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RESEARCH ARTICLE

Efficiency Improvement of Three Phase Induction Motor Using Artificial Intelligent Technique

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Abstract

Induction Motors have many applications in the industries because of the low maintenance and robustness of induction motors. Most of these applications need fast and smart speed control system. This work presents efficiency maximization of three phase induction motor based on Fuzzy logic approach for an indirect vector controlled motor 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. Induction Motor is modelled in synchronous reference frame in terms of dq form. In order to achieve maximum performance and energy saving the efficiency maximization of Induction Motor is the main issue. This work introduces efficiency maximization by reducing the core losses. The model is carried out using Matlab/Simulink computer package. The simulation results show the superiority of the fuzzy logic controller in controlling three-phase induction motor with indirect field oriented control technique.
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1. Introduction

The induction motor is considered since its discovery as actuator privileged in the applications of constant speed, and it has lots of advantages, such as less cost, high efficiency, good self starting, easy to design. But, induction motor has disadvantages, such as complex, nonlinear, and complex mathematical model of induction motor,and the induction motor is not inherently capable of providing variable speed operation. These disadvantages can be solved through the use of good motor controllers and adjustable speed controllers, such as scalar control drive and vector control drive. In FOC the magnitude, frequency and instantaneous change of voltage, current and flux linkage vector are controlled and valid for steady state as well as transient conditions. FOC is a technique that provides a method of decoupling the two components d and q of stator current: one corresponds to the air gap flux and the other producing the torque respectively. Conventional control of an induction motor is difficult due to its strong nonlinear magnetic saturation effects and temperature dependency of the motor's electrical parameters. As the conventional control technique require a complex mathematical model of the motor to develop controllers for quantities like speed, torque, and position. so, to avoid the inherent undesirable characteristics of conventional control approaches, Fuzzy Logic Controller (FLC) is being introduced. FLC gives a linguistic approach to develop control algorithms for any system. It maps the input-output relationship based on human expertise and so, FLC does not require an accurate mathematical model of the system and can handle the nonlinearities . This consequently makes the FLC tolerant to parameter variation and more accurate and robust. In many applications efficiency optimization of induction motor (IM) which is the most used electrical motor presents an important factor of control especially for autonomous electrical traction. In high dynamic performance control schemes used in industrial applications like vector control and direct torque control, the flux is usually maintained constant equal to its nominal value; in this situation the induction motor run efficiently around the nominal point. When the load is reduced considerably, the efficiency is also greatly reduced and the electrical energy consumption is highly affected. The very extensive use of induction motor implies that if losses in Induction Motor drives can be reduced by just a few percent, it will have a major impact on the total electrical energy consumption, so designing the control technique for lower load is necessary for improving the overall performance of the drive. When overall performance of induction motor improves then the overall efficiency of the drives also will increase. This will help in saving electric energy. There is some advantage of fuzzy logic controller as compared to conventional PI, PID and adaptive controller such as it does not require any mathematical model and it is based on linguistic rules within IFTHEN structure, which is related to the human logic.

In this paper the design of fuzzy logic controller of indirect vector control of induction motor for the efficiency maximization has been investigated.

2. INDUCTION MOTOR MODEL

In general, for any arbitrary value of θ, the transformation of stator ABC phase variables [F_{ABC}] to d,q stator variables [F_{Odq}] is carried out through Park transform from the equivalent circuit shown in figure 1.Thefollowing modeling equations can be developed.

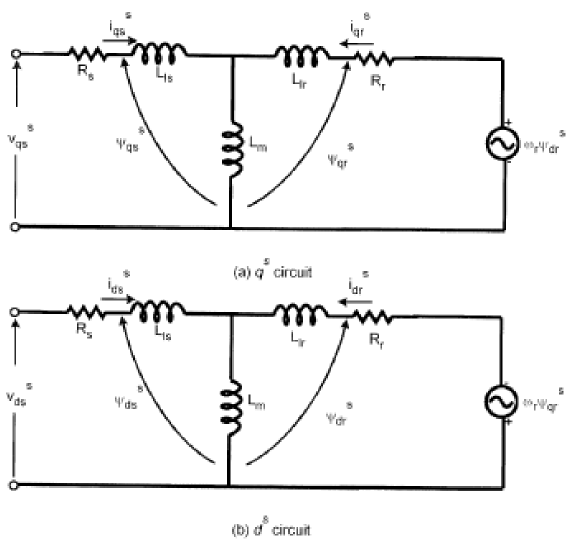

Fig 1. d^s**-** q^s **equivalent circuit**

$$\frac{di_{ds}}{dt} = -\frac{\left(L^2{}_m R_r + L_r{}^2 R_s\right)}{aL_s L^2{}_r} i_{sr} + \frac{L_m R_r}{aL_s L^2{}_r}\psi_{qr} + \frac{PL_m}{2aL_s L_r}\psi_{dr}\omega_r + \frac{V_{ds}}{aL_s}$$

