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# Implementation of Intelligent Control on Interacting Tank system

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***Abstract—****Industries where liquid level and flow control are essential. Liquids will be processed by chemical or mixing treatment in the tanks, but always the level of fluid in the tanks must be controlled and the flow between tanks must be regulated. Conventional PID control is used for controlling. Industry consists of interacting as well as non-interacting tank system. In interacting tank, flow between the tanks is affected by level of liquid in both the tanks. This interaction of parameter in tank system makes control of system complicated .In this paper we take an interacting tank system in consideration for study. Mathematical modeling of the system is obtained by mass balance equation and flow resistance is also calculated depending on the difference of liquid level. After the open loop transfer function is found various control scheme are deployed to control the level of tank2 like PID and Fuzzy logic control (FLC). Paper present simulation and implementation of FLC. Further comparison between various control schemes is done according to their performance.*

***Keywords—****Interacting Tank, PID, Fuzzy logic control, Level Control*

## I. INTRODUCTION

In process industries mainly four parameters are measured and control that are pressure, temperature, flow and level. All the above mentioned parameters are interlinking to each other in process industries and have overall effect on process. This paper deals with measurement and control of liquid level in interacting tank system. The process industries required liquids to be pumped, stored in tank and then pumped to another tank[1][2]. Level and control of level is essential for safety of boilers and overflow and spill prevention of tanks and silos

- Point level measurement is a measurement identified where the only concern is whether the amount of material is within the desired limits.

- Continuous level measurement is a method to track the changes of a level over a range of values to monitor inventory or for determining when to add or remove material from containers.

Conventional controllers are widely used in industries as they are simple easy to implement and familiar to field operator. Still the performance of system can be improved by implementation of intelligent control schemes. The paper present the implementation of Fuzzy logic control (FLC) and comparison of response of system based on conventional PID controller and FLC[1].

## II. PROCESS DESCRIPTION

For the primary collectionof input and output data, take a real system in consideration. Fig. 1 shows the diagram of process model on which data is collected.

 

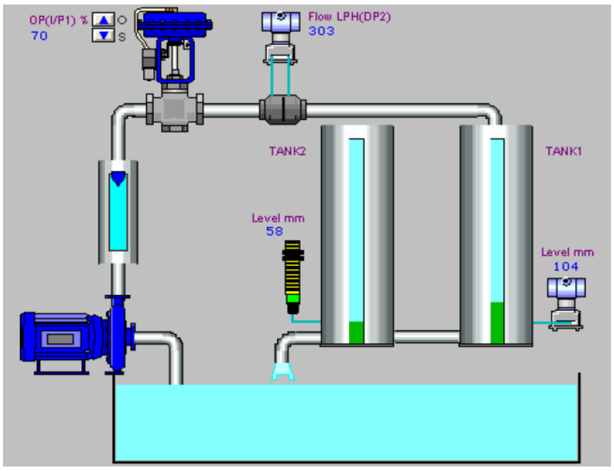


Fig.1 Schematic of interacting tank system

It consist of reservoir, pump, control valve, two process tank, level transmitter, rotameter, two differential pressure transmitter five manual operated valve, compressor pump to provide compressed air for operation of pneumatic control valve, I to P converter and instrumentation panel that supply power to the various component in the process an collect data from the process[1].

*A. Working Principle*

The primary aspect of the process is level of liquid in tank2. Water is pump with the help of motorized pump which flow through rotameter, control valve, tank1and then tank2. Level of water in tank2 is measure with the help of level transmitter and level in tank1 is measure with the help of differential pressure transmitter. The entire output signal is fed to data acquisition system (DAS). The output of all transmitters is (4-20mA) that is fed to DAS. In this system control variable is height of liquid in tank2 and manipulated variable is flow of water in process. Flow can be visualize through rotameter and it can also be measured using assembly of orifice and differential pressure transmitter which gives flow in electrical quantity (4-20 mA) that can feed to DAS[1]. According to reading obtained, graph is plotted and required calculations are made and various parameter of process is evaluated.

