Pid Controller Design For Cstr Plant Using Genetic Algorithm Based Pid Controller

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Abstract: The present paper is an attempt to improve the performance of the CSTR plant by means of controlling the temperature and concentration of the reactants with the application of various control methods like Proportional Integral Derivative (PID), adaptive PID . The temperature and concentration in CSTR are selected and the second order system is employed for process modeling. The tuning of the PID controller is done by using Ziegler-Nichols (ZN) method and optimization method like Genetic Algorithm (GA).

Index Terms: PID, Controller, Adative, CSTR, Genetic Algorithm.

1 INTRODUCTION

In the modern era, many industries face control and actuator problems in the field of process control. Many processes especially chemical processes are non-linear by nature. Each process varies either with load or with time which is non-stationary. The widespread use of a non-linear process called Continuous Stirred Tank Reactor (CSTR) has led to the design of different control mechanisms for handling temperature and concentration effectively. The problem of controlling the non-linear process based on its characteristics is considered to be an attractive and controversial issue, especially for control engineers. A control mechanism that would make proper changes on the processes and their non-linear characteristics may not produce any negative impact upon the desired operation of the CSTR plant.

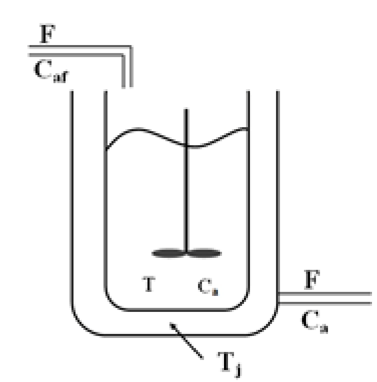

Figure 1.1 *CSTR Plant*

2 LITERATURE REVIEW

PID Tuning

PID controllers give satisfactory performance for many of the control processes.

Due to its simplicity and usefulness, PID controller has become a powerful solution for the control of a large number of industrial processes. The control system performance is complicated by the non-linear dynamics of the process. Several processes exhibit second order plus time delay system with a zero transfer function model. Examples for such processes are jacketed CSTR (Bequette 2003), distillation column (Jacobsen 1999), autocatalytic CSTR (Padmasree and Chidambaram 2006) and crystallizer (Kausthubh and Chidambaram 2000). Many recycle processes where in energy and mass recycle take place are represented by transfer function model (Jacobsen 1999) In the conventional PID controllers, the proportional, integral and derivative actions on error are placed in the forward path. The proportional or derivative action on the error causes an abrupt change in the controller output when the set point change is introduced. This issue is the main drawback of the conventional PID controller (Kiam 2005).

Ziegler-Nichols (ZN) tuning

Ziegler & Nichols (1942) have described simple mathematical procedures for tuning the PID controllers. Both the techniques make a priori assumption on the system model, but do not require the model to be specifically known. Ziegler-Nichols formulae for specifying the controllers are based on the plant step response.

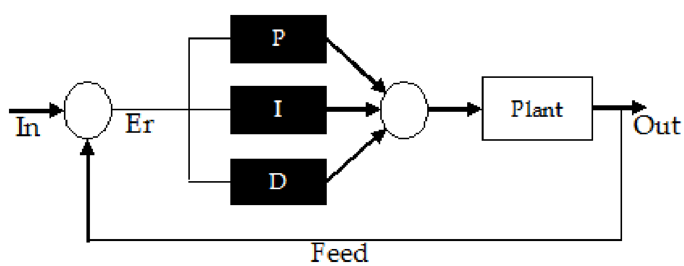

Figure 2.1 *Block Diagram of PID control loop*

3 METHODOLOGY

To improve the performance of the CSTR plant further, the current research tries to overcome the drawbacks in the conventional PID controller by implementing the adaptive controller to control the CSTR plant. Though the PID controllers satisfy most of the system needs, more specific cases like functional cases in system parameters seek adaptive methods for much accurate response. The problem of high t_r, M_p, t_p and t_s can be rectified by GA PID. The desired

- *Prabhu K is currently working as an Assistant Professor in Kongu Engineering College, Erode, PH-9865067310. E-mail: gomuprab@gmail.com* *At first, PID and adaptive PID controllers for a second order system are designed. The controller parameters are tuned with ZN tuning which shows fluctuations by validating with the time domain parameters like rise time (tr), overshoot (Mp), peak time (tp) and settling time (ts).*

system response can be obtained by adjusting the PID controller parameters using the conventional ZN method. Tuning of GA based PID controller shows notable improvement in the system response in terms of time domain parameters than the conventional PID controller. Transient response of the CSTR plant is improved by designing suitable controllers like PID using GA optimization algorithm with achieving less t_r, M_p, t_p and t_s. The optimal parameters of the PID controllers are obtained. Hence the optimized PID controller provides improved transient response of the CSTR plant with less oscillations and M_p than the PID controller.

