EEL 3040

Control System

Lab - 6

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COUPLED TANK SYSTEM VCTS-01

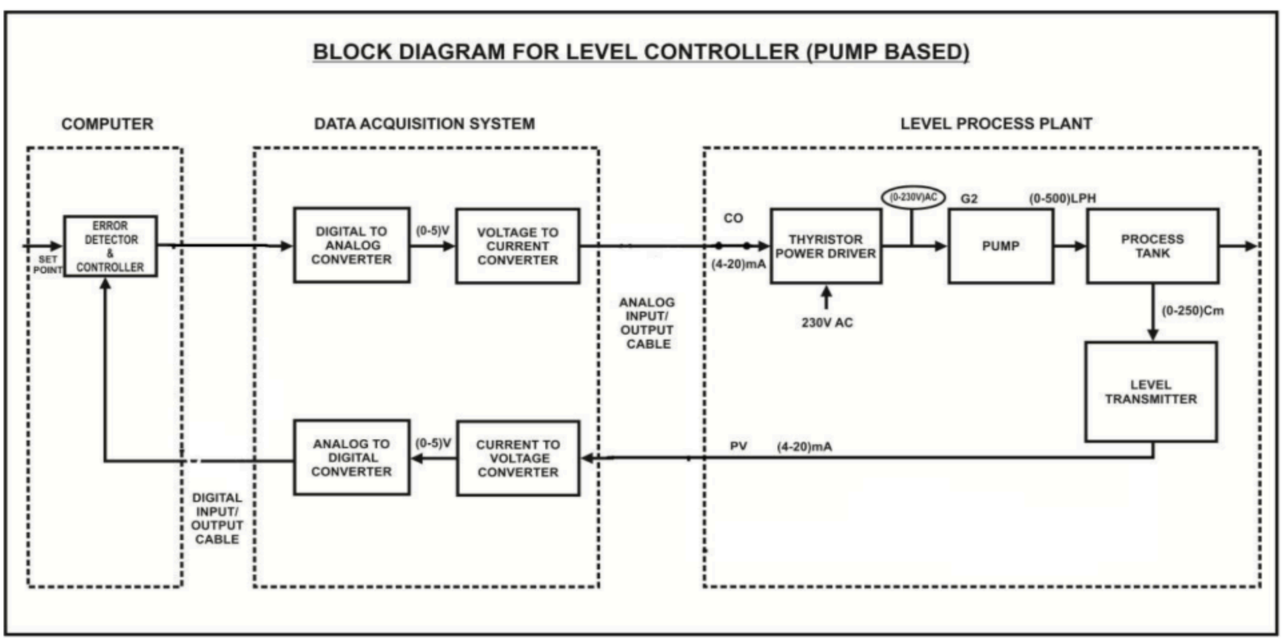
Content

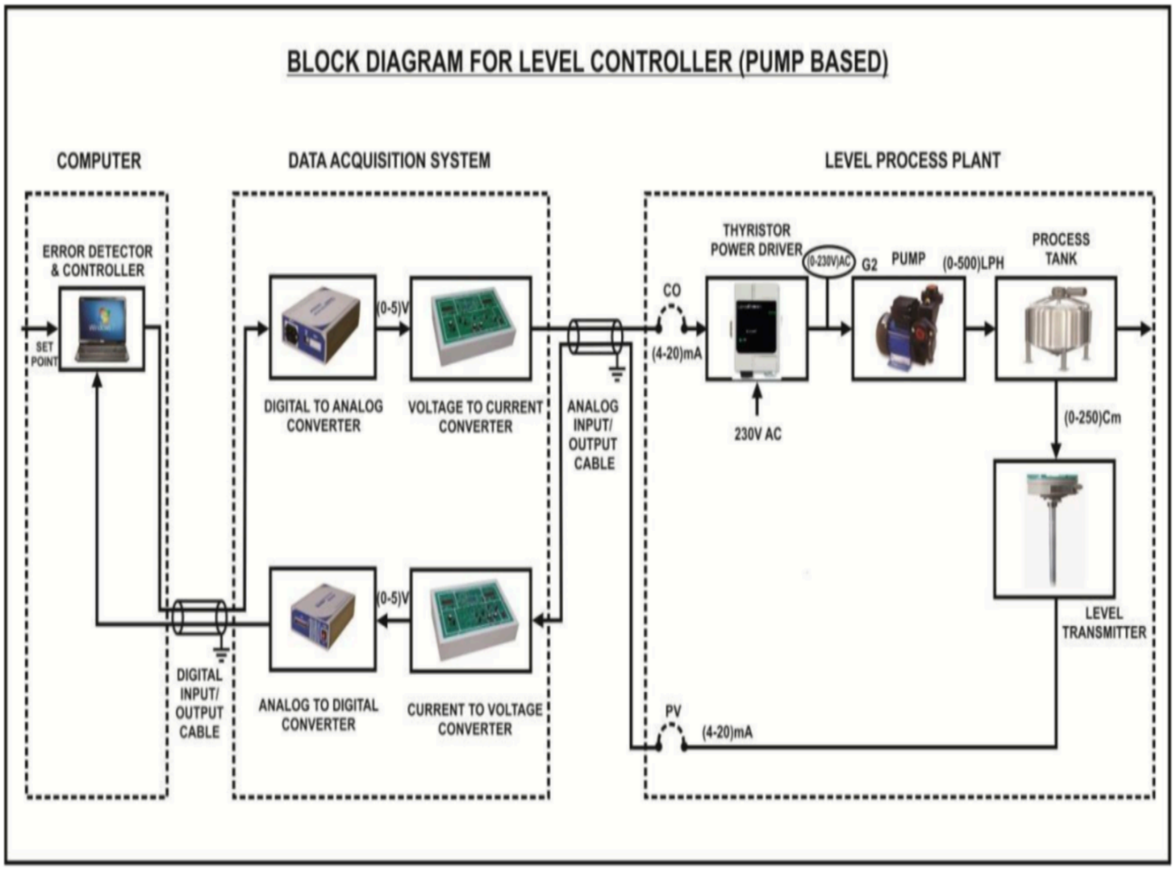
Introduction :-

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

Description :-

The coupled tank system is a widely used setup in control theory for studying liquid level control, important in many industries. It consists of a process tank where the liquid level is measured and controlled using a level transmitter that converts the level into a 4–20 mA signal. This signal is processed through an ADC and sent to a computer, which acts as the PID controller, comparing the set point with the actual level and generating a control voltage. The DAC converts this voltage to an analogue signal, which drives the SCR/Thyristor power circuit to control pump operation. The pump regulates water flow into the tank, ensuring the level is maintained at the desired value despite disturbances.



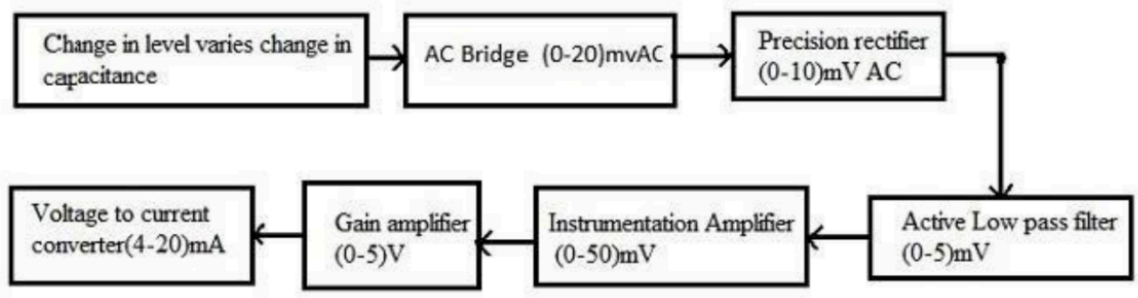


Process Tank :-

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.

