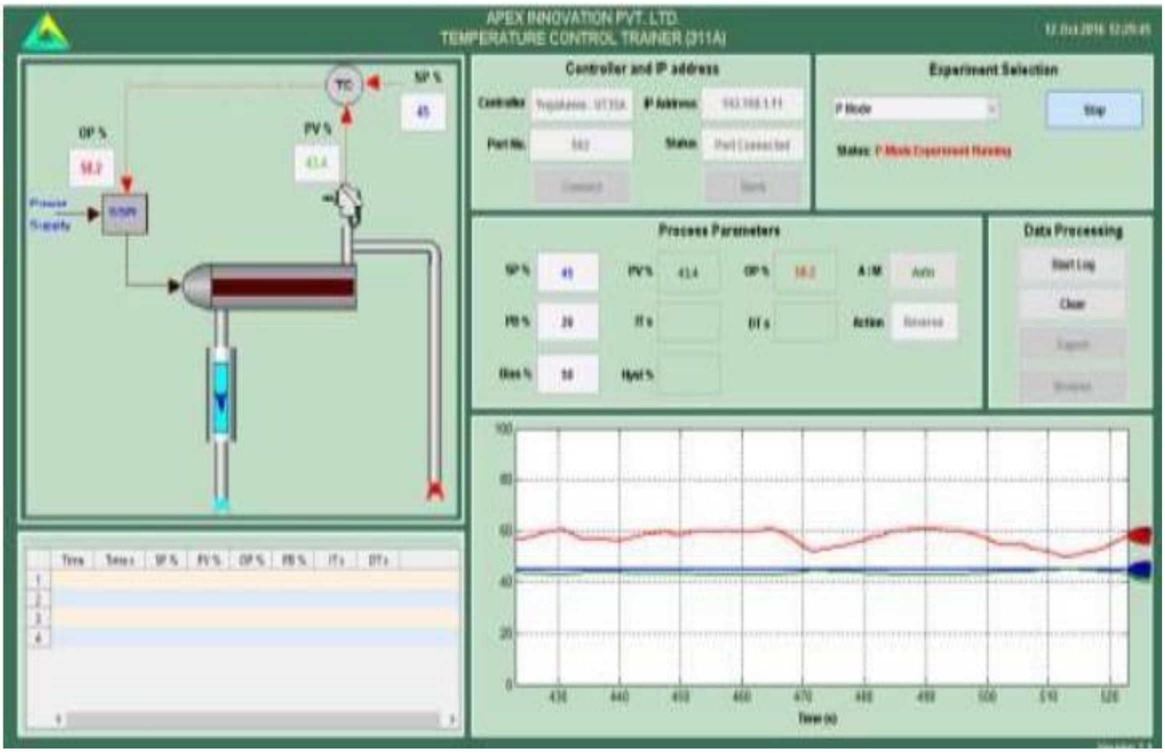

Fig. 2.3 P response

- Observe steady state error decreases as proportional band decreases.
- Observe the effect of very low proportional band values (system works in oscillatory mode).

2. Study of Proportional Controller

- Switch on electric supply. Switch on Mains.
- Switch on the pump and adjust the bypass valve to set rotameter flow at 100 LPH.
- Switch on the compressed air source and adjust the air regulator to set supply air pressure at @ 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop.
- Select product Temperature Control Trainer (311A)
- Select Yokogawa (UT35A)
- Click Continue >> Connect >> Select Experiment
- Select P Mode and click Start
- Keep the set point to 40%. (Set point should be 10% more than inlet water temperature) Change output mode to Manual. Adjust output value so as to match the process value with set point and apply this output value as bias value to the controller. Adjust the proportional band to 50%.
- Switch the controller to auto mode.
- Apply step change to set point, step change should be of 2 to 3 % and observe the response.
- Switch the controller to Manual mode. Decrease proportional band to half of the previous value & then shift controller to Auto mode. With each decrease, obtain a new response of the step change. Ensure that the set point changes are around the same operating point (@ 2-3% only).
- Using trial and error approach find a value of proportional band so that the response to a step change has at most one overshoot and one undershoot.
- Set the controller to the settings obtained in the above step and wait for the system to reach at steady state.

3. Study of Proportional- Integral controller

- Switch on electric supply. Switch on Mains.
- Switch on the pump and adjust the bypass valve to set rotameter flow at 100 LPH.
- Switch on the compressed air source and adjust the air regulator to set supply air pressure at @ 2 kg/cm^2
- Switch on the computer.
- Double click on Apex Process Trainers icon on the desktop.
- Select product Temperature Control Trainer (311A)
- Select Yokogawa (UT35A)
- Click Continue >> Connect >> Select Experiment
- Select PI Mode and click Start
- Adjust the process value by changing the output of controller in manual mode to a particular pressure (set point =40%).
- Set the proportional band estimated in Proportional control. Set derivative time to 0 sec and integral time 1000 sec, which will cut off the derivative action and widen the effect of integral action.
- Allow the process to reach at steady state. Record the steady state error.
- Switch the controller to manual mode. Reduce the integral time to 2 -3% of the previous value.
- Switch to Auto mode and apply step change to the set point. Note the response of the system.
- Using trial and error, find out an integral time, which gives satisfactory response to the step change in set point.

<u>Observations</u> (PI Mode)

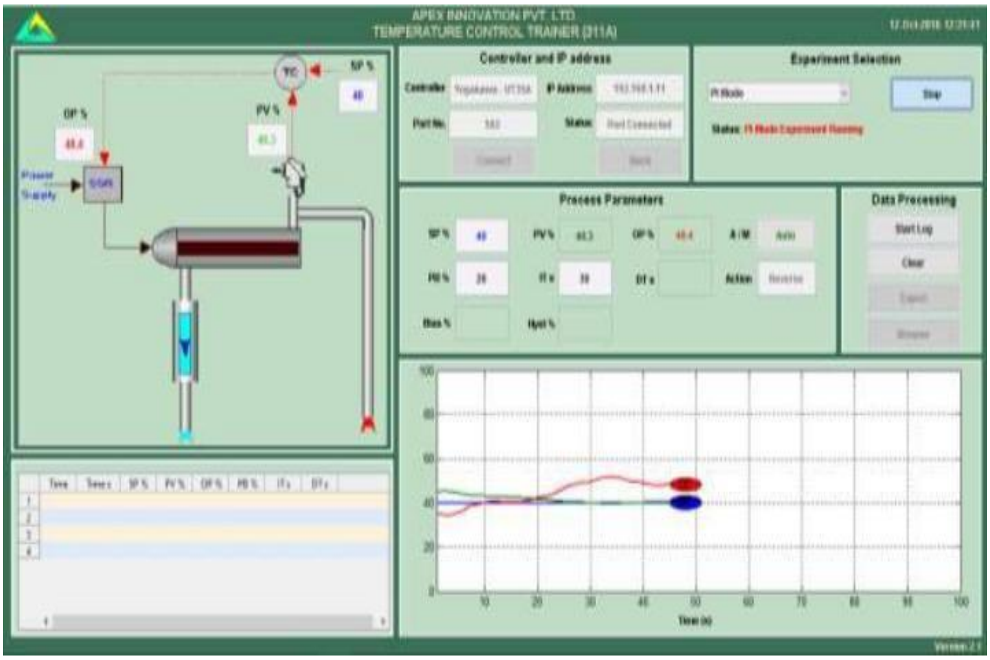

Fig. 2.4 PI response

<u>Observations</u> (PD Mode)

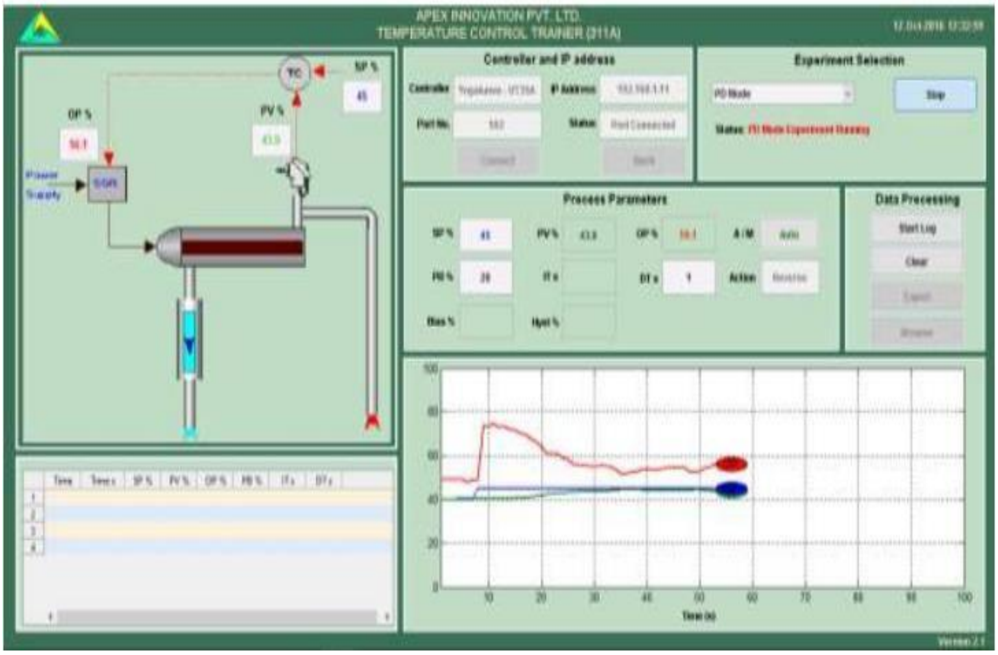

Fig. 2.5 PD response

4. Study of proportional derivative controller

- Switch on electric supply. Switch on Mains.
- Switch on the pump and adjust the bypass valve to set rotameter flow at 100 LPH.
- Switch on the compressed air source and adjust the air regulator to set supply air pressure at @ 2 kg/cm^2
- Switch on the computer >> Double click on Apex_Process_Trainers icon on the desktop.
- Select product Temperature Control Trainer (311A)>>Yokogawa (UT35A)
- Click Continue >> Connect >> Select Experiment
- Select PD Mode and click Start
- Select PD controller. Set the proportional band estimated from Proportional control (P only). Start with derivative time=0 and integral time=6000 sec., which will cut off the derivative action and widen the effect of integral action.
- Set the set point to desired value (@40%). Allow the process to reach at steady state. Note the response of the system.
- Switch the controller to manual mode Increase the derivative time by 1 sec. Switch to Auto mode and apply step change to the set point by 2 to 3%. Note the response of the system.
- Increase the derivative time gradually and observe the process response for step change.

