Modifying OCF for Efficient Load Sharing Between H/W & S/W Crypto Engine

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Abstract—Vector control of an induction motor has permitted fast transient response by decoupling torque and flux. The PI controller has been widely used due to simple control and easy implementation, Matlab model of Induction motor drives is constructed. This paper presents a fuzzy controller of a direct field oriented induction motor drive for high performance. A superiority of the proposed fuzzy controller over conventional PI controller in handling nonlinear induction motor has been effectively demonstrated by comparing speed controller with PI controller under varying operating conditions like step change in speed reference and torque reference. The results validate the robustness and effectiveness of the proposed fuzzy logic controller for high performance of induction motor drive system**.**

Keywords: induction motor drive, direct vector control, fuzzy controller, PI controller.

I. INTRODUCTION

Induction motors are widely used in industry because they are less costly, more rugged and reliable than DC motors. Though induction motors have a few advantageous characteristics, they also possess nonlinear and time-varying dynamic interactions. Using PI controller, it is very difficult and complex to design a high performance induction motor drive system. The fuzzy logic controller is better approach, which can handle the motor parametric variations and difficulty in obtaining an accurate mathematical model of induction motor due to rotor parameter and time constant variations. In order to have fast transient response, the controller must have the robustness against speed variations and external perturbations. The fuzzy logic controller is control technique, which permits the control of a nonlinear system such as induction motor. It has three main characteristics. 1) it is not necessary to find the exact and accurate mathematical model of system 2) the FLC is an ideal flexible nonlinear type controller, it can overcome the influence of nonlinear variations 3)the FLC has a strong robustness, as it is not sensitive to parametric variations of the controlled process. In this paper, we describe the speed control strategies of an direct field oriented induction motor. Next, with help of the Matlab/Simulink, we propose the fuzzy controller, which is suitable for speed control of induction motor drives and explain how it works. Finally we compare its simulation results to conventional PI controller. The simulation results prove the robustness of the proposed fuzzy logic controller for high performance of induction motor drive.

II. INDUCTION MOTOR DYNAMICS & CONTROL

The state equations of a squirrel-cage induction motor drive in a synchronously rotating frame can be expressed as follows (1):

$$\begin{bmatrix} V_{qs} \\ V_{ds} \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} R_s + sL_s & w_e L_s & sL_m & w_e L_m \\ -w_e L_s & R_s + sL_s & -w_e L_m & sL_m \\ sL_m & (w_r - w_{e)} L_m & R_r + sL_r & (w_e - w_{r)} L_r \\ -(w_e - w_{r)} L_m & sL_m & -(w_e - w_{r)} L_r & R_r + sL_r \end{bmatrix} \begin{bmatrix} i_{qs} \\ i_{ds} \\ i_{qr} \\ i_{dr} \end{bmatrix}$$

where S is the Laplace operator. If the speed Wr is considered as constant, then knowing the inputs Vqs, vds, and We the currents i qs, ids, iqr , and idr can be solved from equation (1).

The torque equation as a function of stator currents and stator fluxes is

$$T_e = \frac{3P}{4} \frac{Lm}{Lr} (\psi_{dr}\, i_{qs} - \psi_{qr}\, i_{ds)} = Jp\ \ W_r + B\, W_r + T_L \qquad (2)$$

$$\sigma = 1 - L_m^2 / (L_r\, L_s) \qquad (3)$$

J=total mechanical inertia, B=total damping coefficient basically, the direct field-oriented for an induction motor drive can be regarded as one of predictive control.

$$W_{sl} = \frac{L_m\, R_r}{\psi_r L_r}\, i_{qs} = \frac{R_r\, i_{qs}}{L_r i_{ds}} = \frac{1}{T_r^*} \frac{i_{qs}^*}{i_{ds}^*} \qquad (4)$$

and i_{qs}^* are the d and q-axes stator current commands set by the field and speed controllers. In this case, 1) $\psi_{dr}^* = L_m i_{ds}^*$ and ψ_{qr} =0 and

2) $Te = (\frac{3}{4} P \frac{L_m}{L_r} \psi_{dr}^*) i_{qs}^* = (\frac{3}{4} P \frac{L_m^2}{L_r} i_{ds}^*) i_{qs}^*$ (5)

The control schematic of direct vector induction motor with proposed speed controller is drawn Figure 1. The reference speed is compared with the actual speed and the error is fed to the fuzzy logic controller. To determine the torque component of current of the system the controller employs the error and change of error as fuzzy inputs. The vector rotate transforms the currents in the synchronously rotating reference frame to three-phase reference currents in stationary reference frame. The reference currents are compared with the actual currents to switch the current-controlled voltage source inverter.

