Open access Journal International journal of Emerging Trends in Science and Technology

Simulation and Speed Control of Induction Motor Using Fuzzy Logic PID Controller

Authors

Rajnee Bala Minz[1], Rajesh Thinga[2], C.S. Sharma[3]

[1]PG Scholar/ Dept. of EE, Samrat Ashok Technological Institute, Vidisha, M.P, India
Email: *er.rajneebala@gmail.com*
[2]PG Scholar/Dept. of EE, Samrat Ashok Technological Institute, Vidisha, M.P, India
Email: *raj.rgtu@gmail.com*
[3]Associate Prof./Dept of EE, Samrat Ashok Technological Institute, Vidisha, M.P, India
Email: *hi_css21@yahoo.co.in*

Abstract:
Three phase induction motor drives have various industrial applications. In this thesis work indirect vector control technique is used which is based upon the Fuzzy PID speed controller. This method of speed control using fuzzy logic in induction motor altogether forms a closed loop control system. Result evaluated and obtained for speed control in Simulink provides reasonable accurate output at the end.
This thesis provides a technique for implementing a rule-based fuzzy logic PID controller applied to a closed loop indirect vector control the speed control of an induction motor. In this the d-q axis theory is used for the modeling of induction motor. For the speed control of IM using indirect vector control technique, a reference speed has been used and the control architecture includes the rule base. The controller has been tuned by hit and trial error method. The errors in the system are evaluated according to the rules which have defined membership functions.
Keywords: *Induction motor, Fuzzy logic controller, Indirect vector control, PID Controller, closed loop parameters.*

INTRODUCTION

Ac motors, particularly squirrel-cage induction motor have many inherent advantages like simplicity, reliability, low cost and virtually maintenance-free [3]. Three phase drives are widely used in electrical drive application.There are number of significant control methods available for induction motors including scalar control, vector or field oriented control, direct torque and flux control, sliding mode control and the adaptive fuzzy control. The numerous successful applications of fuzzy control have sparked a flurry of activities in the analysis and design of fuzzy control. In the last few years, fuzzy logic has met a growing interest in many motor control applications due to its non-line arities handling features and independence of the plant modelling. The fuzzy controller (FLC) operates in a knowledge-based way, and its knowledge relies on a set of linguistic if-then rules, like a human operator.

INDUCTION MOTOR DRIVES

Three phase induction motors are of two types: squirrel cage and wound rotor.Squirrel cage induction motors are very popular in variable-speed drives due to simple, ruggedness and inexpensive too. These are available at all power ratings [7]. In squirrel-cage, the rotor consists of longitudinal conductor-bars shorted by circular connectors at the two ends while in wound-rotor motor, the rotor also has a balanced three-phase distributed winding having same poles as stator winding. However, in both, stator carries a three-phase balanced distributed winding [5].

A. *Analysis and performance*

Per-phase equivalent circuit of a three-phase induction motor is shown in fig. 1(a).

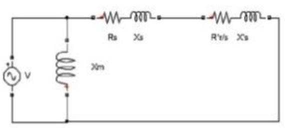


Fig.1(a)

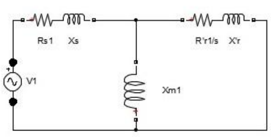


fig.1(b)

R'r and X'r are the stator referred values of rotor resistance Rr and rotor reactance Xr. Slip is defined by

$$s=\frac{Wms-Wm}{Wms} \qquad (1)$$

Where, Wm and Wms are rotor and synchronous speeds, respectively. Further

$$Wms=\frac{4\pi f}{p}\text{rad/sec} \qquad (2)$$

Where f and p are supply frequency and number of poles, respectively.

Since, stator impedence drop is generally negligible compared to terminal voltage V, the equivalent circuit can be simplified to that shown in fig. 1(b).

