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Performance of Induction Motor Drive by Indirect Vector Controlled Method using Fuzzy Logic Approach

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Abstract— The objective of the paper is to provide the precise solution for speed control of three phase induction motor for high speed variable speed drives. The performance of indirect vector control induction motor drive is enhanced using different controller & comparative performance has been presented & analyzed in this work. The proposed work includes a voltage source PWM inverter-fed indirect vector control system of induction motor. Traditional indirect vector control system of induction motor introduces conventional PI regulator in outer speed loop. Because of the simplicity and stability, it is proven that the low precision of the speed regulator debases the performance of the whole system. To overcome this problem, replacement of PI controller by an intelligent Controller based on fuzzy set theory is proposed. The Fuzzy logic controller provides an effective solution for achieving better performance compared to PI controller. The performance of the intelligent controller is designed and simulated through digital simulation using MATLAB-SIMULINK under varying operating conditions. The simulation results demonstrate that the performance of the proposed controller is better than that of the conventional PI controller.

Key words: Induction motor drives, PI controller, Fuzzy logic, intelligent controllers, Indirect vector control

I. INTRODUCTION

For the development of the vector control techniques, Induction motors have been used more in the industrial variable speed drive system. Though the variable speed drives increase the automation and productivity as well. With the approach of the vector control method, an induction motor has been easily controlled like a separately excited DC motor for high performance applications. Dynamic performance is mandatory for superior performance of electric drives, so for the changes in command speed and torques, the response to these changes is necessary. These AC drives requirements can be fulfilled by the vector control system.

For the choice of a motor, Speed control is one of the best assorted application imposed constraints. Hence, it has been studied by many and various methods in the last few years and for the same have been developed. However, the highly non-linear nature of the induction motor control dynamics demands strenuous control algorithms for the control of speed. The traditional indirect vector control system uses conventional PI controller in the outer speed loop because of the simplicity and stability. However, unexpected change in load conditions or environmental factors would produce overshoot, oscillation of motor speed, oscillation of the torque, long settling time and thus causes deterioration of drive performance.

The PI controller offers a very efficient solution to numerous control problems in the real world. If PI controllers are tuned properly, they can provide a robust and reliable control. This very feature has made PI controllers exceedingly popular in industrial applications. The only problem associated with use of conventional PI controllers is speed control of induction motors is the complexity in design arising due to the non-linearity of Induction Motor dynamics. The conventional controllers have to linearise the non-linear systems in order to calculate the parameters. In order to obtain a perfect non-linear model is almost impossible. To overcome this, an intelligent controller based on Fuzzy Logic can be used in the place of PI regulator. The fuzzy logic has certain advantages compared to classical controllers such as simplicity of control, low cost, and the possibility to design without knowing the exact mathematical model of plant.

The Fuzzy Logic Controller (FLC) owes its popularity to linguistic control. Here, an exact mathematical model for the system to be controlled is not required. Hence, Fuzzy logic basically tries to replicate the human thought process in its control algorithm. The FLC has thereby proven to be very beneficial in the industries as it has the proficiency to provide complex non-linear control to even the uncertain nonlinear systems. In addition to the aforementioned attributes, a fuzzy logic controller also makes good performance in terms of stability, precision, reliability and rapidity achievable. When a new control strategy of a converter or a drive system is formulated, it is often convenient to study the system performance by simulation before building the breadboard or prototype. The simulation not only validates the systems operation, but also permits optimization of the systems performance by iteration of its parameters. Besides the control and circuit parameters, the plant parameter variation effect can be studied. Valuable time is thus saved in the development and design of the product, and the failure of components of poorly designed systems can be avoided.

The complete paper is organized as follows: section 2 describes the indirect vector control system & the design and description of intelligent controller is provided. The simulation results are presented in section 3 .Conclusion in section 4.

II. METHODOLOGY

A. Concept of Indirect Vector Control Strategy:

Vector control is a method of speed control where both magnitude and phase alignment of vector variables can be controlled. The vector control method is classified into two types, such as direct vector control method and indirect vector control method .In direct vector control method field angle is calculated by terminal voltage and current or hall sensor or flux sensing windings. The Indirect Vector Control method is used in this proposed scheme, in this method field angle is calculated by rotor flux position or with motor parameters but not voltage or current variables .Indirect vector control method is a fast dynamic response and speed response without cogging or torque pulsations at low speed, smooth speed reversal under any torque conditions.

