COUPLED TANK SYSTEM

(Model No: VCTS-01)

USER MANUAL

Version 2.0

COUPLED TANK SYSTEM VCTS-01

INTRODUCTION

The coupled tank system is a widely used system in control theory. Liquid level control has a very large application domain in industry. It's most representative didactical equipments are the tank systems, i.e. one, three or four tank systems.

TECHNICAL SPECIFICATION

Level Transmitter

Source	-	Switzer Instruments.
Type	-	LT
Sensor	-	Capacitive Type.
Input	-	(0-250) mm.
Supply	-	+24V DC.
Output	-	(4-20) mA at 24VDC / 4 wire system.

Rotameter

Source	-	Tellin
Range	-	(0-500) Litre / Hour

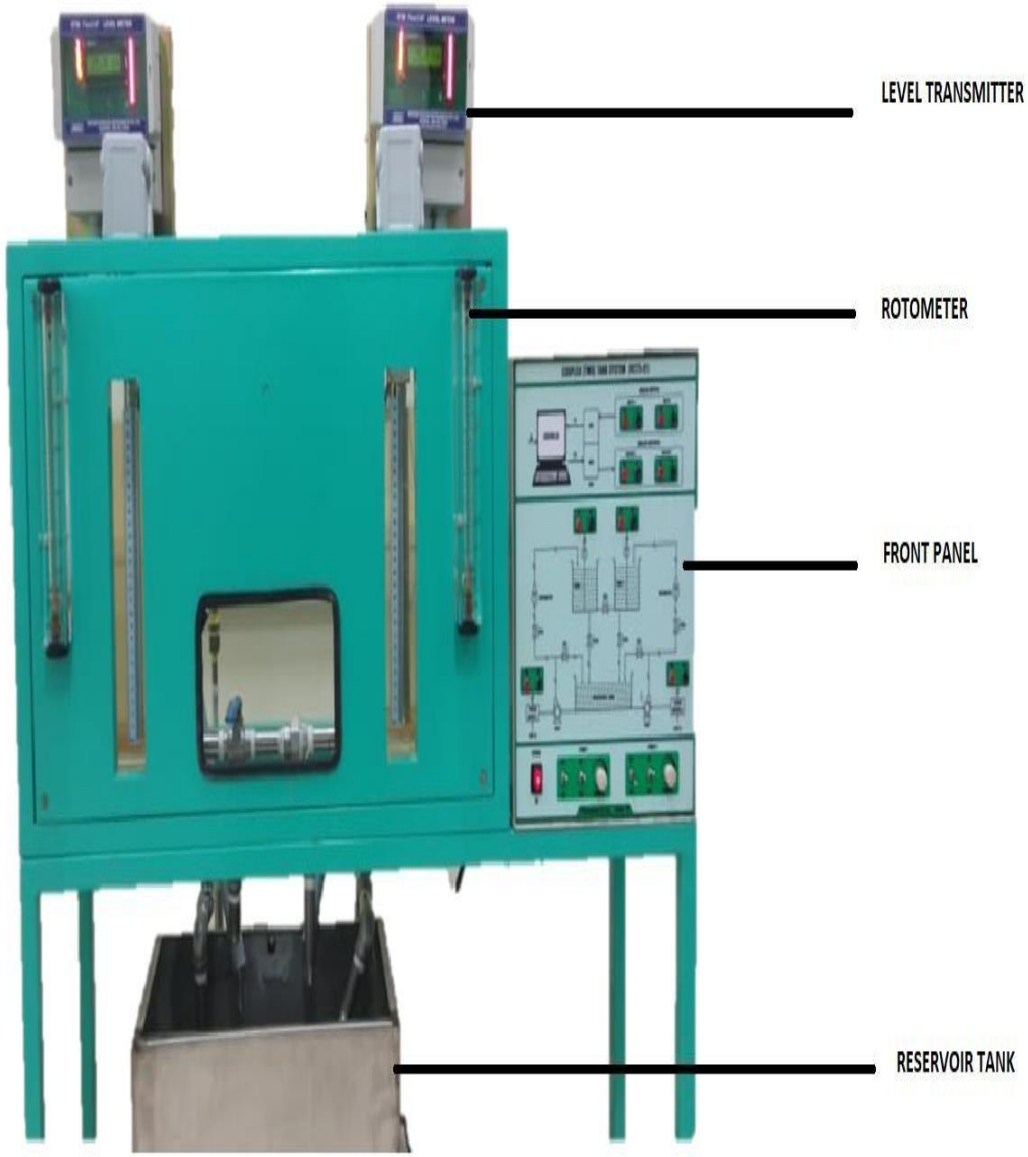
Thyristor power driver

Supply Input	-	220V AC.
Signal input	–	(4-20) mA.
Output supply	–	(0-220) VAC.
Firing	-	phase angle firing.

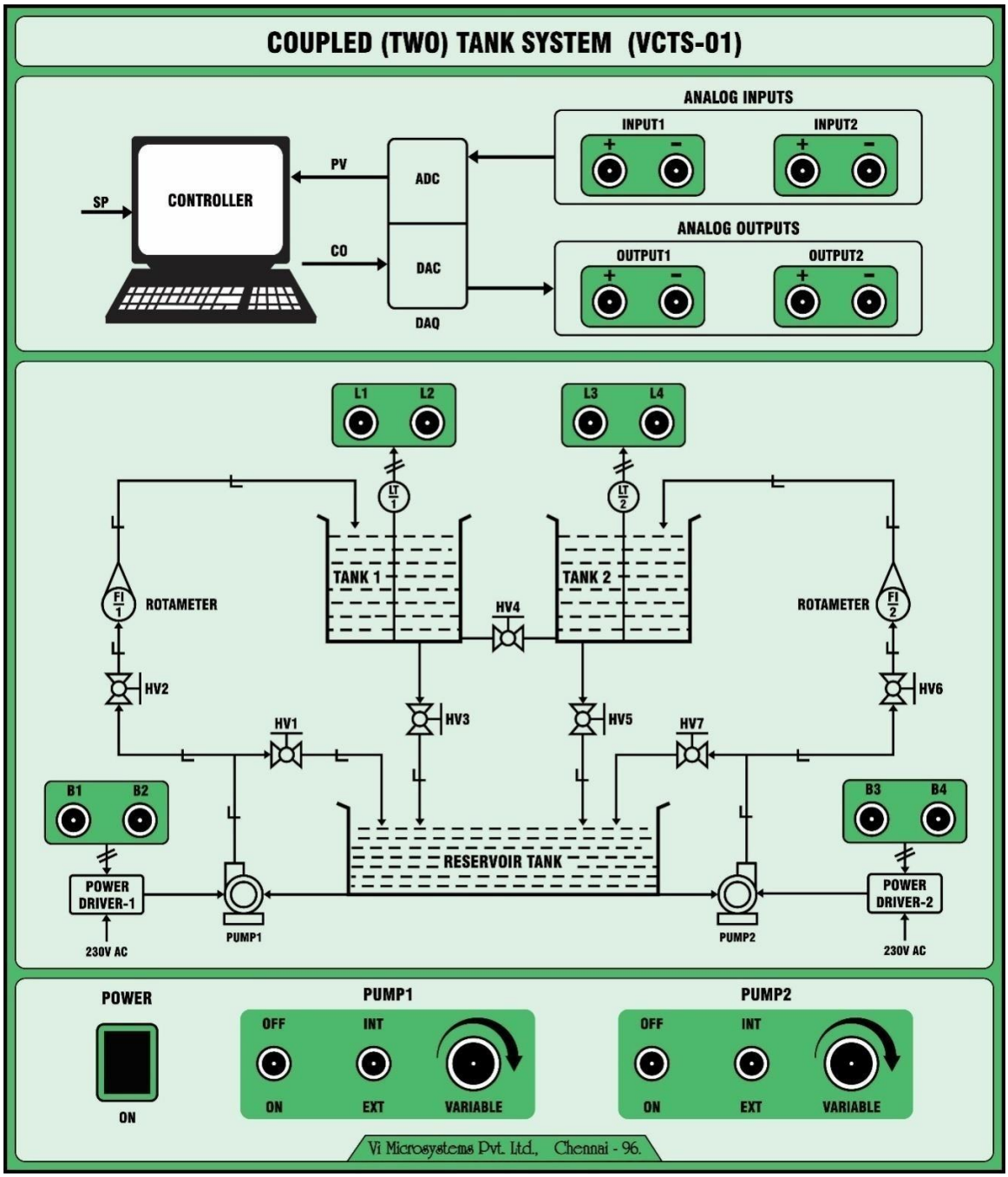
Pump

Source	-	Tullu - 80
Voltage	-	230 VAC/ DC, 50Hz
Discharge	-	800 LPH

PHYSICAL MODELING:



