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Research on Artificial Intelligence Controller of DC Motor

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Abstract

This paper combines PID control and fuzzy control to control the DC motor. First of the DC motor PID control simulation, given the large range of parameters, the setting process numerous lock, so adopt the genetic algorithm of PID parameters, through the simulation, setting process greatly simplified, and then adopt fuzzy self-setting method to control DC motor, finally, various control scheme for simulation, the results of comparative analysis, shows that the fuzzy self-setting controller performance not only has good dynamic and static quality, and has strong anti-interference ability and parameter time-varying adaptability.adjust

Keywords

PID Control; Fuzzy Control; Fuzzy Self-setting PID Control.

1. Introduction

For the speed regulation of DC motor, the traditional PID control is often used, but when there are complex dynamics such as multivariable coupling, time-change, large time delay and strong interference, it is difficult for the traditional PID control to obtain the ideal control effect, and even produce instability. In addition, the adjustment of the traditional controller parameters or control output is based on the state analysis and synthesis of the process model described by a set of differential equations, and the setting process is complex and tedious[1], Based on this, this paper first simulates the PID control of DC motor, improves the parameters by using the PID setting based on genetic algorithm, and conducts simulation analysis. Then the fuzzy self-setting PID control is applied to the DC motor to compare the fuzzy controller with the traditional PID control system and verify the excellent control performance.

2. Mathematical Model of the DC Motor

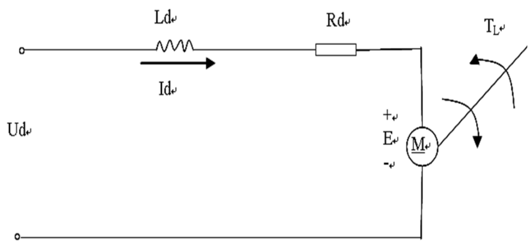

Figure 1. Equivalent control circuit of the DC motor

Although the structure of the DC motor is more complex than the AC motor and the production and operation cost is relatively high, it has the advantages of large starting torque and wide speed regulation range, and has certain applications in steel rolling machine, electric

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locomotive and other aspects. In the speed regulation system of DC motor, he excited DC motor is usually used as the control object. In this paper, he excited DC motor is used as an example to analyze the mathematical model of DC motor, and its equivalent control circuit is shown in Figure 1.

The input amount of the system is the motor armature voltage u_d, The output of the control system is x_cIs the rotational speed of the motor, n. According to the voltage law, the differential equation of the armature circuit can be obtained:

$$e_d + i_d R_d + L_d + L_d \frac{d_{id}}{d_t} = u_d$$

The reverse electromotive force generated by the motor is:, the dynamic equation of the motor: $e_d = c_e n$

$$c_e n + i_d R_d + L_d \frac{d_{id}}{d_t} = u_d$$

The second equation of the motor is the mechanical equation of motion, and the differential type of the ideal mechanical motion equation without a load is

$$M = \frac{GD^2}{375} \frac{dn}{dt}$$

i_d Eliminate the intermediate variable M, and get the mathematical model in the form of the excitation DC motor

$$\frac{L_d}{R_d} \frac{GD^2}{375} \frac{R_d}{C_m C_e} \frac{d^2 n}{dt^2} + \frac{GD^2}{375} \frac{R_d}{C_m C_e} \frac{dn}{dt} + n = \frac{u_d}{C_e}$$

$T_d T_m \frac{d^2 n}{dt^2} + T_m \frac{dn}{dt} + n = \frac{u_d}{C_e}$ Furthermore, it can be found that the mathematical model of his excitation type is obtained

$$W(S) = \frac{X_C}{X_r} = \frac{1/C_e}{T_d T_m S^2 + T_m S + 1}$$

3. DC Motor Controller Modeling

3.1. Simulated PID Control

The PID controller is a linear controller that constitutes a control deviation (error) according to the given value r (t) and the actual output value y (t), combining the proportion (P), integral (I) and differential (D) of the deviation to control the controlled object.