Also from eqn 1.

$$Wm = Wms(1-s) \quad (3)$$

From fig.2

$$I'r = V\frac{V}{(Rs+R'r/s)+j(Xs+X'r)} \quad (4)$$

Power transferred to rotor (or air-gap power)

$$Pg = 3(I'r)^2(R'r)/s \quad (5)$$

Rotor copper loss is

$$Pcu = 3(I'r)^2R'r \quad (6)$$

Electrical power converted into mechanical power

$$Pm = Pg - Pcu = 3\,(I'r)^2R'r\,(\frac{1-s}{s}) \quad (7)$$

Torque developed by motor

$$T = Pm/Wm \quad (8)$$

From equation (3) and (7)

$$T = \frac{3}{Wms}I'r^2R'r/s \quad (9)$$

From equation (4)

$$T = \frac{3}{Wms}\left[\frac{V^2R'r/s}{(Rs+\frac{R'r}{s})+(Xs+X'r)^2}\right] \quad (10)$$

Comparing equation (5) and (9)

$$T = \frac{Pg}{Wms} \quad (11)$$

Motor output torque is obtained by deducting friction windage and core-loss torques from the developed torque [5].

The developed torque is a function of slip only. Differentiating T in equation (10) w.r.t 's' and equating to zero gives the slip for maximum torque

$$Sm = \pm\frac{R'r}{(R^2s+(Xs+X'r)^2)^{½}} \quad (12)$$

Substituting equation (12) in (10) yields expression for maximum torque

$$Tmax = \frac{3}{2Wms}\left[\frac{V^2}{Rs\pm(Rs^2+(Xs+X'r)^2)^{½}}\right] \quad (13)$$

SPEED CONTROL FOR INDUCTION MOTOR

Usually a motor draws 5 to 7 times rated current during starting. When load torque during starting and motor-load-inertia are not large, the starting process is over in few seconds and therefore, motor temperature does not exceed the permissible value. In such applications motor can always be started direct on line, provided the voltage dip caused by large starting current is not beyond a permissible value. When either the load torque during starting is high or load inertia is large, the starting process takes long time. If motor carries large current during starting, it will get damaged due to overheating. Therefore, motor cannot be started direct on line. Hence various methods are used for improved starting [5].

A controller is a device which controls each & every operation in the system making decisions. From the control system point of view, it is bringing stability to the system when there is a disturbance, thus safeguarding the equipment from further damages. It may be hardware based controller or a software based controller or a combination of both[6].

Following methods are the significant control methods available for induction motors including scalar control, vector or field oriented control, direct torque and flux control, sliding mode control and adaptive fuzzy control.

B. *Scalar Control*

Synchronous speed, therefore, the motor speed can be controlled by varying supply frequency. Voltage induced in stator is proportional to the product of supply frequency and air-gap flux. If stator drop is neglected, terminal voltage can be considered proportional to the product of frequency and flux. Any reduction in the supply frequency, without a change in the terminal voltage, causes an increase in the air-gap flux.

C. *Vector Control*

Vector control, also called Field-oriented controlFOC), is a variable frequency drive (VFD) control method which controlsthree-phase AC electric motor output by means of two controllable VFD inverter output variables:

- Voltage magnitude
- Frequency

FOC is a control technique that is used in AC synchronous and Induction motor applications that was originally developed for high-performance motor applications which can operate smoothly over the full speed range, can generate full torque at zero speed, and is capable of fast acceleration and deceleration but that is becoming increasingly attractive for lower performance applications as well due to FOC's motor size, cost and power consumption reduction superiority.

Not only is FOC very common in induction motor control applications due to its traditional superiority in high-performance applications, but the expectation is that it will eventually nearly universally displace single-variable scalar volts-per-Hertz (V/f) control.

D. *Direct Torque and Flux Control*

Direct torque control (DTC) is one method used in variable frequency drives to control the torque (and thus finally thespeed) of three-phase AC electric motors. This involves calculating an estimate of the motor's magnetic flux and torque based on the measured voltage and current of the motor.