The proposed project focuses the speed control of three phase induction motor drive based on fuzzy logic controller compared with PI controller. This includes a voltage source PWM inverter-fed indirect vector control system of induction motor.

The Block Diagram shows the Indirect Vector Control Strategy for Induction Motor

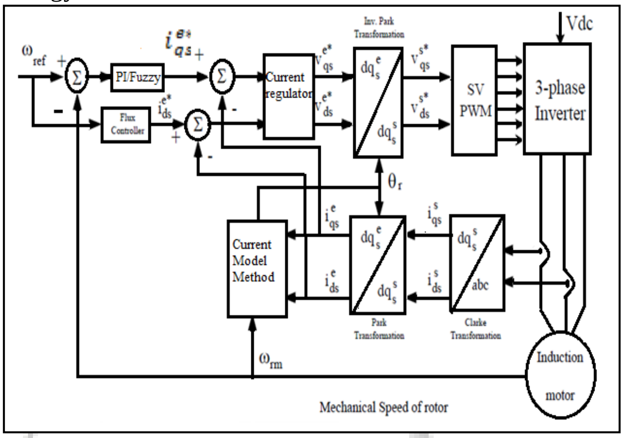


Fig. 1: Indirect Vector Control Scheme For Induction Motor

In indirect vector control method, the rotor flux and torque can be separately controlled by the stator direct-axis current *ids* and quadrature –axis current *iqs* respectively. The indirect method is based on the calculation of the slip speed, required for correct field orientation. However, in the implementation of field-oriented control, *ids* and *iqs* in the stationary reference frame is known. So, to know the angular position of the rotor flux to transform *ids* and *iqs* from the excitation frame to the stationary frame.

1) By using slip frequency ω_{slip},actual rotor speed rotor ω_{rm},flux position θ_r is obtained.

$$\theta_r = \int (\omega_r\, dt) = \int (\omega_{rm} + \omega_{slip})dt = \theta_{rm} + \theta_{sl}$$

2) The rotor flux linkage given by

$$\varphi_r = \frac{L_m\, i_{ds}}{1 + \tau_r S}$$

Where $\tau_r = \frac{L_r}{R_r}$ is the rotor time constant

3) The direct axis stator current excitation frame $i_{ds}^{e*}$is given by

$$i_{ds}^{e*} = \frac{|\varphi_r^*|}{L_m}$$

The induction motor drive with vector or field oriented control offers a good dynamics performance and the closed-loop control provide the long term stability of the system. Induction Motor drives are used in a multitude of industrial and process control applications requiring high performances. In high-performance drive systems, the motor speed should closely follow a specified reference trajectory regardless of any load disturbances, parameter variations, and model uncertainties. In order to achieve high performance, field-oriented control of induction motor (IM) drive is employed. However, the controller design of such a system plays a crucial role in system performance. The decoupling characteristics of vector-controlled IM are adversely affected by the parameter changes in the motor So the vector control is also known as an independent or decoupled control.

B. PI Controller:

A controller in the forward path, which changes the controller output corresponding to the proportional plus integral of the error signal.

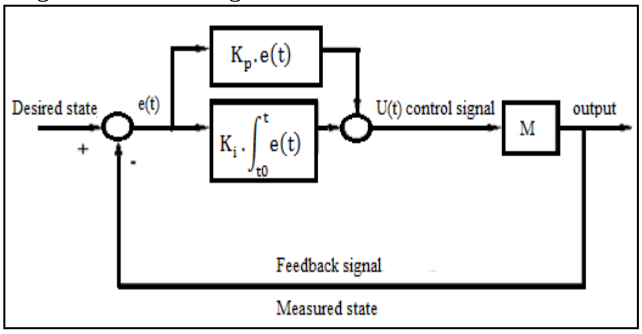


Fig. 2: Block Diagram of PI Controller

Output of PI controller is given by

$$U(t) = K_p.e(t) + K_i.\int_{t0}^{t} e(t) \quad \text{and}$$

Transfer Function $K_p + \frac{K_i}{s}$

In this project complete mathematical model of FOC induction motor is described and simulated in MATLAB/SIMULINK for 50 HP (37KW) induction motor has been considered. The performance of FOC drive with proportional plus integral (PI) controller are presented and analyzed. As order increases, system relatively becomes less stable as Ki must be designed in such a way that the system remains in stable condition. so that to maintain the stability of the system. Second order system is always stable. Steady state error reduces tremendously for some type of inputs.