The control rule of PID is:

$$u(t) = Kp[error(t) + \frac{1}{T_I}\int_0^t error(t)dt + \frac{T_D derror(t)}{dt}]$$

Transfer function form:

$$G(s) = \frac{U(s)}{E(s)} = K_P[1 + \frac{1}{T_I s} T_D S]$$

3.2. The PID Setting based on the Genetic Algorithm

PID control is the most widely used control method in industrial control process, the optimization of PID controller parameters

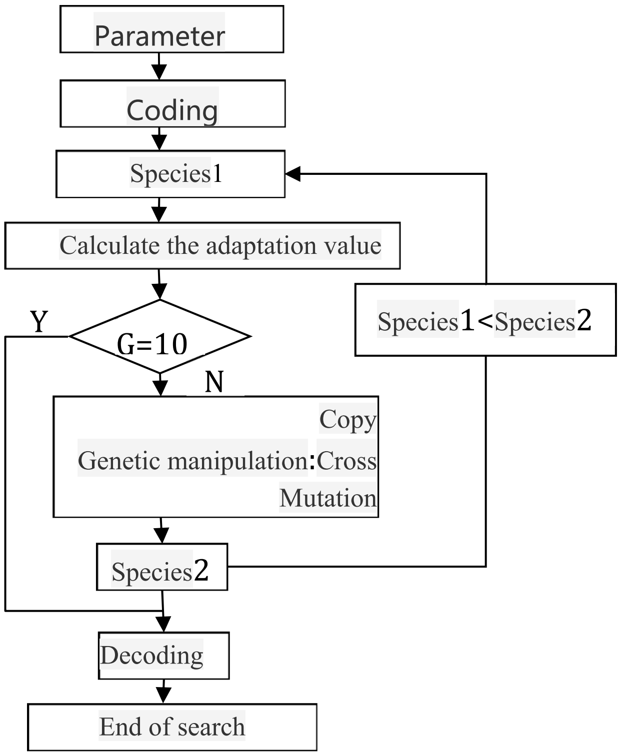

Figure 2. Flow chart of the genetic algorithm

There are many ways to optimize PID parameters that affect the control effect. Here, genetic algorithm is used to find optimization. This method does not need any initial information and can seek an efficient optimal combination of global optimal solutions.

The PID setting process based on the genetic algorithm is represented in Figure 2.

3.3. The PID Setting based on the Real-number Encoding Genetic Algorithm

To obtain the satisfactory transition process characteristics, the absolute value of error time integration performance index is used as the minimum objective function of parameter selection. To prevent excessive control energy, the square term of the control input is added to the objective function. The following equation is chosen as the optimal index for weight:

$$J=\int_0^{\infty}(W_1|e(t)|+W_2u^2(t))dt+W_3t_u$$

Where e (t) is the systematic error; u (t) is the output of the controller; t_uFor rise time; W_1,W_2,W_3For the weight.

In order to avoid overshoot, the penalty function is adopted. Once the overshoot is generated, the overshoot is taken as one of the optimal index, and the optimal index is:

$J=\int_0^{\infty}(W_1|e(t)|+W_2u^2(t)+W_4|ey(t)|)dt+W_3t_u$ Where, W_4>>W_1; ey (t) =y (t) -Y (t-1); y (t) is the output of the controlled object[2]

3.4. Fuzzy Self-setting PID Controller Modeling

The parameter self-setting method of fuzzy controller is to apply fuzzy set theory and method to achieve online self-setting and achieve the best adjustment[3], Its structure diagram is shown in Figure Figure 3.

Three parameters k are considered from the aspects of system stability, response speed, overshoot and steady-state accuracy$_p$,k_i,k_dThe setting of the PID parameters must consider the role of the three parameters and the interconnection between each other at different times.

be directed against k_p,k_i,k_dThe fuzzy control rules of the three parameters are shown in Tables 1,2 and 3.

