International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 04 Issue: 10 | Oct -2017 www.irjet.net p-ISSN: 2395-0072

Fuzzy Controlled Permanent Magnet Synchronous Motor Drive by Space Vector Pulse Width Modulation.

B.V.S.Prasad[1], Dr.G.V.Siva Krishna Rao[2]

[1]*Student, Dept. Of Electrical Engineering, Andhra University, Andhra Pradesh, India*
[2]*Professor, Dept. Of Electrical Engineering, Andhra University, Andhra Pradesh, India*

***

Abstract - *This paper proposes a fuzzy logic approach to control the speed of permanent magnet synchronous drive by space vector pulse with modulation with disturbance voltage observer. In this control we are comparing the results with two different controllers as 1.PI controller and 2. Fuzzy speed controller. Then it is preceded with comparison through these two conditions. The simulation has been done and results are verified and validated in MATLAB /SIMULINK with different test conditions.*

Keywords- PMSM; FC; disturbance voltage observer

I. INTRODUCTION

When the running conditions alternate the conventional speed controllers such as proportional integral (PI) controller can't give adequate performance, for a vector controller PMSM drives[1,2].These days, some flexible controllers have been adapted in both AC and DC motor drives such as model reference adaptive controller (MARC) [3] and sliding mode controller(SMC) [4], etc. Thus the performance of the motor drive system can be improved by all these types of controllers. However the system models are usually based on the parameters and structure. It will lead to complicated computation when the system model is uncertainty. As the controlled system does not need mathematical model, so fuzzy controllers have been applied to many industrial fields of fuzzy reasoning in handling uncertain information. The results indicate the PMSM drive with adaptive fuzzy controller will have the ability of quick recovery of the speed from any disturbances on parameter variations, has been testified by simulation by proposed control scheme consequently the proposed PMSM drive will have better dynamic performance and robustness.

II. DISTURBANCE VOLTAGE OBSERVER OF THE PMSM

Induction motors were initially controlled by vector control method, then it was applied to PMSM later. Decoupling the stator current to get direct axis (d-axis) and quadrature axis (q-axis) components is the basic principle involved. The vector control strategy is formulated in the synchronously rotating reference frame. To make the direct-axis current i_d zero so that the torque becomes dependent only on quadrature-axis current an efficient control strategy of the vector control technique is used. The stator voltage equations of a PMSM in the synchronously rotating reference frame are described as follows

$$u_d = R_s i_d + L_d i_d - L_q \omega_r i_q$$
$$u_q = R_s i_q + L_q i_q + L_d \omega_r i_d + \varphi_f \omega_f \qquad 1$$

Where

u_d d-axis voltage in synchronous frame, [V];
u_q q-axis voltage in synchronous frame, [V];
R_s motor phase resistance, [Ω];
L_d d-axis inductance, [H];
L_q q-axis inductance, [H];
i_d d-axis current in synchronous frame, [A];
i_q q-axis current in synchronous frame, [A];
ω_r motor electrical angular velocity, [Rad/s];
I_d d-axis flux linkage in synchronous frame, [Wb];
lq q-axis flux linkage in synchronous frame, [Wb];
l_f PM flux linkage in synchronous frame, [Wb].

Accordingly, the discrete-time equation can be obtained as follows[7,8]

$$u_d(n) = R_s i_d(n) + \frac{L_d}{T}\left[i_d(n) - i_d(n-1)\right] - L_q \omega_r i_q(n) \qquad (2)$$

$$u_q(n) = R_s i_q(n) + \frac{L_q}{T}\left[i_q(n) - i_q(n-1)\right] + L_d \omega_r i_d(n) + \psi_f \omega_r \qquad (3)$$

where T is the sampling period.