4 MODELING OF CSTR PLANT

The mathematical model equations are obtained by a component mass balance and energy balance principle for the reactor is given by

$$\frac{dc_a}{dt}=\left(\frac{F}{V}\right)(Ca_f\text{-}C_a)\text{-}k_0\exp\left[\frac{E}{R.(T+460)}\right]C_a$$

$$\frac{dT}{dt}=\left(\frac{F}{V}\right)(T_f\text{-}T)\text{-}\frac{\Delta H}{\rho C_p}\left[k_0\exp\left[\frac{-E}{R.(T+460)}\right]C_a\right]\text{-}\left(\frac{UA}{\rho C_p V}\right)(T\text{-}T_j)$$

CSTR is modelled with the parameters given in Table 4.1

Table 4.1 *Parameters of CSTR plant*

Variables	Values	Units
Ea	32400	BTU/lb mol
K0	15*10^12	Hr^{-1}
dH	-45000	BTU/lb mol
U	75	BTU/hr-ft^2-of
Rho*C_p	53.25	BTU/ft^3
R	1.987	BTU/lb mol-of
V	750	ft^3
F	3000	ft^3/Hr
Ca_f	0.132	Lb mol/ft^3
T_f	60	Of
A	1221	ft^2

The second order transfer function of the CSTR plant which is commonly used for simulation studies for standard data specification is obtained as below.

$$cstr_{tf}=\frac{2.293s+9.172}{s^2+10.29s+25.17}$$

5. GENETIC ALGORITHM (GA)

GA is an optimization tool that lies on the platform of heuristic approaches. Based on the Darwin's principle of the survival of the fittest, GA is introduced to commence optimization problems in soft computing. The first category is termed as initial population and all the individuals are candidate solutions. Simultaneous study of the population including all the candidates and the next phase of solutions are generated following the steps of GA (Goldberg 1989). Involving the iterative application of operators on the selected initial population is the initial process of GA. Further steps are devised based on the valuation of this population. The reason for using GA is that it handles large and poorly understood search spaces easily and improves well for addressing non-linear control optimization problems.

Tuning of PID controller using GA

The tuning of PID controller is done by using the GA optimization method as given below.

1 Generate 50 sets of K_p, K_i and K_d randomly.
2 Feed every set of value in SIMULINK model one by one and calculate the error in the form of MSE and ITAE.
3 Apply roulette wheel selection on 50 sets of PID controller parameters according to the corresponding error.
4 Select approximately 60% of set value of K_p, K_i and K_d and the rest of the 40% by crossover operation with the factor of 0.8.
5 Apply uniform mutation on the newly generated set of values with the traction of 0.7.
6 Repeat step 2

Record the best value in every iteration with minimum MSEs and ITAEs. The initial parameters selected for the system under study are given below.

Initial population	:	50
Fitness functions		MSE and ITAE
Selection		Roulette Wheel
Crossover		Two-point (0.7)
Mutation		Random (0.8)

These parameters are the genetic parameters used to optimize the PID controller. The performance indices used to reduce the error between the actual value and the desired value are

$$MSE=mean(Error^2)$$

$$ITAE=(sum(abs(Error)))$$

6 SIMULATION RESULTS

There are two cases that are considered in analyzing the performance of CSTR plant. In the first case, the controller is analyzed with PID controller while in the second case, the GA based PID controller is analysed. The comparative analysis is made between the two cases.

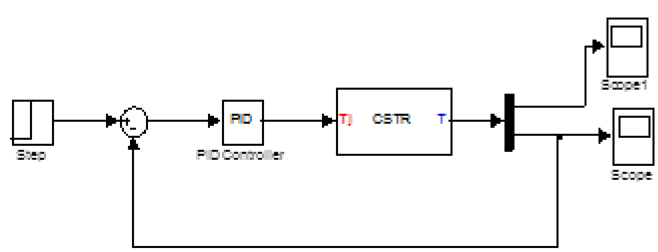

Figure 5.1 *Simulink model for CSTR plant with optimized PID controller using GA*

The parameters are obtained using GA PID are K_p =10, K_i=100 and K_d=0.01. Figure 5.2 shows the response of the fitness function which reveals the best fitness value at 65^{th} iteration.

