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Fuzzy Logic Controller Vs Pi Controller for Induction Motor Drive

KEYWORDS fuzzy logic controller, Induction motor, PI controller, speed control

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ABSTRACT *The paper presents a novel fuzzy logic controller for closed loop Volts/Hz induction motor drive system. Basically, in this paper the motor drive system comprises a voltage source inverter-fed induction motor (VSIM): namely a three-phase voltage source inverter and the induction motor. The squirrel-cage induction motor voltage equations are based on an orthogonal d-q reference rotating frame where the coordinates rotate with the controlled source frequency. Fuzzy logic is a part of artificial intelligence(AI), which is an important branch of computer science or computer engineering. The inputs to the fuzzy logic controller are the linguistic variables of speed error and change of speed error, while the output is change in switching control frequency of the voltage source inverter. In this paper a comparison between fuzzy logic controller and traditional PI controllers are presented. The results validate the robustness and effectiveness of the proposed fuzzy logic controller for high performance of induction motor drive. Simulink software that comes along with MATLAB was used to simulate the proposed model.*

I INTRODUCTION

Simulink induction machine models are available in the literature [1-2], but they appear to be black boxes with no internal details. Some of them in [1-2] recommend using S functions, which are software source codes for Simulink blocks. This technique does not fully utilize the power and ease of Simulink because S-function programming knowledge is required to access the model variables. Another approach is using the Simulink Power System Block set [3] that can be purchased with Simulink. This block set also makes use of S-functions and is not as easy to work with as rest of the Simulink blocks. Reference [4] refers to an implementation approach similar to the' one in this paper but fails to give any details. In this paper, a modular, easy to understand Simulink induction motor model is described. With the modular system, each block solves one of the model equations. Though induction motors have few advantageous characteristics, they also posse's nonlinear and time-varying dynamic interactions [5 6], Using conventional PI controller, it is very difficult and complex to design a high performance induction motor drive system. The fuzzy logic control (FLC) is attractive approach, which can accommodate motor parametric variations and difficulty in obtaining an accurate mathematical model of induction motor due to rotor parametric and load time constant variations. The FLC is a knowledge-based control that uses fuzzy set theory and fuzzy logic for knowledge representation [7]. This paper presents a novel fuzzy logic controller suitable for speed control of induction motor drives.

II. INDUCTION MOTOR MODEL

One of the most popular induction motor models derived from this equivalent circuit is Krause's model [6]. An induction machine model can be represented with four differential equations. To solve these equations, they have to be rearranged in the state-space. form, X=Ax+b Where X=[Fqs FdsFdr Fdr w r] T is the state vector.

$$\frac{dFqs}{dt} = \omega b\left[vqs - \frac{\omega e}{\omega b}Fds + \frac{Rs}{Xls}(Fmq + Fqs)\right] \text{.....(1)}$$

$$\frac{dFds}{dt} = \omega b\left[vds + \frac{\omega e}{\omega b}Fqs + \frac{Rs}{Xls}(Fmd + Fds)\right] \text{.....(2)}$$

$$\frac{dFqr}{dt} = \omega b\left[vqr - \frac{(\omega e - \omega r)}{\omega b}Fdr + \frac{Rr}{Xlr}(Fmq - Fqr)\right] \text{.....(3}$$

$$\frac{dFdr}{dt} = \omega b\left[vdr + \frac{(\omega e - \omega r)}{\omega b}Fqr + \frac{Rr}{Xlr}(Fmd - Fdr)\right] \text{.......(4)}$$