$$\frac{di_{qs}}{dt} = -\frac{\left(L_m{}^2 R_r + L_r{}^2 R_s\right)}{aL_s L_r{}^2} i_{ds} + \frac{L_m R_r}{aL_s L_r{}^2}\psi_{dr} - \frac{PL_m}{2aL_s L_r}\psi_{qr}\omega_r + \frac{V_{qs}}{aL_s}$$

$$\frac{d\psi_{dr}}{dt} = \frac{L_m R_r}{L_r} i_{ds} + \frac{R_r}{L_r}\psi_{dr} - \frac{P}{2}\psi_{qr}\omega_r$$

$$\frac{d\psi_{qr}}{dt} = \frac{L_m R_r}{L_r} i_{qs} - \frac{R_r}{L_r}\psi_{qr} + \frac{P}{2}\psi_{dr}\omega_r$$

$$\frac{d\omega_r}{dt} = \frac{3PL_m}{4L_r J}\left(\psi_{dr} i_{qs} - \psi_{qr} i_{ds}\right) - \frac{T_l}{J} - \frac{B\omega_r}{J}$$

$$\frac{dT_e}{dt} = \frac{3PL_m}{4L_r}\left(\psi_{dr} i_{qs} - \psi_{qr} i_{ds}\right)$$

3. Fuzzy Logic Controller For Induction Motor

The block diagram of flux control system using fuzzy logic controller (FLC) is shown in Figure 2 Here the first input is the error in ids and second is the integral of error '$\int edt$' at sampling time 't_s'. The input variable $e(t_s)$ is calculated at each sampling time as,

$$i_{ds}^{*} - i_{ds}$$

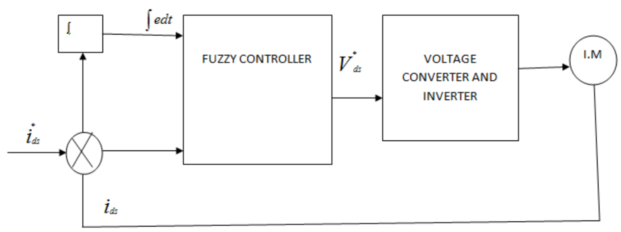

Fig 2 block diagram of Fuzzy Logic Control system

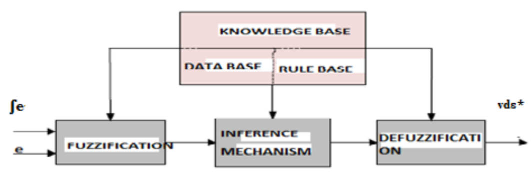

Fig .3 Internal structure of fuzzy logic controller

FL requires some numerical parameters in order to operate such as what is considered significant error and significant rate-of-change-of-error, but exact values of these numbers are usually not critical unless very responsive performance is required in which case empirical tuning would determine them. The above figure shows the block diagram of fuzzy logic control system. In this a Fuzzy controller block and a voltage converter and inverter block is included. The Fuzzy controller block includes the Fuzzification, Inference mechanism, Defuzzification blocks are included. The knowledge base or data base gives the information for this block. There will be a Fuzzy rule base it generates the rules. Where '$\int edt$' denotes the integral square of error 'e', $i_{ds}^{*}(t_s)$ is the reference stator d axis current, $i_{ds}(t_s)$ is the actual current. The output variable is the change in V_{ds}^{*} which is to be given to the converter inverter set. As shown in Figure.3, the fuzzy logic controller has four blocks, Fuzzification, inference mechanism, knowledge base and Defuzzification.

A. Fuzzifications:

In this stage the crisp variables of input e(ts) and ∫e (ts)are converted into fuzzy variables. The fuzzification process maps the error and Integral Square of error into linguistic labels of fuzzy sets. Membership function is assigned to each label with triangular shape, which has two inputs and one output. The following linguistic labels are used for error VS, S, M, L, VL are used and for integral square of error MN,N,Z,P,MP are used by the proposed controller. With all these five linguistics each of the inputs and output contain membership function.

