International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

MRAS Observer for Sensorless Control of Induction Motor Using Fuzzy Pi Controller

Shylin Babu R[1], Uvaraj P[2]

[1]PG scholar, Department of Electrical and Electronics, Sri Krishna College of Engineering and Technology, Coimbatore, India

[2] Assistant Professor, Department of Electrical and Electronics, Sri Krishna College of Engineering and Technology, Coimbatore, India

Abstract: ***In recent years, the field oriented control of induction motor drive is widely used in high performance drive system. MRAS technique is been introduced as the sensorless speed estimator. The nonlinearity of induction motor makes its control a difficult one. Thus the linear Proportional Integral (PI) control is not a well established control method in motor drive. Whereas fuzzy logic control has the ability to control nonlinear and uncertain systems even where no mathematical model is available for the control system. Fuzzy Logic Control is implemented in the system for maintaining the motor speed response to be constant when the load varies. Hybridization of fuzzy logic (FL) and PI controller for the speed control of given motor is performed to get rid of the disadvantages of FL controller (steady-state error) and PI controller (overshoot and undershoot). From the analysis of simulation results the rise time, overshoot, and settling time are improved with the hybrid controller.***

Keywords: Vector control, MRAS system, PI controller, Fuzzy Logic Controller.

1. Introduction

The AC induction motor is the most popular motor used in consumer and industrial applications and represented the "muscle" behind the industrial revolution. Traditionally, for perfect wide range speed control, dc motors were used. Nowadays with progress in power electronic industry and development of inexpensive convertors and many advantages of ac motors than dc motors, use of ac motors are usual in electrical drives. Lack of commutator is the major advantage in using ac machines. Induction motors are robust and have better performance in high speed and torque. The motor does not have a brush/commutator structure like a brush DC motor has, which eradicates all the problems associated with sparking; such as electrical noise, brush wear, high friction, and poor reliability. The absence of magnets further strengthens reliability, and also makes it very economical to manufacture. In high horsepower applications (such as 500 HP and higher), the AC induction motor is one of the most efficient motors in existence, where efficiency ratings of 97% or higher are possible. However, under light load conditions, the quadrature magnetizing current required to produce the rotor flux represents a large portion of the stator current, which results in reduced efficiency and poor Power Factor operation.

2. Vector Control

Vector control, also called field-oriented control (FOC), is a variable-frequency drive (VFD) control method where the stator currents of a three-phase AC electric motor are identified as two orthogonal components that can be visualized with a vector. The magnetic flux of motor and the torque are the two components. The control system of the drive calculates from the flux and torque references given by the drive's speed control the corresponding current component references. Proportional-integral (PI) controllers are used to maintain the measured current components at their reference values. The pulse-width modulation of the variable-frequency drive defines the transistor switching according to the stator voltage references that are the output of the PI current controllers. In vector control, an AC induction or synchronous motor is controlled under all operating conditions like a separately excited DC motor. It means that the AC motor behaves like a DC motor in which the field flux linkage and armature flux linkage created by the respective field and armature (or torque component) currents are aligned orthogonally so that, when torque is controlled, it does not disturb the field flux linkage, thus performing dynamic torque response. The control variables of an AC induction motor are made stationary (DC) using mathematical transformations. So that it tries to control an induction motor by imitating DC motor operation as it deals with stationary parameters.

The two possible methods for achieving field orientation are direct flux orientation where the field orientation is achieved by direct measurement or estimation of the flux, and indirect field orientation where the field orientation is achieved by imposing slip frequency derived from the rotor dynamic equations. The field orientation with respect to the rotor flux alone gives a natural decoupling between two components, fast torque response and stability; whereas the stator and air-gap flux decoupling control methods give nonlinear torque-slip characteristic with limited starting torque capability, though these methods are having ease of flux computation.

