

Sensor less Speed Estimation of an Foc Induction Motor Drive using Mras Speed Controller and Fuzzy Current Controller

C.Lavanya, S.Sridhar

Abstract: This paper mainly presents fuzzy current controller depending on speed estimator of MRAS with field oriented controlled induction motor drives. This paper consists of three main techniques used for configurations of MRAS speed estimators that is Rotor Flux, Back - EMF and Instantaneous Reactive power. The MRAS estimators are then included into a direct field oriented controller and also a comparison is done between PI and fuzzy current controllers completely tested on MATLAB/SIMULINK. The resulting controller achieves an acceptable level of execution over wide range of good operating conditions.

Keywords: Fuzzy Logic Controller (FLC), Field Oriented Control (FOC), Model Reference Adaptive System (MRAS), Sensor Less Speed Control.

I. INTRODUCTION

Now days, the induction motor drives (IMDs) with adaptable speed drives (ASDs) are very important as its high discharge, rugged design and mostly operates in industries such as; battery operated frictions and composite motor vehicles, switch engine propulsion, scheme of scalar control which gives better invariant response, however it gives low active response. The methods of both steady state and also transient state give good satisfactory responses [1]. The IMD of DC motor performs like separately excited motor known as vector control or the field oriented control (FOC) and it was first suggested earlier in 1970's [2] by Hassle (Indirect FOC) and F. Blaschke (Direct FOC).

In the method of FOC having good characteristics and it suffers from some limitations, which are essential of some synchronized changes, controller currents, easily effected by parameter variations these are the disadvantages of FOC method [3]. Techniques of reduced new control strategy that is IFOC method, in early 1980's which are presented by Isao Takahashi and Toshihiko Noguchi. In the direct field oriented control of an induction motor drive is very essential for the angular position of rotating shaft information; rotating shaft is attainable by considering the sensors of speed (i.e. speed encoding) else from the IMD parameters to estimator observer by the use of currents and voltage signaling. The main aim of speed encoder is corresponding with some

disadvantages are, essential of shaft extension, automatic vibrancies of the machine drive is decreased, the operating motor accuracy is decreased and does not suitable for the uncertain atmosphere changes, and high expensive. These disadvantages leads to speed sensor less of indirect field oriented controlled IMD having good features above typical DFOC control. Speed sensor less drive, which does not have any sufficient space for the sensor speed to the essence of the nature which do not allow for any extra speed sensors of rotor.

Over the past decades, many schemes are introduced for the rotor speed estimation in the sensor less vector control of IMDs [4-10]. Some of the methods are (i) method of signal injection [4], (ii) method of state observers [5], (iii) method based on model configurations [6]. Signal injection method tolerates from difficulty calculations and essential for the outer equipments for the signal injection method. According to all the schemes of MRAS [7-10] speed estimators is usual working procedure because of their good characteristics, merely contrasting the scheme of injecting signal. Back-emf [4], rotor-flux [7], reactive power [5] and active power [10] are the most desired methods of MRAS. The method of back emf which gives good execution when speeds are high, although speed estimation is more complex at initial condition and it possess less speedy and hardly empathetic to motor constant. Hence, to prevent these disadvantages, rotor flux of MRAS method is most popular and it was first proposed by C Schnauzer in [11].

II. SIX PHASE INDUCTION MACHINE MODELLING

Six phase induction motor (6PIM) of dual three phase having compatible arrangement, and it mainly focuses between five and six phase multi-phase induction machine. The induction machine is having of two sets of three phase loops displaced geographically by 30° (in asymmetrical mode) or 60° (in symmetrical mode) electrically with one or two typical objective points. The asymmetrical configurations are having good torque performance compared to symmetrical one. The two typical objective points are maximizes the use of dc-link of 6PIM and it deflects the zero sequence currents of degree freedoms. The two isolated neutral point having healthy mode operations, while fault tolerant applications are for single isolated neutral point.