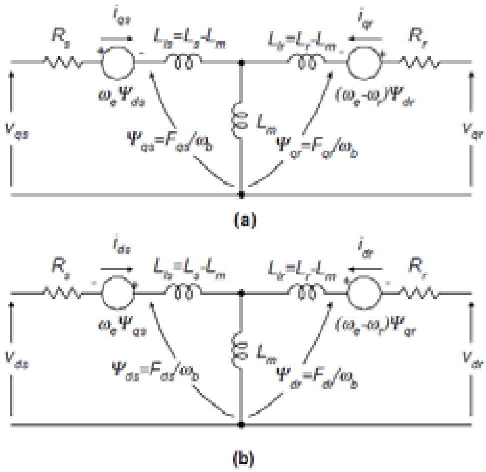
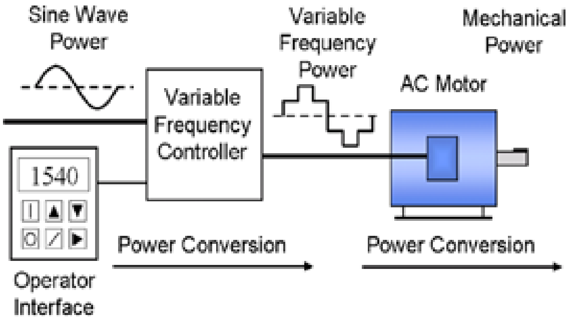


Fig 1 Dynamic or d-q equivalent circuit of an induction Machine

Where d : direct axis,
q : quadrature axis,
s : stator variable,
r : rotar variable,
vqs, vds : q & d axis stator voltages,
vqr, vqr : q&d axis rotar voltages,
Fmq,Fmd : q& d axis magnetizing flux linkages
Rr : rotor resistance,
Rs : stator resistance,
Xls : stator leakage reactance (we Lls),
Xlr : rotor leakage reactance (we Llr)

VFD MOTOR:

The motor used in a VFD system is usually a three-phase induction motor. Some types of single-phase motors can be used, but three-phase motors are usually preferred. Various types of synchronous motors offer advantages in some situations, but induction motors are suitable for most purposes and are generally the most economical choice. Motors that are designed for fixed-speed operation are often used. Certain enhancements to the standard motor designs offer higher reliability and better VFD performance, such as MG-31 rated motors.



III SIMULINK IMPLEMENTATION

The inputs of a squirrel cage induction machine are the three-phase voltages, their fundamental frequency, and the load torque. The outputs, on the other hand, are the three phase currents, the electrical torque, and the rotor speed.

The d-q model requires that all the three-phase variables be transformed to the two -phase synchronously rotating frame Consequently, the induction machine model will have blocks transforming the three-phase voltages to the d-q frame and the d-q currents back to three-phase

The induction machine model implemented in this paper is shown in Fig. 2. It consists of five major blocks: the o-n conversion, abc-syn conversion, syn-abc conversion, unit vector calculation, and induction machine d-q model blocks.

The following subsections will explain each block

A. O-N Conversion Block:

This block is required for an isolated neutral system, otherwise it can be bypassed. The transformation done by this block can be represented as follows:

$$\begin{bmatrix} v_{an} \\ v_{bn} \\ v_{cn} \end{bmatrix} = \begin{bmatrix} +\frac{2}{3} & -\frac{1}{3} & -\frac{1}{3} \\ -\frac{1}{3} & +\frac{2}{3} & -\frac{1}{3} \\ -\frac{1}{3} & -\frac{1}{3} & +\frac{2}{3} \end{bmatrix} \begin{bmatrix} v_{ao} \\ v_{bo} \\ v_{co} \end{bmatrix} \qquad (5)$$

B. Unit Vector Block Calculation

Unit vectors cos$_{\theta}$e and sin$_{\theta}$e are used in vector rotation blocks, "abc-syn conversion block" and "syn-abc conversion block". The angle θe is calculated directly by integrating the frequency of the input three-phase voltages, *ωe.*

$$\theta e = \int \omega e \; dt. \qquad (6)$$

The unit vectors are obtained simply by taking the sine and cosine of *Be'* This block is also where the initial rotor position can be inserted, if needed, by adding an initial condition to the Simulink "Integrator" block. Note that the result of the integration in (6) is reset to zero each time it reaches*2n* radians so that the angle always varies between 0 and *2n.*