III. DESIGN OF FUZZY CONTROLLER FOR INDUCTION MOTOR

The purpose of this paper is to synthesize a controller without the exact knowledge of a model, numerically simple and simulated on Matlab. Giving good performance in terms of overshoot, fast and accuracy under the speed variations. In this paper, fuzzy logic controller employs speed error and change of speed error as inputs, the changes in torque component of current that drives the induction motor is output.

$$e(k) = W_{ref} - W_r$$

$$\Delta e(k) = e(k) - e(k-1)$$

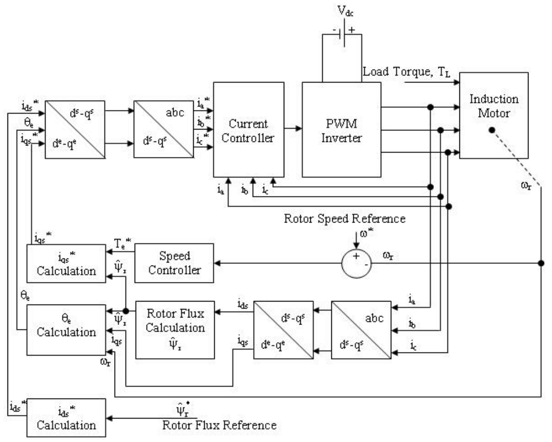

Fig. 1: Direct vector control block

where, Wref is the reference speed and Wr is the actual rotor speed. The reference current i_{qs}^{*} *(k)* that is applied to the vector control system.

$$i_{qs}^{*}(k) = i_{qs}^{*}(k-1) + Ci_{qs}^{*}(k)$$

In the first stage, the crisp variables *e(k)* and Δ*e(k)* are converted into fuzzy variables. The fuzzification maps the error, and the error changes to linguistic labels of the fuzzy sets. The proposed controller uses following linguistic labels: {NB Negative Big), NM(negative Medium), NS(Negative Small), ZE(Zero), PS(Positive Small), PM(Positive Medium), PB(Positive Big)}. Each fuzzy label has an associated membership function. The membership functions of triangular type as shown in Figure2.

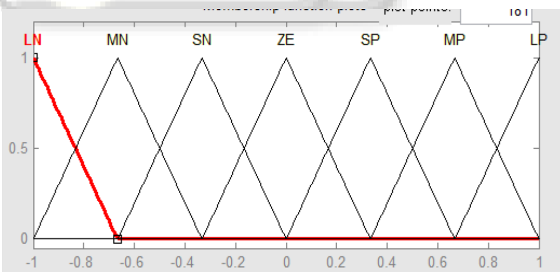

Fig.2: Triangular Membership function

Knowledge base involves defining the rules represented as statements governing the relationship between input and output variables in term of membership functions. The control rules are represented as a set if then rules. The fuzzy rules of proposed controller for speed control of induction motor are presented in Table1. Can be evaluated as below:

If *e(k)* is PB and *ce(k)* is then $i_{qs}^{*}(k)$ is PB

E CE	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NM	NM	NS	ZE	PS
NS	NB	NM	NS	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PS	PM	PB
PM	NS	ZE	PS	PM	PM	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

Table. 1: rule base

We have used fuzzy Mamdani model for fuzzy vector control of induction motor. The defuzzification method used is centroid/ centre of area, the calculations are below.

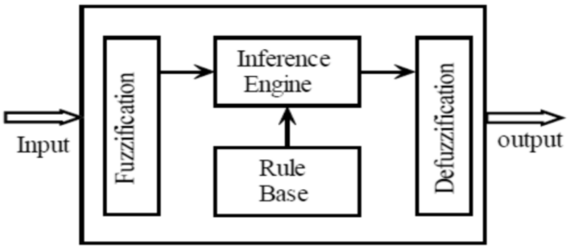

Fig.3:fuzzification process

$$Z_{COA} = \frac{\int_z \mu_{A(z)} Z \, dz}{\int_z \mu_{A(z)} \, dz};\quad \mu_{A(z)} \text{ is aggregated output MF.}$$

The proposed fuzzy vector control is shown in fig. 4.

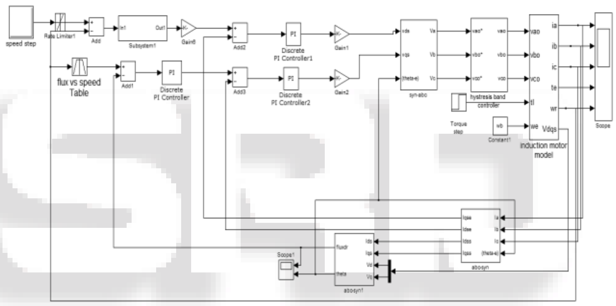

Fig.4: Fuzzy vector control simulation

Direct vector control for theta_e estimation & flux_dr is used. The drive gives good performance under varied command reference.

Speed step is given at 0.5 sec to track 100 rps from 60 rps. Torque step is at 0.8sec to move from 5 Nm to 20 Nm.The performance of FLC is compared with that of PI controller.

