SET POINT TRACKING CAPABILITY ANALYSIS FOR AN INDUSTRIAL IPDT PROCESS MODEL

Priyanka Singh[1], Dr.Pradeep kumar Juneja [2], Ruchika Jangwan[3] and Anuj Kumar[4]

[1234]Deptt. Of Electrical and Electronics Graphic Era University Dehradun

ABSTRACT

In this paper the Proportional integral controllers based on Internal Model Control principles tuning technique for a pure integrating process with dead time is designed. The performance of these controllers with different closed loop time constants is analyzed and compared for its set point tracking capability. The controller with best performance for the selected time constant is decided.

KEYWORDS

IPDT, Taylors approximation, Pade approximation, IMC tuning

1. INTRODUCTION

For any design procedure to yield a control algorithm which works satisfactorily in real environment, the following must be specified:

- Process model
- Model uncertainty bounds
- Type of inputs
- Performance objectives

Every tuning procedure is centered on process model. The understanding of the operator who knows how the plant responds to the different inputs is the simplest model. Neglecting model uncertainty leads controllers unstable in the real world operations. The input is to be decided according to their importance. Finally the design specifications are given for good performance[1].

A process model is a set of equations including the necessary input data to solve the equations that allows us to predict the behaviour of a chemical process system[2].The process whose model to be prepared may be with time delay or without time delay. The processes with time delay are the complex processes which are difficult to analyze .The delay time in the process is due to the transportation lag i.e. delay is always present with movement and due to the location of the sensors. The delay in the process may also be caused due to the delay in any part of the system. The delay in the process creates a serious problem in the designing process control system. The system with time delay are difficult to analyze and can be classified as first order plus dead time (FOPDT),second order plus dead time (SOPDT) and integral plus dead time (IPDT). The time delay present in the process can be approximated by different approximating techniques like Taylor's approximation, Pade's approximation etc.

The IPDT process is the integral plus dead time having the transfer function which is identical to [3]

$$G_c(s) = k\frac{e^{-s\theta}}{s} \qquad (1)$$

where k is the gain and Θ is the delay .

The systems with large time constant can be approximated by IPDT process .The IPDT process contains only two parameters namely time delay and process gain .Since it contains only two parameters it is very easy to identify and analyze integrating processes. Integrating processes are generally encountered in the process industries and IPDT model represents the dynamics of many chemical processes. Integrating systems with time delay are found in the modeling of liquid level systems. The common examples of these processes are distillation column, chemical reactor and level control of the boiler steam drum [3].PI controllers are suitable for the liquid level system[5] . The PI controllers are generally used in to improve the steady state response of the system. The proportional integral (PI) controller are widely used in the process industries due to its simplicity and wide range of applicability in the regulatory control. Pumping water at a constant rate from tank is an integrating process [3]. The liquid level system is an integrating system or it can be modeled as an integrating process with dead time (IPDT). In industries generally the controllers used are PID type but still PI controllers are more reliable in the liquid level system.Proper tuning rules for PI controllers are needed for complex processes represented by transfer functions. Model based tuning methods, were found attractive for practitioners because they have only one tuning parameter.

2. IMC METHOD

The Internal Model Control name emerges from the fact that t he controller has explicit model of the plant as its part. IMC tuning technique designed on the principle that in reality we do not have knowledge of actual process but of approximation of actual process. This approximated process is termed as process model. Although the correct model is designed, we may not achieve accurate measurement of process parameters from this model. Therefore, the imperfect model should be factored as part of controller design [4] .

The process transfer function is represented by

$$Gp(s)= \frac{Ke^{-s\theta}}{s} \qquad (2)$$

The IMC controller is divided into two parts. One part is inverse of stable portion of process and other part is IMC filter as shown on figure. In this transfer function the unstable pole is integrator part. IMC integrator is also treated as unstable pole for the design of IMC controller[5] .

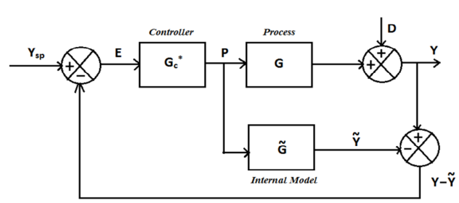

Fig1 basic block diagram of IMC tuning technique[5]

According to Chein aand Fruehauf the IMC controller depends only on two factors : 1) closed loop time constant 2) the delay in the process .IMC controller can be tuned to have a good set point tracking response. IMC tuning method has a credible result for wide classes of process models [5] .