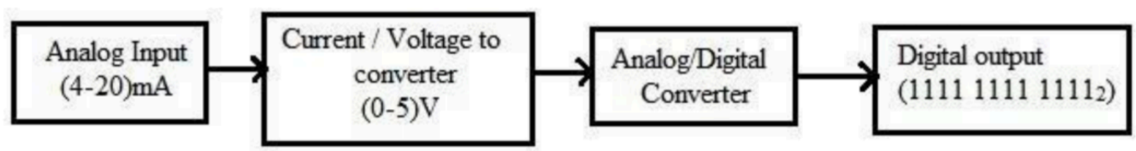
Level Transmitter :-

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



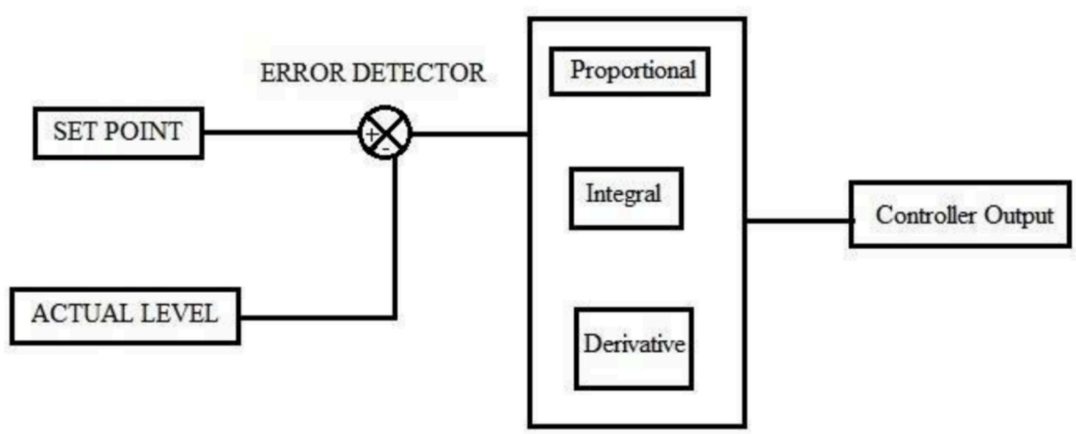
Analogue to digital Converter :-

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