The phasor diagram Figure.1 presents these axes. When the machine input currents change sinusoidally in time, the angle θ_e keeps changing. Thus the problem is to know the angle θ_e accurately, so that the d-axis of the d-q frame is locked with the flux vector.

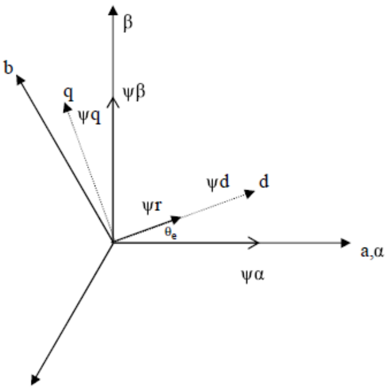

Figure1: Phasor Diagram of the Field Oriented Drive System

The advantages and disadvantages of the field orientation with different orientation schemes were studied in the literature, from which it was concluded that the rotor flux oriented control only gives the natural decoupling of flux and torque, fast torque response and stability, whereas the stator and air gap flux orientation give nonlinear torque-slip characteristics and limited starting torque capability. The study and design procedures of PI controllers are given in. The hysteresis controller has fast transient response and the magnitude of the error of controlled parameter is bounded, whereas in steady-state, the ripple is high. In PI controllers, the effective gains are decreased as a function of the increased motor speed which can be overcome by a synchronous PI regulator. With PI controllers, the steady-state error becomes zero. The control inputs can be specified in two phase synchronously rotating d-q frame as i_{ds}^{e} and i_{qs}^{e}

such that i_{ds}^{e} being aligned with the d-axis or the flux vector.

These two phase synchronous control inputs are converted into two-phase stationary quantities and then to three-phase stationary control inputs. To accomplish this the flux angle θ_e must be known precisely.

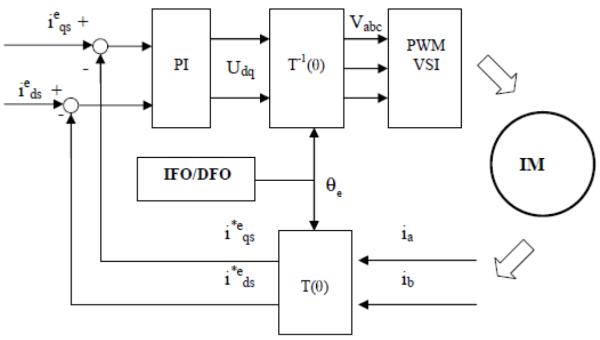

Figure 2: Field Oriented induction Motor Drive System

The angle θ_e can be found either by Indirect Field Orientation control (IFO) or by Direct Field Orientation control (DFO). The block diagram representing Field Oriented Control is shown in Figure 2 The controller implemented in this fashion that can achieve a decoupled control of the flux and the torque is known as field oriented controller. In the field-oriented controller the flux can be regulated in the stator, air-gap or rotor flux orientation.

3. Proposed Controllers

3.1 PI Controller

A proportional-integral controller (PI controller) is a control loop feedback mechanism (controller) widely used in industrial control systems. A PI controller calculates the difference between a measured process variable and a desired setpoint as an error value. Then the controller minimize the error by adjusting the process through use of a manipulated variable. The final form of the PI algorithm defining u(t) as the controller output is

$$u(t) = K_p e(t) + K_i \int_0^{\tau} e(t)dt \qquad (1)$$

Where K_p is the proportional gain, K_i is the integral gain, a tuning parameters. P depends on the present error whereas I on the accumulation of past errors based on current rate of change. The sum of these two actions is used to adjust the process through any control. By tuning the three parameters in the PI controller algorithm, the controller can provide control action designed for specific requirements.

