Comparison of Various PID Controller Design Method for First order With Dead time

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Abstract: This paper presents a comparison of various tuning formulas of PID controllers for first order with dead time. The values of the three coefficients of PID controllers for the given FOPDT i.e. proportional gain (k_c), integral gain (k_i) and derivative gain (k_d) are calculated using these formulas and then a simulink model has been designed. By designing the controller using different method it has been concluded that ISTE-Set point method is better because it produce less rise time, less overshoot and less settling time.

Keywords- FOPDT, ISE-set point, ISE-load, ISTE-set point.

I. Introduction

PID controllers are so called because they have three modes i.e Proportional, Integral and Derivative control mode. They are used in most automatic process control applications in industry. PID controllers can be used to regulate flow, temperature, pressure, level, and many other industrial process variables. Basically we deal with the tuning of PID controllers which can be done manually or automatically. There are various methods for tuning of PID [1]. This paper includes the comparison of various methods and implementation of simulink model for each. The response outputs we get after simulation are compared on the basis of rise time, settling time and overshoot. For a method to have better performance, its rise time and settling time must be less. We cannot conclude that which method is best but we can have a general conclusion that which method is better on the basis of simulink model output. Based on the application for which we are using this controller, we can justify which method works out to be the best for that application [2]. So the selection of best method depends on the application. This paper shows the simulink model as well as the simulation results of various methods.

II. Methodology

Here, we consider a first order process with dead time (FOPDT). The general equation for process model is:-

$$P(s) = \frac{k}{Ts+1} e^{-\tau s} \text{..... (i)}$$

Where

k is any integer
T – Time constant
τ - Dead time

Then we calculate the values of k_p, τ_i and τ_d using the formulas which are given below in the table. And lastly we form a simulink model by putting these values in the equation of PID controller which is given as [6]

$$k = k_c + \frac{k_i}{s} + k_d s \text{...... (ii)}$$

$$k = k_c\left(1 + \frac{1}{\tau_i s} + \tau_d s\right) \text{...... (iii)}$$

Where:-

k_c= Proportional gain
k_i= Integration coefficient
k_d= Derivative coefficient
τ_i = Integral time constant
τ_d = Derivative time constant

Here we consider some optimum integral error based methods [1] like for load disturbance (ISE-load, ISTE-load) and for set point change (ISE-set point, ISTE-set point) are used. The table given below shows the formulas for these methods to calculate the value of k_c, τ_i and τ_d.

Method	k_c	τ_i	τ_d
ISE-setpoint	$\frac{1.048}{k}\left(\frac{\tau}{T}\right)^{-0.897}$	$\frac{T}{1.195-0.368\left(\frac{\tau}{T}\right)}$	$0.489T\left(\frac{\tau}{T}\right)^{0.888}$
ISE-load	$\frac{1.473}{k}\left(\frac{\tau}{T}\right)^{-0.970}$	$\frac{T}{1.115}\left(\frac{\tau}{T}\right)^{-0.753}$	$0.550T\left(\frac{\tau}{T}\right)^{0.948}$
ISTE-setpoint	$\frac{1.042}{k}\left(\frac{\tau}{T}\right)^{-0.897}$	$\frac{T}{0.987-0.238\tau/T}$	$0.385T\left(\frac{\tau}{T}\right)^{0.906}$
C-C(cohen-coon)	$\frac{T}{k\tau}\left(\frac{16T+3\tau}{12T}\right)$	$\frac{\tau\left(32+\frac{6\tau}{T}\right)}{13+\frac{8\tau}{T}}$	$\frac{4\tau}{11+\frac{2\tau}{T}}$

Table 1. Various PID tuning formulas

To illustrate this, let us consider first order process model as

$$P(s) = \frac{1}{2s+1}e^{-0.6s}$$

Then we calculate the values of k_c, τ_i and τ_d using the formulaes given in above table. The calculated values are given in the table below.

Method	k_c	τ_i	τ_d
ISE-setpoint	3.0851	1.8439	0.3357
ISE-load	4.7358	4.4410	0.3513
ISTE-setpoint	3.0682	2.1843	0.2586
C-C (cohen-coon)	4.6944	1.3168	0.2068

Table 2. PID settings tuned by various methods

III. Simulink Model

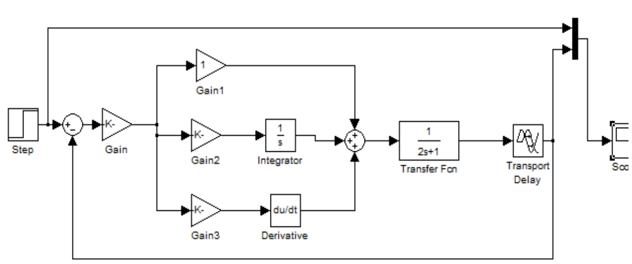

Fig. 1. Fig.1. simulink model of PID controller

Figure 1 depicts the model of all methods in simulink to simulate the feedback controller system. The above model is designed by taking the reference of equation-ii *i.e.* the model will be different for each method because the values of k_c, τ_i and τ_d will be different as shown in Table 2. This model is the general model used for implementation of all methods. Here, four gains with integrator and derivative form a PID and then a standard transfer function is taken. Delay is used so that the response does not change at the same time when input changes.

