Fuzzy Adaptive PID Strategy for Asynchronous Machines Direct Torque Control

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Abstract. In order to tackle the issues of serious torque and flux ripple in Motor direct torque control, an amendatory direct torque control method based on Fuzzy Adaptive PID Controller is presented in this paper. This method can reduce the torque and flux ripple in static run and enhance the performance of low speed. The simulation experimental results indicate that this method is feasible and robust.

Keywords: Asynchronous machine, fuzzy adaptive PID controller, direct torque control.

1 Introduction

Direct torque control method (DTC) is new style control policy in alternating current drive field after vector control method. DTC methods don't need complicated coupling computation and multifarious coordinate commutation. DTC method controls directly motor torque in stator coordinate, and produces PWM signal by discrete deuce control (Bang-bang control). Torque dynamic response of DTC system is rapid and not excessively been adjusted. Because Asynchronous Machine is often used in sudden and accurate location control, velocity loop of servo system should have good low-speed performance. Velocity loop has good dynamic response performance and brief structure based on direct torque control methods. However, torque fluctuation of DTC system is serious because of discrete deuce control in motor flux and adjusted torque. Electromagnetic torque, stator flux and current fluctuation seriously affects the performance of whole system when alternating servo mechanism is running in low rotary speed [1].

As a popular control strategy, PID controller is widely used in industry field. The control object of PID strategy is known, but the control object of fuzzy strategy is unknown. Fuzzy strategy reflects human wisdom and is easily established. The control object of adaptive strategy include known and unknown target. Its control parameter can automaticly be adjusted to exterior, itself parameter and exterior disturbance change. The effect of the error

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of model can be overcomed by adaptive control strategy and Asynchronous Machine runs in optimization condition in some degree.

Asynchronous Machine mathematics model is established and fuzzy adaptive nerve network control method is introduced in Asynchronous Machine DTC method in this paper. The basic rule, condition and method of fuzzy adaptive nerve network control are stored in computer memory, and parameters based on fuzzy rule are operated and adjusted for actual response. Network study velocity can be quickened and local dinky value can be avoided, fluctuates of torque, stator flux and current can be reduced and non-linear of Asynchronous Machine is finally compensated by fuzzy adaptive nerve network control method.

2 Asynchronous Machine DTC Control Method

Under $d-q$ coordinate, Asynchronous Machine stator flux equation is:

$$\begin{cases} u_{sd} = R_s i_{sd} + \frac{d}{dt}\psi_s \\ u_{sq} = R_s i_{sq} + \omega_{\psi s}\psi_s \end{cases} \tag{1}$$

u_{sd} and u_{sq} are d and q coordinate stator voltage heft, R_s is stator resistance, i_s is stator current vector heft, $\omega_{\psi s}$ is rotor angle frequency of stator flux vector.

Electromagnetic torque of Asynchronous Machine is gained:

$$T_{ei} = \frac{3}{2}\frac{p}{R_s}\psi_s\left(u_{sq} - \omega_{\psi s}\psi_s\right) \tag{2}$$

p is pole of Asynchronous Machine, ψ_s is rotor flux' coupling flux on stator. The control effect of electromagnetic torque of Asynchronous Machine is realized by the change of stator voltage vector.

3 Fuzzy Adaptive PID Control

As the input signal of fuzzy adaptive PID controller, error e and error change ec are adjusted based on fuzzy control rule in order to satisfy the demand of different time parameter.

In PID adaptive rule, the relation of between the control parameter(include k_p, k_i and k_d) e and ec should be found, then e and ec are tested and adjusted constantly. Therefore the control object has well dynamic and static performance.

The Fig.1 is the theory of fuzzy adaptive PID controller. The Fig.2 is flow chart of the theory.

The following is the error range of fuzzy adaptive PID control system.

e, ec={ -5,-4,-3,-2,-1,0,1,2,3,4,5 }.

