http://ansinet.com/itj

ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet

Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 9 (7): 1495-1499, 2010
ISSN 1812-5638

Fuzzy Logic based Current Control Schemes for Vector-controlled Asynchronous Motor Drives

[1]Gan Jia-Liang, [2]Zhang Hong-Xia and [2]Zhao Jin
[1]Xiaogan University, Xiaogan, People's Republic of China
[2]Huazhong University of Science and Technology, Wuhan, People's Republic of China

Abstract: In this study, a kind of two-dimensional fuzzy PID controller is designed acted as current regulator of SVPWM asynchronous motor vector-controlled drives for the sake of improving the dynamic and steady state performance of current control of this type of system. Two kind of control schemes are proposed here according to the different requirements for current response performance of d and q axis in vector control. One kind is that a fuzzy PID controller is applied to the q-axis current loop and a conventional PI controller is applied to d-axis current loop. The other one is that a fuzzy PID controller is applied to the q-axis current loop and a conventional PI controller is applied to d-axis current loop. The simulation results show that the current regulator with fuzzy PID controller possesses better dynamic and steady state performance compared to counterpart of general PI controller.

Key words: Current control, asynchronous motor, fuzzy control, proportional integral controller

INTRODUCTION

There are generally two ways of stator current control for the SVPWM asynchronous motor vector control drives (Bose, 2002). One is to acquire the transient stator current reference by ways of vector transformation. Three current controllers are applied for a closed loop control of the three phase alternating current, in this condition, current control is conducted in three phase rest frame. The other way is to conduct current control in synchronous rotated frame of axes. The current loops included d-axis and q-axis current loops. The d-axis stator current i_d and q-axis stator current i_q are regulated respectively. Currently, the conventional PI controllers are generally used to regulate the d-axis and q-axis currents. The main problem is the prominent contradictory between the overshoot and the rapidity. The practical d-axis current i_d is easily affected by q-axis current i_q and does not have strong anti-disturbance ability.

In this study, a kind of fuzzy PID current controller based on fuzzy logic is designed to implement on-line self-adjusting of the parameters Kp, Ki and Kd of the conventional PID controllers. In order to enhance the anti-disturbance ability of the d-axis current loop, here a kind of fuzzy PID current controller is applied to d-axis current and a conventional PI controller is applied to q-axis current. In order to improve the dynamic and steady state performance of q-axis current, a fuzzy PID current controller is applied to q-axis current loop and a conventional PI controller is applied to d-axis current loop. The simulation results shown in the following part demonstrate that the two schemes taken here are satisfied with expected goals and can achieve better control performance of the current loops.

VECTOR-CONTROLLED MODEL OF INDUCTION MOTOR

In d-q synchronous rotary coordinate, if we assume stator currents and rotor fluxes as state variables, then the relationship between stator currents and rotor flux leakages of 3-phase induction motor in the synchronous rotating d-q reference frame can be expressed as follows:

$$\begin{aligned}\frac{d}{dt}i_d &= -\left(\frac{R_s}{L_\delta}+\frac{R_r L_m^2}{L_r^2 L_\delta}\right)i_d + w_e i_q + \frac{R_r L_m}{L_r^2 L_\delta}\psi_{dr} + w_r\frac{L_m}{L_r L_\delta}\psi_{qr} + \frac{1}{L_\delta}v_d \\ \frac{d}{dt}i_q &= -\left(\frac{R_s}{L_\delta}+\frac{R_r L_m^2}{L_r^2 L_\delta}\right)i_q - w_e i_d + \frac{R_r L_m}{L_r^2 L_\delta}\psi_{qr} - w_r\frac{L_m}{L_r L_\delta}\psi_{dr} + \frac{1}{L_\delta}v_d\end{aligned} \quad (1)$$

$$\begin{aligned}\frac{d}{dt}\psi_{dr} &= -\frac{R_r}{L_r}\psi_{dr} + \frac{R_r L_m}{L_r}i_{ds} + w_s\psi_{qr}, \\ \frac{d}{dt}\psi_{qr} &= -\frac{R_r}{L_r}\psi_{qr} + \frac{R_r L_m}{L_r}i_{qs} - w_s\psi_{dr},\end{aligned} \quad (2)$$

where, i_d, i_q are the d-axis and q-axis stator currents respectively, v_d, v_q are the d-axis and q-axis stator voltages, ψ_{dr}, ψ_{qr} are the d-axis and q-axis rotor flux leakages, R_s, R_r are the stator and rotator resistances respectively, L_s, L_r, L_m are the stator inductance, the

Corresponding Author: Zhao Jin, Huazhong University of Science and Technology, Wuhan, People's Republic of China

