ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

Speed, Torque analysis of IVCIM drive by using Fuzzy MRAC controller

M. Anka Rao[1], Prof.M. Vijaya Kumar[2], Y.Sai Theja Reddy[3]

Assistant Professor, Dept. of EEE, JNTUA College of Engineering, Anantapur, Andhra Pradesh, India[1]

Professor, Dept. of EEE, JNTUA College of Engineering, Anantapur, Andhra Pradesh, India[2]

PG Student [PID], Dept. of EEE, JNTUA College of Engineering, Anantapur, Andhra Pradesh, India[3]

ABSTRACT: This paper presents the speed and torque response of the indirect controlled induction motor drive for three controllers, i.e. PIES controller, Fuzzy PI controller and the Fuzzy MRAC controller. Introduction of the artificial intelligence in the controllers is path breaking in engineering fields, especially for the modern day motor drives. This paper presents the combined responses of the three controllers. PI controller is widely used in the industry for various drives. But the addition of the machine intelligence to the PI controller enhances the performance of the PI controller. The settling time of the Fuzzy PI is less and is more helpful when the actual mathematical model of the system is not known and Fuzzy MRAC is the best controller among the three and is way ahead in terms the settling time. Of the three controllers the Fuzzy MRAC is the only controller which is parameter insensitive. MRAC is compared with the existing controllers and its settling time is compared.

KEYWORDS: PI, Fuzzy PI, MRAC, IVCIM.

I. INTRODUCTION

Induction motor is the most important AC motor in the industry in terms of the usage and also the ruggedness. However, the speed control of the induction motor is not so easy due to its complexity and also due to the non-linear mathematical model. The parameters of the motor vary with the temperature, frequency and other conditions. To optimise the control of the speed and torque some artificial intelligence in needed. And there are many artificial intelligence techniques that are available. This paper is confined to the Fuzzy logic. For achieving the speed control, frequency control method is the best method among all the speed control techniques. Where ever there is a need for the quick control of the torque of the motor, the most preferred motor is DC motor instead of the Induction motor. The main reason is that the DC motor has the torque and speed as two quadrature components. If the induction motor is to be used in those applications, then the induction motor should also be modelled in a similar way. The torque and speed components of the induction motor are to be made in the quadrature way. This is made possible with the vector control of the induction motors. In the vector control the torque and speed components of the induction motor are controlled in the quadrature manner and thus making it resembles the DC motor operation. The vector control is implemented in two ways, the Direct vector control and the Indirect vector control. The direct vector control relies on direct sensing of the rotor flux using rotor sensors. The second method is essentially the same as the direct vector control, only the unit vector signals are generated in feedforward manner, by using sensors to find out the rotor position and stator currents. The indirect vector control method is used in this paper. To that indirect vector controlled drive, the controllers are embedded. The three controllers listed above are used.

II. LITERATURE SURVEY

For the advancement of the modern drives, the driving point is the vector control of the AC machines. This is a path breaking achievement in the field of power electronics. Here are the books and journals that have been the timescale of this paper. 'Vector Control of AC machines' by P. Vas provides the basics that are needed for the establishing the needed information regarding the control of induction motor drives. A research paper by M.M. Uddin, T.S. Radwan and M.A. Rahman, 'Performances of Fuzzy Logic based Indirect vector control for induction motor' explores the

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

analysis of the indirect vector control. The drawbacks presented in this paper forms the problem formulation of this paper. Later, due to the advancements of the Human intelligence, there are many fields that have their usage. And of those, a paper by M. Masaila, B. Vafakhak, A. Knight and J. Solomon, ‘ Performance of PI and Fuzzy logic speed control of the field oriented Induction machine drives’ provides the required insight of the fuzzy logic application to the modern drives. And Fuzzy logic based MRAC was proposed by Gilberto C.D. Sousa, Bimal K. Bose and Kyung S. Kim in their research paper, ‘Fuzzy Logic Based On-line MRAC tuning of slip gain for an indirect vector controlled Induction motor drive’. This is the advancement of the contemporary fuzzy controllers. MRAC application in that paper is effectively utilised in the design of the MRAC block in this paper.