C. abc-syn conversion block:

To convert three-phase voltages to voltages in the two phase synchronously rotating frame, they arc first converted to two-phase stationary frame using (7) and then from the stationary frame to the synchronously rotating frame using

$$\begin{bmatrix} v_{qs}^{s} \\ v_{ds}^{s} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & -\frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} \end{bmatrix} \begin{bmatrix} v_{as} \\ v_{bs} \\ v_{cs} \end{bmatrix} \qquad (7)$$

$$\begin{Bmatrix} v_{qs} = v_{qs}^{s} \cos\theta_e - v_{ds}^{s} \sin\theta_e \\ v_{ds} = v_{qs}^{s} \sin\theta_e + v_{ds}^{s} \cos\theta_e \end{Bmatrix}$$

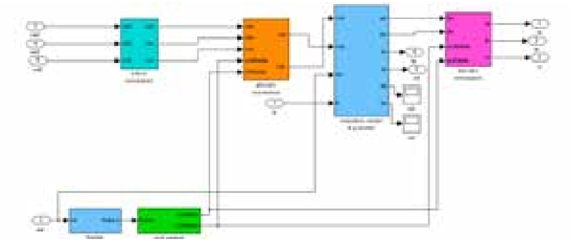
where the superscript "s" refers to stationary frame

D. syn-abc conversion block:

This block does the opposite of the abc-syn conversion block for the current variables using (5) and (6) following the same implementation techniques as before.

$$\begin{Bmatrix} i_{qs} = v_{qs} \cos\theta_e + v_{ds} \sin\theta_e \\ i_{ds} = -v_{qs} \sin\theta_e + v_{ds} \cos\theta_e \end{Bmatrix} \qquad (9)$$

$$\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{qs}^{s} \\ i_{ds}^{s} \end{bmatrix} \qquad (10)$$



E.Induction machine d-q model block

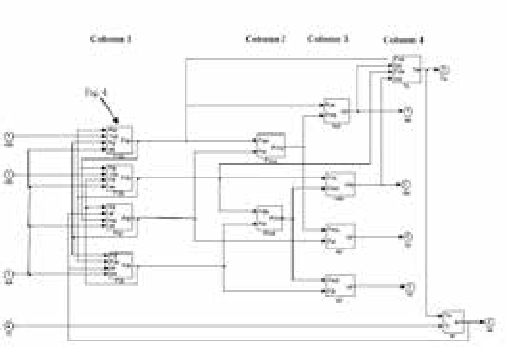


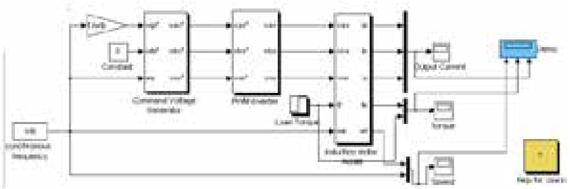
Fig.3 Induction machine dynamic model implementation

The resulting model is modular and easy to follow. Any variable can be easily traced using the Simulink 'Scope' blocks. The blocks in the first two columns calculate the flux linkages, which can be used in vector control systems in a flux loop. The blocks in Column 3 calculate all the current variables, which can be used in the current loops of any current control system and to calculate the three-phase currents. The two blocks of Column 4, on the other hand, calculate the torque and the speed of the induction machine, which again can be used in torque control or speed control loops, These two variables can also be used to calculate the output power of the machine.

III. OPEN-LOOP CONSTANT *V/HZ* OPERATION

Fig. 4 shows the implementation of open-loop constant V*1Hz*control of an induction machine. This figure has two new blocks: command voltage generator and 3-phase PWM inverter blocks. The first one generates the three-phase voltage commands, and it is nothing more than a "syn-abc" block explained earlier.

