

Fuzzy Logic Based SVPWM Technique for MRAS Controlled Induction Motor Drive

Mohammad Haseeb Khan¹ and Arshia Azam²

^{1,2}EEE Dept., MJCET, Hyderabad, Andhra Pradesh, India

ABSTRACT:

Of the various sensorless control techniques Model referencing adaptive system finds a lot of attention due to its simplicity and robustness. However, there are ripples present in the current and torque of conventionally used MRAS observer. The conventional methods use voltage source inverter that introduces ripples in the current and torque waveforms. Hence, to improve the performance in terms of ripples in this paper a novel MRAS based speed observer using space vector pulse width modulation (SVPWM) is proposed for sensorless control of induction motor. Conventional methods utilized PI controllers that get affected during load torque variations. Hence, to make the induction motor robust to external disturbances in this paper the conventional PI controller is replaced by a fuzzy logic controller (FLC). Hence, by using the proposed fuzzy logic based SVPWM, not only the ripples are reduced but at the same time the motor becomes robust to external disturbances. Simulation results are presented and analyzed to show the effectiveness of the proposed method.

Keywords: Sensorless control, MRAS, SVPWM, Fuzzy logic controller.

I. INTRODUCTION

Of the various sensorless control methods presented in the literature model referencing adaptive system (MRAS) is one of the best methods due to its simplicity and design [1-4]. The different MRAS techniques are usually either based on instantaneous reactive power [3] or back e.m.f. [5, 6] or rotor flux [7, 8]. The rotor flux based MRAS which is used in this method is the most popularly used method and efforts are made to improve the performance of this method.

The conventional two level inverter produce ripples in the flux and torque and THD is also high in the line current. To overcome the above drawbacks SVPWM is found to be one of the most widely used techniques. Conventionally PI controllers are

used in the adaptation mechanism of MRAS speed observer by majority of adaptation schemes. Conventional controllers have few drawbacks such as: they require accurate mathematical model of a plant or system, applicable to linear systems, gets affected to external disturbances. Hence, in this paper SVPWM techniques along with FLC, is proposed which gives better performance by reducing ripples and making the motor robust to external torque disturbances.

II. MODEL REFERENCING ADAPTIVE SYSTEM

The main essence of MRAS is the reduction of error between two models such that it tends to zero. The basic principle of rotor flux based MRAS speed observer for estimation of speed can be easily understood from model shown in Fig 1. As shown in Fig. 1, it consists of two models, reference model and adaptive model and an adaptation mechanism which minimizes the error between the two models. The reference model also known as voltage model represents the stator equations and is given in matrix form by eq. (1) and current model is given by eq. (2)

$$\begin{bmatrix} p \psi_{rd} \\ p \psi_{rq} \end{bmatrix} = \frac{L_r}{L_m} \left\{ \begin{bmatrix} v_{sd} \\ v_{sq} \end{bmatrix} - \begin{bmatrix} R_s + \sigma L_s p & 0 \\ 0 & R_s + L_s p \end{bmatrix} * \begin{bmatrix} i_{sd} \\ i_{sq} \end{bmatrix} \right\} \tag{1}$$

$$\begin{bmatrix} p \hat{\psi}_{rd} \\ p \hat{\psi}_{rq} \end{bmatrix} = \begin{bmatrix} -\frac{1}{T_r} & -\omega_r \\ \omega_r & -\frac{1}{T_r} \end{bmatrix} * \begin{bmatrix} \hat{\psi}_{rd} \\ \hat{\psi}_{rq} \end{bmatrix} + \frac{L_m}{T_r} \begin{bmatrix} i_{sd} \\ i_{sq} \end{bmatrix} \tag{2}$$

where $p = \frac{d}{dt}$, $T_r = \frac{L_r}{R_r}$ is rotor time constant and $\sigma = 1 - \frac{L_m^2}{L_s L_r}$ is leakage coefficient.

