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Speed Control of Three Phase Squirrel Cage Induction Motor Using Fuzzy Logic Controller.

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ABSTRACT-
This paper present the scalar speed control of three phase squirrel cage induction motor .In this scalar control method both input and output command are speed. PI and fuzzy logic controller are operated according to speed error to utilize the advantages of both controllers .In fuzzy logic controller two input and one output is used in control operation. Speed of the motor is adjusted by Fuzzy logic controller (FLC) with the help of predefined rules for input and output of fuzzy controller. Two inputs to the FLC are error and change in error. Its output is frequency of AC input of the motor. The control scheme keeps voltage and frequency ratio of induction motor constant. The voltage and frequency input to the induction motor are control in order to obtain desired speed response. This proposed fuzzy controller utilizes the advantages on PI controllers. The simulation results proved that the fuzzy controller performance is superior due to fast response under reference speed and load torque variations. They are comparing in terms of maximum overshoot and settling time with PI and fuzzy controllers.
KEYWORDS –Induction motor, PI controller, and fuzzy logic controller, scalar control Method V/F Control, MATLAB/ SIMULINK

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I INTRODUCTION

An induction or asynchronous motor is a type of AC motor where power is supplied to the rotor by means of electromagnetic induction, rather than a commutator or slip rings as in other types of motor**.** The distinguishing feature of an induction motor is that no DC field current is required to run the machine [1-3]. These motors are widely used in industrial drives, particularly polyphase induction motors, because they are rugged and have no brushes.

Their speed is determined by the frequency of the supply voltage, so they are most widely used in constant-speed application.

The use of induction motor has increased tremendously since the day of its invention. They are used as actuators in various industrial process, robotics, and house appliances. The use of this motor is associated with its simple and rugged construction, low cost, minimum maintenance, and sufficiently high speed. Speed control is one of the various imposed constraints for the choice of a motor. Hence, in the last few year it has been studied by many, and various method for the same have been developed. Various types of adjustable speed AC motor drives have been developed over the years depending upon control principal, drive can be classified as scalar controlled or vector controlled[4][5].

Several studies are going on in the field of vector control due to better dynamic response. However, Scalar control is widely used in industries because of its simple structure characterized by low steady-state error. Vector control method is very complex. However scalar control method is very simple and can achieve low steady state error. Therefore, scalar control based on constant V/F ratio is used in this work. The field of power electronics has contributed immensely in the form of voltage frequency converts which has made it possible to vary the speed over a wide range [6][7]. However, the highly non –linear nature of induction motor control dynamics demand strenuous control algorithm for the control of speed. The controllers types that are used are: proportional integral (PI), fuzzy logic controller (FLC) or a blend between them.FLCs have the ability to adapt with nonlinearity. Also, the control performance is less affected by plant parameter variations.

FLCs are based on certain well defined linguistic rules Fuzzy logic controller can work under non-linear condition. Performance of fuzzy controller is analyzed and explains with the rule.

This paper starts with introduction which describes about three phase induction motor, the control technique and the two controllers PI and FLC which is used for motor controlling. The 2 section explain about the system overview of three phase induction motor and it's controlling by scalar control method. The 3 section shows space vector model of induction motor and electrical system equation .The 4 section consist of different speed control technique of 3 phase induction motor. The 5 section explain about voltage frequency control. The 6 section explain about fuzzy logic controller and how the fuzzy controller is design. The 7 section shows the simulation result of speed control of three phase induction motor by PI and fuzzy logic controller. The 8 section explain conclusion and references at the last.

II SYSTEM OVERVIEW

The speed control of induction motor is shown by the block diagram in fig 1.The frequency and supply voltage of induction motor is varied such that it operates at steady state at desired speed. In scalar control method, both the input and output command are speed, unlike the vector control where it is torque/flux and reference current respectively.

