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A Fuzzy Based Speed Controller for Induction Motor Drive

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Abstract

Induction motor is widely used in all industrial application. When given supply at required specification it runs at rated speed. Most of the applications demand variable speed. So it becomes a mandatory to provide variable speed induction motor. There are various techniques available to accomplish this requirement. Here in this paper we provide a fuzzy based speed control for induction motor using a dsPIC controller.

Keywords: Space Vector Pulse Width Modulation (SVPWM), Fuzzy Logic Controller (FLC), digital signal Peripheral Interface Controller (dsPIC).

I. INTRODUCTION

Ac motor drives are most widely utilized in industrial application which requires high performance [2,4]. Variable speed Induction Motor (IM) demands both wide operating range of speed and expeditious torque replication, irrespective of load variations. This calls for more advanced control methods to meet the authoritative ordinances.

The conventional control techniques include methods like frequency control, voltage control [1,2]. These methods workout well for less precision in speed control, but when more precision and expeditious replication is needed, advance control techniques are required.

Artificial Astuteness is a emerging technology which provides promising results in the area of advance control methods[8]. Control methods which employs artificial astuteness is termed as intelligent control. Intelligent control can be sub-divided into 2 categories: Hard computation and Soft computation [10]. Expert system falls under

hard computation which has been the first artificial keenly intellective technique. Soft computation technique include the following methods,
1. Artificial Neural Network (ANN)
2. Fuzzy Logic Set (FLS)
3. Fuzzy-Neural Network (FNN)
4. Genetic Algorithm Based system (GAB)
5. Genetic Algorithm Assisted system (GAA)

Fuzzy logic is a form of multi-valued logic; it deals with reasoning that is inexact rather than exact. Fuzzy logic is a technology which can impersonate human cognitive thinking and derive conclusions. Fuzzy controller is designed to mimic human control logic.

In this paper artificial intelligence technique in specific fuzzy logic is applied to control the speed of induction motor. Vector control of motor is employed in particular indirect vector control of induction motor is used here and its explained in section II. Switching is done by means of Space vector pulse width modulation which is explained in section III. Section IV deals about fuzzy logic controller and section V about the design of fuzzy logic controller. Section VI explains the block diagram of the system. Simulation results are given that shows the advantage of the scheme and its described in Section VII. Conclusion and reference given in VIII section.

II. INDIRECT FIELD-ORIENTED INDUCTION MOTOR DRIVE

The indirect vector control method is similar to the direct vector control but in indirect vector control the unit vector engendered in an indirect manner which utilizes the quantified speed ωr and slip speed ωsl[5,9].To implement indirect vector control method the following equations are considered[6].

$$\theta_e = \int \omega_e dt = \int(\omega_r + \omega_{sl}) = \theta_r + \theta_{sl} \qquad (1)$$

The rotor circuit operation can be defined by the equations (2 & 3)

$$\frac{d\psi_{dr}}{dt} + \frac{R_r}{L_r}\psi_{dr} - \frac{L_m}{L_r}R_r i_{ds} - \omega_{sl}\psi_{qr} = 0 \quad ②$$

$$\frac{d\psi_{qr}}{dt} + \frac{R_r}{L_r}\psi_{qr} - \frac{L_m}{L_r}R_r i_{qs} + \omega_{sl}\psi_{dr} = 0 \quad ③ \qquad (2\ \&\ 3)$$

For decoupling control the value of ψqr is 0, So the total flux $\hat{\psi}_r$ directs on the de axis.

$$\frac{L_r}{R_r}\frac{d\hat{\psi}_r}{dt} + \hat{\psi}_r = L_m i_{ds} \qquad (4)$$

The frequency of slip can be calculated as

$$\omega_{sl} = \frac{L_m R_r}{\hat{\psi} L_r} i_{qs} \qquad (5)$$

When the rotor flux ψr value is considered as constant, dψr/dt=0, by substituting this value in equation (4) . It yields the rotor flux set as

$$\hat{\psi}_r = L_m i_{ds} \quad (6)$$

The developed electromechanical torque is given by

$$T_e = \frac{3}{2}\frac{P}{2}\frac{L_m}{L_r}\hat{\psi}_r i_{qs} \quad (7)$$

III. SPACE VECTOR PWM

Space vector pulse width modulation is a well known switching scheme [8]. This is used for generation of switching sequence for 3 phase voltage source inverter as shown in fig 1.

