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MRAS BASED SENSORLESS INDUCTION MOTOR DRIVE USING VARIABLE STRUCTURE CONTROL

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ABSTRACT

Induction motor drives are widely used in industries for its simple and easy control. Variable structure controller (VSC) for an induction motor drive is an effective method of control in case of non linearities and uncertainties to enhance robustness. Dynamic performance of Induction motor drives is an essential characteristic for many industrial applications. Quality of the product is an industry and the profit of the industry are mainly depends on the performance of the induction motor drive. Transient state performance of the VSC based an induction motor drive to be improved. Since conventional VSC based induction motor drive has PI controller based speed controller. To enhance the performance of the system this paper proposes Model reference Adaptive System based speed controller in VSC. The design is simple and easy to be implemented. The entire system is simulated using Matlab / Simulink to analyze the performance of a drive. Performance of a drive using Model reference Adaptive System VSC is analysed and compared with conventional Proportional and Integral VSC. To analyze the dynamic performance of the system machine is subjected to constant and variable load in this paper.

Keywords: Induction Motor, variable structure controller, Model reference Adaptive System, PI controller.

1. INTRODUCTION

In many industries induction motors plays vital role like backbone of an industry. it is used for its reliability and low cost. performance of an induction motor drive decides the efficiency of an industry. so many researchers analysed to enhance the performance of a drive. recently, many researchers presented the advanced control strategies for pwm inverter fed induction motor drive. particularly, the vector control, which guarantees high dynamic and static performances like dc motor drives, has become very popular and has been developed and improved. fast digital processor and power devices in the vector control drives provides the possibility of achieving high performance induction motor drive control. there are many works devoted to the vector control, but only few deals with the improving the performance of controller structure [1]. classical control theory using conventional pi controllers provides good performance only in case of linear processes whose exact model is known. however, it is not possible to deal always with linear process. to achieve effective control using pi controller needs precise knowledge of motor and load parameters this is not possible in always.

Variable structure controller (VSC) is a system to deal with nonlinearities [2]. The variable structure system is inherently aimed at dealing with system uncertainties, lead to good performances even in presence of strong and fast variations of the motor parameters. Many authors analyzed the performance of variable structure systems with a sliding mode [3-5]. The VSC works on the principle of imposing the system motion to occur on a given manifold in the state space, which is defined according to the control tasks. VSC is more advantageous for its robustness, insensitivity to parameter variations, fast dynamic response. In the conventional VSC based induction motor drive PI controller is used [6][7]. Again it leads to all drawbacks by the PI controller in the VSC system too. Fuzzy logic controller (FLC) and Fuzzy Gain Scheduling (FGS) Controller are analyzed many researchers for the speed control in the induction motor drive [8-9]. Since then, fuzzy logic control has become an active and fruitful research area with

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many theoretical works and industrial applications being reported [10] [11] [12-14]. Still to obtain the complete adaptive nature, specific adaptive control techniques are needed. Adaptive control changes the control algorithm coefficients in real time to compensate for variations in environment or in the system itself. It also varies the system transfer function according to situation. Out of many adaptive control schemes, this paper mainly deals with the model reference adaptive control approach. In MRAC [15-19], the output response is forced to track the response of a reference model irrespective of plant parameter variations. The controller parameters are adjusted to give a desired closed-loop performance.

2. VARIABLE STRUCTURE CONTROL ALGORITHM DESCRIPTION

The vector controlled induction motor drives are easily adoptable to VSC algorithm. In a sliding mode (SM) control, the reference model is stored in the form of a predefined phase plane trajectory, and the system response is forced to follow or slide along the trajectory by a switching control algorithm [20]. Sliding surface or sliding line is defined as the starting point of a sliding mode control design [21]. Ensuring the ablity of the system to reach or cross the chosen sliding line is the next stage of a control algorithm. After the system crossing the Sliding line, it will be able to cross it again for an infinite number of times.

In this paper, the motor speed is controlled in order to obtain a constant motor speed. So, the vector control task is to impose the convergence of the motor speed magnitude to a reference one. This goal can be fulfilled applying the VSC synthesis procedure to the error speed system equation.