3.2 Fuzzy Logic Controller

Fuzzy control is a versatile and effective approach to deal with non-linear and uncertain system. The block diagram of the fuzzy logic controller is shown in figure3. Fuzzy Logic control (FLC) is an effective tool for complex, non-linear and imprecisely defined processes for which standard model based control techniques are impractical or impossible. Fuzzy logic is widely used in machine control. The term "fuzzy" refers to the fact that the logic involved can deal with concepts that cannot be expressed as "true" or "false" but rather as "partially true". Even though alternative techniques such as genetic algorithms and neural networks can perform just as well as fuzzy logic in many cases, fuzzy logic has the major advantage that the solutions can be cast in terms that human operators can understand, so that their experience can be used in the design of the controller. This makes it easier to model various tasks that are already successfully performed by humans.

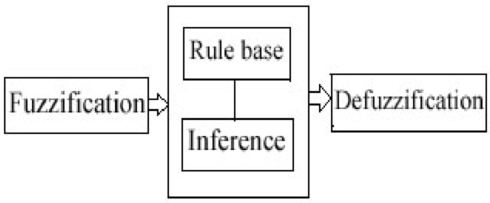

Figure 3: Block Diagram of Fuzzy Logic Controller

A membership function is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1. All the membership functions are symmetrically spaced over the universe of discourse. The rules used in the rule base rules with are given in tables shown in TABLE 1. Rule base is basically a matrix used for determining the controller output from their input as it holds the input/output relationships. The linguistic terms used for input and output variables are described as: ‘Z’ is Zero, ‘NB’ is Negative Big, ‘NS’ is Negative Small , and ‘PB’ is Positive Big, ‘PS’ is Positive Small.

Table 1: Rules of Fuzzy System

e\de	NB	NS	Z	PS	PB
NB	PS	NB	NB	NS	PB
NS	NS	NS	NB	PB	NS
Z	NB	NS	Z	NS	NB
PS	NB	Z	NS	NS	NB
PB	PS	NS	NS	NB	NB

3.3 Model Referencing Adaptive System (MRAS)

The principal of the MRAS is to estimate the speed by an adaptation mechanism. Normally, MRAS has two models a reference model and an adjustable model as shown in fig.4. As a speed estimator, the output of the adaptation mechanism is the estimated speed which feedbacks to the adjustable model as an adjustable parameter. The input of the adaptation mechanism is the error formed by the reference model and the adjustable model. By forcing this error to be zero, speed estimation can be observed.

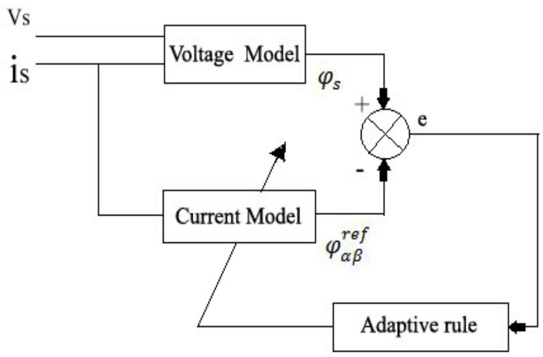

Figure 4: Principle of MRAS Method

The speed is determined through the closed-loop signal from the output of the proportional–integral (PI) controller operated by the flux-error signal. It consists of two models: reference model and adjustable model. These two models are independent rotor flux expressions in a stationary reference frame. The voltage-model-based rotor flux calculation is independent of the rotor speed . Therefore, it is taken as reference model as follows

$$\lambda_s = \int (V_s - R_s I_s) dt \tag{2}$$

From the reference model, the flux obtained from (1) is used as the reference flux. By adjusting the estimated rotational speed, the error between the reference flux and the flux estimated from (2) is reduced.

$$\lambda_{\alpha\beta}^{ref} = \frac{L_r}{L_m} (\lambda_s - L_s \sigma I_s) \tag{3}$$

The MRAS has been widely used for sensorless FOC. It has proved to be a very useful, valuable, and reliable observer. An important advantage of the MRAS is its fewer cumulative errors compared with a sliding-mode observer.