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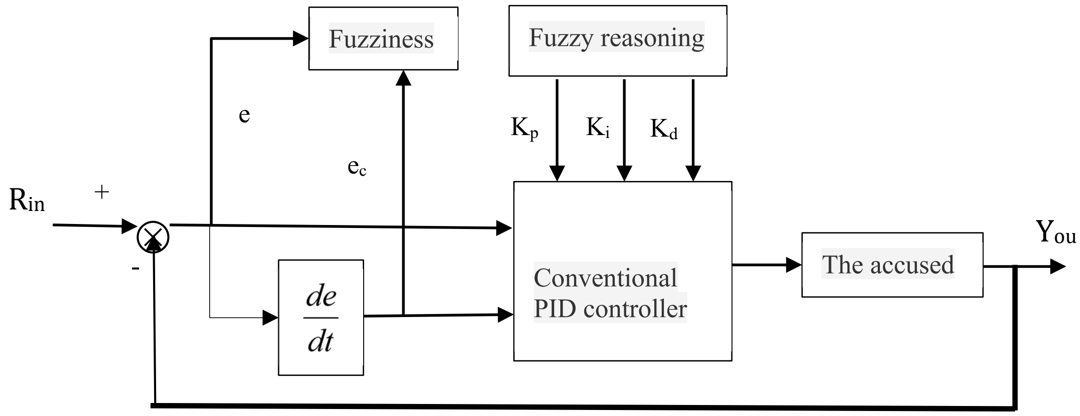

Figure 3. Self-setting fuzzy controller structure of PID parameters

Table 1. k_pOf The fuzzy control rule table

△k_p		e_c						
		NB	NM	NS	ZO	PS	PM	PB
e	NB	PB	PB	PB	PB	PB	PB	PB
	NM	—	PM	—	—	—	PM	—
	NS	—	—	PB	—	PB	—	—
	ZO	—	—	—	—	—	—	—
	PS	—	—	PB	—	PB	—	—
	PM	—	PB	—	—	—	PM	—
	PB	PB	PB	PB	PB	PB	PB	PB

Table 2. k_iOf The fuzzy control rule table

△k_i		e_c						
		NB	NM	NS	ZO	PS	PM	PB
e	NB	ZO	ZO	ZO	ZO	ZO	ZO	ZO
	NM	—	PS	—	—	—	PS	—
	NS	—	—	PB	—	PB	—	—
	ZO	—	—	—	—	—	—	—
	PS	—	—	PB	—	PB	—	—
	PM	—	ZO	—	—	—	PS	—
	PB	ZO	ZO	ZO	ZO	ZO	ZO	ZO

Table 3. k_dOf The fuzzy control rule table

△k_d		e_c						
		NB	NM	NS	ZO	PS	PM	PB
e	NB	PS	PS	PS	PS	PS	PS	PS
	NM	—	PM	—	—	—	PM	—
	NS	—	—	PM	—	PM	—	—
	ZO	—	—	—	—	—	—	—
	PS	—	—	PM	—	PM	—	—
	PM	—	PS	—	—	—	PS	—
	PB	PS	PS	PS	PS	PS	PS	PS

e, e_cThe membership function curve of is shown in Figure 4; k_p,k_i,k_dThe membership function curves of are shown in Figure 5.

