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Design of State Feedback Control for a FOPDT System

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ABSTRACT

In this paper, the author has presented the first order plus dead time system (FOPDT) as a state space model, PI controller has been designed on the basis of the state space model. And a pole placement method is used to obtain the desired closed loop poles of the system to achieve overshoot of less than 5% and rise time less than 1 second. Then, the desired new closed loop poles are placed to find the values of PI control gains. The obtained PI control gain values are implemented and tested in MATLAB Simulink environment. Simulation works were carried for various analysis such as closed loop, setpoint tracking and disturbance rejection analysis. The effectiveness of the state feedback control has been demonstrated in the system response.

1. Introduction

A PID controller is a three-term controller is majorly using in industry to control the process parameters such as temperature, pressure, level, flow and so on. Defining Set point and process variable is considered to be the primary parameter for control. A process variable is the one which needs to be controlled and set point is the desired value for the parameter, you are controlling. Designing a PI controller is an essential process in any closed loop process which needs to be adapted for the process, thus determining the controller gain values for proportional(k_p), integral(k_I), and derivative (k_d) is an effective part in controlling a process.

Past 50 years research society are working on designing [1,2,3] new control algorithm for getting better closed loop control. The aim of this paper is to test the performance of state feedback PI control design in a FOPDT state space model. In this work, PI control control setting is found out using state feedback design.

2. State feedback Control

State feedback control is a design works based on the state variables of the systems. Design procedure of the state feedback design. At first, desired loop poles of the system are to be found using the root locus method [5]. Secondly, normally system dynamic is represented in-terms of differential equation or transfer function, convert the system transfer function [6] into the state space model as follows.

$$\frac{dx}{dy} = Ax + Bu \tag{1}$$

A and B are the matrices of the system coefficients and x is the vector of the system states and u is the input of the system. And finally, find the gain values using pole placement method. The figure 1 shows the closed loop P control block diagram of state feedback control design.

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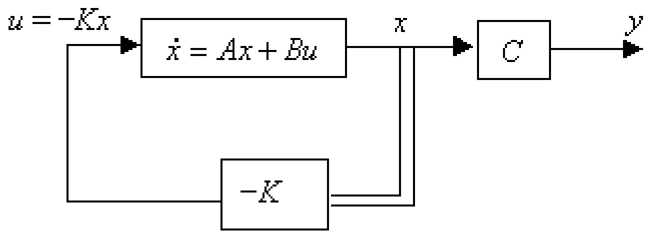

Figure 1. State feedback control design

3.Simulation and results

In this work, a first order plus dead time transfer function is considered for analysis. FOPDT model is expressed to be three terms are process gain (K), Time constant(Ʈ) and dead time (t_d). The equation 2 represents the general form of the FOPDT transfer function.

$$G(s) = \frac{K_p e^{-t_d s}}{\tau s + 1} \quad (2)$$

To test the performance and robustness of the state feedback design, the following transfer function is considered for analysis.

$$G(s) = \frac{5}{15s+1} e^{-2s} \quad (3)$$

In the above equation 3, systems dynamics process gain is considered as 5, time constant as 15 seconds and dead time is 2 seconds. In equation 4, the equation 3 is represented in state space form.

$$A = \begin{bmatrix} -1.0667 & -0.0667 \\ 1 & 0 \end{bmatrix}; B = \begin{bmatrix} 1 \\ 0 \end{bmatrix} \quad (4)$$

$$C = [-0.3333 \quad 0.3333]; D=0 \quad (5)$$

On the next stage, desired closed loop poles are obtained by the root locus method. Desired closed loop poles are obtained for achieving overshoot of less than 5% and rise time less than 1 second. i.e Ɛ = 0.7 and w_n=1.7.

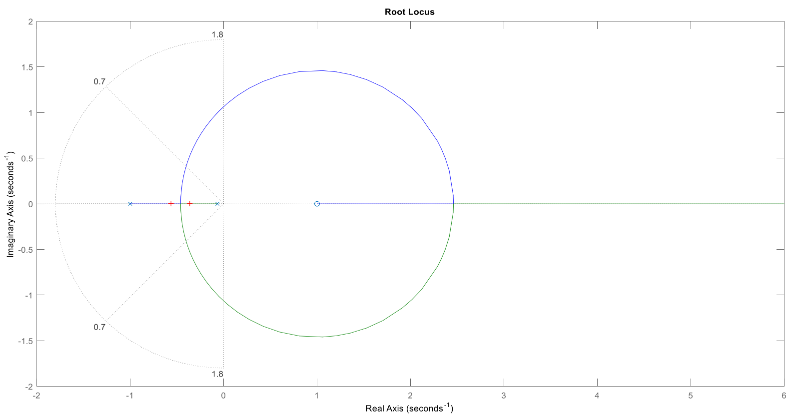

Figure 2. Root locus design

The selected point of the root locus is -1.4167 + 0.7643i, for this pole gain values are obtained as K_1= 2.1666, K_2= 0.4088, which gives proportional control action. These gains are implemented and result is presented in figure 3.

