Department of Instrumentation & Control Engineering

Manipal Institute of Technology, Manipal

A Constituent Institute of Manipal Academy of Higher Education

MANIPAL-576104

CERTIFICATE

This is to certify that the Laboratory Manual for the lab titled Process Control Laboratory (ICE 3162) by Mr / Ms ______________________________________ (Reg. No:__________________) of Vth Semester, B.Tech of Instrumentation and Control Engineering for the academic year 2022 / 2023 has been submitted as per laboratory course requirements, which has been evaluated and duly certified.

Place:

Date: Lab In-Charge

ICE-3162 Process Control Lab [0-0-3-1]

Total number of Lab Sessions: 10

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References:

1. Curtis D. Johnson –Microprocessors in Process Control, PHI. 1993
2. George Stephanopoulos Chemical Process Control. 2005
3. Coughner Process Analysis & Control, Tata Mcgraw Hill. – 1991
4. Thomas Marlin - Process Control, Designing Processes and Control Systems for Dynamic Performance – 2nd Edition

HARDWARE & SOFTWARE IDENTIFICATION

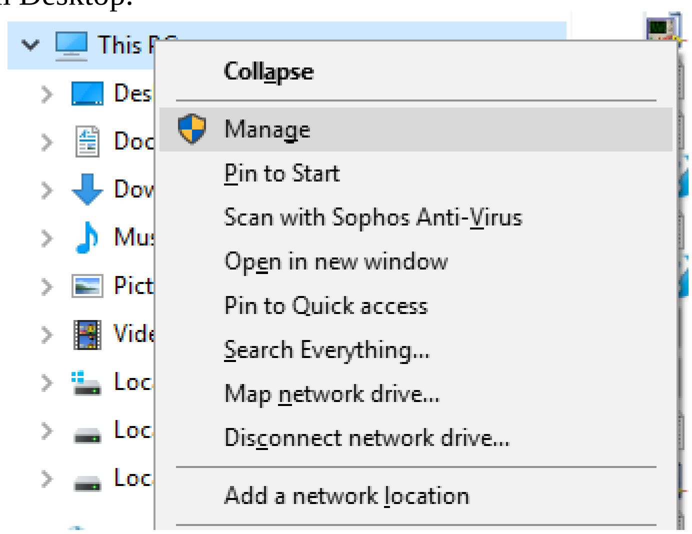
Hardware:

The Process Trainers, their product codes and controller name are tabulated below:

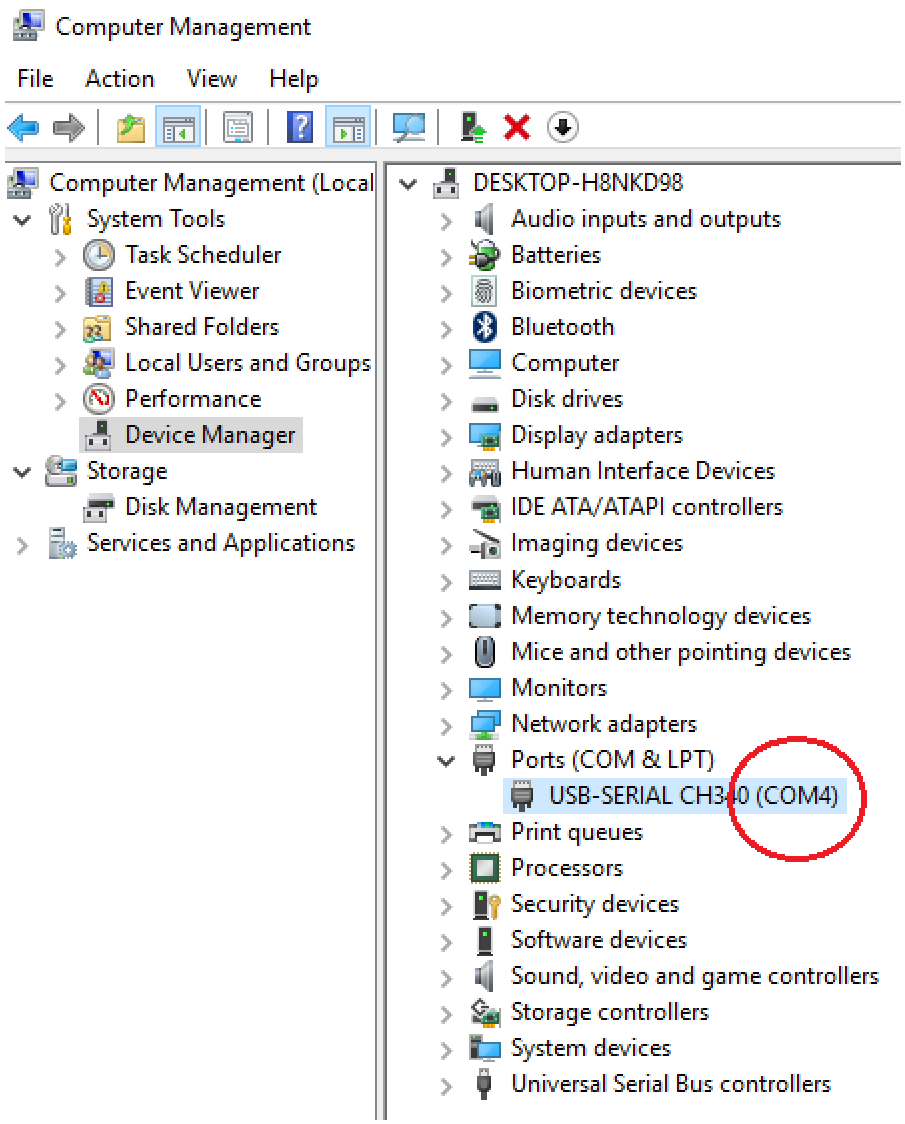
Sl. No.	Description	Hardware Product Code	Software Product Code	Controller
1.	Temperature Control Trainer	311A	ACE 104	Yokogawa UT32A
2.	Flow Control Trainer	312A	ACE 102	Yokogawa UT321E
3.	Level Control Trainer	313A	ACE 101	Yokogawa UT321E
4.	Pressure Control Trainer	314A	ACE 104	Delta DTB9696B
5.	Cascade Control Trainer	318A	ACE 106	Delta DVP EX2 PLC
6.	Multi Process Trainer	326A	ACE 108	ACE 2007 WiFi DAQ
7.	Nonlinear Process Trainer	331A	ACE 303	Delta DTB9696B

Device Connection:

1. Open 'Mange' by right clicking 'My Computer' or 'This PC' by opening Windows Explorer or from Desktop.



2. Select Device Manager ---> Ports (COM & LPT). Locate your device port No. (COM4 as shown below)

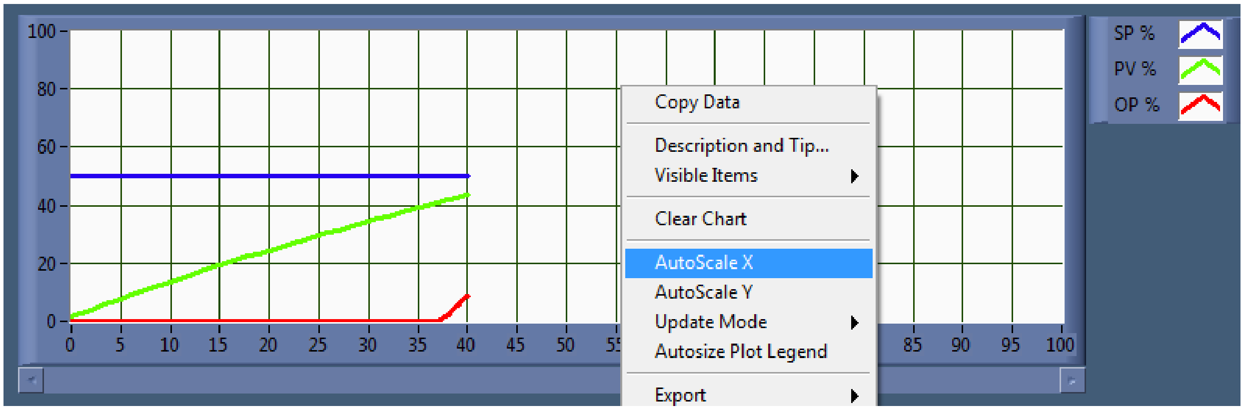


3. If no device is visible, ensure your communication cable is connected properly, check for polarity or driver software.

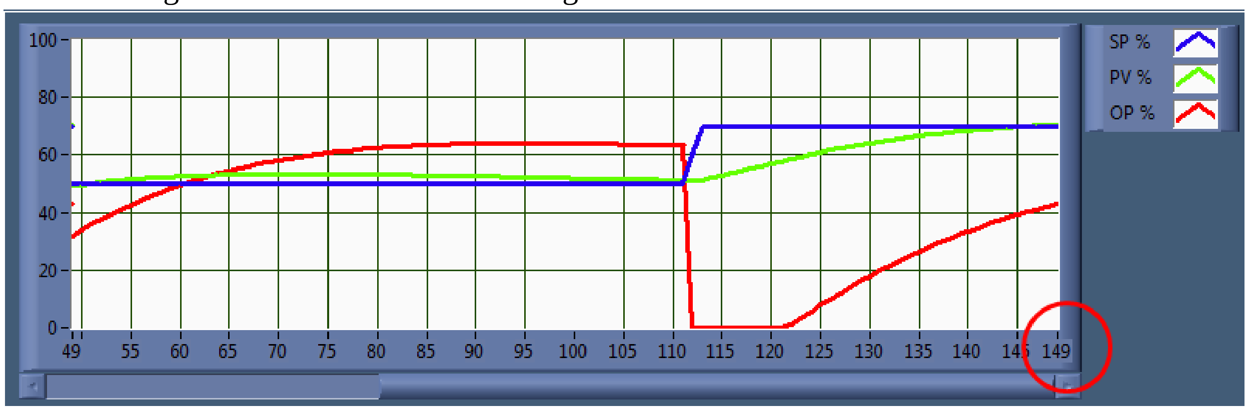
Software:

a) Features:

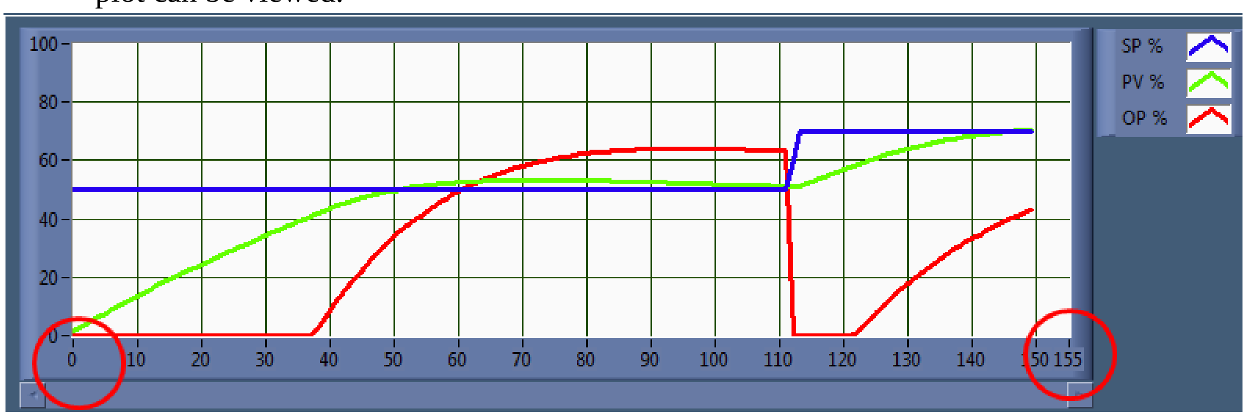
1. Graph axis control:
   - Right click on the graph and disable AutoScale X as shown below:



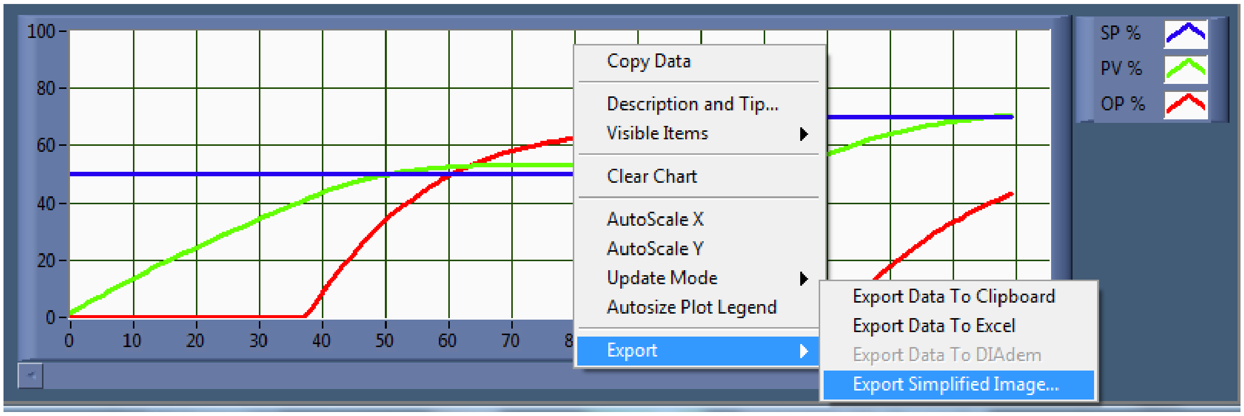
- Double click the left bottom axis value and change it to a new value. Then double click the right bottom axis value and change it to 0.