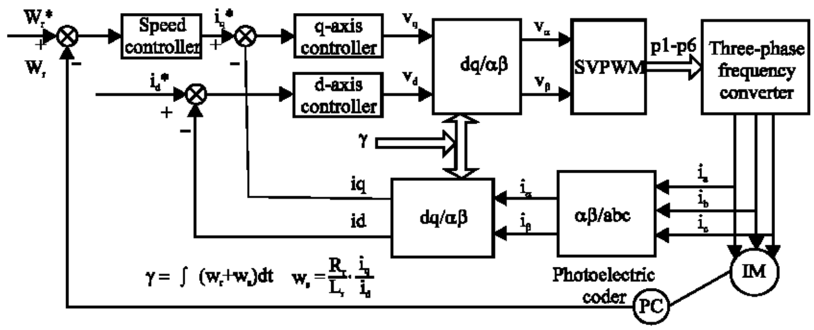

Fig. 1: The structure of vector control regulating speed system of induction motor

rotator inductance and the mutual inductance, w_e, w_r, w_s are the synchronous angular velocity, the rotor angular velocity and the slip angular velocity, moreover, L_δ, w_s are respectively defined as $L_\delta = L_s - L_m^2/L_r$, $w_s = w_e - w_r$.

In addition, the torque equation is described as $Te = k_r(\psi_{dr} i_q - \psi_{dr} i_d)$, in which the torque constant is defined as:

$$k_r = \frac{3}{2}\cdot\frac{p}{2}\cdot\frac{L_m}{L_r}$$

The vector-controlled method of induction motor is conducted by projecting the rotator flux vector which has a synchronous rotation speed onto the direction of d-axis, when the q-axis flux linkage $\psi_{dr} = 0$ and according to the equation $\psi_{dr} = L_r i_{dr} + L_m i_d$ and the Eq. 1 we can derive two equations as follows:

$$\begin{aligned} \frac{d}{dt} i_d &= -\frac{R_s}{L_\delta} i_d + w_e i_q + \frac{R_r L_m}{L_r L_\delta} i_{dr} + \frac{1}{L_\delta} v_d, \\ \frac{d}{dt} i_q &= -\left(\frac{R_s}{L_\delta} + \frac{R_r L_m^2}{L_r^2 L_\delta}\right) i_q - w_e i_d - w_r \frac{L_m^2}{L_r L_\delta} i_d + \frac{1}{L_\delta} v_q - \frac{L_m}{L_\delta} w_r i_{dr}, \end{aligned} \quad (3)$$

where, i_d, i_q denote d-axis and q-axis rotator currents respectively, here, the torque can be described as $Te = k_r \psi_{dr} i_q$.

Hence, the structure of vector control tunning system of induction motor is shown in Fig. 1 (Shengjie and Chunjuan, 2004). It can be seen from Fig. 1 that the practical three-phase stator currents are converted to two-phase currents in d-q reference frame, then d-axis and q-axis currents are compared to the reference values respectively, error values are acquired. The error values are acted as the input values of the two current controllers respectively, the two-phase stator voltages in d-q reference frame are the outputs of the two current controllers. Obviously, the current controllers are acted as the inner loops of the AC regulating speed system.

DESIGN OF FUZZY PID CURRENT CONTROLLER

Based on conventional PID controller, fuzzy inference theory is applied to implement on-line self-adjusting of

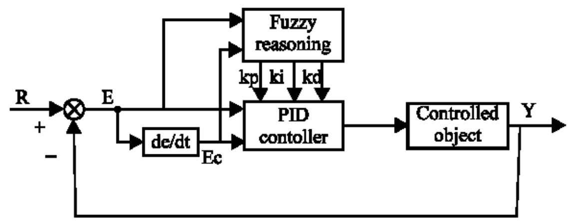

Fig. 2: The structure of the control system with the proposed fuzzy PID controller

PID parameters according to different error E and error change rate Ec. Here a fuzzy PID controller with two inputs and three outputs is designed ,namely ,using error E and error change rate Ec as the inputs and the three parameters Kp (proportion factor), Ki (integration factor) and Kd (differential factor) of PID controllers as outputs. The basic structure of the fuzzy self-adjusting system is shown in Fig. 2.