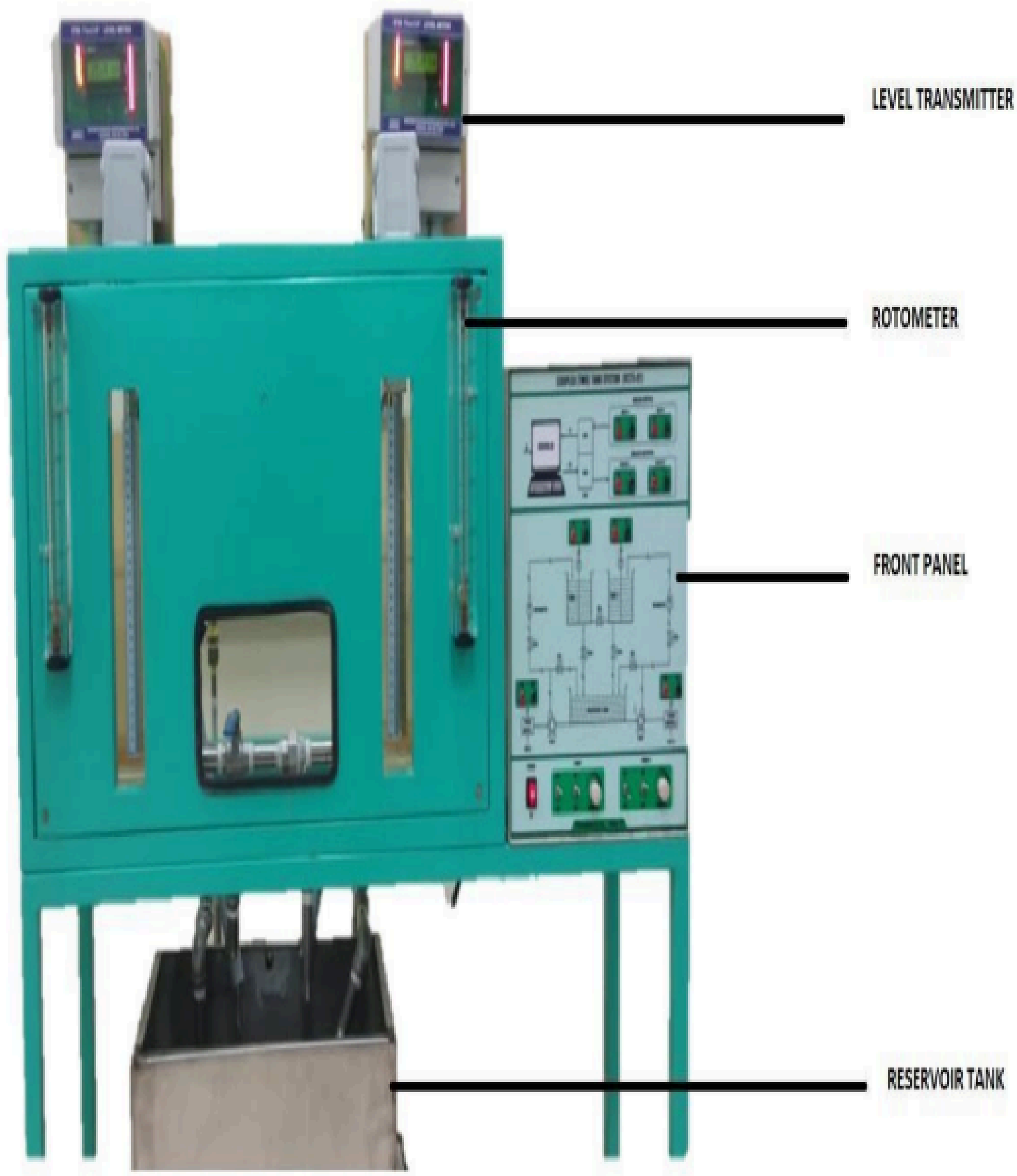


Controller :-

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



Physical Modeling :-



Experiment - 01

Aim : -

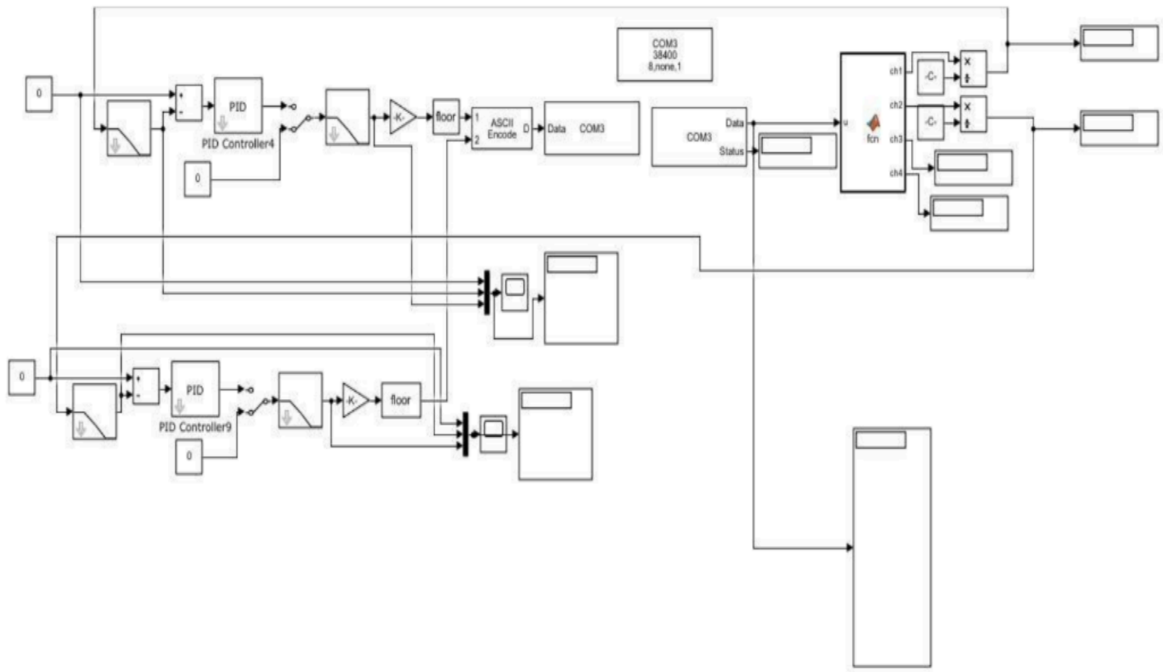
To study the characteristics and a control action of PID on tank 1.