- The axis will be automatically readjusted to the new value as shown below and the entire plot can be viewed.

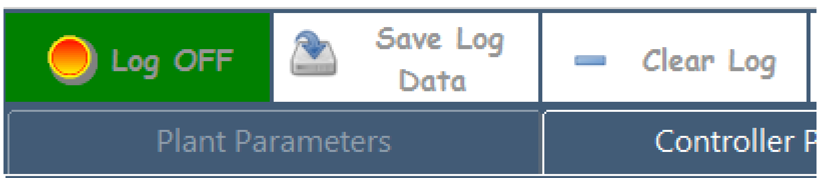


2. Export Graph:
   - The graph can be exported to a simplified image by right clicking on the graph as shown below:



- In the above case the graph background will be changed to white and scale will be converted to auto scale.
- The graph image as it is can be exported to an image file by clicking on the 'Export Graph' button on the menu bar.
- Graph data can exported to either excel or clipboard by clicking appropriate option as shown above.

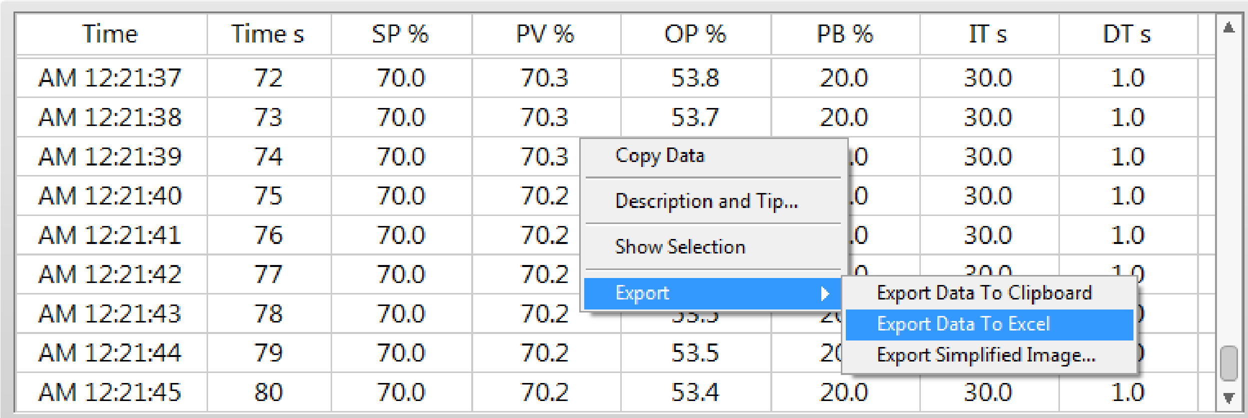
3. Log data:
   - The data can be logged from any point of time to any other time value using 'Log ON' button. Use the same button to stop log. A indicator will be turned on to indicate the log process is ON.



- The values will be displayed in the log table. Use 'Clear Log' to clear the data from Log table.

Time	Time s	SP %	PV %	OP %	PB %	IT s	DT s
AM 12:20:53	28	70.0	71.6	54.1	20.0	30.0	1.0
AM 12:20:54	29	70.0	71.6	54.2	20.0	30.0	1.0
AM 12:20:55	30	70.0	71.5	54.3	20.0	30.0	1.0
AM 12:20:56	31	70.0	71.5	54.4	20.0	30.0	1.0
AM 12:20:57	32	70.0	71.5	54.5	20.0	30.0	1.0
AM 12:20:58	33	70.0	71.5	54.6	20.0	30.0	1.0
AM 12:20:59	34	70.0	71.4	54.6	20.0	30.0	1.0
AM 12:21:00	35	70.0	71.4	54.7	20.0	30.0	1.0
AM 12:21:01	36	70.0	71.4	54.7	20.0	30.0	1.0

- The data can be exported by right click on the Log table ---> Export ---> Export Data To Excel or Export Data to Clipboard



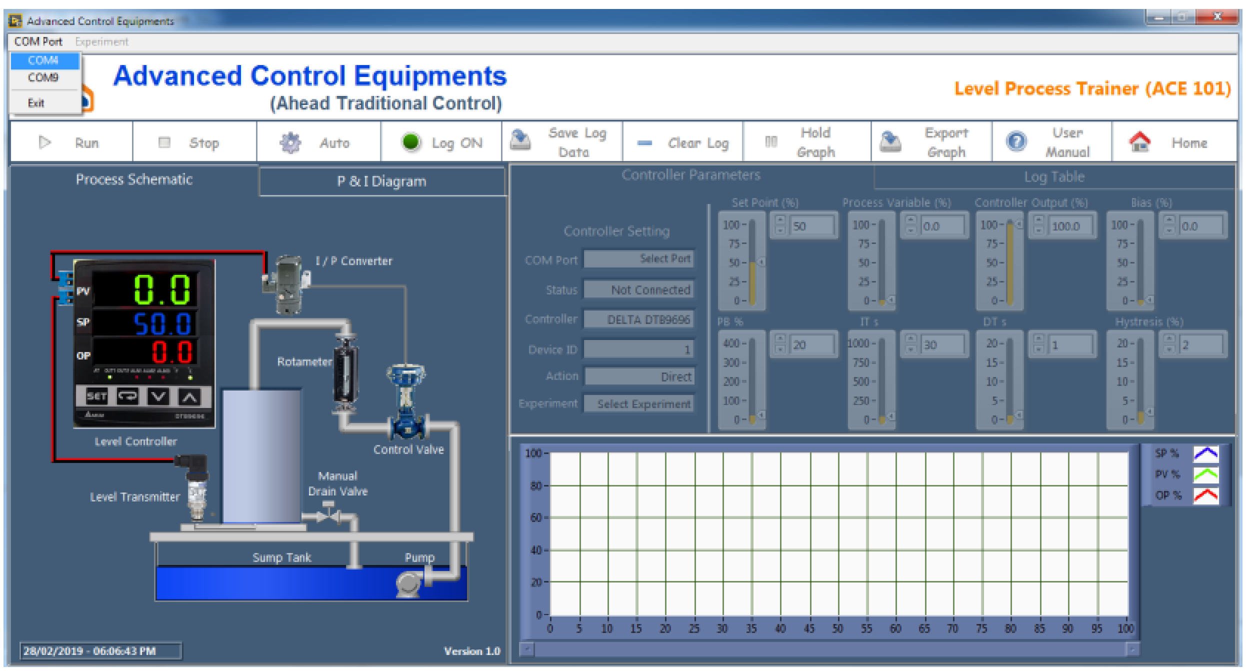
- Save Log Data will be used to export the data directly to excel.

b) Working with the software:

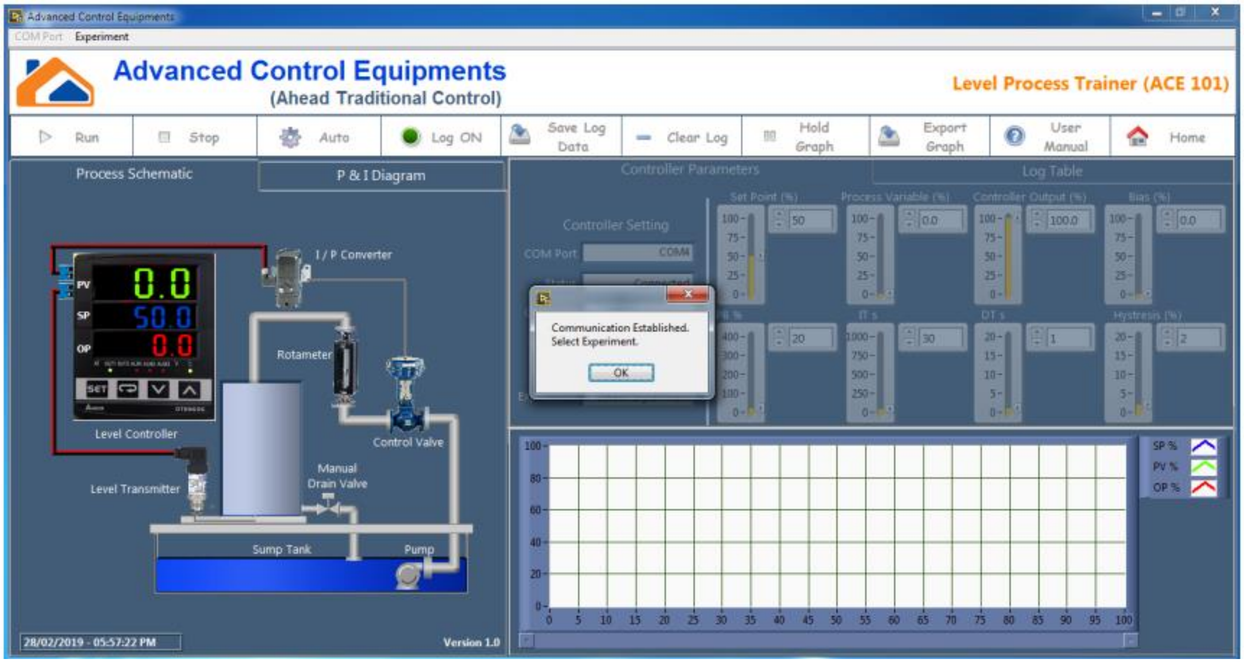
1. Select COM Port from the Menu Bar.

*Note:

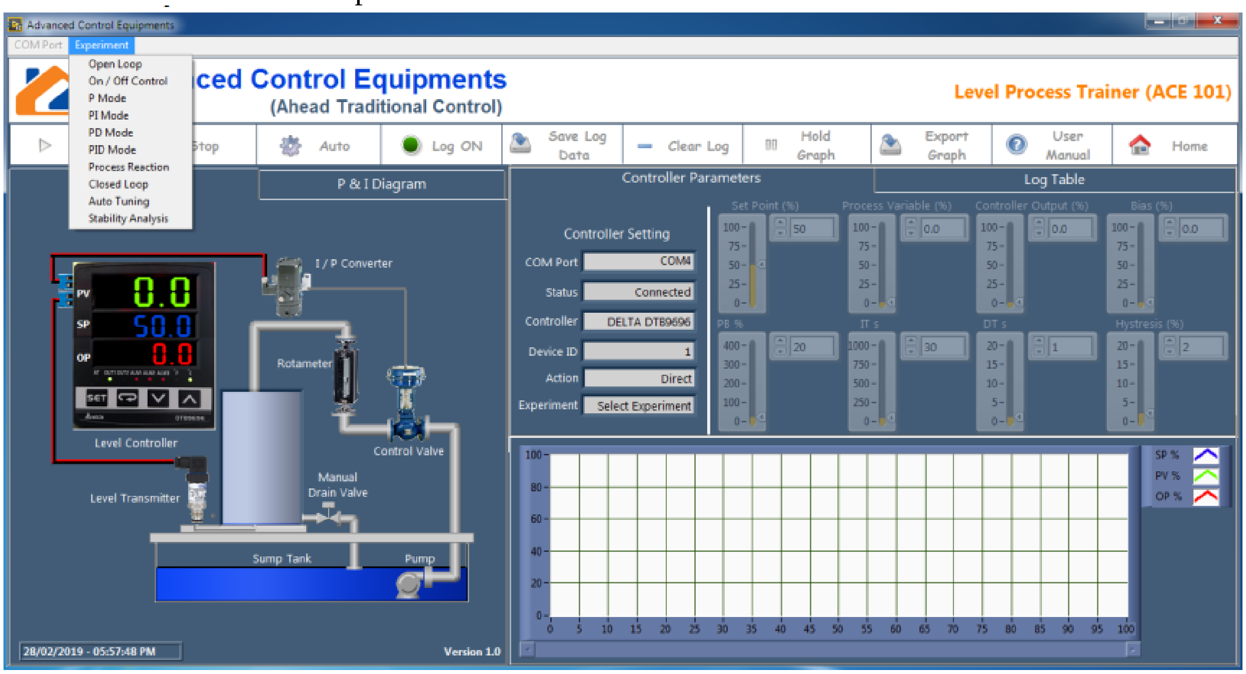
a. Enabled COM ports will be automatically identified and displayed here. If 'No Device' is displayed, check your communication cable. Also ensure your RS485 to USB converter is installed properly.