The difference of the outputs of the two estimators known as error is given by eq. (3)

$$\xi = X - X^1 = \hat{\psi}_{rd} \psi_{rq} - \hat{\psi}_{rq} \psi_{rd} \tag{3}$$

This is used as speed tuning signal that is given as input to adaptation mechanism, which forms the main part of the MRAS scheme.

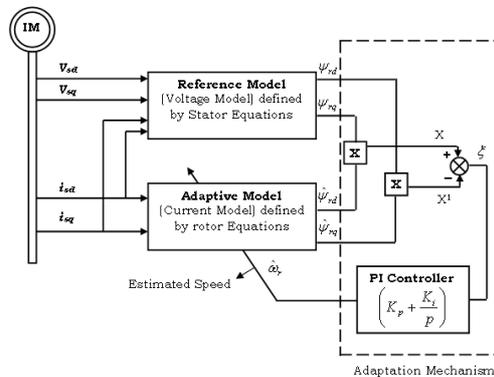


Fig. 1 Principle of Conventional MRAS

III. SVPWM ALGORITHM

For a three phase VSI, there exist two possibilities for each phase, which in effect means that the total number of combinations possible for switching states will be 2^3 or 8. The 8 switching codes or states are numbered from 0 to 7. The possible 8 switching states are given as $V_0(000)$, $V_1(100)$, $V_2(110)$, $V_3(010)$, $V_4(011)$, $V_5(001)$, $V_6(101)$, $V_7(111)$. Among the 8 possible switching states, 6 states i.e. states from V_1 to V_6 are known as active voltage vectors and 2 states, i.e. V_0 and V_7 are known as zero vectors. The maximum boundary of the space vectors form the hexagon and the circle, shown in Fig.2, is the maximum trajectory of the sinusoidal outputs.

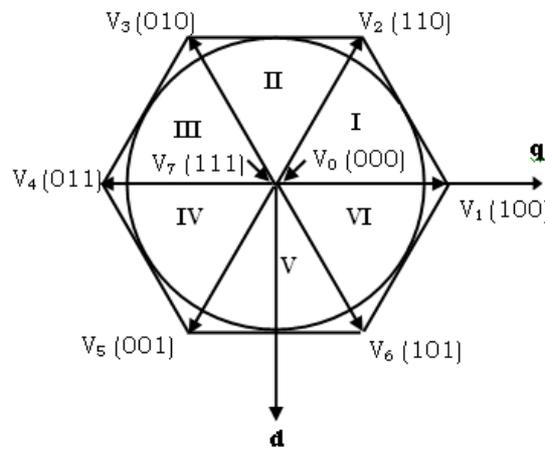


Fig.2 Voltage space vectors of VSI

IV FUZZY LOGIC CONTROLLER

In the proposed MRAS observer conventionally used PI controller in the adaptation mechanism of MRAS based speed observer is replaced by a FLC. The block diagram of two input single output fuzzy logic controller is shown in Fig. 4. Speed tuning signal ξ and its change $\Delta\xi$ are the two inputs to the proposed FLC. The main aim of FLC is to obtain output signal Δu , known as change in output signal, which is based on ξ and $\Delta\xi$. Knowing the value of Δu the output signal “ u ” can be given as in eq. (4) and estimated speed is given by eq. (5). The extra logic of FLC is contained mainly in the rules which are given in Table 1

$$u(k) = u(k - 1) + \Delta u(k) \tag{4}$$

and

$$\hat{\omega}_r(k) = \hat{\omega}_r(k - 1) + \Delta \hat{\omega}_r(k) \tag{5}$$

Table 1 Fuzzy control rule table with 49 rules

ξ	NL	NM	NS	ZE	PS	PM	PL
$\Delta\xi$							
NL	NL	NL	NL	NL	NM	NS	ZE
NM	NL	NL	NL	NM	NS	ZE	PS
NS	NL	NL	NM	NS	ZE	PS	PM
ZE	NL	NM	NS	ZE	PS	PM	PL
PS	NM	NS	ZE	PS	PM	PL	PL
PM	NS	ZE	PS	PM	PL	PL	PL
PL	ZE	PS	PM	PL	PL	PL	PL