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 :-

1. Ensure sufficient water is available in the storage tank.
2. Set the hand valves: HV1 & HV3 partially open, HV2 fully open, HV4 fully closed.
3. Connect the unit to the data acquisition system and computer as per the diagram.
4. Switch ON the unit, data acquisition card, and computer.
5. Launch MATLAB software on the computer.
6. Open the coupled tank system model file in MATLAB.
7. Set the process parameters such as set point, Kp, Ki, and Kd.
8. Keep the Auto/Manual switch in Auto mode and set the INT/EXT switch to EXT.
9. Switch ON Pump1 and start the simulation to observe system response.
10. Study the PID response for different parameter values, save results, then switch OFF Pump1.



Analysis / Calculations :-

The pump constant Km determines how effectively the applied voltage (Vp) is converted into inflow to the tank. A higher Km means greater sensitivity of inflow to voltage, making it a critical parameter for accurate level control in the experiment.

The inflow to the tank is directly proportional to the pump voltage ($F_{in} = K_m \cdot V_p$), while the outflow depends on the water head and orifice area as per Bernoulli's principle (**$F_{out} = a_1\sqrt{(2gL_1)}$**).

The net flow rate is given by the difference of inflow and outflow,

i.e., **$F_{in} - F_{out} = K_m \cdot V_p - a_1\sqrt{(2gL_1)}$**.

Calculations :-

The inflow to the tank is

$$F_{in} = k_m V_p \ cm^3/s$$

k_m = Pump const , V_p = volt applied = 220 V

Overflow rate is : $F_{out} = a_0 \sqrt{2gL_1} \ cm^2/s$.

flow rate through tank is

$$F_{in} - F_{out} = k_m V_p - a_0 \sqrt{2gL_1}$$

$$\frac{dv}{dt} = \frac{k_m V_p - a_0 \sqrt{2gL_1}}{a_1}$$

Given,

$a_i = 0.78 \ cm^2$

$g = 980 \ cm/s^2$

$a_0 = 3.14 \ cm^2$

$L_1 = 5 cm$

At steady state, $\frac{dv}{dt} = 0$.