The error between the motor speed and its reference can be obtained as follows;

$$\omega_{err} = \omega_r^*(t) - \omega_r(t) \qquad (1)$$

and its derivative can be obtained as [2];

$$\omega_{err}^0(t) = \left(-\frac{B}{J} + \frac{3P}{2}\frac{L_m}{L_r}k\right)\omega_{err}(t) \qquad (2)$$

Where, k is a linear feedback-gain, B is the viscous friction, J is the moment of inertia, p is the number of pair poles, Lm is the mutual inductance, and Lr is the self inductance of the rotor per phase of the induction motor. So, the equivalent dynamic behavior of control system can be rewritten as [1];

$$\omega_{err}^0 \quad (t) = (a + bk)\,\omega_{err}(t) \qquad (3)$$

Where, £ = −B/J, ¥ = 3p/2. Lm/Lr, k is a feedback gain, and (£ + ¥k) is designed to be strictly negative. The switching surface with an integral component for the sliding mode speed controller is designed as follows [1];

$$S(t) = \omega_{err}(t) - \int_0^t (a + bk)\,\omega_{err}(\Gamma)\,d\Gamma \qquad (4)$$

It is obvious from the equation (3) that the speed error will converge to zero exponentially if the pole of the system is strategically located on the left-hand plane. Thus, the overshoot phenomenon will not occur, and the system dynamic will behave as a state feedback control system. Based on the developed switching surface, a switching control law, which satisfies the hitting condition and guarantees the existence of the sliding mode, is then designed. So, the variable structure speed controller is designed as the following,

$$I_q^s(t) = k\ \omega_{err}(t) - \beta\,\mathrm{sgn}(S(t)) \qquad (5)$$

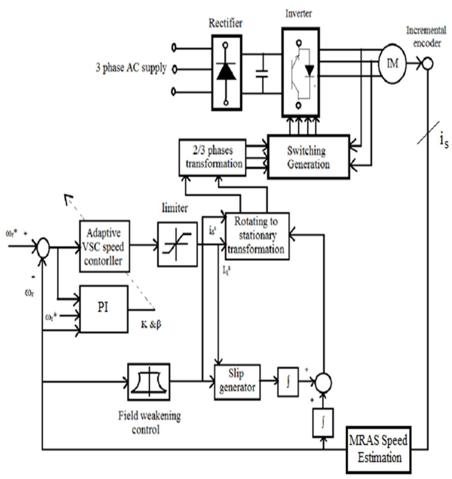

Fig. 1. MRAS Based VSC For Vector Controlled Induction Motor Drive

Where, β is denoted as switching gain, with the following assumption, β≥ 0, Iq is the reference torque component current, and sgn (·) is a signum function defined as,

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$$\mathrm{Sgn}(S) = \begin{cases} 1 & \text{for } S > 0, \\ 0 & \text{for } S = 0, \\ -1 & \text{for } S < 0, \end{cases} \qquad (6)$$

Hence, the dynamic behavior on the sliding surface can be described by Equation (3), and the tracking error err (t) converges to zero exponentially. The torque current command can be obtained according to Equation (5). The values of k and β play an important role in control structure. In this paper PI controller based determination of these parameters and performance of drive are analysed.

3. ADAPTIVE SCHEME FOR SPEED ESTIMATION

Adaptive scheme is applied to estimate the speed of induction motor without the help of speed sensor. Model reference based adaptive system of speed estimation block is shown in figure.

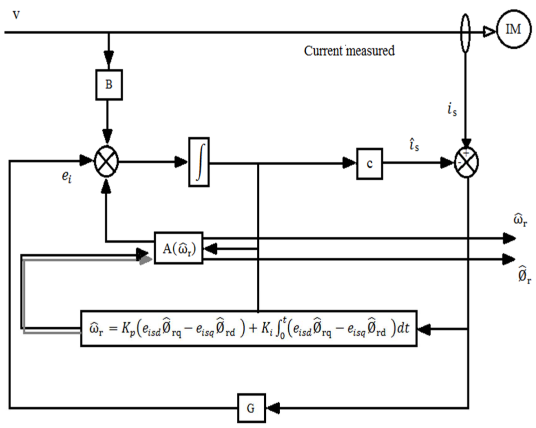

Fig. 2. Model Reference Based Speed Observer

Consider the Lyapunov function candidate [13]:

$$V = V_1 - V_2 \qquad (7)$$

$$V_1 = e^T e \qquad V_2 = \frac{e_{\omega}2}{\lambda} \qquad (8)$$

With (λ > 0), is the positive constant ensuring the positive definiteness of V_2 and which will be tuned in (19) to improve observer dynamics.$e_{\omega} = \omega_r - \hat{\omega}_{\cdot r}$ and $e^T = [i_{sd} - \hat{\imath}_{\cdot sd} \;\; i_{sq} - \hat{\imath}_{\cdot sq} \;\; 0 \;\; 0]$ because we supposed that $\emptyset_r = \hat{\emptyset}_{\cdot r}$