III. DESIGN OF THE IVCIM

The induction motor is supplied through a current controlled voltage source inverter (CC-VSI). PWM regulator sends the gating signals. The d^s-q^s axes are stator axes. The d^r-q^r axes are fixed on the rotor, moving at a speed ω_r. The unit vector signal is as shown below.

$$\theta e = \int \omega e \, dt = \int (\omega r + \omega sl) dt = \theta r + \theta sl \qquad (1)$$

The rotor position slips at a frequency of ω_{sl}. The corresponding equations are as shown below.

$$\begin{bmatrix} v_{qs}^e \\ v_{ds}^e \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} R_s + \rho L_s & \omega_e L_s & \rho L_m & \omega_e L_m \\ -\omega_e L_s & R_s + \rho L_s & -\omega_e L_m & \rho L_m \\ \rho L_m & (\omega_e - \omega_r) L_s & R_r + \rho L_r & (\omega_e - \omega_r) L_r \\ -(\omega_e - \omega_r) L_m & \rho L_m & (\omega_e - \omega_r) L_r & R_r + \rho L_r \end{bmatrix} \begin{bmatrix} i_{qs}^e \\ i_{ds}^e \\ i_{qr}^e \\ i_{dr}^e \end{bmatrix} \qquad (2)$$

$$T_e = J_m \frac{dw_r}{dt} + B_m + T_L \qquad (3)$$

$$T_e = \frac{3}{2}\frac{P}{2} L_m (i_{qs}^e i_{dr}^e - i_{ds}^e i_{qr}^e) \qquad (4)$$

$$\frac{d\theta_r}{dt} = \omega_r \qquad (5)$$

In the above equations v_{ds}^e and v_{qs}^e are the d, q-axis stator voltages, i_{ds}^e and i_{qs}^e are the d, q-axis stator currents, i_{dr}^e and i_{qr}^e are d, q-axis rotor currents.
R_s and R_r are the stator and rotor resistances per phase.
L_s and L_r are the self-inductances of the stator and rotorrespectively.
L_m is the mutual or magnetizinginductance.
ω_e is the speed of the rotating magnetic field.
ω_r is the rotor speed.
P is the number of poles.
ρ is the differential operator (*d/dt*).
T_e is the developed electromagnetic torque.
T_L is the load torque.
J_m is the rotor inertia;
B_m is the rotor damping coefficient .and θ_r is the rotor position.

Using these above equations the Indirect vector controlled induction motor drive is constructed. In the construction of the IVCIM, the important blocks are the flux calculation block, the current calculation block, park’s transformation block, the inverse park’s transformation block, the theta calculation block and most important one, the hysteresis current regulator block. This current regulator block is used to give the control signals to the gate of the thyristor that is being used in the inverter. Thus the construction of the IVCIM is done with the help of the above mentioned blocks. The block diagram of the IVCIM looks like the one presented here. It is the MATLAB model of the IVCIM. That model is used further for the construction of the whole drive.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

