Speed Control of Induction Motor and Improvement of Efficiency using Fuzzy Logic Controller

Umesh kumar bansal
Dept. of electrical engineering
M.I.T.S. Gwalior

Shalandra Bhartiya
Dept. of electrical engineering
M.I.T.S. Gwalior

Rakesh Narvey
Dept. of electrical engineering
M.I.T.S. Gwalior

shailu_bhartiya@rediffmail.com shailu.3999@gmail.com rakeshnarvey@yahoo.com

ABSTRACT

In large industrial application the induction motor is widely used because of the low maintenance and robustness so that the speed control of induction motor is more important to achieve max torque control. The sensor less vector control and field oriented control are discussed in this paper. The soft computing tech. fuzzy logic is applied in this paper for the speed control of induction motor, to achieve max torque with min loss. The simulated design is tested using various tool boxes in mat lab. The result concludes that with speed control, the efficiency is also improved.

INTRODUCTION

Induction motors are being applied today to a wider range of applications requiring variable speed. Generally, variable speed drives for Induction Motor (IM) require both wide operating range of speed and fast torque response, regardless of load variations. This leads to more advanced control methods to meet the real demand. The conventional control methods have the following difficulties

1. It depends on the accuracy of the mathematical model of the systems
2. The expected performance is not met due to the load disturbance, motor saturation and thermal variations
3. Classical linear control shows good performance only at one operating speed
4. The coefficients must be chosen properly for acceptable results, whereas choosing the proper coefficient with varying parameters like set point is very difficult.

To implement conventional control, the model of the controlled system must be known. The usual method of computation of mathematical model of a system is difficult. When there are system parameter variations or environmental disturbance, the behavior of the system is not satisfactory. Usually classical control is used in electrical motor drives. The classical controller designed for high performance increases the complexity of the design and hence the cost.

Advanced control based on artificial intelligence technique is called intelligent control. Every system with artificial intelligence is called self-organizing system. On the 80th decade the production of electronic circuits and microprocessors with high computation ability and operating speed has grown very fast. The high power, high speed and low cost modern processors like DSP, FPGA and ASIC IC's along with power technique switches like IGBT made the intelligent control to be used widely in electrical drives[2].

Intelligent control, act better than conventional adaptive controls. Artificial intelligent techniques divide two groups: hard computation and soft computation. Expert system belongs to hard computation which has been the first artificial intelligent technique. In recent two decades, soft computation is used widely in electrical drives. They are,

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)

Neural networks and fuzzy logic technique are quite different, and yet with unique capabilities useful in information processing by specifying mathematical relationships among numerous variables in a complex system, performing mappings with degree of imprecision, control of nonlinear system to a degree not possible with conventional linear systems.

Fuzzy logic is a technique to embody human-like thinking into a control system. A fuzzy controller can be designed to emulate human deductive thinking, that is, the process people use to infer conclusions from what they know. Fuzzy control has been primarily applied to the control of processes through fuzzy linguistic descriptions. Fuzzy control system consists of four blocks as shown in Fig. 1.

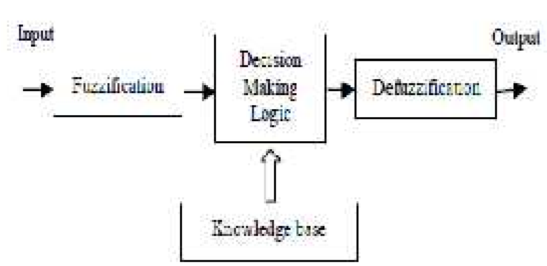

Fig. 1 Fuzzy Control System

This paper deals about the sandwich of artificial intelligence technique particularly fuzzy logic in the speed control of Induction motor. Various control techniques are discussed in Section II. The Section III describes the block diagram of the conventional fuzzy controller. Section IV describes fuzzy logic controller. Simulation results are given to demonstrate the advantage of proposed scheme is described in Section V. Conclusion and reference studies are mentioned in the last section.

II.VARIOUS CONTROL TECHNIQUES

Due to advances in power electronic switches and microprocessors, variable speed drive system using various control technique have been widely used in many applications, namely Field oriented control or vector control[1], Direct torque control, Sensor less vector control.

