Fuzzy Logic Based Speed Control System “Comparative Study”

A.D. Ghorapade
Post graduate student
Department of Electronics
SCOE Pune, India
abhijit_ghorapade@rediffmail.com

Dr. A.D. Jadhav
Professor
Department of Electronics
SCOE Pune, India
ajay_jadhav@rediffmail.com

Abstract — This paper presents a compact soft computing fuzzy logic control system for induction motor scalar speed control. The speed control of induction motor is more important to achieve maximum torque and efficiency. The control strategy consists of keeping constant the voltage frequency ratio of the induction motor supply source. The fuzzy logic controller proposed to obtain comparatively good performance compared to the conventional PI speed controller. A Soft computing technique – Fuzzy logic is proposed here for better speed control of induction motor with minimum loss. Fuzzy logic control method has the ability to handle errors in control operation with system nonlinearity and its performance is less affected by system parameter variations. The pros and cons of fuzzy logic controller are elaborated below on review.

Keywords— fuzzy logic control (FLC), induction motor, Membership function, Torque, Proportional integral (PI)

I. INTRODUCTION

Induction motors are the most widely used motors for industrial control and automation; hence, they are also called the workhorse of the motion industry. They are robust and reliable. When power is supplied to an induction motor at the recommended specifications, it runs at its rated speed. But many applications need variable speed operations. For example, a washing machine may use different speeds for each wash cycle. Induction motor Speed

control is complex due to its nonlinear characteristics.[1] there are two types of controlling speed of induction motor these are scalar control and vector control. Several studies have been carried out in the field of speed control system, but scalar speed control system shows simple structure by low steady state error. The constant V/f scalar control system is considered for study. Variable Voltage Variable Frequency (VVVF) or V/f is the most common method of speed control in open loop approach. [1]This method is most suitable for applications without position control requirements or the need for high accuracy of speed control.

In the last few years, fuzzy logic has a growing interest in many motor control applications due to its non-linear ties handling features and independence of the plant modeling. The Fuzzy Logic Controller (FLC) operates in a knowledge-based way, fuzzy-based control method has the ability to deal with system nonlinearity and its control performance is less affected by system parameter variations. Fuzzy techniques uses a linguistic if then rule base which is designed by taking advantage of system qualitative aspects and expert knowledge. These features are important with the need for a precise mathematical model of the plant, making the system design simpler to implement, even when empirical methodology is applied for fine-tuning procedure.[2]-[5]

II. V/f CONTROL OF INDUCTION MOTOR

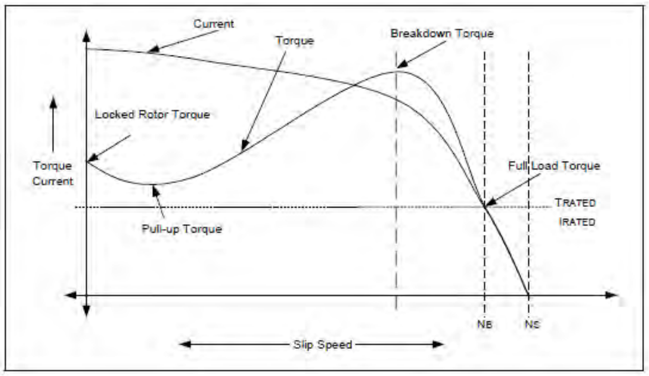

Fig.1. Speed-torque Characteristics of Induction Motor

Fig.1. shows the typical speed-torque characteristics of an induction motor. [6] The induction motor's speed- toque characteristic states that the induction motor draws rated current and delivers the rated torque at the base speed. The relation of Induction motor is given below.

Stator Voltage (V) ∝ Stator Flux (φ) x Angular Velocity (ω)

$$V \propto \phi \times 2\pi f$$

$$\phi \propto V/f \qquad (1)$$

This makes constant V/f the most common speed control of an induction motor. Fig.2. shows the relation between the voltage and torque versus frequency.