PI controller can be tuned by trial and error tuning method. There is systematic way of changing PI parameters. Initial value of Kp gain is started, where Ki=0.when Kp had a large value, the faster rise time and an increase in overshoot occur. To improve on the effect of Kp, an additional Ki value is also set to a small value. Adding integral gain had a great effect on reducing steady state error.

C. Fuzzy Logic Controller

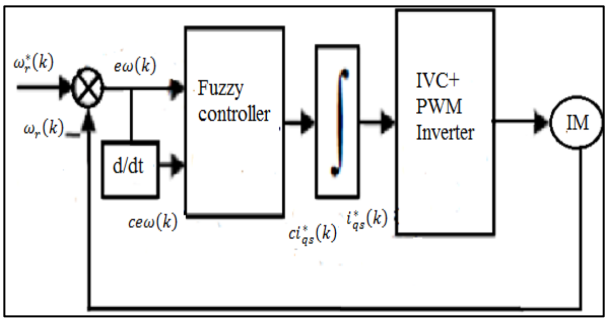


Fig. 3: Block Diagram of Fuzzy Logic Speed Control System For IVCIM

Fig3 shows an Indirect Vector Control Method of induction motor for the controller of fuzzy logic. It consists of a slip frequency calculation, Inverter, Voltage and Current sensing Elements, integrator of error speed signal Speed sensor element.

The fuzzy logic controller block in Fig 3 consists:

1) Input & output variables

2) Fuzzification
3) Fuzzy Inference Engine & Knowledge base
4) Defuzzification

The fuzzy logic controller takes in crisp inputs, viz. speed error and change in error and gives an output called change in control. The output of the fuzzy logic speed controller is the variation of command current, which is integrated to get reference command current. The next stage is fuzzification, here the crisp variables are converted in to fuzzy variables and then the knowledge bases involves defining the rules and governing the relationship between input and output variables, these variables are processed by an inference engine called fuzzy inference engine and final stage so called defuzzification, here crisp values of the output variables is obtained .and also the reference value of command current is applied to vector control system.

The design of a Fuzzy Logic Controller requires the choice of Membership Functions. The membership functions should be chosen such that they cover the whole universe of discourse. After the appropriate membership functions are chosen, a rule base should be created. It consists of a number of Fuzzy If-Then rules that completely define the behavior of the system.

Input Linguistic Variables:

The inputs to the Fuzzy Logic Controller are:

1) Speed Error (e).
2) Change in Error (ce) or derivative of speed error.

Rule Base Design for the Output :

The Rule Base for deciding the output of the inference system consists of 49 If-Then rules in this case since there are 7 fuzzy sets in each of the inputs. The table representing the rule base of fuzzy logic is as follows.

(e) speed error / (ce) change in error	NL	NM	NS	ZE	PS	PM	PL
NL	NL	NL	NM	NM	NM	NS	NS
NM	NL	NM	NM	NS	NS	NS	ZE
NS	NM	NM	NS	NS	ZE	ZE	PS
ZE	NM	NS	ZE	ZE	PS	PS	PM
PS	NS	ZE	PS	PS	PM	PM	PL
PM	ZE	PS	PS	PM	PM	PL	PL
PL	ZE	PS	PM	PM	PL	PL	PL

Table 1: Fuzzy Controller Rules

The Fuzzy Logic Controller is therefore designed and rule based inputs and the outputs are verified. Hence designing of the Fuzzy Logic Controller is now complete. This FIS file can now be loaded into the Fuzzy Logic Controller in the MATLAB/SIMULINK® and the simulation can be run. The controller can be refined accordingly to get the desired result during the simulation.

III. MATLAB SIMULATION RESULT & ANALYSIS

The simulation tests are carried out on indirect vector controlled induction motor drive using PI controller for various operating condition. The time response and steady state error were analyzed.