In the PID controller, let us take the effects of the three parameters Kp, Ki and Kd on the system performance into consideration: Kp is used to accelerate the response speed of the system so as to improve the adjusting precision, but too big Kp will result in the instability of the system; Ki is used to eliminate the steady-state error of the system; Kd is used to improve the dynamic performance of the system. For the different error absolute value |E| and the error change rate absolute value |Ec|, the general rules used for adjusting the parameters Kp, Ki and Kd are as follows (Jinkun, 2003):

- When |E| is relatively bigger, Kp should be relatively bigger and Ki should be relatively smaller to speedup the system response and to avoid resulting in bigger overshoot, certain limit should be placed on integration factor, Ki is usually set to be 0
- When |E| is medium, smaller Kp is applied to make system response reach a smaller overshoot. Ki should be proper and Kd has a great effect on the system response

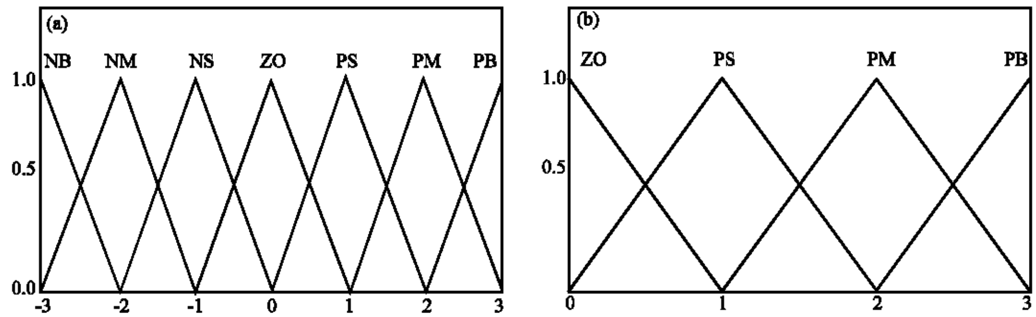

Fig. 3: Membership function distribution curves. (a) Membership function curve of E and Ec and (b) Membership function curve of Kp, Ki and Kd

- When |E| is smaller, Kp and Ki should be bigger so as to achieve a better steady performance of the system.Meanwhile to avoid resulting in oscillation in vicinity of set value, the selection of Kd is in term of Ec: When |Ec| is smaller, Kd should be bigger. When |Ec| is larger, Kd should be smaller, generally Kd should be medium

According to the above rules, we can find out the fuzzy relationship between the parameters Kp, Ki and Kd of the PID controller and the error absolute value |E| and the error change rate |Ec|, then by checking the real changes of |E| and |Ec| to adjust the three parameters Kp, Ki and Kd on-line according to the fuzzy control rules, hence to achieve a good dynamic and steady state performance of the control system.

Assuming the fuzzy subset of the input variables E and Ec as {NB, NM, NS, ZO, PS, PM, PB} and the error absolute value |E| and the absolute value of the change rate in the error |Ec| to an interval of {-3, 3}. In the same way, assuming the fuzzy subset of outputs Kp, Ki and Kd as {ZO, PS, PM, PB} and quantifying Kp, Ki and Kd to an interval of {0, 3}. The membership function curves of the input and output variables are shown in Fig. 3a and b.

SYSTEM SIMULATION BASED ON FUZZY SELF-ADJUSTING PID CURRENT CONTROLLER

In order to verify the control performance of the fuzzy PID current controller, we set up a vector-controlled SVPWM speed regulating system of asynchronous motor with fuzzy self-adjusting PID current controller under MATLAB environment. Using 5.5KW two amtipodal asynchronous machine as the controlled objective, the basic parameters of induction machine are as follows: I_n = 13A, R_s = 0.813Ω, R_r = 0.531Ω, L_s = 106.26 mh, L_r = 108.75mh, L_m= 102.4 mh, J = 0.02 kg m^2.

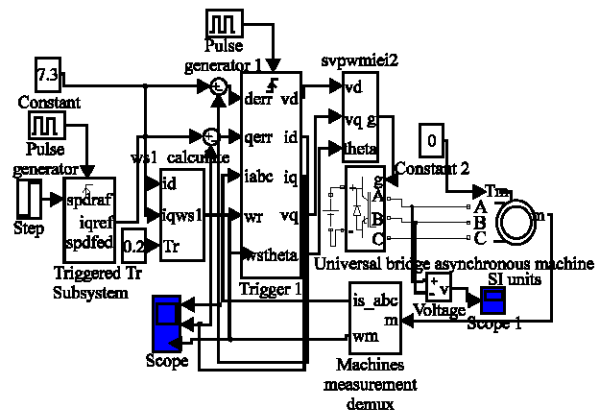

Fig. 4: The SIMULINK simulation model

Figure 4 is the SIMULINK simulation model of SVPWM asynchronous machine speed regulating system, the DC voltage of the power inverter is 540 V, the given value of i_d is 7.3 A and the sampling time of speed loop is 1 msec and the sampling time of the current loops is 50 μsec.

In order to make comparisons conveniently, based on parameter-optimized rules, two conventional PI controllers are designed for the current loops. The optimum parameters got here are Kp = 62 and Ki = 7750. The simulation results of the d-axis and q-axis current loops with two conventional PI controllers are as follows: The variation range of id affected by the change of iq is [6.1, 8.17]; The rising time of iq is 700 μsec and the biggest overshoot is 5.3%.