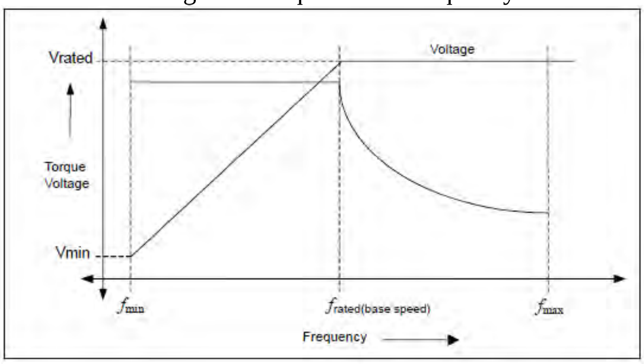

Fig.2.The relation between the voltage and torque versus frequency [6]

As shown in fig.3. at low frequencies and at low voltages the drop across the stator impedance prevents sufficient voltage availability. Therefore, to maintain sufficient torque at low frequencies, a voltage more than proportional needs to be given at low speeds.

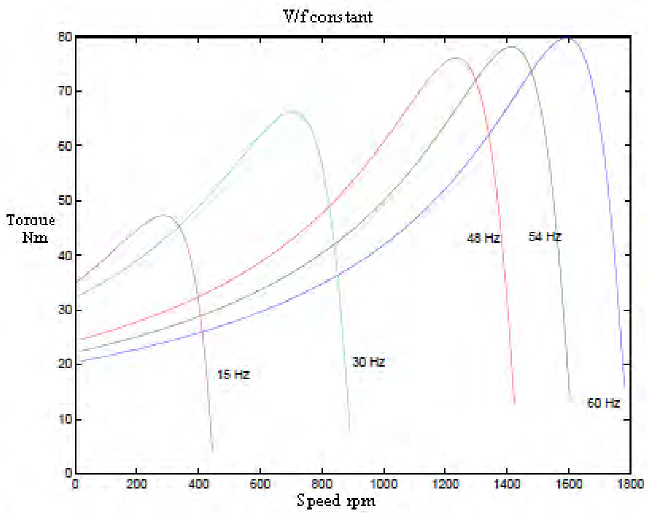

Fig.3.Torque-speed curves with V/f constant [6]

The values and parameters of induction motor are given in Table I.

Table I. Induction motor parameters for Experiments

Power	250W
Stator resistance	6.5Ω
Rotor resistance	3.4Ω
Number of pole pairs	2
Stator inductance	0.0103H
Rotor inductance	0.0154H
Mutual inductance	0.2655H
Inertia	0.0012kgm2
Rated speed	1725RPM

Table II. Shows the speed characteristics of delay time, rising time, settling time and maximum overshoot. [7]

Table II. Induction motor parameters for Experiments

		Conventional Vector control system	FLC System
No Load	Delay Time(s)	0.17	0.126
	Rising Time(s)	0.239	0.131
	Settling Time(s)	0.611	0.365
	Overshoot (RPM)	60	120
Load	Delay Time(s)	0.292	0.216
	Rising Time(S)	0.362	0.246

III.FLC SYSTEM

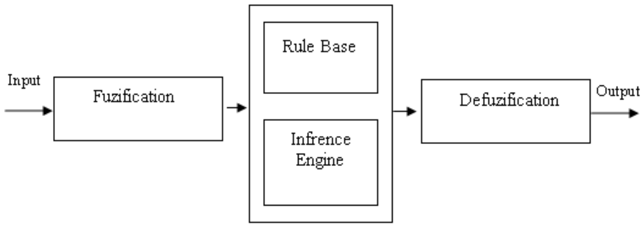

Fig.4. Blocks of Fuzzy Logic Controller

Fuzzy Logic Control system blocks are shown in Fig.4.Fuzzy Logic Controller is a technique is similar to human-like thinking into a control system. A fuzzy controller can be designed to follow human deductive thinking, that is, the process people use to suppose conclusions from what they know. Fuzzy logic has met a growing interest in many motor control applications due to its non-linearity's handling features and independence of the plant modeling. The Fuzzy Logic Controller (FLC) operates in a knowledge-based way, and its knowledge relies on a set of linguistic if-then rules, like a human operator. [6]-[8]