When the PMSM parameters vary during the operation, it will cause the disturbances f_d (n) and f_q (n),giving[7]

$$f_d(n) = \Delta R_s i_d(n) + \frac{\Delta L_d}{T}\left[i_d(n) - i_d(n-1)\right] - \Delta L_q \omega_r i_q(n) \quad (4)$$

$$f_q(n) = \Delta R_s i_q(n) + \frac{\Delta L_q}{T}\left[i_q(n) - i_q(n-1)\right] + \Delta L_d \omega_r i_d(n) + \Delta \psi_f \omega_r \quad (5)$$

Where

$\Delta R_s = R_s - R_o, \Delta L_d = L_d - L_{do,}$

$\Delta L_q = L_q - L_{qo,} \Delta\omega_f = \varphi_f - \varphi_{fo,}$ And subscript "0" denotes the nominal value. By a simple time delay control approach The steady-state response of the predictive control can be effectively improved. In the time delay control, it is considered that the values of $f_d(t)$, $f_q(t)$ and at the present time are very close to those at time t-τ ($\tau = LT$) in the past for a small time r delay, and can be expressed when L=I is chosen as follows[8]

$$f_d(n) = f_d(n-1)$$

$$f_q(n) = f_q(n-1) \quad 6$$

By approximating the disturbances at the present time with those of (n-1)th time step and using (5) and (6), the simple approximates for the disturbances are derived as below[7]

$$\hat{f}_d(n) \approx \hat{f}_d(n) = u_d(n) - [R_{s0} i_d(n) + \frac{L_{d0}}{T}(i_d(n) - i_d(n)) - L_{q0}\omega_r(n) i_q(n)] \quad (7)$$

$$\hat{f}_q(n) \approx \hat{f}_q(n) = u_q(n) - [R_{s0} i_q(n) + \frac{L_{q0}}{T}(i_d(n) - i_q(n)) + L_{d0}\omega_r i_d(n) + \psi_{f0}\omega_r(n)] \quad (8)$$

Considering equation (7) and (8) contain The high-order harmonic components, in the application Process, a low-pass filter is needed. Therefore, Disturbances voltage caused by the parameters changes can be expressed as [7]

$$\hat{f}_{df}(n) = \frac{2 - aT}{2 + aT}\hat{f}_{df}(n-1) + \frac{aT}{2 + aT}[\hat{f}_d(n) + \hat{f}_d(n-1)] \quad (9)$$

$$\hat{f}_{qf}(n) = \frac{2 - aT}{2 + aT}\hat{f}_{qf}(n-1) + \frac{aT}{2 + aT}[\hat{f}_q(n) + \hat{f}_q(n-1)] \quad (10)$$

With parameter variations and External disturbance, the disturbances voltage, by which $u_d^* and\ u_q^*$ and u_q will be revised on-line, can be calculated from equation (9) and (10)

III. STRUCTUREOF FUZZY SPEED CONTROLLER

Major PMSM controllers for industrial applications prefer a fixed gain PI controller this fixed gain scheme works better for few operating conditions. And its performance under other operating conditions decreases. Using time consuming trial-and-error methods appropriate PI gains are obtained. The performance of PMSM drive can be increased by an adaptive speed controller with fuzzy logic is proposed. The block diagram for proposed scheme is shown in fig 1. The output of fuzzy speed control is reference value of quadrate axis.

$e_{s1}(n) = \omega_r^*(n) - \omega_r(n)$

$e_{s2}(n) = \omega_r^*(n-1) - \omega_r(n)$

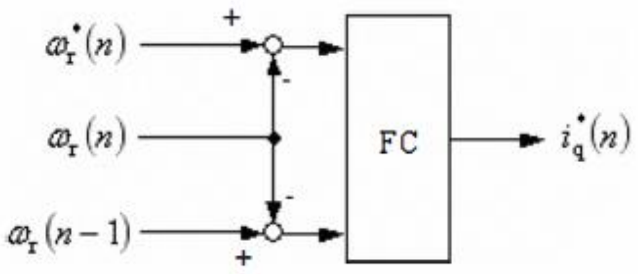
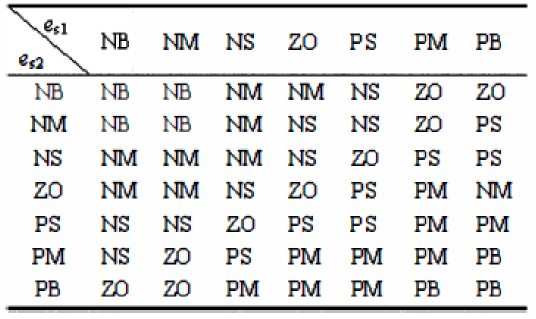


Figure 1. Membership functions of FC

The universe of all input and output variables are normalized to [-1 1]. The fuzzy membership functions of the input variables and output variable of the fuzzy controller are shown in Fig 2. And the corresponding fuzzy logic rule is shown in Table 1. respectively. In real time implementation, using the reference speed and the actual speed, we can calculate esl and es2, and the new reference value of the quadrature axis current i: can be obtained from the speed fuzzy controller. Once the parameter variations and external disturbance appear, the reference values of quadrature axis and direct axis voltage will be revised by the output of the disturbance voltage observer.

