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Research Paper

COMPARATIVE STUDY OF INTEGER ORDER PI-PD CONTROLLER AND FRACTIONAL ORDER PI-PD CONTROLLER OF A DC MOTOR FOR SPEED AND POSITION CONTROL

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This paper includes the comparative study of fractional order PI and PD control system. In this paper both controllers are used for the speed control and position control of the DC machine. Both these controllers are designed on time domain. The closed loop performances of PI and PD fractional order controllers are then compared with the classical integer PI and PD controllers' performance. The result shows that fractional order PI and PD controllers are better than classical integer order PI and PD controllers.

Keywords: Transfer function, Gain margin, Simulink

INTRODUCTION

Control of mechatronic systems is the biggest challenge due to their interdisciplinary nature. PID controllers are simple in nature and robust, thus they are used for linear mechatronic systems. Another method fractional order controllers are also used for controlling purpose. Speed Control of DC motors is common example of mechatronic domains.

The control strategies for DC motors have been ranged from simple PID controller to advance fractional order controller. Fractional order PID controllers have extra tuning parameters in comparison to classical PID controllers because of which they have the capacity to increase the closed loop performance and robustness of the closed loop systems.

In Fractional order controllers the performance criteria are usually specified in terms of gain crossover frequency, phase crossover frequency, phase margin, gain margin and robustness to open loop gain variations.

This paper illustrates the basic time domain and frequency domain concepts. This paper

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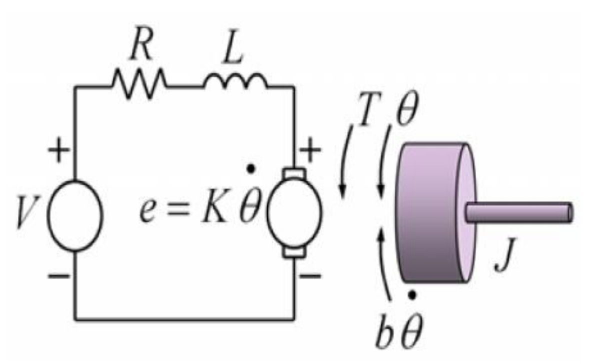
represents the tuning procedure for Fractional order PI controllers as well as tuning example for the speed control of DC motors. Also the tuning methods for Fractional order PD controllers and position control of DC motors are represented in this paper.

Speed Control of DC Motors

For the speed control, the controlled variable is the angular velocity.

Figure 1: General Model of DC Motor



$$P_{DC\_motor}(s) = \frac{\omega(s)}{V_a(s)} = \frac{K_m}{(L_a s + R_a)(Js + b) + K_b K_m} \quad ...(1)$$

$$P_{DC\_motor}(s) = \frac{K_m}{R_a(Js+b)+K_bK_m} = \frac{\frac{K_m}{R_ab+K_bK_m}}{\tau s+1} = \frac{K_{DC\_motor}}{\tau s+1} \quad ...(2)$$

Equation (2) represents a simplified model where time constant of the armature $\tau_a = \frac{L_a}{R_a}$ is taken as constant.

The transfer function from ¯(*t*) as controlled variable to armature voltage V_a (manipulated variable) will be:

$$P_{DC\_motor}(s) = \frac{\theta(s)}{V_a(s)} = \frac{K_{DC\_motor}}{s(\tau s + 1)} \quad ...(3)$$

In the first experimental set up, the speed control DC motor using fractional order PI controller is done. The transfer function of Fractional order PI controller is given as:

$$H_{FO-PI}(s) = k_p\left(1 + \frac{k_i}{s^{\mu}}\right) \quad ...(4)$$

Equation (4) implies the following things:

- An imposed gain crossover frequency of the open loop system is 1.
- An imposed phase margin of the open loop system is (–® + ¨$_m$).
- Condition for robustness to gain variations is zero.

The identification of a system was based on a Pseudo Random Binary Signal (PRBS). To generate this following command is used in MATLAB:

- idinput(127, 'PRBS', [0 1/1], [-1 1])

By using Prediction Error Method (PEM) the system's model is defined. The transfer function of DC motor can be given as:

$$H_P(s) = \frac{0.25}{(1.45s + 1)} \quad ...(5)$$

Imposed performance specifications are, μ_{cg} = 1.5, ¨$_m$ = 50

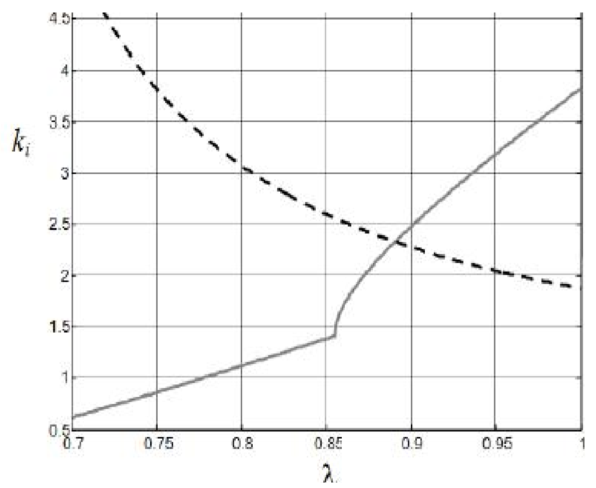
The intersection of the two curves yields solution for k_i and «. Final values of k_i = 2.26 and « = 0.79 are used to compute the value of third parameter k_p.