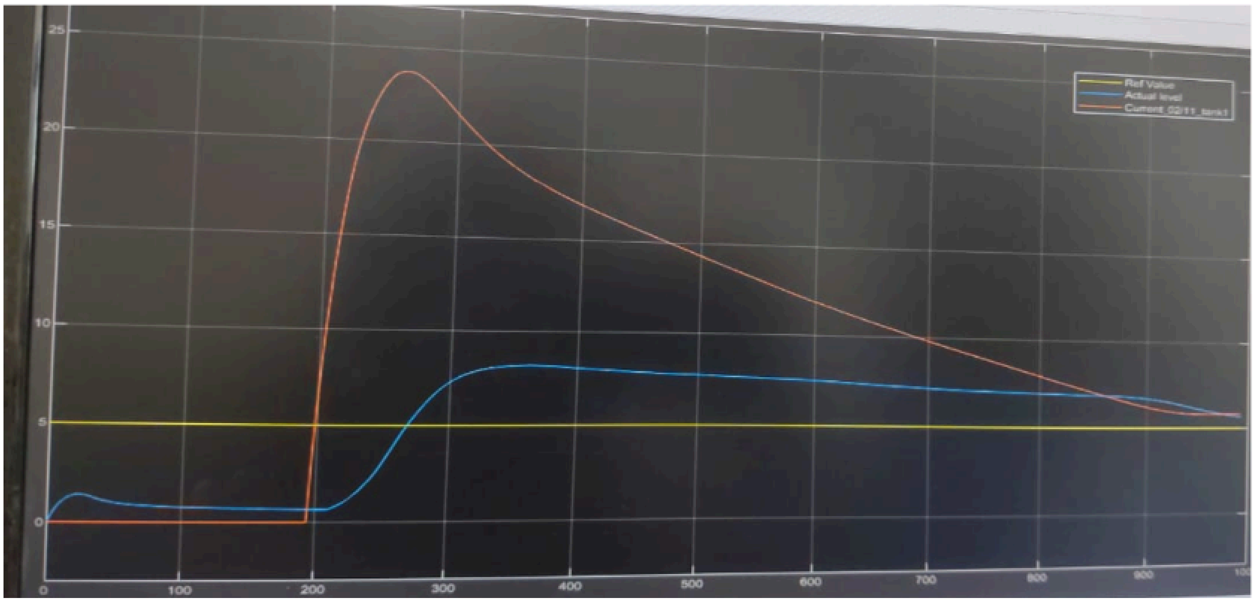
$$k_m V_p = a_0 \sqrt{2gL_1}$$

$$k_m = \frac{a_0 \sqrt{2gL_1}}{V_p}$$

$$= \frac{3.14 \times \sqrt{2 \times 980 \times 5}}{220}$$

$$\boxed{k_m = 1.41 \ cm^3/s.V}$$

Graph :-



Result :-

Thus, the characteristics of the level transmitter and the effect of PID control action on Tank-1 were studied, and the response of the system was observed for a set point and controller parameter.

Experiment - 02

Aim : -

To study the characteristics of coupled tank systems 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.

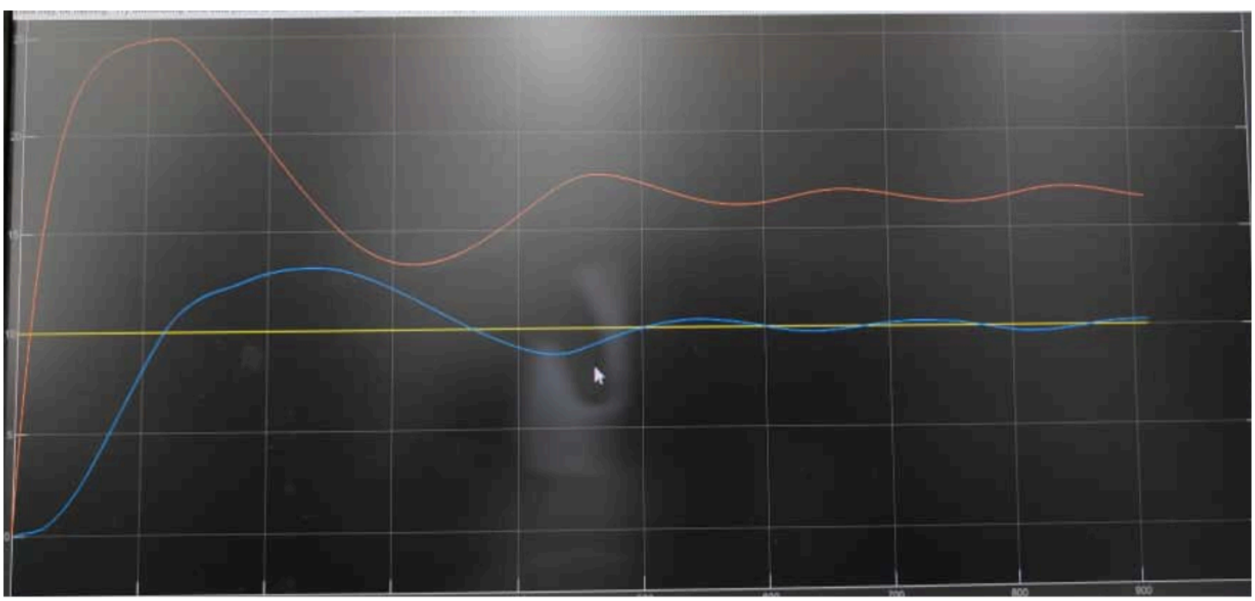
PROCEDURE:-

1. Ensure that the storage tank has sufficient water.
2. Set hand valves: HV1, HV3, HV4, HV5, HV7 partially open and HV2, HV6 fully open.
3. Connect the unit with the Data Acquisition system and computer as per the given diagram.
4. Switch ON the coupled tank unit, DAQ card, and computer.
5. Open MATLAB (Start → All Programs → MATLAB 2019a).
6. From the File → Open menu, browse and load coupled tank system.mdl.
7. Set parameters: enter the desired set point in the block and adjust PID values (Kp, Ki, Kd).
8. Keep Auto/Manual switch in Auto mode; turn ON Pump1 and Pump2; set INT/EXT switch to EXT mode.
9. Start the simulation and view the process response on MATLAB scope.
10. Tune the PID parameters to obtain optimum response, observe performance for different values, then switch OFF both pumps and save the responses.