Fig 4 shows the simulation result of indirect vector control of three phase induction motor using PI-controller and the plots for reference speed ,theta, rotor speed and electromagnetic torque using PI Controller were observed.

The following are the waveform of simulated indirect vector control method of three phase induction motor using PI controller is shown.

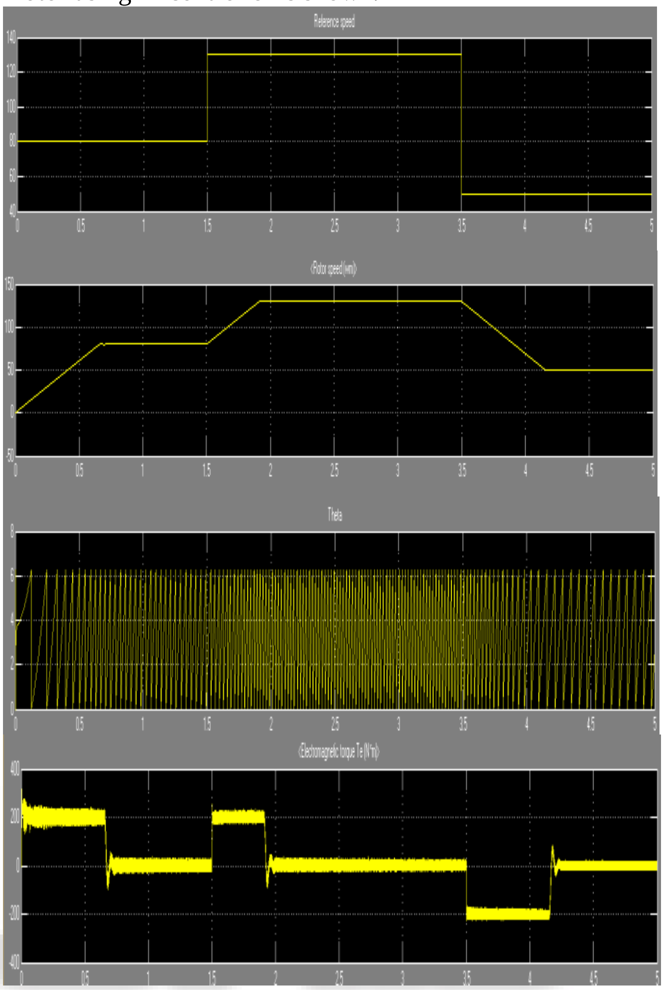
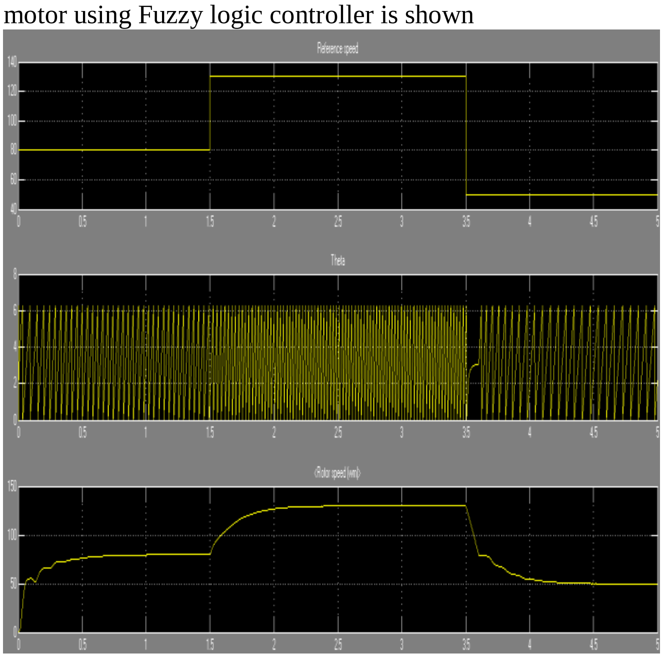


Fig. 4: Waveform of Reference speed, Rotor speed, Theta and Electromagnetic Torque is Simulated Indirect Vector Control Of Three Phase IM using PI-Controller.

