Design and Simulation of Fractional-Order Controller for Double Closed-Loop DC Speed Regulating System

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Abstract

This paper discusses the design of fractional order PI controller for the current and speed double closed-loop DC speed regulating control system. Study the design method of fractional order PID controller speed loop and its parameter setting, in the double loop DC motor speed control system. Simulation and comparison the control effect of the fractional order control scheme with the traditional integer order scheme . Verify the fractional order controller PIλmakes the system have better dynamic performance and robustness.

Keywords

Double Close Loop DC Adjusting Speed System；Parameter Adjustment；Fractional Order Control.

1. Introduction

The speed and current double closed-loop speed control system, s till plays an important role in the field of industrial production of DC and AC. At present, the industrial production requires speed control system have more stability , speediness and robustness . The mechanical characteristics of DC motor is excellent, simple control, high reliability, the DC speed still plays an important role in the field of industrial control. At present, double closed loop speed regulation system for integer order PID controller, and with the increasingly in-depth study of the fractional order, fractional order controller is gradually introduced to the control field, in order to obtain good dynamic effect and strong robustness. In this paper, a double closed-loop speed control system as the control object, the system of speed control method. The system adopts the traditional integer order controller of current loop, current loop corrected object as a control object link speed, speed controller using fractional order PI controller. Respectively design IOPI controller and FOPI controller, and the simulation model, compare the control effect.

2. The mathematical model of double loop speed control system

Double closed-loop speed control system dynamic structure diagram as shown in Figure 1, The inner current loop dynamic structure diagram as shown in Fig 2. Ignore the dynamic effects of electromotive force, equivalent to a unit negative feedback system, and small inertia processed, dynamic structure diagram of equivalent current link as shown in Fig. 2 (b). The current regulator ACR using the traditional integer order PI controller, the transfer function as shown in formula (1). The current link is ajusted as a typical I system, current corrected dynamic structure as shown in figure 3. According to figure 3, the transfer function of current link as shown in formula (2).

$$W_{\mathrm{ACR}}(s)=\frac{K_{\mathrm{i}}(\tau_{\mathrm{i}}s+1)}{\tau_{\mathrm{i}}s} \tag{1}$$

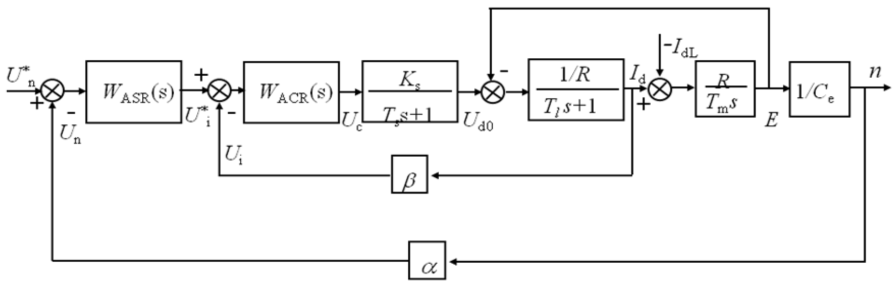
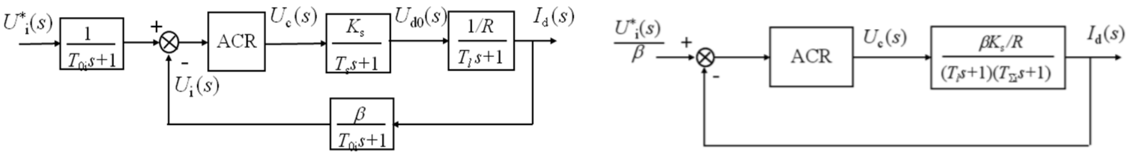


Fig.1. The dynamic structure diagram of double closed loop speed regulation system



a) Ignore the effect of electromotance b）The simplified dynamic structure diagram