The latter first compares the reference voltage, Vref to the command voltages to generate PWM signals for each phase, then uses these signals to drive three Simulink "Switch" blocks switching between +V*J2* and -*Vd/2* (Vd: dc link voltage). The open-loop constant V/Hz operation is simulated for 1.2s ramping up and down the speed command and applying step load torques.



IV. CLOSED LOOP CONSTANT V/Hz OPERATION

The closed loop circuit has the fuzzy logic controller as the new component. The inputs to the fuzzy logic controller are the speed error and rate of change of speed error. The output is fed to the power converter-pwm inverter, which is used to adjust the inverter switching control frequency. The output of FLC controls the firing angle of the inverter, thereby varying the output voltages. The reference speed of the pwm inverter is modified each time when there is a different output of the fuzzy controller. These outputs are found from the truth table (rule table). The pwm inverter output is then fed to the induction machine where a constant V/Hz operation is carried out.

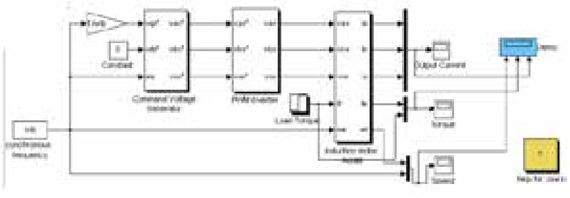


Fig.4.Open loop V/Hz Operation

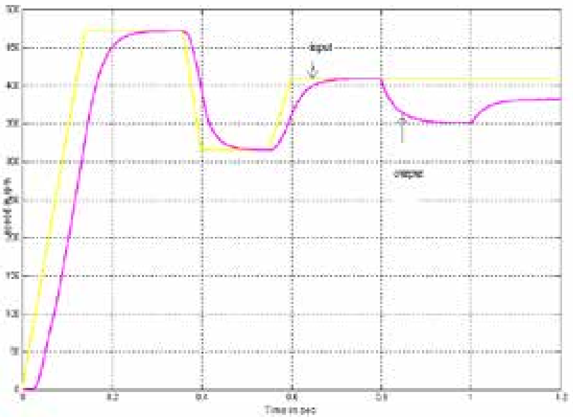


Fig 5 Speed v/s time for Open Loop constant V/ Hz

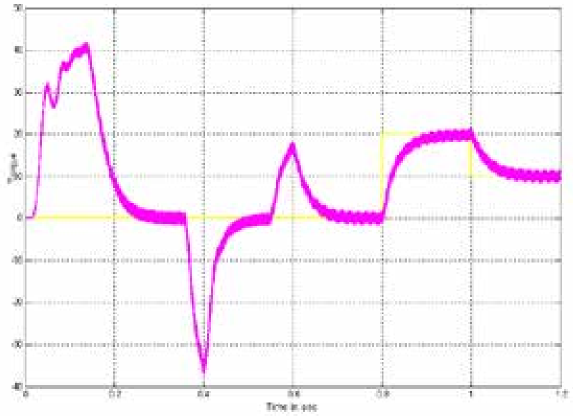


Fig 6 Torque v/s Time open loop constant V/Hz

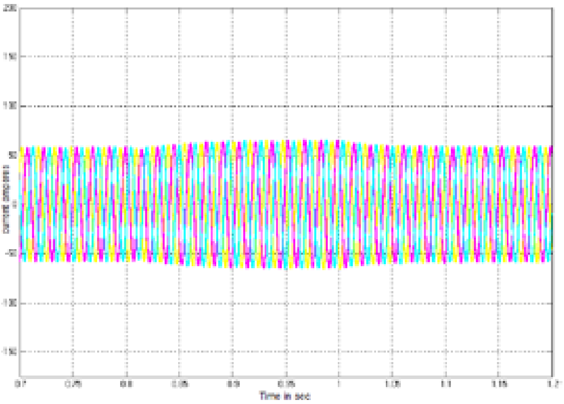


Fig 7 Current v/s Time open loop constant V/Hz

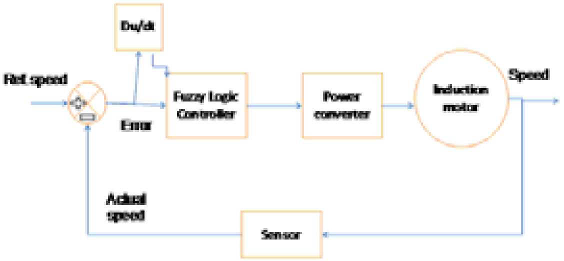


Fig 8 Block diagram of closed loop using fuzzy logic controller

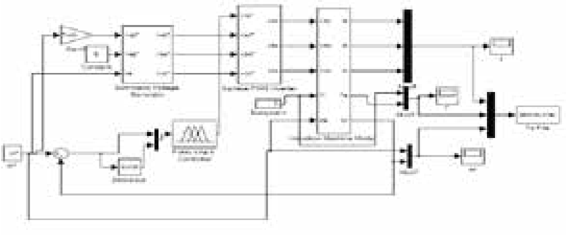


Fig.9 Closed Loop constant V/Hz control using fuzzy logic controller

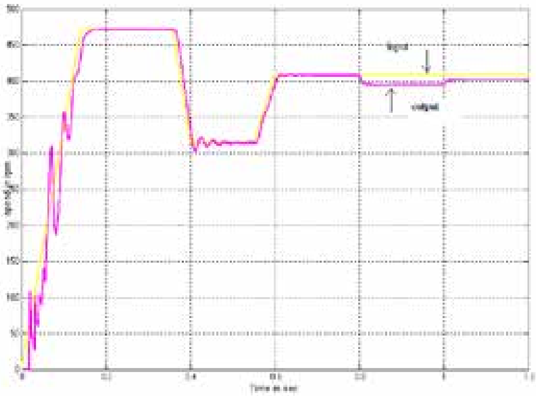


Fig10 Speed v/s Time for Closed Loop constant V/Hz with fuzzy logic controller

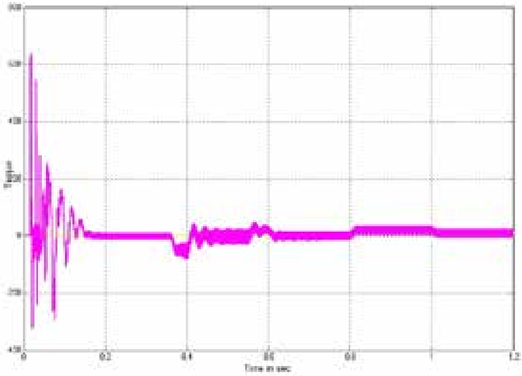


Fig11 Torque v/s time for closed loop V/Hz using Fuzzy logic controller

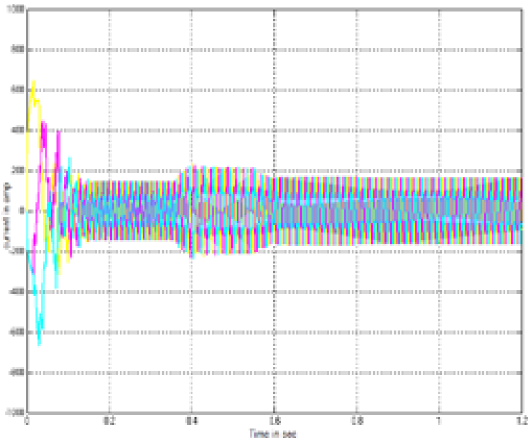
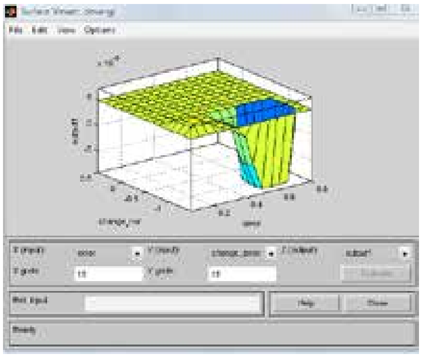


