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Fuzzy Adaptive Internal Model Control Schemes for Pmsm Speed-Regulation System

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ABSTRACT - *In this paper we are regulate the speed of permanent magnet synchronous motor (PMSM) system is based on vector control. The speed of PMSM is based on Internal Model Control (IMC) method is designd. The internal model controller is designed based on a first order model of PMSM by analyzing the relationship between reference quadrature axis current and speed. For the control of two current loops by using of PI controllers. The disadvantages of standard IMC method is sensitive to control input saturation and may lead to poor speed control and load disturbance rejection performances. More ever the modified IMC scheme is developed based on a two port IMC method, where a feed back control action is added to form a adaptive IMC schemes with different adaptive laws are proposed. The method of control of modified IMC method is based on disturbance observer is adopted to identify the inertia of PMSM and its load. Then a linear adaptive law is developed by analyzing the relationship between the internal model and identified inertia. For Considering the control input saturation in practical applications, a fuzzy adaptive law based IMC scheme is developed based on apriori simulation tests, where a fuzzy inferencer based supervisor is designed to automatically tune the parameter of speed controller according to the identified inertia. The effectiveness of the proposed methods have been verified by Matlab simulation results.*

INTRODUCTION

World-wide intensive research in the field of advanced control schemes for drives has been performed during the last few years. Now-a-days energy saving has become an increased concern in industrial applications. Manufacturers across many industries are placing increased emphasis on machine designs that support sustainability initiatives and drive financial affluence. Machines that recover safety, diminish waste, ingest less energy and convey supreme arrival on investment are critical to the accomplishment of any maintainable creation.

Building such a machine needs a holistic attitude analysing effective proficiency, protection, functionality, yield, material custom, comfort of operation and preservation. Electrical motor drives are a key factor to realize this goal, and among the numerous existing options, the market of industrial drives for low- and medium power applications is extra difficult to proposal as several applications do not involve high concert. Induction motors are the most extensively used in domestic, profitable and various industrial requests. Mostly, the squirrel cage type is characterized by its ease, robustness and low cost, which has constantly finished it very attractive, and it has consequently captured the leading place in manufacturing sectors. As a result of its extensive usage in the industry, induction motors ingest a significant percentage of the complete produced electrical energy. The minimization of electrical energy ingesting through an improved motor design becomes a major anxiety.

In this paper, internal model control (IMC) method is presented. The IMC design is lucid for the following reasons: 1)controller parameters are expressed directly in certain machine parameters, 2) it separates tracking problem from regulation problem and 3) the design of controller is relatively straight forward. This method mainly based on model of the plant. So the crucial part of designing controller is modeling of the plat properly. We have different methods of modelling available like traditional mathematical modelling , neural networks modelling, fuzzy modelling . For application of IMC control, permanent magnet synchronous motor (PMSM) drive is taken as example. Now a day, various types of AC motors are widely used. Among all of them PMSM is preferred because of some of its advantageous features like high efficiency, high torque to current ratio, low noise and robustness .

Vector control is implemented in PMSM drive to give better control performance. Garcia and Morari firstly introduced IMC method. During some past years IMC is under research and development and hence application of IMC is extended to the motor control system from process control system. The IMC includes an internal model of controlled plant and an internal model controller. Whereas an internal model controller consist of an internal model of controlled plant and a low pass filter. Low pass filter is added in series with inverse of plant to make degree of denominator greater than or equal to degree of numerator. Modified design of filter is proposed in . Conventional IMC method provides good tracking performance, robustness and disturbance rejection. It also provides a good platform for analysis of control system performance i.e. issues related to stability and robustness.

Third, further considering the case of load inertia variations, two adaptive IMC schemes are developed respectively. A torque disturbance observer (DOB) based method is employed to estimate the inertia of PMSM with load. Since the varying inertia can be estimated, the corresponding control (inertia) parameter in the internal model and the internal model controller can be linearly tuned with the change of inertia, then an adaptive IMC scheme based on linear adaptive law is developed. This method is straightforward and easy to implement.