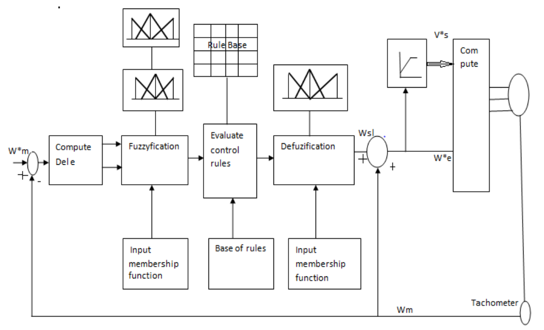

Figure 1 Block diagram of the scalar IM control with fuzzy logic controller

As shown in block diagram w_m^* is chosen as reference signal. The use of speed as reference signal justified as the o/p of the system is speed. A techo-generator, attached to the shaft of induction motor, provides the current speed of the motor w_m. Which is compared with reference speed w_m^* . Thus providing us with the speed error **(e).**change-of-errorΔe,that is the derivative of speed error is computed and both error and change in error are; **e and** Δe are fed to the fuzzifier for Fuzzyfication.

The inference system then processes these two fuzzy inputs using the fuzzy control rules and the database, which are defined by the programmer based on the chosen membership function and fuzzy rule table, to give an output fuzzy variable. The fuzzy output thus obtained is defuzzified by the defuzzifier to give a crisp value, i.e. change-of-control (w_{sl}). This $w_{sl}$is then added to the motor speedw_m.which in turn forms the input to $w_e^*$to the voltage source inverter and V/F controller.

Nomenclature

$\bar{v}$ = voltage space vector [V]	$\omega_{m=}$ rotor speed [rad/s]
$\bar{\iota}$ = current space vector [Wb]	$T_{E=}$ electromagnetic torque[N.m]
$\bar{\lambda}$ = flux linkage space vector[Wb]	$T_{L=}$ load torque [N.m]
R = resistance [Ω]	J = Moment of inertia [kg.m^2]
L = Inductance [H]	P= number of poles
$f_{0=}$ base frequency [Hz]	r = inverse of inductance [H^{-1}]
$\omega_{0=}$ base frequency [rad/s]	
$\omega_{k=}$ speed of dq frame [rad/s]	

III SPACE VECTOR MODEL OF INDUCTION MOTOR

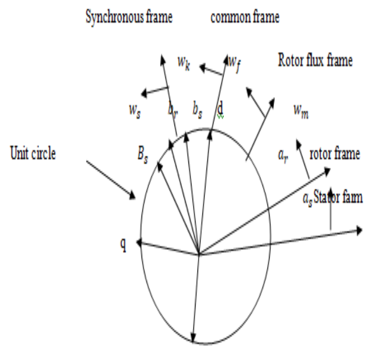

figure. 2Reference frame in induction machine analysis

The relationship between the speed of induction motor and synchrnous speed is given by

n=(1–s) n_s (1)

n_s =120f /p (2)

ELECTRICAL SYSTEM EQUATION

$v_{s} = R_S i_S + \frac{d\overline{\lambda s}}{dt} + w_k M\overline{\lambda s}$ (3)

$v_r = R_r \overline{\iota r} + \frac{d\overline{\lambda r}}{dt} + (\omega_k - \omega_m)$ (4) (4)

Flux linkage – current relations

$\lambda s = L_S \bar{I}_S + L_m \bar{I}_r$ (5)

$\bar{I}_S = r_s\, \lambda s + r_m\, \overline{\lambda s}$ (6)

$\overline{\lambda s} = L_m \bar{I}_S + L_r \bar{I}_r$ (7)

$\bar{I}_r$ = - $r_m\, \overline{\lambda s}$ ++ $r_m\, \overline{\lambda r}$ (8)

$L_S = L_m + L_{Sl} L_r = L_m + L_{rl}$ (9)

$r_s = \frac{L_r}{\Delta}$ (10)

$r_r = \frac{L_s}{\Delta}$ (11)

$r_m = \frac{L_m}{\Delta}$ (12)

$\Delta = L_m + L_{Sl} + L_m + L_{rl} + L_{sl} + L_{rl}$ (13)

Mechanical system equation

$T_e = J\frac{d\omega mec}{dt} + B_m\, \omega mec + T_L$ (14)