B. Knowledge base and inference stage:

Knowledge base defines the rules represented as IF-THEN rules statements giving the relationship between input and output variables in terms of membership functioning this stage the input variables $e(t_S)$and $\int edt\,(t_S)$are processed by then inference mechanism that executes 5*5 rules represented in the rule table. By considering the first rule, it is represented as IF integral square error is MN and change in ids that is error is VS, THEN the output will be S.Here Mamdani's algorithm is used for inference mechanism used.

C. Defuzzification:

To produce fuzzy set value for the output fuzzy variable, defuzzification introduces different methods. Here the centre of gravity or centroids method is used to compute the final fuzzy value. In Defuzzification using COAmethod gives crisp output which is obtained by using centre of gravity. The following figures shows the membership function for the input variable1.Here triangular membership functions are used for input1, input2,and output.

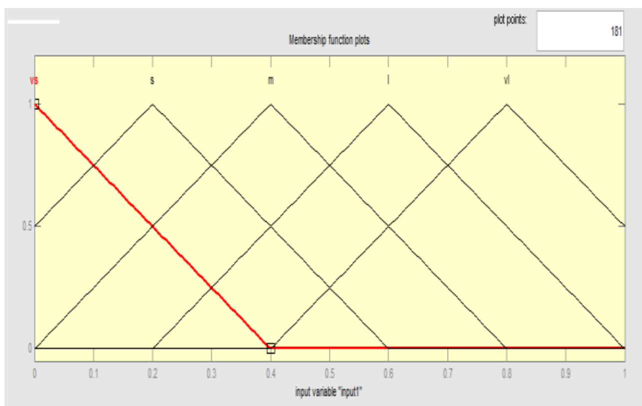

Fig.4 Triangular Member ship function for input variable

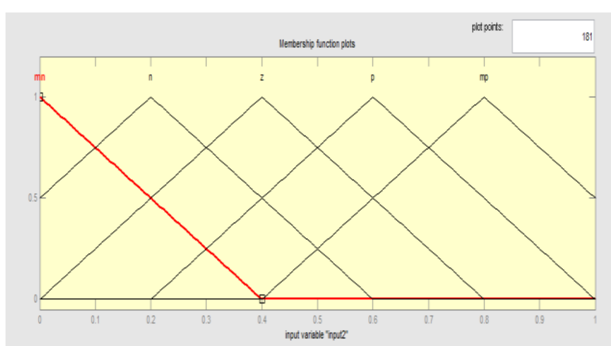

Fig.5 Triangular Member ship function for input variable 2

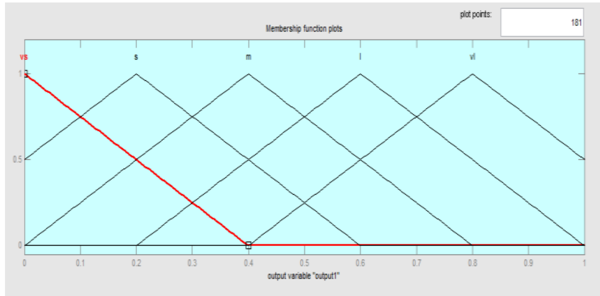

Fig.6 Triangular Member ship function for output

The fuzzy logic is an aggregation of rules, based on the input state variables condition with a corresponding desired output. According to the optimization principle, two input variables are considered flux current component I_{ds} and its integral variation. The output of the fuzzy controller is the V_{ds}^{*}, which is calculated to minimize iron losses.

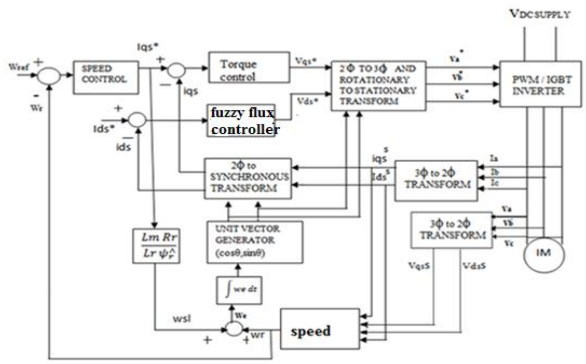

Fig.7 Block diagram of the indirect vector control system

A simplified block diagram of the optimization procedure is depicted in Fig7. Here the speed from the motor is compared with a reference speed ω_r^* and the error is fed to a PID controller that controls the speed and the output will be i_{qs}*,The i_{qs}* is compared with i_{qs} and error is fed to the torque controller and the output of the torque controller is v_{qs} that is given to the converter inverter set and the motor. Here the ids* is compared with the ids and the error is given to the fuzzy controller and the fuzzy controller produces new idsref ,from that v_{ds}* is generated and it is given to the inverter and then to the motor .So, here by controlling the ids we can control the flux, that means we can control the flux density. If we can control the flux we can control the core loss. And we can achieve maximum efficiency. The following Table 1 shows the Rule Base considered for the improvement of efficiency by minimizing the iron losses.