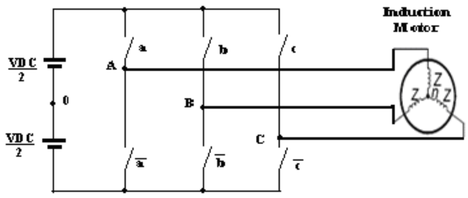

Fig 1. 3 phase VSI

The three phase sinusoidal and balance voltages given by the equations as follows:

$$V_{An} = V_m \cos \omega t \quad (8)$$

$$V_{Bn} = V_m \cos\left(\omega t - \frac{2\pi}{3}\right) \quad (9)$$

$$V_{Cn} = V_m \cos\left(\omega t + \frac{2\pi}{3}\right) \quad (10)$$

$$\vec{V} = \frac{2}{3}\left[V_{An} + aV_{Bn} + a^2 V_{Cn}\right] \quad (11)$$

Are applied to the three phase induction motor, using Equation(11). The switches must be controlled so that at no time are both switches in the same leg turned on or else the DC supply would be shorted. This requisite may be met by the complementary operation of the switches within a leg. i.e. if A+ is on then A− is off and vice versa. This leaves us with eight possible switching vectors for the inverter, V0 through V7 with six active switching vectors and two zero vectors.

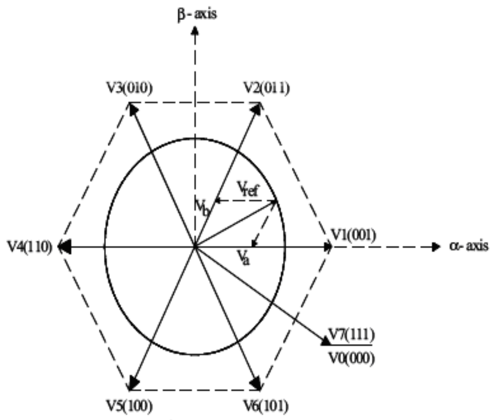

Fig 2. Space voltage vectors of 3 phase VSI

TABLE I Summary of inverter switching states

Name	A	B	C	V_{An}	V_{Bn}	V_{Cn}
V_0	0	0	0	0	0	0
V_1	1	0	0	$2V_{DC}/3$	$-V_{DC}/3$	$-V_{DC}/3$
V_2	1	1	0	$V_{DC}/3$	$V_{DC}/3$	$-2V_{DC}/3$
V_3	0	1	0	$-V_{DC}/3$	$2V_{DC}/3$	$-V_{DC}/3$
V_4	0	1	1	$-2V_{DC}/3$	$V_{DC}/3$	$V_{DC}/3$
V_5	0	0	1	$-V_{DC}/3$	$-V_{DC}/3$	$2V_{DC}/3$
V_6	1	0	1	$V_{DC}/3$	$-2V_{DC}/3$	$V_{DC}/3$
V_7	1	1	1	0	0	0

IV. FUZZY LOGIC CONTROLLER

In drive operation, the speed can be controlled indirectly by controlling the torque which, for the mundane operating region, is directly proportional to the voltage to frequency. Fuzzy Logic control (FLC) has proven efficacious for involutes, non-linear and imprecisely defined processes for which standard model predicated control techniques are impractical or infeasible[7]. Fuzzy Logic, unlike Boolean or crisp logic, deals with quandaries that have vagueness, dubiousness and use membership functions with values varying between 0 and 1.

In fuzzy logic a particular object has a degree of membership in a given set, which is in the range of 0 to 1. The essence of fuzzy control algorithms is a conditional verbal expression between a fuzzy input variable A and fuzzy output variable B. In general a fuzzy variable is expressed through a fuzzy set, which in turn is defined by a membership function. The consummate block diagram of the fuzzy logic controller is shown in figure 3 and the function of each block is explicated below [11].

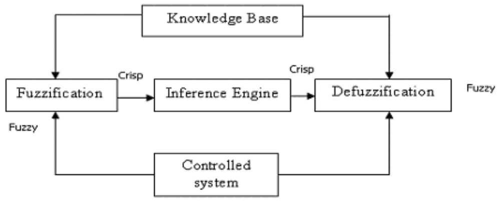

Fig 3. Block diagram of fuzzy logic controller

A. Configuration of FLC

Fuzzy controller is composed of the following principal blocks

a) A fuzzification interface
b) A knowledge base
c) A decision-making logic and
d) A defuzzification interface.

(a) Fuzzification

For every input and output variable culled, we define membership functions (MF), customarily three but can be more. We have to define a subjective category for each one of them, In this paper: big, medium or small. The shape of these functions can be diverse but we will customarily work with triangles and trapezoids. We have used triangular membership function for the paper.