$T_e = k(\overline{\lambda s} \otimes \bar{I_S}) = k(M\overline{\lambda s}.\bar{I_S}) = k(\bar{\lambda}_{ds}\bar{\iota}_{qs} - \bar{\lambda}_{qs}\bar{\iota}_{ds})$ (15)

Te = $k(\bar{\iota s} \otimes \bar{\lambda}_S) = k\, L_m\, (\bar{I_r} \otimes \bar{I_s}) = k\,\frac{lm}{lr}$

$(\bar{\lambda}_r \otimes I_s) = k r_m\, (\bar{\lambda}_r \otimes \bar{\lambda} s)$ (16)

$\omega mec = \frac{2}{P}\omega m$ k= $\frac{3}{2}\frac{P}{2}$

IV SPEED CONTROL TECHNIQUE

1 voltage frequency control
2 stator voltage control
3 rotor resistance control
4 slip power recovery
5 pole changing

5. V/F Control method

The Volts/Hertz control is basically a scalar control technique where only the magnitudes of the control variables are varied (in this case, voltage and frequency). Scalar control, though easier to implement than vector control, provides inferior dynamic performance[9][10].The former cannot operate at peak performance under dynamically varying loads.In variable-speed applications in which a small variation of motor speed with loading is permissible, scalar control scheme can produce satisfactory performance.From the torque speed curve it can be seen that the same torque at the same value of slip speed will be obtained if we operate at constant air gap flux this , in fact , is the basis for constant volts/hertz control of an induction motor[11].

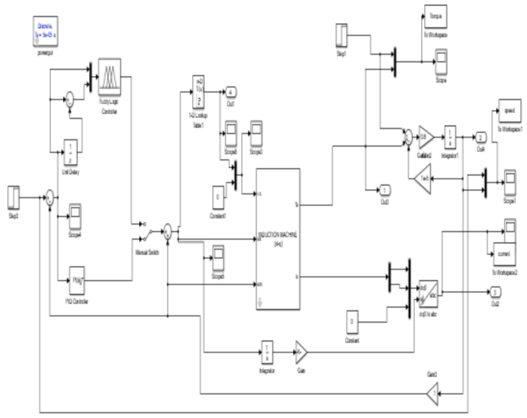

Figure 2 Complete simulink model

V FUZZY LOGIC CONTROLLER

Fuzzy logic controller is excellent controller as it can work under non-linear condition[6-8]. Fuzzy logic controller process work as human thinking. The inputs to the Fuzzy logic controller are speed error and change in error. The output is frequency of the AC input of the motor. The design of a Fuzzy Logic Controller requires the choice of fuzzy sets and Membership Functions .

The membership functions should be chosen such that they cover the whole universe of discourse[12]. It should be taken care that the membership functions overlap each other. This is done in order to avoid any kind of discontinuity with respect to the minor changes in the inputs. To achieve finer control, the membership functions near the zero region should be made narrow. Wider membership functions away from the zero region provides faster response to the system. Hence, the membership functions should be adjusted accordingly. After the appropriate membership functions are chosen, a rule base should be created.

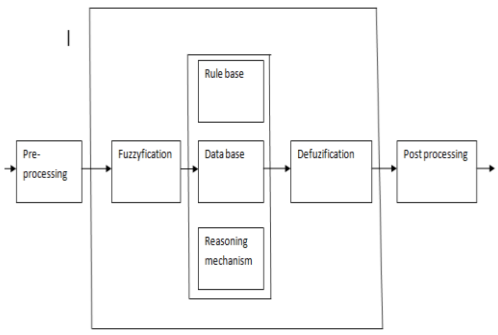

Fig 3 fuzzy logic controller structure

Table -1 Fuzzy Rule Base

Δe|e	NL	NM	NS	ZE	PS	PS	PL
NL	NL	NL	NLM	NM	NMS	NS	ZE
NM	NL	NLM	NM	NMS	NS	ZE	PS
NS	NLM	NM	NMS	NS	ZE	PS	PM
ZE	NM	NMS	NS	ZE	PS	PMS	PM
PS	NMS	NS	ZE	PS	PMS	PM	PLM
PM	NS	ZE	PS	PMS	PM	PLM	PL
PL	ZE	PS	PMS	PM	PLM	PL	PL

VI SIMULATION AND RESULT.