5. Study of proportional integral derivative controller

- Switch on electric supply. Switch on Mains.
- Switch on the pump and adjust the bypass valve to set rotameter flow at 100 LPH.
- Switch on the compressed air source and adjust the air regulator to set supply air pressure at @ 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop.
- Select product Temperature Control Trainer (311A)>> Yokogawa (UT35A)
- Click Continue >> Connect >> Select Experiment
- Select PID Mode and click Start • Switch the controller to manual mode.
- Change the proportional band to the value that estimated in proportional controller. Set integral time and derivative time based on the responses in previous experiments.
- Change the controller to Auto mode. Apply step change by 2 to 3% to the set point and observe the response of the process
- Change the proportional band, integral time, derivative time and observe the response of the process for step change for each change in setting.

Observations **(PID Mode)**

Compare the steady state response of the PID controller with P, PI and PD controller obtained in the above experiment.

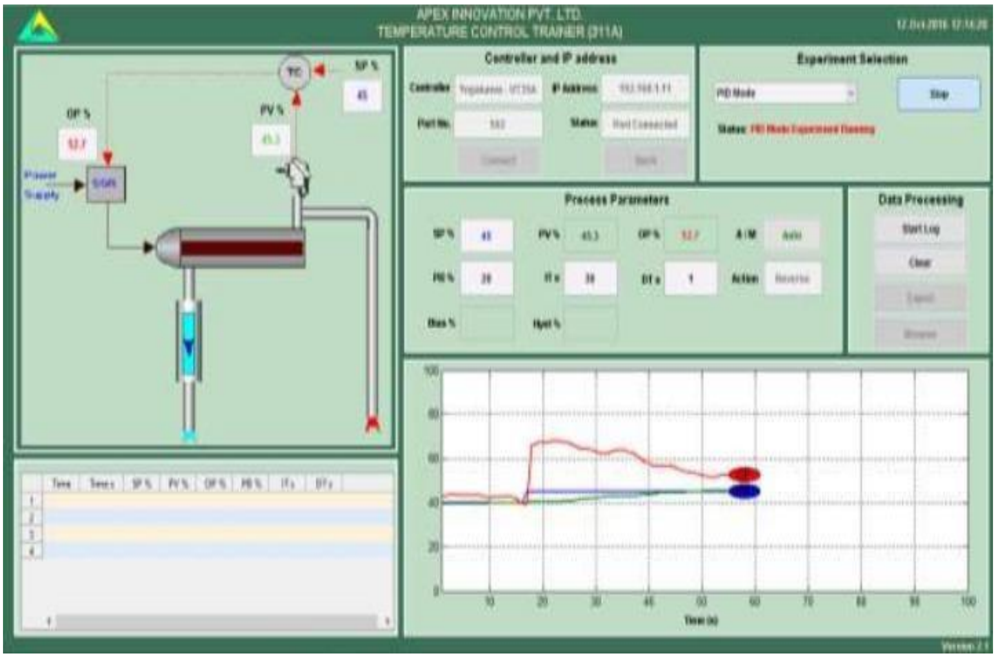

Fig. 2.6 PID response

Result

The performance of P, PI, PD and PID controllers are studied for temperature control and the response curves are plotted.

EXPERIMENT NO. 3

FLOW CONTROL USING P, PI, PD AND PID CONTROLLERS- STUDY OF OUTPUT RESPONSE

Aim

To study the performance of P, PI, PD and PID controllers in a Flow control system.

Apparatus required

Flow Control trainer

Theory

Fig. 3.1 shows the block diagram of a closed loop control system. The function of the controller is to receive the measured output signal, which is to be compared with the set point to produce the actuating signal in such a way as to bring the output to the desired value. The input to the controller is the error signal which is the defined as the difference between the measured output signal and set point. The basic feedback controllers are given below.

1. Proportional controller

Proportional controller produces a signal that is proportional to the error e(t). This action may be expressed as, $P(t) = K_C\, e(t) + P_S$, where P_S is controller bias signal which is a constant, K_c is gain, p(t) is output and e(t) is error. The P controller is described by K_C or equivalently by proportional band (PB), where $PB = 100/K_C$. P controller produces an oscillatory response with overshoot which always produces offset.

2. Proportional- Derivative controller

Proportional Derivative Controller is represented as Controller O/P, P(t) = $K_c\, e(t) + K_C \tau_d \frac{de(t)}{dt} + P_S$

,where τd is the derivative time constant and 'e' and 'P'are functions of time. Here the response exhibits a smaller overshoot and smaller oscillations compared to P controller. The offset is also is less than that of P controller.

3. Proportional- Integral Controller

This mode of controller is represented as :

Controller O/P, P(t)= $K_c\, e(t) + \frac{K_C}{\tau_I} \int_0^t e(t)dt + P_S$,where τ_I is the integral time constant and 'e' and'P' are functions of time. PI controller eliminates offset. The peak overshoot is same as that of P controller and the settling time is relatively large.

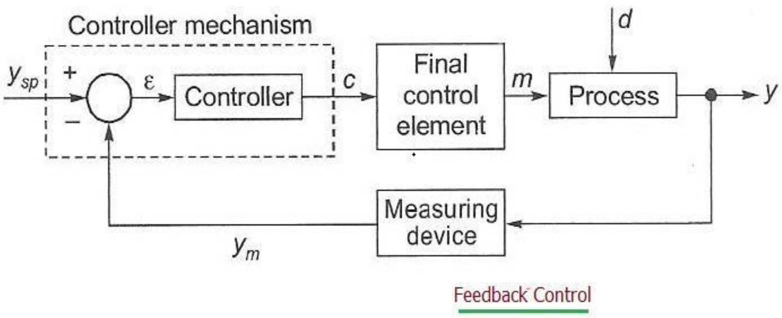

Fig. 3.1 Block Diagram of a closed loop control system

Note: For component specific problems refer Components' Manual

Problems	Possible causes / remedies
Incorrect flow reading	• Air trap in pressure signal line to flow transmitter • Choked pressure signal connections from orifice to flow transmitter due to scaling in water. • Reversed High-Low pressure signal connections from orifice to the flow transmitter
Control valve does not operate	• Valve diaphragm leakage/breakage • Faulty I/P converter • No output from Controller
I/P converter does not work	• Insufficient supply air pressure • Faulty electrical input signal • Clogged orifice
No communication with computer	• Check communication settings for IP addresses of computer and controller. Default setting computer 192.168.1.2 and controller 192.168.1.12

Table 3.1 Troubleshooting

Product	Flow control trainer
Product code	312A
Differential pressure transmitter	Make Yokogawa, Model EJA110E-JMS5J-912NN, Calibration range 0-200 (SQ RT) mm H2O, Output square root
Digital indicating controller	Make Yokogawa, Model UT35A-002-11-00 with Ethernet communication
I/P converter	Make Control air inc, Type T500-AC, Input 4-20 mA DC, output 3-15 psig, end connection 1/4 NPT
Control valve	Make Pneucon, Type globe 2 way, Model 119, size 1/2"x1/8", Screwed end(F), Body CCS, Trim SS, Travel 14.3, CV=0.63, Air to CLOSE, Spring range 0.2-1, actuator 12 sq inch.
Rotameter	Make Eureka, Model MG 11, Range 10-100 lph, Connection ¼" BSP back, screwed, Packing PTFE + Silicon
Pump	Model HQB 4500, Head max. 4.5m, Output 5000 lph, Watts 100, Volts 220-240 AC, 50Hz.
Air filter regulator	Make Airmatic, Model MB10-02-1-PAP-PD (Alu body, Polycarbonate bowl, G1/4 BSP, Range 0-2 Kg/cm^2, Relieving, 25M Plastic element, Bunan diaphragm.
Pressure gauge	Make Wika, Dia.2.5", Gly. filled, Brass internls, S.S. casing, Range 0-2.5 Kg/cm^2 and 0-35 PSI, 1/4"BSP (M) back connection without bracket.
Pressure gauge	Make Wika, Dia.2.5", Gly. filled, Brass internls, S.S. casing, Range 0-7 Kg/cm^2 and 0-100PSI, 1/4"BSP (M) back connection without bracket.

Table 3.2 Details of Equipment Used

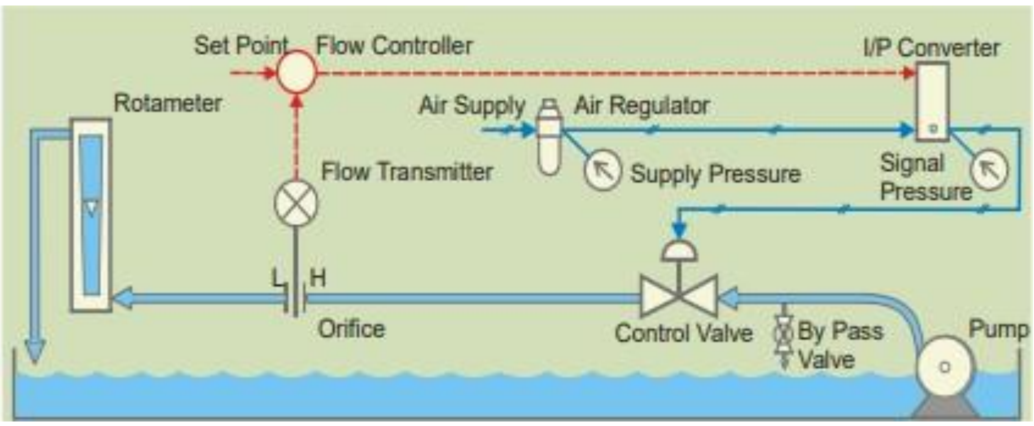

Fig. 3.2 Flow Control System Diagram

4. Proportional- Integral- Derivative Controller

PID Controller is represented as Controller O/P, $P(t) = K_c\, e(t) + \frac{K_c}{\tau_I} \int_0^t e(t)dt + K_c \tau_d \frac{de(t)}{dt} + P_S$,

where 'e' and 'P' are functions of τ_I time. The response has lower overshoot and returns to set point more quickly.