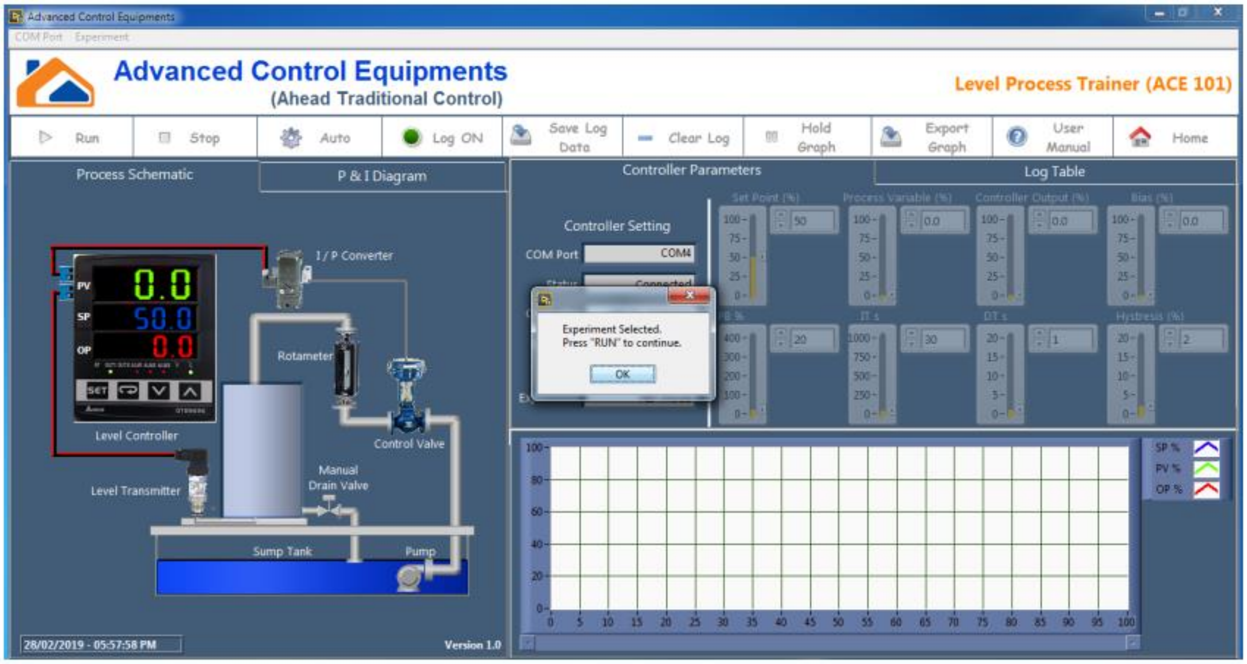
2. Once communication is established you will get a message as shown below. 'Experiment' menu will be enabled and 'COM Port' menu will be disabled.



3. Click 'OK' and select 'Experiment'.



4. Once experiment is selected, you will get a message "Experiment Selected. Press 'RUN' to continue". Click OK and Click 'Run' button.



Go through the experiment procedure and perform the experiment

Experiment 1
Study of ON/OFF, P, PI, PD and PID control actions using Temperature Control Trainer

Aim:

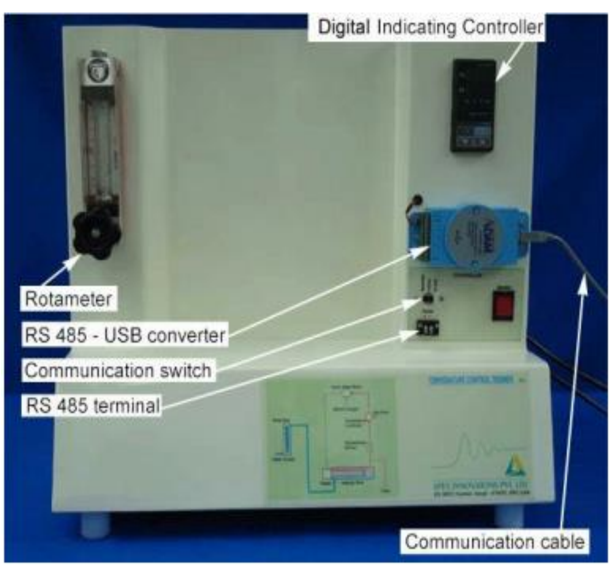
- To study about the Open Loop, ON / OFF, P, PI, PD and PID control actions using Temperature Control Trainer.

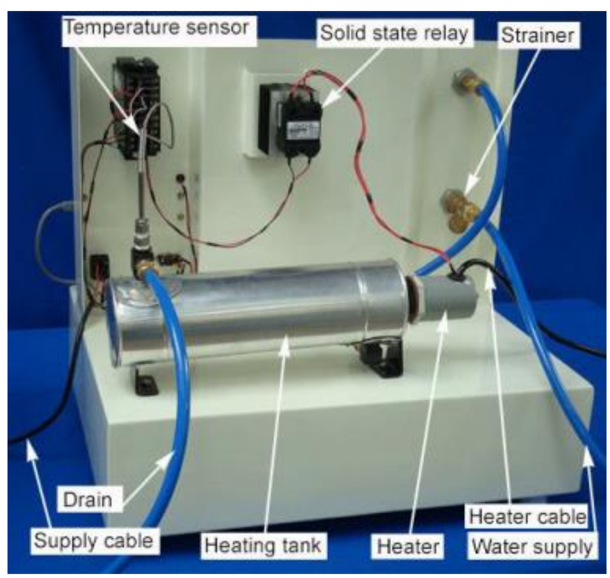
Equipments & Components Required:

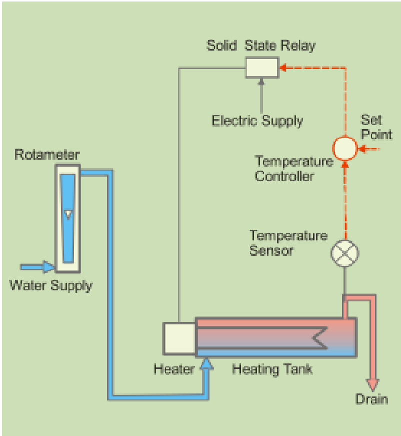
- Temperature Control Trainer (Product Code: 311A)
- Heater Supply and Running Water Supply
- Prosoft software

Description:

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. The schematic of the process station is given in next page.







P&I Diagram of Temprerature Process Control Trainer

General Procedure:

- Plug the supply cables of interfacing unit/control module and thyristor firing unit to switchboard and switch on MAINS**.**
- Plug the supply cable of computer to the power supply & switch on.
- Switch on the Heater. **(Ensure that running water supply is available. Don't switch on the Heater without running water supply).**
- Run the software and follow the instructions given earlier to open temperature control interface.

Part 1: Open Loop Analysis

Procedure:

- Start the set up and adjust flow rate @40 LPH.
- Execute the software.
- Select COM Port and Select Open Loop.
- Decrease the controller output to 0%. Note down steady state process value.
- Apply the step change by 10% to controller output and wait for the new steady state value. Note down the process value.
- Repeat the above step until the controller output reaches to maximum i.e. 100% and for each change, note steady state process value.
- Use 'Log on', 'Export', 'Clear Graph', 'Hold Graph' options as and when required. You can also change the graph axis scale. Click here for more details.
- Press 'Stop' button to finish the experiment or to jump to some other experiment. Press Ok or Cancel button on the popup window.

Observations:

- Tabulate the observations as follows

Controller output in %	Process Value in %
0	
10	

20	
…	
100	

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

Part 2: On / Off Controller

Procedure:

- Start the set up and adjust flow rate @40 LPH.
- Execute the software.
- Select COM Port and Select On / Off Control
- Change Hysteresis value to 5%. (Range 1-10%)
- Change the values of the set point and observe the On-Off control operation.

Observations:

1. Observe that if process value exceeds the set point and increases than the value of (1 x Hysteresis), controller switches off the SSR and if process value decreases below the set point by (1 x Hysteresis), SSR switches on i.e. controller operates like On/Off switch.
2. Plot the response for a hysteresis value of 3%. Use data logging | Export | jpeg.

Part 3: Proportional (P) controller

Procedure:

- Select COM Port and Select P Mode.
- Keep the set point to 40%. Allow the process to stabilize.
- Switch to Manual mode. Adjust output value so as to match the process value with set point and apply this output value as bias value to the controller.
- Switch the controller to Auto mode. Adjust the proportional band to 100%.
- Apply step change to set point (say 40% to 50%) and observe the response.
- 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.
- 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.

Observations:

1. Observe steady state error decreases as proportional band decreases.
2. Observe the effect of very low proportional band values (system works in oscillatory mode).
3. Observe the response of the system to load change. Load change can be given by slightly varying the inlet flow rate.
4. Apply a setpoint change (say 40% to 50%) with the proportional band obtained using trial and error approach. Plot the response. Use data logging | Export | jpeg.

Part 4: Proportional - Integral (PI) controller

Procedure:

- Select PI Mode Experiment. (Select Experiment | PI Mode).
- Set the proportional band estimated from Proportional control (P only) and with integral time = 50.
- Set the set point to desired temperature (@40%). Allow the process to reach steady state.
- Decrease the integral time by half the previous value.
- Apply step change to set point (say 40% to 50%) and observe the response.
- Decrease the integral time again half of the previous value and observe the process response for step change.
- Repeat the procedure until a satisfactory control is obtained with one overshoot and one undershoot and with very less offset.

Observations:

1. Observe the effect of reducing integral time on the response of the process. Also note that the process may show very less or null offset as effect of integral action but with a sluggish response.
2. Apply a setpoint change (say 40% to 50%) with the integral value obtained using trial and error approach. Plot the response. Use data logging | Export | jpeg.

Part 5: Proportional - Derivative (PD) controller

Procedure:

- Select PD Mode Experiment. (Select Experiment | PD Mode).
- Set the proportional band estimated from Proportional control (P only) and with derivative time=1.
- Set the set point to desired temperature (@40%). Allow the process to reach at steady state.
- Increase the derivative time by 1 sec.
- Apply step change to set point (say 40% to 50%) and observe the response.
- Increase the derivative time gradually (1 to 2 and 2 to 3) and observe the process response for step change.

Observations:

1. Observe the effect of increasing derivative time. Also note that the process may show offset as effect of integral action is cut off.
2. Apply a setpoint change (say 40% to 50%) with the proportional band obtained using trial and error approach. Plot the response. Use data logging | Export | jpeg.

Part 6: Proportional – Integral – Derivative (PID) controller

Procedure:

- Select PID Mode Experiment. (Select Experiment | PID 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 to set point (say 40% to 50%) and observe the response.
- Change the proportional band, integral time, derivative time as per the requirement and observe the response of the process for step change for each change in setting.

Observations:

1. Compare the steady state response of the PID controller with P, PI and PD controller obtained in the previous experiments.
2. Apply a setpoint change (say 40% to 50%) with the tuning parameters obtained using trial and error approach. Plot the response. Use data logging | Export | jpeg.

Shutdown procedure:

- Switch off the thyristor supply. Exit from the software. Shut down computer.
- **Allow the water to circulate through the system for few minutes** & then close tap water supply.
- Switch off interfacing unit/control module, if the temperature is less than 30 deg.

Result & Conclusion:

ON/OFF Mode:

Hysteresis:

P Mode:

PB: Bias:

PI Mode:

PB: Ti:

PD Mode:

PB: Td:

PID Mode:

PB: Ti: Td:

Experiment 2

Study of P, PI, PD and PID control actions using Flow Control Trainer

Aim:

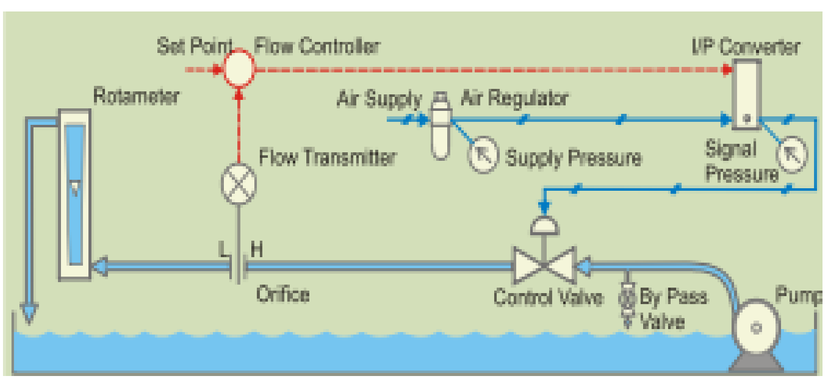
- To study about the P, PI, PD and PID control actions using Flow Control Trainer.

Equipments & Components Required:

- Flow Control Trainer (Product Code: 312A)
- Instrument Air Supply
- Prosoft software

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.