The derivatives of this lyapunov candidate function in thus:

$$\frac{dV}{dt} = e^T[(A - GC)^T + (A - GC)]e \; - 2 \qquad (9)$$

$$e^T[(A - GC)^T + (A - GC)] \qquad (10)$$

With $Q = \mathcal{E} l_n$ and $\mathcal{E} > 0$

The stability of adaptive observer has proved if we respect two conditions as follows:

The eigen-value of the observer is selected to have negative real parts so that the states of the observer will converge to the desired states of the observed system. The term in factor of $(\omega_r - \hat{\omega}_{\cdot r})$ the equation (9) must be zero. The expression of the derivative of estimated speed becomes then:

$$K\left(e_{isd}\hat{\emptyset}_{\cdot rq} - e_{isq}\hat{\emptyset}_{\cdot rd}\right) - \frac{1}{\lambda}\frac{d}{dt}\hat{\omega}_{\cdot r} = 0 \qquad (11)$$

$$\frac{d}{dt}\hat{\omega}_{\cdot r} = \lambda K\left(e_{isd}\hat{\emptyset}_{\cdot rq} - e_{isq}\hat{\emptyset}_{\cdot rd}\right) \qquad (12)$$

However this adaptive law of the speed

$$\hat{\omega}_{\cdot r} = K_i \int_0^t \left(e_{isd}\hat{\emptyset}_{\cdot rq} - e_{isq}\hat{\emptyset}_{\cdot rd}\right)dt \qquad (13)$$

Has obtained for the satatorique frame his dynamic has adjusted by K_i (finite positive constant). For augmented the dynamic of this observer during the transitory phase of rotor speed, we estim the speed by large PI regulator; we added a supplementary term proportional of error. Then

$$\hat{\omega}_{\cdot r} = K_p\left(e_{isd}\hat{\emptyset}_{\cdot rq} - e_{isq}\hat{\emptyset}_{\cdot rd}\right) + K_i \int_0^t \left(e_{isd}\hat{\emptyset}_{\cdot rq} - e_{isq}\hat{\emptyset}_{\cdot rd}\right)dt \qquad (14)$$

Where SZ and S' are adaptive gains for speed estimator. An identification system for speed is shown in Fig.2, which is constructed from a

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10th June 2014. Vol. 64 No.1

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linear time-invariant forward block and a nonlinear time-varying feedback block.

4. PI CONTROLLER IN VSC

PI controller is the simple method of control and widely used in industries. Proportional plus Integral Controller increases the speed of response of the system [22]. It produces very low steady state error. Two PI controllers are proposed in this paper for k and β. In this paper speed Error (e) is given as input to both PI controllers. General equation of the PI controller is

$$U(s) = K_p E(s) + \frac{K_i}{s} E(S) \qquad (15)$$

Where K_p is proportional gain, K_i is the integral gain, E(s) is the controller input and U(s) is the controller output.

In this paper Ziegler Nichols' method of tuning is implemented to find the optimum value of K_p & K_i values. But the drawback of this controller is, it produces the high overshoot and long settling time.

5. SIMULATION RESULTS AND ANALYSIS

To analyze the performance of variable structure controlled induction motor 5 HP squirrel induction motor is taken. It is analyzed using various controllers such as PI and MRAS under various speeds and loads. Parameters of induction motors are shown in table 1:

Table 1: Motor Parameters

Line Voltage	415
Frequency	50 Hz
Stator Resistance (R_s)	1.15Ω
Rotor Resistance (R_r)	1.083Ω
Stator inductance (L_s)	5.974 mH
Rotor inductance(L_r)	5.974 mH
Mutual inductance(L_m)	0.2037H
Moment of Inertia (J)	0.02 $Kg.m^2$
Number of poles (P)	4

Simulation model of MRAS based VSC controlled induction motor drive is shown in fig. 3.