The following are the waveform of simulated indirect vector control method of three phase induction motor using Fuzzy logic controller is shown



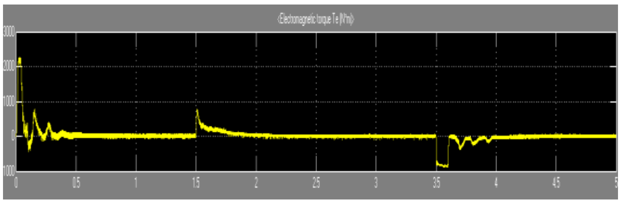


Fig. 5: Waveform of Reference speed, Rotor speed, Theta and Electromagnetic Torque is Simulated Indirect Vector Control of Three Phase IM using Fuzzy logic Controller

The following table represents the comparison between PI & fuzzy logic controller with set time, reference speed & steady state response time or settling time as well.

Controllers	PI Controller			Fuzzy Logic Controller		
Set Time (sec)	0	1.5	3.5	0	1.5	3.5
Reference speed (rad/sec)	80	130	50	80	130	50
Settling time (sec)	0.7	1.9	3.7	0.3	1.7	3.3

Table 2: Comparison between PI &FLC

IV. CONCLUSION

The proposed project is complete mathematical model of field orientation control induction motor is described and simulated in MATLAB for a 50 HP(37KW), cage type induction motor has been considered. The proposed control systems use fuzzy logic controller to enhance the performance of induction motor drives & also helps to achieve precision in control. From the SIMULINK results obtained it is observed that the Fuzzy logic controller shows better performance than the PI controller.

V. FUTURE ENHANCEMENT

Hardware implementation can be carried out for the above method with the desired values. For tuning the controller; different strategies like genetic algorithms can be used and can easily be adopt a neuro-fuzzy logic controller instead of just fuzzy controller so as to achieve desirable result

REFERENCE

[1] M. N. Uddin, T. S. Radwan, and M. A. Rahman, “Performances of Fuzzy-Logic-Based Indirect Vector Control for Induction Motor Drive”, IEEE Transactions On Industry Applications, Vol. 38, No. 5, pp. 1219-1225, Sept./Oct. 2002.
[2] F. Biaschke, “ The principle of field oriention as applied to newtransvector closed loop control system for rotating field machine,” Siemens Rev, vol. 34,,pp 217-220’may 1972
[3] P. Vas, and J. Li, “Simulation Package for Vector Controlled Induction Motor Drives”, Oxford University press, 1993
[4] J. C. Hung, “Practical Industrial Control techniques”, in Proc. IEEE IECON’94, pp. 7-14.
[5] Miki, N. Nagai, S. Nishigama, and T. Yamada, “Vector control ofinduction motor with fuzzy PI controller”, IEEE IAS Annu. Meet. Conf. Rec., pp. 342-346, 1991.
[6] W. P. Hew, M. R. Tamjis, and S. M. Saddique, “Application of FuzzyLogic in Speed Control of Induction Motor Vector Control”, Proc. Ofthe international conference on Robotics, vision and Parallel Processingfor Industrial Automation, pp. 767-772, Ipoh, Malasiya, Nov. 28-30,1996
[7] E. Cerruto, A. Consoli, A. Raciti and A. Testa, “ Fuzzy Adaptive VectorControl of Induction Motor Drives”, IEEE Trans, on Power Electronics,Vol.12, No. 6, pp. 1028-1039, Nov. 1997.
[8] B. Hebetler, L. Xu, and Y.Tang, “Fuzzy Logic Enhanced Speed Controlof Indirect Field Oriented Induction Machine Drive”, IEEE Trans. OnPower Electronics, Vol.12, No.5. pp. 772-778, Sept.1997.
[9] G. C.D. Sousa, B.K. Bose and J.G. Cleland, “Fuzzy Logic based On-Line Efficiency Optimization Control of an Indirect Vector Controlled Induction Motor Drive”,IEEE Trans. On Industrial Electronics, Vol.42, No. 2 , pp.192-198, April 1995.
[10] Minh Ta-Cao, J. L. Silva Neto and H. Le-Huy, “Fuzzy Logic based Controller for Induction Motor Drives”, Canadian Conference on Electrical and Computer Engineering, Volume 2, Issue, 26-29 May 1996 Page(s):631 - 634 vol.2.