FRONT PANEL DIAGRAM



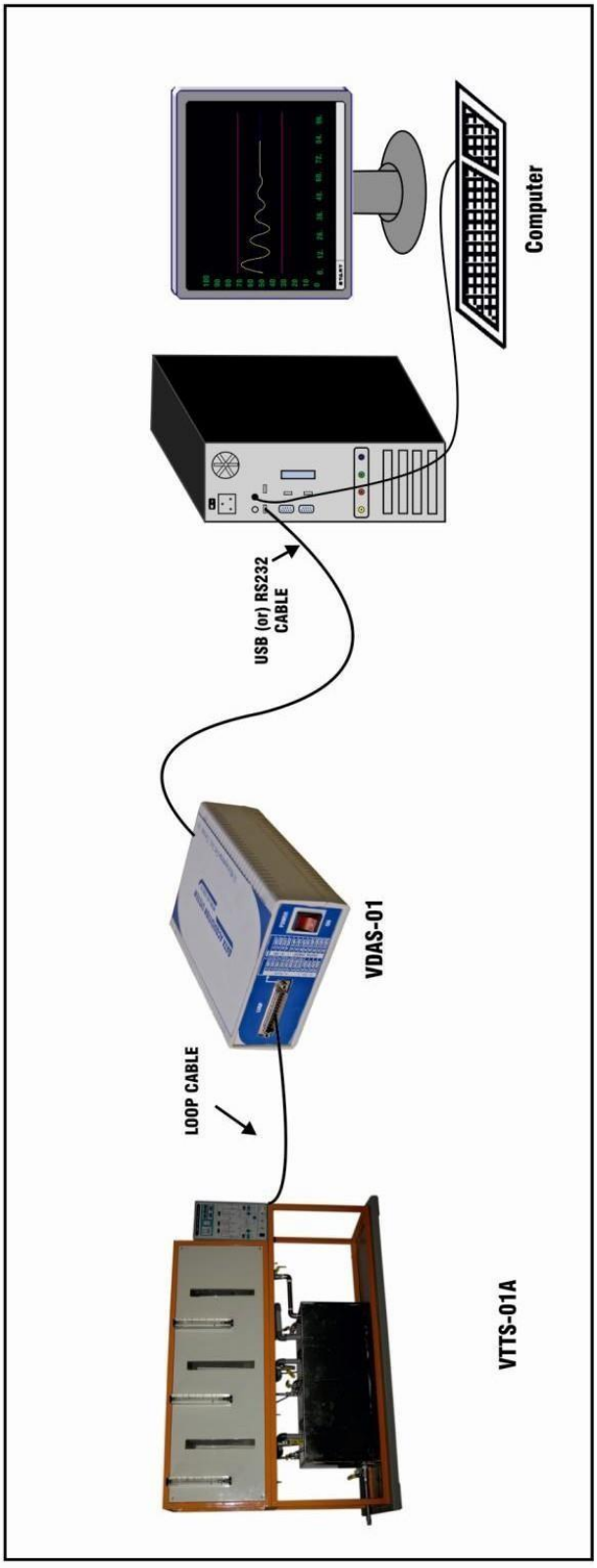
FRONT PANEL DESCRIPTION

Power ON/OFF Switch	-	Switch ON/OFF the unit.
Pump 1ON/OFF switch	-	Switch ON/OFF the pump 1.
Pump 2 ON/OFF switch	-	Switch ON/OFF the pump 2.
Input 1 (+, -)	-	1- Inbuilt 24V power supply. 2- Channel 1 ADC input.
Input 2 (+, -)	-	1- Inbuilt 24V power supply. 2 - Channel 2 ADC input.
Output 1 (+, -)	-	Channel - 1 analog output (4-20mA).
Output 2 (+, -)	-	Channel - 2 analog output (4-20mA).
B1, B2	-	Input of Power Driver (1)
B3, B4	-	Input of Power Driver (2)
L1	-	LT1 input is 24V DC
L2	-	LT1 output (4-20) mA
L3	-	LT2 input is 24V DC
L4	-	LT2 output (4-20) mA
Analog I/O	-	To interface the analog signal from/to DAQ.

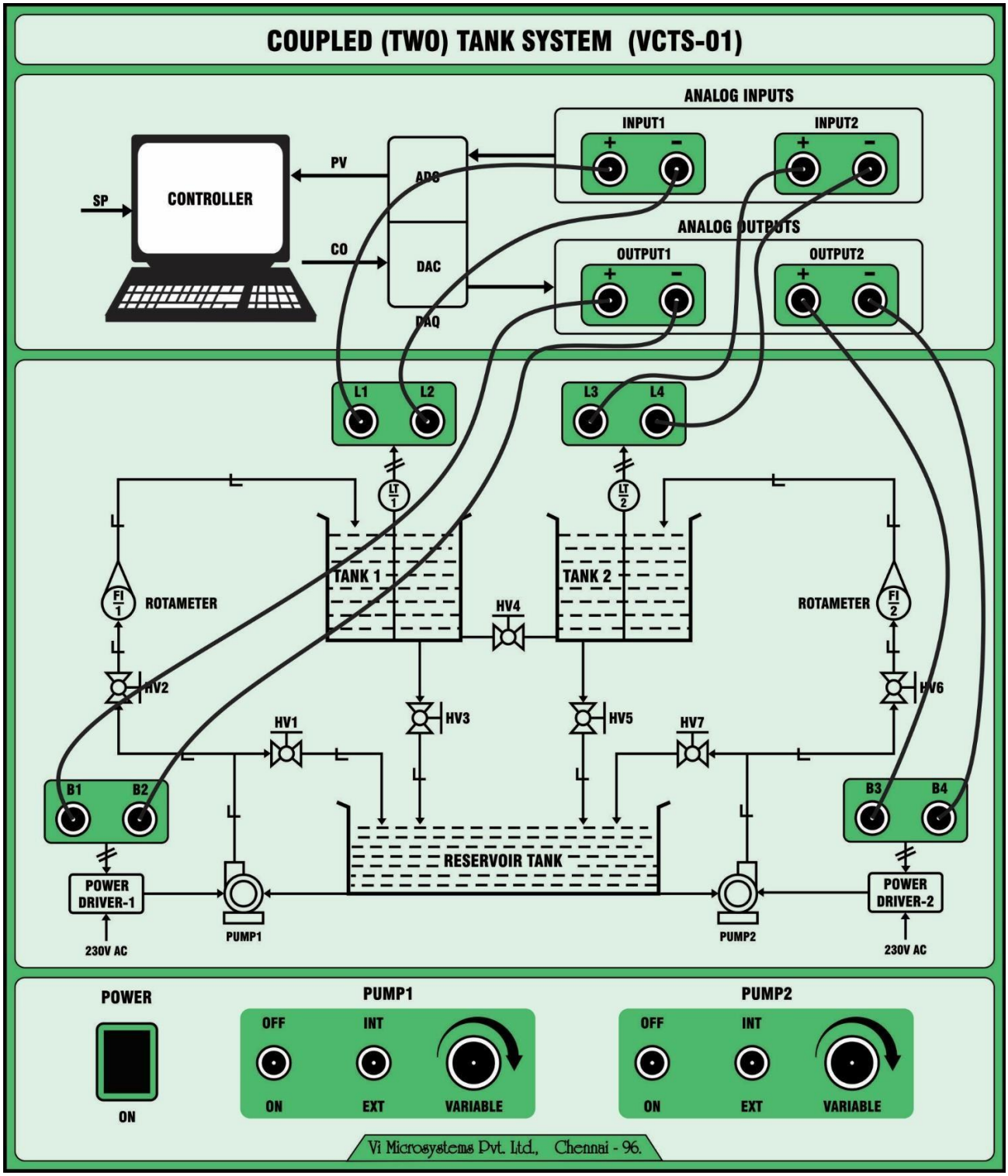
HAND VALVE DESCRIPTION

HV1	-	Pump 1 Bypass Valve.
HV2	-	Inlet valve for process tank 1.
HV3	-	Process Tank 1 Outlet Valve.
HV4	-	Interaction valve between process Tank 1 & Tank 2.
HV5	-	Process Tank 2 Outlet Valve.
HV6	-	Inlet Valve for process tank2.
HV7	-	Pump 2 Bypass Valve.

