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Indirect Vector Control Drive with PI Controller

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ABSTRACT

This paper proposes the neural network solution incorporating an adaptive neuro fuzzy controller to the indirect vector control of three phase induction motor. The basic equations and elements of the indirect vector control scheme are given. The proposed control scheme is realized by using an adaptive neuro-fuzzy controller and two feed forward neural network. The neuro-fuzzy controller incorporates fuzzy logic algorithm with five layer (ANN) structure. The conventional PI controller is replaced by adaptive neuro-fuzzy inference system (ANFIS) which tunes the fuzzy inference system with hybrid learning algorithm. The two feed forward neural network are used as estimator, learned by the Levenberg Marquardit algorithm with data taken from PI control simulations. The performance of proposed scheme is investigated at different load and speed conditions. The results of the proposed scheme are compared with PI controller. The simulation study shows the robustness and suitability of drive for high performance drive applications.

Keywords: Adaptive Fuzzy logic controller(FLC), Hybrid learning algorithm, PI controller, Artificial Neural Network (ANN), Neuro-Fuzzy Inference System(ANFIS), Back propagation algorithm.

I. INTRODUCTION

Three phase induction motors find wide scale application in industries because they are rugged, reliable, economical and unsusceptible to massive overloads. Nonetheless use of induction motor has its short comings mainly the controllability due to its nonlinear behavior and complex mathematical model [2]. A special control mechanism for induction motor drives has been developed based on vector control or field oriented control theory. Using this mechanism an induction motor can be controlled just like a separately excited DC motor. This method facilitates us with the control of field and torque of the induction motor in parallel (decoupling) by manipulating the analogous field oriented quantities and parameters. There exist two methods for PWM current controlled inverter - direct and indirect vector control [16, 2, 8]. Only indirect control method comes under the scope of this paper, where the slip angle, the direct and quadrature axes stator current set point components in synchronous reference frame are computed from the torque and rotor flux set points and used for vector control. There are many theses which suggest neural network applications for indirect vector control drive. In [3] a feed forward neural network and back propagation learning are used for angular velocity estimation and control of induction motor using only stator current measurement. Paper [7] proposes a technique of neural network velocity evaluation and control of induction motor based on voltage, flux and current model. In [14] a neural controller is improvised based on TMS320C30 microprocessor in order to imitate an indirect vector control of an induction motor drive. Several theses have been put forward advocating fuzzy logic application for indirect vector controlled induction motor drives. In [11] indirect vector control of induction motor drive with the help of a fuzzy learning enhanced speed control is proposed. In [12] the functioning of fuzzy logic controller has been examined and evaluated against conventional PI controller at diverse operating situations. The paper [6] proposes a model reference adaptive plan in which the adjustment mechanism is accomplished with the help of a fuzzy logic and PI controller. In paper [15] a comprehensive vector control mechanism of induction motor integrated with fuzzy logic controller has been effectively executed in real time by making use of digital signal processor controller board DS1102. A fuzzy logic speed controllers and proportional-integral operating in indirect field orientation [13] are devised and evaluated under no load and variety of load conditions with several reference speeds.

Fuzzy Logic control (FLC) has been established efficient for compound, dense, nonlinear and inaccurately defined procedures for which benchmark model based control methods are unfeasible or unattainable [9, 10] . Fuzzy Logic, deals with predicaments that are indistinguishable, ambiguous and use membership functions with values changing between 0 and 1 [9, 10]. It means if the data accessible is not consistent, or if the system is too intricate to obtain the requisite decision rules, then the fabrication of a fuzzy logic controller becomes quite tedious. In this case, the specialized knowledge can be employed for setting up the proper conventions which can be further employed to manipulate or tune the controller for obtaining the enhanced result. Artificial Neural Network (ANN) has the potent ability for learning, adjusting, ruggedness and speed. As a result the benefit of ANN has been used for setting up the proper conventions of the fuzzy logic controller by adjusting and improvising algorithm which is called ANFIS controller. This paper presents a format of indirect vector control of Induction motor with ANN estimator and an ANFIS controller for perfecting the transient response, when it is subjected to torque variation. The required data for training the ANN estimator and ANFIS controller is deduced by simulation of the closed loop system with PI controller.

