Tuning of PID Controller for Three Tank Mixing Process using Matlab

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ABSTRACT

Today, many process control problems can be adequately and routinely solved by conventional PID control strategies. The overriding reason that the PID controller is so widely accepted is its simple structure which has proved to be very robust with regard to many commonly met process control problems as for instance disturbances and nonlinearities. Relay feedback methods have been widely used in tuning proportional-integral-derivative controllers due to its closed loop nature. In this work, Relay based PID controller is designed and successfully implemented on three tank mixing process. The performance of a Relay based PID controller for control of three tank mixing process is investigated and performed satisfactorily. The results are compared with bode plot methods for tuning PID Controller.

Keywords – **Three tank mixing System, Relay feedback method, Bode Plot, Matlab, PID Controller**

I. INTRODUCTION [7]

This process consists of two streams A and B, mixed in three series tanks, and the output concentration A is controlled by manipulating the flow of stream A as shown in Fig A.The Goal of the process is to maintain outlet concentration close to its set point.

While deriving the non linear and linearised models following assumptions are made :

1. All the tanks are well mixed
2. Dynamics of the valve and sensor are negligible
3. No transportation delays (dead time) exists
4. A Linear relationship exists between the valve opening and the flow of component A
5. Densities of the components are equal

The present system can be represented by the block diagram of Fig..I with the process transfer function given in equation by:

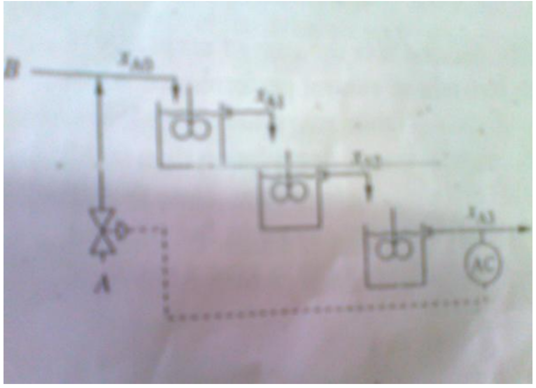


Fig A DIAGRAM OF THREE TANK SYSTEM

$$\mathrm{Gp(s)} = \frac{Kp}{(\tau s+1)^3}$$

$$Kp = 0.039\ \frac{\%A}{\%\_opening}$$

$$\tau = \frac{V}{F_{Bs}+F_{As}} = 0.5\mathrm{min}$$

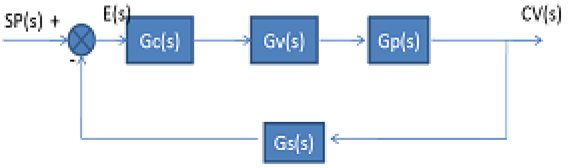


Fig I BLOCK DIAGRAM OF SYSTEM

Note that the sensor transfer function has been taken as 1.0. The final Transfer function of the process for three tank mixing process comes to by assuming the data of flow rate , volume of the each tank ,concentration s of A in all tanks and outlet flow, concentrations of stream A and B etc.

II PID Controller [2]

A PID controller is a simple three-term controller. The letters P, I and D stand for:

P - Proportional
I - Integral
D – Derivative

The transfer function of the most basic form of PID controller,

$$C(s) = Kp + \frac{Ki}{s} + Kds = Kds^2 + Kps + Ki$$

where Kp = Proportional gain, Ki = Integral gain and Kd =Derivative gain.

We are most interested in four major characteristics of the closed-loop step response. They are

1. Rise Time: the time it takes for the plant output y to rise beyond 90% of the desired level for the first time.

2. Overshoot: how much the the peak level is higher than the steady state, normalized against the steady state.

3. Settling Time: the time it takes for the system to converge to its steady state.

4. Steady-state Error: the difference between the steady-state output and the desired output.

III RELAY BASED PID CONTROLLER [1][2]