A. The Direct Torque Control

The Direct Torque Control (DTC)[5] scheme is very simple. In its basic configuration it consists of DTC controller, torque and flux calculator and VSI. In principle, the DTC method selects one of the inverter's six voltage vectors and two zero vectors in order to keep the stator flux[3] and torque within a hysteresis band around the demand flux and torque magnitudes. The torque produced by the induction motor can be expressed as shown below

$$T_{em} = \frac{3}{2}\frac{P}{L_s}\frac{L_m}{L_r}\left|\overline{\lambda_r}\right|\left|\overline{\lambda_s}\right|\sin\alpha$$

This shows the torque produced is dependent on the stator flux magnitude, rotor flux magnitude and the phase angle between the stator and rotor flux vectors. The induction motor stator equation is given by

$$\overline{V_s} = \frac{d\overline{\lambda_s}}{dt} - \overline{I_s}r_s$$

Can be approximated as shown below over a short time period if the stator resistance is ignored, then

$$\Delta\lambda s = Vs\,.\Delta t$$

This means that the applied voltage vector as shown in the Fig. 2 determines the change in the stator flux vector as shown in Fig. 3. If a voltage vector is applied that changes the stator flux to increase the phase angle between the stator flux and rotor flux [3] vectors, then the torque produced will increase. Two problems are usually associated with DTC drives which are based on hysteresis comparators are:

i. Variable switching frequency due to hysteresis comparators used for the torque and flux estimators.
ii. Inaccurate stator flux estimations which can degrade the drive performance.

Some schemes have managed to maintain an average constant switching frequency by utilizing apace vector modulation, predictive control, and dead beat control. All of these techniques increase the complexity of the drive systems.

B. Sensor less Vector Control

The sensor less control method is valid for both high and low speed range. Using the traditional method, the stator terminal voltages and currents estimate the rotor angular speed, slip angular speed and the rotor flux. In this case, around zero speed, the slip angular velocity [4] estimation becomes impossible since division by zero takes place.
Another strategy is, as short sampling time is assumed, we could solve the linearized differential equations, then get an algebraic equation for the estimation of rotor parameters. The problem of achieving high dynamic performance in AC motor drives without the need for a shaft position/speed sensor has been under study widely.

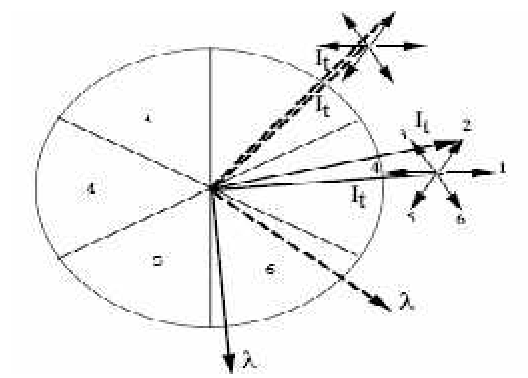

Fig. 2 Applied Voltage Vector

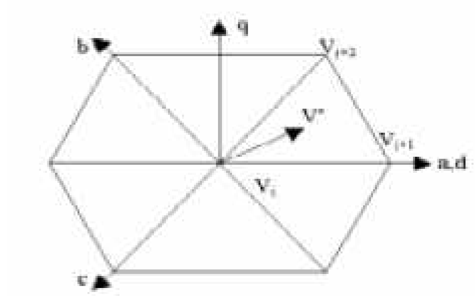

Fig. 3 Stator Flux Vector

The advantages of speed sensorless operation of the drives are lower cost, reduced size of the drive machines, elimination of the sensor cable and increased capability. The zero rotor speed problem persisting in the sensorless speed control scheme was resolved sacrificing the dynamic and steady state performance.

C. Field Oriented Control

Field oriented control (FOC) technique is intended to control the motor flux, and thereby be able to decompose the AC motor current into "flux producing" and "torque producing" components. These current components can be treated separately, and then recombined to create the actual motor phase currents. This gives a solution to the boost adjustment problem, and also provides much better control of the motor torque, which allows higher dynamic performance.

III THE CONVENTIONAL FUZZY CONTROLLERS

Fuzzy control[7] uses the principles of fuzzy logic based decision making to achieve the control tasks. The decision making approach is typically based on rule of inference. A fuzzy rule in the knowledge base of the control task is generally a linguistic relation. We have a rule base with a set of the rule form as follows.