Trainer Kit 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 to 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 Ethernet port for monitoring the process in SCADA mode.

Product	Flow control trainer
Product code	312A
Type of control	SCADA
Control unit	Digital indicating controller with Ethernet communication
Communication	Ethernet
Differential pressure transmitter	Type Capacitance, two wire, Range 0–200 mm, Output 4–20 mA sq.root
I/P converter	Input 4-20mA, Output 3-15 psig, make Control Air
Control valve	Type: Pneumatic; Size: 1/4", Input: 3–15 psig, Air to close
Rotameter	10-100 LPH
Pump	Fractional horse power, type submersible
Supply tank	SS304
Flow measurement	Orifice meter
Air filter regulator	Range 0-2.5 kg/cm^2
Pressure gauge	Range 0-2.5 kg/cm^2(1No), Range 0-7 kg/cm^2(1No)
Overall dimensions	550Wx480Dx525H mm
Optional	Mini Compressor

Table 3.3 Specifications

Procedure

1. Study of open loop response (Manual Control)

- Switch on electric supply. Switch on Mains.
- Switch on the pump and adjust the bypass valve to set rotameter flow at 100 LPH.
- Switch on the compressed air source and adjust the air regulator to set supply air pressure at @ 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop.
- Select product Flow Control Trainer (312A)
- Select Yokogawa (UT35A)
- Click Continue
- Click Connect
- Click on Select Experiment.
- Select Open Loop and click Start
- Close the control valve by increasing the controller output to 100%.
- Apply the step change by 10% to controller output and wait for process value to reach the steady state value.
- Repeat the above step until the controller output reaches to minimum 0%.
- From the above data, note the output required for maintaining the flow at desired set points.

2. Study of Proportional Controller

- Switch on electric supply. Switch on Mains.
- Switch on the pump and adjust the bypass valve to set rotameter flow at 100 LPH.
- Switch on the compressed air source and adjust the air regulator to set supply air pressure at @ 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop.
- Select product Flow Control Trainer (312A)
- Select Yokogawa (UT35A)
- First click Continue, then Connect and then click on Select Experiment
- Select P Mode and click Start
- Adjust the process value by switching the controller to manual mode to a particular flow (say 50 %) on the screen and apply output of the controller as bias value. Change the proportional band to 100%.
- Switch the controller to auto mode and apply step change of 10% to set point.
- Compare the steady state response of the PD controller with PI controller obtained in the previous experiment. Note the effect of noisy flow measurement on the derivative action
- Switch the controller to manual mode. Decrease proportional band to half of the previous value. With each decrease, obtain a new response of the step change. Ensure that the set point changes are around the same operating point (Say 50%).
- Using trial and error approach find a value of proportional band so that the response to a step change has at most one overshoot and one undershoot.
- Set the controller to the settings obtained in the above step and wait for the system to reach at steady state.

<u>Observations</u> (Manual Mode)

Controller output (in %)	Process Value (%)

<u>Observations</u> (P Mode)

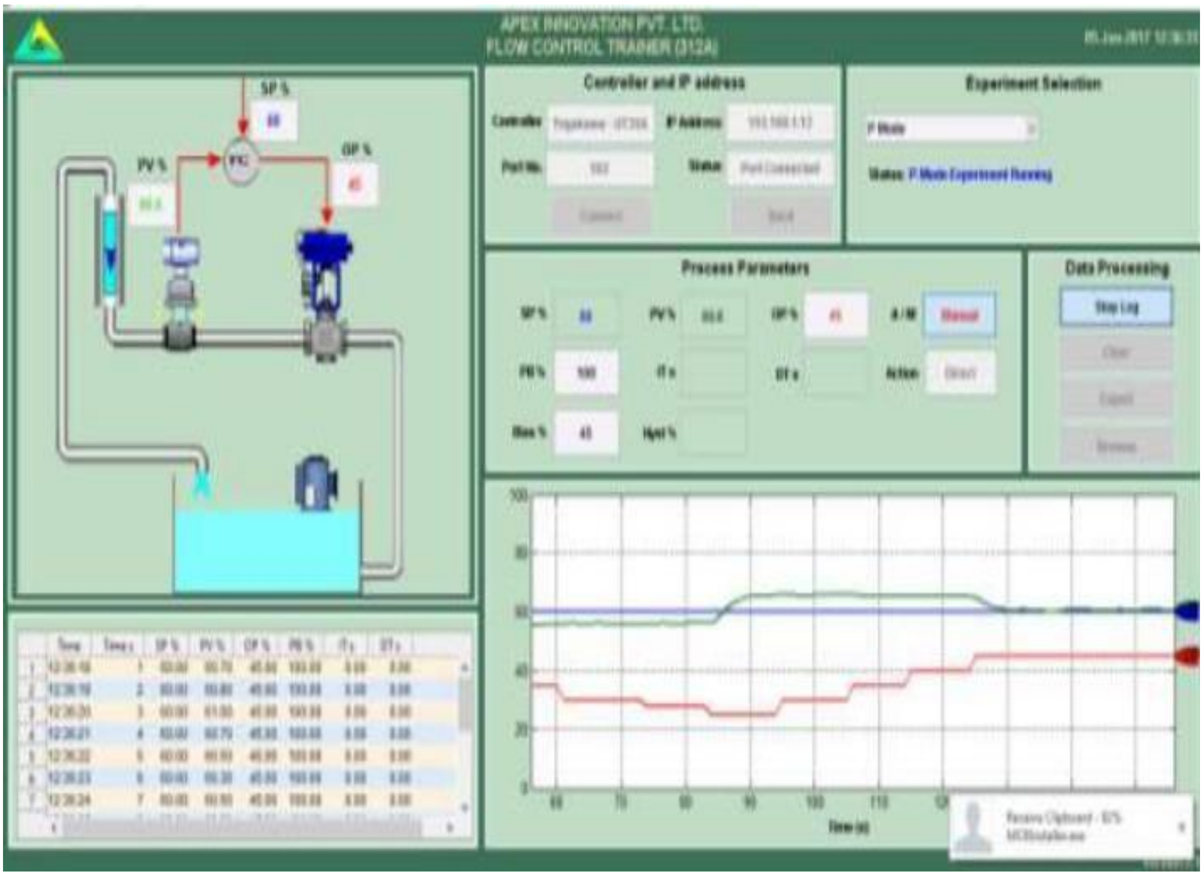

Fig 3.3 P response

- Observe steady state error decreases as proportional band decreases.
- Observe the effect of very low proportional band values (system works as on-off control).
- Observe the response of the system at load change. Load change can be given by slightly varying the flow rate with the help of rotameter manually.

<u>Observations</u> (PI Mode)

Observe the effect of reducing integral time on offset and on the response of the process

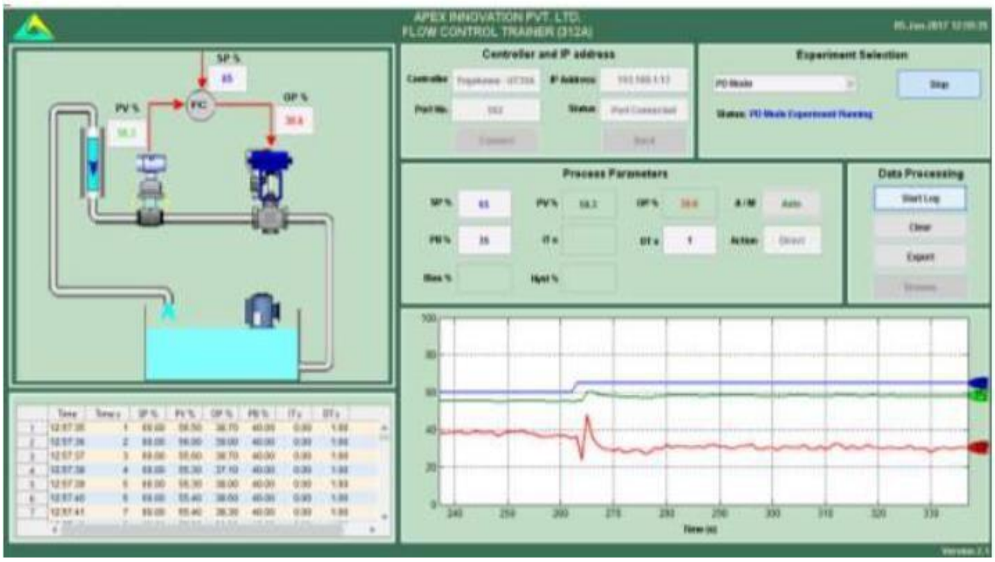

Fig. 3.4 PI response

<u>Observations</u> (PD Mode)

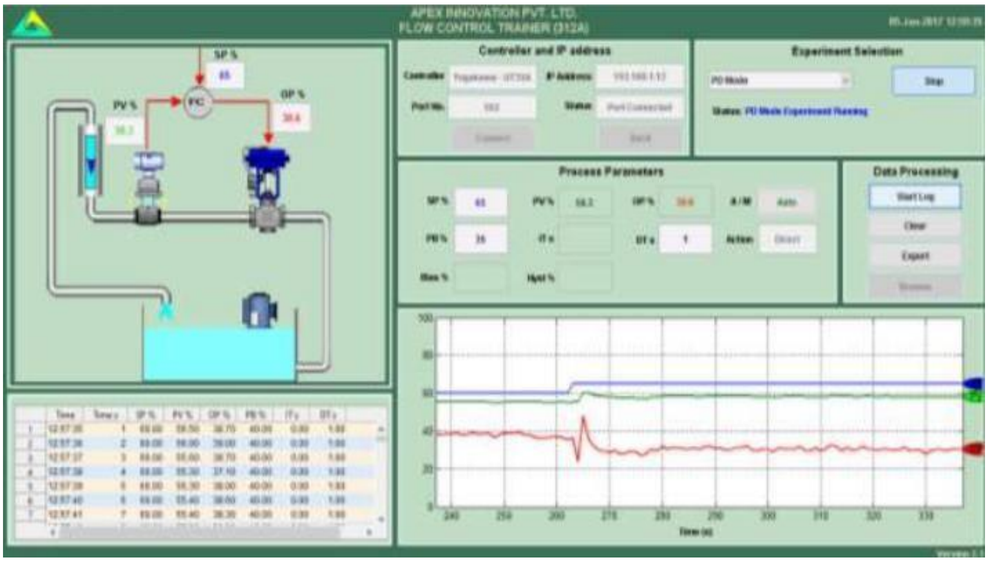

Fig. 3.5 PD response

Compare the steady state response of the PD controller with PI controller obtained in the previous experiment. Note the effect of noisy flow measurement on the derivative action.