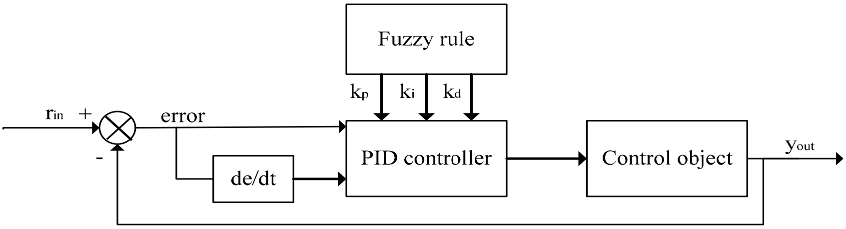

Fig. 1. Fuzzy adaptive PID controller

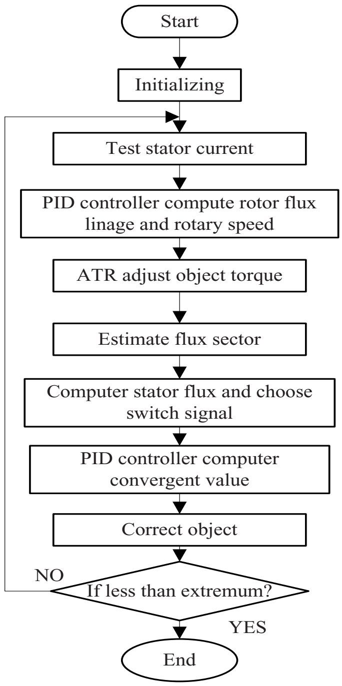

Fig. 2. Flow chart of DTC system based on fuzzy adaptive PID controller

e is fuzzy subset, ec={NB,NM,NS,ZO,PS,PM,PB}. e, ec, k_p, k_i and k_d are normal school and found by subject degree. PID fuzzy parameter matrix is computed based on subprogram subject degree value and parameter control model, the correctional result should looked up and computed unceasingly.

$$\begin{cases} k_p = k_p' + \{e_i, ec_i\}_p \\ k_i = k_i' + \{e_i, ec_i\}_i \\ k_d = k_d' + \{e_i, ec_i\}_d \end{cases} \tag{3}$$

4 Analysis of Simulation Result

In this simulation of Asynchronous Machine model, the power is 4kW, voltage is 380V, frequency is 50Hz, rotary speed is 1430r/min, stator resistance is 1.395 ohm, inductance coefficient is 0.1722H, moment of inertia is $0.0131 kg.m^2$, friction coefficient is 0.002985, pole is 2, simulation track torque signal periods is 40kHz, output torque is 12N.m.

The simulation results of the controlled track of referenced torque from Fig.3 to Fig. 6 are rectangular. From these results, the torque response and rotor rotary speed of fuzzy adaptive PID mended DTC system is rapid and smooth, and the parameter of system can been adjusted automatically. The result of torque track indicate the merit of DTC control system. The whole trail error of fuzzy adaptive PID mended DTC system can be controlled in little range, then the dynamic respond error is almost ignored. The robust and adaptive performance is ideal. The structure of fuzzy adaptive PID mended DTC system is very simply and can be used in widely field.