Schematic of a Flow Control loop

General Procedure:

- Plug the supply cables of interfacing unit/control module & pump and switch on MAINS. Plug the supply cable of computer to the power supply & switch on.
- Run the software and follow the instructions given earlier to work with the software.

Part 1: Open Loop Analysis

Procedure:

- Select COM Port and Select Open Loop.
- Decrease the controller output to 0%. Note down steady state process value.
- Apply the step change by 10% to controller output and wait for the new steady state value. Note down the process value.
- Repeat the above step until the controller output reaches to maximum i.e. 100% and for each change, note steady state process value.
- Use 'Log on', 'Export', 'Clear Graph', 'Hold Graph' options as and when required. You can also change the graph axis scale. Click here for more details.
- Press 'Stop' button to finish the experiment or to jump to some other experiment. Press Ok or Cancel button on the popup window.

Observations:

- Tabulate the observations as follows

Controller output in %	Process Value in %
0	
10	
20	
…	
100	

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

Part 2: Proportional (P) controller

Procedure:

- Select COM Port and P Mode Experiment.
- Keep the set point to 50%. Allow the process to stabilize.
- 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.
- Switch the controller to Auto mode. Adjust the proportional band to 200%.
- Apply step change to set point (say 50% to 70%) and observe the response.
- 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% to 70%).

- 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.

Observations:

1. Observe steady state error decreases as proportional band decreases.
2. Observe the effect of low proportional band values (system works in oscillatory mode).
3. Observe the response of the system to load change. Load change can be given by slightly varying the outlet flow.
4. Apply a setpoint change (say 50% to 70%) with the proportional band obtained using trial and error approach. Plot the response. Use data logging | Export | jpeg.

Part 3: Proportional - Integral (PI) controller

Procedure:

- Select COM Port and PI Mode Experiment.
- Set the proportional band estimated from Proportional control (P only) and with integral time = 50.
- Set the set point to desired flow (@50%). Allow the process to reach steady state.
- Decrease the integral time by half the previous value.
- Apply step change to set point (say 50% to 70%) and observe the response.
- Decrease the integral time again half of the previous value and observe the process response for step change.
- Repeat the procedure until a satisfactory control is obtained with one overshoot and one undershoot and with very less offset.

Observations:

1. Observe the effect of reducing integral time on the response of the process. Also note that the process may show very less or null offset as effect of integral action but with a sluggish response.
2. Apply a setpoint change (say 50% to 70%) with the integral value obtained using trial and error approach. Plot the response. Use data logging | Export | jpeg.

Part 4: Proportional - Derivative (PD) controller

Procedure:

- Select COM Port and PD Mode Experiment.
- Set the proportional band estimated from Proportional control (P only) and with derivative time=1.
- Set the set point to desired flow (@50%). Allow the process to reach at steady state.
- Increase the derivative time by 1 sec.

- Apply step change to set point (say 50% to 70%) and observe the response.
- Increase the derivative time gradually (1 to 2 and 2 to 3) and observe the process response for step change.

Observations:

1. Observe the effect of increasing derivative time. Also note that the process may show offset as effect of integral action is cut off.
2. Apply a setpoint change (say 50% to 70%) with the proportional band obtained using trial and error approach. Plot the response. Use data logging | Export | jpeg.

Part 5: Proportional - Integral-Derivative (PID) controller

Procedure:

- Select COM Port and PID Mode Experiment.
- 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 to set point (say 50% to 70%) and observe the response.
- Change the proportional band, integral time, derivative time as per the requirement and observe the response of the process for step change for each change in setting.

Observations:

1. Compare the steady state response of the PID controller with P, PI and PD controller obtained in the previous experiments**.**
2. Apply a setpoint change (say 50% to 70%) with the tuning parameters obtained using trial and error approach. Plot the response. Use data logging | Export | jpeg.

Shutdown procedure:

- Close the software. Switch off pump, controller mains and turn off air pressure supply.
- Shutdown the computer.

Result & Conclusion:

P Mode:	PB:	Bias:	
PI Mode:	PB:	Ti:	
PD Mode:	PB:	Td:	
PID Mode:	PB:	Ti:	Td:

Experiment 3

Study of ON/OFF, P, PI, PD and PID control actions using Level Control Trainer

Aim:

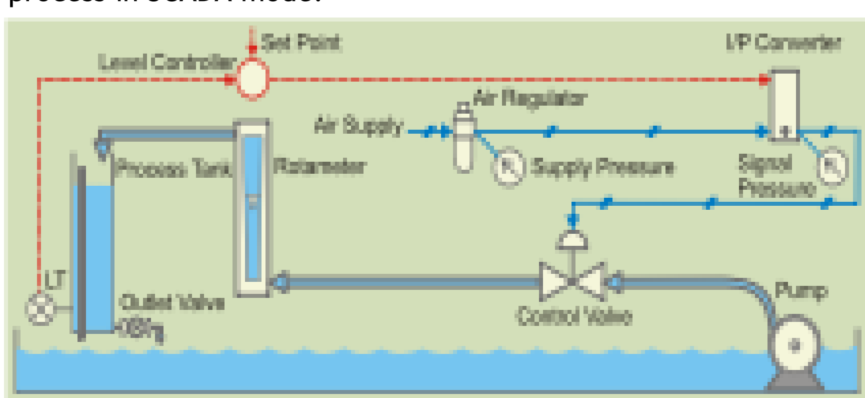
- To study about the ON/OFF, P, PI, PD and PID control actions using Level Control Trainer.

Equipments & Components Required:

- Level Control Trainer (Product Code: 313A)
- Instrument Air Supply
- Prosoft software

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. A Capacitance type, two wire, Range 0-300 mm, head mounted level transmitter transmits signal in the form of 4-20mA to interfacing unit. 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.



Schematic of a Level Control loop

General Procedure:

- Plug the supply cables of interfacing unit/control module & pump and switch on MAINS. Plug the supply cable of computer to the power supply & switch on.
- Run the software and follow the instructions given earlier to open flow control interface.

Part 1: Open Loop Analysis

Procedure:

- Select COM Port and Select Open Loop.
- Decrease the controller output to 0%. Note down steady state process value.
- Apply the step change by 10% to controller output and wait for the new steady state value. Note down the process value.
- Repeat the above step until the controller output reaches to maximum i.e. 100% and for each change, note steady state process value.
- Use 'Log on', 'Export', 'Clear Graph', 'Hold Graph' options as and when required. You can also change the graph axis scale. Click here for more details.
- Press 'Stop' button to finish the experiment or to jump to some other experiment. Press Ok or Cancel button on the popup window.

Observations:

- Tabulate the observations as follows

Controller output in %	Process Value in %
0	
10	
20	
…	
100	

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

Part 2: On / Off Controller

Procedure:

- Start the set up and adjust flow rate @100 LPH.
- Select COM Port and Select On-Off Mode Experiment.
- Change Hysteresis value to 1%. (Range 1-10%)
- Change the values of the set point and observe the On-Off control operation.

Observations:

1. Observe that if process value exceeds the set point and increases than the value of (1 x Hysteresis), controller switches off and if process value decreases below the set point by (1 x Hysteresis), controller switches on, i.e. controller operates like On/Off switch.
2. Plot the response for a hysteresis value of 5%. Use data logging | Export | jpeg.

Part 3: Proportional (P) controller:

Procedure:

- Select P Mode Experiment. (Select Experiment | P Mode)
- Keep the set point to 50%. Allow the process to stabilize.
- 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.
- Switch the controller to Auto mode. Adjust the proportional band to 100%.
- Apply step change to set point (say 50% to 60%) and observe the response.
- 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% to 60%).
- 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.

Observations:

1. Observe steady state error decreases as proportional band decreases.
2. Observe the effect of low proportional band values (system works in oscillatory mode).
3. Observe the response of the system to load change. Load change can be given by slightly varying the outlet flow.
4. Apply a setpoint change (say 50% to 60%) with the proportional band obtained using trial and error approach. Plot the response. Use data logging | Export | jpeg.

Part 4: Proportional - Integral (PI) controller

Procedure:

- Select PI Mode Experiment. (Select Experiment | PI Mode).
- Set the proportional band estimated from Proportional control (P only) and with integral time = 50.
- Set the set point to desired level (@50%). Allow the process to reach steady state.
- Decrease the integral time by half the previous value.
- Apply step change to set point (say 50% to 60%) and observe the response.
- Decrease the integral time again half of the previous value and observe the process response for step change.
- Repeat the procedure until a satisfactory control is obtained with one overshoot and one undershoot and with very less offset.

Observations:

1. Observe the effect of reducing integral time on the response of the process. Also note that the process may show very less or null offset as effect of integral action but with a sluggish response.
2. Apply a setpoint change (say 50% to 60%) with the integral value obtained using trial and error approach. Plot the response. Use data logging | Export | jpeg.

Part 5: Proportional - Derivative (PD) controller

Procedure:

- Select PD Mode Experiment. (Select Experiment | PD Mode).
- Set the proportional band estimated from Proportional control (P only) and with derivative time=1.
- Set the set point to desired level (@50%). Allow the process to reach at steady state.
- Increase the derivative time by 1 sec.
- Apply step change to set point (say 50% to 60%) and observe the response.
- Increase the derivative time gradually (1 to 2 and 2 to 3) and observe the process response for step change.

Observations:

1. Observe the effect of increasing derivative time. Also note that the process may show offset as effect of integral action is cut off.
2. Apply a setpoint change (say 50% to 60%) with the proportional band obtained using trial and error approach. Plot the response. Use data logging | Export | jpeg.

Part 6: Proportional - Integral-Derivative (PID) controller

Procedure:

- Select PID Mode Experiment. (Select Experiment | PID 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 to set point (say 50% to 60%) and observe the response.
- Change the proportional band, integral time, derivative time as per the requirement and observe the response of the process for step change for each change in setting.

Observations:

1. Compare the steady state response of the PID controller with P, PI and PD controller obtained in the previous experiments**.**
2. Apply a setpoint change (say 50% to 60%) with the tuning parameters obtained using trial and error approach. Plot the response. Use data logging | Export | jpeg.

Shutdown procedure:

- Close the software and Switch off pump, controller mains and turn off air pressure supply.
- Shutdown the computer.

Result & Conclusion:

ON/OFF Mode:

Hysteresis:

P Mode:

PB: Bias:

PI Mode:

PB: Ti:

PD Mode:

PB: Td:

PID Mode:

PB: Ti: Td:

Experiment 4

Study of P, PI, PD and PID control actions using Pressure Control Trainer

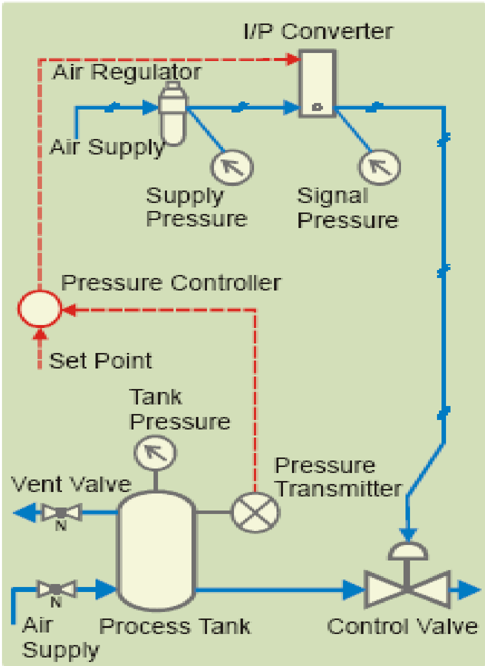
Aim:

- To study about the P, PI, PD and PID control actions using Pressure Control Trainer.

Equipments & Components Required:

- Pressure Control Trainer (Product Code: 314A)
- Instrument & Process Air Supply
- Prosoft software

Description:



The process setup consists of a pressure tank with pressure supply and a pressure transmitter. Pressure transmitter senses the pressure inside pressure tank and transmits the signals to interfacing unit / control module. The output of interfacing unit / control module is connected to I/P converter. A pneumatic control valve adjusts compressed air flow from the tank outlet. The process parameter (pressure) is controlled through computer or µp controller by manipulating the control valve. These units along with necessary piping are fitted on support housing designed for tabletop mounting.

General Procedure:

- Plug the supply cables of interfacing unit/control module & pump and switch on MAINS. Plug the supply cable of computer to the power supply & switch on.
- Run the software and follow the instructions given earlier to open flow control interface.

Part 1: Open Loop Analysis

Procedure:

- Select COM Port and Select Open Loop.
- Decrease the controller output to 0%. Note down steady state process value.
- Apply the step change by 10% to controller output and wait for the new steady state value. Note down the process value.
- Repeat the above step until the controller output reaches to maximum i.e. 100% and for each change, note steady state process value.
- Use 'Log on', 'Export', 'Clear Graph', 'Hold Graph' options as and when required. You can also change the graph axis scale. Click here for more details.
- Press 'Stop' button to finish the experiment or to jump to some other experiment. Press Ok or Cancel button on the popup window.

