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Matlab/Simulink Based Modeling and Simulation of Fuzzy PI Control for PMSM

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Abstract.

According to the disadvantages of PID control, this paper aims at applying fuzzy control in FOC control of PMSM. The controller automatically adjusts the two parameters of the PI controller based on changes in e and ec. The simulation result shows that more dynamic and steady-state can be obtained by using fuzzy PI control.

Keywords: PI control, fuzzy control, FOC, PMSM

1 Introduction

High precision servo control system not only has fast response, but also requires strong robustness under external disturbance. When the motor is subjected to change or disturbance of motor parameters, traditional PI control can not fundamentally solve the contradiction between dynamic and static performance and meet the fast tracking requirements of servo system [1].

Therefore, in order to make up the disadvantages of PI control. In this paper, fuzzy control is applied in control of PMSM by adjusting PI control parameters, and the simulation of the system is established in Simulink. The result shows dynamic of the system which uses fuzzy PI control is improved.

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2 FOC of PMSM

2.1 PMSM Control

According to the theory of FOC, and the hysteresis loss of permanent magnet synchronous motor is neglected, the voltage flux equations in D-q coordinate system which are based on the principle of power invariance, are obtained respectively as follows[2-3].

$$u_d = R_s i_s + L_d \frac{di_d}{dt} - w_e L_q i_q \tag{1}$$

$$u_q = R_s i_q + L_q \frac{di_q}{dt} + w_e (L_d i_d + \varphi_f) \tag{2}$$

$$T_e = 1.5p[i_d \left(L_d - L_q\right) + i_q \varphi_f] \tag{3}$$

u_d (u_q) is the d(q)-axis components of stator voltage. R_s is the resistance of three-phase winding. i_s is the current of stator three-phase winding. i_d (i_q) is the current of d(q)-axis components. L_d (L_q) is the d(q)-axis components of inductance. w_e is the electric angular velocity. φ_f is the flux of permanent magnet. p is the pole-pair numbers of motor.

When $i_d = 0$, there is a linear relationship between T_e and i_q, and PMSM can be equivalent to the model of the excited DC motor.

2.2 FOC Model

By decoupling the torque generation and magnetization function in an AC induction motor, FOC makes the torque producing components of the stator flux controlled independently, and this property leads to the widely usage of FOC in high performance motor applications[4-5].

As shown in Fig.1, in this paper, the FOC system is consisted of speed loop(outside loop), 2 current loops(inside loop) and SVPWM.

In this system, current loop is using the traditional control. Meanwhile, speed loop is using the fuzzy control aimed at improving speed of response and correcting the influence of motor parameter error. Besides, SVPWM is used for the synthesis of space voltage vector, it can reduce switching frequency and improve speed regulation performance compared with conventional PWM.

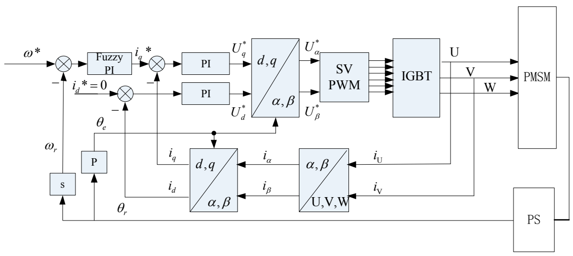


Figure.1 FOC Schematic

3 Fuzzy PI Control

3.1 Fuzzy Control Foundation

Because of disadvantages of traditional PI control, it can't modify PI parameters online, but fuzzy control can improve the performance of the control system. In this paper, e (the speed error) and ec (rate of error) is set as the input parameters, Schematic of fuzzy control is shown in Fig.2 .

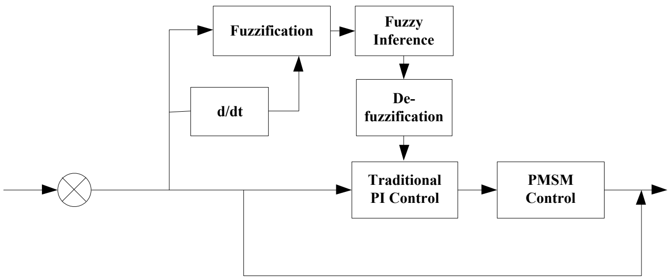


Figure.2 Schematic of Fuzzy Control

3.2 The Design of Fuzzy Control

Due to actual value range of e and ec, the quantitative level of e, ec, Δk_p (output parameters) and Δk_i (output parameters) are {-3,-2,-1,0,1,2,3}. The fuzzy subset is set as {3N,2N,1N,0Z,1P,2P,3P } (in ascending order), in addition, each input and output follows the triangle subjection function[6].

Comprehensive consideration of system stability and response speed, the fuzzy rulers are set as follows[6].

(1)When e is at the high quantitative level, k_p are added and k_i maintain the same for fear of the overshoot of the system.

(2)When e is at the medium quantitative level, it depends on ec, when $ec \bullet e < 0$, k_p and k_i should reduce because the control is changing in the direction of the given value, when $ec \bullet e < 0$, k_p and k_i should be added because the control is deviating from the given value.

(3)When e is at the low quantitative level, k_p can be reduced slighting and k_i should be set as the highest quantitative level.