3. Study of Proportional Integral Controller

- Switch on electric supply. Switch on Mains.
- Switch on the pump and adjust the bypass valve to set rotameter flow at 100 LPH.
- Switch on the compressed air source and adjust the air regulator to set supply air pressure at @ 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop.
- Select product Flow Control Trainer (312A)
- Select Yokogawa (UT35A)
- Click Continue
- Click Connect
- Click on Select Experiment
- Select PI Mode and click Start
- Set the proportional band estimated in Proportional control. Set derivative time to 0 sec and integral time 6000 sec, which will cut off the derivative action and widen the effect of integral action.
- Set the set point to desired flow value (@70%). Allow the process to reach at steady state. Record the steady state error.
- Switch the controller to manual mode. Reduce the integral time to half of the previous value. Switch to Auto mode and apply step change (+/- 10%) to the set point. Note the response of the system.
- Repeat above step to observe the effect of changes in Integral setting.

4. Study of Proportional Derivative Controller

- Switch on electric supply. Switch on Mains.
- Switch on the pump and adjust the bypass valve to set rotameter flow at 100 LPH.
- Switch on the compressed air source and adjust the air regulator to set supply air pressure at @ 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop.
- Select product Flow Control Trainer (312A)
- Select Yokogawa (UT35A)
- Click Continue >> Click Connect >>Click on Select Experiment
- Select PD Mode and click Start
- Set the proportional band estimated from Proportional control (P only) Set derivative time to 0 and integral time=6000 sec.
- Set the set point to desired value (@70%). Allow the process to reach at steady state. Note the response of the system.
- Switch the controller to manual mode Increase the derivative time by 1 sec. Switch to Auto mode and apply step change to the set point by 5 to 10%. Note the response of the system.
- Increase the derivative time gradually and observe the process response for step change.

5. Study of proportional integral derivative controller
- Switch on electric supply. Switch on Mains.
- Switch on the pump and adjust the bypass valve to set rotameter flow at 100 LPH.

- Switch on the compressed air source and adjust the air regulator to set supply air pressure at @ 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop.
- Select product Flow Control Trainer (312A)
- Select Yokogawa (UT35A)
- Click Continue >> Click Connect >>Click on Select Experiment
- Select PID Mode and click Start • Switch the controller to manual mode.
- Change the proportional band to the value that estimated in proportional controller. Set integral time and derivative time based on the responses in previous experiments.
- Adjust the set point to @ 50 %. Switch the controller to auto mode. Apply step change of 10%. Observe the process response.
- Change the proportional band, integral time, derivative time and observe the response of the process for step change for each change in setting.

<u>Observations</u> (PID Mode)

Compare the steady state response of the PID controller with P. PI and PD controller obtained in the above experiment.

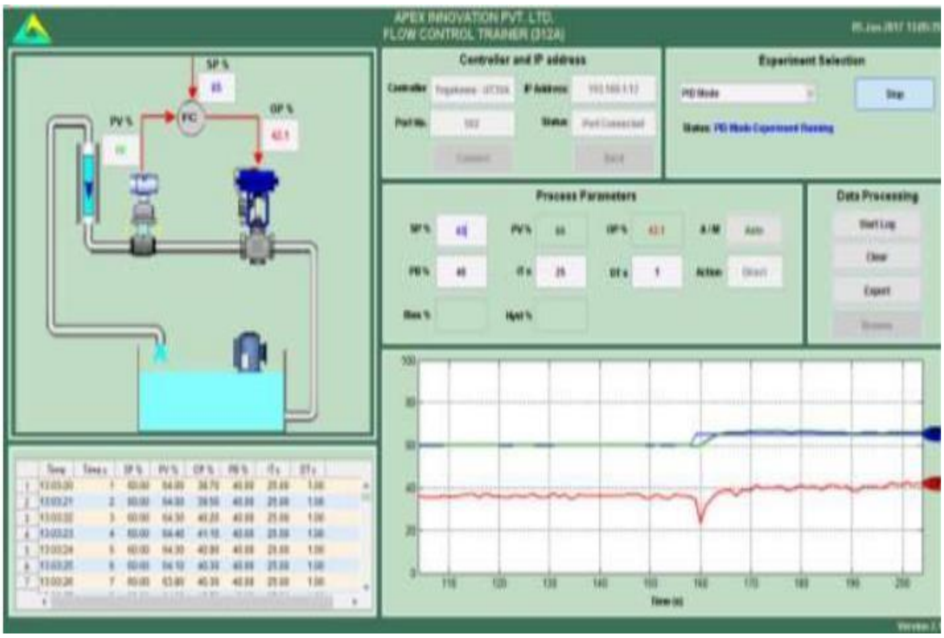

Fig. 3.6 PID response

<u>Result</u>

The performance of P, PI, PD and PID controllers are studied for flow control and the response curves are plotted.

EXPERIMENT NO. 4
LIQUID LEVEL CONTROL USING P, PI, PD AND PID CONTROLLERS- STUDY OF OUTPUT RESPONSE

Aim

To study the performance of P, PI, PD and PID controllers in a level control system.

Apparatus required

Level Control trainer

Theory

Fig 4.1 shows the block diagram of a closed loop control system. The function of the controller is to receive the measured output signal, which is to be compared with the set point to produce the actuating signal in such a way as to bring the output to the desired value. The input to the controller is the error signal which is the defined as the difference between the measured output signal and set point. The basic feedback controllers are given below.

1. Proportional controller

Proportional controller produces a signal that is proportional to the error e(t). This action may be expressed as, $P(t) = K_C\, e(t) + P_S$, where P_S is controller bias signal which is a constant, K_c is gain, P(t) is output and e(t) is error. The P controller is described by K_C or equivalently by proportional band (PB), where $PB = 100/K_C$. P controller produces an oscillatory response with overshoot which always produces offset.

2. Proportional- Derivative controller

Proportional Derivative Controller is represented as:

Controller O/P, P(t) = $K_c\, e(t) + K_C \tau_d \frac{de(t)}{dt} + P_S$, where τ_d is the derivative time constant and 'e' and 'P' are functions of time. Here the response exhibits a smaller overshoot and smaller oscillations compared to P controller. The offset is also is less than that of P controller.

3. Proportional- Integral Controller

This mode of controller is represented as Controller O/P, P(t) = $K_c\, e(t) + K_C \tau_d \frac{de(t)}{dt} + P_S$,

where τ_I is the integral time constant and 'e' and'P' are functions of time. PI controller eliminates offset. The peak overshoot is same as that of P controller and the settling time is relatively large.

4. Proportional- Integral- Derivative Controller

PID Controller is represented as :

Controller O/P, P(t) = $K_c\, e(t) + \frac{K_c}{\tau_I} \int_0^t e(t)dt + K_C \tau_d \frac{de(t)}{dt} + P_S$ where 'e' and 'P' are functions of

τ_I time. The response has lower overshoot and returns to set point more quickly.

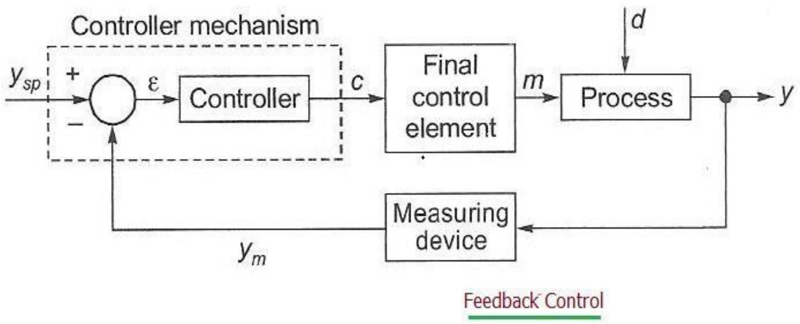

Fig. 4.1 Block Diagram of a closed loop control system

Note: For component specific problems refer Components' Manuals

Problems	Possible causes / remedies
Control valve does not operate	• Valve diaphragm leakage/breakage • Faulty I/P converter • No output from Controller
I/P converter does not work	• Insufficient supply air pressure • Faulty electrical input signal • Clogged orifice
No communication with computer	• Check communication settings for IP addresses of computer and controller. Default setting computer 192.168.1.2 and controller 192.168.1.13