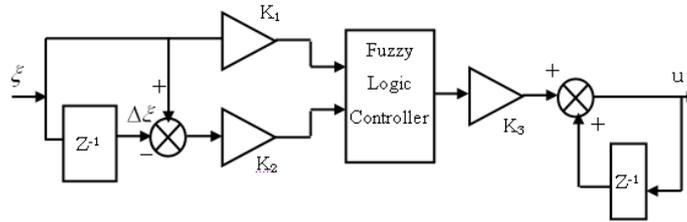


Fig. 4 Block diagram of FLC

VPROPOSED FLC BASED SVPWM FOR SENSORLESS CONTROL

The block diagram of proposed FLC based SVPWM-MRAS is shown in Fig. 5.

In the V_{ref} (reference voltage vector) calculator block shown in Fig. 5 the reference and actual values of the d & q axes stator fluxes are compared and the error is given by the eq. (6)

$$\Delta\psi_{sd} = \psi_{sd}^* - \psi_{sd}, \Delta\psi_{sq} = \psi_{sq}^* - \psi_{sq} \tag{6}$$

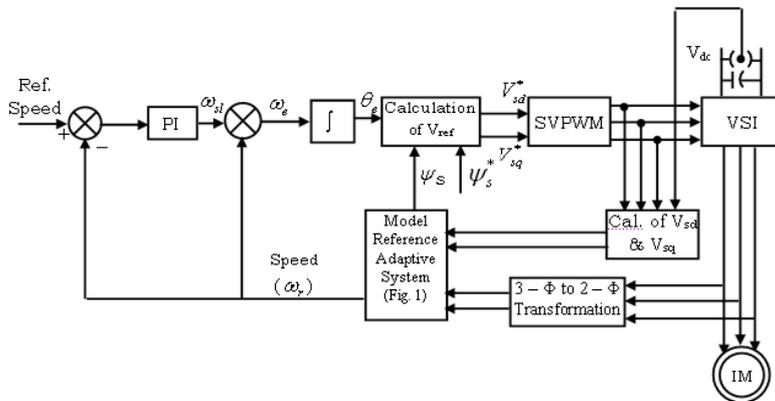


Fig. 5 FLC based SVPWM-MRAS speed observer

By knowing the values of stator flux error in d and q axes and the stator ohmic drop the appropriate reference voltage space vectors can be calculated by utilizing the eq.s (7).

$$V_{sd}^* = \frac{\Delta \psi_{sd}}{T_s} + R_s i_{sd}, \quad V_{sq}^* = \frac{\Delta \psi_{sq}}{T_s} + R_s i_{sq} \tag{7}$$

T_s is the duration of sampling period or which is half of the period of the switching frequency which means that the flux is controlled twice per switching cycle.

VI RESULTS AND DISCUSSION

Simulations are performed to validate the proposed FLC base SVPWM-MRAS speed observer for sensorless control of induction motor drive. In Fig. 6 the response of conventional MRAS is shown for 1300 rpm on no load in which there are ripples present in the torque and current wave. The response of the proposed FLC-SVPWM base MRAS is shown in Fig. 7, it can be observed that the ripples present in the current and torque are N-m applied at 1 sec and Fig. 9 shows the response of the proposed MRAS. From the simulated results it can be observed that by utilizing the proposed FLC based SVPWM for sensorless control of induction motor using MRAS the ripples in the current and torque are reduced considerably.