Due to the fuzzy rulers above, the fuzzy control ruler of Δk_p and Δk_i can be got, as shown in Table.1 and Table.2.

Finally, the output depends on centroid method which is used in defuzzification.

Table.1 The Rulers of Δk_p

e \ ec	3N	2N	1N	0Z	1P	2P	3P
3N	3P	3P	2P	2P	1P	0Z	0Z
2N	3P	3P	2P	1P	1P	0Z	1N
1N	2P	2P	2P	1P	0Z	1N	1N
0Z	2P	2P	1P	0Z	1N	2N	2N
1P	1P	1P	0Z	1N	2N	2N	2N
2P	1P	0Z	1N	2N	2N	2N	3N
3P	0Z	0Z	2N	2N	2N	3N	3N

e ec Table.2 The Rulers of Δk_i

	3N	2N	1N	0Z	1P	2P	3P
3N	3N	3N	2N	2N	1N	0Z	0Z
2N	3N	3N	2N	1N	1N	0Z	0Z
1N	3N	2N	1N	1N	0Z	1P	1P
0Z	2N	2N	1N	0Z	1P	2P	2P
1P	2N	1N	0Z	1P	1P	2P	3P
2P	0Z	0Z	1P	1P	2P	3P	3P
3P	0Z	0Z	1P	2P	2P	3P	3P

Based on the above analysis, the control model is set up by Simulink. Fuzzy control structure is shown in Fig.3 and System model is shown in Fig.4.

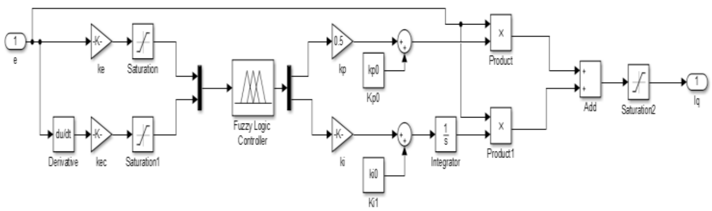


Figure 3 Fuzzy Control Structure

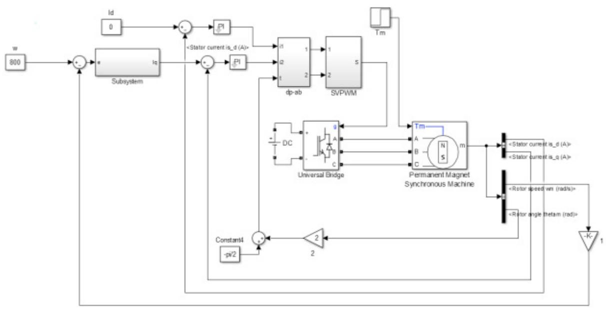


Figure.4 System Simulink Model

4 Analysis

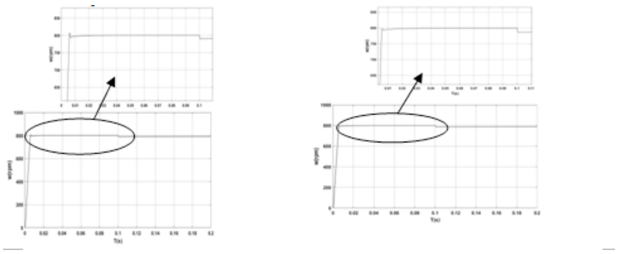
The parameters of PMSM are set as shown in Tab.3.

Table.3 The Parameters of PMSM

Parameter	Value	Parameter	Value
R_s	0.458 Ω	L_d / L_q	0.00334H
φ_f	0.171WB	p	4
J	0.001469kgm^2		

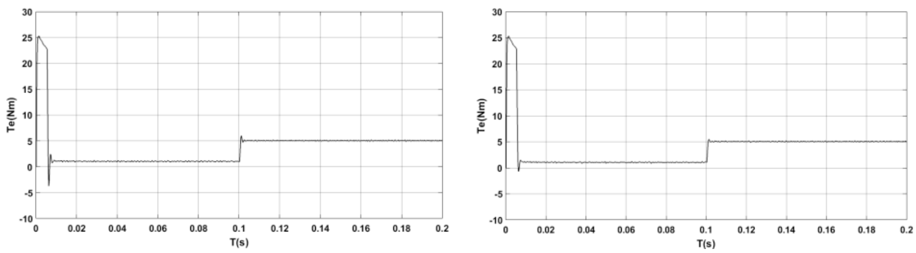
The simulation conditions are set as that the PMMS is set as running at 800 rpm without load at the beginning and at 0.1s, the 5Nm load puts on the PMSM, then the speed of motor (w) and the torque of motor (T_e) are chosen as the observed variable.

As Fig5 and Fig6 shows, when PMSM runs with impact load, the fuzzy control has the shorter adjustment time and more steady performance compared with traditional ways. The result of simulation proves fuzzy control makes system has a better traceability and robustness.



(a)Traditional Control (b)Fuzzy Control

Figure 5 Simulation results（ w ）



(a)Traditional Contro l(b)Fuzzy Control

Figure 6 Simulation results (T_e)

5 Acknowledgments

In this paper, fuzzy PI control is proposed for PMSM control, and experiment which uses the simulation models are carried out. The result indicates that fuzzy control improves steady-state performance and dynamic property of PMSM control.

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