With Fuzzy Logic the first step is to understand and characterize the system behavior by using our knowledge and experience. The second step is to directly design the control algorithm using fuzzy rules, which describe the principles of the controller's regulation in terms of the relationship between its inputs and outputs. The last step is to simulate and debug the design. If the performance is not satisfactory we only need to modify some fuzzy rules and re-try .Fuzzy Logic control mainly applied to the control of processes through fuzzy linguistic descriptions. [7, 8]

The performance comparison of PI and FLC is given in Table. III [8,9]

Table III. Comparison results of PI and proposed FLC

Tests		**PI System**	**FLC System**
Starting response	Settling time	11.28 s	4.56 s
	overshoot	Not Visible	Not Visible
Step increase of speed	Settling time	3 s	0.4 s
	overshoot	20 rad	25 rad
Step Decrease of speed	Settling time	2.4 s	0.8 s
	undershoot	10 rad	Not Visible
Step increase of Load	Settling time	1 s	0.5 s
	undershoot	25 rad	8 rad
Step Decrease of Load	Settling time	1.8 s	0.3 s
	overshoot	45 rad	20 rad

IV.SIMULATION RESULT

A .Comparative Analysis with Conventional PI and PID Controllers

Comparative analyses with conventional PI and PID controllers are carried out in order to validate the proposed fuzzy controller. Therefore, step reference, ramp reference and load torque variation experiments were carried out for the performance analyses. Fig.5. illustrates the speed response in each controller. According to the results, the fuzzy controller and PID controller eliminated the overshoot and ripple in relation to the speed response of the PI controller. It should be mentioned that when the PI gains were adjusted to the best performance in step-up and step-down reference experiments (fast response and low overshoot), its response performance deteriorated in the ramp reference variations (higher reference error). The PI controller gain parameters were therefore adjusted empirically so that they could produce a good performance in both experiments. The load torque applied to the induction motor rotor shaft varies from approximately 2.3 Nm when the speed is 900 rpm to 4.0 Nm at 1600 rpm.[10,11]

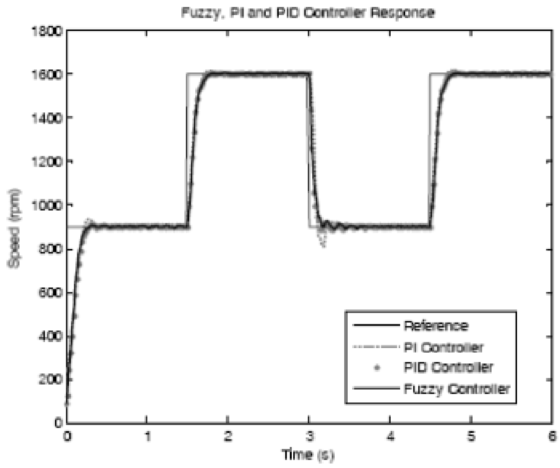

Fig.5. Fuzzy and PI controller response related to the reference step variations. [11]

B. Linguistic Rule Table

If the universes are discrete, it is always possible to calculate all thinkable combinations of inputs before putting the controller into operation. In a table based controller the relation between all input combinations and their corresponding outputs are arranged in a table. With two inputs and one output, the table is a two-dimensional look-up table.

Table IV Rule Base for Controlling Speed

		SPEED ERROR						
SPEED ERROR VARIATION		NL	NM	NS	ZZ	PS	PM	PL
	NL	NL	NL	NL	NM	NM	NS	ZZ
	NM	NL	NM	NM	NS	NS	ZZ	PS
	NS	NM	NM	NS	NS	ZZ	PS	PS
	ZZ	NM	NS	NS	ZZ	PS	PS	PM
	PS	NS	NS	ZZ	PS	PS	PM	PM
	PM	NS	ZZ	PS	PS	PM	PM	PL
	PL	ZZ	PS	PM	PM	PL	PL	PL

The array implementation improves execution speed, as the run-time inference is reduced to a table look-up which is a lot faster, at least when the correct entry can be found without too much searching. A typical application area for the table based controller is where the inputs to the controller are the error and the change in error. The controller can be embedded in a larger system, a car for instance, where the table is downloaded to a table look-up mechanism. [10,11] The fuzzy logic controller operation is based on the control operation shown in Table IV. Total 49 rules are generated as shown in fuzzy control system data base.