Fig.2 Experimental setup of system

 

*B. Mathematical modelling of a two-tank interacting level Process*

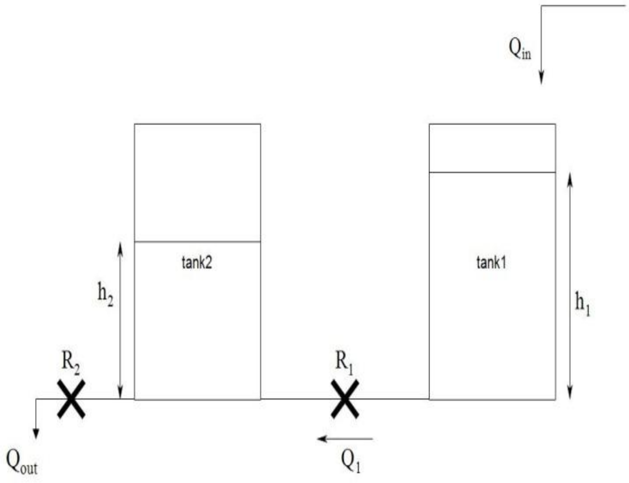


Fig.3 Schematic diagram of process

$Q_{in}$ = Input flow rate in $m^3$/sec
$Q_{out}$ =Output flow rate in $m^3$/sec
$Q_1$ = flow between tank1 and tank2 in $m^3$/sec
$h_1$ = Height of liquid in tank1 in m
$h_2$ = Height of liquid in tank2 in m
$A_1$ = Area of tank1 in $m^2$
$A_2$ = Area of tank2 in $m^2$

As explained, process have two tank.tank1 and tank2 that is shown in fig.2 with input flow rate $Q_{in}$ and output flow rate $Q_{out}$ . The height of water level in tank is represented by h1 for tank1 and h2 for tank2

$$A_1 \frac{dh_1}{dt} = Q_{in} - Q_1 \qquad (1)$$

The linear flow resistance is given by

$$Q_1 = \frac{h_1 - h_2}{R_1} \qquad (2)$$

Substituting above expression of Q1in equation we get

$$R_1 A_1 \frac{dh_1}{dt} + h_1 = R_1 Q_{in} + h_2 \qquad (4)$$

Time constant $T_1 = A_1 R_1$

$$T_1 \frac{dh_1}{dt} + h_1 = R_1 Q_{in} + h_2 \qquad (5)$$

Taking Laplace transformation on both side

$$h_1(s)(T_1 s + 1) = R_1 Q_{in}(s) + h_2(s) \qquad (6)$$

Similarly for tank 2

Time constant $T_2 = A_2 R_2$

$$h_2(s)(T_2 s + 1 + \frac{R_2}{R_1}) = \frac{R_2}{R_1} h_1(s) \ (12)$$

 

Above equation gives the relationship of $h_1$ and $h_2$ in terms of $R_1$, $R_2$ and $T_2$ Substituting value of $h_1$ in term of $h_2$ and rearranging the term finally

$$\frac{h_2(s)}{Q_{in}(s)} = \frac{R_2}{T_2T_1s^2+(T_2+T_1+R_2A_1)s+1} \qquad (16)$$

Above expression give the relationship between the inflow of liquid and height of liquid in tank2 [5] To obtain the value of $R_1$and $R_2$, it is needed to perform experiment and collect experimental data [4].

*C. Procedure to obtain $R_1$ and $R_2$*

- First of all setup the interacting tank system as shown in fig.2
- Give constant inputliquid flow to the system say 300 lph and wait for the level to settle down at steady state. This is said initial state of system
- Take down the reading of liquid level in tank1 and tank2 also note down the flow
- Now give a step change in flow e.g. 400 lph
- Again note down the reading of liquid level in tank1 and tank2. This is final state of system

Performing above procedure we get following values

TABLE I. DATA OF PROCESS

| Flow in lph | Height in tank1 (cm) | Height in tank2 (cm) |
|---|---|---|
| 200 | 102 | 55 |
| 100 | 56 | 35 |