IV. Results And Discussion

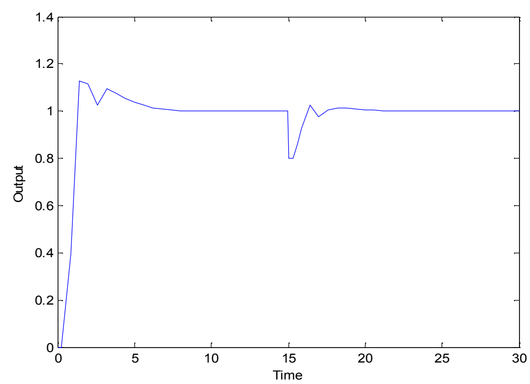

Fig. 2. Output response of system using ISE-Set point method

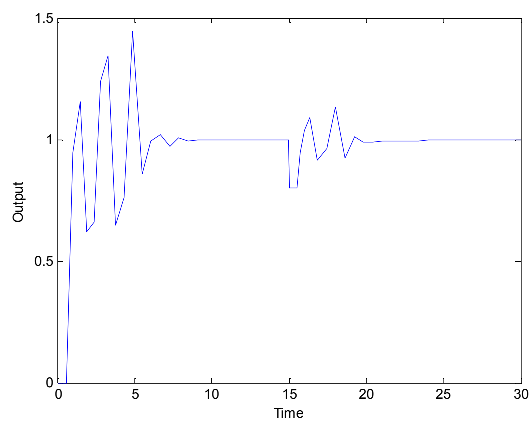

Fig. 3. Output response of system using ISE-Load method

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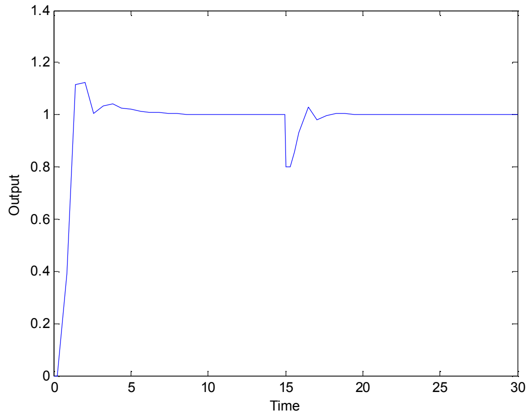

Fig. 4. Output response of system using ISTE- Set point method

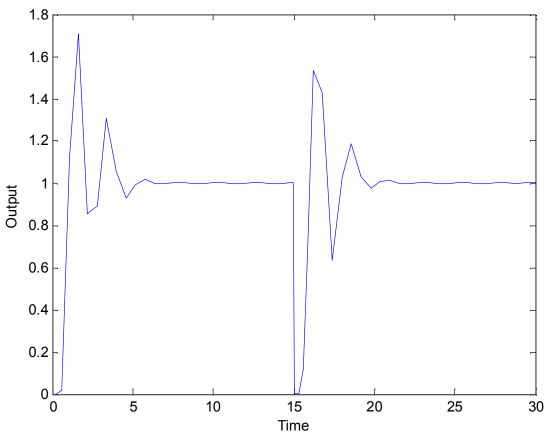

Fig. 5. Output response of system using cohen-coon method

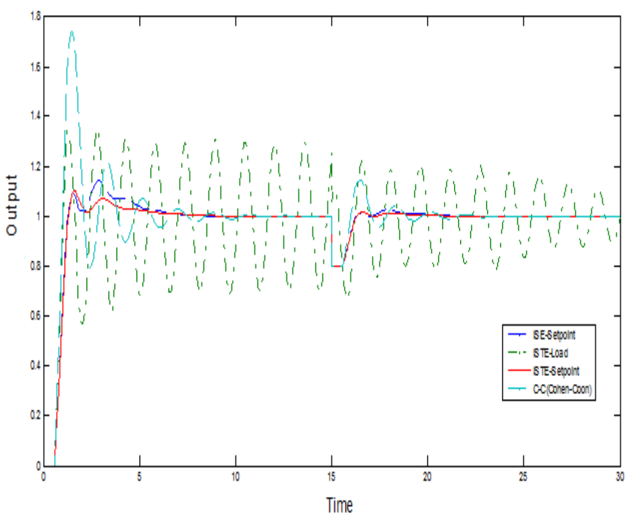

Fig. 6. Consolidated Output response of system using different method

The simulations are carried out in MATLAB/SIMULINK. Analysis shows that the design of the PID controller using
ISTE-setpoint method gives better results than other tuning methods.Fig.6 concludes that the ISTE-setpoint method produce less rise time, less overshoot and less settling time.

V. CONCLUSION

This paper represents the designing and performance evaluation of PID controller for different methods (ISE-setpoint, ISE-load, ISTE-setpoint, C-C (cohen-coon).The various results presented above shows that ISTE-setpoint is a better technique of PID tuning for first order with dead time than other tuning methods. From the time domain specifications it has been justify that ISTE-setpoint method produce less overshoot, less rise time and less settling time.

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