TABLE I. THE FUZZY LOGIC RULE



e_{s1} / e_{s2}	NB	NM	NS	ZO	PS	PM	PB
NB	NB	NB	NM	NM	NS	ZO	ZO
NM	NB	NB	NM	NS	NS	ZO	PS
NS	NM	NM	NM	NS	ZO	PS	PS
ZO	NM	NM	NS	ZO	PS	PM	NM
PS	NS	NS	ZO	PS	PS	PM	PM
PM	NS	ZO	PS	PM	PM	PM	PB
PB	ZO	ZO	PM	PM	PM	PB	PB

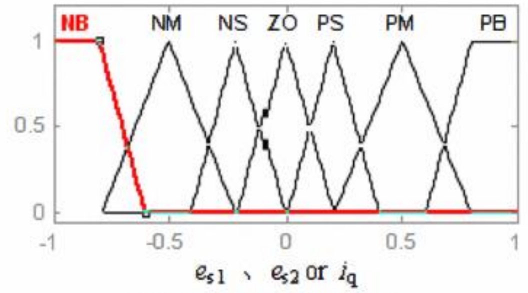


Figure 2. Membership functions

IV. RESULTS OF SIMULATION

A block diagram of the proposed PMSM drive is shown in Fig 3. The parameters of PMSM are shown in Table 2. And the availability is confirmed by computer simulations. The simulation conditions are: J= I.5Jo, Rs=2Rso.φ_f =0.8φ_f, L_d=1.3L_{do}, Lq=1.3L_{qo}, and n =1800r/min, T_z=100N.m, the results under the PI speed controller and the proposed scheme are shown in Fig.4, and Fig.5, respectively. Under the above simulation conditions, Fig.4 and Fig.5 show that the dynamic response performances of the PMSM drive based on the proposed scheme has been improved to some extent compared with the system based on the conventional PI speed controller.

TABLE 2. PARAMETERS OF PMSM

Rated voltage U_N(V)	440
Rated speed(r/min)	1800
Rated current (A)	90
Stator resistance Rs (Ω)	0.06
d-axis stator inductance L_d (mH)	2.526
q-axis stator inductance L_q (mH)	3.080
Rotor flux linkage φ_r (Wb)	0.69

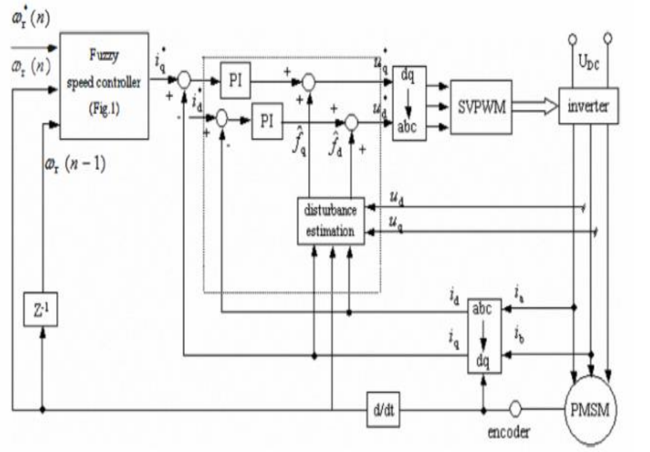
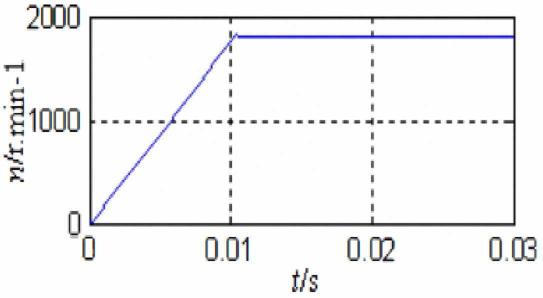
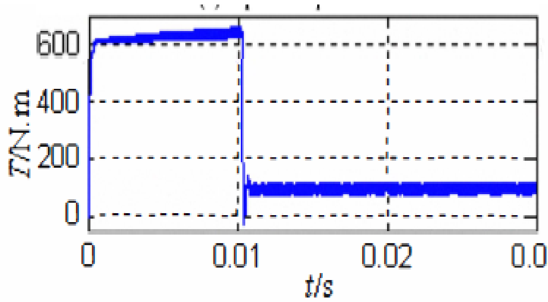