The simulation and implementation of the Relay based PID Controller on the three tank mixing process in a SISO configuration. Mainly, the relay feedback method of tuning is discussed. In order to implement the relay tuning method on a MIMO system it is essential to first understand its implementation on a simple SISO system. With this in mind, a SISO relay auto-tuner is first developed and implemented on the three tank mixing process. In this case the concentration of stream A is the controlled variable with manipulated variable being the mixing of stream A in first tank. As is evident from the relay feedback theory, the method aims to identify the plant model at one particular frequency and use this information to establish the values of the P, I and D parameters. The relay tuning procedure demands that the process be capable of sustaining stable oscillations (limit cycle oscillations) when placed under relay feedback control. So, the crux of the method is to be able to bring the system to limit cycle oscillations. So, the relay characteristics such as the relay magnitude, dead zone, hysteresis is what determines the above said two characteristics of oscillations.[5]. Unfortunately, there exist no thumb rules or guidelines on how one should go about selecting the relay characteristics. What could be a good specification of relay characteristics for one kind of process may not be good for some other process. However, some key observations are as follows:

1. The upper and lower limits on the relay magnitude are dictated by how big a perturbation can be tolerated in the process under steady state of operation.

2. The size of relay hysteresis depends primarily on what kind of noise levels are expected in the process control loop. Also the hysteresis band would decide the amplitude of limit cycle oscillations.

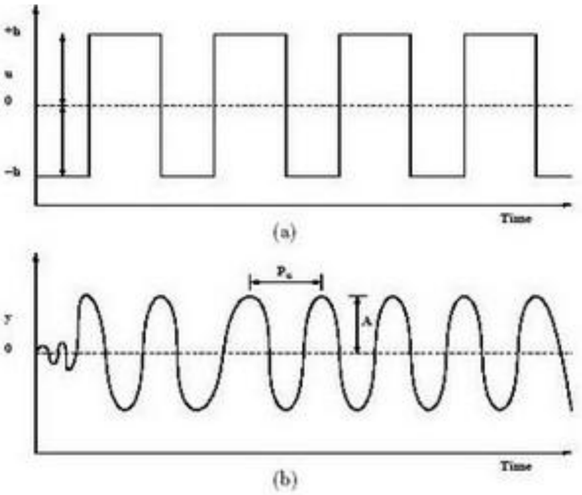


Fig.2 Waveforms of relay output in closed loop

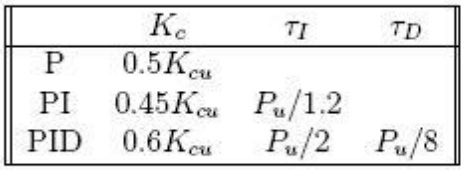
The closed-loop response of the plant, subject to the above described actions of the relay controller, will be similar to that depicted in Figure2 (b).Initially, the plant oscillates without a definite pattern around the nominal output value (denoted as 0 in the Fig. 3) until a definite and repeated output response can be easily identified. When we reach this closed-loop plant response pattern the oscillation period (Pu) and the amplitude (A) of the plant response can be measured and used for PID controller tuning. In fact, the ultimate gain can be computed as:

$$K(u) = (4 * a)/(\pi * M)$$

Having determined the ultimate gain K_{cu} and the oscillation period P_u the PID controller tuning parameters can be obtained from the following table:

TABLE I

Zeigler Nicholas Tuning Rules



	K_c	τ_I	τ_D
P	$0.5K_{cu}$		
PI	$0.45K_{cu}$	$P_u/1.2$	
PID	$0.6K_{cu}$	$P_u/2$	$P_u/8$

IV BODE PLOT TUNING METHOD [7]