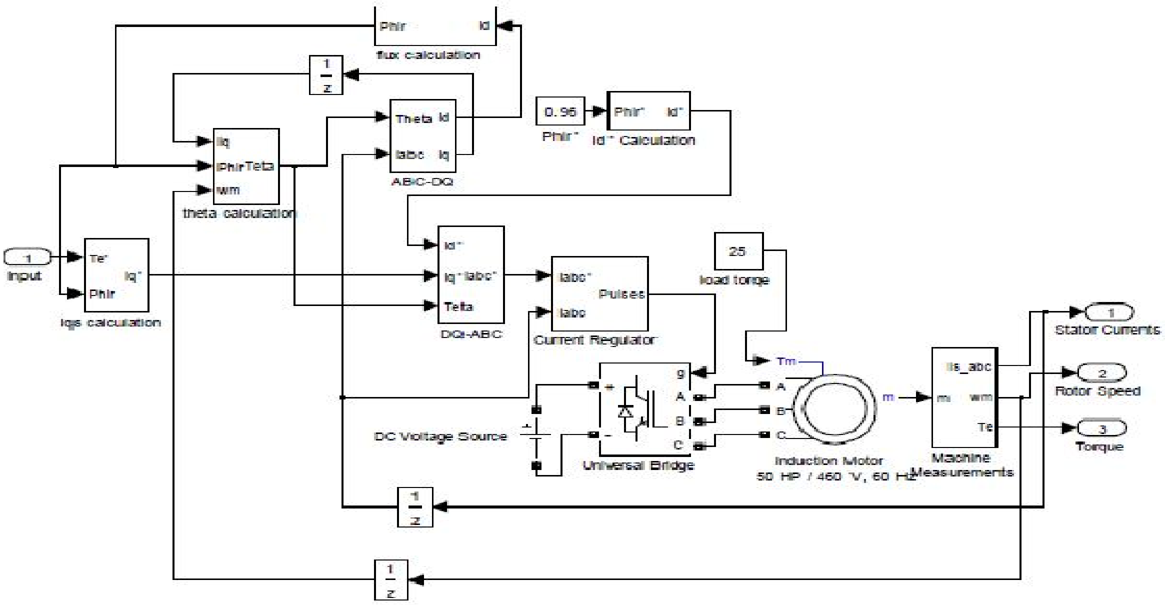

Fig. 1 MATLAB model of IVCIM

IV. PI CONTROLLER

The PI controller has two terms in it, the proportional term and the integral term. The function of the proportional term is that it adds the bias based of the size of the controller error at each time. The error grows or shrinks as the bias is added grows or shrinks. The PI controller doesn't take into consideration, the past history and the current trajectory. As the proportional term takes the error only at the time of the calculation, the history which isn't taken into consideration is being considered by the integral term. The Integral action eliminates the offset. There are the challenges in the PI algorithm. The interaction of the tuning parameters and their mutual effect is to be balanced. And the other primary challenge is that the integral term's tendency to oscillate. This is to be taken care and the proper design ensures that this doesn't happen. The MATLAB model of the PI controller is shown below.

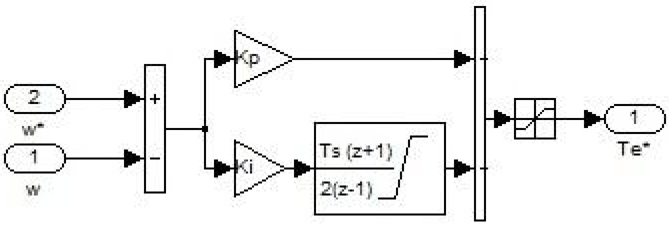

Fig. 2 PI controller

V. FUZZY PI AND FUZZY MRAC

The parameters in the PI are the proportional term and the integral term. In Fuzzy PI these two terms are not fed directly. These two are taken from the fuzzy controller. Thus there is an imprint of the human logic that is being added to the controller. This makes it more versatile and also robust. The fuzzy logic tool box has many tools.(1) The Fuzzy Inference System or FIS editor, (2) The membership Function Editor, (3) The rule editor, (4) The rule viewer, (5) The surface viewer. Using these tools the fuzzy membership functions are to be defined for the variables. The error (e) and the change in error(ce) are the two variables. The rule base is built with the help of the rule based matrix. The

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

parameter values are given from the rule base. Thus more effective output is given and the speed of the response is also high. The time taken by the torque to reach the final output is reduced when compared with the normal PI. The MRAC is the acronym of the Model Reference Adaptive Control. In the model reference adaptive control, the d axis voltage and the reactive power equations are used as the base for the slip gain tuning. The fuzzy MRAC block and the fuzzy membership functions are as given below

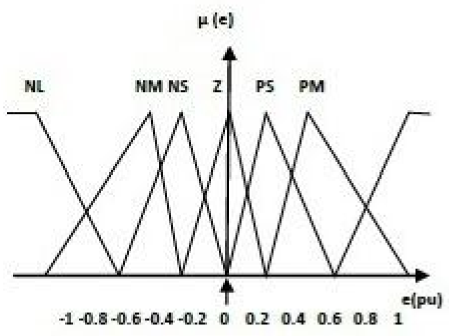

Fig. 3 Membership function for error

The above figure shows the membership function of the error for the MRAC circuit. The change in error is also one of the parameters that needs to be taken into account. And the membership function of the change in the error is given here.