3.4 Hysteresis PWM Current Control

In this work, the current control of converter is a hysteresis current controller. It is used due to simple, fast dynamic response and insensitive to load parameters. In this method each phase consists of comparator and hysteresis band. One of the simplest current control PWM techniques is the hysteresis band (HB) control shown in this fig.5. Basically, it is an instantaneous feedback current control method in which the actual current continuously tracks the command current within a pre assigned hysteresis band. As indicated in the figure 5, if the actual current exceeds the HB, the upper device of the half-bridge is turned off and the lower device is turned on. As the current decays and crosses the lower band, the lower device is turned off and the upper device is turned on. The harmonic quality of the wave will improve if the HB is reduced but this increases the switching frequency. This in turn causes higher switching losses.

This same logic can applied to three phase waveform also. 120 phase shift is used In three phase reference signal and is compared with load current. Advantages are excellent dynamic response, low cost and easily implementation.

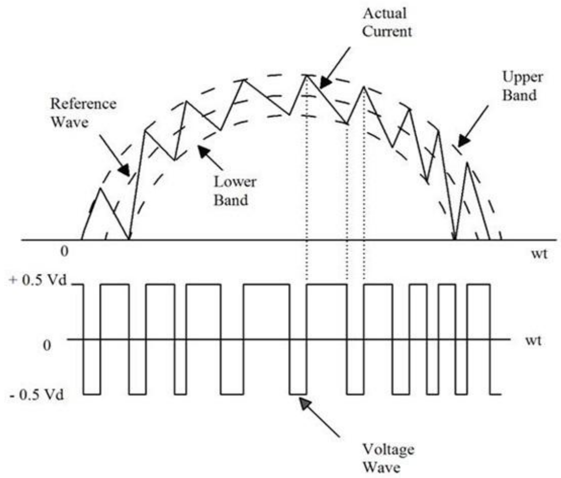

Figure 5: Hysteresis Band Current Controller

The switching logic is realized by three hysteresis controllers, one for each phase. Fig. 5 shows the hysteresis band operation. The switching signals are generated due to error in the current. The error comes from comparing between the reference current and actual current. The main task of this method of control is to force the input current to follow the reference current in each phase. Each controller determines the switching-state of one inverter half bridge in such a way that the corresponding current is maintained within a hysteresis band.

4. Result and Discussion

Control of induction motor using MRAS technique with PI and fuzzy controller were performed by using MATLAB/ Simulink. The direct axis and quadrature axis currents are shown in figure 6. The stator currents as shown in fig.7. become smoother without any distortions due to renovation in the dq-axes current components. The stator current settles down to constant value with out disturbance when the torque becomes steady.