Stator flux linkage is estimated by integrating the stator voltages. Torque is estimated as a cross product of estimated stator flux linkage vector and measured motor current vector. The estimated flux magnitude and torque are then compared with their reference values. If either the estimated flux or torque deviates from the reference more than allowed tolerance, the transistors of the variable frequency drive are turned off and on in such a way that the flux and torque errors will return in their tolerant bands as fast as possible. Thus direct torque control is one form of the hysteresis or bang-bang control.

E. Fuzzy Logic Control

A fuzzy control system is a control system based on fuzzy logic—a mathematical system that analyzes analog input values in terms of logical variables that take on continuous values between 0 and 1, in contrast to classical or digital logic, which operates on discrete values of either 1 or 0 (true or false, respectively).Fuzzy logic is widely used in machine control. The term "fuzzy" refers to the fact that the logic involved can deal with concepts that cannot be expressed as "true" or "false" but rather as "partially true". Although alternative approaches such as genetic algorithms and neural networks can perform just as well as fuzzy logic in many cases, fuzzy logic has the advantage that the solution to the problem can be cast in terms that human operators can understand, so that their experience can be used in the design of thecontroller. This makes it easier to mechanize tasks that are already successfully performed by humans.

The main use of fuzzy control system is based on empirical rules is more effective. Fuzzy systems are easily upgraded by adding new rules or new features to improve performance. Fuzzy control can be used to improve existing traditional control systems by adding a layer of intelligence to the current control method. The fuzzy logic controller consists of Fuzzy Inference System Editor. The output of the controller is crisp value. This Graphical User Interface consists of FIS Editor, Membership function Editor, Rule Editor, Rule Viewer and Surface Viewer [8].

Fuzzy sets support a flexible sense of membership and is defined to be the pair (x , μÃ(x)) where μÃ (x) could be discrete or could be described by continuous function.
Fuzzy set theory is an effective tool to tackle the problem of uncertainty [4].

- **Fuzzy Sets:**

Fuzzy sets support a flexible sense of membership of elements to a set. While in crisp set theory, an element either belongs to or does not belong to a set, in fuzzy set theory many degrees of membership (between 0 or 1) are allowed [4]. The input variables in a fuzzy control system are in general mapped by sets of membership functions similar to this, known as "fuzzy sets". The process of converting a crisp input value to a fuzzy value is called "fuzzification".
Fuzzy control system design is based on empirical methods, basically a methodical approach to trial-and-error [4]. The general process is as follows:

- Document the system's operational specifications and inputs and outputs.
- Document the fuzzy sets for the inputs.
- Document the rule set.
- Determine the defuzzification method.
- Run through test suite to validate system, adjust details as required.

- Complete document and release to production.

The block diagram below shows the speed control system using FLC. The FLC has two inputs and speed errors and change in speed error and output which represents the change in quadrature reference current.

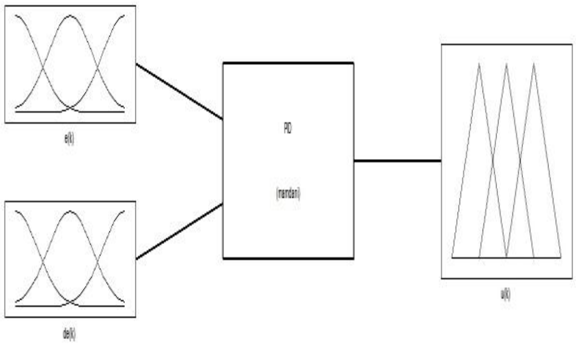


Fig.3 Block Diagram of fuzzy controller

- **Fuzzy Rule:**

A fuzzy rule is defined as a conditional statement in the form:

IF *x is A*
THEN *y is B*

where x and y are linguistic variables; A and B are linguistic values determined by fuzzy sets on the universe of discourse X and Y, respectively [4].

To determine a fuzzy rule from each input-output data pair, the first step is to find the degree of each data value in every membership region of its corresponding fuzzy domain. The variable is then assigned to the region with the maximum degree. When each new rule is generated from the input-output data pairs, a rule degree or truth is assigned to that rule, where this rule degree is defined as the degree of confidence in the developed method a degree is assigned which is the product of the membership function degree of each variable in its respective region [7].