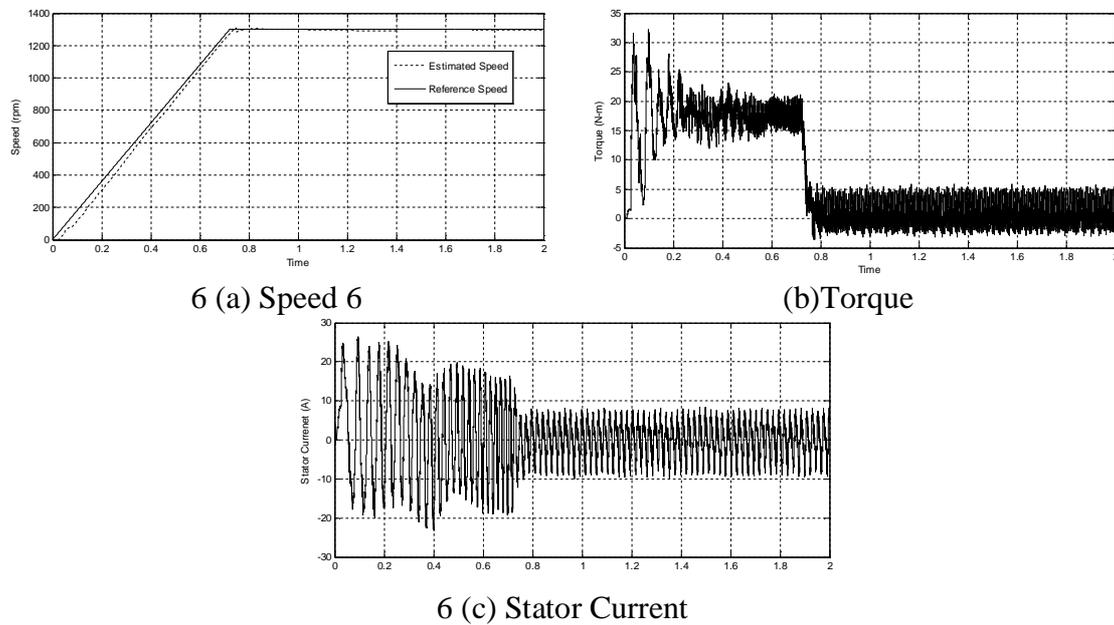
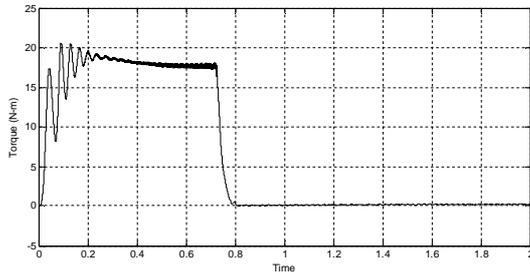
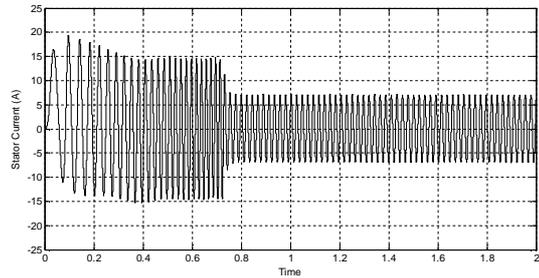


Fig. 6. Response of Conventional MRAS at 1300 rpm

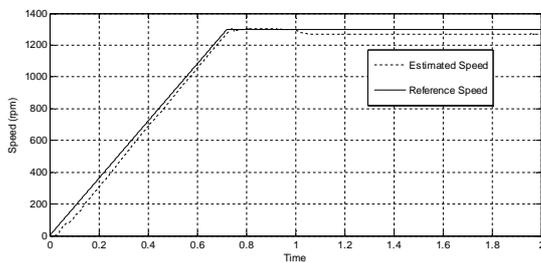


7 (a) Torque 7

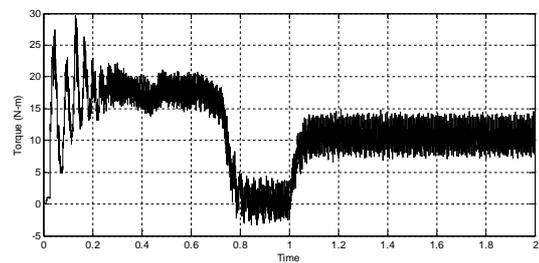


(b) Stator Current

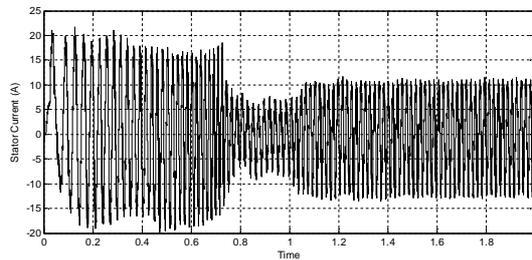
Fig. 7 Response of proposed SVPWM based MRAS at 1300 rpm.