Now

$$R_1 = \frac{dh_1}{dQ}$$

Substituting the values from above table

$$R_1 = \frac{(102 - 56)mm}{(305 - 193)lph}$$

That result in $R_1$ = 1478.57 sec/m$^2$
Similarly for $R_2$

$$R_2 = \frac{dh_2}{dQ}$$

Substituting the values from above table

$$R_2 = \frac{(55 - 35)mm}{(305 - 193)lph}$$

That result in $R_2$ = 642.86 sec/m$^2$
Now time constant is given as $T_1 = A_1 R_1$ and $T_2 = A_2 R_2$
That result $T_1 = 21.42$ and $T_2 = 9.31$
Finally substituting this value in expression (16) we get

$$\frac{h_2(s)}{Q_{in}(s)} = \frac{643}{199.42\, s^2 + 40.04\, s + 1}$$

Above is transfer function of system in s- domain, that present gain of system is 643 with two poles at -0.029 and -0.171 damping coefficient is 1.41 and damped natural frequency is 0.0708 rad. Matlab is provided with identification tool that can be used to identify model of system. So using this tool we identify model of system as below

$$\frac{h_2(s)}{Q_{in}(s)} = \frac{0.00022205}{s^2 + 0.04392\ s + 0.0003794}$$

*D. Open loop response of two-tank interacting system*

The Simulink model for the open loop step response is shown in Fig.4.Thestep response of open loop system for the same is shown in Fig.5 below with settling time and rise time

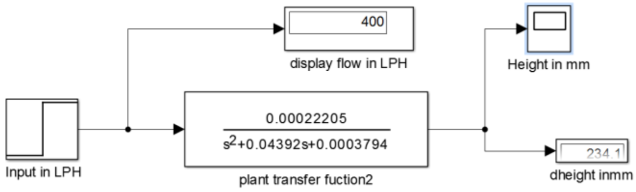


Fig.4 Simulation block for Open loop system

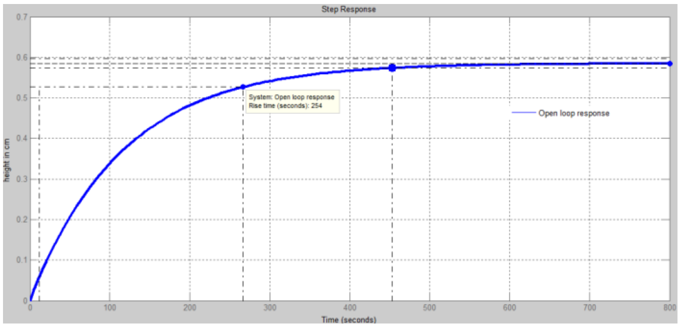


Fig.5 Simulated Open loop response of system

## III. CONTROL SCHEMES

*A. PID tuning methods*

Ziegler-Nichols Method mostly used for PID tuning [6]. Two classical methods for determining the parameters of PID controllers were presented by Ziegler and Nichols in 1942. These methods are still widely used, either in their original form or in some modification. They often form the basis for tuning procedures used by controller manufacturers and process industry.

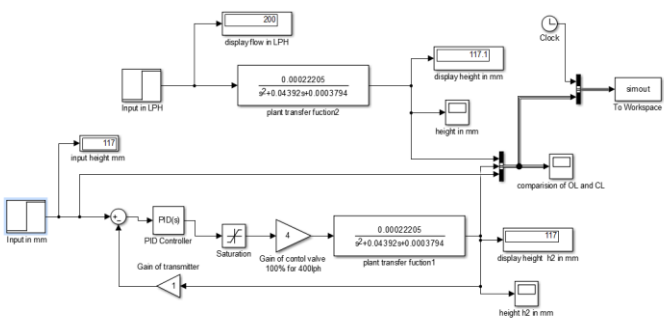


Fig.6 Implementation of PID controller

*1) Good gain method*

 

The Good Gain method [8] is a simple, experimental method which can be used on a real process (without any knowledge about the process to be controlled), or simulated system (in this case you need a mathematical model of the process).

