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Modelling of Interacting Three Tank System

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Abstract— **This paper presents the modelling of an Interacting Three Tank System. The objective of the work is to control the ratio and level of a mixing process in the three tanks. The work carried out includes the identification of the process and design of a PID controller for the same. The three tank system is interfaced to MATLAB and SIMULINK using an 841 microcontroller DAQ. The process is identified and control parameters are obtained using Ziegler Nichols two point method and Offline method respectively. The response of the system is presented in this paper.**

***Keywords* -Three tank, PID, Mixing, Ratio & level control**

I. INTRODUCTION

The three tank system is a widely used laboratory system in control theory. Liquid level's most representative didactical equipment is a three tank system. The system under consideration consists of two control valves controlling the flow to tank 1 and tank 3 respectively. A pump which is discharging the water from reservoir and supplies to process tanks through the Rotameter and control valve. The accumulation of the liquid in the tank is known as level of the tank. The differential pressure transmitter is used to transmit the level of the process tank to control room. The analog signal is fed to ADµC841 controller which does the ADC/DAC, and it is interfaced with PC using RS232. The error is the difference between the user defined set point and digital form of level transmitter output, fed as input to a PID controller. The controller output is also digital signal which is converted into the analog signal. For maintaining the level, the inflow is manipulated.[8]

The basic requirements that needed to be accomplished were:

- The mixing was to be carried out between Tank 1 and Tank 3, and the final product would be present in Tank 2, which would be drained.
- In order to do this, the mixing ratio was to be fixed, which was fixed to 1:0.5 between Tank 1 and Tank 3.
- The ratio and level of all tanks had to be maintained at all times.

The schematic of the process is shown in Fig 1.and Table 1.shows the inlets and outlets as adjusted.

Table I

Tanks	Inlets and Outlets	
	Inlets	***Outlets***
Tank 1	1	1
Tank 2	2	1
Tank 3	1	1

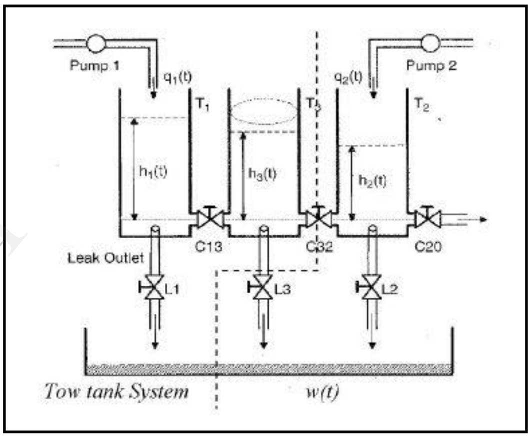

Fig. 1.Three Tank System Schematic

The governing equation is:-

$$Q = \frac{h}{R} \qquad (1)$$

Where,

Q = Flow rate
h = level of the tank
R= Resistance offered (Resistance to flow offered between two interacting tanks)

Using the above equation, we realize that:-

- If Ratio is to be maintained, h or R must be controlled.
- So that the ratio is maintained by controlling the inflow.

A. Assumptions made

- Number of inflows and outflows are fixed for all tanks.
- Tank 1 and 3 outflow is fixed for measurements.

B. Need of a controller

A controller inputs the setpoint from the user then tracks and manipulates the output to match the input in a closed loop system. In areas where offset is not tolerated and good stability is a must, all the three parameters are controlled to give a PID controller. The basic equation of a parallel acting PID in Laplace domain is given by

$$U(s) = E(s)[K_P + \frac{K_I}{s} + K_D s] \qquad (2)$$

U(s) is the controller output, E(s) is the error, K_p,K_I, K_D being the proportional, integral and derivative gain respectively.
There are many control strategies in use today, of which the best one for the system in use can be determined by a heuristic approach alone. The control algorithm used in this paper is that of Ziegler Nichols Open loop method or 2 point method for identification. Ziegler-Nichols open-loop tuning rules use three process characteristics: process gain K, dead time t_d, and time constant of process τ

$$\tau(i) = 1.5(t_2(i) - t_1(i)) \qquad (3)$$

$$t_d(i) = t_2(i) - \tau(i) \qquad (4)$$

$$K(i) = \text{Output/Input} \qquad (5)$$

The method used above assumes the transfer function to be of first order with dead time (FOPDT) type, which is given by

$$Y(s) = \frac{K}{\tau s+1} e^{-t_d s} \qquad (6)$$

Fig 2.illustrates the open loop method by drawing a tangent at the point of inflection, but the method used here is by drawing a horizontal line at 28.3 % and 63.2% of final steady state value [12]