The simulated result shows that the plot for speed cuurrent and torque using both PI and fuzzy logic controller. It shows the speed versus time plot with reference speed varying from 0.425 to 0.825 and the torque versus time plot with refrence torque varying from 0.250pu to 0.50pu.

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Table II Parameter of induction motor

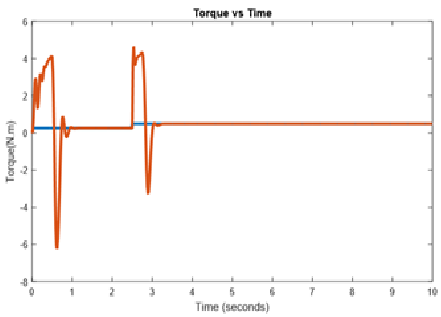
Stator resistance = 0.030 pu	Base frequency = 100Π rad/sec
Rotor resistance = 0.018 pu	Number of poles = 2
Stator leakage inductance =0.12 pu	Moment of inertia = 0.6 pu
Rotor leakage inductance = 0.02 pu	Viscous fricition coefficient = 1e-5 pu
Magnetizing inductance = 3.1pu	

Table-III PI parameter

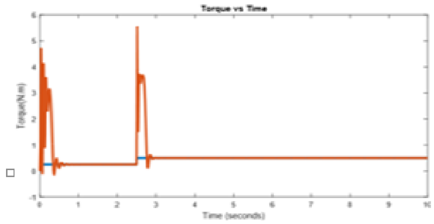
Proportional constant	0.6
Integral constant	5.6
Saturation limit	1.32

when speed and torque varying with refrence speed

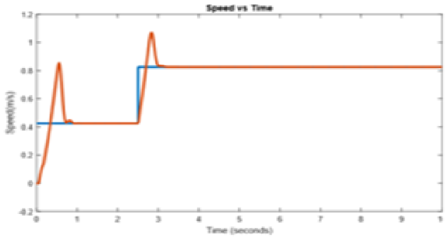
Torque versus time with refrence speed varying from 0.250pu to 0.500pu with PI controller.



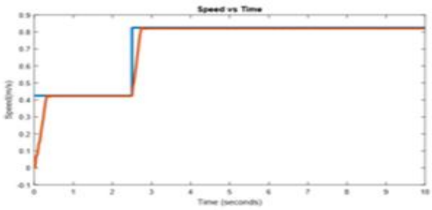
Torque versus time with refrence speed varying from 0.250pu to 0.500pu with fuzzy controller



Speed vesus time with refrence speed varying from 0.425pu to 0.825pu with fuzzy controller



Speed vesus time with refrence speed varying from 0.425pu to 0.825pu with fuzzy controller



Current with PI controller

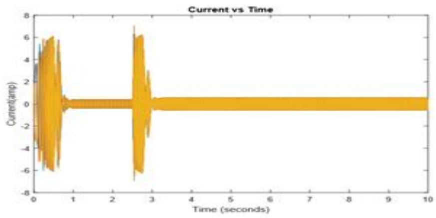


Table IV –Controller response parameter

PI controller	Overshoot	Settling time
Torque	4.65	3.5
Speed	1.06	3.4

Fuzzy controller	Overshoot	Setting time
Torque	5.55	3.15
Speed	0.82	2.95

VII CONCLUSION

The fuzzy logic controllers that are used in this simulation has advantage along with some drawback.The drawback is that in torque vs time characterstics the max overshoot with fuzzy controllers is greater as compared to the PI controllers. The advantages is that the settling time decreases with fuzzy in torque vs time and speed vs time. in this simulation we have taken trapezoidal and triangular membership function for input and output.In order to refine the control and get better result we can chose gaussian membership function.

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