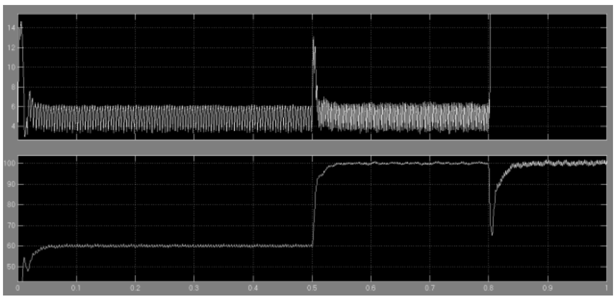

Fig.5: speed & torque response for FLC

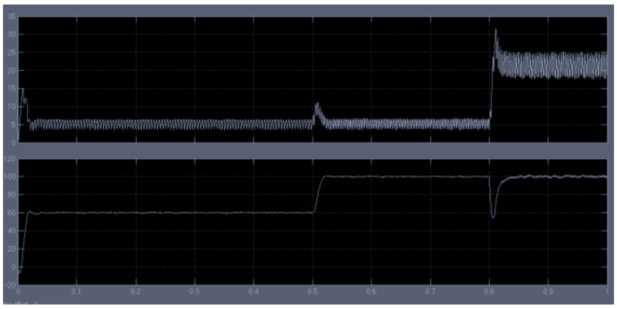

Fig.6: speed & torque response for PI controller

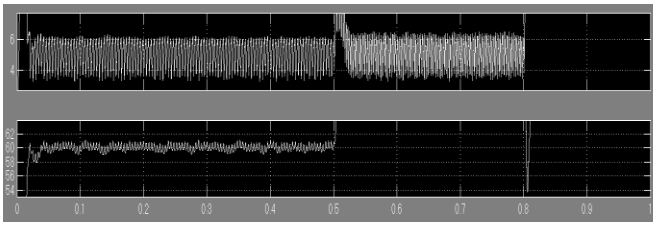

Fig.7: Magnified view of FLC response

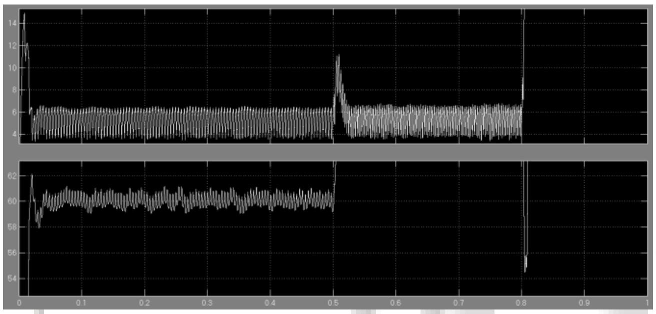

Fig.8: Magnified view of PI controller

SPEED RESPONSE	PI CONTROLLER	FUZZY LOGIC CONTROLLER
Max^{m} Peak Overshoot (rps)	62	61
Rise Time (s) T_R	0.021	0.02
Settling Time (s) T_s	0.05	0.025
Oscillations near reference in steady state (RPS)	± 1	± 0.5

Table.2:Drive characteristics for 60 rps speed tracking from standstill

SPEED RESPONSE	PI CONTROLLER	FUZZY LOGIC CONTROLLER
Max^{m} Peak Overshoot (rps)	101.9	100.5
Rise Time (s) T_R	0.527	0.52
Settling Time (s) T_s	0.53	0.525
Oscillations near reference in steady state (rps)	± 1	± 0.5

Table.3: Drive characteristic for step speed change from 60 to 100 rps

TORQUE RESPONSE	PI CONTROLLER	FUZZY LOGIC CONTROLLER
Max^{m} Peak Overshoot (Nm)	14.5	14.2
Rise Time (s) T_R	0.008	0.009
Settling Time (s) T_s	0.025	0.02
Oscillations near reference in steady state (Nm)	± 1.4	± 1

Table.4: Drive characteristics for 5 Nm tracking of torque from standstill

IV. CONCLUSIONS

- Initial torque variations in IM drive using PI controller is higher compared to the IM drive using FLC.
- Torque ripple is high in the case of PI controller but torque ripple is very small in the case of FLC.
- In the case of PI controller, under load torque variations, there have some irregularity in torque produced which is absent in FLC
- Under load torque variations, speed is settled to a lower value of reference speed in the case of PI controller. But the rotor speed follows reference speed in the case of a FLC.
- Under load torque variations, the desired torque can be obtained gradually in the case of PI controller. While using FLC desired torque can be obtained in a fraction of a second.
- So, overall performance of FLC is much better than PI controller.

ACKNOWLEDGMENT

I would like to be very thankful to the almighty, my loving parents, my brothers, my family, my friends, my guide & my dept. for their concern & best wishes during my endeavour.

APPENDIX

Motor parameters

HP=5.4; Frequency=50; Rs=1.405; Rr=1.395;

Llr=0.005839; Lls=0.005839; lm=0.1722;

p=4; J=0.0131. Rotor: squirrel cage I.M.

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