(b) Knowledge base

The Knowledge Base of an Fuzzy Logic Controller(FLC) encapsulates expert erudition along with its consists of a data Base (membership functions) and also Rule-Base of an controller. Optimization connected with most of these Cognizance base components is usually significant to the behavior of the controller and has conventionally been achieved through a process of tribulation and error.

(c) Decision making

The decision-making logic is the core of an FLC. It has the ability of simulating human decision-making predicated on fuzzy concepts and of inferring fuzzy control actions employing fuzzy implicative insinuation and the rules of inference in fuzzy logic.

(d) Defuzzication

Defuzzification will be the process associated with engendering an quantifiable result in fuzzy logic, given fuzzy sets and corresponding membership degrees. This can be archetypally required throughout fuzzy control systems. Defuzzification is interpreting the membership degrees of the fuzzy sets into a categorical decision or authentic value.

B. Rules creation and inference

In general, fuzzy systems map input fuzzy sets to output sets. Fuzzy rules are cognations between input/output fuzzy sets. The modes of deriving fuzzy rules are predicated either of the following.

1. Expert experience and control engineering erudition.
2. Operator’s control actions.
3. Learning from the training examples.

In this thesis the fuzzy rules are derived by learning from the training examples. The general form of the fuzzy control rules in this case is

IF x is Ai AND y is Bi THEN z =fi (x, y)

where x, y and z are linguistic variables representing the process state variables and the control variable respectively.

Ai, Bi are the linguistic values of the linguistic variables, fi (x,y) is a function of the process state variables x, y and the resulting fuzzy inference system (FIS) is called a first order fuzzy model.

C. Fuzzy inference engine

The function of the inference engine is to calculate the overall value of the control output variable predicated on the individual contributions of each rule in the rule base. (i.e.) the defuzzification process. There is no systematic procedure for culling defuzzification. In first-order sugeno fuzzy model each rule has a crisp output and overall output is obtained as weighted average thus eschewing the time consuming processof defuzzification required in a conventional FLC.

V. DESIGN OF FUZZY LOGIC CONTROLLER

To change the Speed of the motor the voltage applied to the motor has to be changed. By operating the switches of inverter the voltage applied to the motor can be varied [3]. We need to operate the switches of inverter in unique way. This can be achieved by varying the duty cycle of the pulses applied to switches.Here a fuzzy logic controller has been designed to accomplish this. Irrespective of load fluctuations the speed of induction motor sustain around same value by using this fuzzy logic controller. The use of fuzzy logic also finds the advantage of fast response of the system.

The fuzzy logic controller takes error and change in error as inputs therefore its output is change in duty cycle [5]. Designing the fuzzy controller involves three steps, they are fuzzification, inference mechanism and defuzzification.

In fuzzy logic instead of numerical variables linguistic variables are used. The conversion of a numerical variable into a linguistic variable is done by fuzzification. For this work five linguistic variables Negative Big(NB), Negative Small(NS), Zero(Z), Positive Small(PS), Positive Big(PB) are used. For input and output variables triangular membership function is assigned and they are defined in different universe of discourses. They are shown in fig 4.

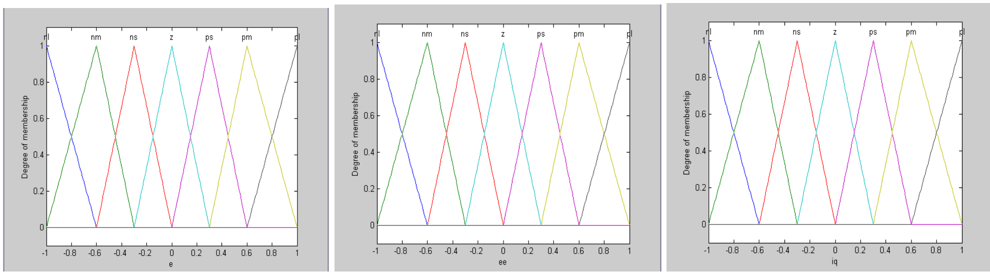

Fig.4 Membership functions used for fuzzy controller

THE INFERENCE MECHANISM

Table 1: fuzzy rules

ce \ e	Nl	nm	ns	z	ps	pm	pl
nl	Nl	nl	nl	nl	nm	ns	z
nm	Nl	nl	nl	nm	ns	z	ps
ns	Nl	nl	nm	ns	z	ps	pm
z	Nl	nm	ns	z	ps	pm	pl
ps	Nm	ns	z	ps	pm	pl	pl
pm	Ns	z	ps	pm	pl	pl	pl
pl	Z	ps	pm	pl	pl	pl	pl

