Design and Simulation of Fractional Order Pseudo-Derivative Feedback Control System

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Abstract. This paper designs a kind of fractional order control system which applying the pseudo-derivative feedback controlling structure, fractional order pseudo-derivative feedback (FOPDF). Use FOPDF control to integer and fractional first-order motion control plant which parameters are tuned by Bode's ideal transfer function, the step response indicates FOPDF control may result in a more rapid, more accurate and more robust control system. FOPDF method is of the practicability and effectiveness.

Keywords: Pseudo-derivative feedback; robustness; Bode's ideal transfer function.

1. Introduction

Pseudo-derivative feedback (short for PDF)control system introduced by Phelan in 1977[1],this system is simple yet effective . PDF structure provides all the control aspects of PID control, but without system zeros that are normally introduced by a PID compensator. Phelan named this structure "Pseudo-derivative feedback (PDF) control from the fact that the rate of the measured parameter is fed back without having to calculate a derivative. The PDF structure internalizes a pre-filter, one would apply to cancel the zeros introduced in the PI (or PID) equivalent system[2].The PDF structure is usually introduced into the design of electro-hydraulic servos[3],automatic control systems of electric traction[10],it offers a good disturbance rejection performance and promotes the response speed. In this paper the fractional PID algorithm is introduced into FOPDF systems to promote the property of fractional PID control system, the simulation results to a first-order controlled plant illustrate that the FOPDF control method has superior performances to IOPDF structure.

The Bode's ideal transfer function method of design FOPDF is easy and effective .It suggested an ideal shape of the open-looptransfer function of the form[5]:

$$G_{opi}(s)=\left(\frac{\omega_c}{s}\right)^{\alpha},\alpha\in R \tag{1}$$

Where ωc is the gain crossover frequency, In fact, the transfer function $G_{opi}(s)$ is a fractional-order differentiator for $\alpha>0$ and a fractional-order integrator for $\alpha<0$. Assume gain crossover frequency ωc, the phase margin Φm; Can easily get the structure and the parameters of FOPID controller:

$$G_c(s)=\frac{G_{opi}(s)}{G_P(S)} \tag{2}$$

2. Establishing FOPDF Control System Model and Simulation Model

According to the basic structure of PDF[1],establish the FOPDF control system model to a first-order controlled plant 1/(Ts+1), 1/(Ts γ +1), the model for integer plant is shown in Fig1. We suggest a basic structure of FOPDF system like Fig.1, where, the FOPI maybe a single FOPI controller or conbined by FOPI controllers. The parameter Kd can be tuned of Chenliu method[9],as a basic tuning parameter of design FOPDF controll structure. The Kd value is 5.44.Then the internal-loop can be treated as a whole controlled object. The equivalent open-loop block diagram of

Fig.1 is shown in Fig.2.From Fig.2 the transfer function of FOPI controller designed based on Bode's ideal transfer function can be expressed as:

$$G_{cFOPI}(s)=\frac{G_{opi}(s)}{G_{pop}(s)}=\frac{\left(\frac{\omega_c}{s}\right)^{\alpha}}{\frac{1}{Ts+1+K_d}}=(\omega_c)^{\alpha}\cdot[Ts^{1-\alpha}+(1+K_d)\cdot s^{-\alpha}] \quad (3)$$

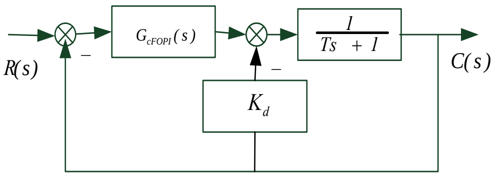

Fig. 1 Block diagram of FOPDF control of system aimed to first-order controlled object

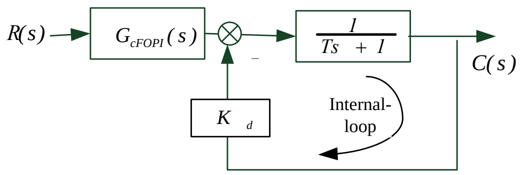

Fig. 2 Open-loop block diagram of FOPDF control aimed to first-order controlled object

Assume T is 0.4s, the expected crossover frequency ωc is 10 rad/s,the phase margin Φm is 70o,then equation of the controller can be determined as (4):

$$G_{c1FOPI}(s)=(10)^{\frac{11}{9}}\cdot[0.4s^{-\frac{2}{9}}+6.44s^{-\frac{11}{9}}] \quad (4)$$

For 1/(Ts γ +1),assume γ is 0.5,T is 0.4s,(the other parameters are same as ineger first-order control plant),the FOPDF structure is the same as integer one, but the equation of the controller is expressed as (5): $G_{c2FOPI}(s)=(10)^{\frac{11}{9}}\cdot[0.4s^{-\frac{13}{18}}+6.44s^{-\frac{11}{9}}]$ (5)

Establishing FOPDF control system simulation model as Fig.3.