8 (a) Speed

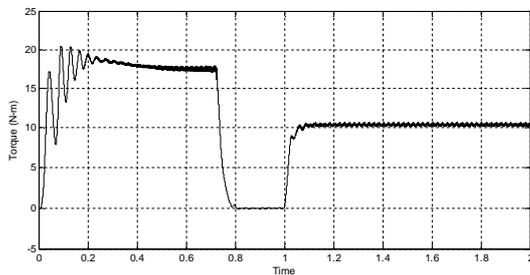


8 (b) Torque

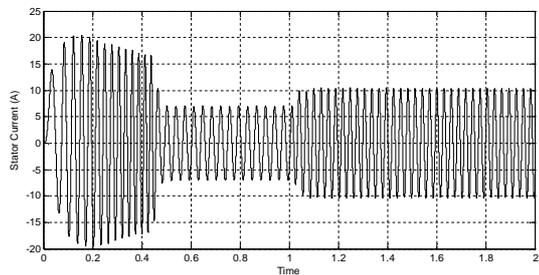


8 (c) Stator Current

Fig8. Response of Conventional MRAS with load of 10N-m



a) Torque



b) Stator Current

Fig. 9. Response of proposed SVPWM based MRAS with load of 10 N-m.

VII CONCLUSION

In this paper a novel method based on SVPWM technique is proposed for reducing ripples present in the torque and current of sensorless control of induction motor drive using MRAS. Conventional controllers are prone to external disturbances, hence to make the induction motor robust to external load torque variations; FLC is also proposed that replaces the PI controller in the adaptation mechanism of the MRAS speed observer which makes the drive robust to external disturbances.

REFERENCE:

- [1] J.Holtz and J.Quan, "Drift and parameter compensated flux estimator for persistent stator frequency operation of sensorless controlled induction motor," *IEEE Trans. Industry Appl.*, vol.39, no.4, July/August 2003, pp1052-1060.
- [2] M. Rashed and A.F. Stronach, "A stable back-EMF MRAS-based sensorless low speed induction motor drive insensitive to stator resistance variation, " *IEE Proc. Electr. Power Appl.*, vol. 151, no. 6, November 2004, pp. 685-693.
- [3] Y. Hori C. Ta, T. Uchida. MRAS-based speed sensorless control for induction motor drives using instantaneous reactive power IECON, 1417-1422, Nov. 1991.
- [4] S.D.Huang, Y.N.Wang, J.Gao, et al, "The vector control based on MRAS speed sensorless induction motor, " *Conf. of the 5th ICA*, Hangzho, pp. 4550-4553, 2004.
- [5] M.N.Marwali A. Keyhani, "A comparative study of rotor flux based MRAS and back EMF base MRAS speed estimator for speed sensorless vector control of induction machines, " *IEEE Proceedings of IAS Annual Meeting*, pp.160-166, 1997
- [6] X.H.Nian, T.Wang, J. Wang, et al, "Adaptive Stator Resistance Estimation Speed sensorless DTC Controlled IM Drives, " *IEEE Proc. of IPEC*, pp. 214-221, 2007.
- [7] R. Cardenas, R. Pena, G. Asher, et al, "MRAS observer for doubly fed induction machines, " *IEEE Tran on Ind. Energy Conversion*, vol.19, no.2, pp.467-468, 2004.
- [8] C. Schauder, "Adaptive speed identification for vector control of induction motors without rotational transducer, " *IEEE Tran. on Ind. App.* vol.28, pp.1054-1061 1992.