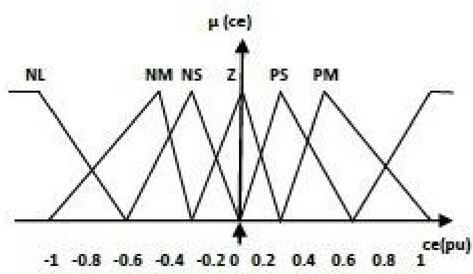

Fig.4 Membership function of change in error

By using the above two membership functions the output of the MRAC controller is designed. Now the output is also designed based on the requirements. The more accurate output needs more precise rule base. And that depends on the designer and the constraints. If the complexity is not an issue then there is a scope for using more membership variables and better output. The overall block diagram of the MRAC is as shown below. That included the two fuzzy controllers that are used in the MRAC. The first fuzzy block is used for the computation of the slip gain. The second block is used for the fast convergence of the output. The outputs after comparison of the model reference and actual are made in the form of per unit. This is for the effective output. Whenever the output is made in per unit, the scaling factors are easy to be implemented. After the computation of Ks, it is given to the theta calculation block and from then onwards the output is taken from that block. Thus the reference values are taken into consideration for the fast convergence and the output is more finer compared to the other controllers. The overall block diagram of this scheme is given here.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

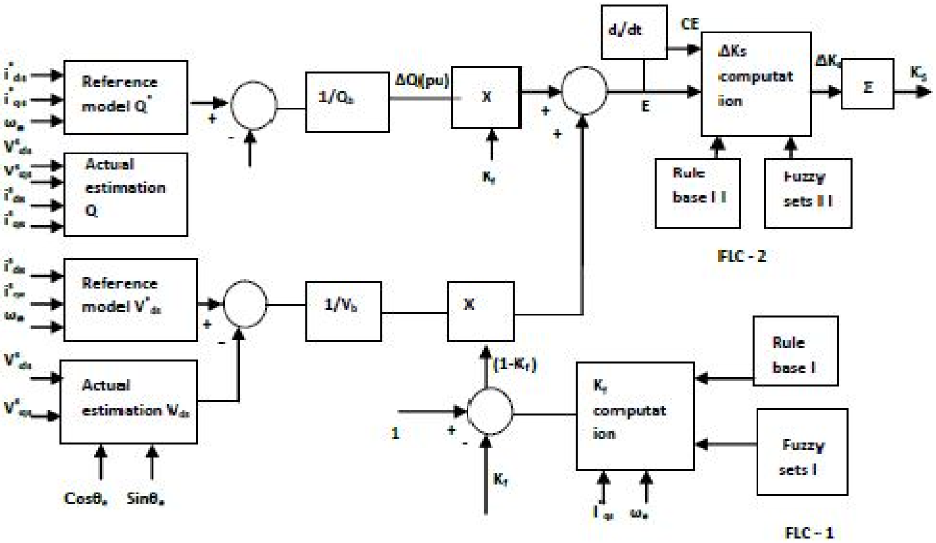

Fig. 5 MRAC block diagram

VI. RESULT AND DISCUSSION

The torque response of the PI controller shows that the time taken by the torque value to reach the steady state is far higher when compared to the time taken by the Fuzzy PI and Fuzzy MRAC. Of the three controllers, the Fuzzy MRAC has the fastest response and it is parameter insensitive too. When the resistance is changed by the 25% , the other two controllers have reduced their value. But the Fuzzy MRAC has not changed. Hence it is more robust and also takes less time to reach the steady state. The MATLAB responses of the torque are shown below.

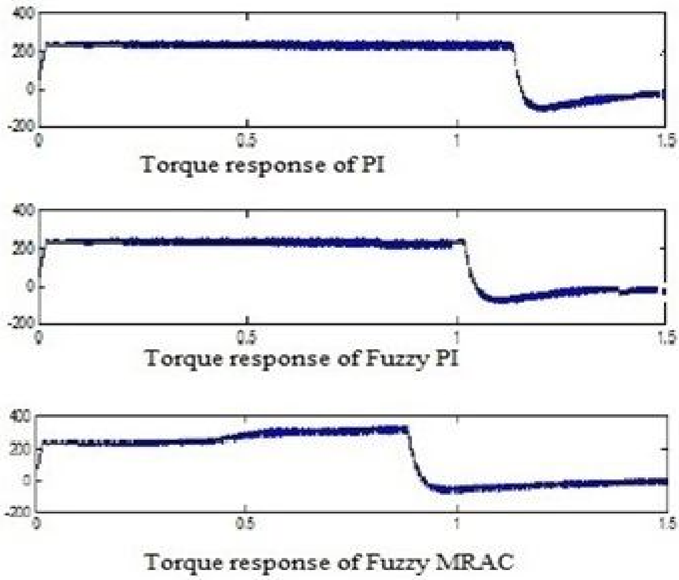

Fig. 6 Torque waveforms of the three controllers

Similar to the torque waveforms, the speed waveforms are alike for the three controllers except for the time that it takes to reach the set speed value. The time that the three controllers take is also listed in the tabular form that is following section. The speed waveforms of the three controllers are as shown below.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