INTERFACING DIAGRAM

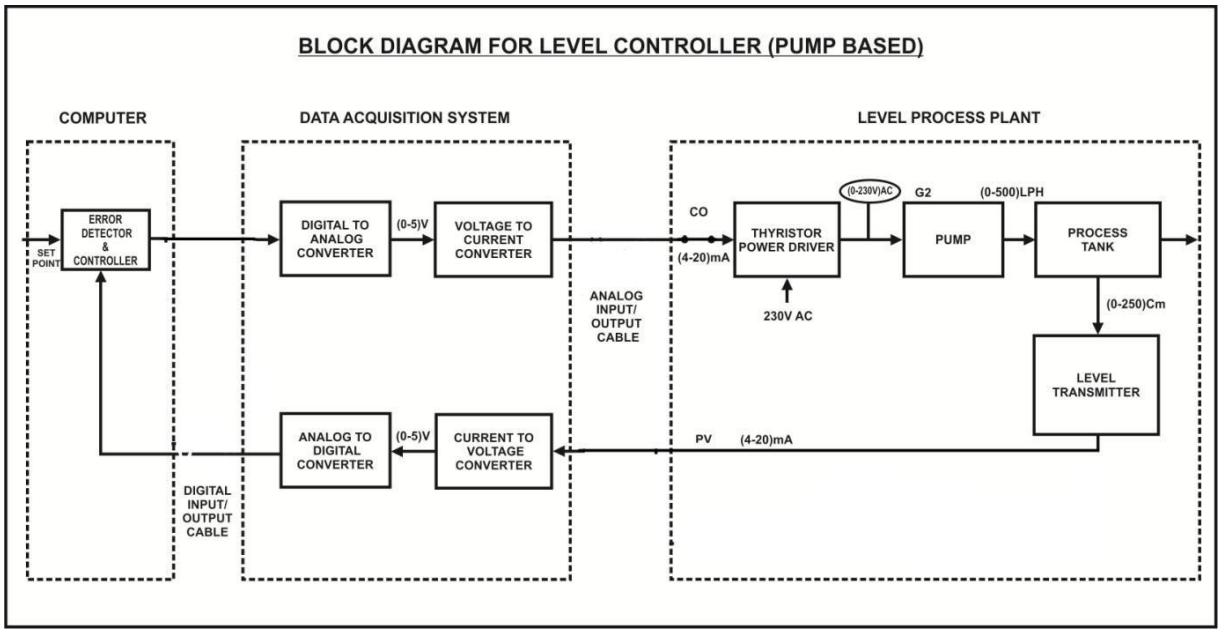


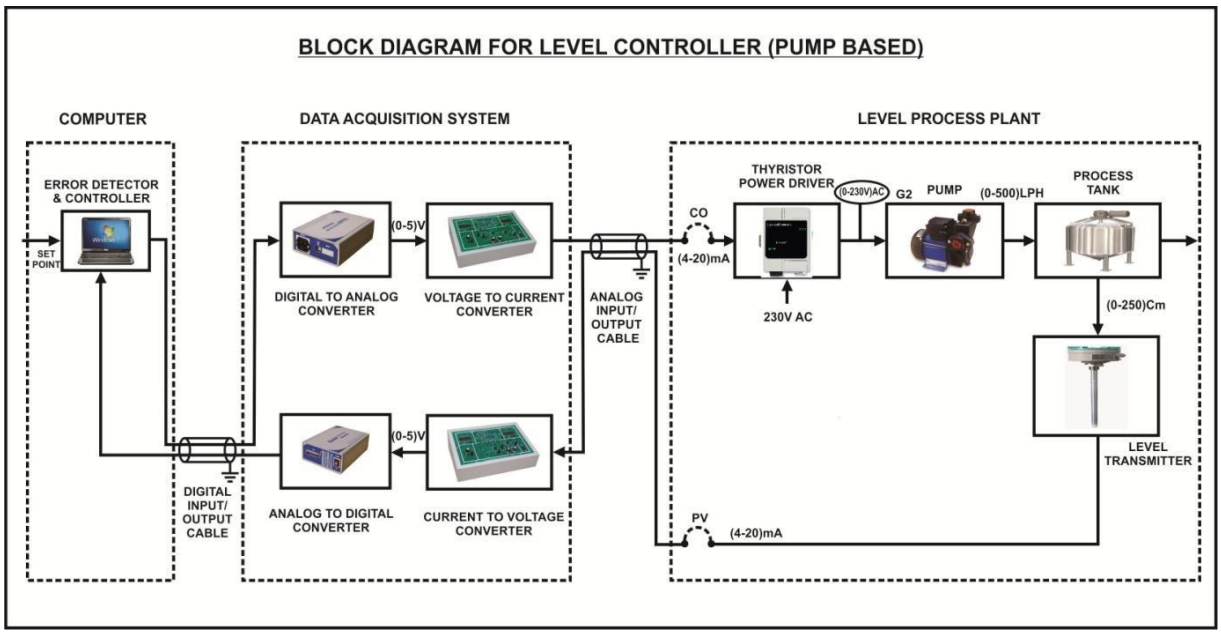
PATCHING DIAGRAM



DESCRIPTION

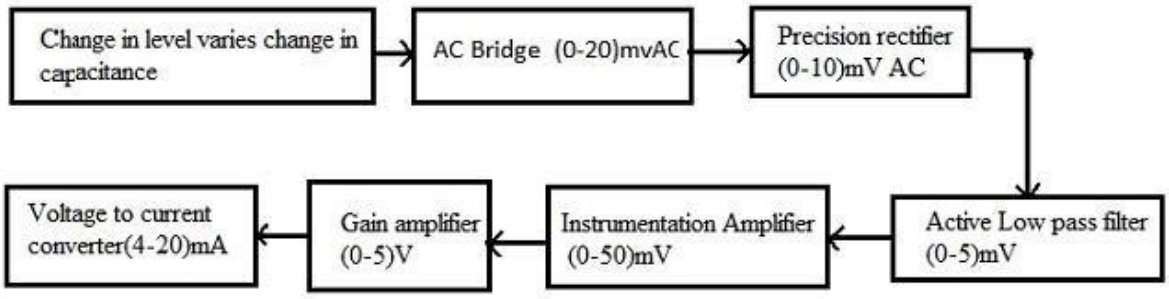
The level control is essential in an industrial application. In this unit, we can study the performance of the level controller. It consists of process tank, level transmitter, and SCR/Thyristor power driver, pump. The Level is controlled by varying the pump power supply.



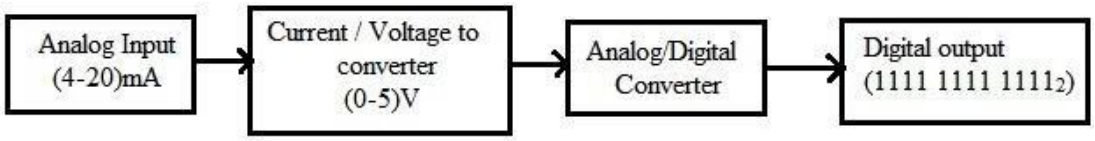


Process tank: The coupled tank system is used to perform the control of level in the process tank. Here, the level of the Process tank is to be measured and controlled by computer. From this process also study the characteristics of level transmitter and justify the various control action on the process.

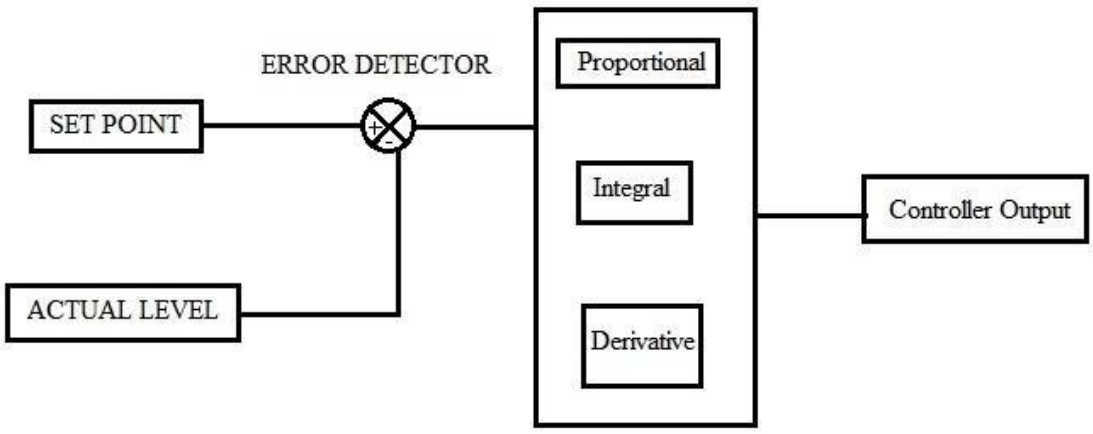
Level transmitter: It is used to measure/sense the level of the process tank and gives the corresponding current output (4-20mA).

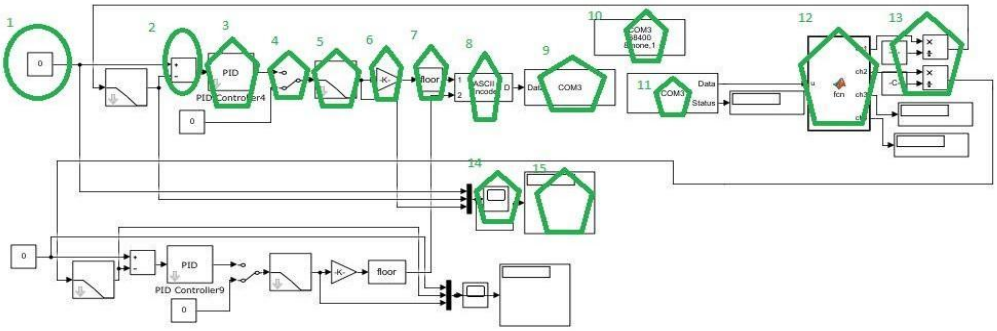


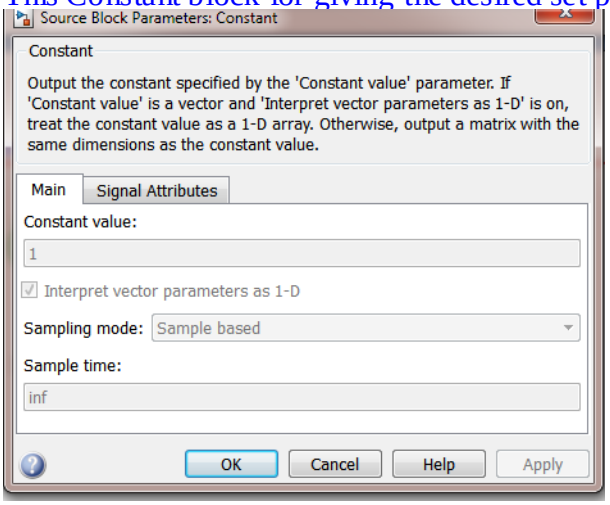
Analogue to digital converter: The transmitter output is given to the Analogue to digital converter in Data Acquisition system.

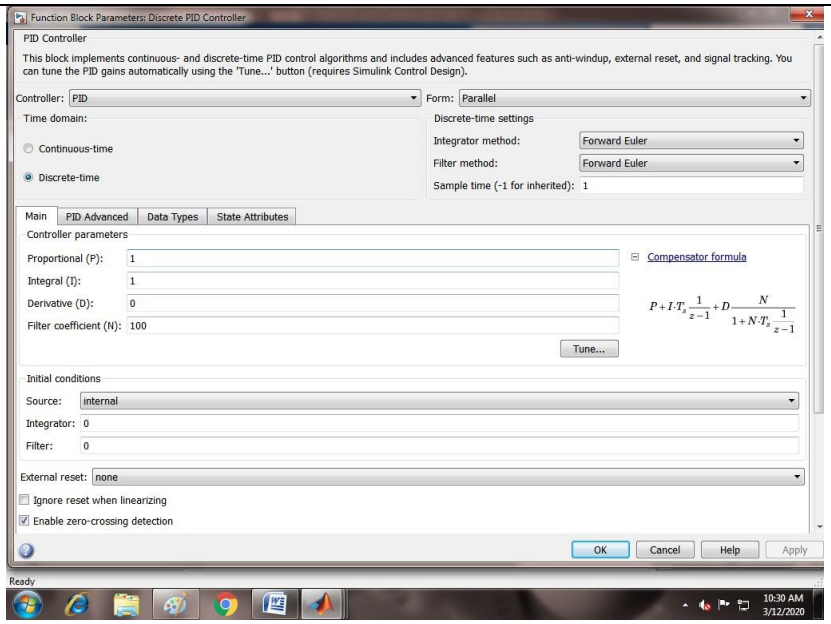


Controller: Here, a Computer acts as an error detector and controller. Desired level is given through the key board. A PID controller is programmed; it gets the process variable and compares it with set point. Controller produces a control voltage for corresponding error signal. According to the error signal, it generates a control signal

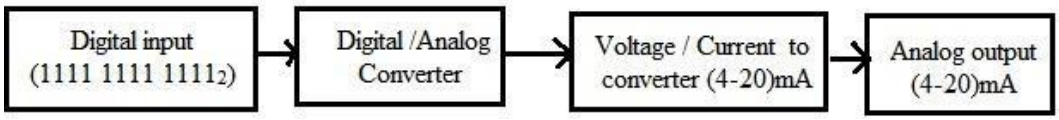




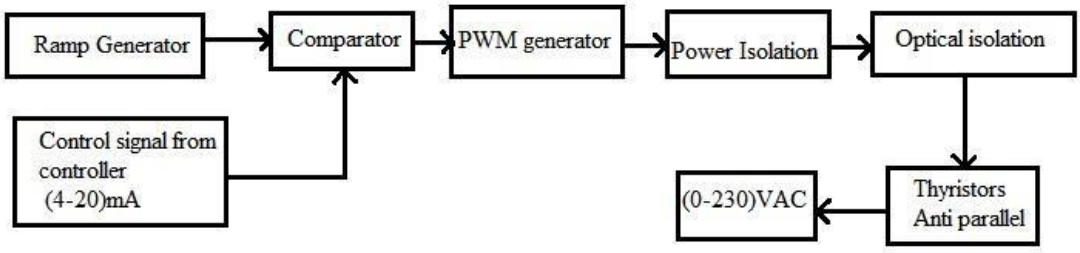
1	Set point	This Constant block for giving the desired set point. 
2	Error detector	This block performs the error calculation on its set point and process variable inputs.
3	PID	The PID Controller output is a sum of the proportional input signal, the integral of the input signal, and the derivative of the input signal.

