Controller Design and its Comparative Analysis for a Pure Integral Delayed Process Model

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Abstract – Different controllers are designed on the basis of the different tuning techniques. Five controller techniques are selected for designing the controllers. PI Controllers are designed for the industrial integral plus dead time model. The step response of these controllers is analyzed. On the basis of set response set point tracking capability of the controllers is analyzed. On the basis of the time specifications of the closed loop system the best controller is decided.

Index Terms – Controller, PI, Dead Time Model.

1. INTRODUCTION

The stability of the control system is affected by the time delay in the system. The effect of time delay on the performance of the control system has drawn the attention of many researchers in different engineering disciplines. Efforts have been made to minimize time delays. Though, time delay cannot be removed completely due to its inherent nature. Time delay not only results in degradation of the performance of the control system but also cause instability on the system response.

A system having dead time represents a broad class for the modelling and the analysis of transportation and propagation phenomena of matter or energy. In addition, the location of sensors and their response time, the controllers and the final control element can generate considerable delays [1]. Literature review that has been done author used in the chapter "Introduction" to explain the difference of the manuscript with other papers, that it is innovative, it are used in the chapter "Research Method" to describe the step of research and used in the chapter "Results and Discussion" to support the analysis of the results [2]. If the manuscript was written really have high originality, which proposed a new method or algorithm, the additional chapter after the "Introduction" chapter and before the "Research Method" chapter can be added to explain briefly the theory and/or the proposed method/algorithm [4].

The integral plus dead time system can be modelled as:

$$(s) = Ke^{-s\theta}/s$$

Where K is the process gain and Θ is the time delay.

The IPDT process is easy is to analyze as it contains only two parameters to tune. A large number of tuning techniques are evaluated for integrating process [2]. The tuning of the process without delay is comparatively easy from tuning process with delay.

2. RELATED WORK

Chien and Fruehauf (1990) proposed an internal model control (IMC) method to find the settings for a PI controller in a process consist of an integrator and a time delay [3].Tyreus and Luyben (1992) pointed out that the method could lead to poor control unless care was taken in selecting the closed-loop time constant. A substitute approach that avoids the problem is suggested based on classical frequency response methods. The approach can yield the best settings attainable for a specified degree of closed-loop damping [4]. Wang and Cluet (1997) discussed the control problem in the processes with integrator and time delay [5] .In [6], a method based on the maximum peak resonance specification is proposed for PI controller tuning of integrating processes.

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 select different tuning techniques for the purpose of designing PI controllers.
- To design different PI controllers for the selected IPDT model.
- 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 on the basis of closed loop time specifications.

3. PORPOSED MODELLING

In the present analysis, the process modelled as an IPDT is selected for analysis [7]

Gp (s) =.00449 $e^{-s\theta}$/ s 2

Then the controllers tuning technique is selected for designing the PI controller. PI controllers are designed for the model on the basis of the selected tuning techniques .The selected tuning techniques with corresponding tuning formulas is shown in Table 1.

The closed loop responses achieved from controller are compared and analyzed for determining the set-point tracking capability of the controllers.

Table 1 PI controller parameters [8]

Tuning Technique	Controller gain (Kc)	Integral Time (Ti)
Chidambaram & Sree	$K_c = \frac{1.1111}{K\theta}$	$T_i = 4.5\theta$
Rotach	$K_c = \frac{0.75}{K\theta}$	$T_i = 2.41\theta$
Ziegler & Nichols	$K_c = \frac{0.9}{K\theta}$	$T_i = 3.33\theta$
Skogested	$K_c = \frac{0.49}{K\theta}$	$T_i = 3.77\theta$
Shinskey	$K_c = \frac{0.9259}{K\theta}$	$T_i = 4\theta$