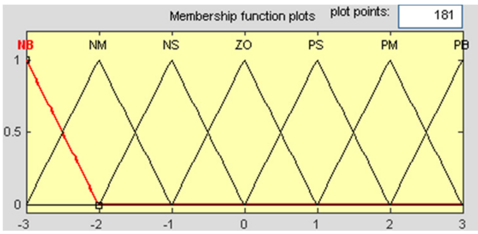

Figure 4. e and e_cThe membership function of

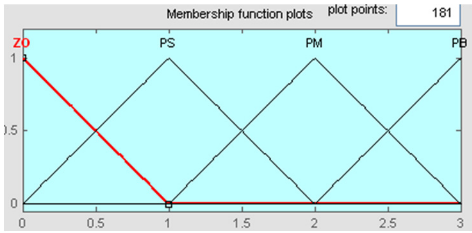

Figure 5. k_p, k_iAnd k_dThe membership function of

The control system was simulated using SIMULINK[4], Open the fuzzy logic controller for editing, and the fuzzy logic controller is shown in Figure 6.

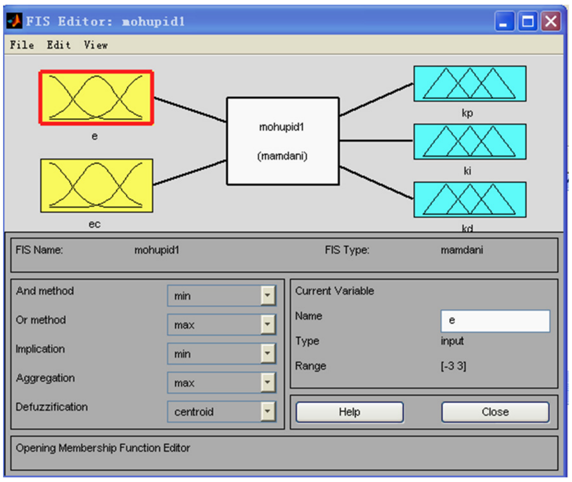

Figure 6. Fuzzy logic controller

k_p,k_d,k_iAfter the fuzzy control rule table, according to the fuzzy subset membership value table and the parameter fuzzy control model, the application of the PID correction fuzzy matrix table (executed in the program parameters) found out the correction parameters, online operation, the control system through the fuzzy logic rule result processing, check and operation, complete to correct the PID parameters online[5]

4. Simulation and Result Analysis of Various Controllers

Now the DC motor is the controlled object for control. Known parameters of the DC motor:

any power-generating or power-driven machine: P_{nom}=150kw; n_{nom}=1000r/min; I_{nom}=700A; R_a=0.05Ω. major loop:R_d=0.08Ω; L_d=2mH. Load and moment of inertia of the motor: GD^2= 125kg.m^2.

The relevant parameters of the DC motor are calculated as follows:

Electropotential constants: $C_e = \dfrac{u_{nom} - I_{nom} R_a}{n_{nom}} = 0.185V/(r \cdot \min^{-1})$

torque constant: $C_m = \dfrac{C_e}{0.03} = \dfrac{0.185}{0.03} = 0.18kg \cdot mA$

Electromagnetic time constant: $T_d = \dfrac{L_d}{R_d} = \dfrac{0.002}{0.08} = 0.025s$

electro mechanic time constant: $T_m = \frac{GD^2}{375}\frac{R_d}{C_m C_e} = \frac{125 \times 0.08}{375 \times 0.18 \times 0.182} = 0.8s$

Transfer function expression of the DC motor mathematical model obtained from the above parameters:

$$W(s) = \frac{X_C}{X_r} = \frac{1/C_e}{T_d T_m S^2 + T_m S + 1}$$

$$= \frac{1/0.185}{375 \times 0.8S^2 + 0.8S + 1} = \frac{270.5}{s^2 + 40s + 50}$$

Simulations were performed at Simulink, taking the r_{in}=1000,

4.1. Simulated PID Control Model and Simulation Waveform

The simulation model for the simulated PID control is shown in Figure 7.

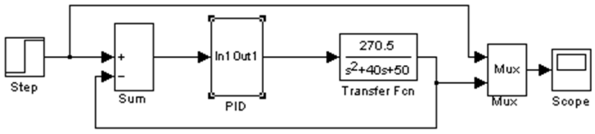

Figure 7. Simulation model for simulating PID control

The PID controller is a subsystem and packaged, and its internal structure is shown in Figure 8.