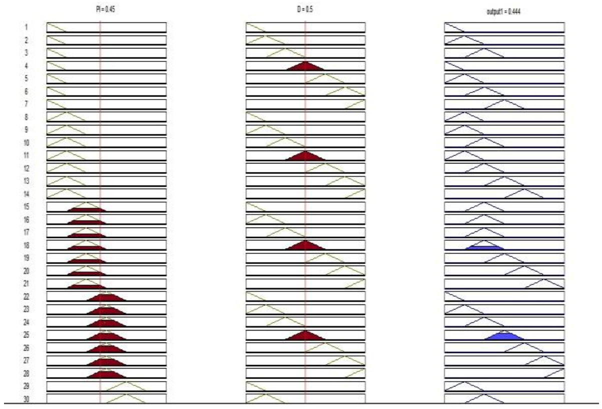
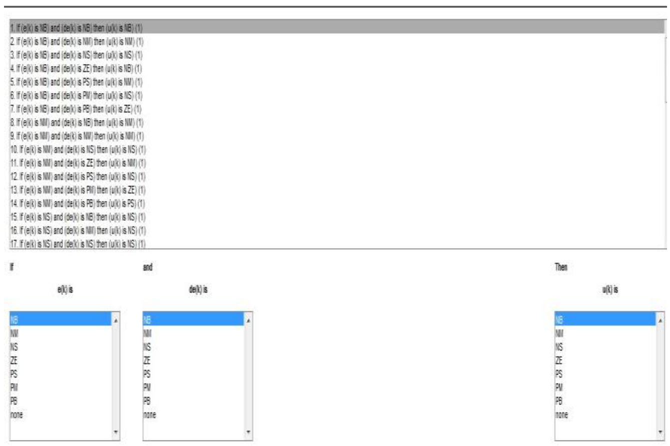


Fig. 4 fuzzy rule viewer

RULES IN FLC:



- **Membership Functions**:

The membership function of a fuzzy set is a generalization of the indicator function in classical sets. In fuzzy logic, it represents the degree of truth as an extension of valuation. Degrees of truth are often confused with probabilities, although they are conceptually distinct, because fuzzy truth represents membership in vaguely defined sets, not likelihood of some event or condition.

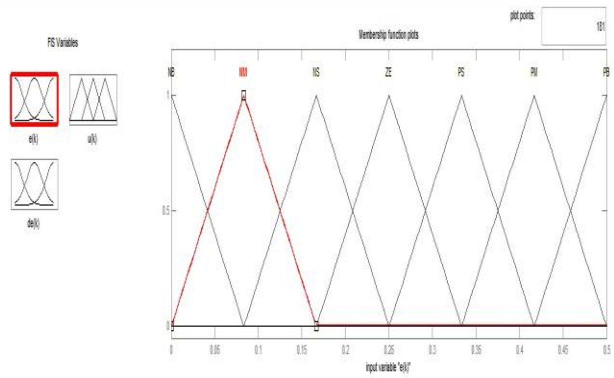


Fig. 5 Both I/Ps membership functions

TABLE1- Relationship between e(k) and de(k)

e(k)→ de(k)↓	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NM	NM	NS	ZE	ZE
NM	NB	NB	NM	NS	NS	ZE	ZE
NS	NB	NM	NS	NS	ZE	PS	PS
ZE	NM	NM	NS	ZE	PS	PM	PM
PS	NM	NS	ZE	PS	PS	PM	PB
PM	ZE	ZE	PS	PS	PM	PB	PB
PB	ZE	ZE	PS	PM	PM	PB	PB