It should be noted that result reflect a similar performance. Therefore, in order to evaluate with precise numbers, mean relative error and standard deviation (STD) with respect to reference speed were calculated, as illustrated in Table V with the ramp reference, the fuzzy controller shows less error than the PID controller.[11]

Table V Comparative Table showing controller performances.

Ramp Reference		
	Error %	**STD %**
PI	3.45	9.82
PID	3.00	10.1
Fuzzy	2.76	9.70

V.CONCLUSION

The proposed fuzzy logic scalar speed control system has a simplified architecture which reduces memory-space requirements. Although it implies an additional computational cost, this does not compromise the practical performance in a V/f control system. The validity of the proposed controller is confirmed through the simulation results. The comparative analysis with conventional PI controllers demonstrated that the proposed method achieved better results by suppressing speed overshoot and ripple. Thus, the proposed fuzzy-control system is an acceptable alternative method for V/f common control applications, where a high dynamic and precise response is not required

REFERENCES

[1] B. Lu, T. G. Habetler and R. G. Harley, "A survey of efficiency estimation methods for in-service induction motors", IEEE Transactions on Industry Applications, vol. 42, no. 4, pp. 924-933, 2006.

[2] A. Goedtel, I. N. da Silva and P. J. A. Serni, "Load torque identification in induction motor using neural networks technique", Electric Power Systems Research, vol. 77, no. 1, pp. 35-45, 2007.

[3] N. Islam, M. Haider and M. B. Uddin, "Fuzzy logic enhanced speed control system of a VSI-fed three phase induction motor", Proceedings of 2nd International Conference on Electrical and Electronics Engineering, pp. 296-301, 2005.

[4] G. El-Saady, A. M. Sharaf, A. Makky, M. K. Sherbiny and G. Mohamed, "A high performance induction motor drive system using fuzzy logic controller", Proceedings of 7th Mediterranean Electrotechnical Conference, vol. 3, pp. 1058-1061, 1994.

[5] V.Chtra, and R.S.Prabhakar "Induction Motor Speed Control using Fuzzy Logic Controller" World Academy of Science, Engineering and Technology 23 2006.

[6] J.Deng L.Tu., "Improvement of direct torque control low-speed performanceby using fuzzy logic technique", Proceedings of IEEE International Conference on Mechatronics and Automation, pp. 2481-2485, 2007

[7] M. Nasir Uddin, , Z. Rui Huang, and Md. Muminul I. Chy "A Simplified Self-Tuned Neuro-Fuzzy Controller Based Speed Control of an Induction Motor Drive" Proceedings of the 2004 IEEE International Conference on Industrial Technology, ICIT, 2004, 1-4244-1298-6/07

[8] Pundaleek. B. H., Manish G. Rathi, Vijay Kumar M. G. "Speed Control of Induction Motor: Fuzzy Logic Controller v/s PIController" IJCSNS International Journal of Computer Science and Network Security, VOL.10 No.10, October 2010

[9] [9] R.Arulmozhiyal and K.Baskaran, " Space vector pulse width modulation based speed control of Induction motor using Fuzzy PI controller", International Journal of Computer and Electrical Engineering, ISSN 1793-8198, Volume 1, Number 1 (2009), pp 98-103.

[10] N. Islam, M. Haider and M. B. Uddin, "Fuzzy logic enhanced speed control system of a VSI-fed three phase induction motor", Proceedings of 2nd International Conference on Electrical and Electronics Engineering, pp. 296-301, 2005.

[11] Marcelo Suetake, Ivan N. da Silva, Member, IEEE, Alessandro Goedtel "Embedded DSP-Based Compact Fuzzy System and Its Application for Induction Motor V/f Speed Control", vol. pp, no.99, 2010.