		
4	Manual Switch	The Manual Switch selects PID outputs and open loop manual mode output to pass through to the output.
5	Low pass filter	Allows low frequency signals.
6	Gain block	It multiplies the controller output by a constant value (2.55). 0-100% into (0-2^8).
7	Rounding Function	The Rounding Function block applies a rounding function to the input signal to produce the output signal.
8	ASCII Encode	The ASCII Encode block generates a UINT8 output vector that contains a NULL-terminated string based on a printf like format string and data on the input ports.
9	Serial Send	The Serial Send block sends binary data from your model to the specified remote machine using the serial protocol.
10	Serial Configuration	The Serial Configuration block configures parameters for a serial port that you can use to send and receive data. You must set the parameters of your serial port before you set up the Serial Receive and the Serial Send block. You must first specify the configuration of your serial port before you configure the Serial Receive and Serial Send blocks. The Receive and Send blocks will prompt you to add a Configuration.
11	Serial Receive	The Serial Receive block configures and opens an interface to a specified remote address using the Serial protocol. The configuration and initialization occur once at the start of the model's execution. The block acquires data during the model's run time.
12	MATLAB Function	Include MATLAB code in models that generate embeddable C code.
13	Divide	Divide scalars and non scalars.

Digital to analogue converter: The controller output is given to the Digital/analogue to converter in Data Acquisition system.

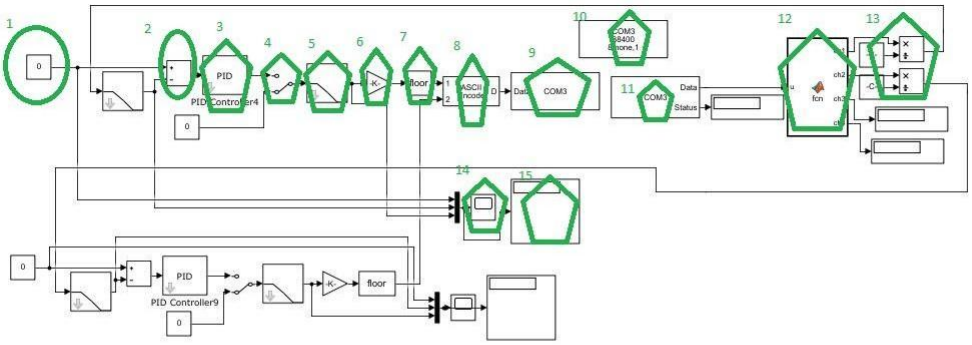


Thyristor power driver: the analogue output from Digital/Analogue converter is given to the SCR/Thyristor power driver. It drives the power driver circuit. The comparator compares in built ramp signal with control signal. The comparator signal is feed to the gate of the anti-parallel connected SCR/Thyristor power pack. Based on the triggering pulses,



Pump: The Pump delivers the water from reservoir and gives to process tank. The pump flow is manipulated, for maintaining the level of the process tank.

Conclusion: Based on the set point, disturbance and PID parameter, the pump power is controlled to maintain the desired Level.



EXPERIMENATAL SECTION

EXPERIMENT - 1

AIM: To study the characteristics and a control action of PID on the tank 1.

APPARATUS REQUIRED

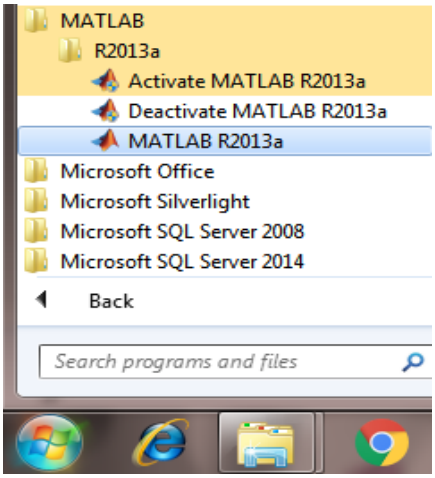
1. COUPLED TANK SYSTEM (VCTS-01) unit.
2. Computer with software.
3. Data acquisition system (VDAS –01).
4. Power chord, Loop cable, USB cable.

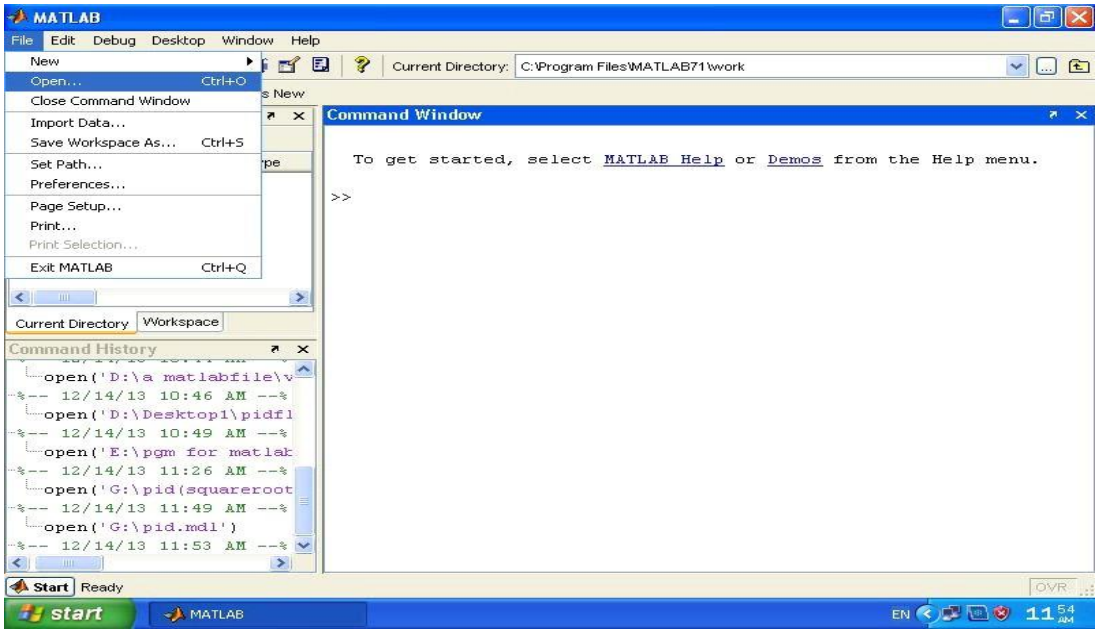
PROCEDURE

- Ensure the availability of water in the storage tank.
- Make sure the hand valve settings for this experiment.

  HV1, HV3 - Partially open
  HV2 - Fully opened
  HV4 - Fully closed.

- Ensure the interfacing of the unit with data acquisition and computer as per the diagram.
- Make sure the patching connection as per the diagram.
- Switch ON the unit, the Data acquisition card and computer.
- Invoke MATLAB software in Computer.



- In Computer, select **"Start →Menu → All Programs → MATLAB 2019a".**
- The following window will be appeared,
- 

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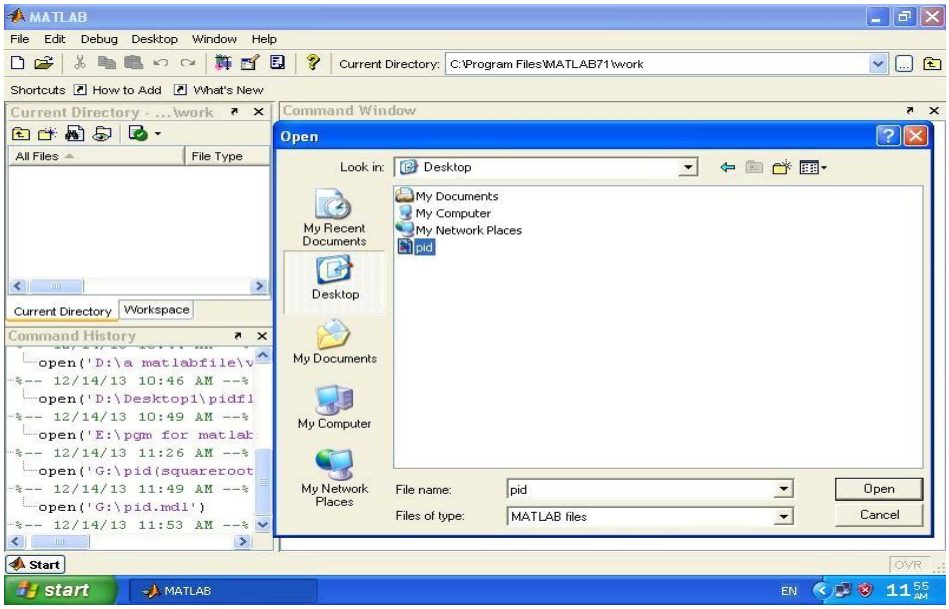
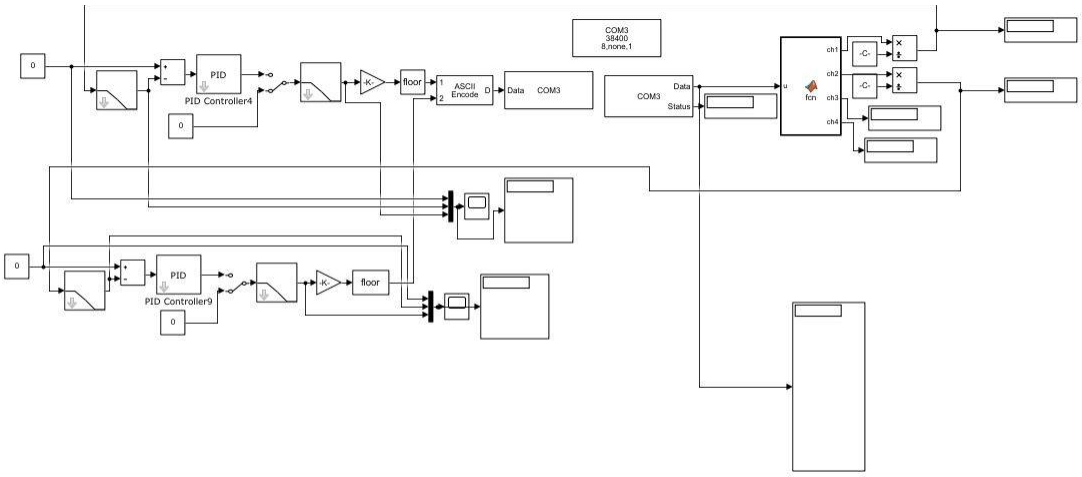
file" menu the popup menu will be shown below,