Observations:

- Tabulate the observations as follows

Controller output in %	Process Value in %
0	
10	
20	
…	
100	

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

Part 2: Proportional (P) controller:

Procedure:

- Select P Mode Experiment. (Select Experiment | P Mode).
- Adjust the inflow valve and bring the system within controllable limits.
- Keep the set point to 50%. Allow the process to stabilize.
- 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.
- Switch the controller to Auto mode. Adjust the proportional band to 100%.
- Apply step change to set point (say 50% to 60%) and observe the response.

- 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% to 60%).
- 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.

Observations:

1. Observe steady state error decreases as proportional band decreases.
2. Observe the effect of low proportional band values (system works in oscillatory mode).
3. Observe the response of the system to load change. Load change can be given by slightly varying the outlet flow.
4. Apply a setpoint change (say 50% to 60%) with the proportional band obtained using trial and error approach. Plot the response. Use data logging | Export | jpeg.

Part 3: Proportional - Integral (PI) controller

Procedure:

- Select PI Mode Experiment. (Select Experiment | PI Mode).
- Set the proportional band estimated from Proportional control (P only) and with integral time = 50.
- Set the set point to desired pressure (@50%). Allow the process to reach steady state.
- Decrease the integral time by half the previous value.
- Apply step change to set point (say 50% to 60%) and observe the response.
- Decrease the integral time again half of the previous value and observe the process response for step change.
- Repeat the procedure until a satisfactory control is obtained with one overshoot and one undershoot and with very less offset.

Observations:

1. Observe the effect of reducing integral time on the response of the process. Also note that the process may show very less or null offset as effect of integral action but with a sluggish response.
2. Apply a setpoint change (say 50% to 60%) with the integral value obtained using trial and error approach. Plot the response. Use data logging | Export | jpeg.

Part 4: Proportional - Derivative (PD) controller

Procedure:

- Select PD Mode Experiment. (Select Experiment | PD Mode).
- Set the proportional band estimated from Proportional control (P only) and with derivative time=1.
- Set the set point to desired pressure (@50%). Allow the process to reach at steady state.
- Increase the derivative time by 1 sec.
- Apply step change to set point (say 50% to 60%) and observe the response.
- Increase the derivative time gradually (1 to 2 and 2 to 3) and observe the process response for step change.

Observations:

1. Observe the effect of increasing derivative time. Also note that the process may show offset as effect of integral action is cut off.
2. Apply a setpoint change (say 50% to 60%) with the proportional band obtained using trial and error approach. Plot the response. Use data logging | Export | jpeg.

Part 5: Proportional - Integral-Derivative (PID) controller

Procedure:

- Select PID Mode Experiment. (Select Experiment | PID 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 to set point (say 50% to 60%) and observe the response.
- Change the proportional band, integral time, derivative time as per the requirement and observe the response of the process for step change for each change in setting.

Observations:

1. Compare the steady state response of the PID controller with P, PI and PD controller obtained in the previous experiments.
2. Apply a setpoint change (say 50% to 60%) with the tuning parameters obtained using trial and error approach. Plot the response. Use data logging | Export | jpeg.

Shutdown procedure:

- Press STOP and close the software.
- Switch off pump, controller mains and turn off air pressure supply.
- Shutdown the computer.

Result & Conclusion:

P Mode:

PB: Bias:

PI Mode:

PB: Ti:

PD Mode:

PB: Td:

PID Mode:

PB: Ti: Td:

Experiment 5
Study of Control Valve Characteristics

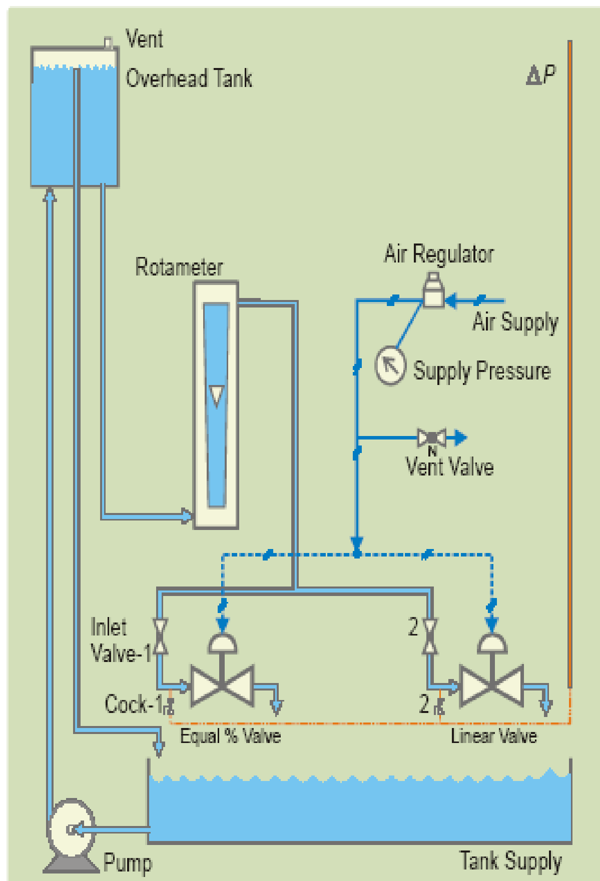
Aim:

- To understand the principle, working, components and characteristics of a control valve.

Equipments & Components Required:

- Control Valve Trainer (Product Code: 318)
- Instrument Air Supply

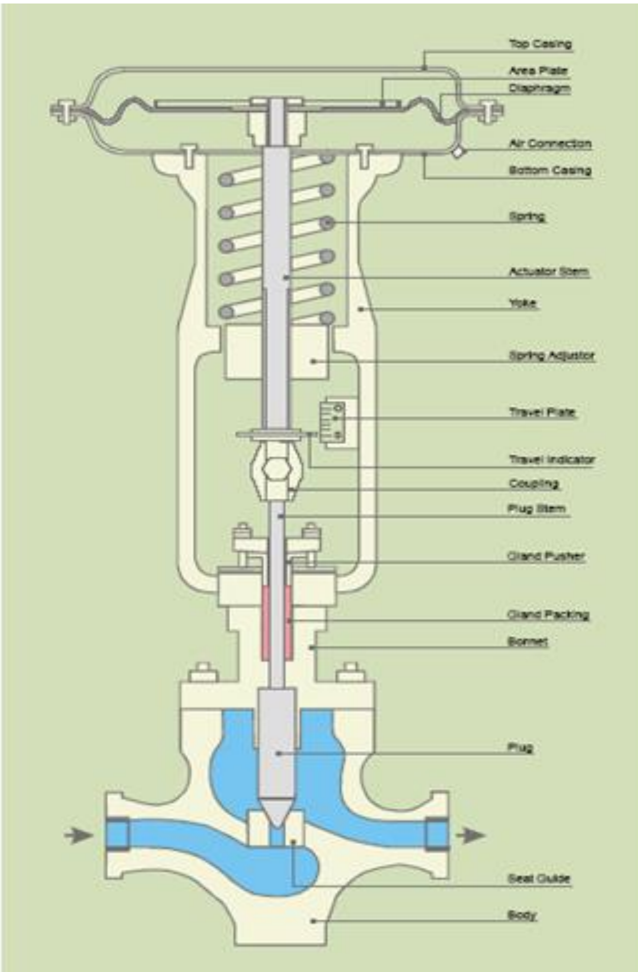
Description:



The setup is designed to understand the control valve operation and its flow characteristics. It consists of pneumatic control valves of linear, equal% & quick opening type, stainless steel water tank with pump for continuous water circulation and rotameter for flow measurement.

An arrangement is made to measure pressure at the valve inlet in terms of mm of water. An air regulator and pressure gauge is provided for the control valve actuation. In case of additional optional requirement a valve positioner is fitted on linear valve. The setup is stand-alone type.

THEORY OF CONTROL VALVE:



Control Valve (Air to Open)

Types of Control valves:

Valve is essentially a variable orifice. Control valve is a valve with a pneumatic, hydraulic, electric (excluding solenoids) or other externally powered actuator that automatically, fully or partially opens or closes the valve to a position dictated by signals transmitted from controlling instruments. Control valves are used primarily to throttle energy in a fluid system and not for shutoff purpose. The figure shows basic elements and internal parts of typical pneumatic control valve. Depending upon the valve plug design the control valves can be classified as quick opening, linear and equal percent type.

Linear: Flow is directly proportional to valve lift.

Q = ky

Where

Q = flow at constant pressure drop

y = valve opening

k = constant

Equal%: Flow changes by a constant percentage of its instantaneous value for each unit of valve lift.

$Q = b \times e^{ay}$

Where

Q = flow at constant pressure drop

y = valve opening

e = base of natural logarithms

a and b = constants

Constants a and b can be evaluated to give more convenient form

$$Q = Q_0 \times e^{\{(\log R / y\max) \times y\}}$$

Where

Qo = Flow at constant drop at zero stroke.

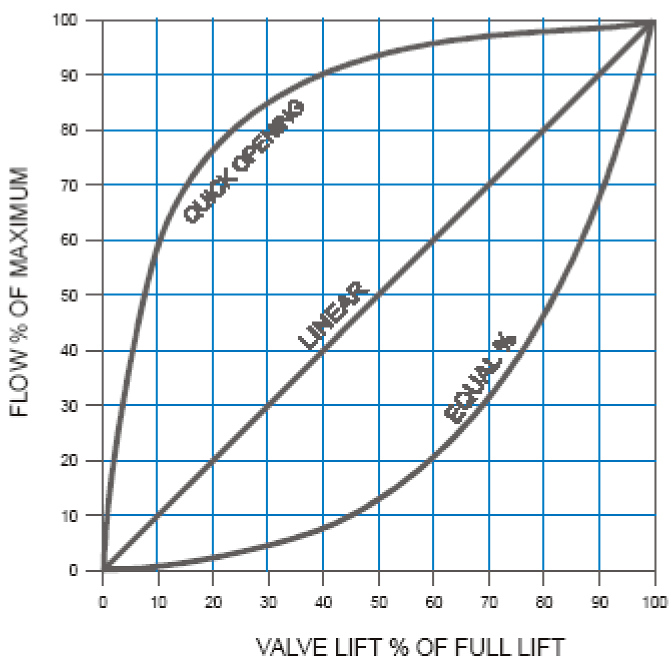
R = Flow range of valve, maximum to minimum at constant drop.

y_{max} = maximum rated valve opening.

Quick opening: Flow increases rapidly with initial travel reaching near its maximum at a low lift. It is generally not defined mathematically.

Valve actions and actuator mechanism:

Different types of actuators are used to control the stem travel of the valve, like electrical actuators, pneumatic actuator, Hydraulic actuators etc. In this product pneumatic actuators are used for control valves. Spring opposed diaphragm actuator positions the valve plug in response to the controller signals. Mostly the controller signals are in the range of 3 - 15 psig.



Direct acting actuator (air to close):

Direct acting actuators basically consist of a pressure tight housing sealed by a flexible fabric reinforced elastomer diaphragm. A diaphragm plate is held against the diaphragm by a heavy compression spring. Signal air pressure is applied to upper diaphragm case that exerts force on the diaphragm and the actuator assembly. By selecting proper spring rate or stiffness, load carrying capacity, and initial compression, desired stem displacement can be obtained for any given input signal.

Reverse acting actuator (air to open):
In case of reverse acting actuators the stem gets retracted with increase in pressure.

Control valve flow coefficient
A control valve regulates the flow rate in a fluid delivery system. In general a close relation exists between the pressure along the pipe and the flow rate so that if pressure is changed, then the flow rate is also changed. A control valve changes the flow rate by changing the pressure in the flow system because it introduces the constriction in the delivery system so we can say that the flow rate through the constriction is given by

$$Q = K\sqrt{\Delta p}$$

The correction factor K in above equation allows selection of proper size of valve to accommodate the rate of flow that the system must support. This correction factor is called as valve coefficient and is used in valve sizing.

Valve coefficient:

$$C_v = 1.16\, Q\sqrt{\frac{\mathrm{G}}{\Delta \mathrm{P}}}$$

Where G is specific gravity of liquid, Q flow in m^3/h, ΔP pressure drop in bar.

Valve Characteristics:
The amount of fluid passing through a valve at any time depends upon the opening between the plug and seat. Hence there is relationship between stem position, plug position and the rate of flow, which is described in terms of flow characteristics of a valve. Inherent and Installed are two types of valve characteristics.

Inherent characteristics:
The inherent flow characteristic of control valve is the relation between the flow and the valve travel at constant pressure drop across the valve. Following are the inherent characteristics for different types of valves.

Installed characteristics:
The Inherent characteristics of the valves described are subject to distortion due to variations in pressure drop with flow. Line resistance distorts linear characteristics towards that of quick opening valve and equal% to that of linear.