Position Control of DC Motors

In the second experimental set up, the position control DC motor using fractional order PD controller is done.

To design fractional order PD controller following equations are used:

Figure 2: Graphical selection for parameters k_i and ª



$$|H_{FO-PD}(j\omega_{gc})| = \frac{1}{|H_p(j\omega_{gc})|} \quad ...(6)$$

$$\angle H_{FO-PD}(j\omega_{gc}) = -\pi + \varphi_m - \angle H_P(j\omega_{gc}) \quad ...(7)$$

In this next tuning parameters for fractional order PD controller is obtained, k_p = 1.03, k_d = 1.1 and ª = 0.6.

RESULTS

$$H_P(z) = \frac{0.032}{z - 0.87} \quad ...(8)$$

Above equation represents the identified model for DC Motor voltage-speed.

For position control discrete model is:

$$H_P(z) = \frac{0.0032z + 0.0031}{z^2 - 1.87z + 0.87} \quad ...(9)$$

Figure 3 represents a simulink model for fractional order PI controller. Result of this model is illustrated in Figure 4. Comparison of Fractional order PI controller is done with Integer order PI controller. The Integer order PI controller has been designed using the same specifications of Fractional order PI controller. In this case « = 1 and tuning parameter are k_p = 1.13 and k_i = 2.23. These observations indicate that fractional order PI controllers are much better than integer order PI controllers.

In the second experimental set up, PD controllers are used to control the position of the DC motor.

Figure 3: Simulink Diagram for DC Motor Speed Control

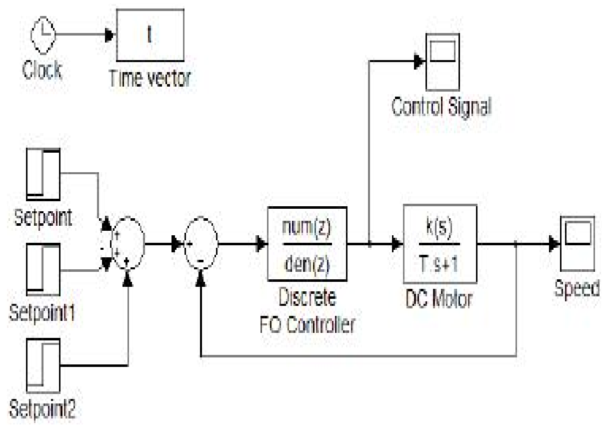


Figure 4: Step Response of DC Motor Speed Control

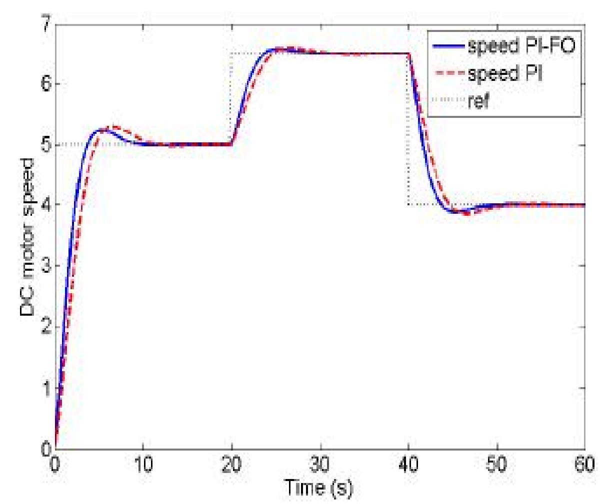
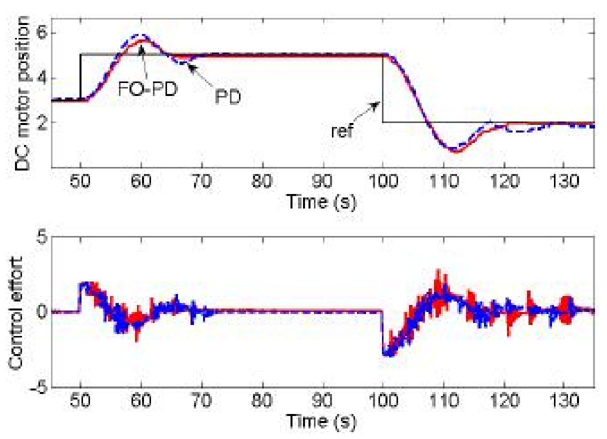


Figure 5: Diagram for Position Control of DC Motor



Experimental parameters for fractional order PD controllers are k_p = 0.85 and k_d = 1.15.

By comparing the experimental results for position control it can be concluded that control effort is similar for both PD controllers but for set point tracking, the fractional order PD controller outperforms than integer order PD controllers.

CONCLUSION

In this paper, speed and position control of DC motors by fractional order PI and PD controllers is done. By experimental and simulation results, it is proved that fractional order PI and PD controllers outperforms the integer order PI and PD controllers.

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