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A. SIX PHASE IM MODELLING

The stationary voltage equations of stator and rotor are expressed as

$$v_s = R_s i_s + p \Psi_s \quad (1)$$

$$0 = R_r i_r + p \Psi_r - j \omega_r \Psi_r \quad (2)$$

The equations of flux linkages are as follows:

$$\Psi_s = L_s i_s + L_m i_r \quad (3)$$

$$\Psi_r = L_m i_s + L_r i_r \quad (4)$$

Where $v_s = v_{s\alpha} + j v_{s\beta}$, $i_s = i_{s\alpha} + j i_{s\beta}$, $i_r =$

$i_{r\alpha} + j i_{r\beta}$, $\Psi_s = \Psi_{s\alpha} + j \Psi_{s\beta}$, $\Psi_r = \Psi_{r\alpha} +$

$j \Psi_{r\beta}$

i_s and i_r Are the currents of stator and rotor

Ψ_s and Ψ_r Are the flux linkages of stator and rotor

R_s and R_r Are the resistances of stator and rotor

L_s, L_r, L_m Are the inductances of magnetizing, rotor and stator,

imaginary unit is represented by 'j', and operating derivative is denoted by p.

The 6PIM of electromagnetic torque is calculated as follows:

$$T_e = 3P \Psi_s \otimes i_s \quad (5)$$

The number of pole pairs is represented by 'p' and cross product represents by \otimes .

The field oriented indirect controller (IFOC) IMD schematic diagram is represented in Fig.1.below, is a method of IFOC [13] which provides a quick occurring line torque as well as stator flux control because of its increased choice of switching vector voltages of both the flux and torques of stator comparisons concurrently in between with the modulating of current controllers. The successive voltage of vectors is related to the machine drives depending on the selected errors in torque and flux of stator incidentally. The IFOC technique for the drive evolves the electromagnetic torque, linkages of both the flux and the stator flux linkage of angular position of vector spaces are determined in the form of d-axis and q-axis module which are given below are:

$$\Psi_s^{\wedge} = \sqrt{\Psi_{ds}^2 + \Psi_{qs}^2} \quad (6)$$

$$T_e = \frac{3p}{2} * ((\Psi_{ds}^{\wedge} * i_{qs} - \Psi_{qs}^{\wedge} * i_{ds})) \quad (7)$$

$$\theta_e = \tan^{-1} \left(\frac{\Psi_{qs}^{\wedge}}{\Psi_{ds}^{\wedge}} \right) \quad (8)$$

where $\Psi_{ds}^{\wedge} = \int (v_{ds} - R_s * i_{ds}) * dt$

$\Psi_{qs}^{\wedge} = \int (v_{qs} - R_s * i_{qs}) * dt$

III. MRAS BASED PI AND FUZZY CONTROLLER OF INDUCTION MOTOR

The proposed method of MRAS which are based on PI current controller and Fuzzy current controller approach. MRAS methods are one of the most popular methods which are used for rotor speed estimation to detect the sensor speed at different speeds. Overall the control of MRAS speed estimation [11], [14]. The stability theorems of non linearity are Lyapunov's stability or Popov's stability schemes of an adaptation law used the design of system is relatively stable. In Significance of identifying the vigorous response of the combining methods which do not produced by the stability theorem of nonlinearity, the adaptation law of stability additionally cannot be undertaken for less speed manner of regeneration. In order to conduct this type of researches, this is essential to adjust induction machine of six phase equations throughout the control point and it transfers the function of the MRAS, which is presented in this paper.

A. Adaptation Law design

State-space equations are considered in general form is as follows:

$$p_x = A_x + B_u \quad (9)$$

$$y = c_x \quad (10)$$

The 6PIM of state space model in the z1, z2 Subspace can be reduced from (11) and (12) equations follow:

$$P \begin{bmatrix} i_{sz1} \\ i_{sz2} \end{bmatrix} = \begin{bmatrix} -R_s & 0 \\ 0 & -R_s \\ L_{1s} & L_{1s} \end{bmatrix} \begin{bmatrix} i_{sz1} \\ i_{sz2} \end{bmatrix} + \frac{1}{L_{1s}} \begin{bmatrix} v_{sz1} \\ v_{sz2} \end{bmatrix} \begin{bmatrix} i_{sz1} \\ i_{sz2} \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} i_{sz1} \\ i_{sz2} \end{bmatrix} \quad (11)$$