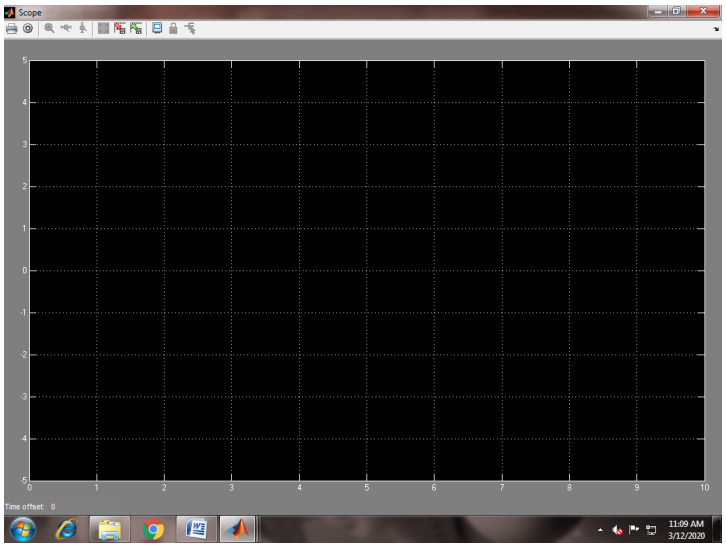
- From the popup menu, click "open" to browse Simulink file.
- In "**Simulink>>open>>coupled tank system.mdl**".



- When open the desired Simulink file, it will display the program will be shown below,



- To set the parameters like set point, kp, ki, kd values
- Enter the desired set point into the block.
- In "PID" blocks to set kp, ki, kd and enter the desired value into the block.
- Auto/Manual switch should be facing the direction of "auto mode".
- Switch ON the Pump1 switch and INT/EXT switch in EXT mode.
- Click "start simulation"  for run the program.
- Click "display" to view the response of process.



Observe the performance of PID in MATLAB scope.

- For getting a desired response, tune the process parameter to optimum values.

- Study the response of PID control action for various values of set point, Kp, Ki, Kd.
- Switch OFF the pump1.
- Save the response and conclude the behavior of process.

ANALYSIS

The inflow to the tank is:

$$Fin = Km*Vp\ cm3/sec$$

Where *Km* is the pump constant and *Vp* is the voltage applied to the pump. The outflow velocity is given by the Bernoulli equation for small orifices:

$$Vo = \sqrt{2gL1}\ cm/sec$$

Where *g* is the gravitational acceleration in cm / sec2 and *L1* is the height of the water level in the tank in cm.

The outflow rate is then:

$$Fout = ao\sqrt{2gL1}\ cm3/sec$$

Where *a1* is the outflow orifice diameter

The flow rate through the tank is then given by

$$Fin - Fout = Km*Vp - ao\sqrt{2gL1}$$

$$\frac{dv}{dt} = \frac{Km * Vp - ao\sqrt{2gL1}}{ai}$$

Given,
ai=0.78 cm^2
ao=3.14 cm^2
L_1=5cm

At steady state it will be zero

- Measure the value of *Vp* and calculate the *Km* for a given height of water.
- Effect on the rising time, peak overshoot, steady state error and settling time when desired tank level, Kp, Ki and Kd change.

RESULT

Thus, the characteristics and control action of PID on the tank 1

EXPERIMENT - 2

AIM: To study the characteristics and a control action of PID on the tank 2.

APPARATUS REQUIRED

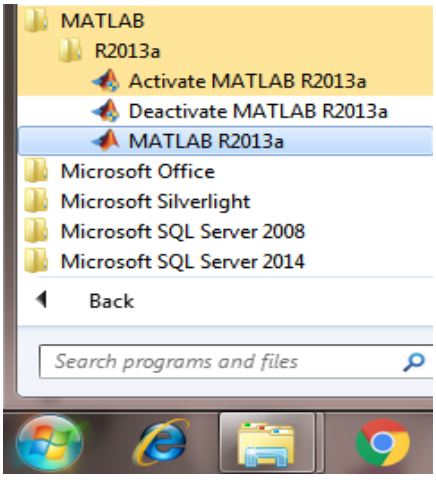
1. COUPLED TANK SYSTEM (VCTS-01) unit.
2. Computer with software.
3. Data acquisition system (VDAS – 01).
4. Power chord, Loop cable, USB cable.

PROCEDURE

- Ensure the availability of water in the storage tank.
- Make sure the hand valve settings for this experiment.

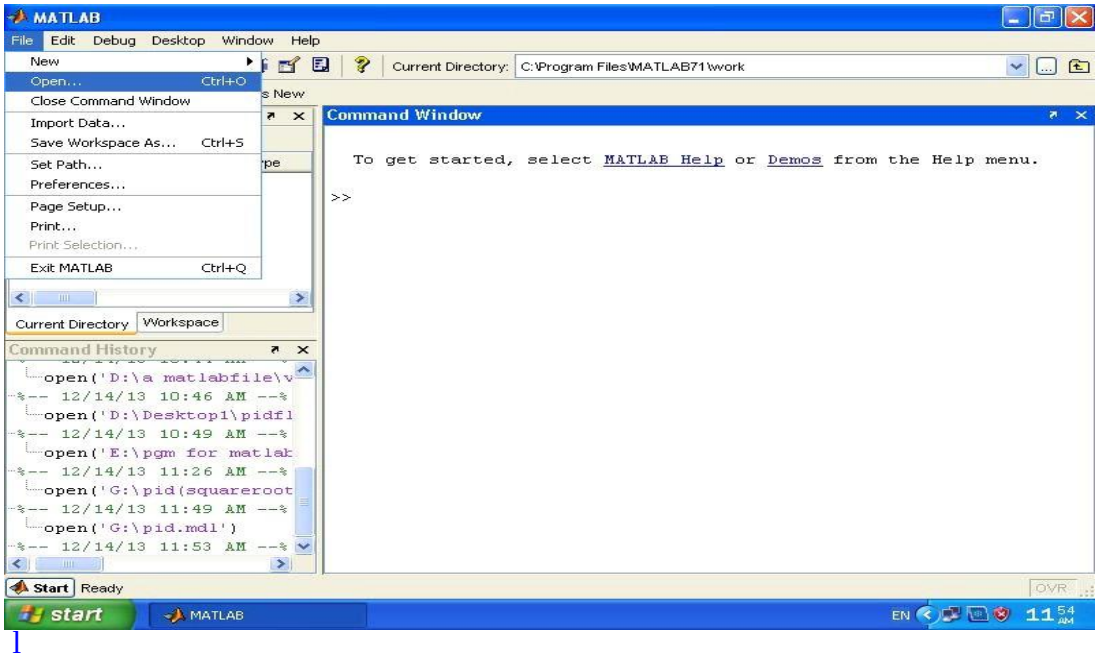
  HV5, HV7 - Partially open
  HV6 - Fully opened
  HV4 - Fully closed.

- Ensure the interfacing of the unit with data acquisition and computer as per the diagram.
- Make sure the patching connection as per the diagram.
- Switch ON the unit, the Data acquisition card and computer.
- Invoke MATLAB software in Computer.