PROBLEM DESCRIPTION

In d-q coordinates, the model of the surface mounted PMSM can be described as [31]

$$\begin{pmatrix} \dot{i}_d \\ i_q \\ \dot{w} \end{pmatrix} = \begin{pmatrix} \frac{-R}{L} & n_p w & 0 \\ n_p w & \frac{-R}{L} & \frac{n_p K_t}{J} \\ 0 & \frac{n_p K_t}{L} & \frac{-B}{L} \end{pmatrix} \begin{pmatrix} i_d \\ i_q \\ w \end{pmatrix} + \begin{pmatrix} \frac{u_d}{L} \\ \frac{u_q}{L} \\ \frac{T_L}{J} \end{pmatrix} \quad (1)$$

where i_d and i_d d-axis and q-axis stator currents, u_d and u d-axis and q-axis stator voltages, number of pole pairs, R stator resistance, L stator inductance, K_t torque constant, w angular velocity, β viscous friction coefficient, J moment of inertia, and T_L load torque. The principle diagram of PMSM system based on vector control is shown in Fig. 1.

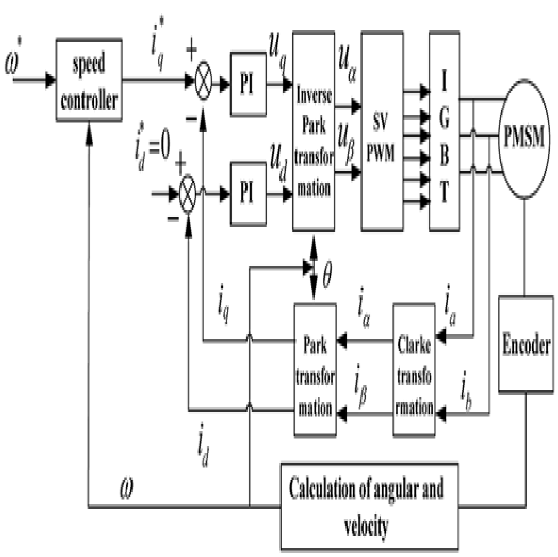

Fig. 1. Principle block diagram of PMSM speed regulation system based on vector control.

Here, $i_d^* = 0$ strategy is used and two PI algorithms are used in the two current-loops respectively. In this paper, we concentrate on the design of speed controller.

CONTROL STRATEGY

A. Speed Controller Design for PMSM

1) Standard Internal Model Controller for PMSM: The Standard IMC method is considered as a robust control method which includes an internal model, and an internal model controller which consists of the inverse internal model and a filter.

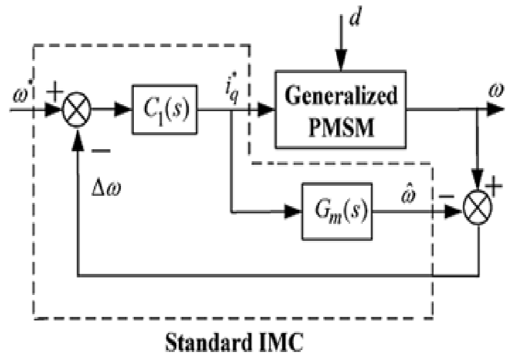

Fig. 2. Block diagram of the standard IMC method for PMSM system

The standard IMC structure for PMSM is shown in Fig. 2, where the "generalized PMSM" includes the PMSM model and the other components of the two current loops, similar to that of Fig. 1, $G_m(s)$ is the internal model, and $C_1(s)$ is the internal model controller. From (1), we can have

Where $d(t) = -\frac{T_L}{K_t - (i_q^* - i_q)}$ represents the lumped disturbance, including the external load disturbance, and the tracking error of current loop of i_q. Therefore, the generalized PMSM (the controlled model) can be described simply as

$$G_p(s) = \frac{1}{a_p s + b_p} \quad (3)$$

Where

$$a_p = \frac{J}{K_t}, \quad b_p = \frac{B}{K_t}$$

The internal model is described as

$$G_m(s) = \frac{1}{a_m s + b_m} \quad (4)$$

where a_m, b_m are the internal model parameters. It should be noted that for the standard IMC method, if the internal model is accurate, i.e., $G_p(s) = G_m(s)$, the closed loop system is stable only if $G_p(s)$ and $C_1(s)$ are both stable. Therefore, we design the internal model controller $C_1(s)$ as follows:

$$C_1(s) = G_m^{-1} Q_1(S) = G_m^{-1} \frac{1}{\varepsilon s + 1} \quad (5)$$

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$$\boldsymbol{\Omega}(s) = \frac{C(s)G_p(s)}{1+C_1(s)[G_p(s)-G_m(s)]}\boldsymbol{\Omega}^*(s) - \frac{G_p(s)[1-C_1(s)G_m(s)]}{1+C_1(s)[G_p(s)-G_m(s)]}\mathrm{D(S)} \qquad (6)$$

If the internal model is accurate, i.e.,$G_p(s) = G_m(s)$,from (5) and (6), we can obtain

$$\Omega(\mathrm{s}) = \frac{1}{\varepsilon s+1}\boldsymbol{\Omega}^*(s) - \frac{\varepsilon s}{(a_p s+b_p)(\varepsilon s+1)}\mathrm{D(S)} \qquad (7)$$

It can be visible from (7) that G_p (s) is protected within the switch function among **Ω**(s) and and D(S) affects the load disturbance rejection performance, regardless of how the parameter ε of the IMC filter Q_1 (s) is tuned. The cause is if there's no version errors and disturbance, the IMC device will become an open loop machine. Due to control input saturation, a few favored control statistics may also misplaced, which may additionally generate a short-sightedness property that could significantly degrade the performance of control system.

2) Modified Internal Model Controller for PMSM: .

Using the two-port IMC structure in, a modified IMC scheme for PMSM is proposed, as shown in Fig.3.

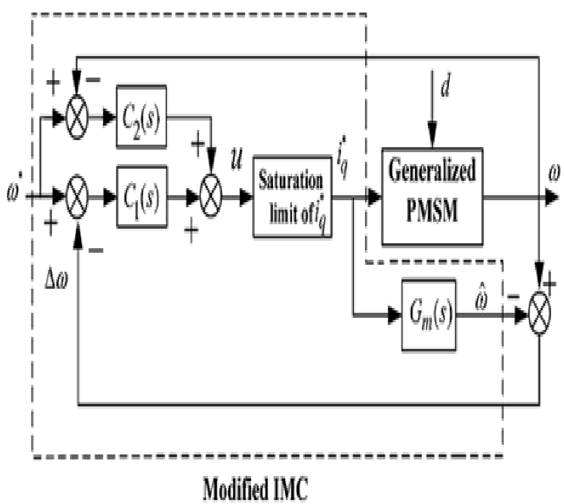

Fig. 3. Block diagram of the modified IMC method for PMSM system

Note that the control input u in practice usually is limited in amplitude. Thus the relationship between i_q^* and u is

$$i_q^* = \begin{cases} u & |u \leq| \; i_{q\,max} \\ i_{q\,max} \, . sign(u), |u| > \; i_{q\,max} \end{cases}$$

.

The feedback control term $C_2(s)$is designed as a proportional term simply, which is shown as follows:

$$C_2(S) = k_p \qquad (8)$$

For the convenience of analysis, just let, $i_q^* = u$ regardless of saturation. From Fig. 3, we can obtain

$$\boldsymbol{\Omega}(s) = \frac{[C_1(s)+C_2(s)]G_p(s)}{1+C_1(s)[G_p(s)-G_m(s)]+C_2(s)G_p(s)}\boldsymbol{\Omega}^*(s) - \frac{G_p(s)[1-C_1(s)G_m(s)]}{1+C_1(s)[G_p(s)-G_m(s)]+C_2(s)G_p(s)}\mathrm{D(s)} \qquad (9)$$

If the internal model is accurate, i.e., $G_p(s) = G_m(s)$,from (5), (8), and (9), we can also obtain

$$\Omega(s) = \frac{(k_p\varepsilon+a_p)s+k_p+b_p}{(k_p+a_p s+b_p)\,(\varepsilon s+1)}\Omega^*(s) - \frac{\varepsilon s}{(k_p+a_p s+b_p)\,(\varepsilon s+1)}D(s) \qquad (10)$$

For load disturbance rejection performance, compared with (7), it can be seen that the feedback control term can be adjusted properly to reduce the time constant, i.e. $\frac{\frac{a_p}{(b_p+k_p)}a_p}{b_p}$ which can make the recovery trajectory in the presence of load disturbance fast to void "a long tail." Besides, when the output of the modified IMC controller is saturated, the output of the feedback control term C_2 can compensate for the effect of control input saturation as antiwindup compensation to improve the tracking performance.