		ERROR				
		VS	S	M	L	VL
DISE	MN	S	M	L	VL	VL
	N	S	M	M	L	VL
	Z	S	S	M	L	L
	P	VS	S	M	M	L
	MP	VS	VS	S	M	L

Table 1 Fuzzy rule base

Power	3HP
Poles	2 No
Stator resistance	3.3 Ω
Rotor resistance	2.2Ω
Statorselfinductance	0.33 H
Rotorself inductance	0.33 H
Mutual inductance	0.286H
Moment of inertia	0.0007 SI

Table 2 Induction Motor parameters

4. SIMULATION DIAGRAMS AND RESULTS

The control system block diagram shown in fig7 is simulated for induction motor in the MATLAB/Simulink environment. The simpower system is used for this modeling work. The advantage of the Simpower system is that it has extensive libraries for machine and power electronics circuits.

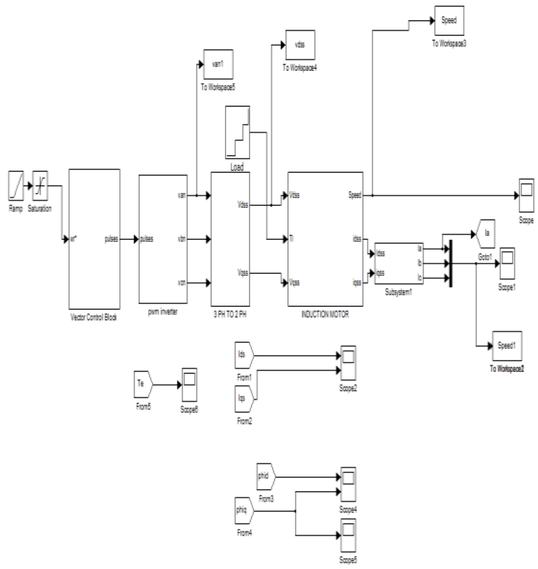

Fig.8 Indirect vector control system

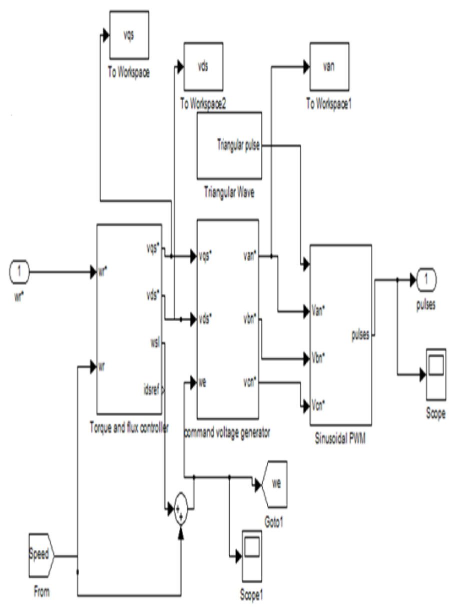

Fig. 9 Vector control block

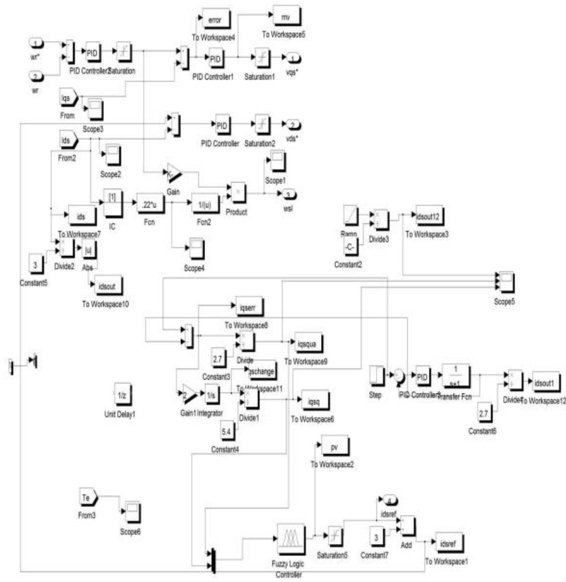

Fig. 10 Torque and flux controller

Simulation tests were carried out on indirect vector controlled induction motor drive using fuzzy logic based intelligent controller for various operating conditions.