Fig. 3. Simulation model of MRAS based VSC controlled induction motor drive

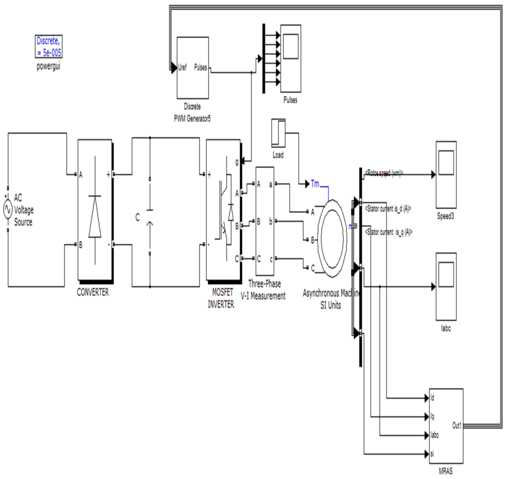

Fig. 3. Simulation Model Of MRAS Based VSC Controlled Induction Motor Drive

The performance of the motor using PI based VSC are shown in fig. 4. The performance is analyzed under a load while the machine is running. The reference speed of the machine is set at 1500 rpm.

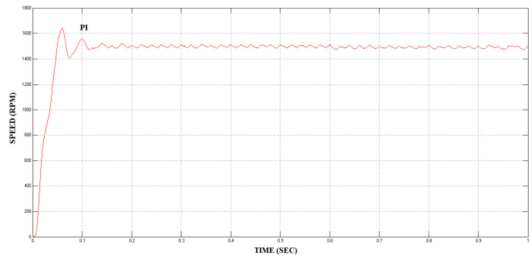

Fig. 4. Speed Performance Of PI Based VSC Control

The performance of the motor using MRAS based VSC is shown in fig. 5. Conditions for analyses are same as a PI controller test.

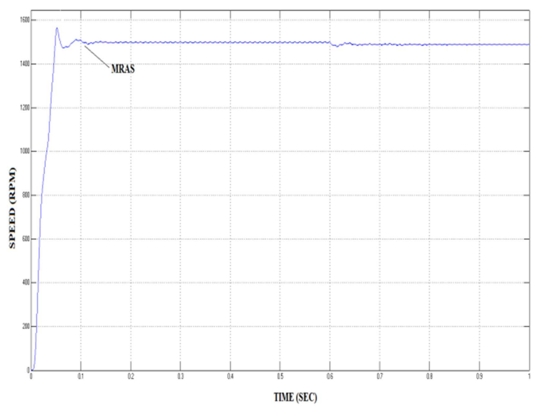

Fig. 5. Speed Performance Of MRAS Based VSC Control

Three phase stator current and flux of MRAS based VSC controlled induction motor drive is shown in fig. 6 and 7.

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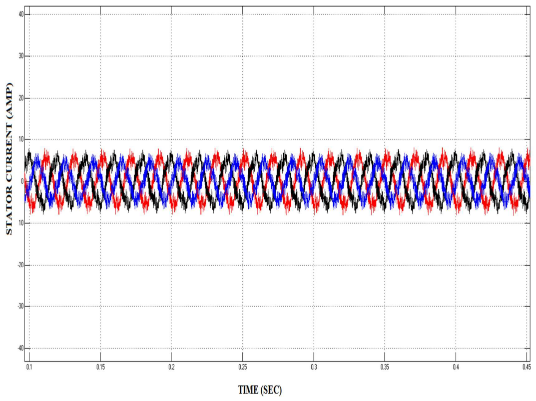

Fig. 6. Three Phase Stator Current Of MRAS Based VSC Control

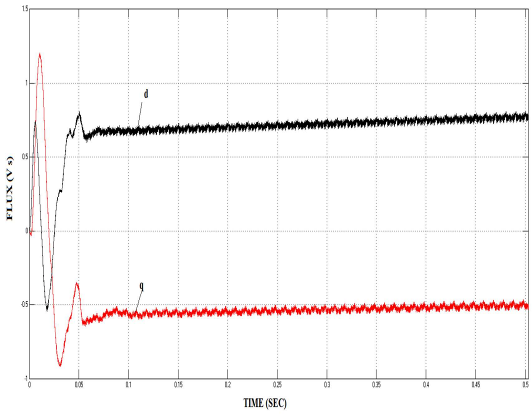

Fig. 7. D And Q Axis Flux Of MRAS Based VSC Control

Fig.8 and Table 2 shows the comparative performance of PI and MRAS based VSC under step change in load at 0.6 seconds and reference speed as 1500 rpm.