Observer state equations can be rewrite as below

$$p_x^{\wedge} = A^{\wedge} x^{\wedge} + B_u \quad (12)$$

$$y^{\wedge} = c_x^{\wedge} \quad (13)$$

The “^” indicates that the sign of approximate value of MRAS. The leakage inductance of stator is kept continuous, the estimation controllers are deduced, when errors are possible, and variations are to be neglected. The error is based on correcting term $G(x \Delta x^{\wedge})$ mentioned, which eliminates in the equation (11), the observer gain matrix is denoted by G, which is a regular convention of estimators of MRAS [16]. The type of observer is known as “natural observer” [20] researched by some analysis. The state variable error matrix is followed by:

$$e = x - x^{\wedge} = [i_{sz1} - i_{sz1}^{\wedge} \quad i_{sz2} - i_{sz2}^{\wedge}]^T = [e_{isz1} \quad e_{isz2}]^T \quad (14)$$

The error matrix of time derivative is estimated by (11), (13), and (14) as

$$p_x = p_x - p_x^{\wedge} = A_e - \Delta A^{\wedge} x \quad (15)$$

where A is given as

$$\Delta A = A^{\wedge} - A = \begin{bmatrix} -1 & 0 \\ L_{1s} & -1 \\ 0 & L_{1s} \end{bmatrix} \Delta R_s \quad (16)$$

The PI controllers are used in conventional systems. PI controller is a combination of proportional and integral controllers with the objective of achieving the desired response with minimum and maximum time of precision. In this PI controller used for estimation, so that it is very difficult to modify. In some cases of the final response which is not achieved, this is a time taking and low processing. Due to this drawback, to overcome this problem fuzzy logic controller came into existence. Fuzzy current controllers of 6PIM are very excellent features controllers over PI controllers; they achieve the final response and stable conditions without any delay.

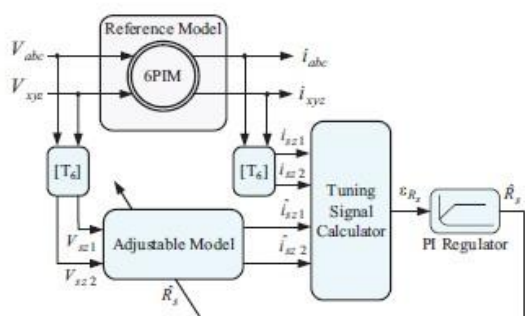


Fig. 1. The Basic schematic block of MRAS.

IV. FUZZY LOGIC CONTROLLER ADAPTATION MECHANISM AND IMPLEMENTATION OF MRAS SPEED ESTIMATION

In recent years, Fuzzy logic modeling [15],[19] replaced many conventional techniques successfully in many areas with respect to MRAS speed estimation[18]. In complex problem solving it is easy to derive control rules by mathematically modeling the process. Mamdani technique is the most commonly used fuzzy inference system techniques and other techniques are Sugeno, Takagi and Kang.

A. Adaptation Mechanism Of Fuzzylogic Controller.

Fuzzy logic controller is the discrete, adjustable governing process, which tends to rugged implementation extending unexpected speed changes and also disturbances in loads. FLC manages complex of non linearity system which is having degrees of unreliability, it do not requires numerical simulation and inconsistent continual parameter obtain and to create PI controller is capable for induction machine drive [13]. Rotor-flux MRAS based FLC mechanism adaptation schematic diagram is as shown in Fig.2. Below.

