International Journal of Scientific & Engineering Research Volume 4, Issue3, March-2013 1
ISSN 2229-5518

Indirect Vector Controlled With Fuzzy Logic of Induction Motor

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Abstract— The paper presents a fuzzy logic speed control system based on fuzzy logic approach for an indirect vector controlled induction motor drive for high performance. The analysis, design and simulation of the fuzzy logic controller for indirect vector control induction motor are carried out based on fuzzy set theory. The proposed fuzzy controller is compared with PI controller with no load and various load condition. The result demonstrates the robustness and effectiveness of the proposed fuzzy controller for high performance of induction motor drive system. The complete control system has been developed, analyzed, and validated by simulation study using MATLAB/SIMULINK software.

KEYWORDS: Indirect Vector Control (IVC), PI Controller, Fuzzy Logic Controller (FLC), MATLAB/SIMULINK

1 INTRODUCTION

With the field orientation control (FOC) method, induction machine drives are becoming a major candidate in high-performance motion control applications, where servo quality operation is required. Fast transient response is made possible by decoupled torque and flux control. The most widely used control method is perhaps the proportional integral control (PI) [1] . It is easy to design and implement, but it has difficulty in dealing with parameter variations, and load disturbances [2].

The drive control generally involves a fixed gain proportional-integral controller [3]. However, the fixed controllers involve parameter sensitivity. Also load disturbances cause delay in settling. Hence a number of adaptive techniques have been proposed [4]-[5]. During the past many years fuzzy control has given great Impetus to active and fruitful research applications of fuzzy Set theory . A survey of FLC is presented and a general Methodology for constructing an FLC and assessing its Performance is described in [6] and [7]. Procedures and guidelines to define the input parameters and to build fuzzy logic rules are discussed comprehensively in [8]

. Also methodologies are proposed to design fuzzy logic controllers [9] - [10] . A theoretical explanation is given for the relationship between the control resolution and fuzziness of Input and output variables. The guidance for designing and tuning the scaling gains is also given. The présent paper discusses a Fuzzy Logic Based Intelligent controller. A FLC does not need appropriate mathematical algorithms. It is based on the IF_THEN linguistic rules.

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2 INDUCTION MOTOR MODELING

An Induction Motor of uniform air gap , with sinusoidal distribution of mmf is considered. The saturation effect and parameter changes are neglected.
The dynamic model of the induction motor is derived by transforming the three phase quantities into two phase direct and quadrature axes quantities. The equivalence between the three-phase and two-phase machine models is derived from the concept of power invariance. The relationship between d-q and a-b-c axes currents is given by

$$i_{ds} = \frac{2}{3} V_d (i_{as} - \frac{i_{bs}}{2} - \frac{i_{cs}}{2}) \quad (1)$$

$$i_{as} = \frac{1}{\sqrt{3}} (i_{cs} - i_{bs}) \quad (2)$$

Where ias, ibs and ics are the three phase currents and Vd is the dc link voltage at the inverter input.

3 INDIRECT VECTOR CONTROL

Indirect vector control method is depicted in the Fig. 1. It Involves the indirect estimation of the slip speed and is a feed forward method of control as compared to the direct vector control.

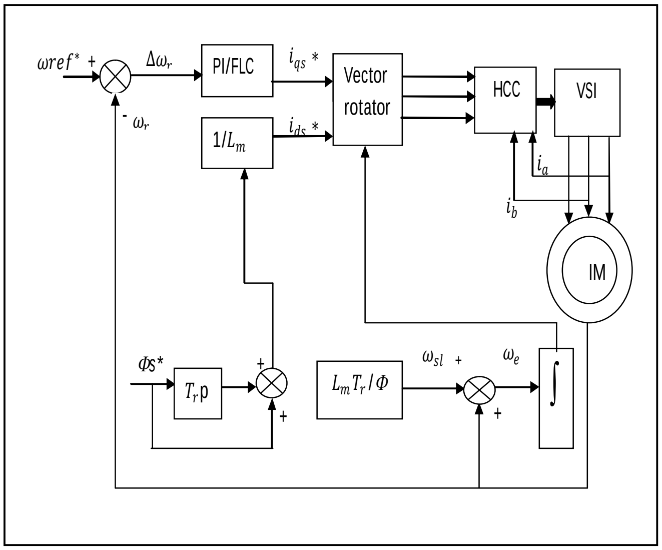

Figure 1: Indirect Vector Control Scheme

The speed error, with the help of a PI controller or any other intelligent controller, is converted into a torque controlling current component iqs*, of the stator current. This current component t is used to regulate the torque along with the slip speed [1]. The control equation which the PI controller involves is given as:

$$i^*_{qs} = k_p \Delta\omega_r + k_i \int \Delta\omega_r dt \quad (3)$$

The PI controller block model is given in Fig. 2.