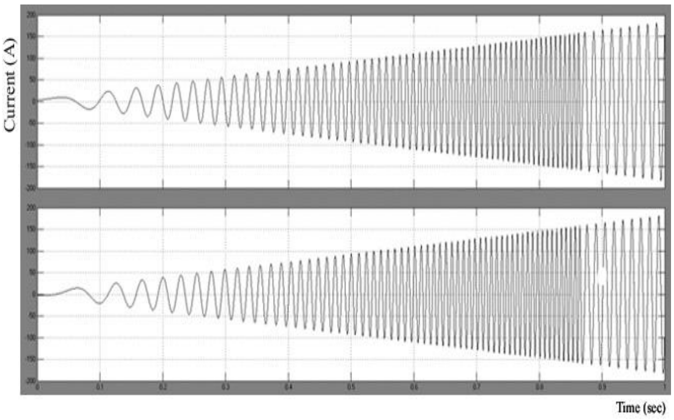

Figure 6: Direct Axis and Quadrature Axis Current

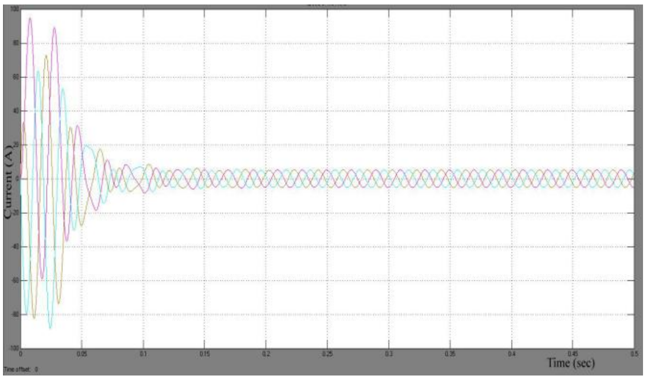

Figure 6: Stator Current Induction Motor Drive

The speed response with PI and hybrid controller are compared. The hybrid controller has less overshoot and settles faster in comparison with PI controller. It is also noted that there is no steady-state error in the speed response during the operation when hybrid controller is stimulated. In addition, no oscillation occurred in the torque response before it finally settles but oscillation occurred at PI controller.

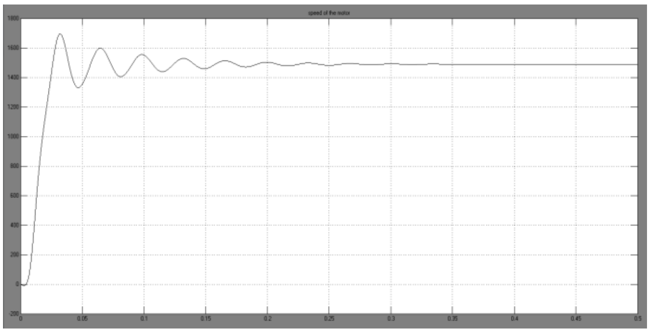

Figure 7: Speed Response of FOC with PI Controller

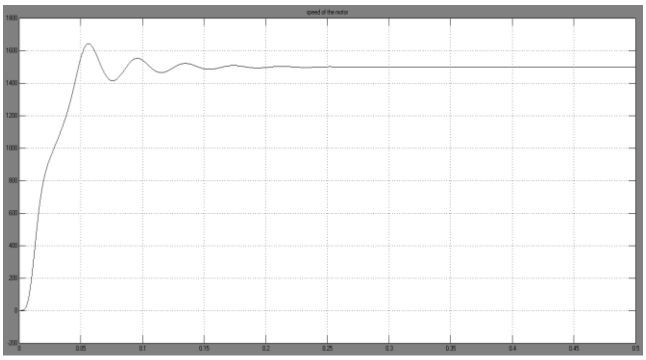

Figure 8: Speed Response of FOC with Fuzzy PI Controller

Good torque response is obtained with hybrid controller at all time instants. With PI Controller implemented the response settles at constant speed at 0.35 secs. But with the PI-Fuzzy hybrid Controller the speed gets settles faster and also the oscillations are eliminated.

Controller	Settling Time (secs)
PI	0.35
Fuzzy-PI	0.25

5. Conclusion

In this paper, Sensorless control of induction motor using Model Reference Adaptive System (MRAS) technique has been proposed. Sensorless control gives the advantage of Vector control without using any shaft encoder. The principle of vector control and Sensorless control of induction motor is been elaborated in this paper. The mathematical model of induction motor has been developed and results have been simulated. Simulation of Vector Control and Sensorless. From the obtained Simulink results the speed response of PI and hybrid controllers are compared and it is shown that the hybrid controller gives faster response in terms of settling time.

References

[1] Fengxiang Wang and Zhe Chen, “Encoderless Finite-State Predictive Torque Control for Induction Machine With a Compensated MRAS”, IEEE Trans. on ind. Informatics, vol. 10, no. 2, may 2014.

[2] Kedar Patil, “Harmonic Analysis of Sine PWM and hysteresis current controller”, International Journal of Advanced Research (IJAREEIE), Vol. 2, Issue 11, November 2013.