Suppose that a sine wave is introduced in the figure I with Gp(s), since the system is linear , all the variable oscillate in a sinusoidal manner. After the system attains a steady state , a standing wave in which the amplitudes do not change . the sine frequency can be selected so that the output signal CV(t) lags the input signal SP(t) by 180˚. After stady state has been attained , the set point is changed to a constant value and the loop is closed. Since this is a closed loop system the sine affects the process output , which is fed back via the error signal to the process input. For the frequency selected with a phase difference of 180˚, the returning signal reinforces the previous error signal because of the negative sign of the comparator. A key factor that determines the behavior of this closed loop system is the amplification as the sine wave travels around the control loop once. If the signal decreases in magnitude every pass, it will ultimately reduce to zero, and the system is stable. If the signal increases in amplitude every pass , the wave will grow without limit and the system is unstable this analysis to the bode plot stability criterion. The Bode stability criterion states that a closed loop linear system is stable when its amplitude ratio is less than 1 at its critical frequency. The system is unstable when its amplitude ratio is greater than 1 at its critical frequency. Finding the bode plot for three tank mixing process we get the GM and PM of the phase plot and gain plot. From the data of the GM and PM we can find Ku and Tu. By substituting the values of Tu and Ku in Ziegler Nicholas chart of Table I we can find the values of Kp, Ki and Kd. By tuning the controller with these values we get the response of the system.

V. SIMULATION RESULTS FOR THREE TANK MIXING PROCESS

The following section will describe the simulation results of Relay, PID Controller based on Relay Parameters, Bode Plot and PID Controller based on Bode Plot Parameters.

The following diagram shows application of relay on three tank mixing process.

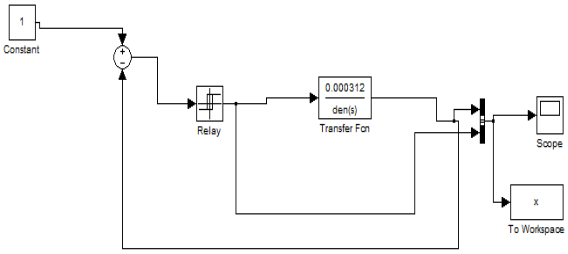


Fig.3 SIMULATION DIAGRAM OF RELAY ON SYSTEM

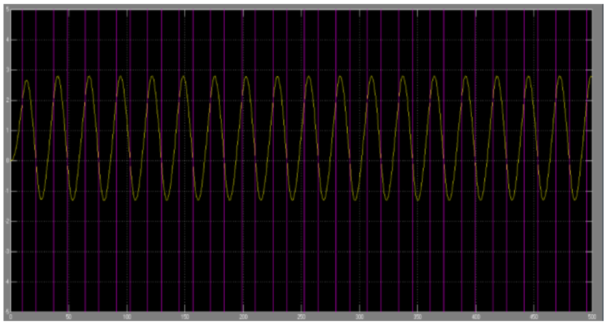


Fig.4 SIMULATION RESULTS OF RELAY

The following result shows the graph of relay applied to the input of tank. The maximum amplitude of relay is M=150 and Ultimate time period is Tu=32 sec. The following diagram shows application of PID Controller on three tank mixing process.

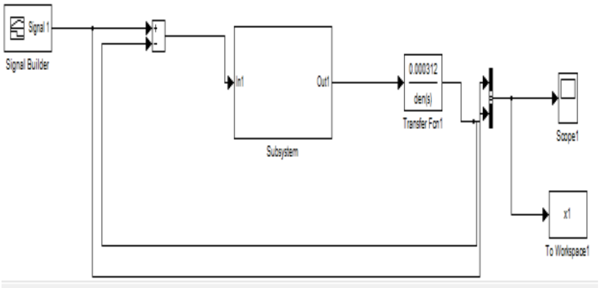


Fig.5 SIMULATION DIAGRAM OF PID ON SYSTEM

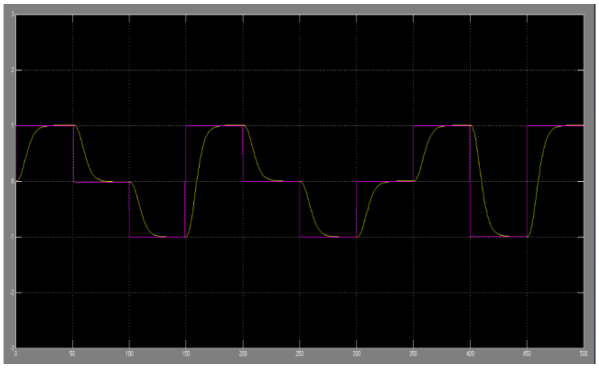


Fig.6 SIMULATION RESULT OF PID WITH MULTISTEPS INPUT

The following result shows the graph of relay applied to tank. As shown in above graph multistep signals are applied to the system with PID tunning.According to Zeigler Nicholas Method the value of Kp= 40, Ki=0.00625 and Kd=4.As shown in graph there is no peak overshoot and settling time is 18.2sec.