- In Computer, select **"Start →Menu → All Programs → MATLAB 2019a".**

- The following window will be appeared,



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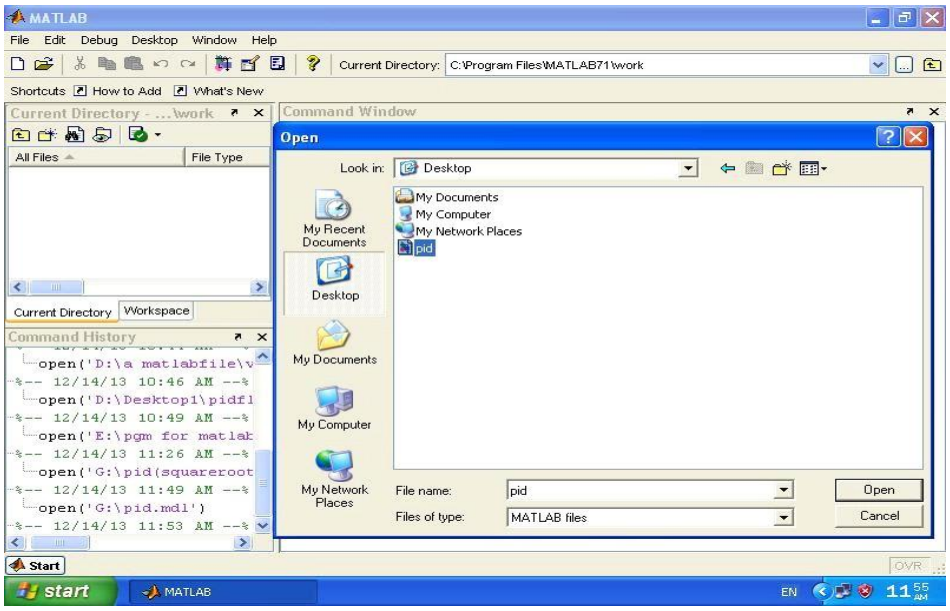
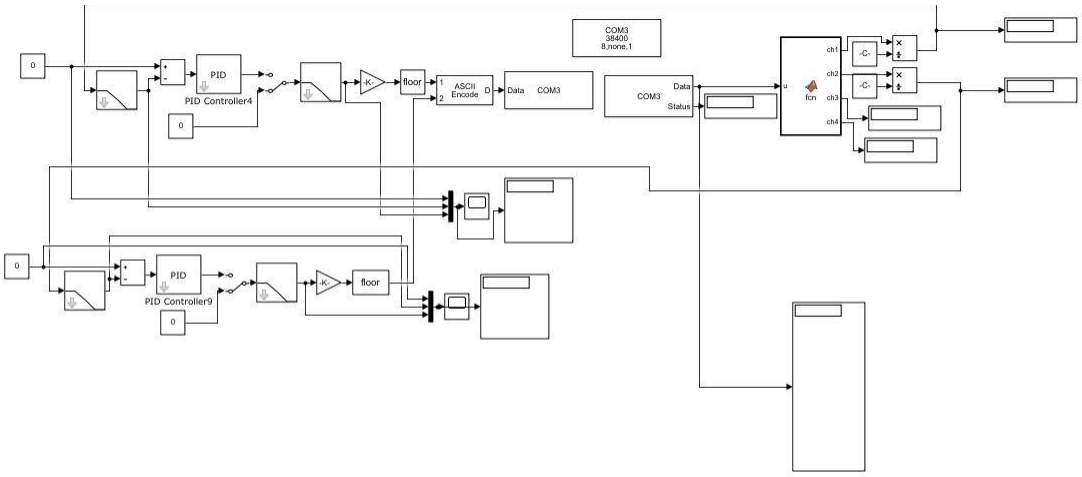
” menu the popup menu will be shown below,

- From the popup menu, click “open” to browse Simulink file.

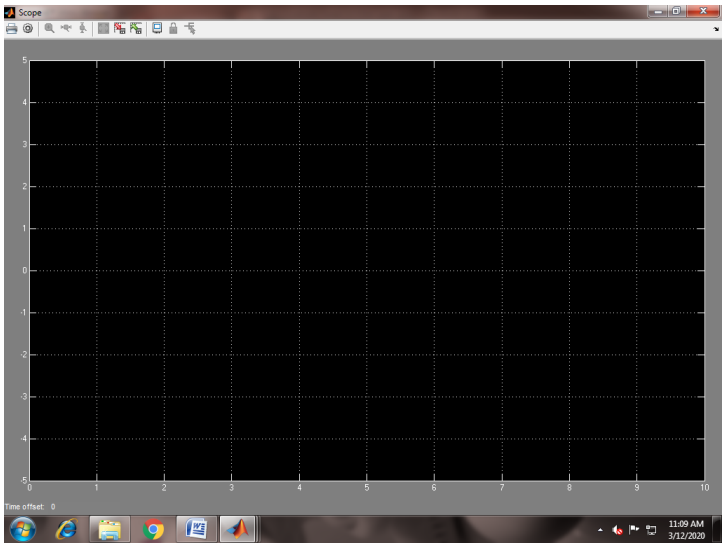
- In “**Simulink>>open>>coupled tank system.mdl**”.



- When open the desired Simulink file, it will display the program will be shown below,



- To set the parameters like set point, kp, ki, kd values
- Enter the desired set point into the block.
- In "PID" blocks to set kp, ki, kd and enter the desired value into the block.
- Auto/Manual switch should be facing the direction of "auto mode".
- Switch ON the Pump2 switch and INT/EXT switch in EXT mode.
- Click "start simulation"  for run the program.
- Click "display" to view the response of process.



Observe the performance of PID in MATLAB scope.

- For getting a desired response, tune the process parameter to optimum values.

- Study the response of PID control action for various values of set point, Kp, Ki, Kd.
- Switch OFF the pump2.
- Save the response and conclude the behavior of process.

RESULT

Thus, the characteristics and control action of PID on the tank 2

EXPERIMENT - 3

AIM: To study the characteristics of coupled tank system in interaction.

APPARATUS REQUIRED

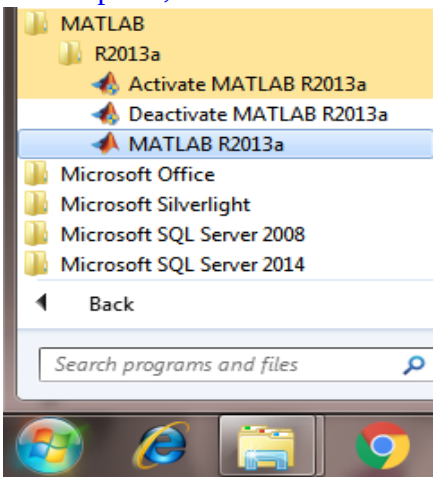
1. COUPLED TANK SYSTEM (VCTS-01) unit.
2. Computer with software.
3. Data acquisition system (VDAS –01).
4. Power chord, Loop cable, USB cable.

PROCEDURE

- Ensure the availability of water in the storage tank.
- Make sure the hand valve settings for this experiment.

  HV1, HV3, HV4, HV5, HV7 - Partially open
  HV2, HV6 - Fully opened

- Ensure the interfacing of the unit with data acquisition and computer as per the diagram.
- Make sure the patching connection as per the diagram.
- Switch ON the unit, the Data acquisition card and computer.
- Invoke MATLAB software in Computer.
- In Computer, select **"Start →Menu → All Programs → MATLAB 2019a".**



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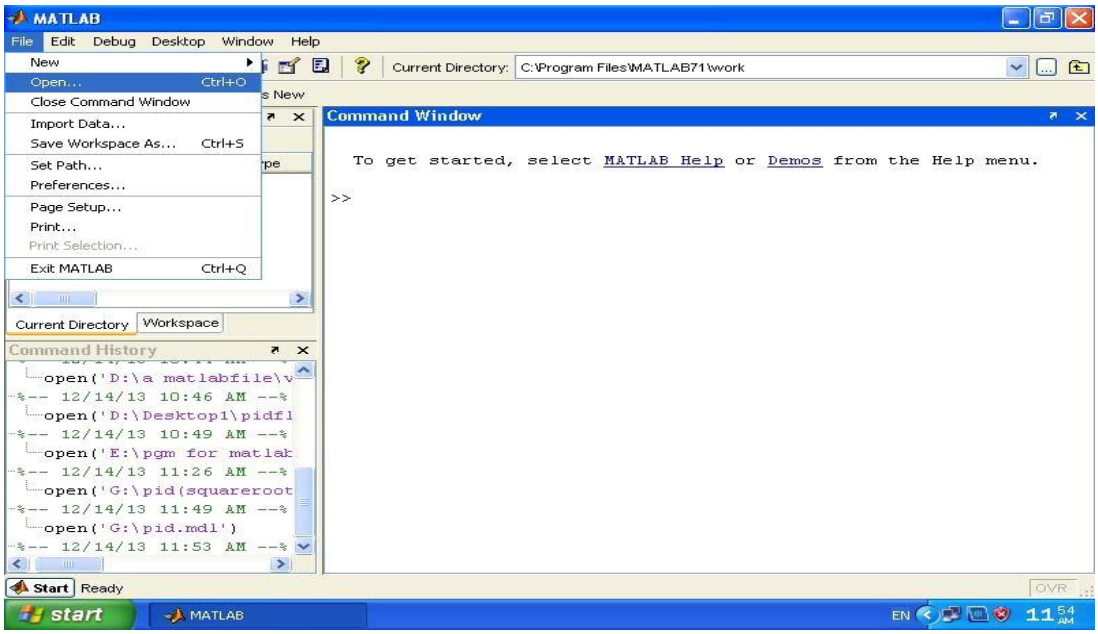
- 

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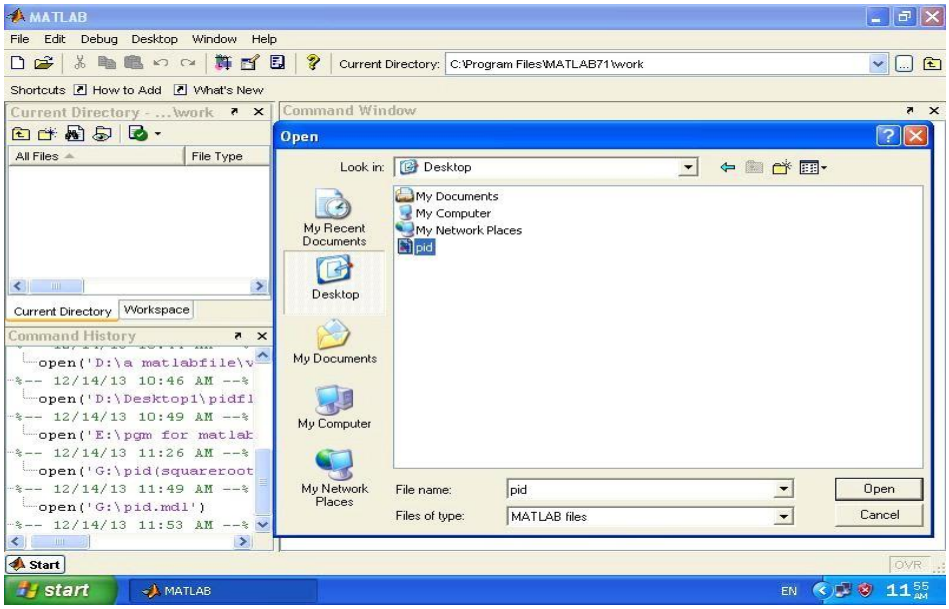
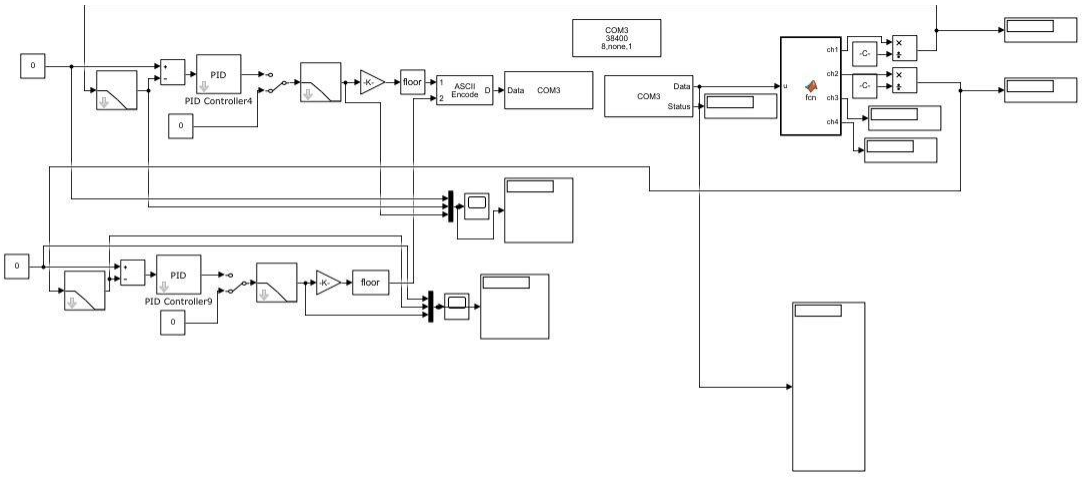
" menu the popup menu will be shown below,