[3] Kannan.R and Kanagaraj “Performance Analysis of an Induction Motor Drive Using Fuzzy Variable Structure Control”, Australian Journal of Basic and Applied Sciences, 7(12) Oct 2013, Pages: 51-59.

[4] Opas Ruksaboon and Chaiyapon Thongchaisuratkrul, “Fuzzy PID Control Compensation System for Speed of VVVF Induction Motor Drive”, International Journal of Computer Theory and Engineering, Vol. 5, No. 6, December 2013

[5] B. Kumar, Yogesh K. Chauhan, and V. Shrivastava, “Efficacy of Different Rule Based Fuzzy Logic Controllers for Induction Motor Drive”, International Journal of Machine Learning and Computing, Vol. 2, No. 2, April 2012.

[6] B. N. Kar, K. B. Mohanty, and M. Singh, “Indirect vector control of induction motor using fuzzy logic controller,” in Proc. International conference on Environment and Electrical Engineering, Rome, 2011, pp. 1-4.

[7] H. Zheng, S.-J. Liu, and O. Hu, “Simulation of fuzzy PID control of heave compensation system for deep-ocean mining,” Word Journal of Modeling and Simulation. England, vol. 8, no. 1, pp. 50-57, 2012

[8] Neema D.D, Patel R. N and Thoke A.S, “Speed Control of Induction Motor using Fuzzy Rule Base”,

International Journal of Computer Applications, Vol.33(5),pp.21-29, 2011.

[9] M.L.N.Kiran Kumar and T.Rama Sastry, "Fuzzy PID Controller Application to Sensorless Induction Motor Based on Model Reference Adaptive System", IJAREEIE, Vol. 2, Issue 8, August 2013.

[10] Benudhar Sahu, K.B.Mohanty and Swagat Pati,, "A Comparative Study on Fuzzy and PI Speed Controllers for Field-Oriented Induction Motor Drive", Modern Electric Power Systems, Wroclaw, Poland MEPS'10, 2010.

[11] O. Ruksaboon and S. Thongchai. "Simulation of 3-phase induction motor control system using fuzzy-vector of variable frequency," in Proc. the 2th RIIT 2009 International Conf., 2009.

[12] Z. Ibrahim and E. Levi, "A Comparative Analysis of Fuzzy Logic and PI Speed Control in High-Performance AC Drives Using Experimental Approach," IEEE Trans. on Industry applications, vol. 38, no. 5, pp. 1210-1218, Sep./Oct. 2002.

[13] M. Masiala, B. Vafakhah, A. Knight, and J. Salmon, "Performances of PI and Fuzzy–Logic Speed Control of Field–Oriented Induction Machine Drives," in Proc. Canadian Conference on Electrical and Computer Engineering, 2007, Canada, pp. 397-400.

[14] D. P. Marcetic, S. N. Vukosavic, "Speed-Sensorless AC Drives with the Rotor Time Constant Parameter Update," IEEE Transactions on Industrial Electronics, vol. 54, no. 5, October 2007.

[15] Y. Koubaa and M. Boussak., "Rotor Resistance Tuning for Indirect Stator Flux Oriented Induction Motor Drive Based on MRAS Scheme," European Transactions on Electrical Power, vol. 15, 2005.

Author Profile

Shylin Babu R received the B.E. degree in Electrical and Electronics Engineering from National Engineering College in 2013. He is now perceiving M.E. degree in Power Electronics and Drives from Sri Krishna College of Engineering and Technology (2013-2015).

Uvaraj P received the B.E. degree in Electrical and Electronics Engineering from Sasurie College of Engineering in 2010 and M.E. degree in Power Electronics and Drives from K.S.Rangasamy College of Technology in 2014. During 2011-2012, he stayed in Al Hadeer Contracting L.L.C, Abu Dhabi, UAE as HR Enginner. He is now working with Sri Krishna College of Engineering & Technology as Assistant Professor.