IF Ai AND Bi THEN Ci

The overall membership function for the complete rule base can be obtained as,

$$\mu(a, b, c) = \max \min[\mu_A(a), \mu_B(b), \mu_C(c)]$$

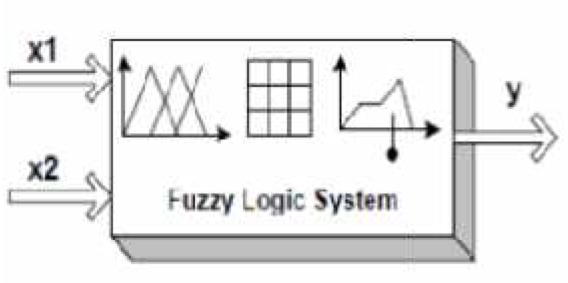

Figure 2. A fuzzy logic system

Figure 2 shows the block diagram of a conventional fuzzy logic system with two input and one output variables. The fuzzy logic systems are used as a controller with various control schemes. The most obvious one is shown in figure 3, where the fuzzy controller is in the forward path in a feedback control system. The process output is compared with a reference, and if there is a deviation, the controller takes action according to the control strategy.

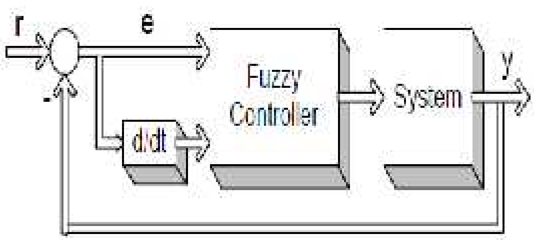

Figure 3. The control system structure with a fuzzy controller

IV. FUZZY LOGIC CONTROLLER

FLC approach is very useful for induction motor speed drives since no exact mathematical model of the induction motor or the closed-loop system is required. FLC[6] has a fixed set of control rules, usually derived from expert's knowledge.

The membership function (MF) of the associated input and output linguistic variables is generally predefined on a common universe of discourse. For the successful design of FLC's proper selection of input and output scaling factors (gains) or tuning of the other controller parameters are crucial jobs, which in many cases are done through trial and error to achieve the best possible control performance[1].

The structure of FLC is shown in figure4. The structure shows four functions,each one materialized by block :

• A fuzzification interface, the fuzzy control initially converts the crisp error and its rate of change in displacement into fuzzy variables; then they are mapped into linguistic labels. Membership functions are defined within the normalized range (-1, 1), and associated with each label: NB (Negative Big), NS (Negative Small), ZE (Zero), PS (Positive Small), and PB (Positive Big). Five MFs are chosen for e(pu) and ce(pu) signals and five for output. All the MFs are symmetrical for positive and negative values of the variables. Thus, maximum 5x5 = 25 rules can be formed as tabulated in Table I.

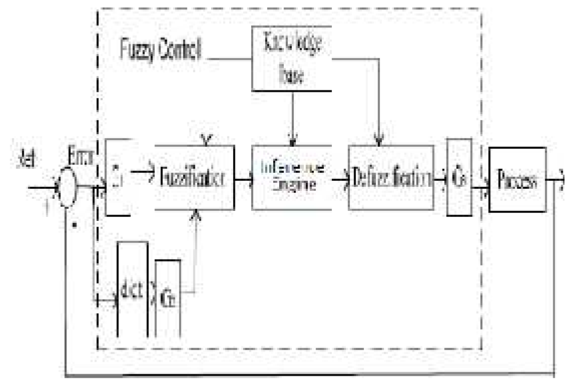

Figure4.Structure of Fuzzy Control

• A knowledge base (a set of If-Then rules), which contains the definition of the fuzzy subsets, their membership functions, their universe discourse and the whole of the rules of inference to achieve good control.

• An inference mechanism (also called an "inference engine" or "fuzzy inference" module), which is heart of a fuzzy control, poses the capacity to feign the human decisions and emulates the expert's decision making in interpreting and applying knowledge about how best to control the plant.

• A defuzzification interface, which converts the conclusions of the inference mechanism into actual inputs for the process. In this work; Center Of Area (COA) is used as a deffuzification method, which can be presented as:

$$X^{crisp} = \frac{\sum_{i=1}^{n} x_i \mu_A(x_i)}{\sum_{i=1}^{n} \mu_A(x_i)}$$

where

n: Number of the discrete elements.

x_i: The value of the discrete element

$\mu_A(x_i)$: The corresponding MF value at the point x_i.