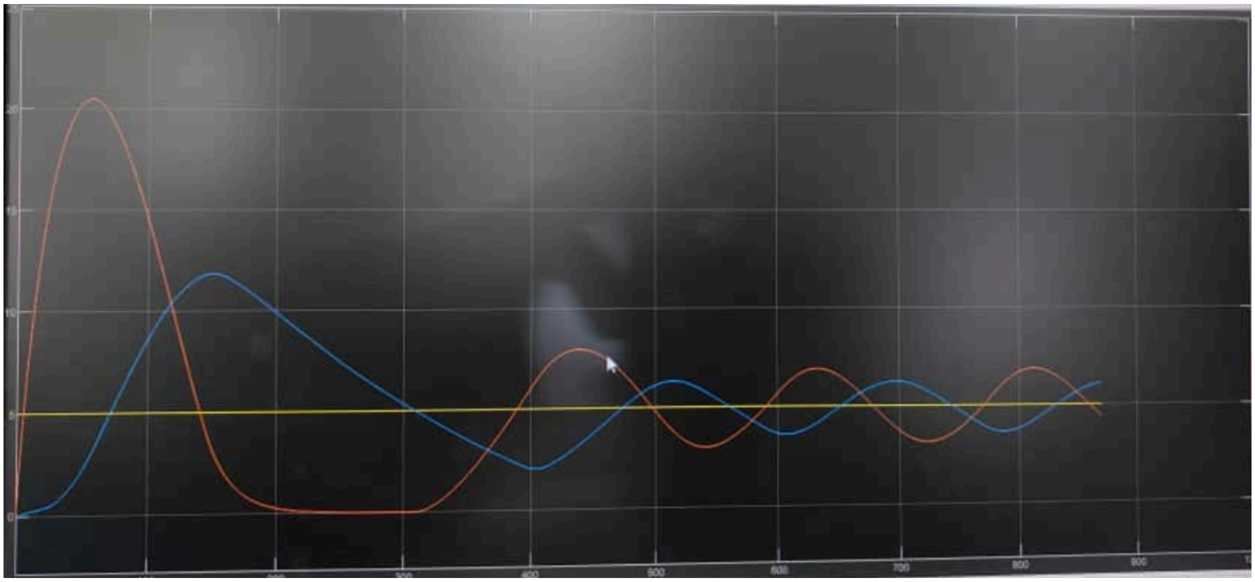
Initial parameters :-

	Tank - 1	Tank - 2
Kp	**1.5**	**1.5**
Ki	**0.02**	**0.02**
Kd	**0.5**	**0.5**

Tank - 1



Tank -2

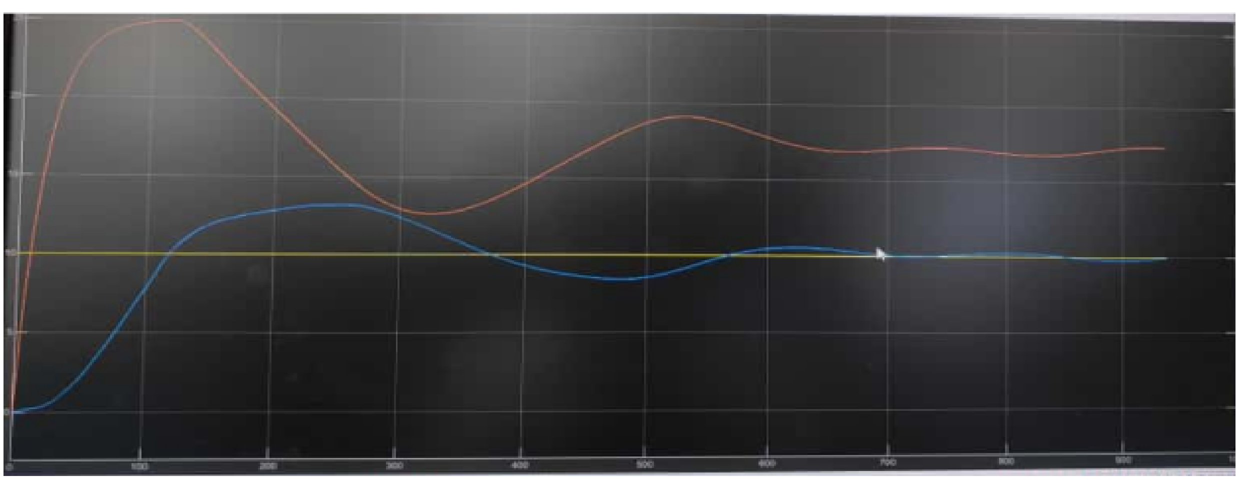


After changing the kp of the tank 1 :-