3) Simulation Results:

To test the execution of the standard IMC technique, simulation on PMSM system have been performed.

The solid lines in Fig. 4 demonstrate the reaction bends of speed i_q^* and under ε = 0.01where (b) is a halfway amplification diagram of (a). The estimation of i_q^* does not exceed as far as possible and the speed reaction has no overshoot and a short settling time (0.04 s). The spotted lines in Fig. 4 demonstrate the reaction bends of speed and i_q^*under ε = 0.005 without considering any saturation constrain.

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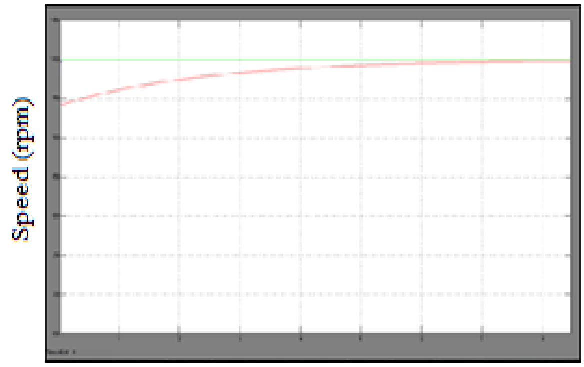
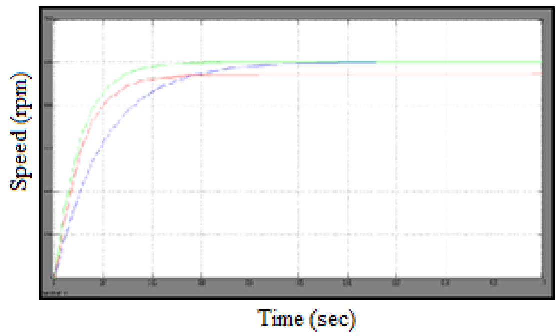


(a)



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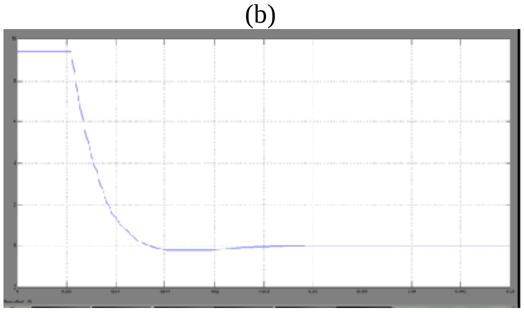
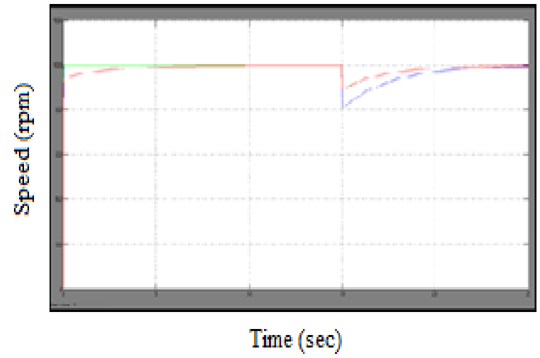


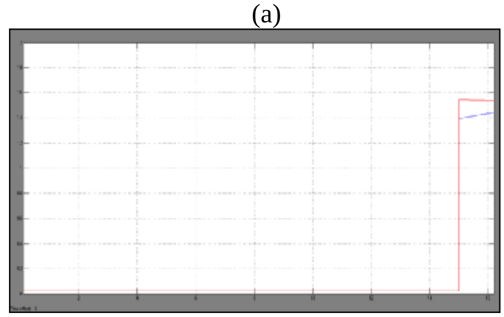
(c)

Fig. 4. Responses under standard IMC (simulation). (a) Speed. (b) Local curve of (a). (c) i_q^*

To test unsettling influence rejection execution of standard IMC strategy, a load torque $T_r = 2N.m$ is connected at . As appeared in Fig. 5, the most extreme abundancy of speed diminish under ε = 0.01 is around 174.8 rpm and the speed recuperation time is 10 s.