The gains G1, G2, and G3 are scaling factors to adapt the variables to the normalized scale. However, the inference strategy is the mamdani algorithm, so the if-then rules for fuzzy scalar control for speed control will be twenty five rules.

MODEL OF INDUCTION MOTOR IN SIMULINK

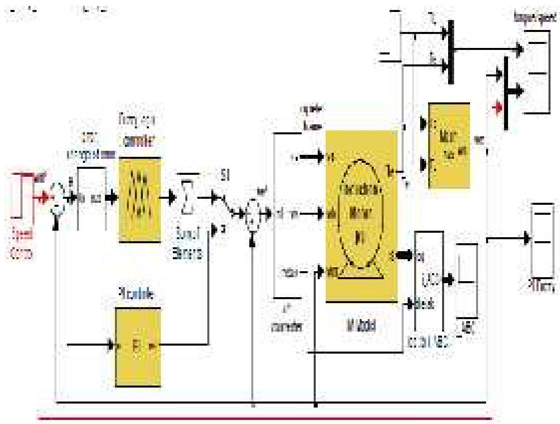

TABLE I
RULES FOR FUZZY CONTROLLER

Δe / e O/P	NB	NS	ZE	PS	PB
NB	NB	NB	NS	NS	ZE
NS	NB	NS	NS	ZE	PS
ZE	NS	NS	ZE	PS	PS
PS	NS	ZE	PS	PB	PB
PB	ZE	PS	PS	PB	PB

TABLE II
PARAMETERS OF INDUCTION MACHINE

Parameters	**Symbols**	**Values**	**units**
Shaft power	P	2	kw
Number of pole pairs	P	2	
Stator resistance	Rs	2.3	Ω
Rotor resistance	Rr	1.35	Ω
Total leakage factor	σ	1.25	
Mutual inductance	M	0.09	H
Stator(rotor) self inductance	Ls=Lr	0.101	H
Inertia moment	J	0.010	SI
Viscous friction coefficient	f	0.002	SI

TABLE III
COMPARED WITH CONVENTIONAL SPEED CONTROL APPLIED ON 3 PHASE,415V,3HP INDUCTION MOTOR(Drum size d=.225m)

S. No	Line Voltage(in volts)	Input current(in amperes)	W1 Input	W2 Input	LoadS1	Load S_2 (in Kg)	Speed Nr(in RPM)
1	350	1	350	35	0	0	1490
2	345	1.20	430	230	0	2	1430
3	340	1.25	600	300	0	4	1420
4	335	1.5	850	380	0	6	1410
5	330	2.3	1050	500	0	8	1400
6	326	2.8	1150	610	0	10	1390
7	320	3	1230	700	0	12	1380
8	314	4	1460	890	0	14	1360

SIMULATION RESULTS

As shows in table 3.the fuzzy logic controller provides fast control response with induction motor .this controller also gives fast response and smooth performance and high dynamic response with changing in transient condition and also increases the efficiency of motor with all these concepts .so that the fuzzy logic controller is widely used in industrial applications.

REFERENCES

[1]. S. H. Kim and S. K. Sul, “Voltage control strategy for maximum torque operation of an induction machine in the field weakening region,” in Proc. IECON’94, 1994, pp. 599–604.

[2]. B. K. Bose, Power Electronics and AC Drives. Englewood Cliffs, NJ:Prentice Hall, 1986.

[3]. X. Xu and D. W. Novotny, “Selecting the flux reference for induction machine drives in the field weakening region,” IEEE Trans. Ind. Applicat., vol. 28, pp. 1353–1358, Nov. /Dec. 1992.

[4]. D. W. Novotny and T. A. Lipo. Vector Control and Dynamics of AC Drives, Oxford University Press, 1997.

[5]. T. G. Habetler et al., “Direct torque control of induction machines using space vector modulation,” IEEE Trans. Ind. Applicat., vol. 28,pp. 1045– 1053, Sept./Oct. 1992.

[6]. Driankov D., Hellendoorn H. and Reinfrank M., An Introduction to Fuzzy Control, Springer-Verlag Berlin Heidelberg, 1996.

[7]. Sim K.B., Byun K.S. and Lee D.W., Design of Fuzzy Controller Using Schema Coevolutionary Algorithm, IEEE Trans. on Fuzzy Systems, vol. 12, issue 4, 2004, pp. 565-570.