The PI controllers designed on the basis of the Table 1 are as follows

1. Chidambaram and Sree controller

The transfer function of the controller is given by equation (3)

$$Gc\text{ (s)} = \frac{1113.3s+24.74}{45s} \quad (3)$$

2. Rotach controller

The transfer function of the controller is given by equation (4)

$$Gc\text{ (s)} = \frac{402.47s+16.70}{24.1s} \quad (4)$$

3. Ziegler & Nichols controller

The transfer function of the controller is given by equation (5)

$$Gc\ (s) = \frac{667.33s+20.04}{33.3s} \quad (5)$$

4. Skogested controller

The transfer function of the controller is given by equation (6)

$$Gc\ (s) = \frac{411.30s+10.91}{37.7s} \quad (6)$$

5. Shinskey controller

The transfer function of the controller designed by Skogested tuning technique is given by equation (7)

$$Gc\ (s) = \frac{848.90s+10.91}{37.7s} \quad (7)$$

Different designed controllers are subjected with the step input and the behaviour of the controller is analyzed. The behaviour of different controllers designed with different tuning techniques is compared. After investigating responses of the controller with the step input the set point tracking capability is determined. The best controller is decided on the basis of the performance evaluation and time specifications.

4. RESULTS AND DISCUSSIONS

In the a figure 1 cltf,cltf1,cltf2,cltf3,cltf4 shows the response of the Chidambaram & Sree controller ,Rotach controller, Ziegler & Nichols controller, Skogested controller and Shinskey controller respectively. The controllers designed is subjected to the step input and the performance of the control system is analyzed on the basis of the steady state and transient characteristics i.e. rise time ,peak time ,settling time and the maximum peak overshoot.

The set point tracking capability of the designed controller is analyzed. The controller with the best set point tracking capability is decided on the control system dynamics.

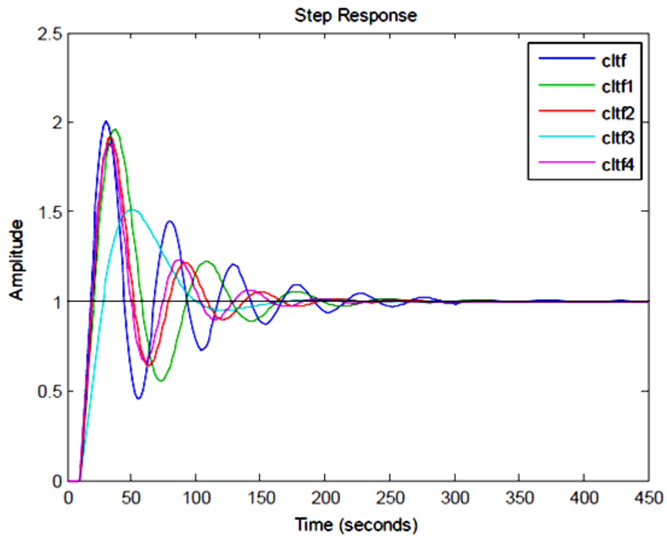

Figure 1 Comparison of set point tracking capability of all selected tuning techniques

The set point tracking capability of the designed controller is analyzed. The controller with the best set point tracking capability is decided on the control system dynamics.

Table 2 shows the values for closed loop step response steady state and transient characteristics for the systems.

Tuning Technique	Tr (sec)	Tp (sec)	Ts (sec)	Mp (%)
Chidambaram & Sree	6.58	30.5	278	101
Rotach	8.66	37.5	221	96
Ziegler& Nichols	7.74	33	186	91.7
Skogested	14	50.4	150	51.2
Shinskey	7.5	32.6	176	88.6

The rise time, peak time, settling time and peak overshoot are listed in Table 2. On analysis it is depicted that the rise time 6.58 sec and peak time 30.5 is better for the Chidambaram & Sree tuning technique .The settling time 150sec and peak overshoot 51.2 % is better for the Skogested tuning technique .On the basis of settling time Skogested tuning technique is better as compared to all other tuning techniques for set point tracking.

5. CONCLUSION

In the present analysis, the parameters of a PI controller are obtained for integrating plus dead time process models. The controllers are designed for the set point tracking capability analysis. Simulation is performed to achieve the step response of the controller. On the basis of simulation result the closed loop time specifications are obtained. The simulation study shows that the Skogested tuning technique is better as compared to all other tuning technique. The simulation studies show that significant improvement is obtained when compared to other selected tuning techniques. Set point tracking capability of the Skogested controller is better as compared to all other designed controllers

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