(a)



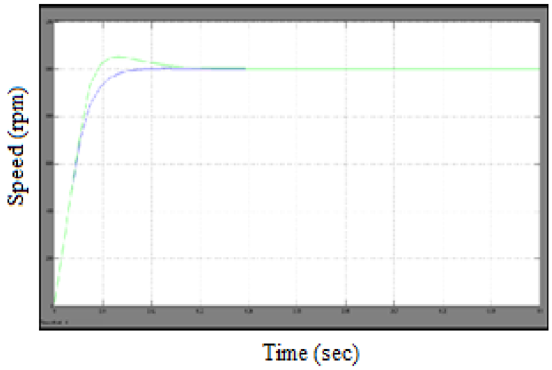
(b)

Fig. 5. Responses under standard IMC method in the presence of load torque disturbance (simulation). (a) Speed. (b) i_q^* .

B. Adaptive Internal Model Controller Design of PMSM

1) Performance Analysis: The above modified inner version manage scheme for PMSM is strong to a degree. However, in practical motion manage systems, there might also exist instances of large variations of load inertia.

The dashed traces in Fig. 6 display the response curves of speed and i_q^* , whilst the inertia of the system is J_n The velocity response has a small overshoot (6.12%) and a brief settling time (zero.01 s). The solid strains in Fig. 6 display the simulation outcomes when the inertia of the system is multiplied to 6J_n . The speed response has a larger overshoot (17.Eighty one%) and a longer settling time (0.024 s).



(a)

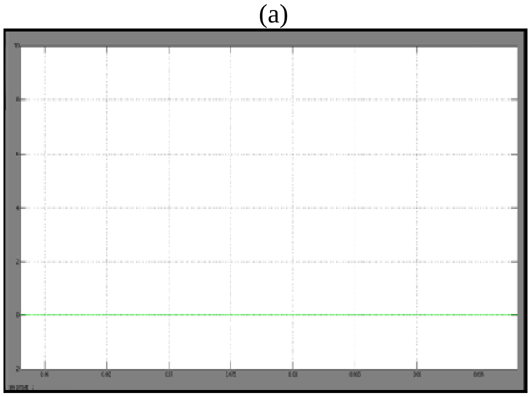
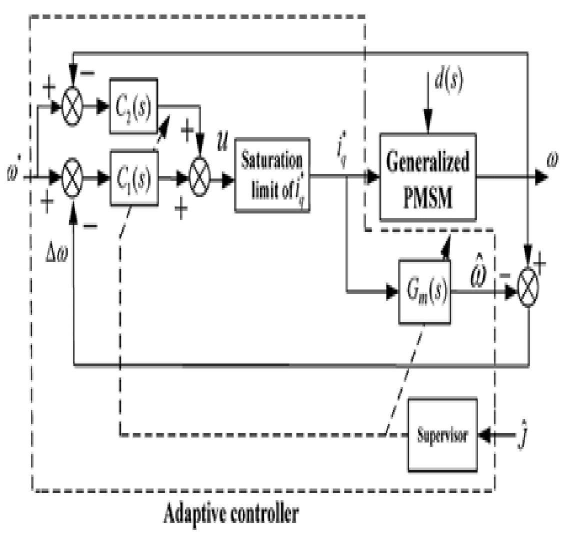

(b)