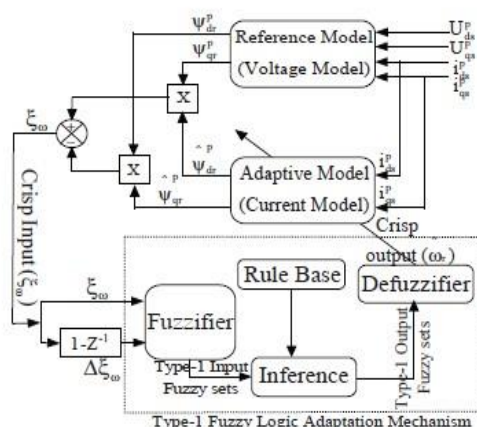


Fig.2. Adaptation mechanism of Fuzzy logic controller (FLC) schematic diagram

a. Rule Base design of fuzzy

FLC shifts a semantic control technique to mechanical power technique, rule base fuzzy designs is knowledgeable. The FLC rule base model is necessary for explaining rules that can associated with the both input and output type variable premises [8,13]. Adaptation mechanism of advanced fuzzy controller aims to evaluate speed of rotor is in control state of induction motor drive. Reference model (RM) and the adjustable model (AM) of both signal errors are used in the adaptation mechanism of fuzzy logic control for the estimation of speed in rotor.

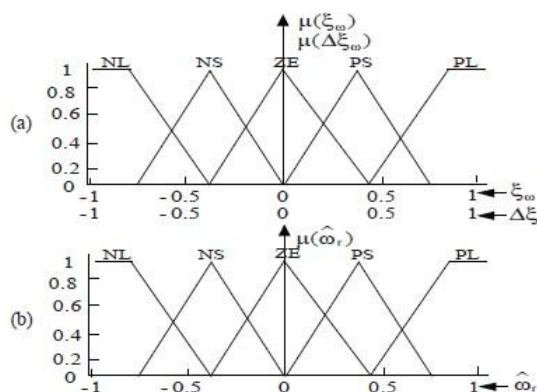


Fig. 3. The normalized triangular M.F's of fuzzy input, fuzzy output variables are: (a) change in speed error, (b) torque reference.

$\Delta \xi_{\omega}$		ξ_{ω}				
		NL	NS	ZE	PS	PL
Change in speed	NL	NL	NL	NM	NS	ZE
	NS	NL	NS	NS	ZE	PM
	ZE	NL	NS	ZE	PS	PL
	PS	NM	ZE	PS	PS	PL

Table.1: fuzzy logic rule base control table.

The input variables of fuzzification stage rotor speed estimators are of signal errors ' ξ_{ω} ' and rate of signal error changing ' $\Delta \xi_{\omega}$ ' and the approximate rated variable output of the speed in rotor ' ω_r '. There are 5 main sets of fuzzy are set to change integer values to the semantic values, which are mentioned below that are negatively larger (NL), negatively smaller (NS), zero error (ZE), positively smaller (PS), and last positively larger (PL), which are briefly mentioned in Table 1. The two variables of input and one variable of output are having same M.F's, they are specified by the use Mamdani maximum-minimum model type of triangle shaped membership functions M.F's below. The universe converse of FLC ranges from -1 to 1 which are selected for both the input control variable and output control variables. In Fig.4. shown as proposed fuzzy logic controller MATLAB/SIMULINK model of 6PIM.

V. SIMULATION RESULTS

This paper simulates that the results taken for the evaluation of MRAS scheme performance to the FLC which is analyzed by a mathematical simulation. The MATLAB/Simulink design is verified in the system [3] individually, with some of the equivalent research papers [7], [8] and [11],[14] with the 10 kHz frequency samples is kept constant below, the no load and the change in command speed and step change of open loop simulation results are mentioned below in Fig. 5, the flux in stator value is kept up to 0.4 Wb and estimation process is activated when t=1s. Clearly, known that the speed estimation is intersects at real value of its divergent with incorrect initial conditions irrespective of the change in speed. Simulation results below the step change of torque at load condition of open loop around 2 Nm and the rated speed are of 2700 rpm and synchronous speed is around 1500 rpm which is mentioned below in Fig. 6, also seen that the stator flux. Fig.5. Shows that simulation modeling of Speed in RPM.