Figure 3. Overall block diagram of PMSM drive based on the proposed control scheme

Figure 3. Overall block diagram of PMSM drive based on the proposed control scheme

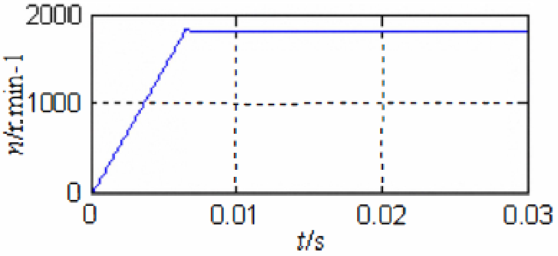


(a) Speed response



(b) Torque response

Figure 4. Results of PMSM control drive based on PI speed controller.



(a) Speed response

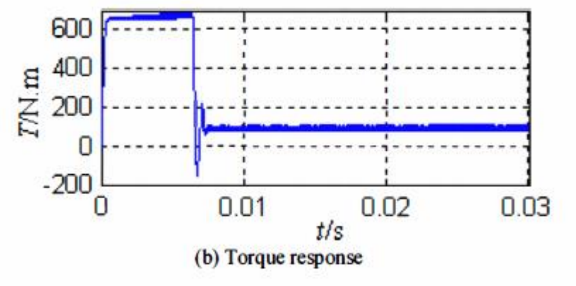


Figure 5. Results of PMSM drive based on the proposed scheme.

V. CONCLUSION

In this paper, a vector control scheme with the fuzzy speed controller with the disturbance voltage observer for the PMSM has been presented. It gives the capability of fuzzy reasoning in handling uncertain information and the ability to compensate of the disturbance voltage observer on-line. which managed to prove that the overall motor system and performance of PMSM have been improved in terms of its speed and torque The results of simulation have shown that the PMSM drive with the proposed control scheme has the merits of simple structure, robustness, quick tracking performance.

REFERENCES

[1] Yang Vi, D. Mahinda Vilathgamuwa, M. A. Rahman, "Implementation of an Artificial-Neural Network-Based Real Time Adaptive Controller for an Interior Permanent-Magnet Motor Drive,"IEEE Transactions on Energy Conversion, vol. 2, 2003, pp. 96-104.

[2] Faa-Jeng Lin, Chih-Hong Lin, " A Permanent Magnet Synchronous Motor Servo Drive Using Self-Constructing Fuzzy Neural Network Controller", IEEE Transactions on Energy Conversion, 2004, pp.66-72.

[3] H. Naitoh, S. Tadakuma, "Microprocessor Based Adjustable Speed dc Motor Drives Using Model Reference Adaptive Control," IEEE Transactions on Industry Applications, vol. 2,1987, pp.313-318.

[4] Y. Dote, R. G. Hoft, "Microprocessor Based Sliding Mode Controller for dc Motor Drives", IEEE/IAS Annual Meeting,1980, pp.64I-645.

[5] Dan Sun and Yikang He, "Fuzzy logic direct torque control for permanent magnet synchronous motors," Proceedings of the 5th world congress on intelligent control and automation, Hangzhou, P.R. China,June 2004, pp. 4401-4405.

[6] Jun Liu and Pusheng Wu, "Application of fuzzy control in direct torque control of permanent magnet synchronous motor," Proceedings of the 5th world congress on intelligent control and automation,Hangzhou, P .R. C hina,June 2004, pp. 4573-4576.

[7] Kyeong-Hwa Kim, Myung-Joong Youn. A simple and robust digital current control technique of a PM synchronous motor using time delay control approach. IEEE Transactions on power electronics, vol. 16, pp.72-82,2001.

[8] K H Kim. Design and performance comparison of a stationary frame digital current control for a PM synchronous motor. IEEE proc.electr.power appl, vol. 150,2003, pp. 357-364.