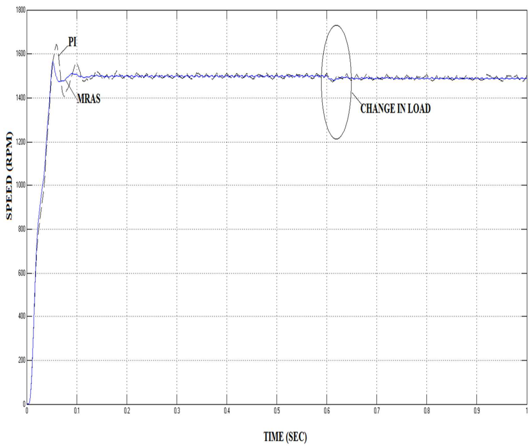

Fig. 8. Comparison Of Speed Performance Of PI And MRAS Based VSC Control

The comparative performance of a drive at the time of starting is shown in fig. 9.

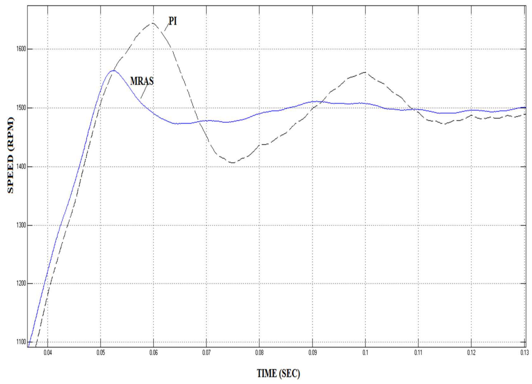

Fig. 9. Comparison Of Speed Performance During Starting Using PI And MRAS Based VSC Control

Table 2: Performance Comparison Of Pi And Mras Controller

Controllers	Peak overshoot in %	Rise time in Sec	Settling time in Sec	Steady state error in %	Change in speed during load change in %
PI	5.67	0.082	0.2	2.667	0.4
MRAS	4	0.05	0.15	0.4	0.26

From the table it is obvious that the MRAS method improves performance of induction motor drive in all aspects such as peak overshoot, rise time, steady state error and drop in speed during change in load.

6. CONCLUSIONS

Induction motors are widely used in many industries in daily applications. Performance enhancement of it is necessary to improve quality of product. The Variable structure control is proposed in this for induction motor drive for its high robustness. It means that the system is completely insensitive to parametric uncertainty and external disturbances. Variable structure controlled Induction motor is analyzed in this paper with PI and Model reference Adaptive System. Simulation is done using Matlab. Performance of VSC based IM using both controllers are analyzed under various speeds and loads. From the simulation results it is obvious that PI controller

Journal of Theoretical and Applied Information Technology
10th June 2014. Vol. 64 No.1

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gives almost quick response but it produces large overshoot, steady state error and high fluctuation in speed while sudden change in load. The Model reference Adaptive System controller performs well in all aspects such as overshoot, steady state error and change in speed while sudden change in load. Therefore it is optimum to use Model reference Adaptive System controller for VSC based Induction motor control.

REFRENCES:

[1] Faa-Jeng Lin, Rong-Jong, Wai-hsin-jang and Shieh, 1998, "Robust control of induction motor drive with rotor time constant adaptation", Electric power systems research, Vol.47 (1), pp.1–9.

[2] CedomirMilosavljevi´c, DraganAnti´c, DarkoMiti´c and Goran Djordjevi´, 1995, "comparative analysis of variable structure systems (VSS) with proportional plus integral (PI) control", Electronics and Energetics vol. 14, pp.1–9.

[3] Ho E Y,Sen, P.C,1990, "A microprocessor-based induction motor drive system using variable structure strategy with decoupling", IEEE Transactions on Industrial Electronics ,Vol.37,pp. 227-235.