Fig.2 Simplified structure diagram of dynamic current loop

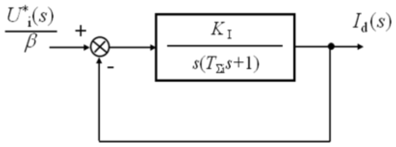


Fig.3 The current link after correction

$$W_{cli}(s)=\frac{I_d(s)}{U_i^*(s)/\beta}=\frac{\dfrac{K_I}{s(T_{\Sigma i}s+1)}}{1+\dfrac{K_I}{s(T_{\Sigma i}s+1)}}=\frac{1}{\dfrac{T_{\Sigma i}}{K_I}s^2+\dfrac{1}{K_I}s+1} \qquad (2)$$

Adopt the approximation method to handle the high order system, ignoring the high-order approximation, descending order, approximate condition (3) to obtain the equivalent transfer function（4）.

$$\omega_{cn}\le\frac{1}{3}\sqrt{\frac{K_I}{T_{\Sigma i}}} \qquad (3)$$

here, ωcn —the cut-off frequency of speed loop open loop frequency characteristic, and $K_I=\dfrac{K_i K_s\beta}{\tau_i R}$, $T_{\Sigma i}=T_s+T_{oi}$

$$\frac{I_d(s)}{U_i^*(s)}=\frac{W_{cli}(s)}{\beta}\approx\frac{\dfrac{1}{\beta}}{\dfrac{1}{K_I}s+1} \qquad (4)$$

Using the equivalent link instead of current link, then from fig.1 we can get fig.4, where ASR is designed as FOPI controller.

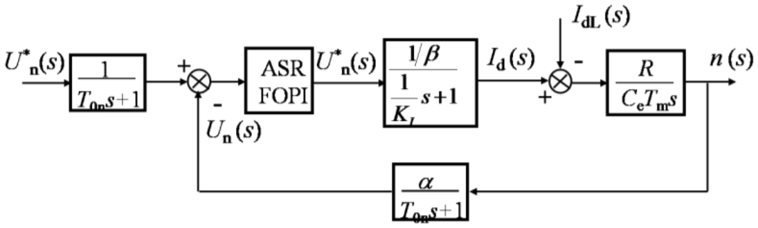


Fig.4 Speed loop dynamic structure diagram

3. Design of FOPI controller

The system parameters are as follows. DC motor：220V, 136A, 1460r/min, Ce=0.132Vmin/r, Allow overload λ=1.5, thyristor device amplification coefficient：Ks=40；the total armature circuit resistance：R=0.5Ω ；time constant：Ti=0.03s, Tm=0.18s；current feedback coefficient：β=0.05V/A（≈10V/1.5IN）, speed feedback coefficient α=0.07Vmin/r（≈10V/nN）.

Integer order PI controller mathematical model is:

$$G_{cIOPI}(s) = K_p + K_i / s \tag{5}$$

The mathematical model of fractional order PI controller is：

$$G_{cFOPI}(s) = K_p + K_i / s^{\lambda} \tag{6}$$

The tuning by engineering method and PSO optimization method for integer order controller. According to the engineering method of IOPI controller parameters for GCIOPI is: $K_{p1} = 11.7$, $K_{i1} = 1.32$；By using the PSO optimization method of IOPI controller parameters of IOPI is $K_{p2} = 6.18$, $K_{i2} = 97.13$.

PSO fractional order PI controller parameters optimization structure as shown in Fig 5.

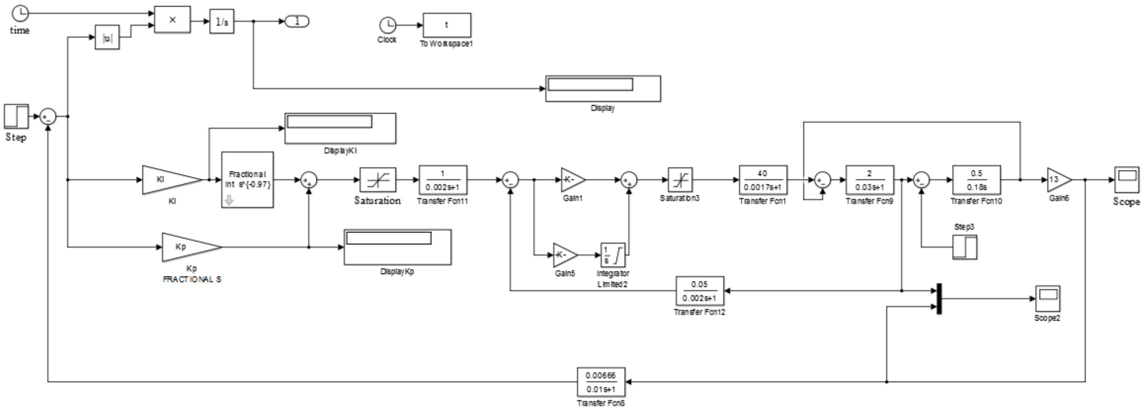


Fig.5 FOPI controller PSO optimization structure diagram

The parameters of fractional order controller FOPI value:

$K_p = 3.75, K_i = 1.32, \lambda = 0.97$

4. System simulation

System simulation diagram as shown in Fig. 6. According to the simulation parameters of the above method, get double loop current and speed control effect as shown in Fig.7. Compared the control effect of IOPI controller design of IOPI controller, FOPI controller and the design of the engineering methods, as shown in Fig.8. Obviously, using FOPI control the speed of the outer loop, the performance index of speed loop, such as rise time, overshoot is better than the other two methods.

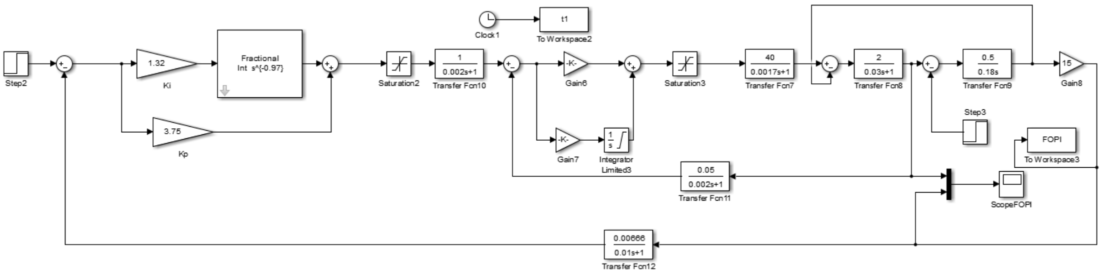
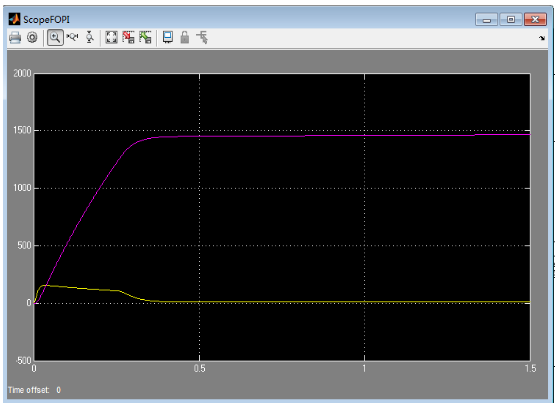


Fig.6 System simulation diagram



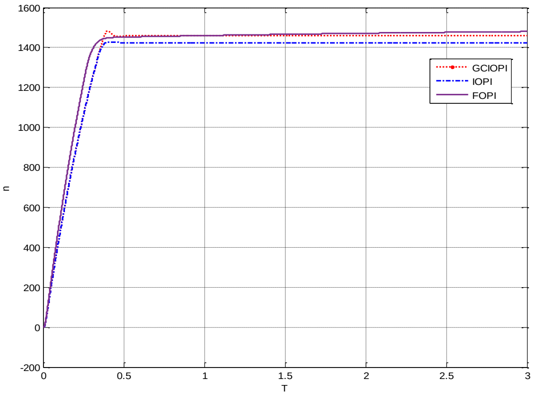


Fig.7 The response results of double closed-loop Fig.8 Results of three speed controller

5. Conclutions

The fractional order PI controller is a kind of new control algorithm, It is the continuation of the advantages of the integer order PI controller, and the control performance is improved. The fractional order PI controller applied to a DC double loop speed control system of the classical speed regulator in this paper, using fractional order controller PI lambda instead of integer order PI controller. The simulation results show that Application of FOPI controller, system step response rise time, settling time is shortened greatly, reduce the overshoot, than the integer order controller has more excellent control performance.

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