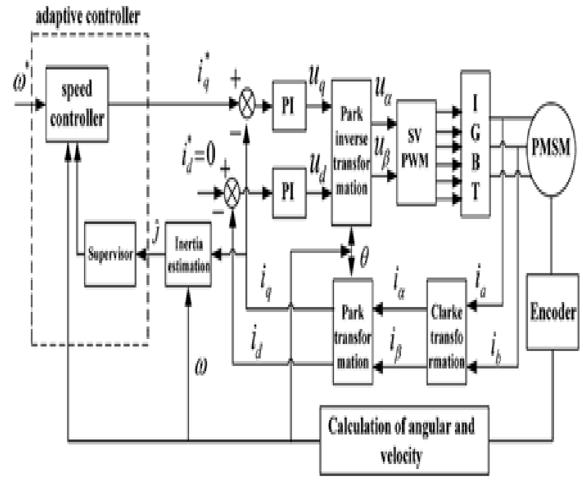
Fig. 6 Responses in the case of J = J_n And J = $6\,J_n$ (SIMULATION) (a) Speed.(b) i_q^*

2) Adaptive Internal Model Control Design:

The square graph of versatile IMC conspire for PMSM speed direction system is appeared in Fig. 7, where (a) demonstrates the entire detail diagram and (b) demonstrates the detail diagram of adaptive IMC plan.



(a)



(b)

Fig.7. Adaptive control scheme for PMSM speed regulation system. (a)The whole schematic diagram. (b) The detail diagram of adaptive IMC.

A parameter auto tuning strategy is adopted to tune the parameter by using the estimated inertia . The expression of adaptive internal model controller is as follows: The internal model

$$\hat{G}_m(S) = \frac{1}{\hat{a}_m S + b_m} \qquad (11)$$

1) Internal model controller

$$C_1(s) = G_m^{-1} Q_1(S) \quad (12)$$

Where $\hat{a}_m$ can be tuned according to the identified inertia.

$$w^*(t+T) = w^*(t)$$

where T is the period of speed command.

C. Adaptive Laws

1) Linear Adaptive Law: When inertia varies, we can tune the parameter $\hat{a}_m$ of the speed controller by the estimation of inertia. To ensure the performance of the system, a linear relationship between $\hat{a}_m$ and J is established, e.g., $\hat{a}_m = J/K_t$. We can obtain the ratio of the actual $\boldsymbol{\partial} = \frac{J}{Jn}$ inertia to the original inertia by the estimation of inertia. Thefinal parameter can be expressed as follows:

$$\hat{a}_m = \partial \mathrm{a_m} \quad (13)$$

2**) Fuzzy Adaptive Law:** $\hat{a}_m$ is theoretically supposed to be linearly tuned with the change of inertia, i.e., $\hat{a}_m = J/K_t$.However, in practical applications, due to the existence of control input saturation, the linear adaptive law may not be the most adequate solution.

The Fuzzy execute is the one-input-one-output case. By simulation , we finally obtain the

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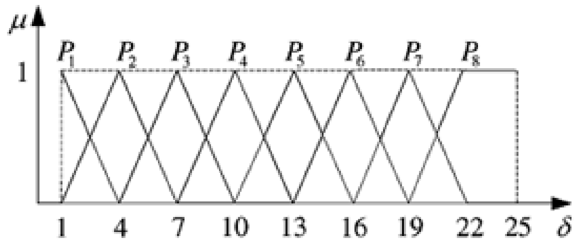
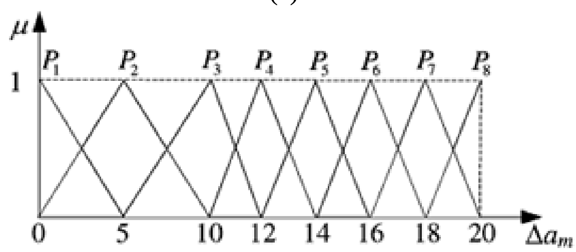
available groups of membership functions and Fuzzy principles, as appeared in Fig.8.