- Bring the process to or close to the normal or specified operation point by adjusting the nominal control signal u0 (with the controller in manual mode)[2].
- $K_p = 0$ , $T_i = 0$ , $T_d = 0$

- Gradual increase value of $K_p$ , until you observe a slight overshoot
.
- Calculate $T_{out}$,$T_{ou}$ is the time between the overshoot and the undershoot of the step response
- Set the integral time $T = 1.5T_{out}$
- Set the D term $T_d = T_i /4$

After submitting these value K=0.85,I=0.015 and D=1.5 in PID controller below response of system can be observed

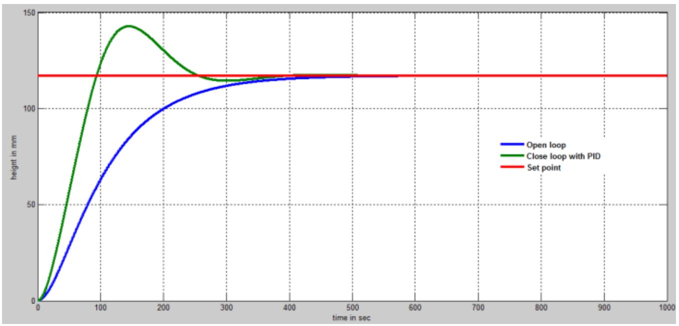


Fig.7 Simulated response of system for tuned PID

*B.* Fuzzy Logic Control

Fuzzy logic control for two interacting tank system is shown in Fig.8. Fuzzy logic controller is designed with two input error and change in error and one output variable.

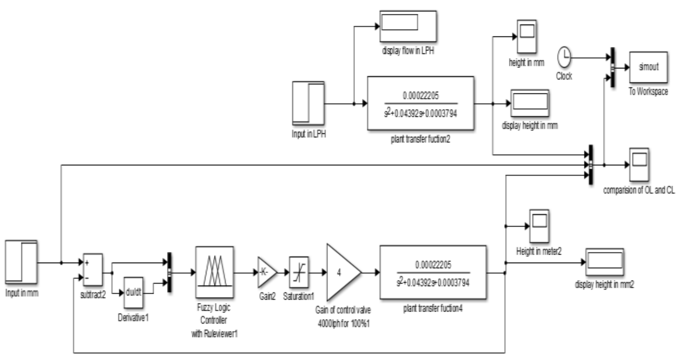

Fig.8 implementation of Fuzzy Logic control

 

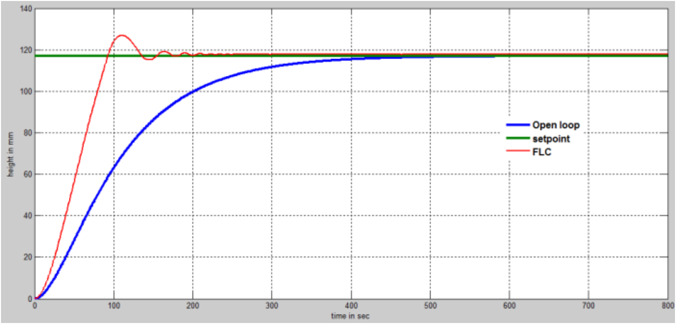


Fig.9 Simulated response of system for tuned PID

The Mamdani-type inference is used to build FLC.Inference is the process of formulating the mapping from a given input to an output using fuzzy logic. The mapping then provides a basis from which decisions can be making.
Table II show the rules that is used to implement FLC for the system.for implementation of FLC five member are used.

TABLE II
FUZZY RULES

| (Δ)e / E | **MN** | **N** | **Z** | **P** | **MP** |
|---|---|---|---|---|---|
| MN | MN | MN | N | N | Z |
| N | MN | N | N | Z | P |
| Z | N | N | Z | P | P |
| P | N | Z | P | P | MP |
| MP | Z | P | P | MP | MP |

MN-More negative, N- Negative, Z-Zero, P-Positive and MP-More positive

## IV. HARDWARE IMPLEMENTATION

For implementation of control scheme on real time hardware one need a medium through which signal can be send to the hardware and the feedback signal can be receive for that purpose we need.
1. Software(MATLAB)
2. Arduino
3. Voltage to Current converter.
4. Current to Voltage converter
Setup required to execute real time implementation of PID controller is shown in fig.10 and fig. 12 one need to set the block in Simulink so that controlling signal can be send and receive by Matlab for plotting graph as shown in fig.13 show run time data receiving by the matlab. XY graph is used to plot the graph in run time. Value of PID parameter can be change and response can be noted down according to them.