- **ABBREVIATIONS USED IN FUZZY RULE BOX**

NB- NEGATIVE BIG

NM- NEGATIVE MEDIUM

NS- NEGATIVE SMALL

ZE- ZERO

PS- POSITIVE SMALL

PM- POSITIVE MEDIUM

PB- POSITIVE BIG

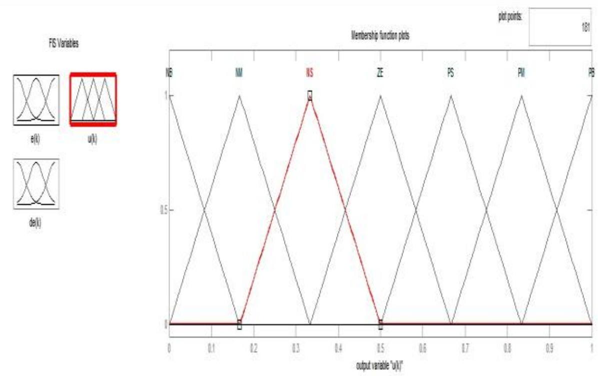


Fig.6 Output membership function

SIMULATION CIRCUIT

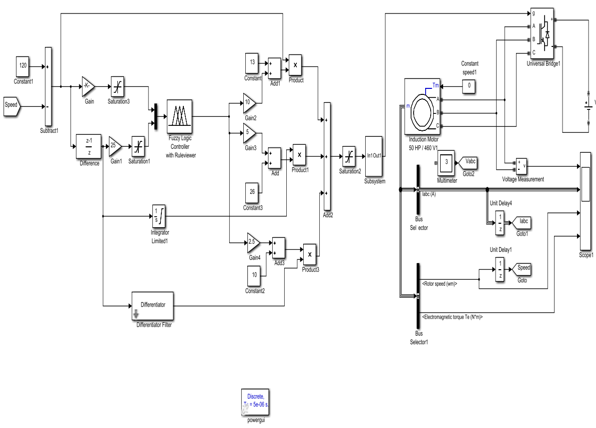


Fig.7 Speed controller using FLC.