Two control schemes are proposed here according to different control requirements for the d –axis and q-axis current loops.

Scheme 1: A fuzzy PID controller is applied to the q-axis current loop and a conventional PI controller is applied to d-axis current loop.

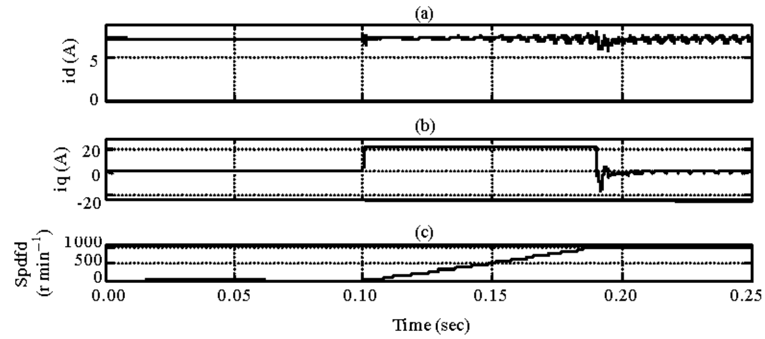

Fig. 5: Response curves of (a) id, (b) iq and (c) speed (spdfd)

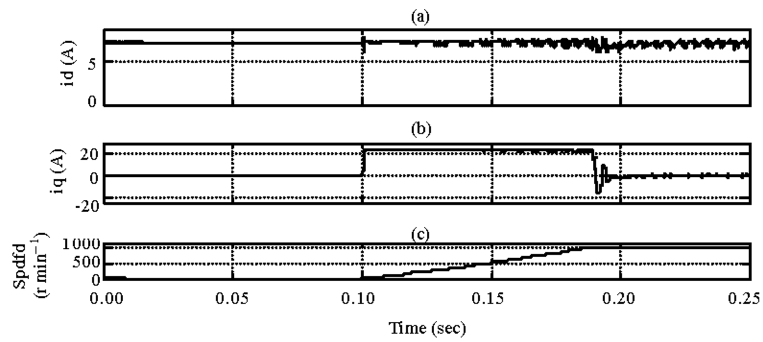

Fig. 6: Response curve of (a) id, (b) iq and (c) speed (spdfd)

Here, investigating rapidity and overshoot of iq response. The given value of speed rises from zero at a speed of 1000 r min^{-1} in step-change mode at 0.1 sec, corresponding response curves of current and speed are shown in Fig. 5a-c. From iq response curve shows that rise time is 600us and the biggest overshoot is 3.5%. Under the same condition, the counterparts taken PI controller are 700 μsec and 5.3%. Obviously, i_q using fuzzy PID controller can achieve better rapidity and lower overshoot compared to the counterparts using conventional PI controller.

Scheme 2: Applied fuzzy PID controller to d-axis current loop and applied conventional PI controller to q-axis current loop.

Here investigating the anti-disturbance ability of the d-axis current loop. The given value of speed rises from 0 r min^{-1} to a speed of 1000 r min^{-1} in step-change mode at 0.1s, the corresponding response curve of the currents and the speed are shown in Fig. 6a-c. As is shown in Fig. 6, i_d is not affected virtually when i_q is varying, the change range of i_d is [6.29, 7.98], which promises an evident improvement compared to the counterpart [6.1, 8.17] applying conventional PI controller. All these show that d-axis current loop taken fuzzy PID controller can enhance its anti-disturbance.

CONCLUSIONS

In this study, a kind of fuzzy PID controller is designed to improve current control performance of SVPWM asynchronous machine speed regulating system. Two control schemes are proposed to meet the different requirements of d-axis and q-axis current response performance. To enhance anti-interference ability of d-axis current loop, a scheme applying conventional PI controller to i_q and fuzzy PID controller to i_d is proposed. To improve dynamic and steady-state response performance of i_q, a scheme applying a conventional PI controller to i_d and a fuzzy PID controller to i_q is proposed. The simulation results demonstrate that both schemes can achieve the expected effectiveness.

ACKNOWLEDGMENT

Thanks for the support of the National Natural Science Foundation of China (No.60874047).

REFERENCES

Bose, B.K., 2002. Modern Power Electronics and AC Drives. 2nd Edn., Prentice Hall, Upper Saddle River, New Jersey, USA., ISBN-10: 013016743, pp: 736.

Jinkun, L., 2003. The Advanced PID Control and its Simulation in MATLAB. Electronic Industry Press, China, Bejing, pp: 300-310.

Shengjie, G. and L. Chunjuan, 2004. Simulation of asynchronous motor vector control system based on self-adjusting fuzzy controller. J. Lanzhou Jiaotong Univ., 343: 62-64.