[4] Ho E Y,Sen, P.C,1990,1991, "Control Dynamics of Speed Drive System Using sliding mode controllers with integral compensation, IEEE Transactions on Industrial application,Vol.27,pp. 883–892.

[5] Zhang, J.Barton, T. H, 1988, "Optimal sliding mode control of asynchronous machine speed with state feedback", in Conf. Rec. IEEE IAS annual meeting, pp. 328–336.

[6] Chern, T. L.Chang, J.Chang, G. K, 1997, "DSP-Based Integral Variable Structure Model Following Control for BrushlessDC Motor Drivers", IEEE Transactions on Power Electronics, Vol.12 (1), pp. 53-63.

[7] Benudhar Sahu, K.B.Mohanty and Swagat Pati, 2010, "A Comparative Study on Fuzzy and PI Speed Controllers for Field-Oriented Induction Motor Drive", Modern Electric Power Systems, Wroclaw, Poland MEPS'10.

[8] Kannan.R and Kanagaraj "Performance Analysis of an Induction Motor Drive Using Fuzzy Variable Structure Control", Australian Journal of Basic and Applied Sciences, 7(12) Oct 2013, Pages: 51-59.

[9] Kannan.R and Kanakaraj "Fuzzy Gain Scheduling Based Induction Motor Drive Using Variable Structure Control" Journal of Applied Sciences Research, 9(10): 5533-5540, 2013.

[10] D. Driankov, H. Hellendoorn, and M. Reinfrank, 1993, "An Introduction to Fuzzy Control", Berlin: Springer-Verlag.

[11] Y.Tang and L.Xu, 1994, "Fuzzy Logic Application for Intelligent Control of a Variable Speed Drive", IEEE Trans Energy Conversion, Vol.9 (4), pp. 679–685.

[12] P.Tripura and Y.Srinivasa Kishore Babu, 2011, "Fuzzy Logic Speed Control of Three Phase Induction Motor Drive", World Academy of Science, Engineering and Technology Vol.60.

[13] Mokrani, L and Abdessemed, R. (2003), "A fuzzy self-tuning PI controller for speed control of induction motor drive", Proceedings of 2003 IEEE Conference on Control Applications, Vol(2), pp; 785-790.

[14] Neema D.D, Patel R. N and Thoke A.S, 2011, "Speed Control of Induction Motor using Fuzzy Rule Base", International Journal of Computer Applications ,Vol.33(5),pp.21-29.

[15] Pankaj Swarnkar, Shailendra Jain, R.K.Nema, "Effect of adaptation gain on system performance for Model reference adaptive control scheme using MIT rule", I*nternational conference of World Academy of science, engineering and technology, Paris, France, October 27-29, 2010.*

[16] Pankaj Swarnkar, Shailendra Jain, R.K.Nema, "Application of Model reference adaptive control scheme to second order system using MIT rule", *International conference on Electrical Power and Energy Systems, August, 26-28, 2010, MANIT, Bhopal, India.*

[17] JK. Benjelloun, H. Mechlih and E.K. boukas, "A modified model reference adaptive control algorithm for DC servomotor", *second IEEE conference on control applications, September 13-16, 1993 Vancouver, B.C.*

[18] M.S.Ehsani, "Adaptive Control of Servo Motor by MRAC Method", *IEEE international conference on vehicle, power and propulsion, 2007.*

[19] Maurizio cirrincione, Marcello Pucci, "An MRAS-based sensorless high performance induction motor drive with a predictive adaptive model", *IEEE transaction on industrial electronics, vol. 52, No. 2, April 2005.*

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

[20] Zhang J Barton T H, 1990, "A fast variable structure current controller for an induction machine drives", IEEE Transactions on Industry applications, Vol.26 (3).

[21] Sabanovic, A., and Izosimov, D, 1981, "Application of sliding modes to induction motor control", IEEE Trans., Vol.17, pp. 41-49.

[22] C. Mohan Krishna M. Tech, G. Meerimatha M.Tech, U. Kamal Kumar M. Tech, 2013, "Indirect Vector Control of Induction Motor Using Pi Speed Controller and Neural Networks", International Journal of Modern Engineering Research (IJMER), Vol.3 (4), pp.1980-1987.