Table 4.1 Troubleshooting

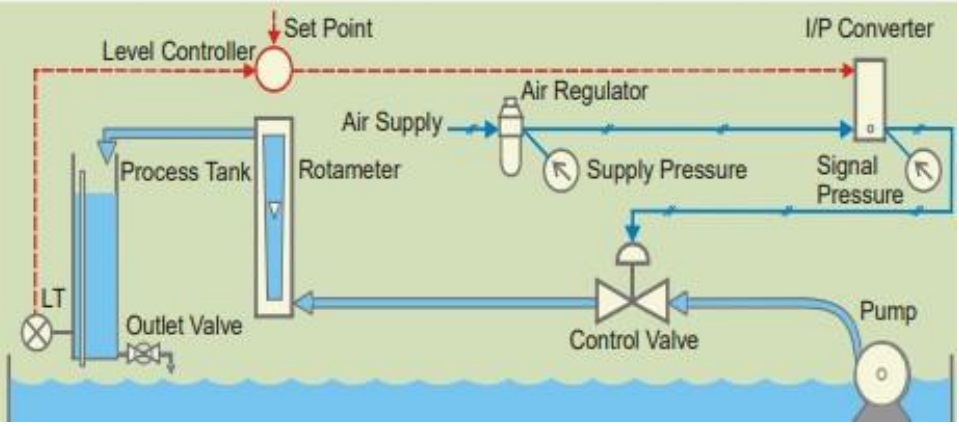

Fig. 4.2 Level Control System

Product	Level control trainer
Product code	313A
Level transmitter	Make WIKA, Model SL-1-A-MAG-ND-ZA4Z-ZZZ and output 4-20 mA, supply 10-30 VDC, conn. 1/2"NPT (M), Range 0-25 mbar.
Digital indicating controller	Make Yokogawa, Model UT35A-002-11-00 with Ethernet communication
I/P converter	Make Control air inc, Type T500-AC, Input 4-20 mA DC, output 3-15 psig, end connection 1/4 NPT
Control valve	Make Pneucon, Type globe 2 way, Model 119, size 1/2"x1/8", Screwed end(F), Body CCS, Trim SS, Travel 14.3, CV=0.63, Air to CLOSE, Spring range 0.2-1, actuator 12 sq inch.
Rotameter	Make Eureka, Model MG 11, Range 10-100 lph, Connection ¼" BSP back, screwed, Packing PTFE + Silicon
Pump	Model HQB 4500, Head max. 4.5m, Output 5000 lph, Watts 100, Volts 220-240 AC, 50Hz.
Air filter regulator	Make Airmatic, Model MB10-02-1-PAP-PD(Alu body, Polycarbonate bowl, G1/4 BSP, Range 0-2 Kg/cm^2, Relieving, 25M Plastic element, Bunan diaphragm.
Pressure gauge	Make Wika, Dia.2.5", Gly. filled, Brass internls, S.S. casing, Range 0-2.5 Kg/cm^2 and 0-35 PSI, 1/4"BSP (M) back connection without bracket.
Pressure gauge	Make Wika, Dia.2.5", Gly. filled, Brass internls, S.S. casing, Range 0-7 Kg/cm^2 and 0-100PSI, 1/4"BSP (M) back connection without bracket.

Table 4.2 Details of Equipment Used

Trainer Kit 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 to 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 table-top mounting. The controller can be connected to computer through Ethernet port for monitoring the process in SCADA mode.

Product	Level control trainer
Product code	313A
Type of control	SCADA
Control unit	Digital indicating controller with Ethernet communication
Communication	Ethernet
Level transmitter	Type Electronic, two wire, Range 0–250 mm, Output 4–20mA
I/P converter	Input 4-20mA, Output 3-15 psig
Control valve	Type: Pneumatic; Size: 1/4", Input: 3–15 psig, Air to close, Characteristics: linear
Rotameter	10-100 LPH
Pump	Fractional horse power, type submersible
Process tank	Transparent, Acrylic, with 0-100% graduated scale
Supply tank	SS304
Air filter regulator	Range 0-2.5 kg/cm^2
Pressure gauge	Range 0-2.5 kg/cm^2(1No), Range 0-7 kg/cm^2(1No)

Table 4.3 Specifications

Procedure

1. Study of open loop response (Manual Control)

- Switch on electric supply. Switch on Mains.
- Switch on the pump and adjust the bypass valve to set rotameter flow at 100 LPH.
- Switch on the compressed air source and adjust the air regulator to set supply air pressure at @ 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop.
- Select product Level Control Trainer (313A) and select Yokogawa (UT35A)
- Click Continue>>Click Connect >> Select Experiment.
- Select Open Loop and click Start

- Open the control valve fully by decreasing the controller output to 0%. (Click on Auto, change it to Man then change OP to 0%)
- Adjust the tank drain valve such that the tank level shall remain between 90 and 100% Change the controller to Auto mode
- Close the control valve by increasing the controller output to 100%.
- Apply the step change by 10% to controller output and wait for process value to reach the steady state value.
- Repeat the above step until the controller output reaches to minimum 0%.
- From the above data, note the output required for maintaining the Level at desired set points.

(Manual Mode)

Controller output (in %)	Process Value (%)

Set the output of the controller to the noted value and at steady state, apply the load change to the process. Load change can be given by slightly varying the drain valve. Observe new steady state process value.

<u>Observations</u> (P Mode)

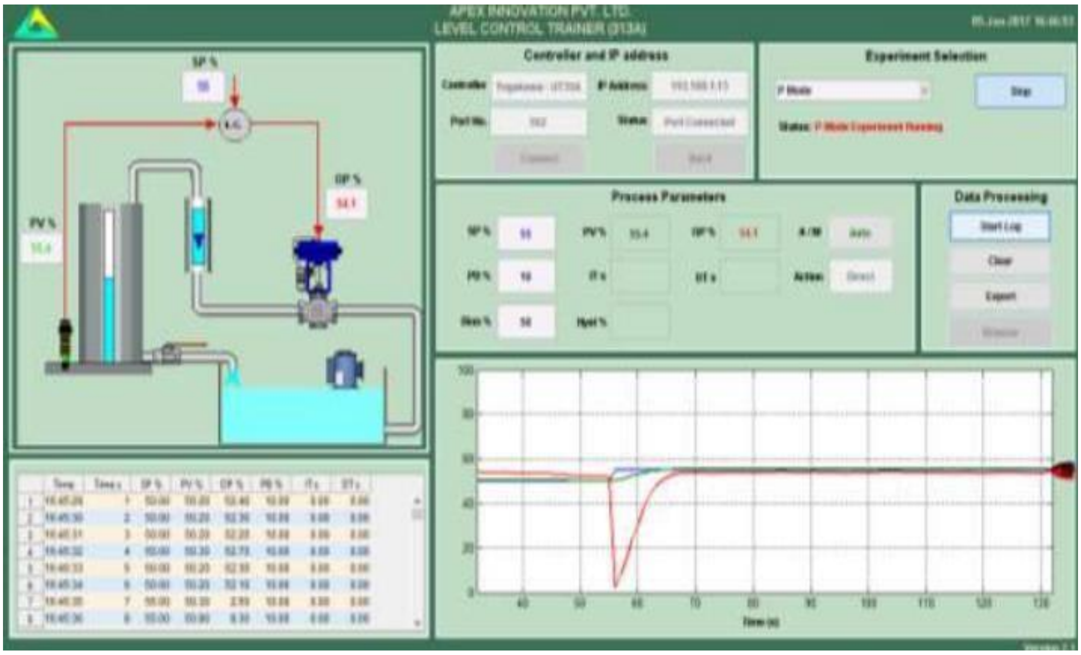

Fig. 4.3 P response

Observe the effect of very low proportional band values (system works as ON- OFF control)

2. Study of Proportional Controller

- Switch on electric supply. Switch on Mains.
- Switch on the pump and adjust the bypass valve to set rotameter flow at 100 LPH.
- Switch on the compressed air source and adjust the air regulator to set supply air pressure at @ 2 kg/cm^2 >>Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop.
- Select product Level Control Trainer (313A)>>Select Yokogawa (UT35A)
- Click Continue >> Connect >> Select Experiment. Select P Mode and click Start
- Open the control valve fully by decreasing the controller output to 0%. (Click on Auto, change it to Manual then change OP to 0%)
- Adjust the tank drain valve such that the tank level shall remain between 90 and 100% Change the controller to Auto mode.
- Adjust the process value by switching the controller to manual mode to a particular flow (say 50 %) on the screen and apply output of the controller as bias value. Change the proportional band to 100%.
- Switch the controller to auto mode and apply step change of 10% to set point.
- Switch the controller to manual mode. Decrease proportional band to half of the previous value. With each decrease, obtain a new response of the step change. Ensure that the set point changes are around the same operating point (Say 50%).
- Using trial and error approach find a value of proportional band so that the response to a step change has at most one overshoot and one undershoot.
- Set the controller to the settings obtained in the above step and wait for the system to reach at steady state.

3. Study of Proportional- Integral Controller

- Switch on electric supply. Switch on Mains.
- Switch on the pump and adjust the bypass valve to set rotameter flow at 100 LPH.
- Switch on the compressed air source and adjust the air regulator to set supply air pressure at @ 2 kg/cm^2
- Switch on the computer and double click on Apex_Process_Trainers icon on the desktop.
- Select product Level Control Trainer (313A) and select Yokogawa (UT35A)
- Click Continue >> Connect >> Select Experiment
- Select PI Mode and click Start
- Open the control valve fully by decreasing the controller output to 0%. (Click on Auto, change it to Man then change OP to 0%)
- Adjust the tank drain valve such that the tank level shall remain between 90 and 100% Change the controller to Auto mode
- Set the proportional band estimated in Proportional control. Set derivative time to 0 sec and integral time 6000 sec, which will cut off the derivative action and widen the effect of integral action.
- Set the set point to desired flow value (@50%). Allow the process to reach at steady state. Record the steady state error.
- Switch the controller to manual mode. Reduce the integral time to half of the previous value. Switch to Auto mode and apply step change (+/- 10%) to the set point. Note the response of the system.
- Repeat above step to observe the effect of changes in Integral setting.

(PI Mode)