The rules are formatted as follow. If error is Pi, and change in error is Qi then output is Ri. Here in this rule "if" part is called the rule-antecedent and this part describes a process state. the rule-antecedent are generally in terms of a logical combination of atomic fuzzy propositions. The "then" part of the rule is called the rule consequent and this part describes the control output. Rule consequent are generally in terms of logical combinations of fuzzy propositions. The rules are tabulated for this fuzzy controller in table 1. Manipulation of rule based on the rule table are given below

Rule1: If error is NB, and change in error is NB then output is NB
Rule2: If error is NB, and change in error is NS then output is NB
Rule3: If error is NB, and change in error is Z then output is NB
.
.
.
Rule49: If error is PL, and change in error is PL then output is PL.

VI. BLOCK DIAGRAM OF THE SYSTEM

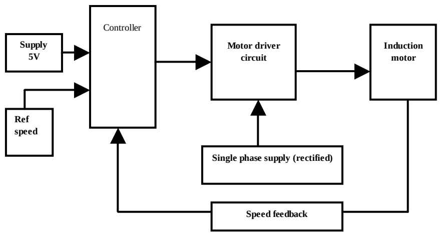

Fig.5 system block diagram

The scheme employs PWM signals for controlling the output voltage and frequency of the motor driver circuit. The Speed feedback is used for accuracy. Feedback is given to the controller. Thus controller produces PWM accordingly to control the speed of IM drive.

VII. SIMULATION RESULTS

The figure below shows the speed vs time curve for 200 rpm. From the figure, it is understood that fuzzy PI response settles the reference speed at 0.65 sec. torque vs time and current vs time curves are also simulated and results show that using fuzzy decreasing the settling time. So it can be concluded that fuzzy logic improves the time response of the system and achieves reference speed very fast.

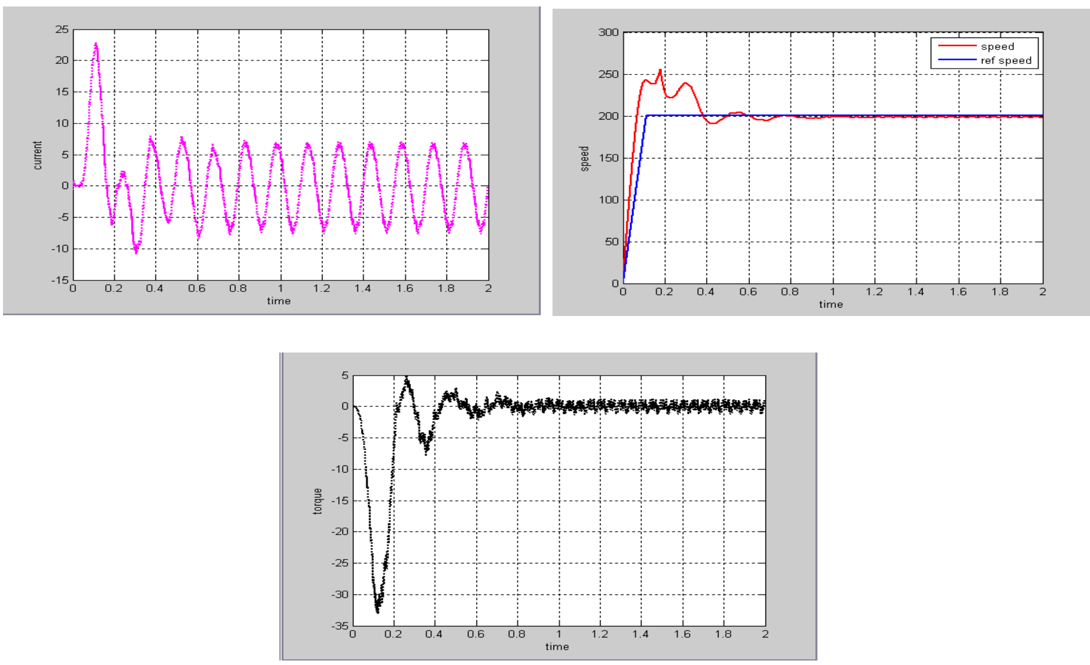

Fig: 6 simulation results

CONCLUSION

This paper presents simulation results of fuzzy logic control for speed control of induction motor. In fuzzy control it is not necessary to change the control parameters as the reference speed changes. With results obtained from simulation, it is clear that for the same operation condition the induction motor speed control using fuzzy logic technique had better performance, mainly when the motor was working at lower speeds. In addition, the motor speed to be constant when the load varies.

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