(a)



(b)

Fig. 8. Membership functions. (a) Membership function of inertia ratio ∂. (b) Membership function of Δa_m.

is utilized as the output of the fuzzy inference engine. The final parameter after fuzzy tuning can be expressed as follows

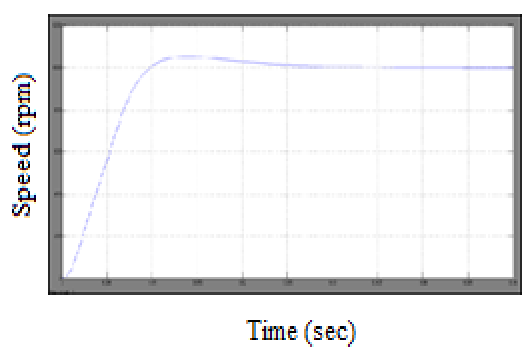
$$\hat{a}_m = a_m + \gamma \Delta a_m \qquad (14)$$

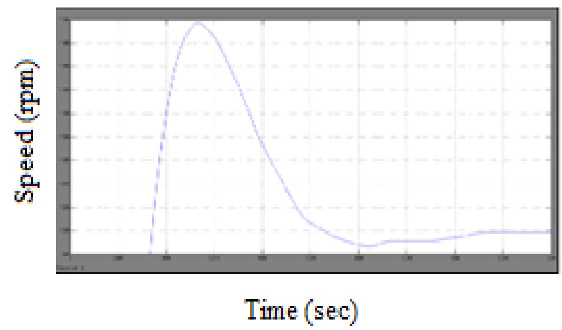
where γ is the proportional factor.

SIMULATION RESULTS

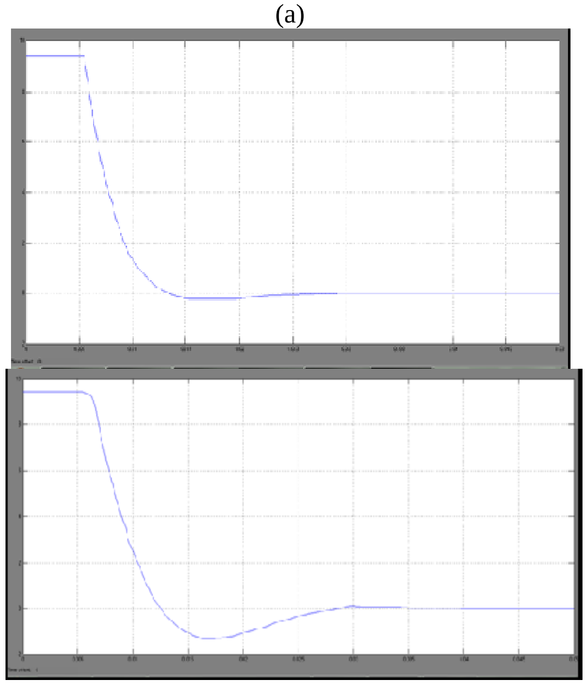
The specification of the PMSM and other parameters of simulation are the same as -A3. To test the inertia, the speed command signal is chosen as $w^* = 500 + 100\sin(40\pi t)$, $\gamma = 1.107 \times 10^4$.

The speed response before and after parameter auto tuning is shown in Fig.9.





(a)



(b)

Fig. 9. Responses under linear adaptive control law and nonadaptive control law (simulation). (a) Speed. (b) i_q^*.

Fig. 10 shows the comparisons under linear adaptive tuning and fuzzy adaptive tuning. Compared with the speed response with linear adaptive tuning (5.12% overshoot and 0.021 s settling time), the speed response under fuzzy adaptive tuning has a smaller overshoot (2.12%) and a shorter settling time (0.015 s).

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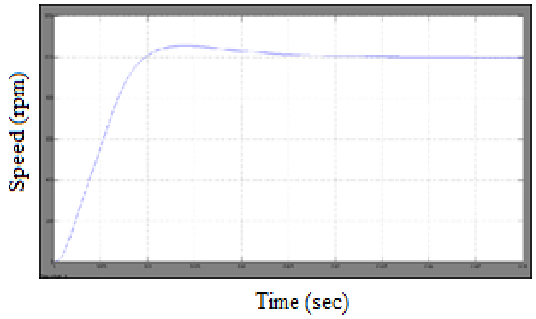

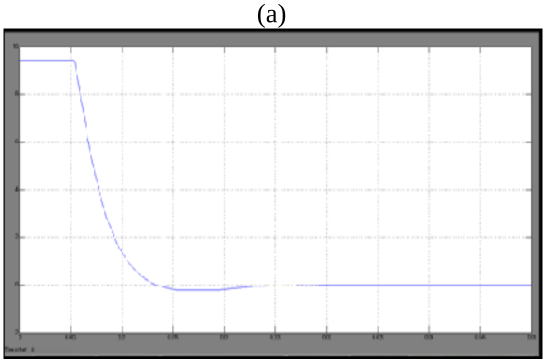

Fig. 10. Responses under linear adaptive control law and fuzzy adaptive control law (simulation). (a) Speed. (b) i_q^*.