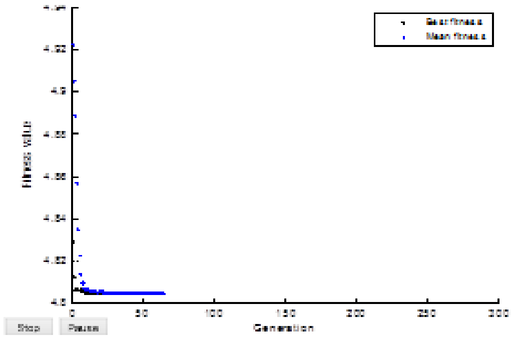

Figure 5.2 *Response of fitness function using GA optimized PID*

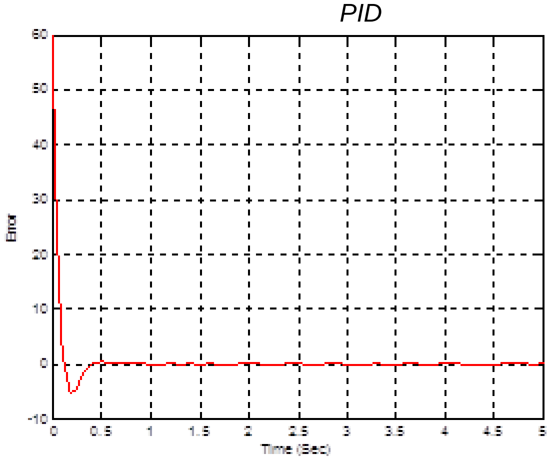

Figure 5.3 *Error response of CSTR using GA optimized PID*

Figure 5.3 shows the error response of the optimized PID controller. The error resolves accurately near to zero after 0.5 second with less oscillation. The error response shows better improvement when compared to the conventional PID. MSE and ITAE in the optimized PID exhibit less errors of 18.66 and 771.62 respectively than that of the conventional PID controller.

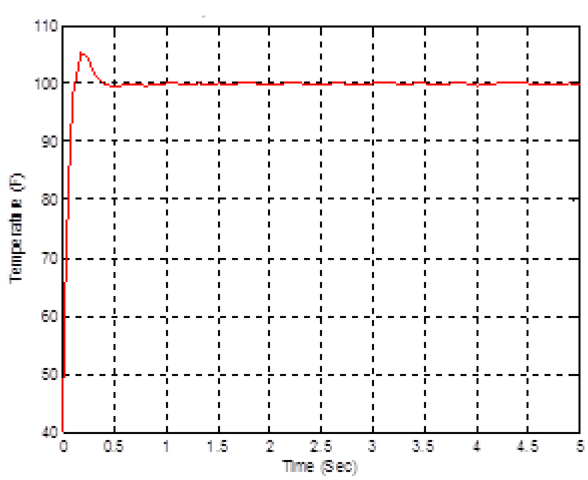

Figure 5.4 *Temperature response of CSTR using GA optimized PID*

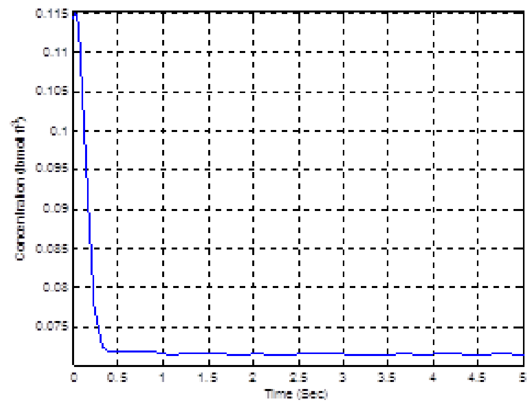

Figure 5.5 *Concentration Response of CSTR using GA optimized PID*

Figure 5.5 shows the concentration response of CSTR with optimized PID controller. The concentration response attains the desirable value of 0.073lbmol/ft^3 on 0.5 second with some fluctuations. The comparative analysis of the time domain parameters for CSTR with PID and GA optimized PID is represented in Table 5.1. With the optimized GA, the process response is enhanced while the rise time is reduced from 0.1600 to 0.0600 seconds.

Table 5.1 *Comparative analysis of time domain parameters for CSTR, PID and GA optimized PID*

Control Methods	Rise Time t_r (sec)	Overshoot M (%)	Peak Time t_p (sec)	Settling Time t_s (sec)
PID	0.1600	25.786	0.3550	1.5875
Optimized GA-PID	0.0600	12.667	0.1550	0.3279

The overshoot is reduced from 25.786% to 12.667% , the peak time from 0.35504 to 0.1550 seconds and the settling time from 1.5875 to 0.3279 seconds. So, it is clear that the GA optimized PID controller performs better than the conventional PID controllers.

7 CONCLUSION

The time domain parameters of CSTR with GA optimized PID controller are analysed. It is observed that the designed controller provides a better response to the CSTR plant. The optimized GA-PID controller shows good transient response compared to that of the conventional PID controller.

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