The following diagram shows bode plot of three tank system.

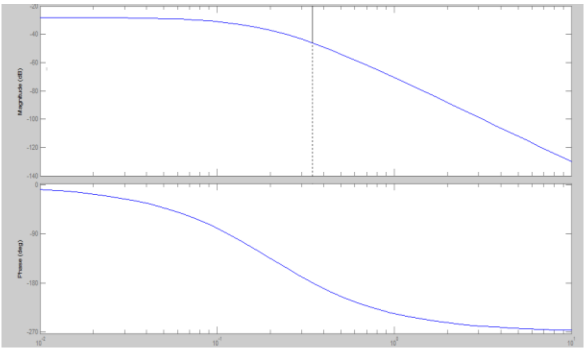


Fig.7 BODE PLOT OF SYSTEM

In the above bode plot figure the Gain Margin is 46.2dB at angular frequency of 0.346 rad/sec.From this the value of Ultimate gain Ku=204.17 and Ultimate time period Tu=18.18 sec.

From this the value of Kp,Ki,Kd according to Zeigler Nicholas rule is 123,0.11 and 2.27 respectively.The graph of PID is as shown below.

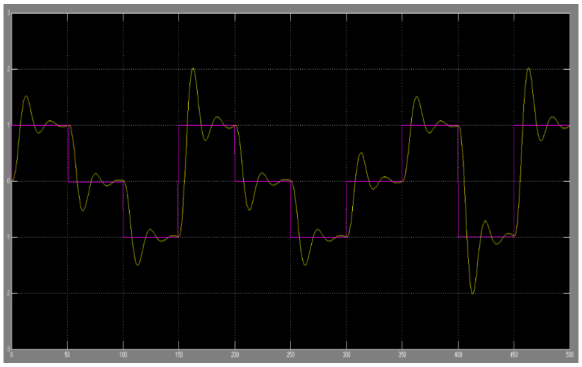


Fig.8 SIMULATION RESULT OF PID USING BODE PLOT.

As shown in above figure peak overshoot is high and settling time is 66 seconds which is more as compared to Relay feedback system.

COMPARISON OF RELAY WITH BODE PLOT PID TUNING RULES

TABLE II

Performance Parameters	Classic Zeigler-Nicholas	
	Relay	Bode Plot
Settling Time (sec)	18.2	66
Peak Overshoot (%)	0	1.6
Offset Error (%)	0	0.8
Disturbance Rejection (%)	Very Good	Poor

VI. CONCLUSION

In this paper PID tuning was implemented using Relay feedback Method and Bode Plot. The PID graph of both is shown in above figures.

The comparison table defines the performance parameters of both processes. From the figure and table the Ultimate Gain and Ultimate time period of bode plot is more as compared to that of Relay Feedback. The peak overshoot in case of Relay is zero and that of Bode is 0.8 %.Using Bode plot Method the system settling time is more than that of Relay and so due to this the performance of system is unstable.

Thus the response of system during Relay Feedback Method is far better than Bode Plot Method. Future research can be performed in looking for a better PID compensation and/or a more complex software model following the reality in a more perfect way. Also, the realisation will be extended with a height measurement system, hence avoiding a necessary contact with the ground level kind of control algorithms. Different control scheme also can be implemented. In order to apply into real platform using other tuning method should be an interesting work for the future.

The further work can be done on improving the system on improving the transfer function. As long as decrease the inaccuracy of transfer function, the control scheme can accept more disturbances or any other influence that we overlook. System identification is a well established technique for modeling of complex systems whose dynamics is not well understood. During identification the parameter of the mathematical model are tuned to obtain a satisfactory degree of conformity of the model with the real system.

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