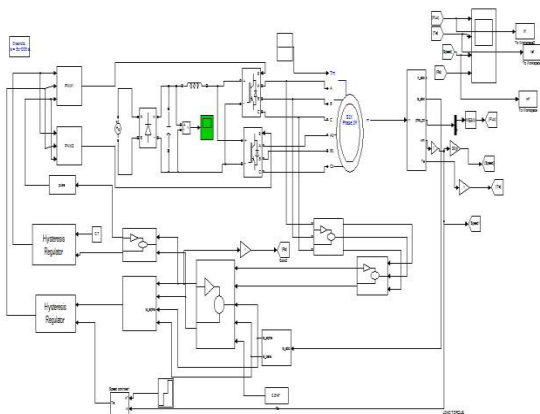


Fig. 4. The proposed fuzzy logic controller of 6PIM MATLAB/SIMULINK Model.

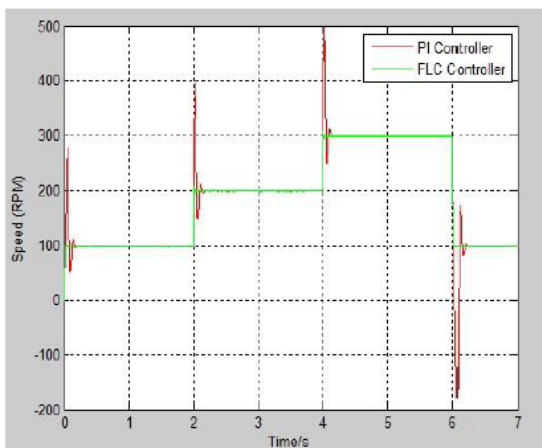


Fig 5.Simulation comparison waveform of fuzzy based MRAS speed (rpm).

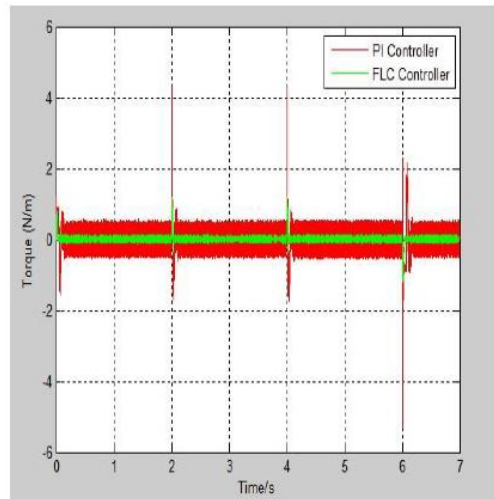


Fig 6.Simulation waveform of fuzzy based MRAS Torque in Nm.

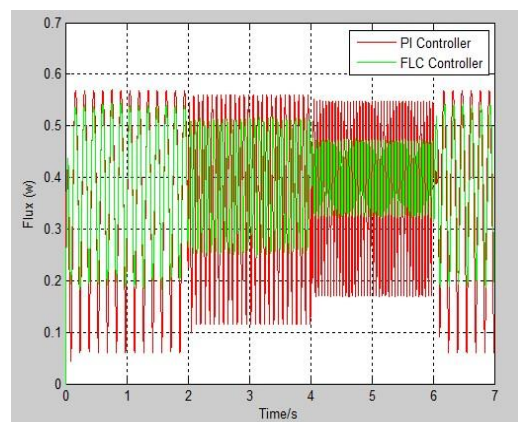


Fig 7.Simulation waveform of fuzzy based MRAS Flux in Wb.

VI. CONCLUSION

This paper addresses the comparison between fuzzy and PI current controllers keeping MRAS controller constant for both the cases. MRAS speed Estimator based back Emf produces more litigations extremely at less speed range below so there is a chance that the back emf is decreased by itself to the less value. Due to this slow process and complexity of PI controller MRAS, fuzzy control MRAS used in the simulation. By using this fuzzy current controllers in the place of PI controller there is improvement in the waveforms of torque and settling time of speed

controllers	Settling time of speed	Torque	Flux
PI controller	0.12 sec	0.5NM	0.55Wb
Fuzzy controller	0.012sec	0.15NM	0.42Wb

Table Ii Pi And Fuzzy Controller Table

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