Fig 12 Current v/s Time for Closed Loop constant V/Hz control with fuzzy controller

V. FUZZY LOGIC CONTROLLER DESIGN

The fuzzy logic controller has been designed using the fuzzy logic GUI provided in Matlab As shown above we have the three FIS variables: Error, change in error and the out put.for each of the following we defind the ranges from the data obtained and then we use the triangular membership function and have such member functions for each FIs

SURFACE VIEWER



FUZZYLOGIC CONTROL ALGORITHM

A fuzzy algorithm consists of situation and action pairs. Conditional rules expressed in IF and THEN statements are generally used. For example, the control rule might be:

if the output is lower than the requirement and the output is dropping moderately then the input to the system shall be increased greatly. Such a rule has to be converted into a more generally statement for application to fuzzy algorithms. To achieve this the following terms are defined: error equals the set point minus the process output, error change equals the error from the process output minus the error from last output: and control input applied to the process. In addition, it is necessary to quantize the qualitative statements and the following linguistic sets are assigned

The membership function are:

NG= Negative biG

NP= Negative small

Z= Zero

PP= Negative

PG= Negative big

TRUTH TABLE

e→ Δe↓	NG	NP	Z	PP	PG
NG	NG	NG	NP	NP	Z
NP	NG	NP	NP	Z	PP
Z	NP	NP	Z	PP	PP
PP	NP	Z	PP	PP	PG
PG	Z	PP	PP	PG	PG

VII. CONCLUSION

This paper presents a simple, novel and robust fuzzy logic speed controller for high performance induction motor drives. The control assignment rules are obtained using heuristic trial and error and human expertise.

REFERENCE [1] P. C. Krause, Analysis of Electric Machinery ,McGraw-Hill Book Company, 1986 f71L.A.Zadeh,"Outlineof a New Approach to the Analysis of Complex Systems and Decision Processes", IEEE Trans. Systems, Man, and Cybernetics,No.3, PP.28-44,1973. | [2] N.T. M. Mohan Undeland and W.P.Robbins, "Power Electronics Converter, Applications and Design" john Wiley & Sons Inc. Canada, 1989. | [3] L. Tang, M. F. Rahman, "A new direct torque control strategy for flux and torque ripple reduction for induction motors drive – a Matlab/Simulink model," IEEE International Electric Machine and Drives Conference,2001,pp.884-890. | [4] Bimal K. Bose,Modern Power Electronics and AC Drives, Prentice Hall, 2002. | [5]. P. C. Krause, Analysis of Electric Machinary, McGraw-Hill Book Compeny,1986 | [6] Burak Ozpineci, Leon M.Tolbert "Simulink Implementation of Induction machine model-A Modular approach@ 2003IEEE | [7] G.J .Klir and T.A .Floger, "Fuzzy SaUncertainty and 1nformation"Prentice Hall, Englewood Clifi,New Jney,U.S.A., 1988. | [8] L. Huibing and Y.C.Hong, "A New Variable-Speed System with Fuzzy Identification and Fuzzy Control". Proc.International Power Engineering Conference March 18-19 1993 Singapore | [9] Y.F.Li,and C.C.Lau, "Development of Fuzzy Algorithm for Servo Systems",IEEE Contr.Syst. Mag.Vol. 9 , NO. 3, PP.65-72, 1989. | [10] R.M.HiUoowala and A.M.Sharaf "A Rule Based Fuzzy Logic Controller for PWM Inverter in A Stand alone Energy Conversion Scheme", IEEE-IAS 93. Industly Applications ,Society Conference Toronto, Canada,Oct2-8,1993 |