Hysteresis of control valve:

Hysteresis is a predictable error resulting from the differences in the transfer functions when a reading is taken from above and below the value to be measured. In case of control valves for same actuator signal different stem travel (hence valve coefficients) are obtained depending upon the direction of change in the signal. The maximum error in stem travel (or valve coefficient) expressed in % for same actuator pressure while opening and closing the valve is indicated as hysteresis.

Rangeability of equal % valve:

Equal% valve has characteristics such that given percent change in stem position produces an equivalent change in flow. Generally this type of valve does not shut off the flow completely in its limit of stem travel. The Rangeability (R) is defined as the ratio of maximum to minimum controllable flow.

$$R = F_{max} / F_{min}$$

Where F_{max} is the flow when the valve stem is at extreme open position and F_{min} is the flow when valve stem is at extreme closed position. (F_{max}, F_{min} represents flow rates measured at constant pressure drop across control valve. Hence rangeability R also can be defined as ratio of $C_{v\ max}$ to $C_{v\ min}$.) For equal percent valve flow have exponential characteristics of rangeability, $F = R^{m-1}$

Where R is the rangeability of the valve and m is its fractional stem position.

Valve positioner:

Valve positioner is a device used with actuator. The actuator stem motion is accurately compared with the signal from controller. Any deviation from the desired position results in an error signal which activates pneumatic relay having an independent air supply. Some of the advantages of positioner are as follows:

- Helps in overcoming valve stem friction
- Matches input signal with valve stroke
- Increases speed of response of control valve
- Possibility of split ranging, alteration in valve characteristics and action reversal

Part 1: Study of Inherent & Installed Characteristics

i. Linear Control Valve:

Procedure:

- Start up the set up. Open the flow regulating valve of the linear control valve (Linear/ Equal%/quick opening). Open the respective hose cock for pressure indication. (Close the flow regulating valves and hose cocks of other control valves.)
- Keep the control valve fully open by adjusting air regulator.

- Adjust the regulating valve and set the flow rate. (Set 400 LPH). Note for measuring flow rates below rotameter minimum range use measuring jar.
- Note the pressure drop at control valve at full open condition.
- Slowly increase/decrease air pressure by regulator and close the control valve to travel the stem by 2mm. Note the pressure drop at control valve and corresponding flow rate.
- Repeat above step and take the readings at each 2mm-stem travel till the valve is fully closed.

Calculations:

$$C_v = 1.16\, Q \sqrt{\frac{G}{\Delta P}}$$

Where,

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

ΔP = Pressure drop across valve (bar) = ΔP in mm of H_2O X 1.013/(10.33X10^3).

G = Specific gravity = 1 for water

Sl. No.	Lift (mm)	Flow (LPH)	Pressure Drop ΔP (mm H_2O)	Valve Coefficient C_V
1				
2				
3				
4				
5				
6				

ii. Equal % Control Valve:

Procedure:

- Open the flow regulating valve of the Equal % control valve.
- Open the respective hose cock for pressure indication. (Close the flow regulating valves and hose cocks of other control valves.)
- Repeat the steps 2 to 6 given in Linear Control Valve.

Sl. No.	Lift (mm)	Flow (LPH)	Pressure Drop ΔP (mm H_2O)	Valve Coefficient C_V
1				
2				
3				

4				
5				
6				

iii. Quick Opening Control Valve:

Procedure:

- Open the flow regulating valve of the Equal % control valve.
- Open the respective hose cock for pressure indication. (Close the flow regulating valves and hose cocks of other control valves.)
- Repeat the steps 2 to 6 given in Linear Control Valve with a flow rate of 600 LPH in step

Sl. No.	Lift (mm)	Flow (LPH)	Pressure Drop ΔP (mm H_2O)	Valve Coefficient C_V
1				
2				
3				
4				
5				
6				

Plot the graph of valve coefficient versus lift to obtain inherent characteristics and flow versus lift to obtain the installed characteristics of the control valve.

Conclusion:

Experiment 6

Study of Cascade control action using Cascade Control Trainer

Aim:

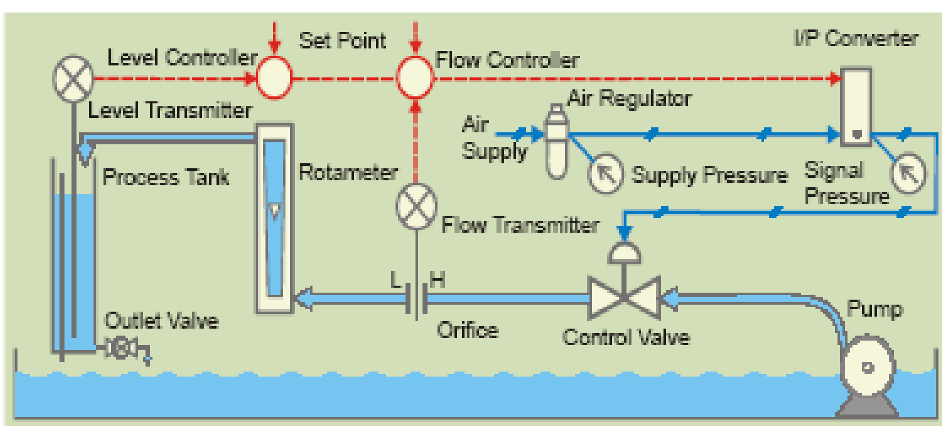
- To study about the cascade control action.

Equipments & Components Required:

- Cascade Control Trainer (Product Code: 315A)
- Instrument Air Supply
- Prosoft software

Description:

The cascade control trainer is designed for understanding basic principles of cascade control used in complex systems. The process setup consists of supply water tank fitted with pump for water circulation. Level transmitter is fitted on transparent process tank. Flow transmitter fitted across orifice meter senses the water flow to the tank. The water flow (secondary loop) to the process is controlled by pneumatic control valve to maintain the level (primary loop) under cascade control logic. The process parameter is controlled through computer. These units along with necessary piping and fittings are fitted on support housing designed for tabletop mounting.



Schematic of a Cascade Control Trainer

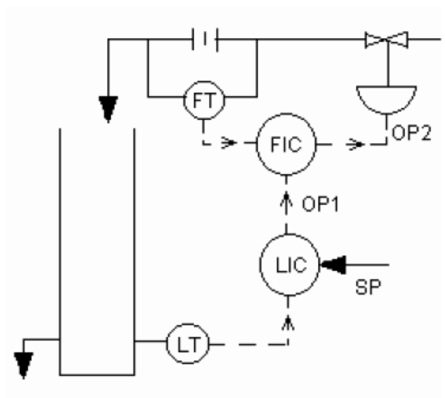
Theory:

The cascade controller consists of two controllers

1) Primary controller
2) Secondary controller

In cascade control arrangement the output of primary controller is used as set point of secondary controller. Each controller has its own measurement input, but only the primary controller has independent set point and the secondary controller has an output to the process. The manipulated variable and, the secondary controller, and its measurement constitute a closed loop within the primary loop.

Tuning of cascade controllers:



Because the secondary loop exists as an element in the primary loop, the secondary controller should be properly tuned before the primary controller, with the primary controller in manual. Whether the secondary should be tuned for optimum set point or load response depends on whether severe load changes are expected in the secondary loop. If so, observing response to load changes simulated by stepping the secondary controller output while in manual should do tuning, followed by transfer to automatic. If not, set point steps should be introduced.

In a cascade system that is cycling, it is often difficult to determine which controller needs detuning. If the period of cycles is too short to belong to the primary loop, the safest action is to widen the proportional band of secondary controller- a few percent changes is enough. In this case, both periods may appear in either or both of the controlled variables. But only one period is evident, widening the proportional band of either controller could dampen the cycle, although it is probably more effective to de-tune the primary controller.

Procedure

- Start the set up and ensure that flow rate is 100 LPH when control valve is fully opened.
- Execute Program | ACE.exe

- Select | Process Control Trainers | Basic Process Control Trainers | Cascade Process Trainer (ACE 106) | Delta DVPEX2 | Cascade Control
- For cascade controller first tune **Secondary Controller.** Tune the controller independently by keeping the Primary controller in manual mode. (Refer Tuning of cascade controller)
- Adjust the output of the primary controller at manual mode to achieve the set point of secondary controller. Apply the step change of10% to the set point (change primary controller output by 10%). Observe the response.
- By trial and error method, get the PB, Ti and Td values that yield a satisfactory secondary loop response.
- Now, tune the primary controller using trial and error approach, select the proportional band and integral time, which gives a satisfactory response to step change in set point.
- Plot the graph between process variable and time for primary and secondary loop separately.

Observations

- It is observed that the speed of response of the level control system is improved. As the flow loop is fast responsive than the level control loop, for a small change in primary controller output, the secondary controller tries to achieve the set point.
- Time required to achieve the primary controller set point is less than the single loop control.

Conclusion:

It is observed by trial and error method that the following values are yielding satisfactory performance and the graphs for step input change and / or load change are drawn.

Primary Loop:

PB: Ti: Td:

Secondary Loop:

PB: Ti: Td:

Experiment 7

Open Loop and Closed Loop PID Controller Tuning using Pressure Control Trainer

Aim:

- To tune the controller variables and thereby study the response of the pressure control system for various values of K_p, K_I, K_D.

Equipments & Components Required:

- Pressure Control Trainer (Product Code: 314A)
- Process & Instrument Air Supply
- Prosoft software

Theory:

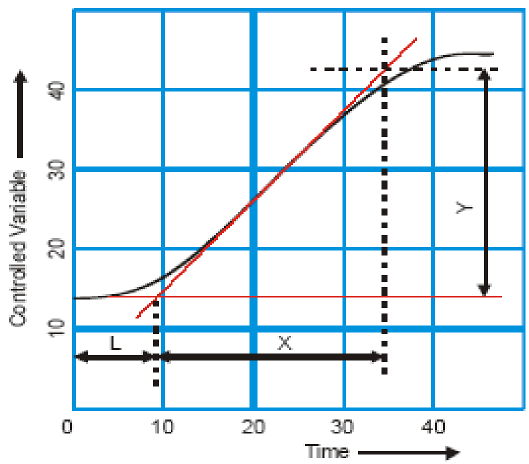
The three-mode controller (PID) is the most common feedback controller used in industrial control. The method of determination of the optimum mode gains, depending on the nature and complexity of the process is known as **loop tuning**.

The three parameters should be selected to meet a set of defined goals. These goals typically require a plant response with minimum steady state error, insensitivity to load disturbances and an acceptable transient response to set point changes and disturbances.

In practice the choice of proportional band, integral time and derivative time is a compromise between the set point tracking and disturbances. If a mathematical model of the process is known, selecting the controller parameters is relatively simple. But in many industrial applications, a reliable mathematical model is not available or it is difficult to determine. So empirical rules are developed for PID tuning which do not require mathematical model. A widely used set of rules is proposed by Ziegler- Nichols by open loop method and close loop method in 1942.

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.



Open loop response for input step change (Process reaction curve)

Where

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

$$R = \frac{\%Change in Variable}{time(\mathrm{min})} = \frac{Y}{X}$$

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 %

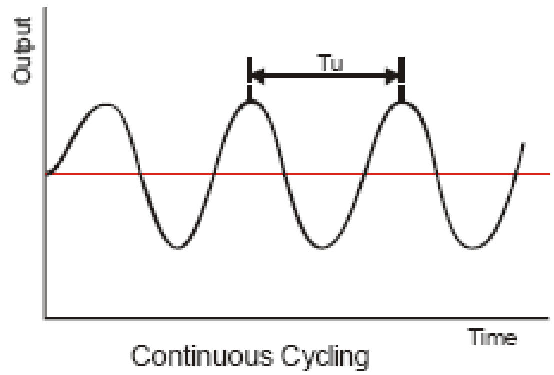
Using these parameters, the empirical equations are used to predict the controller settings for a decay ratio of 1/4.

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

Closed loop method (Ultimate gain method):

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.



Response curve for ultimate gain and period

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

Part 1: Tuning of controller (Open loop method):

Procedure

- Start the set up and adjust the inflow valve so that the system can be controllable.
- Execute Program | Select Open Loop Experiment.
- The default controller output is 90%. Wait for the system to stabilize.
- Start data logging.
- Apply 20 % as controller output. 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 Experiment. 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 and plot the response.

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.

Part 2: Tuning of controller (Closed loop method):

Procedure

- Execute Program | UT321E | Select Closed Loop Experiment.
- The default proportional band is 100%.
- Decrease the proportional band and apply the step change to the set point and observe the process response.
- Repeat the above procedure and find out correct value of proportional band for which the system just goes unstable i.e. continuous oscillations are observed in the output of controller.
- Record the ultimate proportional band and ultimate period from the response.
- Calculate the PID values from the table.
- Select PID Experiment. Set the PID values obtained from the calculations.
- Apply a step change & observe the response of the system.
- Allow the system to reach steady state and plot the response.