Table 1 IMC based PI controller settings for the process[6]

CASE	MODEL	K_c	T_i
IPDT	$\frac{Ke^{-s\theta}}{s}$	$\frac{2\tau c + \Theta}{(\tau c + \Theta)}2$	$2\tau c + \Theta$

3. METHODOLOGY

The objectives of the control system analysis for the process under consideration are

- To select an appropriate Integral Plus Delayed Model (IPDT) for the purpose of controller design
- To design different IMC controllers for the selected IPDT model
- To select different values of desired closed loop time constant values for the purpose of designing IMC controllers
- To analyze the closed loop feedback system for each of these controllers for their set-point tracking capability
- To compare these responses and decide the best controller for the selected process

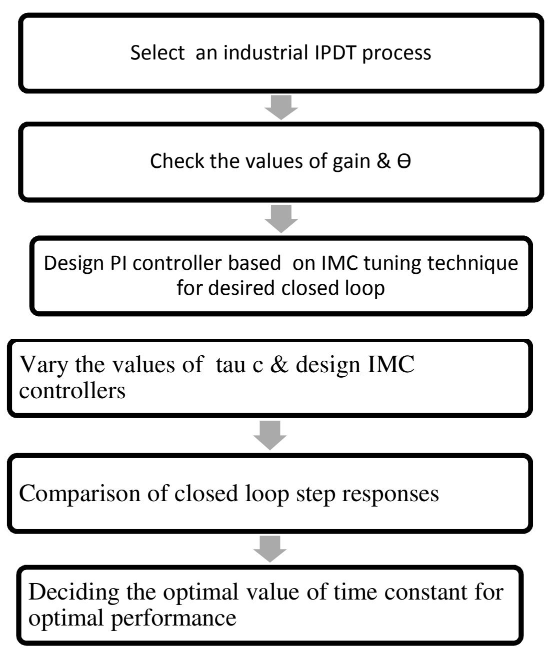

Fig 2 Flowchart for systematic investigation of control system analysis for IPDT model

The transfer function of the process is given by equation (1)
The transfer function of the PI controller is given by

$$Gc(s)=Kc[1+1/sT_i] \quad (3)$$

The present work is directed to design PI controllers for a pure integrating system with time delay using IMC method. PI controllers are designed for each approximation by selecting various values of closed loop constants (τ_c).The performance of the designed controllers based on IMC method for a given transfer function model is compared. The controller with best set point tracking capability and performs best among all designed controller for selected time constant is decided.

The IPDT process transfer function selected from the literature [7]

$$G_p(s)=\frac{0.0449\, e^{-10s}}{s} \tag{4}$$

The transfer function of the process after approximating delay with Taylor's direct approximation is given by

$$e^{-s\theta}=1-s\theta \tag{5}$$

The transfer function of the process after approximating delay with Taylor's approximation is given by

$$Gp(s)=\frac{-.0449s+.00449}{s} \tag{6}$$

Lower order models are comparatively easy to control system design and implementation than higher order models. First order Taylor's series approximation is a general approach to approximate higher order transfer function models with lower order models that have similar static and dynamic characteristics [6].

$$e^{-s\theta}=\frac{1}{1+s\theta} \tag{7}$$

$$G_p(s)=\frac{.00449}{10s^2+s} \tag{8}$$

The transfer function of the process after approximating delay with Pade approximation

$$e^{-s\theta}=\frac{1-s\theta/2}{1+s\theta/2} \tag{9}$$

$$G_{p(s)}=\frac{.00449-.02245s}{5s^2+s} \tag{10}$$

According to the flow chart shown in figure 2, first of all the process is selected which corresponds to the equation (1) .The selected process transfer function is of the water level plant. According to this transfer function, the gain of the transfer function as well the delay associated with the plant is noted.

After investigating the value of the delay and gain of the plant now the controller is designed which will improve its performance and reduce the delay time. The controller which we are generally considered for the level control is PI controller. PI controller is designed according to the internal model control tuning technique therefore also called the IMC controller.

These IMC controllers are designed for different selected closed loop time constant (τc=2,5,7,10). These closed loop time constant are decided on the certain recommendations. Controllers are designed on the basis of these closed loop time constants.

Different designed controllers are subjected with the step input and the behavior of the controller is investigated. The behavior of different controllers is compared with the different controllers in which the delay is the approximated with the different approximation. After investigating responses of the controller with the step input the optimum value of the time constant is decided on the basis of set point tracking .The best controller is decided on the basis of the performance evaluation and time specifications.

4. RESULT AND DISCUSSION

Various PI controllers are designed from the different selected time constant (τ_c) for an IPDT process using IMC tuning method are given in Table2.

The PI controller transfer function for τ_c =2

$$G_c(s)=\frac{280\,s+20}{14\,s} \tag{11}$$

The PI controller transfer function for τ_c =5

$$G_c(s)=\frac{356.3\,s+17.8}{20s} \tag{12}$$

The PI controller transfer function for τ_c =7

$$G_c(s)=\frac{427.5\,s+17.8}{24\,s} \tag{13}$$

The PI controller transfer function for τ_c =10

$$G_c(s)=\frac{890.7\,s+29.69}{30\,s} \tag{14}$$

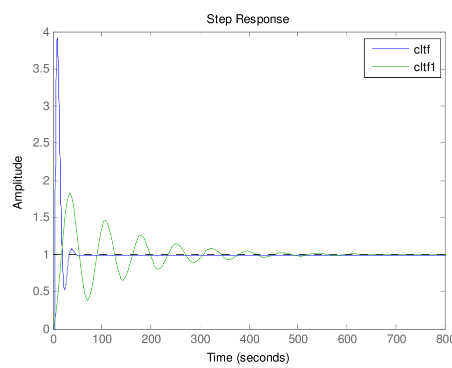

Figure 3 simulation result for comparison for all approximations for τc=2

Figure 3 shows the comparison of step response of IPDT process model , with closed loop time constant τc =2 which shows that Taylor's direct gives the better transient response as well as steady state response to the step input as compared to Pade's I approximation. The rise time ,peak time ,peak overshoot as well as the settling time of the Taylor's direct approximation is better as compared to the Pade"s approximation. Taylor's indirect approximation gives the unrealizable response.