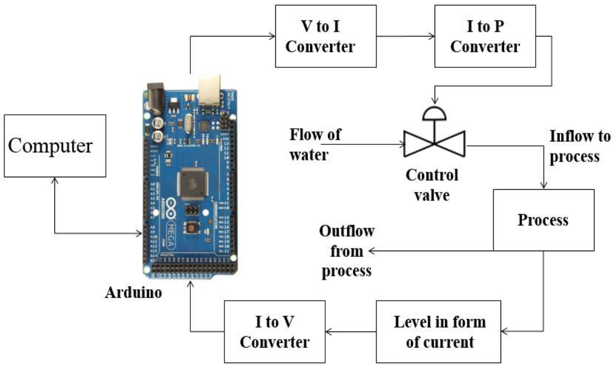


Fig. 10 Block diagram for implementation of control scheme in real time

Fig. 11 Experimental set up for implementation of real time

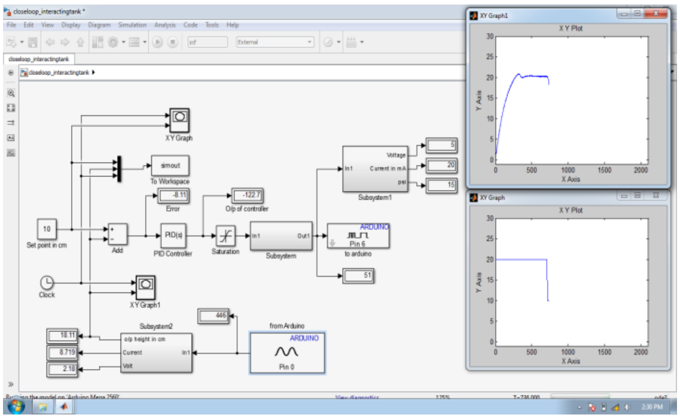

Fig.12 Simulation block required for implementation of real time control on system

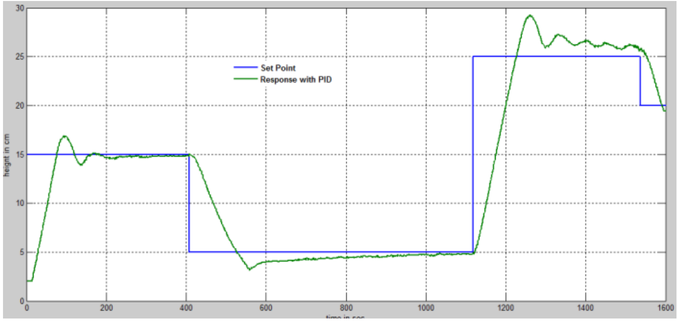


Fig. 13 Graph plotted for different set point

## V. RESULT

Response of system is compare after implementation of control schemes on the basis of rise time settling time and peak overshoot. Below table present numerical data for comparison

Table III presents comparison between two methods used to control system based on their simulated and real time response. .

TABLE III
COMPARISON OF PERFORMANCE WITH PID AND FLC

| Tuning Methods | | Transient Parameters | | |
|---|---|---|---|---|
| | | Rise Time (sec) | Settling Time (sec) | Peak Overshoot (%) |
| Open loop | | 254 | 453 | 0 |
| FLC | Simulated | 100 | 220 | 5 |
| | Real Time | 186 | 230 | 15 |
| PID | Simulated | 85 | 320 | 19 |
| | Real Time | 120 | 360 | 8 |

## IV. CONCLUSION

With the help of simulation results and the data presented in above table, it can be concluded that response of system is better when FLC controller is used instead of conventional PID. Table also interpret that real time response of system is not as simulated that is because of non-linearity in component.

Other intelligent control schemes can be used to control the system like neural and combination of neural and fuzzy that may result in better performance of system.

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