Observations

- Record the ultimate proportional band (Pbu) and ultimate period (Tu) from above experiment.
- Calculate PID values by referring theory part for different control actions.
- Observe the process response for these settings.
- Compare the values obtained with open loop response method.

Result:

From process reaction curve:

- Slope of the process reaction curve R =
- Time lag L=
- PID values obtained from the calculation: **P=** **I=** **D=**

From Closed Loop Method:

- Ultimate proportional band (Pbu) =
- Ultimate period (Tu) =
- PID values obtained from the calculation: **P=** **I=** **D=**

Experiment 8
Study of Feed Forward and Ratio Control

Aim:

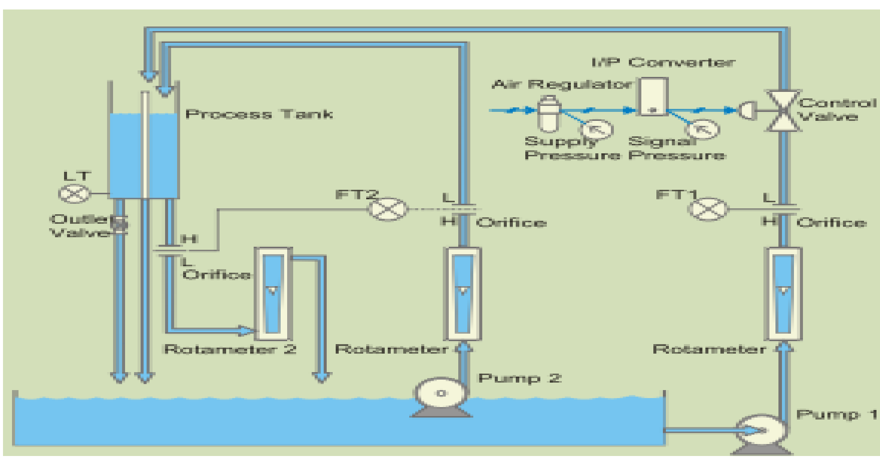
- Study of Feed forward and Ratio control using Multi Process Control Trainer.

Equipments & Components Required:

- Multi Process Trainer (Product Code: 326A)
- Process & Instrument Air Supply
- Prosoft software

Description:

The setup is designed to understand the advanced control methods used for complex processes in the industries. Different experiments like Flow, level, cascade, feed forward and ratio control can be configured and studied with the setup. It consists of water supply tank, pumps, level transmitter, transparent level tank, orifice meters with differential pressure transmitters, rotameters, pneumatic control valve, I/P converter and serial based dual loop controller. These units along with necessary piping are mounted on stand-alone type structure. The setup is connected to computer through USB port for monitoring and control by using PID logics.



Schematic of a Multi Process Trainer

Theory:

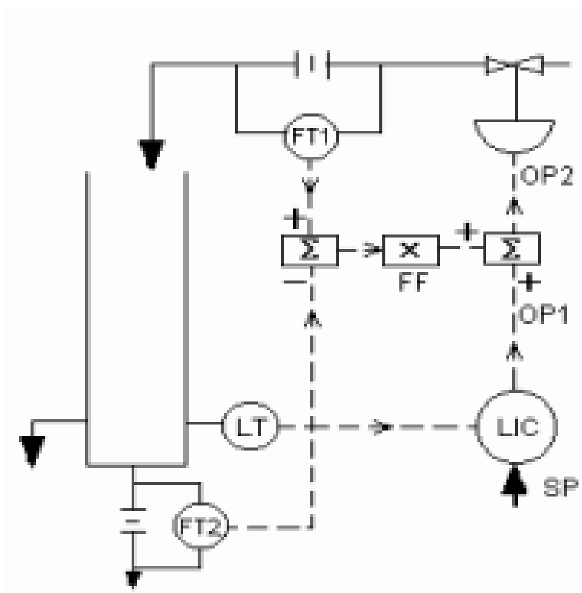
Feed forward control:

In feed forward control the correction is based upon the changes in load variable(s), hence the change in this variable does not affect the controlled variable. This overcomes the serious limitation of economic loss associated with the feedback controller. It applies faster correction. The feed forward control system alone cannot maintain the controlled variable at the set point because of unknown disturbance or any un-measurable process variables. Hence combination with feedback loop helps in maintaining the process variable at the set point.

The inlet flow signal FT1 and the outlet flow signal FT2 are measured and compared. A multiplying factor is added for the calculation. The difference between the two-flow signals is multiplied by the feed forward factor and added to the output of the level controller. If the out flow is less than the inlet flow the positive output of the calculation is added to the LIC output i.e. the output of the controller is increased.

This reduces inlet flow to match with outlet. Any finer correction is applied by output of LIC loop. OP2 = OP1+ FF(FT1-FT2)

There is no feed forward action when FT1=FT2 or when FF=0.



Feed Forward Control Loop

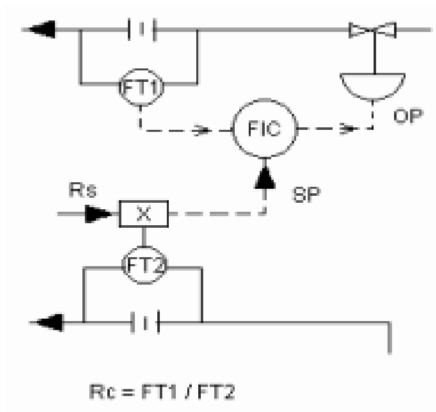
Ratio Control:

Ratio control systems are feed forward systems wherein one variable is controlled in ratio to another to satisfy some higher-level objective. In ratio control systems, the true controlled variable is controlled in the ratio of controllable flow F1 to wild flow F2.

R = F1 /F2

In the above system the ratio set is multiplied by the wild flow and the value is given as a set point to flow controller FIC.

The controllable flow F1 and the wild flow F2 is measured with orifice meters and DP transmitters.



Ratio Control Loop

Ratio Station: The ratio station is the calculation box where the set point is generated for FIC. Calculations to be carried out in the ratio station block:

SP= F2 X Rs

Where

SP: Set point for controllable flow loop F1

F1: Controllable flow displayed in %.

F2: Wild flow displayed in %. (Flow values displayed are square rooted values obtained from respective DP transmitter)

Rs: Ratio set. (Range 0.5 – 2)

Rc: Current ratio = Ratio of current flow values (**F1 / F2**).

Ratio control is utilized in processes where two process variables have to be fed to a process in a definite ratio. For example, in a gas-fired furnace, the flow of gas has to match in a fixed ratio with combustion air, blending of reactants entering a chemical reactor etc.

A. Feedforward Control - General Procedure:

- Plug the supply cables of interfacing unit/control module & pump and switch on MAINS**.**
- Plug the supply cable of computer to the power supply & switch on.
- Switch on Pump-1 and adjust the Rotameter-1 (extreme right) to 100LPH.
- Remove entrapped air, if any from the FT2. For removing air open the vent valves on the DP transmitter.
- Execute Program | ACE.exe

- Select | Process Control Trainers | Basic Process Control Trainers | Multi Variable Process Trainer (ACE 108) | ACE 2007 DAQ | Feedforward + Feedback Control
- The WiFi controller will connect automatically and a message will be displayed.
- Close the drain valve of the tank. Open Rotameter-2 and adjust flow to 50 LPH. From the default values of SP=50, PB=20, IT=30, DT=2, FF=1 observe the response of the system. Note for FF=0 the loop is purely feedback loop.
- With Feed forward factor =1 apply load disturbance by changing the output flow rotameter. Observe the effect of feed forward on LIC output and on process variable.

Observations:

- Because of the feed forward loop the controller responds immediately to the disturbance before the process value is affected. The final correction is done by PID control loop.
- Any error observed in the flow measurement (due to manufacturing inaccuracies or air in signal lines or DP calibration) has no impact on controlling.

Result & Conclusion:

1. Step response graph with FF=1
2. Load disturbance graph with FF = 1

B. Ratio Control - General Procedure:

- Switch on pump and adjust the rotameter no. 3 (middle) and rotameter no.1 (right) to 100 LPH. Remove air entrapped, if any, from the FT2. For removing air open the vent valves on the DP transmitter.
- Select | Process Control Trainers | Basic Process Control Trainers | Multi Variable Process Trainer (ACE 108) | ACE 2007 DAQ | Ratio Control
- Adjust Rotameter no.3 to @ 80 LPH.
- From the default values of PB=75, IT=8, DI=2, Ratio Set (RS) = 1, observe that the flow in rotameter no.1 is automatically adjusted and become equal to that of rotameter no.3.
- Manipulate the flow in Rotameter no. 3 and observe the effect on Rotameter no.1.
- Change the ratio (range 0.5-2) and observe the effect.

Observations:

- The ratio of controlled variable (Flow1) to wild variable (Flow2) can be set and Controlled.

Result & Conclusion:

1. Response graph for 80 LPH to 40LPH
2. Response graph for RS = 2 with 30LPH in rotameter 3

Experiment 9
Study of Three Tank interacting control system using MATLAB and NI USB 6002 Data Acquisition Card

Aim:

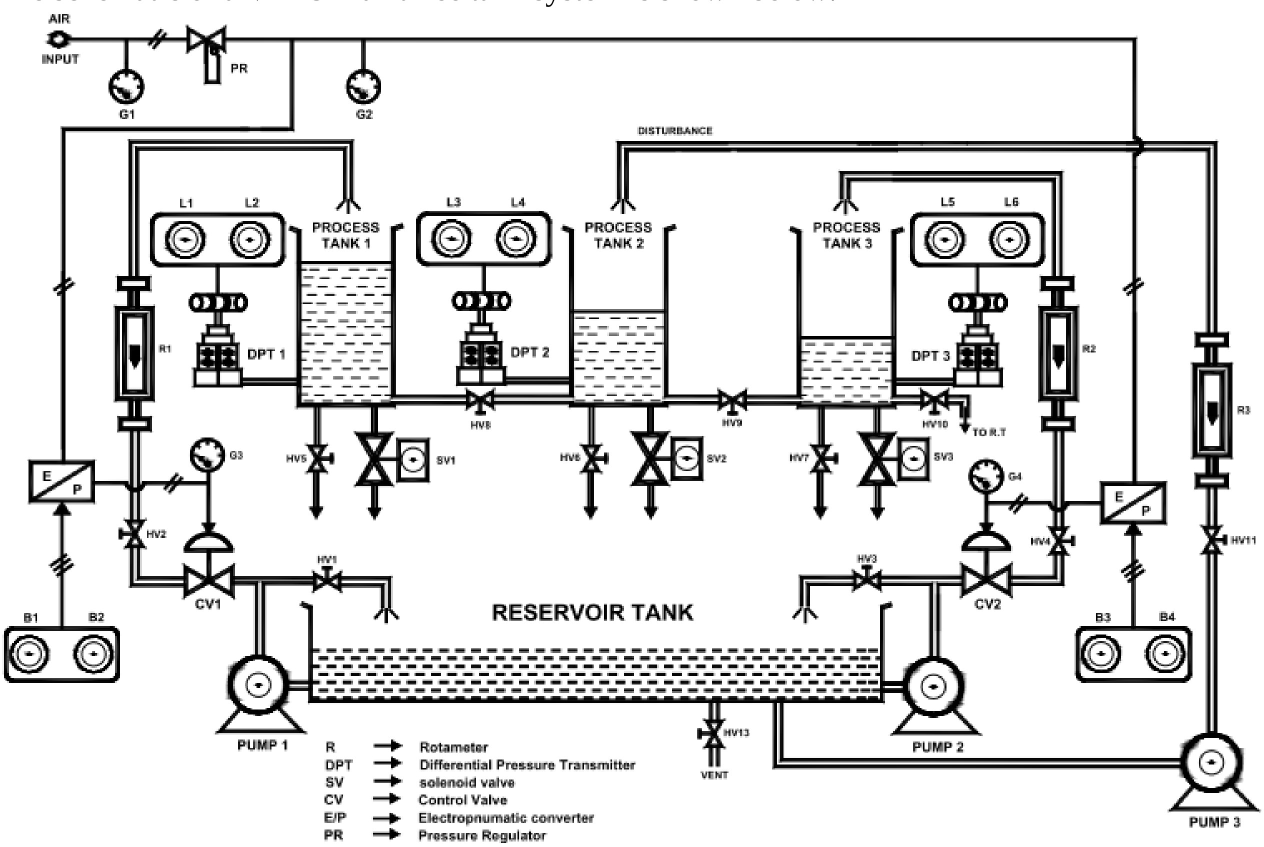
- To study the working of a three-tank interacting system using Matlab and NI USB 6002 Data Acquisition Card.