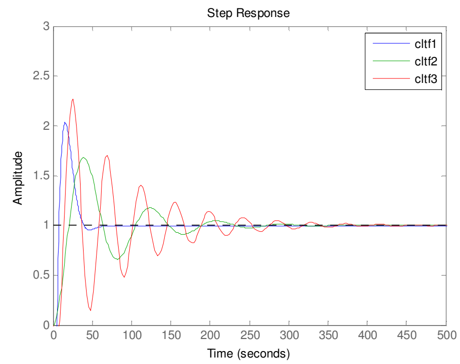

Figure.4 simulation result of comparison for all approximation for τc = 5

Figure 4 shows the comparison of step response of process model with closed loop time constant τc=5 Taylor's direct approximation gives the better transient response as well as steady state response but the peak overshoot is better in the Pade's approximation for the step input.

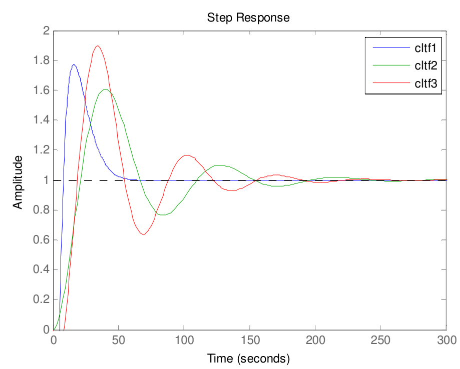

Figure 5 simulation result of comparison for all approximation for τc = 7

Figure 5 shows that the comparison of step response of the process with the closed loop time constant τc =7 , the transient response and steady state response of the Taylor's direct response is better as compared to the other approximations but peak overshoot is better in Pade approximation.

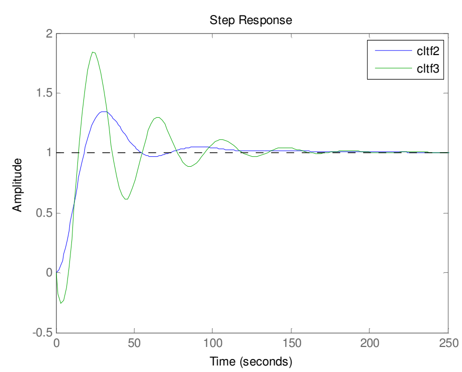

Figure6 simulation result of the comparision for all for τ_c =10

Figure 6 shows the response of the model to the step input with the closed loop time constant τc =10 ,the transient response is better for Taylor's direct approximation but the peak overshoot is better in Pade approximation as compared to all approximation.

Table 3 shows the transient as well as steady state and transient response characteristic for differentdesiredclosedloopconstant(τ_c)

5. CONCLUSION

Controllers based on IMC tuning technique are designed for the selected IPDT process for various values of desired closed loop time constant .

Controllers are compared for their set point tracking capability using important steady state & transient characteristics.

From the control system analysis of the performance of the controllers to the step input , it is concluded that the performance of the controller with the closed loop time constant 10 shows the best set point tracking capability . The delay is approximated with Taylor's direct approximation technique performs better as compared to all other controllers with Pade I &Taylor's indirect approximation. The Taylor's approximated controller with closed loop time constant 10 shown the best transient as well as steady state response for the selected IPDT model.

Table 2 Table for IMC controller parameters for different selected time constant

τc	Kc	Ti
2	20	14
5	17.8	20
7	17.8	24
10	15.5	30

Table 3 Closed loop parameters

Approximation	T_r (sec)				T p (sec)				T_s (sec)				M_p (%)			
τ c →	2	5	7	10	2	5	7	10	2	5	7	10	2	5	7	10
Taylor's (direct)	1.88	2.61	5.95	1.38	5.92	8.28	7.51	5.16	19.92	27.73	40.6	2.13	59	83	75.1	220
Pade I	11.9	13.69	14.2	11	36	39	40.2	29.5	476	258	188	133	83	67.7	60.8	55.8
Taylor's (indirect)	-	7.71	6.65	4.73	-	33.7	30.5	25.9	-	245	208	331	-	103	103	127

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Authors

Priyanka passed Bachelor of Technology from the M.J.P. Rohilkhand University and pursuing Master of Technology in control system from Department of Electrical & Electronics Engineering at the Graphic Era University. She has worked as teaching personnel in the Department of Electrical Engineering at GBPUA&T. The author has a great interest in the field of process control and pursuing her research in this field.