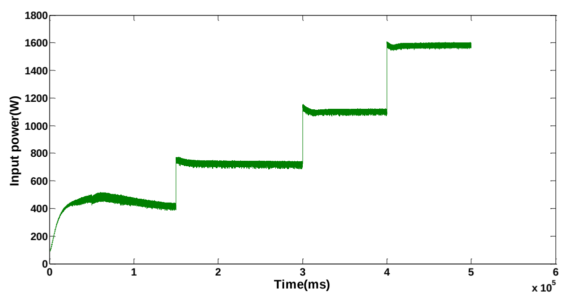

Fig. 11 Total input power

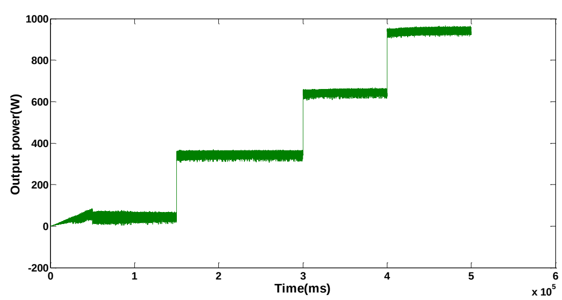

Fig. 12 Total Output Power

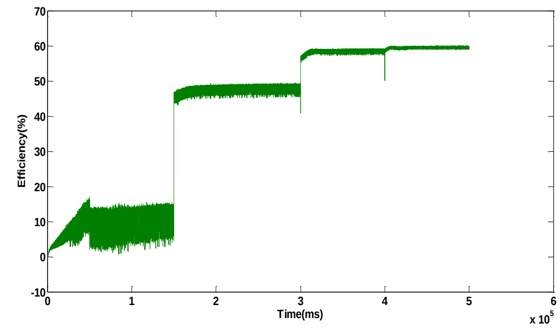

Fig. 13 Efficiency

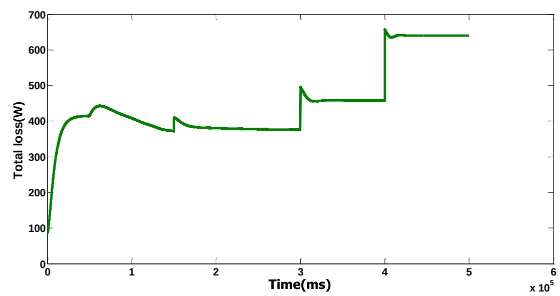

Fig. 14 Total Losses

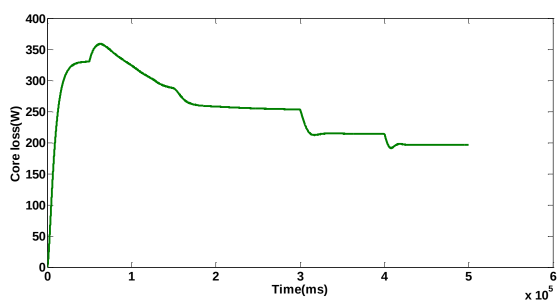

Fig. 15 Core Loss

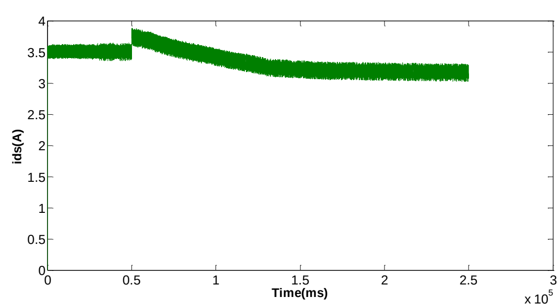

Fig. 16 Stator d axis current

The simulation results include the plot of efficiency, core loss, copper loss, power output, and total losses are included. From the results we can see that by using Fuzzy controller i_{ds} can be controlled. And by controlling the i_{ds}

the flux can be controlled. Here we can see that core losses are reduced at different load conditions. So the efficiency is also improved. Here the efficiency obtained is 67%.

5. CONCLUSION

This paper has presented a fuzzy-based scheme for induction motor drive leading to energy saving. The proposed scheme uses information on speed and torque of the motor to generate the appropriate voltage amplitude that saves the energy. A fuzzy-based model has been configured using a Matlab simulink. Implementation of Fuzzy controller for efficiency improvement next results is obtained: Less torque ripple with flux changes, Less drive sensitivity to load perturbations, Electromagnetic torque margin is controlled so better control Characteristics are obtained, Total power losses are reduced especially when motor works with lower loads.

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