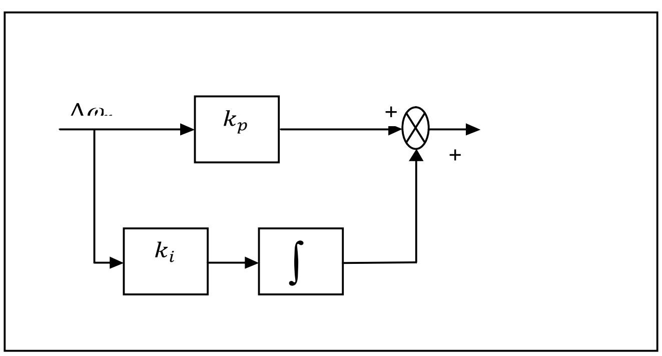

Figure 2: PI Controller block

The slip speed, together with the feedback rotor speed, is integrated to obtain the stator reference flux linkage space vector position θe

$$\theta_e = \int (\omega_{sl} + \omega_r) dt \quad (4)$$

The stator flux space vector position is used to convert the two phase dq-axes current components into the three phase currents. The currents so obtained act as reference values while the real currents from the induction motor are compared with these reference currents. The current errors are fed to two level hysteresis controllers. The hysteresis current controller allows the induction motor currents to vary within a hysteresis band such that the required performance of the machine is obtained. The flux reference is kept constant at its rated value up to the rated speed

4 Fuzzy Logic Controller

Fuzzy Logic implementation requires no exact knowledge of A model. The block diagram implementation of a FLC is shown in Fig. 3. It involves the use of the concept of fuzzy subset and rule based modeling. By permitting certain amount of imprecision, complex solutions are modeled with ease.

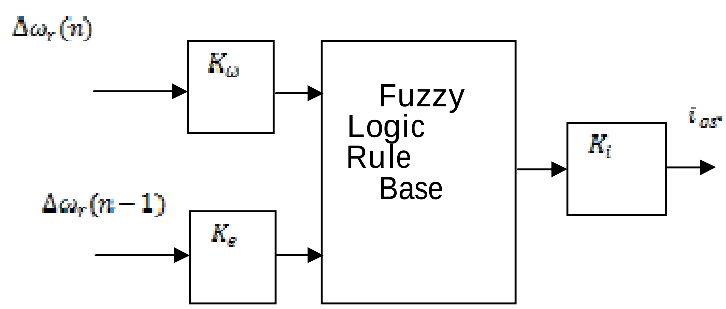

Fig 3: Fuzzy Logic Based Controller block

4.1Concept of fuzzy logic

The present fuzzy logic controller adopted is of the Mamdani Controller type [15]. The speed error and the change in the speed error are given as inputs to the FLC.

4.2 Membership function

The Fuzzy Logic Controller initially converts the crisp error and change in error variables into fuzzy variables and then are mapped into linguistic labels. Membership functions are associated with each label which consists of two inputs and one output.

The linguistic labels are divided into seven groups. They are: NH-negative high, N-Negative, NL-negative low, Z-zero, PL-

ISSN 2229-5518

positive low, P-positive, PH-positive high. Each of the Inputs and the output contain membership functions with all these seven linguistics.
This method of formulation of control algorithms allows implementing heuristic strategies [16]. A straightforward source of deriving the linguistic control strategies are human experience and understanding, which essentially contain the model of the control system in an implicit form

4.3 Knowledge rule base

The mapping of the fuzzy inputs into the required output is derived with the help of a rule base as given in Table 1. Each rule of the FLC is characterized with an IF part, called the antecedent, and with a THEN part called the consequent. The antecedent of a rule contains a set of conditions and the Consequent contains a conclusion. If the conditions of the antecedents are satisfied, then the conclusions of the consequent apply. Considering the first rule, it can be interpreted as: IF change in speed error is NH and change is speed is NH, THEN the output will be NH

4.4Defuzzification

Generally the output obtained is fuzzy in nature and has to be Converted into a crisp value by using any Defuzzification technique.

Table 1: Knowledge Rule Base

CE \ E	NH	N	NL	Z	PL	P	PH
NH	NH	NH	NH	NH	NL	NL	Z
N	NH	NH	N	N	N	Z	PL
NL	NH	N	NL	NL	Z	PL	P
Z	NH	N	NL	Z	PL	P	PH
PL	N	NL	Z	PL	PL	P	PH
P	NL	Z	PL	P	P	PH	PH
PH	Z	PL	P	PH	PH	PH	PH

5 Results and Discussions

The current response of the machine for both case i.e. PI and FLC is presented in the Fig.4 it can be see that the response of FLC is robust to load disturbance. The torque response, shown in the Fig.5. reflects the ripples are less and response in the load condition is quick for the FLC controller. Fig.6. (a)-(b) shows the results under the steady state and the transient condition i.e. from which it can be see that speed reached the rated value in very short period for the FLC controller.