Equipments & Components Required:

- VTTS – 01 Three Tank System
- NI USB 6002 Data Acquisition Card
- Matlab Software
- Instrument Air Supply

Description:

The schematic of a VTTS – 01 three tank system is shown below.



Schematic of Three Tank System

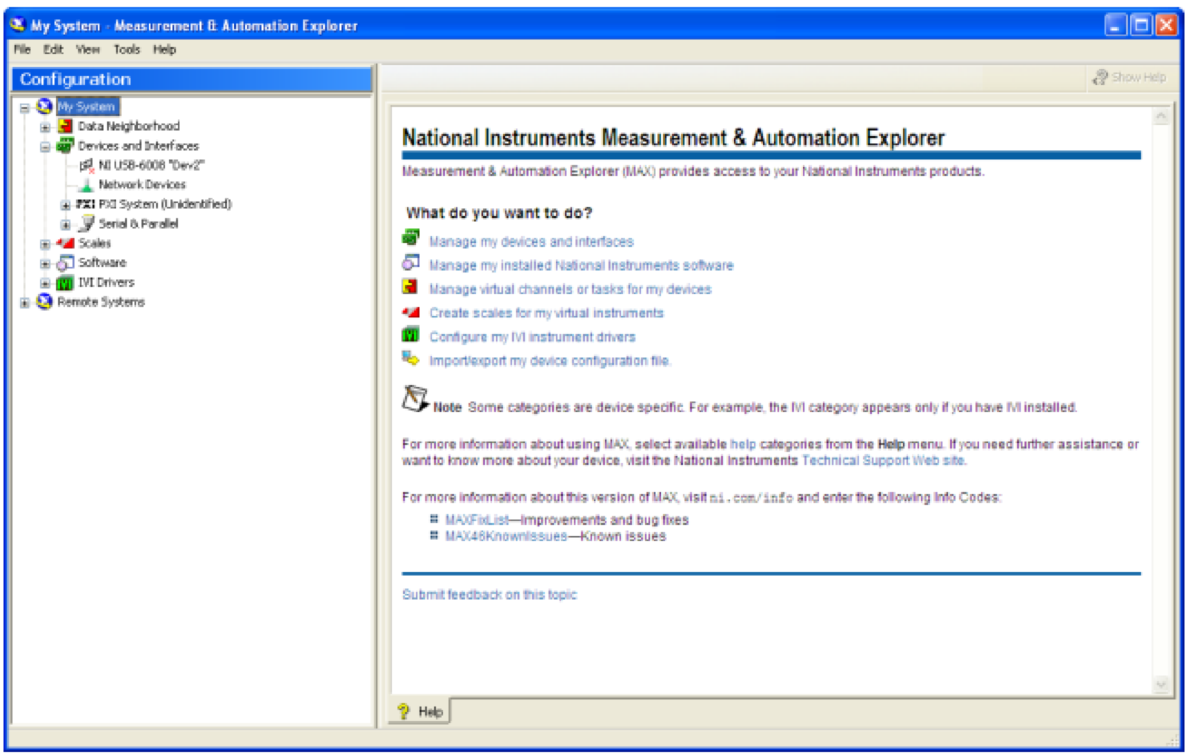
Front Panel Description:

MAINS ON/OFF Switch	- Switch ON/OFF the VTTS-01.
Pump 1ON/OFF switch	- To switch ON/OFF the pump.
Pump 2 ON/OFF switch	- To switch ON/OFF pump 2.
Pump 3 ON/OFF switch	- To switch ON/OFF pump 3.
Input 1 (1, 2)	- 1 - Inbuilt 24V power supply. 2- Channel 1 ADC input.
Input 2	- 1- Inbuilt 24V power supply. 2 - Channel 2 ADC input.
Input 3	- 1- Inbuilt 24V power supply. 2 - Channel 3 ADC input.
Output 1	- Channel - 1 analog output (4-20mA).
Output 2	- Channel - 2 analog output (4-20mA).
Output 3	- Channel - 3 analog outputs (4-20mA).
LT1	- It is used to measure the level of the process tank1.
LT2	- It is used to measure the level of the process tank 2.
LT3	- It is used to measure the level of the process tank 3.
B1, B2	- Input of I/P converter
B3, B4	- Input of I/P converter (2)
L1, L2	- L 1 - LT input is 24V DC L 2 - LT output (4-20) mA
L3, L4	- L 3 - LT input is 24V DC L 4 - LT output (4-20) mA
L5, L6	- Level transmitter 3 supply (5) and load (6) terminals.
G1	- To indicate the compressor pressure.
G2	- To indicate the air regulator output pressure.
G3	- To indicate the control valve 1 input pressure (3-15) Psi.
G4	- To indicate the control valve 2 input pressure (3-15) Psi.
Input 1 DPM	- To indicate the level transmitter output (mA).
Output DPM	- To indicate the electro-pneumatic converter input (mA).
Analog I/O	- To interface the analog signal from/to computer (4 - 20mA).
Digital I/O	- To interface the digital signal from/to computer (0 - 5V).

Note: Understand the physical connection and front panel description of the hardware setup.

MAX – Measurement and Automation Explorer:

- Measurement & Automation Explorer (MAX) provides access to your National Instruments devices and systems.
- With MAX, you can:
  - Configure your National Instruments hardware and software
  - Create and edit channels, tasks, interfaces, scales, and virtual instruments
  - Execute system diagnostics
  - View devices and instruments connected to your system
  - Update your National Instruments software
- In addition to the standard tools, MAX can expose item-specific tools you can use to configure, diagnose, or test your system, depending on which NI products you install. As you navigate through MAX, the contents of the application menu and toolbar change to reflect these new tools.
- A typical MAX window will look like as shown below.

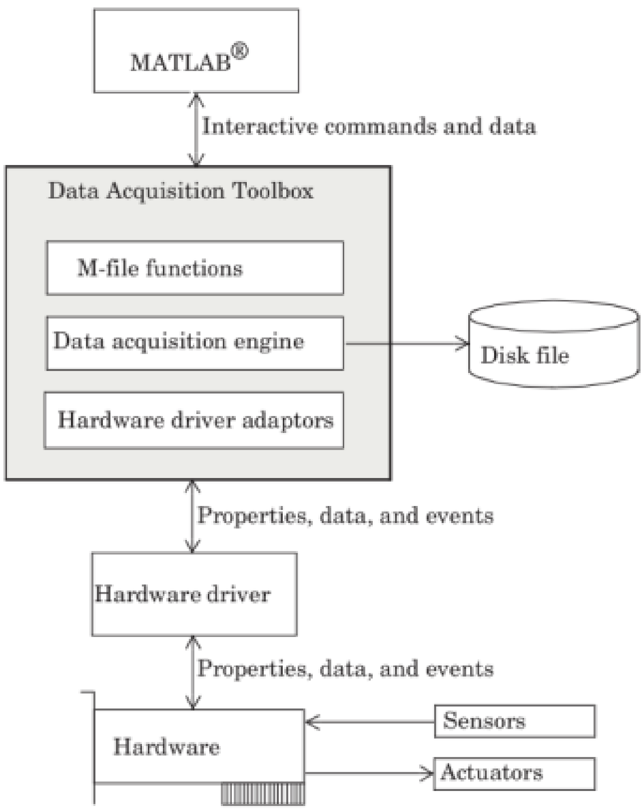


- We will use the Data Acquisition Toolbox in order to write and read data to and from a USB-6002 DAQ device from National Instruments.
- We can create DAQ applications with or without Measurement Studio. In both situations you need the NI-DAQmx driver library.
- NI-DAQmx:

  National Instruments provides a native .NET API for NI-DAQmx. This is available as a part of the NI DAQmx driver and does not require Measurement Studio.

Data Acquisition Toolbox of MATLAB:

- Data acquisition in text based-programming environment is very similar to the LabVIEW NI-DAQmx programming as the functions calls is the same as the NI-DAQmx VI's.
- Data Acquisition Toolbox software provides a complete set of tools for analog input, analog output, and digital I/O from a variety of PC-compatible data acquisition hardware.
- The toolbox lets you configure your external hardware devices, read data into MATLAB and Simulink environments for immediate analysis, and send out data.
- Data Acquisition Toolbox also supports Simulink with blocks that enable you to incorporate live data or hardware configuration directly into Simulink models.
- You can then verify and validate your model against live, measured data as part of the system development process.
- We will use the Data Acquisition Toolbox in order to write and read data to and from a USB-6002 DAQ device from National Instruments.
- Below we see the data flow from the sensors to the MATLAB:



Procedure:

1. Ensure VTTS – 01 Mains is ON.
2. Ensure USB 6002 is connected to PC and VTTS – 01.
3. Find the COM Port from device manager.

4. Create a .m file and type the following Matlab codes.
5. Matlab Code:

```
clear all;clc;
s = daq.createSession('ni');
addAnalogInputChannel(s,'Dev1', 0:3, 'Voltage');
addAnalogOutputChannel(s,'Dev1', 0:1, 'Voltage');
outputSingleScan(s,[-2 2]);
inputSingleScan(s);
```

6. Change the Output of Tank 1 and Tank 3 from 50% to 70%.
7. Tabulate the process value (Level (%)) of Tank 2 with respect to time (s).

Sl. No.	Time (s)	Level (mm)	Level (%)

8. Find the time constant of Tank 2.

Results:

1. step response graph of Tank 2

Experiment 10
Model and Controller Design of a Non-Linear Conical Tank System

Aim:

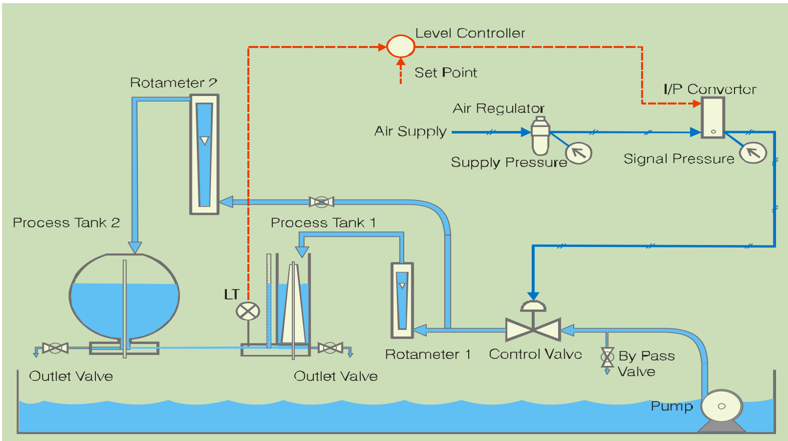
- To model and design a linearized controller for a conical tank level process.

Equipments & Components Required:

- Non-Linear Level Control Trainer (Product Code: 333)
- Instrument Air Supply
- Prosoft

Description:

Nonlinear level control trainer is designed for understanding the principles of nonlinear level control. The process setup consists of SS spherical tank, and conical process tanks and supply water tank with pump for water circulation. A pneumatic control valve with I/P convertor manipulates the water flow in to the process tank. These units along with necessary piping are fitted on support housing designed for tabletop mounting. Level transmitter is used for sensing level in the process tanks. The product is interfaces with computer through NI USB DAQ card and controlled by specially developed MATLAB based control software.



Schematic of a Non-Linear Level Control Trainer

The specification of the conical tank system is given below:

Height :

Top Diameter :

Bottom Diameter :

Material :

L.P.H :

Procedure:

1. Obtain the open loop model system by giving a step change in the input flow.
2. This can also be repeated for various region of the tank (Say divide the total height of the tank into 4 region with each region as 7cm).
3. Obtain the first order process with dead time parameters using the two-point method.
4. Design the PID controller based on Z-N method/Synthesis/Any other methods applicable for FOPDT stable process.
5. Implement the PID controller with the obtained parameters using MATLAB environment.
6. Run the process station and record the output response.

Open loop Modeling:

With the open loop response obtained do the following steps.

1. Give the input flow as 100 LPH in the open loop.
2. Observe the final settling valve of the flow in the rotameter /process simulator.
3. Record the open loop response.
4. The FOPDT model is given as $G(s)=\frac{K}{\tau s+1}e^{-t_d s}$, Where K is the system gain, τ is the time constant and t_d is the dead time parameter. The model allows simple experimental identification from the step response, which can be in most cases easily measured. The method proposed by Sundarsen and Krishnaswamy (1978) avoids the use of point of inflection construction entirely to estimate the time delay. The proposed times t1 and t2 are estimated from a step response curve. These times correspond to 35.3 % and 85.3 % response times.
5. The time constant and time delay are calculated as follows:

$\tau = 0.67(t2 - t1)$

$T = 1.3t1 - 0.29t2$

Controller Design:

1. For the obtained FOPDT model design the various conventional controllers (IEEE/Science Direct paper will be given with selected control configuration) and check the responses in simulation followed by the implementation with real time systems.
2. Compare the obtained results with the synthesis PID controller design.

Result and Inferences:

[Model calculation / Graph]