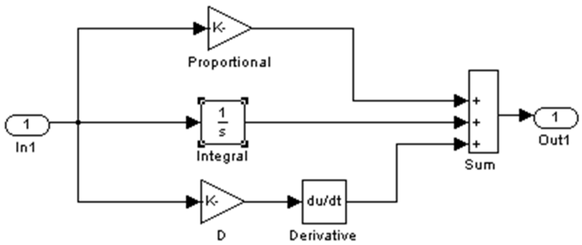

Figure 8. A simulated PID controller

The simulation results are shown in Figure Figure 9.

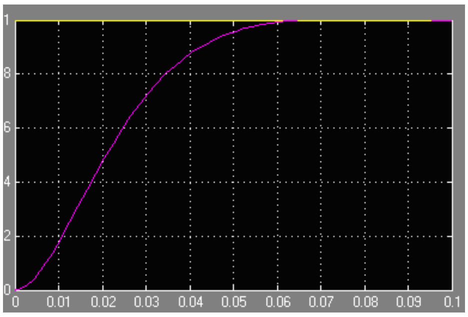

Figure 9. Simulates the response curve of PID control order

The parameter range of the above traditional PID controller changes greatly, so it is necessary to control the results, and the setting method is very complicated.

4.2. PID Setting Modeling and Simulation based on Real Number Encoding Genetic Algorithm

The above DC motor model is still taken as the object, and the real number encoding genetic algorithm is used for control. The number of samples used in the genetic algorithm is 30, and the crossover probability and variation probability are respectively: P_C=0.9,P_m=0.033. parameter k_pOf values of [0,20], k_d,k_iThe range of value is [0,20], take W_1=0.999, W_2=0.001, W_3=2, W_4=100, using real coding, after 100 generations of evolution, the optimization parameters are as follows:

K_p=18.889 K_d=0.2862 K_i=0.8201 J=29.0109

The rectified PID control step response is shown in Figure 10. When G=200, the step response curve is shown in Figure 11; when G=800, the response curve is shown in Figure 12. Comparing several simulation results, it is not obvious that the more the evolutionary generations, the better the optimization effect.

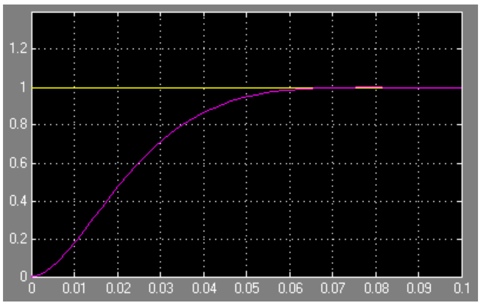

Figure 10. GA setting PID control step response curve (G=100)

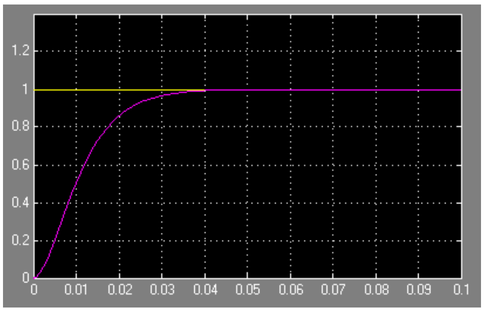

Figure 11. GA setting PID control step response curve (G=200)

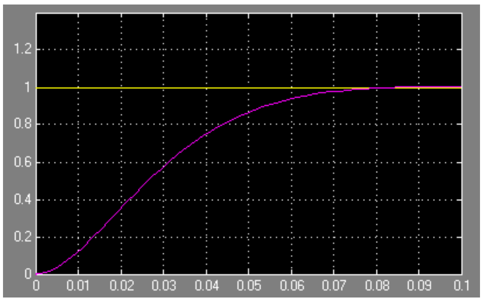

Figure 12. PID (G=800)

4.3. Simulation of the Fuzzy Self-setting PID Controller

By compiling the PID parameter auto-setting fuzzy controller, the mathematical model of the motor is:

$$W(s) = \frac{1}{s^3 + 3s^2 + 2s}$$

Simulsimulation with S imulink to compare the fuzzy self-setting controller with the PID controller, and the simulation model is shown in Figure 13.