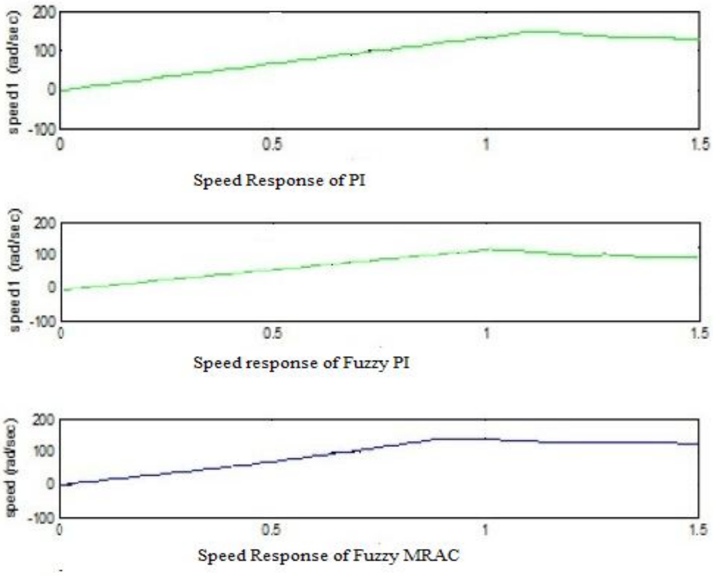

Fig.7 Speed waveforms of the three controllers.

The time taken by the three controllers is listed in a tabular form for the comparison. It can be clearly seen that the Fuzzy MRAC controller takes least time among the three to reach the set speed. And the other two controllers lag behind. Fuzzy PI takes less time to reach the set speed compared to the conventional PI controller. The table is listed here.

Table 1 Settling time comparison of the three controllers

Controller	**Settling time in seconds**
PI	**1.2**
Fuzzy PI	**1.0**
Fuzzy MRAC	**0.82**

VII.CONCLUSION

By inculcating the human intelligence to the machines using the fuzzy logic, the transient response has improved dramatically and the time taken to reach the steady state too has improved. This can be seen in the figure 7 that shows the comparison of the speed waveforms of the three controllers. The torque results in figure 6 show that MRAC is clearly the front runner among the three and it is parameter insensitive compared to the other two. Even the change in the resistance by 25% hasn't changed the output. The settling time of the three controllers is listed in the table. The only drawback of the Fuzzy MRAC is its complexity. The complexity of the fuzzy MRAC is high. As the number of parameters increase the complexity increases too. There is the scope for the improvements in the design of the MRAC.

REFERENCES

[1] P. Vas, Vector control of AC machines, New York: Clarendon, 1990.
[2] B.K. Bose, power electronics and AC Drive. Englewood Cliffs, NJ. Prentice hall, 1986.
[3] M M. N. Uddin, T. S. Radwan, and M. A. Rahman,"Performances of Fuzzy-Logic-Based Indirect Vector Control for Induction Motor Drive", *IEEE Transactions On Industry Applications*, Vol. 38, No. 5, pp. 1219-1225,Sept./Oct. 2002..
[4] Gilberto C. D. Sousa, Bimal K. Bose and Kyung S. Kim, " Fuzzy Logic Based ON-LINE MRAC Tuning Of Slip Gain For an Indirect Vector- Controlled Induction Motor Drive" , 1993 IEEE
[5] Hui- ying Dong, Wen-guang Li, "Design and Simulation a Fuzzy-adaptive PI Controller Based on MRAS" IEEE, Circuits and Systems society, Sixth International Conference on Natural Computation, 2010.
[6] P. Vas, and J. Li, 1993, 'Simulation Package for Vector Controlled Induction Motor Drives' , *Oxford University press*
[7] Bharat Bhushan, Madhusudhan Singh, Prem Prakash, " Performance Analysis Of Field Oriented Induction Motor using Fuzzy PI and Fuzzy Logic based Model Reference Adaptive Control", International Journal of Computer Applications(0975-8887) Volume 17- No 4, March2011