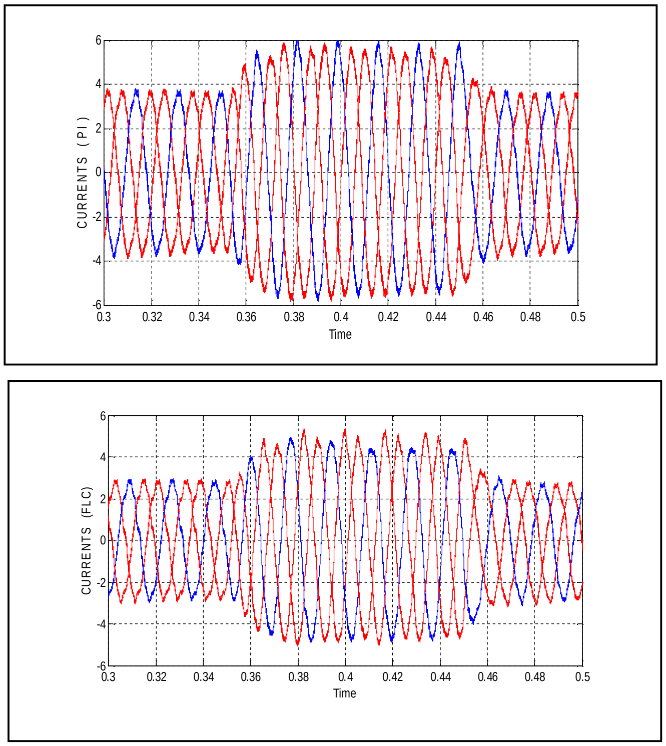

Figure 4:Stator currents response for PI and FLC.

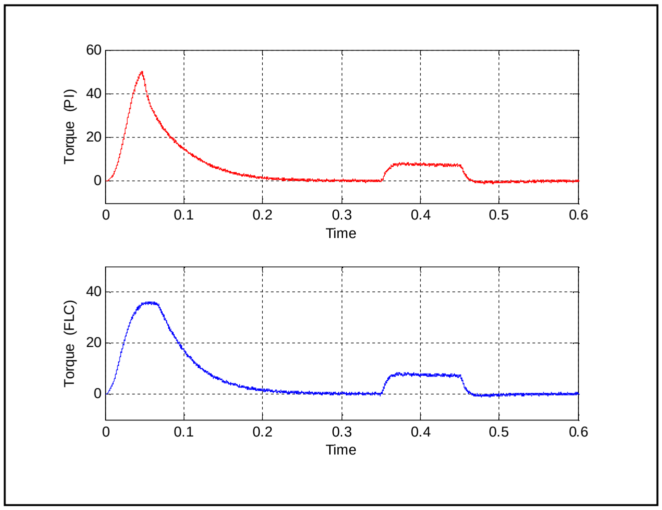

Figure 5:Torque response for PI and FLC

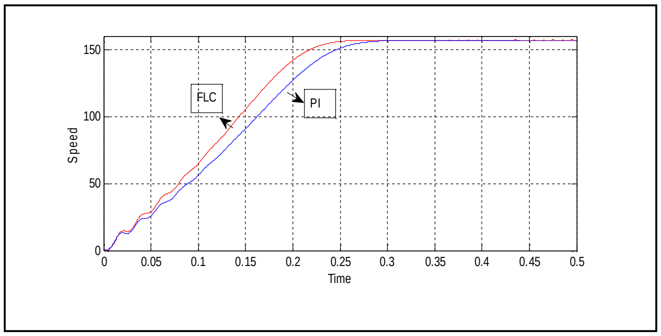

Figure 6(a) :Speed response for PI and FLC.

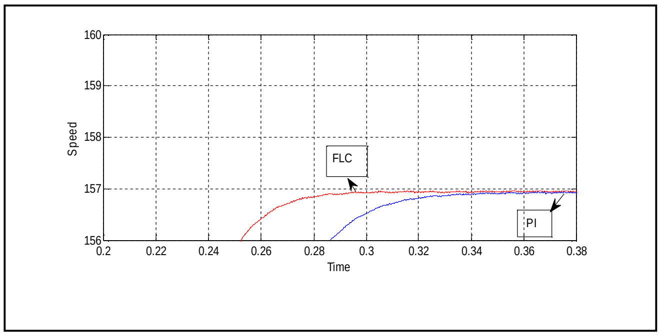

Figure 6(b) :Speed response for FLC(0.275sec) and PI(0.355sec).

6. CONCLUSION

In this paper the concept of fuzzy logic has been presented and the indirect vector controlled induction motor drive is simulated using both PI and Fuzzy Logic based controller. The results of both controllers under the dynamics conditions Are compared and analyzed. The simulation result support that the FLC settles quickly and has better performance than when PI controller.

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