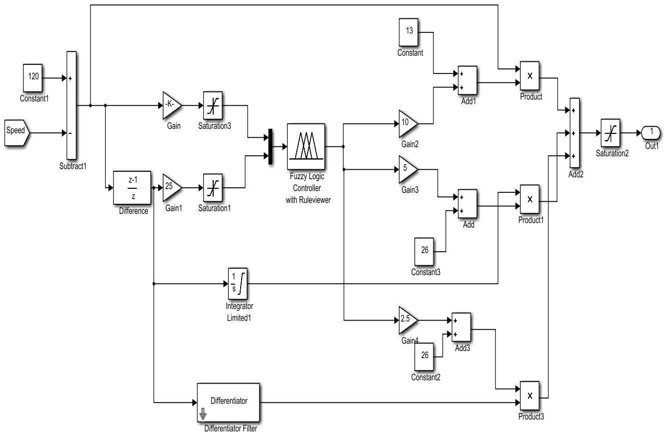


Fig.8 Fuzzy Logic Controller

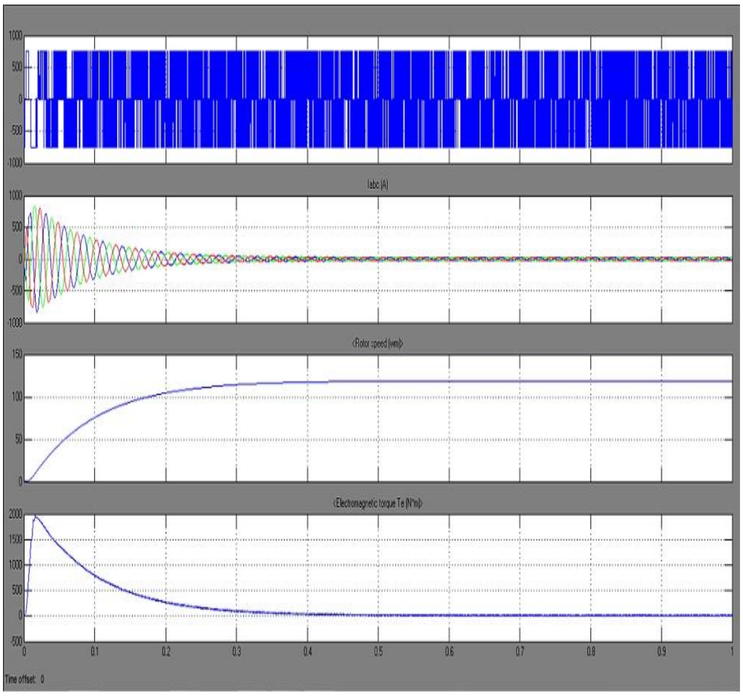


Fig.-9 output characteristics of IM

RESULT AND CONCLUSION

The implementation of indirect vector control for controlling the speed of an induction motor using Fuzzy logic PID controller is presented in this paper. After using the fuzzy PID controller the saturation time is obtained to be T_s= 0.325 sec, which is more reduced as compared to that in convention PID controllers.

The presence of a steady state error makes it impossible for the Fuzzy Logic Controller to be used in any major application but this drawback can be withdrawn from the system by tuning the FLC, which is not possible in the conventional controllers.

The Controller was tuned by trial and error method. The hybrid type membership functions can be used but the area of each membership function has been changed accordingly to get the desired results. It is known that to achieve the finest control, the membership functions near the zero region should be made narrower and membership functions away from the zero region be wider, which provides faster response to the system.

Using the proposed Simulink models we can conclude from the comparison that fuzzy logic PID speed controller is more efficient than the other conventional speed controllers.

REFERENCE

1. Weibo Yu, Yan Wang,Dejiang Zhang,Research on Variable Frequency Energy- Saving control strategy of Precooling Water Pump, 978-1-4244-8165-1/11, 2011, IEEE.
2. Simulation of Vector Control Frequency Converter of Induction Motor Based on Matlab/Simulink, Wu Tao,Zhao Liang,978-0-7695-4296-6/11, 2011 IEEE.
3. Fuzzy Logic Based MRAS For Sensorless Induction Motor Drive, Z.M.Salem, M.M.Khater,S.A.Mahmoud, MEPCON'2006.
4. Neural Networks, Fuzzy Logic, and Genetic Algorithms, Synthesis and Applications,by `S.Rajasekaran and G.A.Vijayalakshmi Pai,PHI LearningPrivate Limited.
5. Fundamentals of Electric Drives by Gopal. K. Dubey ,Second Edition, Narosa Publishing House Pvt. Ltd.
6. Modelling of Induction motor and control of speed using hybrid controller technology, Ashok Kusagur, Dr. S.F.Kodad, Dr. B.V. Sankar Ram,.
7. Performance optimization of asynchronous machine using fuzzy voltage controller, A.A.Ansari and D.M..Deshpande,IJET2(1): 45-49(2011).
8. Fuzzy PID controller application to sensorless induction motor on model reference adaptive system(MRAS), M.L.N.Kiran Kumar, T.Rama Sastry , ISSN (Print) : 2320 – 3765ISSN (Online): 2278 – 8875, 2003.
9. Induction motor speed control using Fuzzy Logic controller, V.Chitra and R.S.Prabhakar.
10. Ziegler-Nichols (Z-N) Based PID Plus Fuzzy Logic Control (FLC) For Speed Control of A Direct Field-Oriented Induction Motor (DFOIM),
11. Srinivas.Singirikonda, Yellaiah.Ponnam, Sravan Kumar.Palarapu
12. ISSN: 2248-9622, Vol. 3, Issue 6, Nov-Dec 2013, pp.755-762.
13. Fuzzy gain scheduling of PID controller, Zhen-Yu-Zhao, Masayoshi Tomizuka and Saturo Isaka, vol. 23 no. 5,september/ october 1993, IEEE.
14. New Results on the Synthesis of PID Controllers,Guillermo J. Silva, Aniruddha Datta, and S. P. Bhattacharyya, IEEE Transactions on automatic