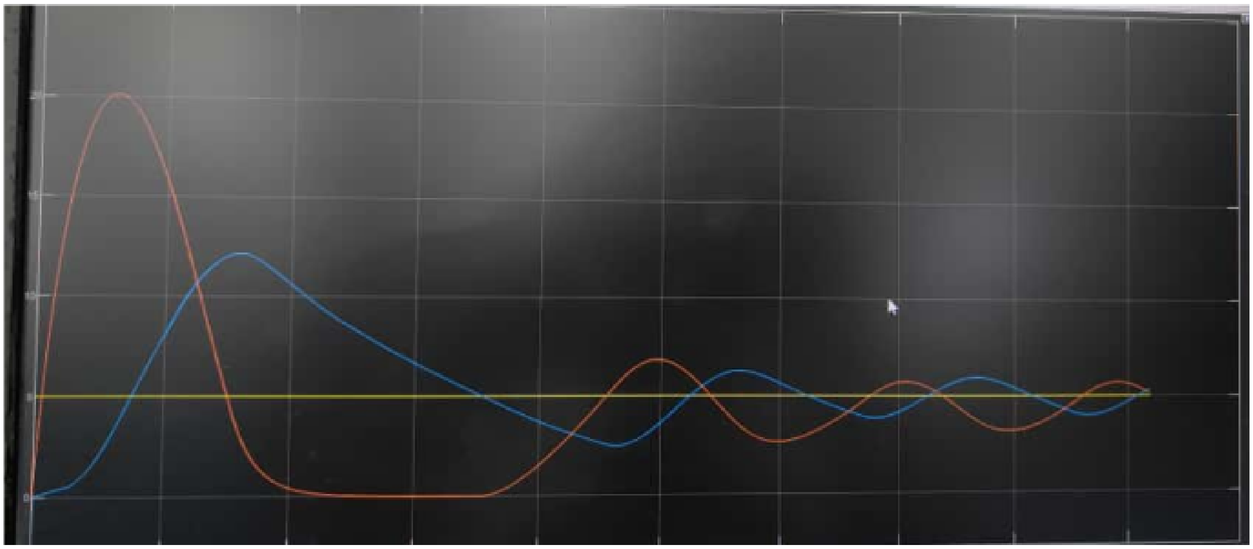
	Tank - 1	Tank - 2
Kp	**1.7**	**1.5**
Ki	**0.02**	**0.02**
Kd	**0.5**	**0.5**

Graphs :-

Tank - 01



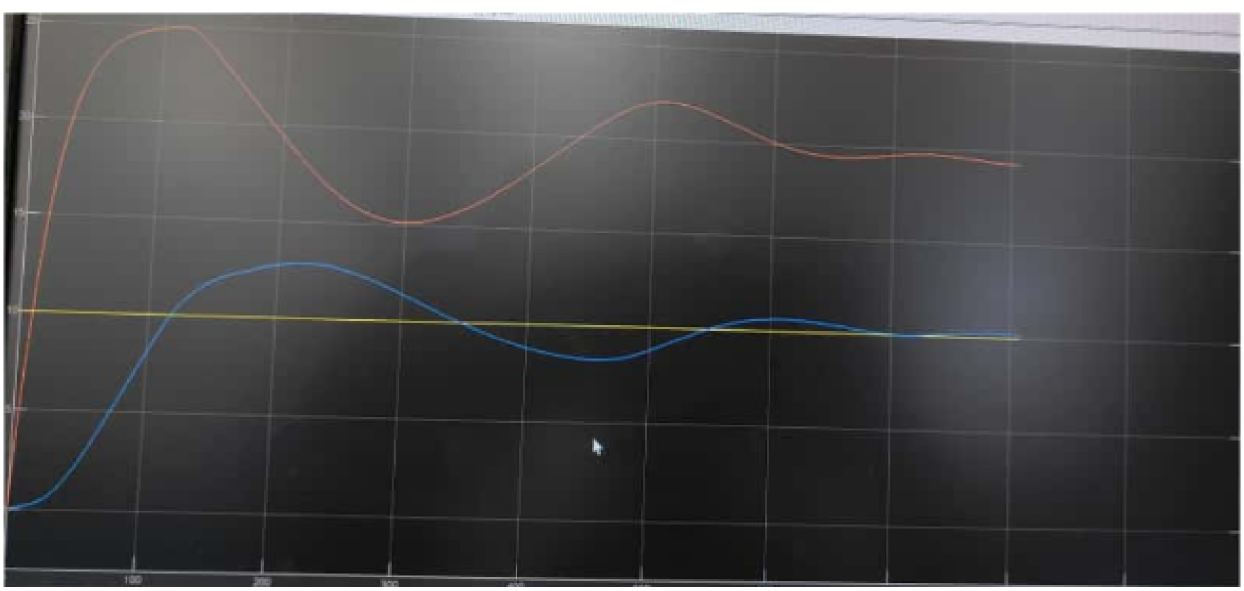
Tank -02



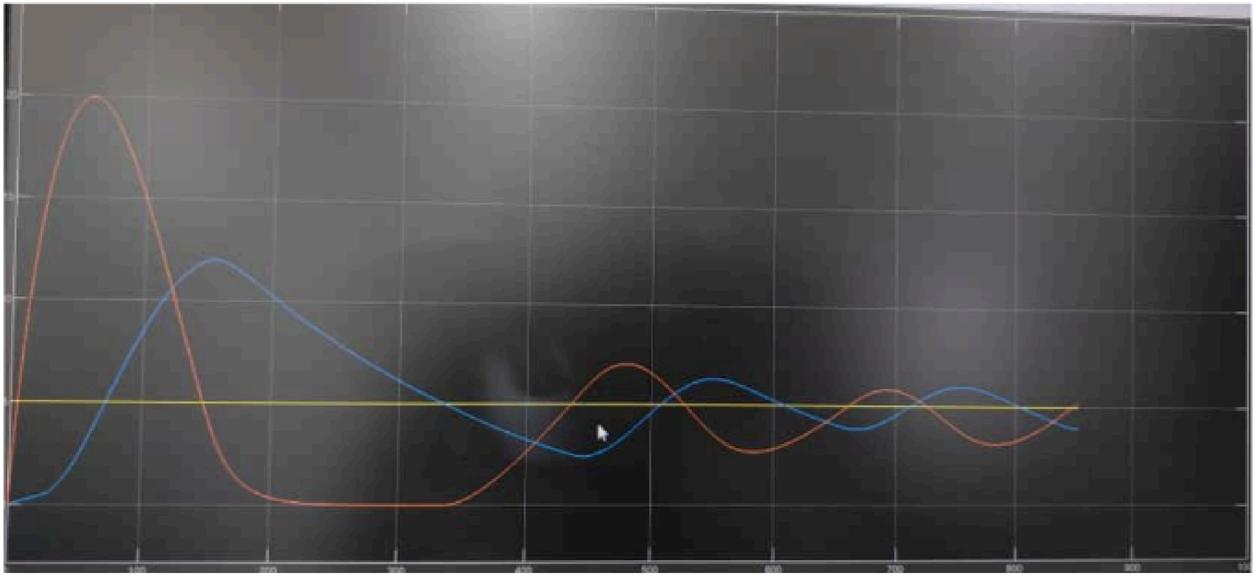
After changing the kd value of the tank -02