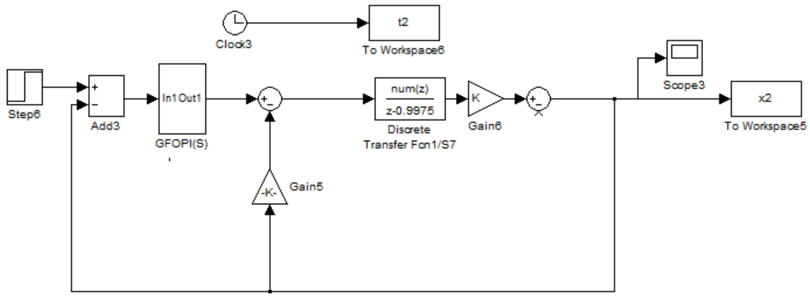

Fig.3 The Simulation Block of FOPDF Aim to Integer First-oder Plant Control System

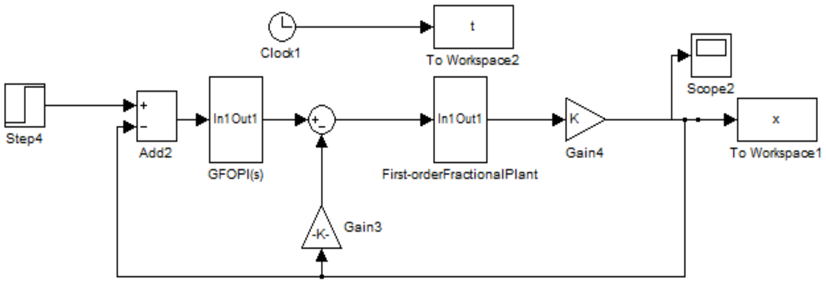

Fig.4 The Simulation Block of FOPDF Aim to Fractional First-oder Plant Control System

3. Simulation and Result of FOPDF System

The parameter of Kd can be tuned to a suitable value to get a desirable step response. The bode diagram of open-loop FOPDF system both for integer or fractional first-order plant are the same ,is shown in Fig.5.Fig.6 is partial enlarged unit step responses of FOPDF control system of integer first-order plant, when changing the system gain K. And Fig.7 is unit step responses of FOPDF control system of fractional first-order plant, when changing the system gain K.

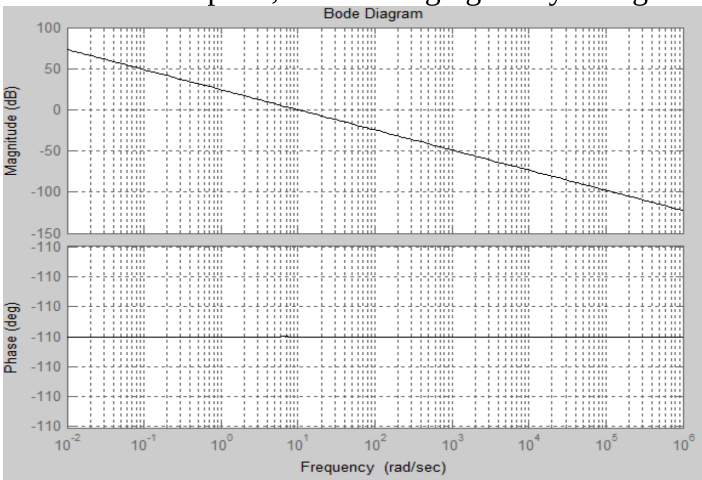

Fig.5 Bode Diagrams of Open-loop the FOPDF System

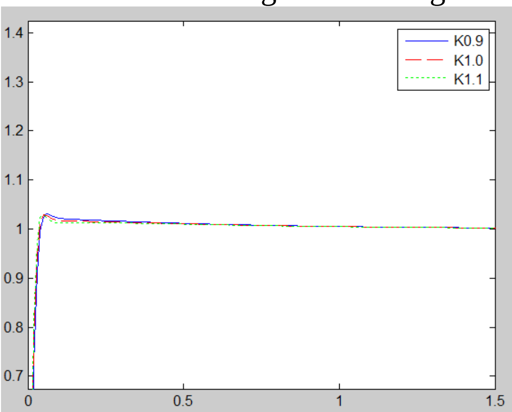

Fig.6 Partial Enlarge Unit Step Responses of FOPDF Control Structue Aim at Integer First-order Plant

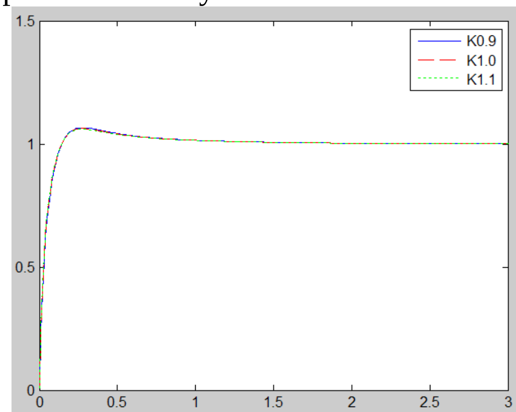

Fig.7 Unit Step Responses of FOPDF Control Structue Aim at Fractional First-order Plant

Fig.6, Fig.7 indicate that FOPDF control structure makes the closed-loop systems robust to gain variations and have an iso-damping property.

4. Conclusion

In this paper, we have presented a new strategy of FOPDF control structure and apply Bode's ideal transfer function method, Chenliu method for parameters tuning. The numerical performances indicate that FOPDF control may result in a more rapid, more accurate and more robust control system. FOPDF method which has iso-damping property is of the practicability and effectiveness. FOPDF control method is likely applied in the hydraulic servo systems and the electric drive systems.

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