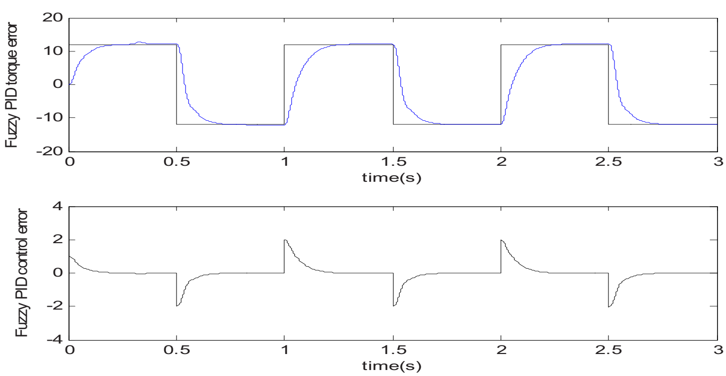

Fig. 3. Torque input skip response and error of Adaptive fuzzy control

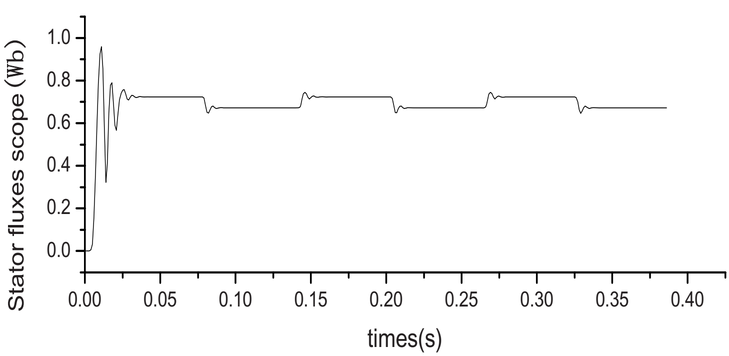

Fig. 4. The stator fluxes scope of asynchronous machine

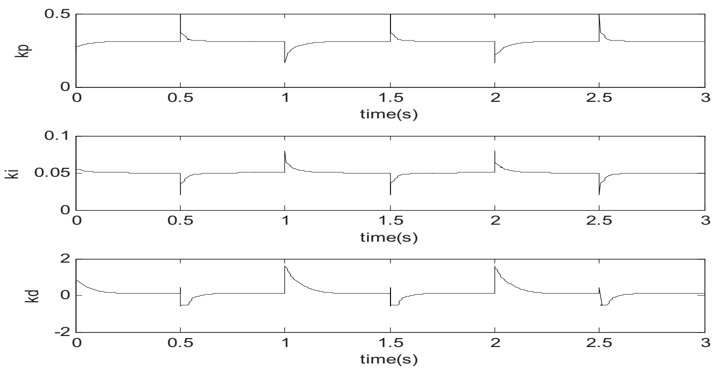

Fig. 5. Adaptive adjust change of k_p k_i k_d

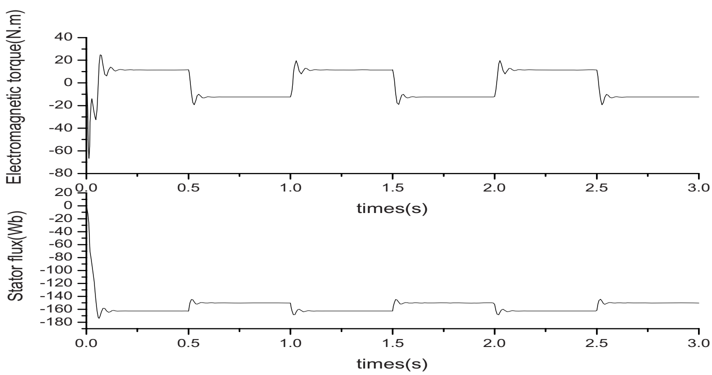

Fig. 6. The stator fluxes scope and rotor rotate speed of asynchronous machine

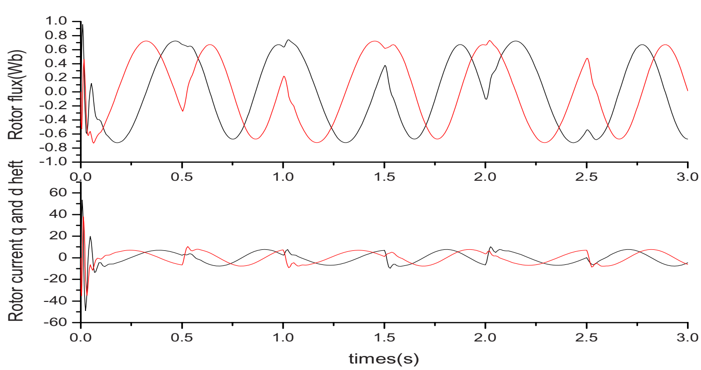

Fig. 7. The rotor flux and rotor current q and d heft of asynchronous machine

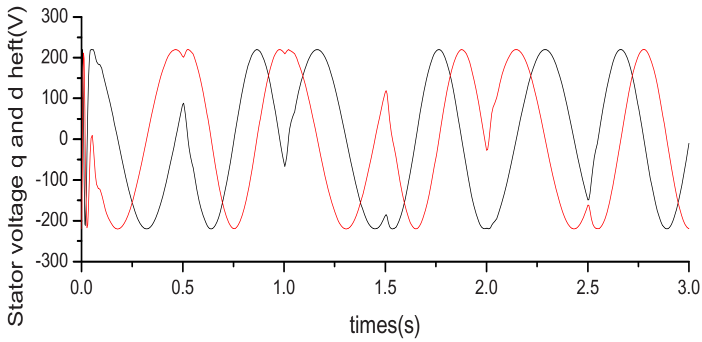

Fig. 8. Stator voltage q and d heft of asynchronous machine

From the result of Fig. 6 to Fig. 8, it can be seen that instantaneous track jump error of fuzzy adaptive PID mended DTC system exceeded 10 percent in enough train time. The track error of fuzzy adaptive PID mended DTC system can be controlled under 1 percent in other phase. The track result is accord with target function and the computation precision is very high. Compared with traditional DTC control system, the excessive rectangular torque track result of fuzzy adaptive PID mended DTC system is limited. The fluctuant response of fuzzy adaptive PID mended DTC system is also little. From the analysis of DTC control theory, the fluctuant response of torque should affect seriously the stator current and flux when motor is running in low-speed. Those seriously disturbed the effect of DTC control system. Therefore, the veracity of fuzzy adaptive PID mended DTC system is promoted greatly. Therefore, RBF mended DTC control system can improved the system precision and has good robust and adaptive characteristic.

5 Conclusions

In order to reduce torque fluctuation problem of Asynchronous Machine DTC method, fuzzy adaptive nerve network control method is introduced in Asynchronous Machine DTC control method in this paper. This method can tentatively adjust fuzzy adaptive nerve network parameter in real time after considering the effect of motor stator flux and rotary speed. This method can reduce the fluctuation of torque, flux and current.

The simulation result indicate that fuzzy adaptive PID mended DTC system can reduce the track error and promote the system precision. This method can quicken the speed of computation, convergence and response, and has good robust characteristics for random disturber.

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