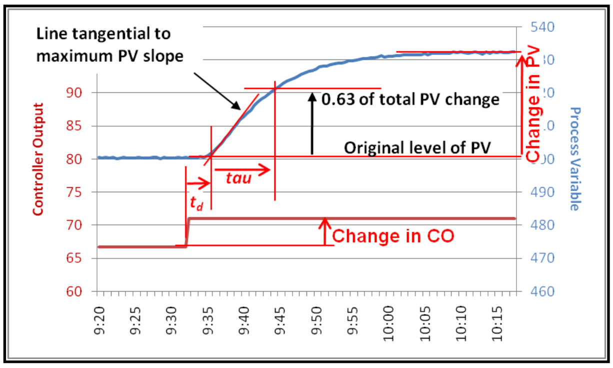

Fig. 2.Two point method

Methodology is first to identify the process dynamics using MATLAB and SIMULINK and then design of the controller using Ziegler Nichols Offline Tuning Method.

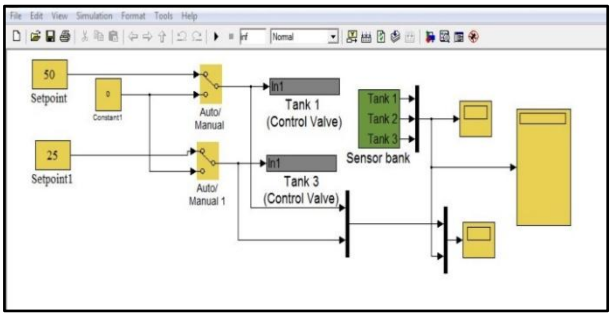

Fig. 3. Simulink Interfacing Model

II. INTERFACING

The three tank was interfaced using a 841µC (ADµC 841 8 bit Controller) DAQ to SIMULINK using RS-232 Cable. The Simulink model used is depicted in Fig 4.

DAQ Specifications: 841 µC, 8 bit, 4 input/ output channels, input 0-5 V,Output 4-20 mA.

III. IDENTIFICATION & CONTROL

A. Identification of Transfer Function

In this system transfer function for Tank 1 & Tank 3 were obtained independently. The Steps involved are described below:-

- The hand valve R1 is fixed to approximately 50% opening of the valve initially, while the flow from R2 to the Tank 2 is cut off. . Since there is only 1 outflow to Tank 1, the outflow rate of tank1 to tank2 can be measured. A step change is given to manipulated variable to tank1 (raise is inflow rate) and the settling point is noted. After Tank 1 attains Steady state, the outflow of Tank 2 is measured.
- Now, R1 is shut off and R2 is opened to 50% of the opening to R1, in order to maintain the ratio 1:0.5. It is given a certain set point and is allowed to settle. When the Tank 3 reaches steady state, the outflow from Tank 2 is calculated which should be half of the inflow from tank1-2. This is done in order to ensure that the ratio is maintained at all times.
- If the outflow rate in step 8 is different from the expected value, then the opening R2 the tank2's second outlet is adjusted in order to get the exact inflow rate to tank1. This takes care of the ratio in which we want the liquid to flow.
- The response obtained from Tank1 and Tank3 are shown in Fig. 4, 2 point method is used to get the process parameters required to derive the transfer function.