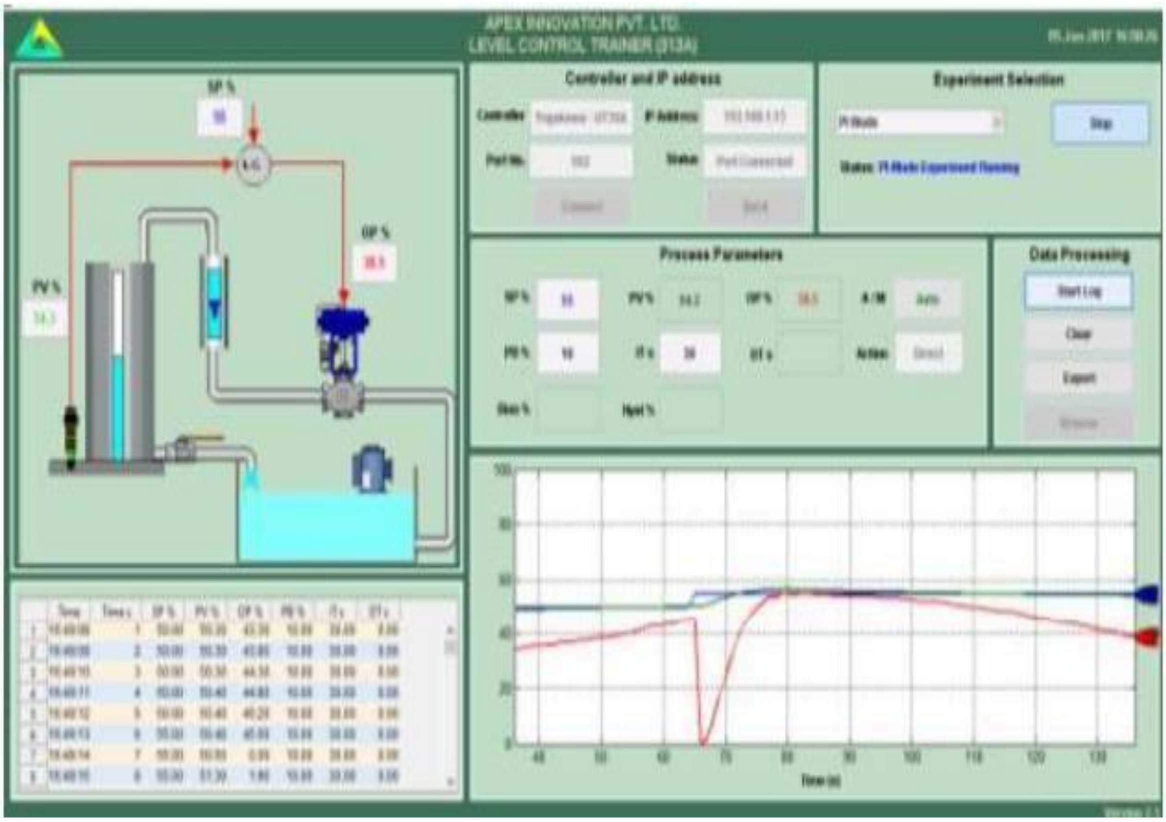

Fig. 4.4 PI response

Observe the effect of reducing integral time on the response of the process.

4. Study of Proportional- Derivative controller

- Switch on electric supply. Switch on Mains.
- Switch on the pump and adjust the bypass valve to set rotameter flow at 100 LPH.
- Switch on the compressed air source and adjust the air regulator to set supply air pressure at @ 2 kg/cm^2
- Switch on the computer >> Double- click on Apex_Process_Trainers icon on the desktop.
- Select product Level Control Trainer (313A) >> Yokogawa (UT35A)
- Click Continue >> Connect >> Select Experiment
- Select PD Mode and click Start
- Open the control valve fully by decreasing the controller output to 0%. (Click on Auto, change it to Man then, change OP to 0%)
- Adjust the tank drain valve such that the tank level shall remain between 90 and 100% Change the controller to Auto mode

(PD Mode)

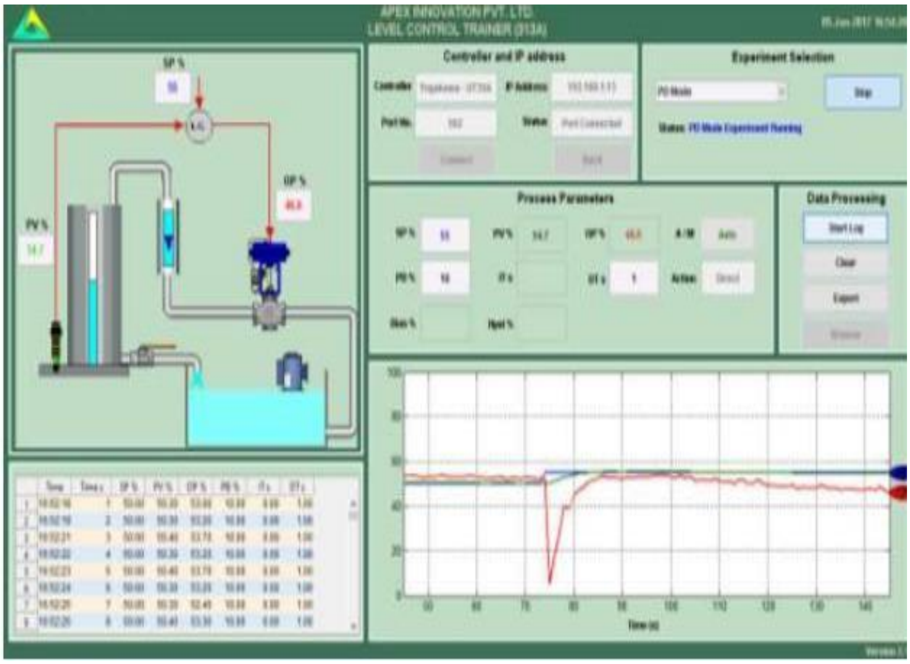

Fig. 4.5 PD response

5. Study of Proportional- Integral- Derivative Controller

- Switch on electric supply. Switch on Mains.
- Switch on the pump and adjust the bypass valve to set rotameter flow at 100 LPH.
- Switch on the compressed air source and adjust the air regulator to set supply air pressure at @ 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop.
- Select product Level Control Trainer (313A) >> Yokogawa (UT35A)
- Click Continue >> Connect >> Select Experiment
- Select PID Mode and click Start
- Open the control valve fully by decreasing the controller output to 0%. (Click on Auto, change it to Man then change OP to 0%)
- Adjust the tank drain valve such that the tank level shall remain between 90 and 100% Change the controller to Auto mode
- Switch the controller to manual mode.
- Change the proportional band to the value that estimated in proportional controller. Set integral time and derivative time based on the responses in previous experiments.
- Adjust the set point to @ 50 %. Switch the controller to auto mode. Apply step change of 10%. Observe the process response.
- Change the proportional band, integral time, derivative time and observe the response of the process for step change for each change in setting.

(PID Mode)

Compare the steady state response of the PID controller with P. PI and PD controller obtained in the above experiment.

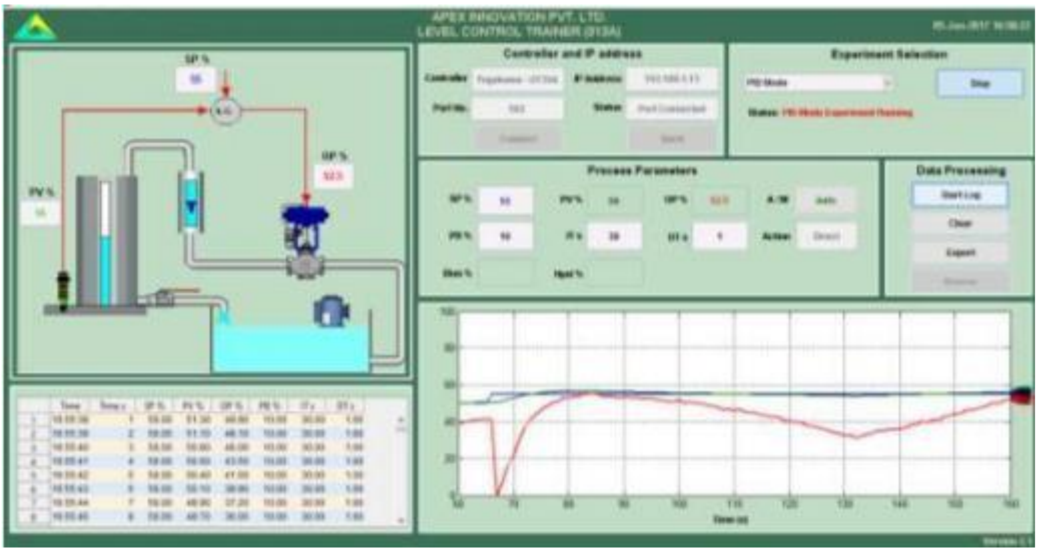

Fig. 4.6 PID response

- Set the proportional band estimated from Proportional control (P only). Set derivative time to 0 and integral time=6000 sec.
- Set the set point to desired value (@70%). Allow the process to reach at steady state. Note the response of the system.
- Switch the controller to manual mode Increase the derivative time by 1 sec. Switch to Auto mode and apply step change to the set point by 5 to 10%. Note the response of the system.
- Increase the derivative time gradually and observe the process response for step change.

<u>Result</u>

The performance of P, PI, PD and PID controllers are studied for level control and the response curves are plotted.

EXPERIMENT NO. 5
PRESSURE CONTROL USING P, PI, PD AND PID CONTROLLERS- STUDY OF OUTPUT RESPONSE

Aim

To study the performance of P, PI, PD and PID controllers in a pressure control system.

Apparatus Required

Pressure Control System trainer kit

Theory

Fig 5.1 shows the block diagram of a closed loop control system. The function of the controller is to receive the measured output signal, which is to be compared with the set point to produce the actuating signal in such a way as to bring the output to the desired value. The input to the controller is the error signal which is the defined as the difference between the measured output signal and set point. The basic feedback controllers are given below.

1. Proportional controller

Proportional controller produces a signal that is proportional to the error e(t). This action may be expressed as, $P(t) = K_C\, e(t) + P_S$, where P_S is controller bias signal which is a constant, K_c is gain, P(t) is output and e(t) is error. The P controller is described by K_C or equivalently by proportional band (PB), where PB = $100/K_C$. P controller produces an oscillatory response with overshoot which always produces offset.

2. Proportional- Derivative controller

Proportional Derivative Controller is represented as:

Controller O/P, P(t) = $K_c\, e(t) + K_C \tau_d \frac{de(t)}{dt} + P_S$, where τ_d is the derivative time constant and 'e' and 'P' are functions of time. Here the response exhibits a smaller overshoot and smaller oscillations compared to P controller. The offset is also is less than that of P controller.

3. Proportional- Integral Controller

This mode of controller is represented as :

Controller O/P, P(t) = $K_c\, e(t) + \frac{K_C}{\tau_I} \int_0^t e(t)dt + P_S$, where τ_I is the integral time constant and 'e' and 'P' are functions of time. PI controller eliminates offset. The peak overshoot is same as that of P controller and the settling time is relatively large.

4. Proportional- Integral- Derivative Controller

PID Controller is represented as Controller O/P, P(t) = K_c e (t) + $\frac{K_C}{\tau_I} \int_0^t e(t)dt + K_C \tau_d \frac{de(t)}{dt} + P_S$

where 'e' and 'P' are functions of $\tau_I$time. The response has lower overshoot and returns to set point more quickly.