	Tank - 1	Tank - 2
Kp	**1.5**	**1.5**
Ki	**0.02**	**0.02**
Kd	**0.5**	**0.6**

Tank - 01



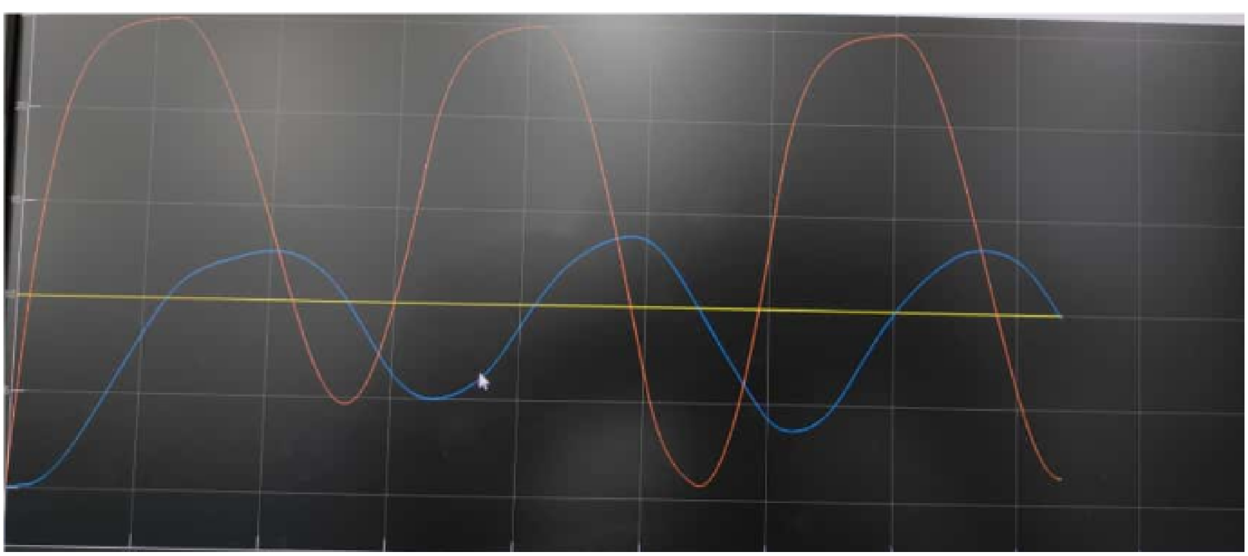
Tank -02



After changing Ki of both Tank1 and Tank2 :-

	Tank - 1	Tank - 2
Kp	**1.5**	**1.5**
Ki	**0.04**	**0.08**
Kd	**0.5**	**0.6**

Tank -01



Tank -02

Observation :-

- The water level in Tank-1 directly governs the inflow to Tank-2, resulting in coupled dynamics between the two tanks.
- Adjustments in the set point or PID parameters of Tank-1 influence the behavior of Tank-2 because of this interaction.
- Increasing the proportional gain (Kp) speeds up the response in Tank-1, but it may introduce overshoot in Tank-2.
- The integral term (Ki) helps eliminate steady-state error; however, it can intensify oscillations across both tanks due to the coupling.
- Proper tuning of the derivative gain (Kd) provides damping, which helps reduce these oscillations and improves the overall system stability.

Result :-

Variations in the set point and PID gains (Kp, Ki, Kd) directly influence the rise time, overshoot, steady-state error, and settling time of the interconnected tanks. Hence, the dynamic behavior and control impact of the PID on both Tank-1 and Tank-2 under interaction mode were effectively analyzed.

Conclusion :-

The coupled tank experiment highlighted how PID parameters (Kp, Ki, Kd) and set point variations impact overall system behavior. Results showed that the proportional gain primarily affects rise time and overshoot, the integral term removes steady-state error, and the derivative component improves stability by minimizing oscillations and reducing settling time. The interaction between Tank-1 and Tank-2 emphasized the coupled nature of the system, where variations in one tank directly influenced the other. With appropriate tuning of PID parameters, the desired liquid levels were achieved with better precision and stability. This confirmed the effectiveness of PID control in regulating liquid levels in an interacting tank system.