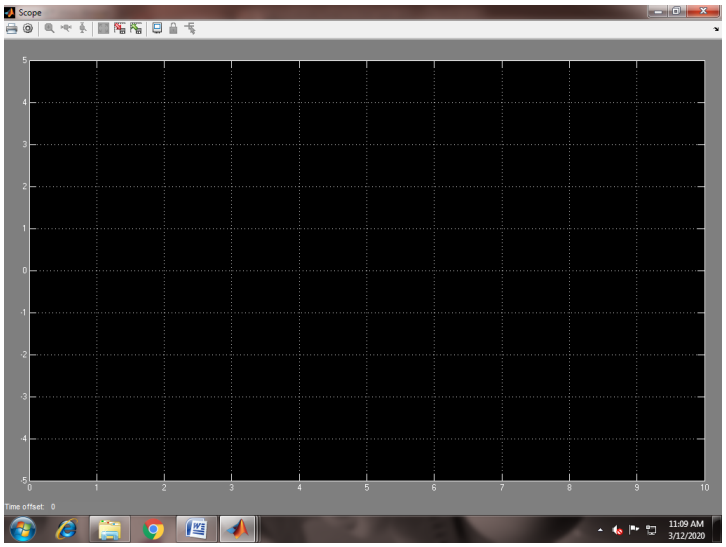
- From the popup menu, click "open" to browse Simulink file.
- In "**Simulink>>open>>coupled tank system.mdl**".



- When open the desired Simulink file, it will display the program will be shown below,



- To set the parameters like set point, kp, ki, kd values
- Enter the desired set point into the block.
- In "PID" blocks to set kp, ki, kd and enter the desired value into the block.
- Auto/Manual switch should be facing the direction of "auto mode".
- Switch ON the pump1 and Pump2 switch and INT/EXT switch in EXT mode.
- Click "start simulation"  for run the program.
- Click "display" to view the response of process.



Observe the performance of PID in MATLAB scope.

- For getting a desired response, tune the process parameter to optimum values.

- Study the response of PID control action for various values of set point, Kp, Ki, Kd.
- Switch OFF the pump1 and pump2.
- Save the response and conclude the behavior of process.

RESULT

Effect on the rising time, peak overshoot, steady state error and settling time when desired tank level, Kp, Ki and Kd change.

Thus, the characteristics and control action of PID on the tank 1 and tank 2 in interaction mode.

EXPERIMENT - 4

AIM: To find out the physical model of the process tank 1 in de-coupled mode.

APPARATUS REQUIRED

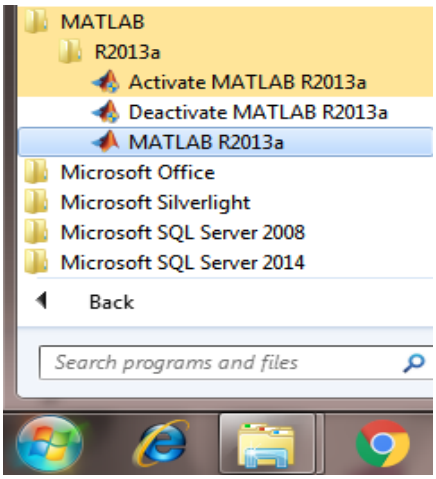
1. COUPLED TANK SYSTEM (VCTS-01) unit.
2. Computer with software.
3. Data acquisition system (VDAS –01).
4. Power chord, Loop cable, USB cable.

PROCEDURE

- Ensure the availability of water in the storage tank.
- Make sure the hand valve settings for this experiment.

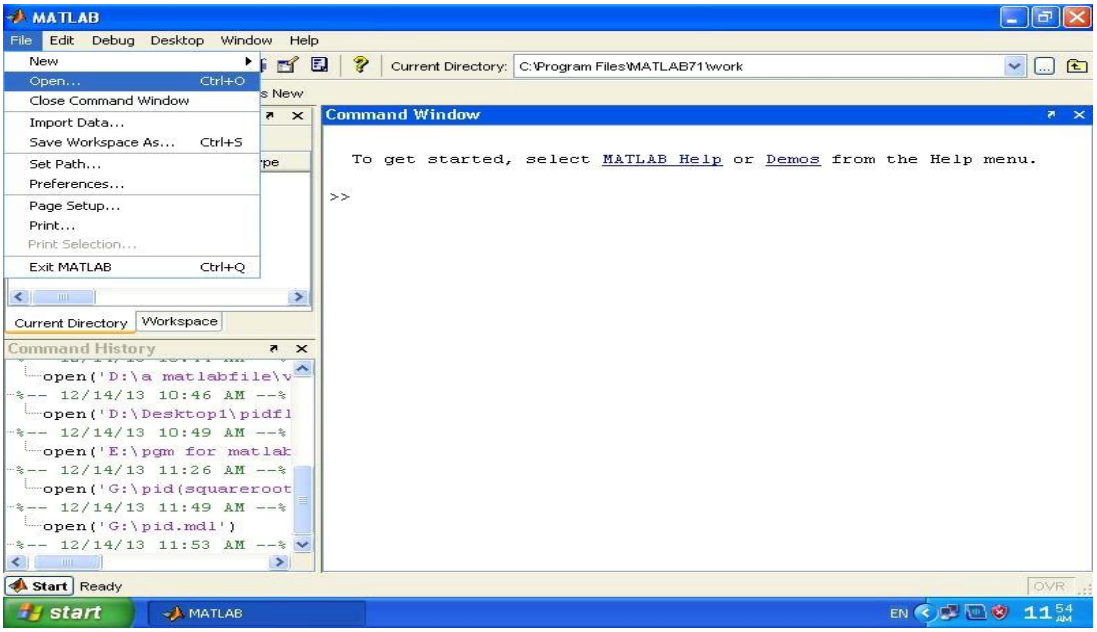
  HV1, HV3 - Partially open
  HV2 - Fully opened
  HV4 - Fully closed.

- Ensure the interfacing of the unit with data acquisition and computer as per the diagram.
- Make sure the patching connection as per the diagram.
- Switch ON the unit, the Data acquisition card and computer.
- Invoke MATLAB software in Computer.

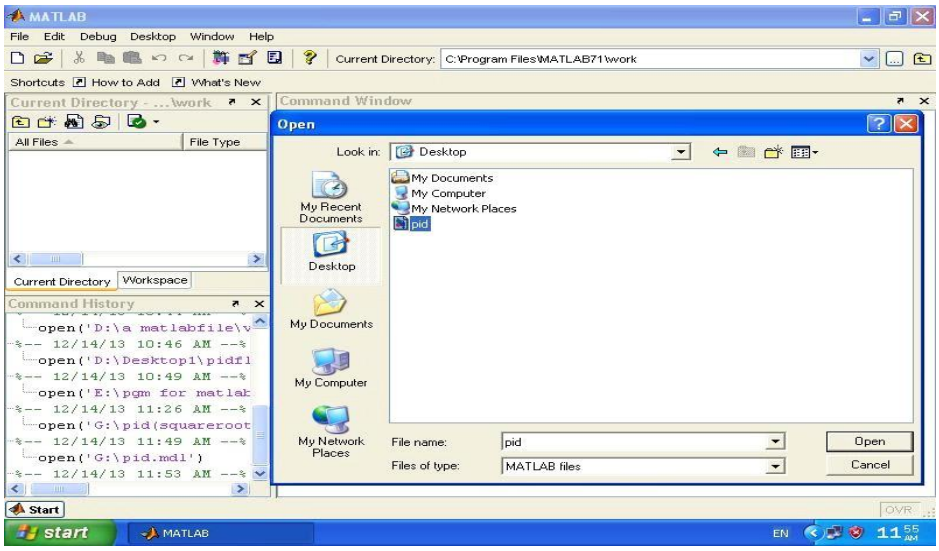


- In Computer, select **"Start →Menu → All Programs → MATLAB 2019a".**

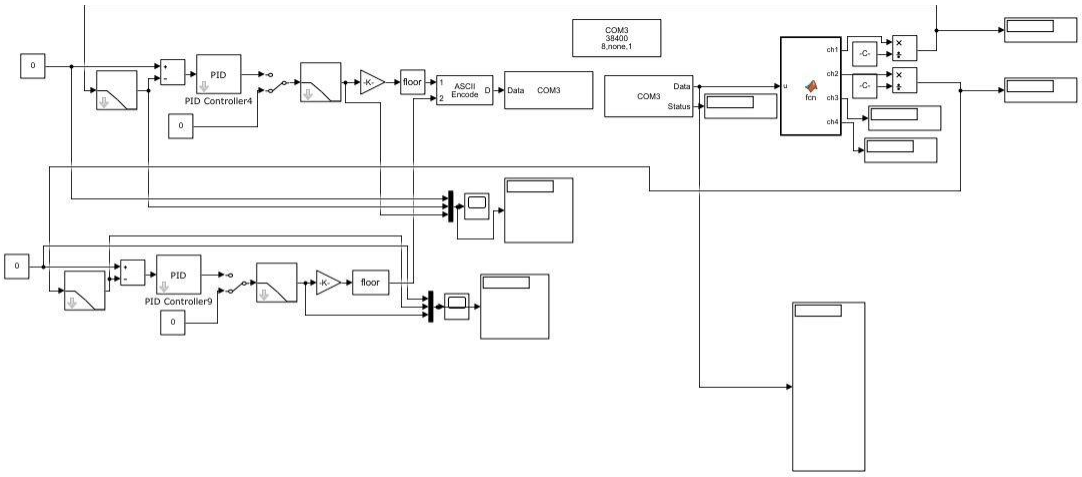
- The following window will be appeared,