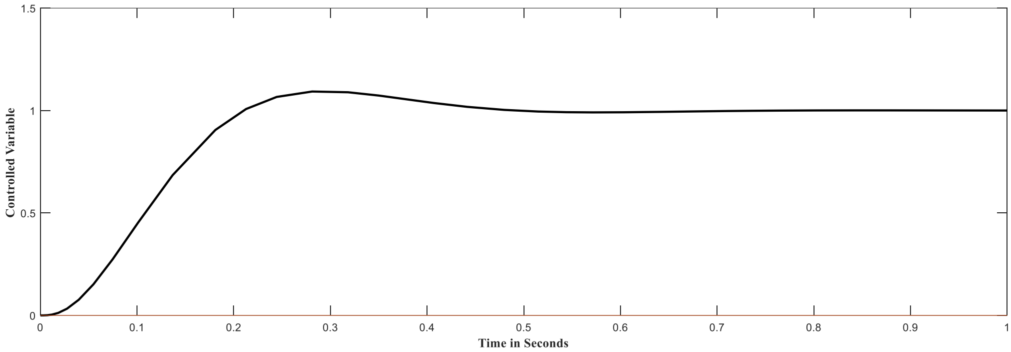

Figure 3. Closed loop response for P control

Then, new set of gain values is to be identified based on the pole placement method. In that way, the obtained new gain values are K_1=101.7667, k_2 544.9839 and K_3=777.3580, the gain values k1 and k2 represents the proportional gain values and k_3 represents the integral gain value. This value gives the combination of proportional plus integral action i.e PI control action. Thus, the state feedback gains are found the implemented in MATLAB Simulink.

The following figure 4 shows the closed loop response of the system with PI control settings based on state feedback control design.

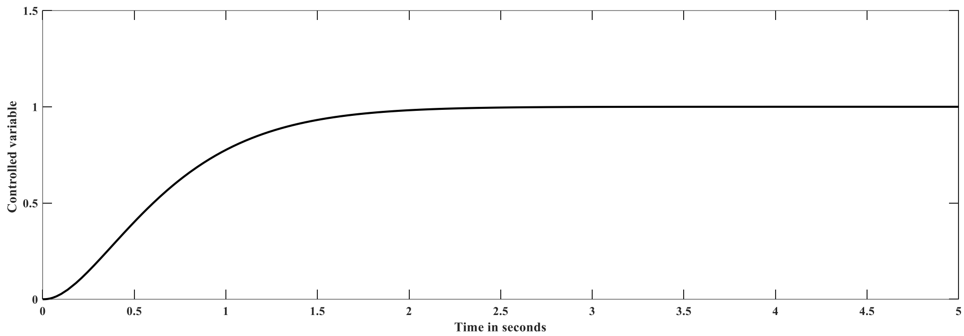

Figure 4. Closed loop response for PI control

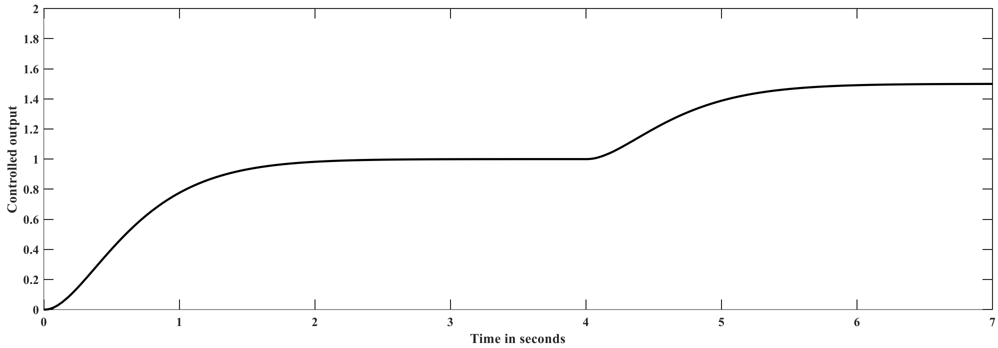

Figure 5. Setpoint tracking response

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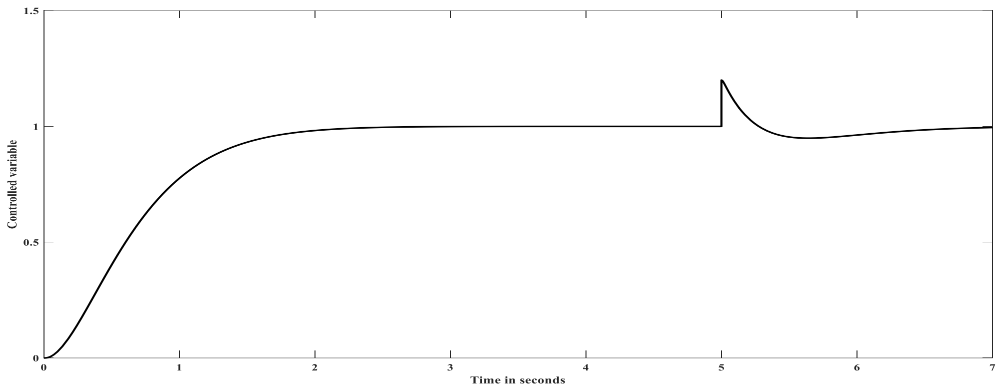

Figure 6. Disturbance rejection response.

Figure 5 and figure 6 shows the setpoint tracking and disturbance rejection analysis of state feedback control design respectively. The proposed PI control settings, which responds to the new set value and reaches the new value, i.e. the proposed control gives a satisfactory response for servo problem and in figure 6, the process is disturbed with a value of 2% of set value, the process reacts to that disturbance and return back to the original set value, the proposed control gives satisfactory response for regulatory problem.

4. Conclusion

The objective of this work is accomplished by implementing and testing a state feedback control design for FOPDT system using MATLAB simulink. Results show the satisfactory response and the design PI control is analyzed by servo and regulatory response which gives a satisfactory response.

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