CONCLUSION

The speed direction issue for a Permanent Magnet Synchronous motor (PMSM) in light of internal model control techniques has been considered. Initial, a standard internal model control conspire has been designed in light of a first request model of PMSM by analyzing the connection between reference quadrature axis current and speed output. Second, since the standard IMC technique is sensitive to control input saturation and may lead poor following and unsettling influence disturbance rejection performances, an adjusted internal model control plot has been created in light of a two-port interior model control strategy. Third, considering about the instance of vast variations of load inertia, two versatile IMC schemes with two distinctive versatile laws have been proposed. A technique in view of DOB has been received to distinguish the inertia of the PMSM and load. A straight versatile law has been created by breaking down the connection between the inner model and distinguished inertia. Considering the control input saturation in practical applications, a fuzzy adaptive law based IMC conspire has been created in view of apriority simulation tests, where a fuzzy inferencer based director has been intended to naturally tune the parameter of speed controller as per the distinguished inertia. The effectiveness of the proposed strategies have been checked by simulation results.

REFERENCES

[1] Y. X. Su, C. H. Zheng, and B. Y. Duan, "Automatic disturbances rejection controller for precise motion control of permanent-magnet synchronous motors,"IEEE Trans. Ind. Electron., vol. 52, no. 3, pp. 814–823, Mar. 2005.

[2]K.H.KimandM.-J.Youn,"AnonlinearspeedcontrolforaPM synchronous motor using a simple disturbance estimation technique," IEEE Trans. Ind. Electron., vol. 49, no. 3, pp. 524–535, Mar. 2002.

[3] I. C. Baik, K.-H. Kim, and M. J. Youn, "Robust nonlinear speed control of PM synchronous motor using boundary layer integral sliding mode control technique,"IEEE Trans. Control Syst. Technol.,vol.8,no.1, pp. 47–54, Jan. 2000.

[4] S. H. Li and Z. G. Liu, "Adaptive speed control for permanent magnet synchronous motor system with variations of load inertia,"IEEE Trans. Ind. Electron., vol. 56, no. 8, pp. 3050–3059, Aug. 2009.

[5] Y. A.-R. I. Mohamed, "Design and implementation of a robust current control scheme for a PMSM vector drive with a simple adaptive disturbance observer,"IEEE Trans. Ind. Electron.,vol.54,no.4,pp. 1981–1988, Apr. 2007.

[6] S. M. Yang and Y. J. Deng, "Observer-based inertia identification for autotuning servo motor drivers," inProc. 40th IAS Annu. Meeting, Hong Kong, 2005, pp. 968–972.

[7] H.H.Choi,N.T.-T.Vu,andJ.-W.Jung,"Digitalimplementationofan adaptive speed regulator for a PMSM,"IEEE Trans. Power Electron., vol. 26, no. 1, pp. 3–8, Feb. 2011.

[8] F.F.M.El-Sousy,"HybridH-infinity-based wavelet-neural-network tracking control for permanent-magnet synchronous motor servo drives,"IEEE Trans. Ind. Electron., vol. 57, no. 9, pp. 3157–3166, Sep. 2010.

[9] T.L.Hsien,Y.Y.Sun,andM.C.Tsai," control for a sensor less permanent-magnet synchronous drive," IEE Proc.-Electr. Power Appl., vol. 144, no. 3, pp. 173–181, 1997.

[10] Y. Luo, Y. Q. Chen, H.-S. Ahnc, and Y. G. Pi, "Fractional order robust control for cogging effect compensation in PMSM position servo sys tems: Stability analysis and experiments," Contr. Eng. Practice, vol. 18, no. 9, pp. 1022–1036, 2010.