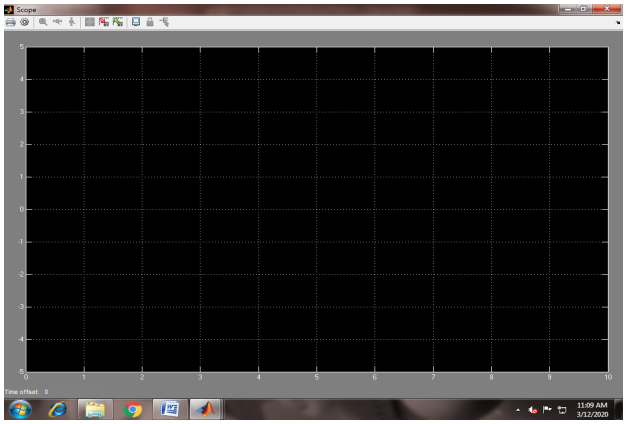
- Select the "file" menu the popup menu will be shown below,
- From the popup menu, click "open" to browse Simulink file.
- In "**Simulink>>open>>coupled tank system.mdl**".



- When open the desired Simulink file, it will display the program will be shown below,



- To set the parameters like set point, kp, ki, kd values
- Enter the desired set point into the block.
- In "PID" blocks to set kp, ki, kd and enter the desired value into the block.
- Select Auto / Manual switch to Manual Mode.
- Enter the Manual Controller power as 50% (for example).
- Make sure the hand valve settings.
- Click "start simulation"  for run the program.
- Switch ON the Pump1 switch and INT/EXT switch in EXT mode.
- Click "display" to view the response of process.



- Observe the response (rise in level) of a process tank.
- Once the level of tank reaches steady state, note down the steady state level (y_{ss}) , input control power (U).
- From the process reaction curve graph,
  - Find out 63.2% and 28.3% of y_{ss}.
  - Time at 63.2% of level is t_1 sec.
  - Time at 28.3% of level is t_2 sec.
  - Time at step input is given as t_0 sec.

Calculate time constant (τ), dead time (t_d) and gain (k).

$$\text{Gain } (k) = \frac{y_{ss}}{U} = \frac{\text{Steady state level (output)}}{\text{Step input (Manual mode power)}}$$

$$\text{Time constant } (\tau) = 1.5\,(t_2 - t_1)$$

$$\text{Dead time } (t_d) = t_2 - t_0 - \tau$$

Substitute the value of k , τ , t_d we will get the Mathematical (physical) model of process tank 1

$$G_1(S) = \frac{K e^{-t_d s}}{\tau S + 1}$$

For process tank 1

$\boxed{\tau = R * C}$, where C= capacitance of the tank = area of the tank =0.018 m^2

Tank diameter D= 0.150 m

$$\text{Then } R = \tau / C = \frac{\text{Height of the tank at Steady state}}{\text{Inflow rate} - \text{Outflow rate}}$$

Valve opening = percentage of valve opening * inner diameter outlet valve (0.016 m)

Note:

Follow the same procedure for

1) Non interacting mode of process tank 2. (Experiment – 2)

2) Interacting mode of process tank 2. (Experiment – 3)

- Switch OFF the pump1.
- Save the response and conclude the behavior of process.

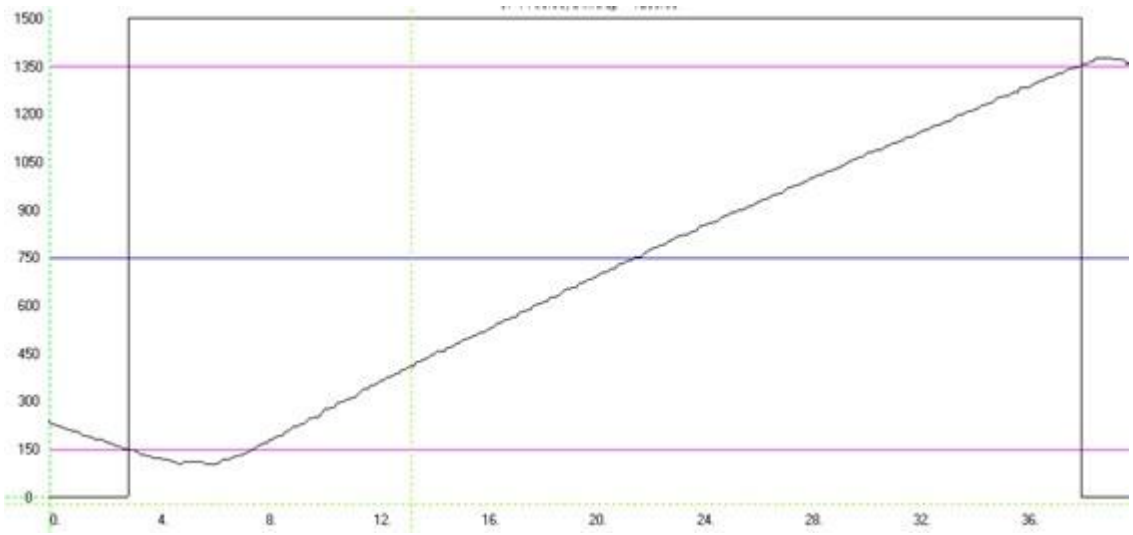
RESULT

Thus, the physical model of the process tank 1 in de-coupled mode was determined.

TROUBLESHOOTING

Components	Cause	Rectification
Level Transmitter (LT)	No current variation & No current output	To check the +24V DC supply. To check loop cable. To check the wiring.
Data Acquisition System	No communication with system	To check the port settings.
Power Driver	No Voltage variation	To check the analog current output. To check the supply Voltage.
Pump	Leakage problem	Check the carbon brush. To replace the oil seal.

Sample reading for process tank model



Step input (U) from 0 1500mm.

Process response (Y) from 104.1mm to 1376mm.

Process gain =process output/step input.

Process gain K = (1376-104)/ (1500-0)

Process gain K = 1271.9/1500.

Process gain K = 0.847933.

T_0 Time at step input = 2.92 sec.

T_1= (0.632*(1376-104.1)) +104=907.9408
Corresponding time = 25.88 sec

T_2= (0.283*(1376-104.1)) +104=464.0477
Corresponding time = 14.78 Sec.

Time constant (Tau) =1.5(25.88-14.78) sec.

Time constant (Tau) =16.65sec

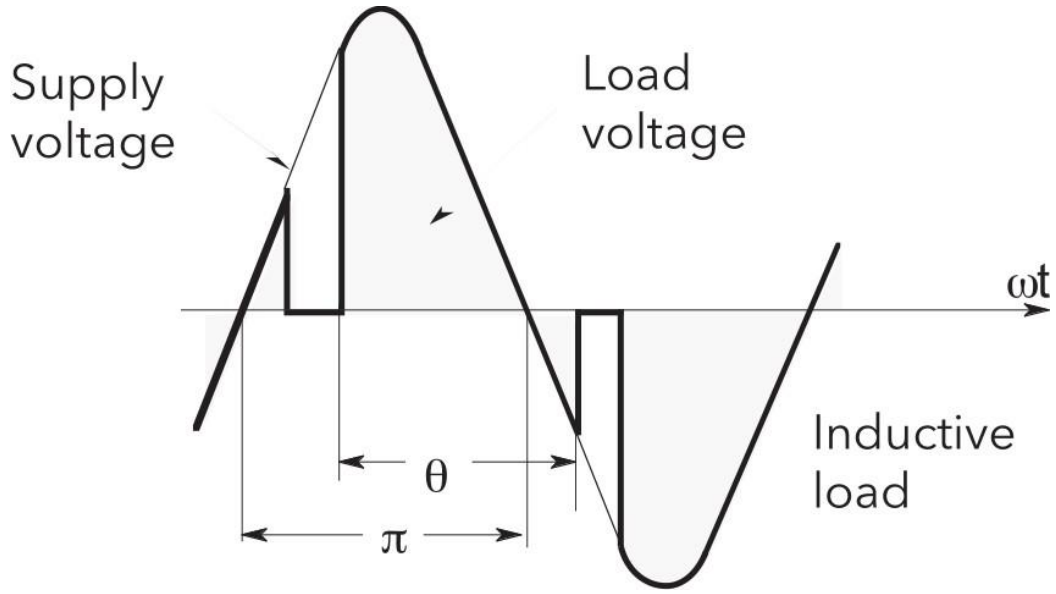
Time constant (Tau) = Tank capacitance * Resistance.
(Tank capacitance = tank area = 3.14*0.15m*0.15m=0.07065 m^2).
Resistance = Time constant/capacitance.
= 16.65 sec/0.07065 m*m.
= 235.67 s/m^2.

Dead time (Td) = 25.88-2.92-16.65

Dead time (Td) = =6.31 sec

Thyristors firing modes

Phase angle: In 'phase angle' thyristor firing mode the power transmitted to the load is controlled by firing the thyristors over part of the supply voltage half cycles.



Load voltage in 'phase angle' firing mode (θ: thyristor firing angle)

ANEXURE:

- LevelSwitchesK-5711
- HA031980ENG_3
- VDAS-01 DATA ACQUISITION SYSTEM (2)