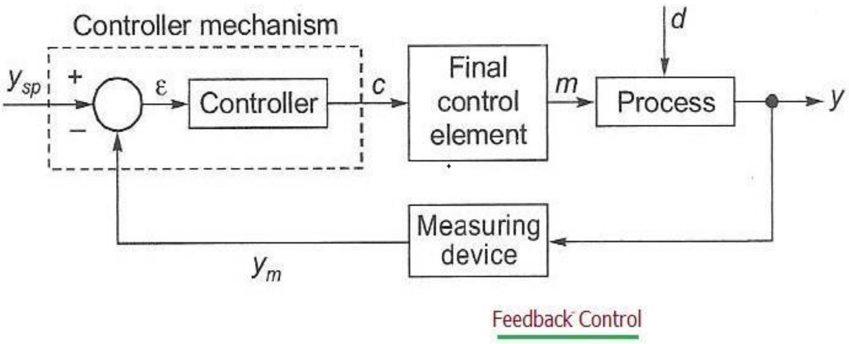

Fig 5.1 Block Diagram of a closed loop control system

Note: For component specific problems refer components' manual

Problems	Possible causes / remedies
Control valve does not operate	• Faulty I/P converter • No output from Controller
I/P converter does not work	• Insufficient supply air pressure • Faulty electrical input signal
No communication with computer	• Check communication settings for IP addresses of computer and controller. Default setting computer 192.168.1.2 and controller 192.168.1.14

Table 5.1 Troubleshooting

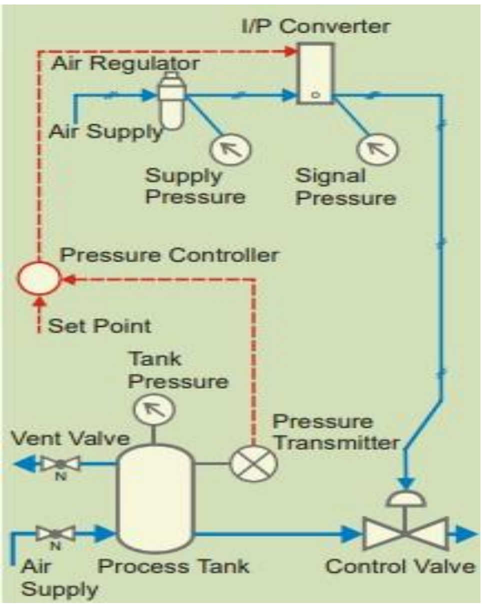

Fig. 5.2 Pressure Control system

Product	Pressure control trainer
Product code	314A
Pressure Transmitter	Make Wika, model Eco, Output 4-20mA (2 wire), Supply 24VDC, range 0-2.5 bar, process conn. 1/4"BSP(male)
Digital indicating controller	Make Yokogawa, Model UT35A-002-11-00 with Ethernet communication
I/P converter	Make Control air inc, Type T500-AC, Input 4-20 mA DC, output 3-15 psig, end connection 1/4 NPT
Control valve	Make Pneucon, Type globe 2 way, Model 119, size 1/2"x1/8", Screwed end(F), Body CCS, Trim SS, Travel 14.3, CV=0.1, Air to CLOSE, Spring range 0.2-1, actuator 12 sq inch.
Air filter regulator	Make Airmatic, Model MB10-02-1-PAP-PD (Alu body, Polycarbonate bowl, G1/4 BSP, Range 0-2 Kg/cm^2, Relieving, 25M Plastic element, Bunan diaphragm.
Pressure relief valve	Make Airmatic, Model MRV-022, Range 0-3.5Kg/cm^2, Size G1/4, Alluminium.
Pressure gauge	Make Wika, Dia.2.5", Gly. filled, Brass internls, S.S. casing, Range 0-2.5 Kg/cm^2 and 0-35 PSI, 1/4"BSP (M) back connection without bracket.
Pressure gauge	Make Wika, Dia.2.5", Gly. filled, Brass internls, S.S. casing, Range 0-7 Kg/cm^2 and 0-100PSI, 1/4"BSP (M) back connection without bracket.

Table 5.2 Details of Equipment Used

Trainer Kit 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 Ethernet port for monitoring the process in SCADA mode.

Product	Pressure control trainer
Product code	314A
Type of control	SCADA
Control unit	Digital indicating controller with Ethernet communication
Communication	Ethernet
Pressure Transmitter	Type Two wire, Range 0–2.5 bar, Output 4–20 mA
I/P converter	Input 4-20mA, Output 3-15 psig
Control valve	Type: Pneumatic; Size: 1/4", Input: 3–15 psig, Air to close, Characteristics: linear
Process tank	Pressure vessel, MS
Air filter regulator	Range 0-2.5 kg/cm^2
Pressure gauge	Range 0-2.5 kg/cm^2(1No), Range 0-7 kg/cm^2(2Nos)

Table 5.3 Specifications

Procedure

1. Study of open loop response (Manual Control)

- Switch on electric supply. Switch on Mains.
- Switch on the pump and adjust the bypass valve to set rotameter flow at 100 LPH.
- Switch on the compressed air source and adjust the air regulator to set supply air pressure at @ 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop, select pro Pressure Control Trainer (314A)
- Select Yokogawa (UT35A)
- Click Continue
- Click Connect
- Click on Select Experiment.
- Select Open Loop and click Start
- Close the control valve by increasing the controller output to 100%.
- Apply the step change by 10% to controller output and wait for process value to reach the steady state value.
- Repeat the above step until the controller output reaches to minimum 0%.

Observations (Manual Mode)

Controller output (in %)	Process Value (%)

From the above data, note the output required for maintaining the process at desired set points. (For particular vent valve opening).

Set the output of the controller to the noted value and at steady state apply the load change to the process. Load change can be given by slightly varying the vent valve. Observe new steady state process value.

2. Study of Proportional Controller

- Switch on electric supply. Switch on Mains.
- Switch on the pump and adjust the bypass valve to set rotameter flow at 100 LPH.
- Switch on the compressed air source and adjust the air regulator to set supply air pressure at @ 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop.
- Select product Pressure Control Trainer (314A) and select Yokogawa (UT35A)
- Click Continue >> Connect >> Select Experiment
- Select P Mode and click Start
- Open the control valve fully by decreasing the controller output to 0%. (Click on Auto, change it to Manual, then change OP to 0%)
- Adjust the tank drain valve such that the tank level shall remain between 90 and 100% Change the controller to Auto mode.
- Keep the set point to 60%. Change output mode to Manual. Adjust output value so as to match the process value with set point and apply this output value as bias value to the controller. Adjust the proportional band to 50%
- Switch the controller to auto mode and apply step change of 10% to set point.
- Switch the controller to Manual mode. Decrease proportional band to half of the previous value & then shift controller to Auto mode. With each decrease, obtain a new response of the step change. Ensure that the set point changes are around the same operating point (@ 5-10% only).
- Using trial and error approach find a value of proportional band so that the response to a step change has at most one overshoot and one undershoot.
- Set the controller to the settings obtained in the above step and wait for the system to reach at steady state.

(P Mode)

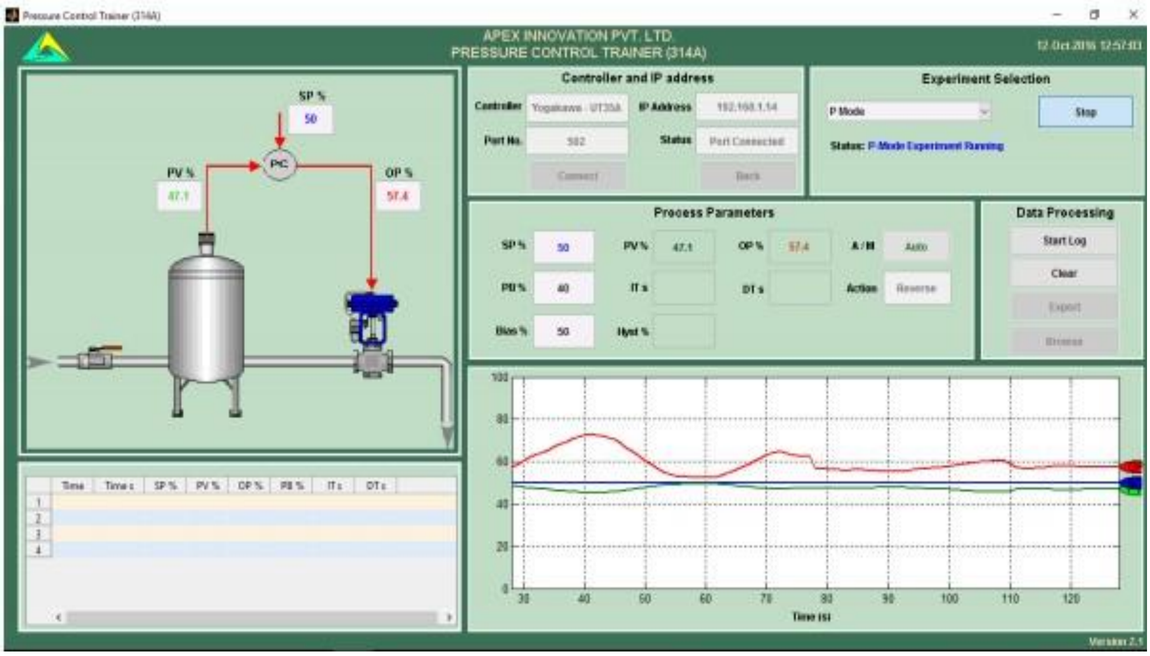

Fig. 5.3 P response

Observe steady state error decreases as proportional band decreases.
Observe the effect of very low proportional band values (system works in oscillatory mode).

3. Study of Proportional- Integral Controller

- Switch on electric supply. Switch on Mains.
- Switch on the pump and adjust the bypass valve to set rotameter flow at 100 LPH.
- Switch on the compressed air source and adjust the air regulator to set supply air pressure at @ 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop.
- Select product Pressure Control Trainer (314A) and select Yokogawa (UT35A)
- Click Continue >> Connect >> Select Experiment
- Select PI Mode and click Start
- Adjust the process value by changing the output of controller in manual mode to a particular pressure (set point =60%).
- Set the proportional band estimated in Proportional control. Set derivative time to 0 sec and integral time 1000 sec, which will cut off the derivative action and widen the effect of integral action.
- Set the set point to desired flow value (@60%). Allow the process to reach at steady state. Record the steady state error.
- Switch on the controller to manual mode. Reduce the integral time to half of the previous value. Switch to Auto mode and apply step change to the set point by 2 to 3%. Note the response of the system.
- Using trial and error, find out an integral time, which gives satisfactory response to the step change in set point.