II. METHODS AND MATERIAL

2. MODELLING

2.1 Induction motor modeling

The mathematical model of a three phase squirrel cage induction motor in synchronous rotating reference frames is represented by the following equations [16, 2, 8]

$$V^e_{ds} = R_s i^e_{ds} + p\lambda^e_{ds} - w_e \lambda^e_{qs} \qquad (1)$$

$$V^e_{qs} = R_s i^e_{qs} + p\lambda^e_{qs} - w_e \lambda^e_{ds} \qquad (2)$$

$$0 = R_r i^e_{dr} + p\lambda^e_{dr} - (w_e - w_r)\lambda^p_{qr} \qquad (3)$$

$$0 = R_r i^e_{qr} + p\lambda^e_{qr} + (w_e - w_r)\lambda^e_{dr} \qquad (4)$$

Where

$$\lambda^e_{ds} = L_s ids^e + L_m idr^e \qquad (5)$$

$$\lambda^e_{qs} = L_s iqs^e + L_m iqr^e \qquad (6)$$

$$\lambda^e_{dr} = L_r idr^e + L_m ids^e \qquad (7)$$

$$\lambda^e_{qr} = L_r iqr^e + L_m iqs^e \qquad (8)$$

and electromagnetic torque

$$T_e = \frac{3}{2}\frac{P}{2} L_m (i^e_{qs} i^e_{dr} - i^e_{ds} i^e_{qr}) \qquad (9)$$

$$w_r = \frac{d\theta_r}{dt} \qquad (10)$$

$$T_e = j_m \frac{dw_r}{dt} + B_m w_r + T_l) \qquad (11)$$

2.2 Indirect Vector Control

Indirect vector control is a procedure employed to regulate the dynamic speed of an Induction motor. In contrast to direct vector control, in indirect vector control, the unit vectors are obtained in an indirect manner. Figure (1) explains the underlying principle of

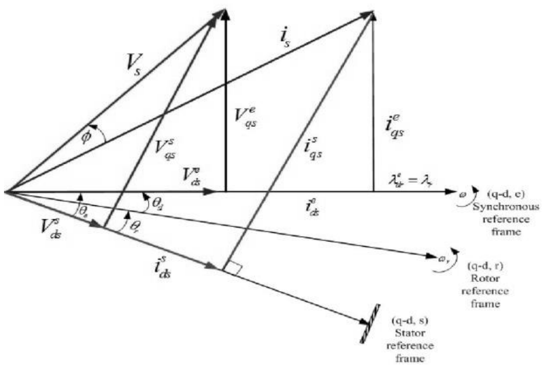

Figure 1. Phasor diagram of indirect vector control principle

Indirect vector control with the help of phasor diagram. The d^s-q^s axes are fixed on the stator and d^r-q^r axes are fixed on the rotor which rotates at a speed.

ω_r Synchronously rotating axes d^e-q^e are rotating ahead of d^r-q^r axes by the positive slip angle θ_{sl} corresponding to slip frequency ω_{sl} . Thus

$$\theta_e = \int w_e dt = \int (w_r + w_{wl}) dt \qquad (12)$$

For decoupling control $\lambda_{qr} = 0$ or $p\lambda_{qr} = 0$ and $\lambda_r = \lambda_{dr}$ Substituting above condition in (3), (4), (7) and (8)

$$w_{sl} = \frac{R_r L_m i_{qs}^e}{L_r \lambda_r} \tag{13}$$

$$T_e = \frac{3}{2}\frac{P}{2}\frac{L_m}{L_r}\lambda_r i_{qs}^e \tag{14}$$

$$i_{qs}^e = \frac{2}{3}\frac{2}{P}\frac{L_r}{L_m}\frac{T_e}{\lambda_r} \tag{15}$$