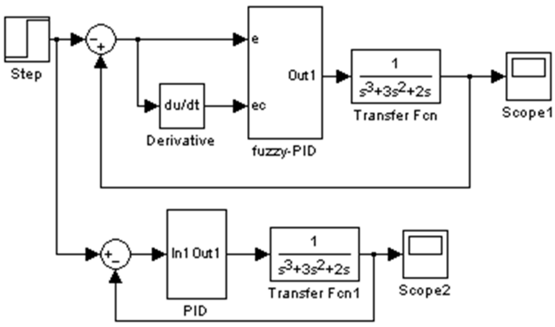

Figure 13. PID parameter self-setting fuzzy controller and PID controller model

The fuzzy self-setting controller adopts the package structure, and the structure diagram is shown in Figure 14.

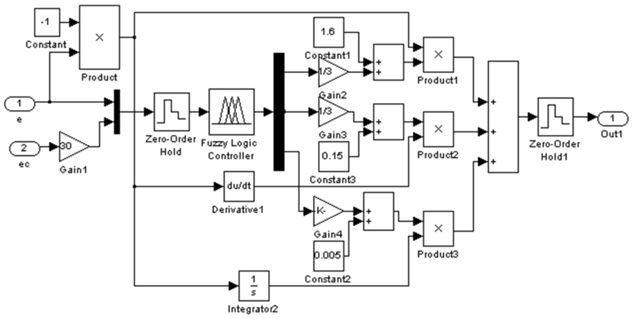

Figure 14. Simulation model of fuzzy self-setting controller

The PID controller is subsystems and the simulation results are shown in Figure 15 and the fuzzy self-setting PID controller are shown in Figure 16.

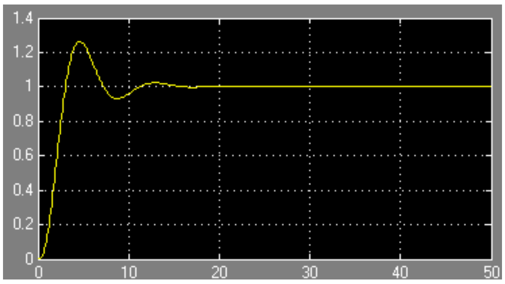

Figure 15. PID control order more response curve

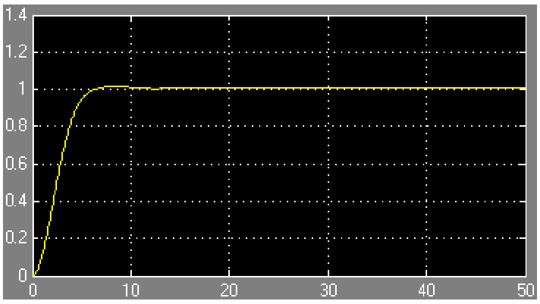

Figure 16. fuzzy self-setting PID control order more response curve

It can be seen that the fuzzy self-setting PID controller has good performance and fast response. It not only has good dynamic and static quality, but also has strong anti-interference ability and time-varying adaptability of parameters.

5. Summary

This paper simulates the traditional PID control of DC motor, by adjusting the PID parameters, obtain the expected control effect, but due to the parameter range setting process numerous lock, so take the PID setting based on the genetic algorithm to improve, through the simulation, the control process is greatly simplified, finally using fuzzy self-setting PID control, the simulation results show that the controller performance is better, not only has good dynamic and static quality, and has a strong anti-interference ability and parameters.

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