(PI Mode)

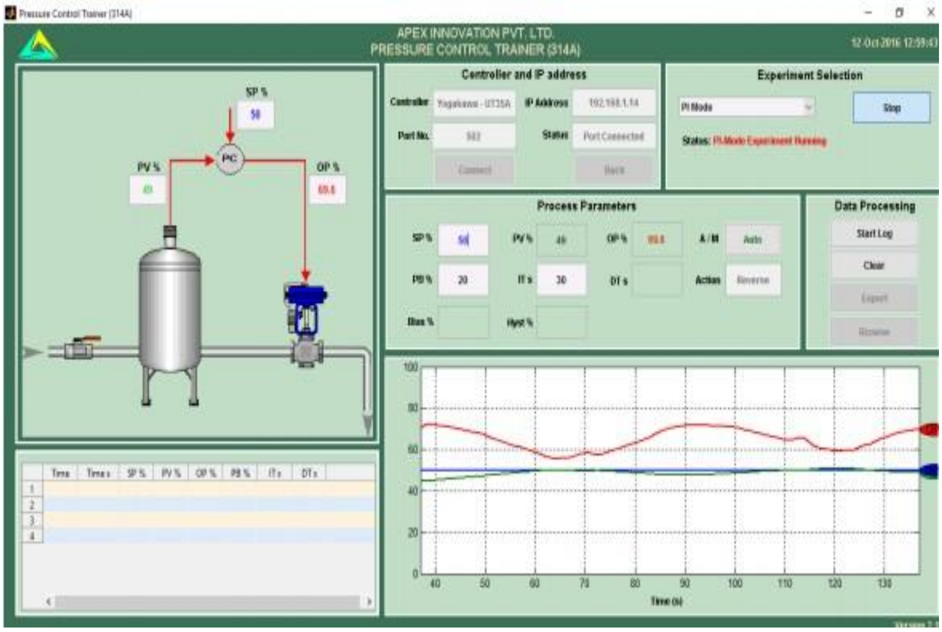

Fig. 5.4 PI response

Observe the effect of reducing integral time on the response of the process

4. Study of Proportional- Derivative Controller

- Switch on electric supply. Switch on Mains.
- Switch on the pump and adjust the bypass valve to set rotameter flow at 100 LPH.
- Switch on the compressed air source and adjust the air regulator to set supply air pressure at @ 2 kg/cm^2
- Switch on the computer >> Double click on Apex_Process_Trainers icon on the desktop.
- Select product Pressure Control Trainer (314A)>> Yokogawa (UT35A)
- Click Continue >> Connect >> Select Experiment
- Select PD Mode and click Start
- Select PD controller. Set the proportional band estimated from Proportional control (P only). Start with derivative time=0 and integral time=6000 sec., which will cut off the derivative action and widen the effect of integral action.
- Set the set point to desired value (@60%). Allow the process to reach at steady state. Note the response of the system.
- Switch the controller to manual mode Increase the derivative time by 1 sec. Switch to Auto mode and apply step change to the set point by 2 to 3%. Note the response of the system.
- Increase the derivative time gradually and observe the process response for step change.

Observations (PD Mode)

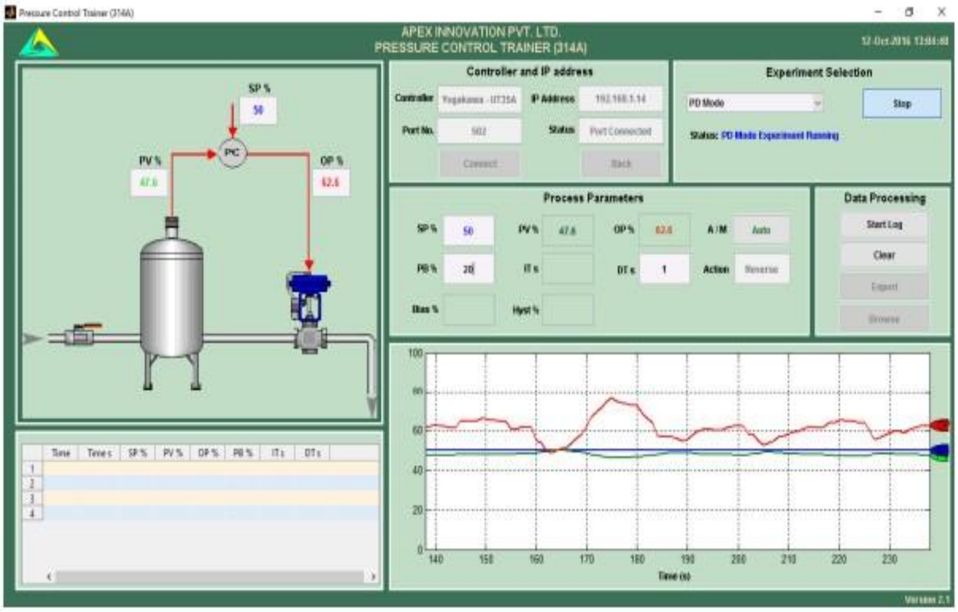

Fig. 5.5 PD response

Observe the effect of increasing derivative time. Also note that the process may show offset as effect of integral action is cut off.

5. Study of Proportional- Integral- Derivative Controller

- Switch on electric supply. Switch on Mains.
- Switch on the pump and adjust the bypass valve to set rotameter flow at 100 LPH.
- Switch on the compressed air source and adjust the air regulator to set supply air pressure at @ 2 kg/cm^2
- Switch on the computer.
- Double click on Apex_Process_Trainers icon on the desktop.
- Select product Pressure Control Trainer (314A) >> Yokogawa (UT35A)
- Click Continue >> Connect >> Select Experiment
- Select PID Mode and click Start
- Switch the controller to manual mode.
- Change the proportional band to the value that estimated in proportional controller. Set integral time and derivative time based on the responses in previous experiments.
- Change the controller to Auto mode. Apply step change by 2 to 3% to the set point and observe the response of the process.
- Change the proportional band, integral time, derivative time and observe the response of the process for step change for each change in setting.

Observations (PID Mode)

Compare the steady state response of the PID controller with P, PI and PD controller obtained in the above experiment.

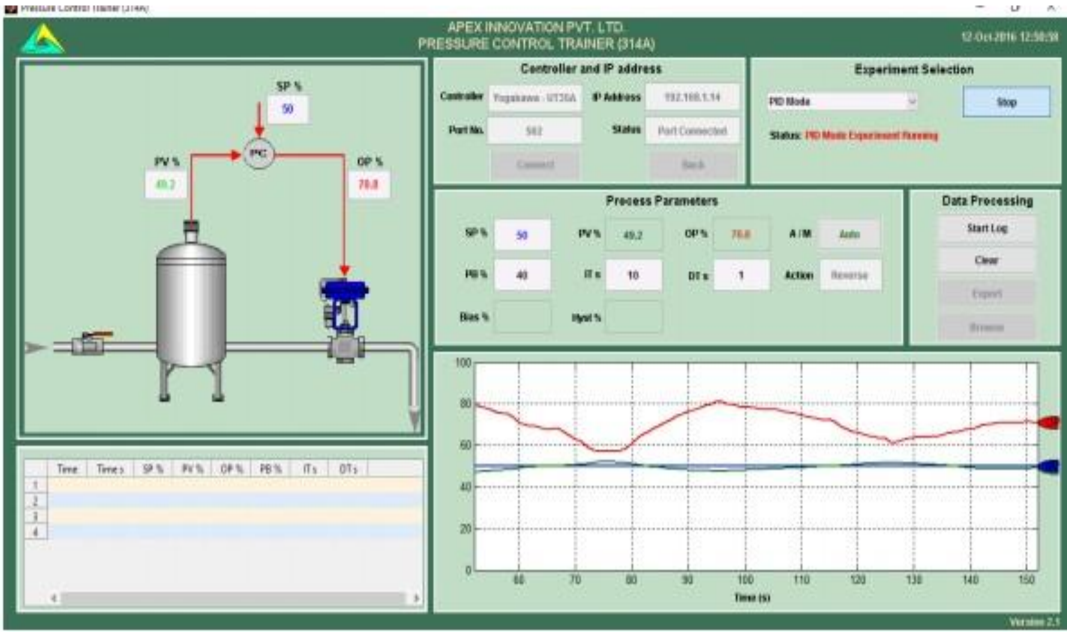

Fig. 5.6 PID response

Result

The performance of P, PI, PD and PID controllers are studied for Pressure control and the response curves are plotted.

EXPERIMENT NO. 6
CONTROLLER TUNING FOR VARIOUS PROCESSES USING ZIEGLER- NICHOLS RULE

Aim

To study and tune the parameters pressure, flow, level and temperature process stations using Ziegler Nichols method.

Apparatus Required

Flow, Level, Temperature, Pressure Process System Trainer kit

Theory

The Ziegler–Nichols tuning method is a heuristic method of tuning a PID controller. It was developed by John G. Ziegler and Nathaniel B. Nichols. It is performed by setting the I (integral) and *D* (derivative) gains to zero. The "P" (proportional) gain, is then increased (from zero) until it reaches the ultimate gain, at which the output of the control loop has stable and consistent oscillations and the oscillation period is used to set the P, I and D gains depending on the type of controller used. These 3 parameters are used to establish the correction u (t) from the error e (t) via the equation:

$$u(t) = K_p \left(e(t) + \frac{1}{T_i} \int_0^t e(\tau) d\tau + T_d \frac{de(t)}{dt} \right)$$

where,

Kp- Proportional Gain

Ki- Integral Gain

Kd— Derivative Gain

Ti- Reset Time or Integral time

Td- Rate time or derivative time

The proportional term in the controller generally helps in establishing system stability and improving the transient response while the derivative term is often used when it is necessary to improve the closed loop response speed even further. Conceptually the effect of the derivative term is to feed information in the rate of change of the measured variable into the controller action. The most important term in the controller is the integral term that introduces a pole at s=0 in the forward loop of the process. Ziegler Nichols Method is also called the **ultimate cycle method**. It is based on adjusting a closed loop until steady state oscillation occurred. Controller settings are then based on the conditions that generate cycling steps for tuning.