$$i_{ds}^e = \frac{1}{L_m}[\lambda_r + \frac{L_r}{R_r} p\lambda r] \tag{16}$$

III. RESULTS AND DISCUSSION

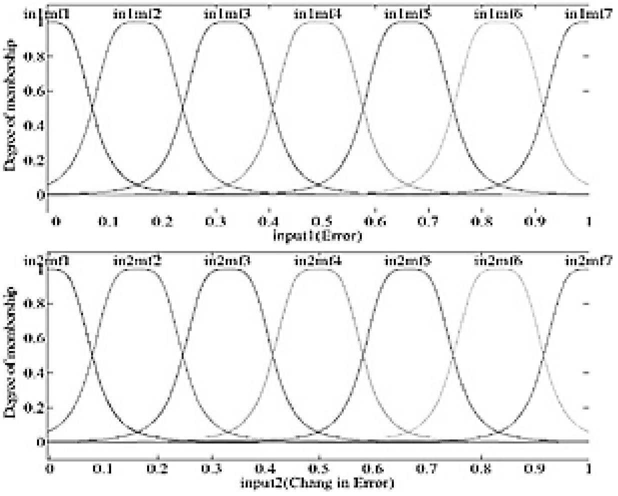

Figure 5. Membership Functions Generated Before Training

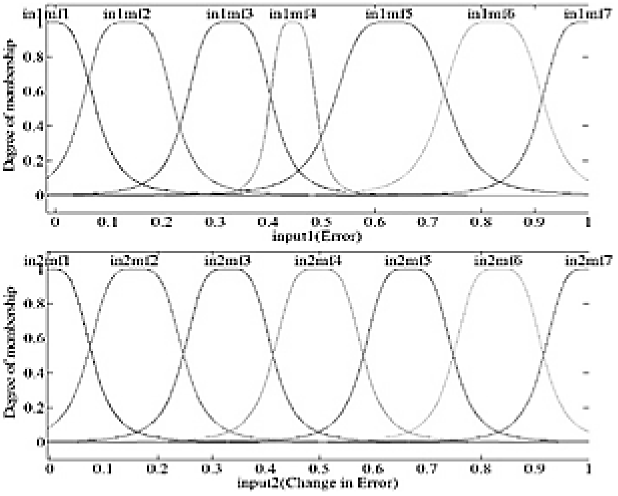

Figure 6. Membership Functions Generated After Training

Ripple in torque at the time of speed change.

Figure (9 and 10) depicts the load disturbance rejection ability of both the controllers, when the load torque is abruptly changed from 25 Nm to 150 Nm. In contrast to the proposed ANFIS scheme there is a significant speed over shoot and speed dip (when the load torque rises) in the scheme with PI controller. Though the rotor flux level barely changes in both the cases.

Table 1. Induction Motor Parameters

Parameter	**Symbol**	**Value**
Rated Power	P_{ratrd}	50HP
Rated Voltage	V	480Volt
Rated Frequency	F	60Hz
Pair of poles	P	2
Stator Resistance	R_s	0.087 Ω
Rotor Resistance	R_r	0.228 Ω
Stator Inductance	L_s	0.8mH
Rotor Inductance	L_r	0.8mH
Mutual Inductance	L_m	34.7mH
Moment of Inertia	J	1.662Kg.m^2