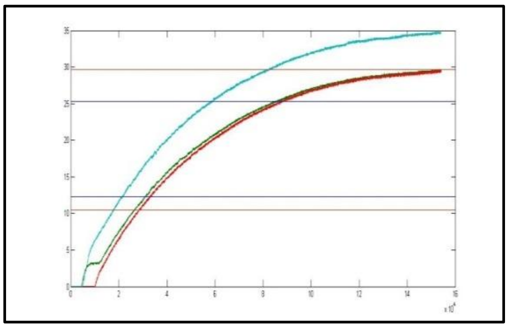

Fig. 4.Response from the 3 tanks

B. *Design of Controller & PID Gain Coefficients*

The chosen control algorithm is PID controller and its parameters are obtained from tuning methods available in current literature, the level in each tanks (T1 and T2) is controlled using separate PID

The parameters obtained are used to design a controller using the formulae:-

$$K_c = 1.2\,\tau/(t_d * k) \quad (7)$$
$$T_i = 0.5 * t_d \quad (8)$$
$$T_d = 2 * t_d \quad (9)$$

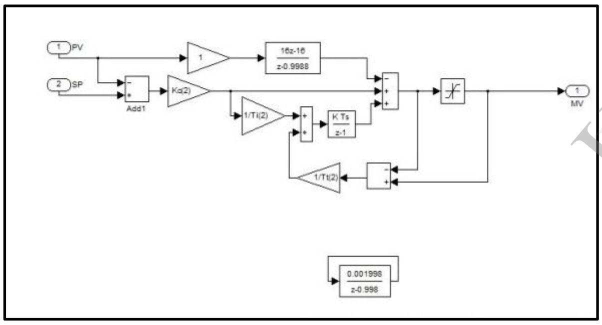

Fig. 5. PID for Tank 1

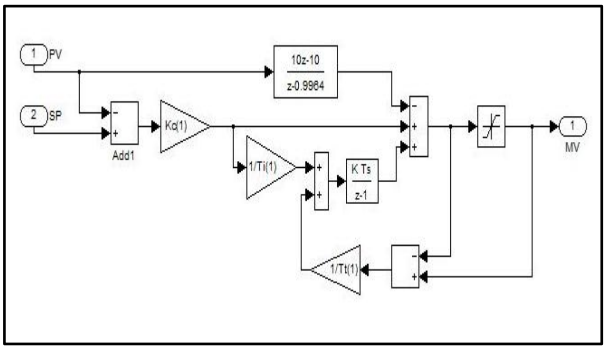

Fig. 6. PID for tank 2

C. *Implementation of PID*

The PID design shown in Fig. 5 and Fig. 6 are in accordance with the PID control with derivative in the feedback loop. This is done in order to reduce the derivative kick. The Ziegler Nichols algorithm is used to retrieve the values of K_c, Tau, T_t, t_d. Derivative Kick occurs due to a sudden change in input due to a disturbance and leads to a sudden jump or kick in controller output which is undesirable. The T_t used is to reduce the integral windup. [6]

The values derived using the Ziegler Nichols Open loop method are in the s domain, but there was an error running it which required the system to be discretized for successful simulation. This was due to the fact that the Sensor Bank subsystem is continuous, but the µsystem is discreet, that is why the system shows an error and has to be discrete

When the tanks reach its steady state values, the outflow of tank2 is measured to make sure the theoretical calculations made before were satisfied to achieve the ratio control. The level of tank2 is fixed and maintained using the same PID controllers. The level can be varied online so as the ratio by changing the SP in tank1:tank2 to the controllers.

IV. CONCLUSIONS

The system response was identified and a transfer function was generated with the parameters found. A controller was designed using Ziegler Nichols Offline method. The system will give required response to the mixing process as long as the level in Tank 1 and Tank 3 is kept more than level in Tank 2 to avoid the backflow. Thus, the assumptions made are correct.

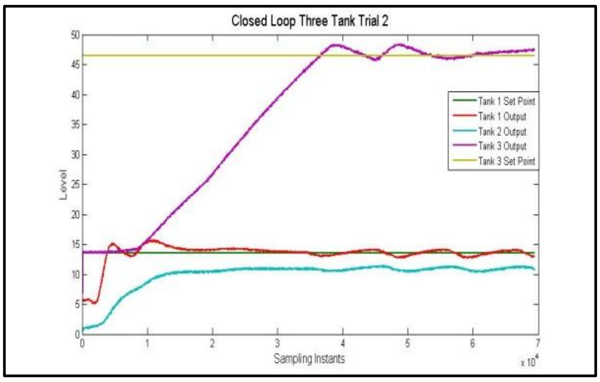

Fig. 7.Final Three tank output

The response was noted and the response of Tank 3 was found to have oscillations. Thus, it was inferred that Ratio is maintained and the flow is stable. Whereas, the level oscillates around set point and is marginally stable.

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