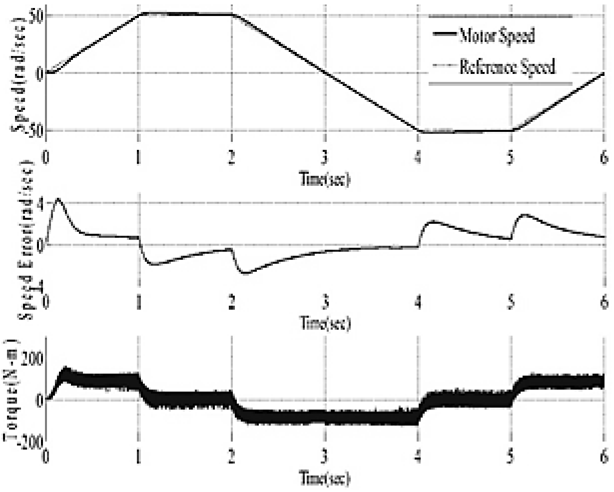

Figure 7. Trapezoidal speed tracking with PI controller

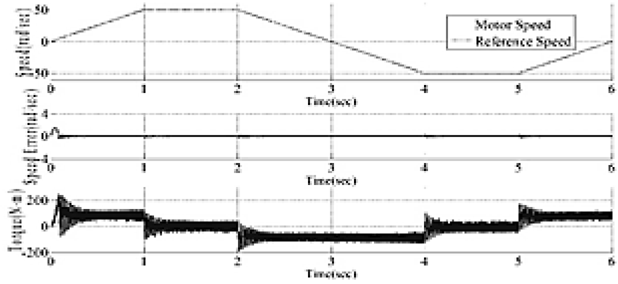

Figure 8. Trapezoidal speed tracking with ANFIS controller

Figure (11 and 12) illustrates the speed transient and step torque change responses. The speed reference changes at time t=2.5 sec from 60 rad/sec to 120 rad/sec and load torque changes at time t=4 sec from 25 Nm to 150 Nm. The magnitude of rotor flux barely changes at the speed and torque change in both the schemes. It is observed that in the proposed design the speed changes with no overshoot and it remains unvarying even when there is a change in torque. The Induction Motor chosen as parameters listed in Table.1 The Proposed induction motor for simulation as parameters which shows that the projected design is expected to with stand the change in the load.

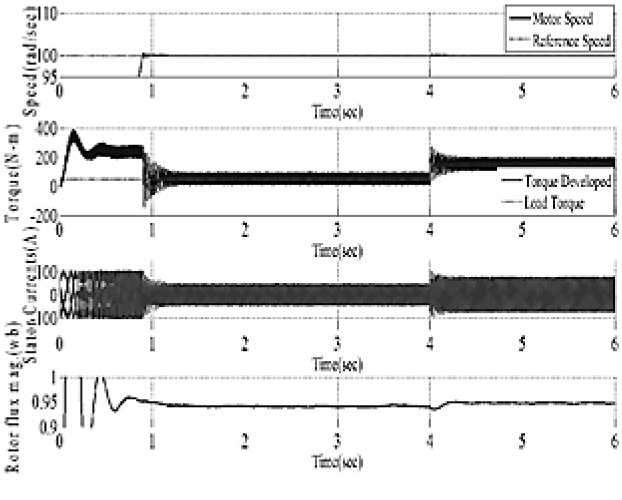

Figure 9. Transient performance under step load with PI controller

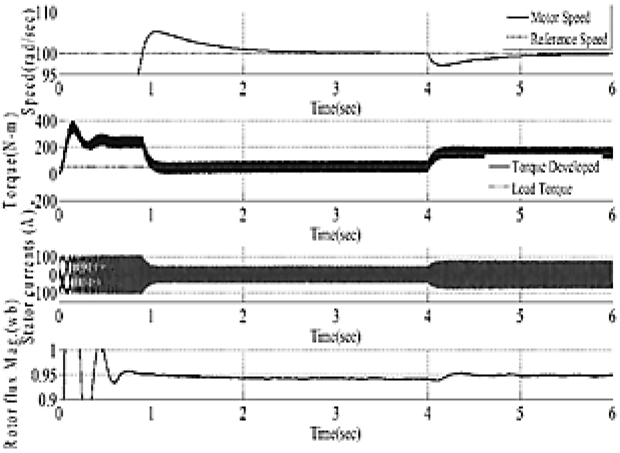

Figure 10. Transient performance under step load with ANFIS controller

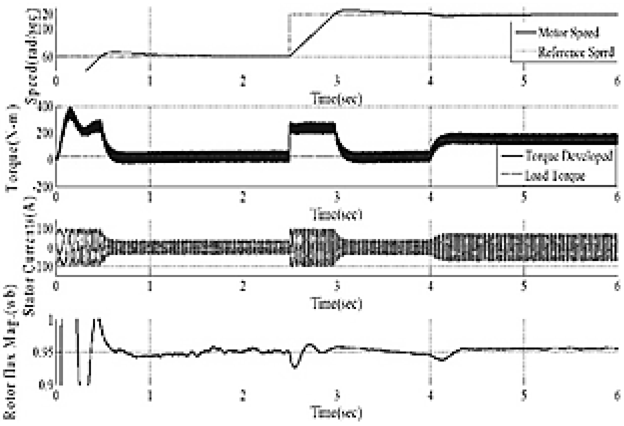

Figure 11. Transient performance under step speed and step load with PI controller

IV. CONCLUSION

This paper lays out a comprehensive relative performance analysis of indirect vector control drive with PI controller and the projected format consisting of ANFIS controller and neural estimator. Simulation results shows that the projected design is more robust during the change in load and eradicates the transients during abrupt Variation in speed. Overall simulation results reveal that the proposed scheme with ANFIS controller has superior performance when weigh against PI controller.