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Adaptive Backstepping Position Controller for PMSM Drive with Uncertainties of Mechanical Parameters

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Abstract

The permanent magnet synchronous motors (PMSMs) are widely used in various industrial applications because of their numerous advantages. However, the performance of conventional controllers (PID) is insufficient in PMSM nonlinear drive systems, which requires high performance. In this paper, we investigate the possible enhancements in performance by using an adaptive backstepping position controller that is designed based on the Lyapunov stability theory. The backstepping technique has been successfully applied for nonlinear systems with external disturbances. The results of the simulation indicate an improved performance due to the designed controller ability to track the position reference signal precisely unlike the conventional controller. The proposed adaptive backstepping controller has improved performance and effectiveness of the PMSM drive systems.

Keywords: Lyapunov stability theory, adaptive backstepping position controller, the permanent magnet synchronous motor(PMSM);

1. Introduction

The permanent-magnet synchronous motor (PMSM) is extremely popular in the industrial applications due to its many attractive features, such as high efficiency nearly no rotor losses and its power density, high torque/power density and high-performance reliability. It is suitable for many applications due to advances in permanent magnetic materials, microelectronics, and modern control technologies for example machine tools, automobiles, robotics, renewable power generation, aeronautics and aerospace domains. [1,2, 3] The traditional proportional integral derivative (PID) controllers are still commonly applied in industrial control processes. Because of the controller design's simplicity and good performance in different cases of operating conditions. Although (PID) controllers can achieve good response characteristics with the linear system, it is not easy for a nonlinear system to get satisfying results. PMSMs represent the system's non-linear function of mechanical parameters and unknown disturbances, therefore the conventional (PID) controllers and linear control strategy are ineligible for designing a controller for the drive system.[4, 5, 6] Recently nonlinear systems are more applicable to the development of control theory and in control design, such as robust theory [7], robust H ∞ controller[8],

Sliding mode control [9],LQR method [10] and backstepping technique [11] have been introduced into the control system of PMSM. The adaptive Backstepping is a systematic procedure and recursive design methodology, which is often applied to design a controller for nonlinear lower triangular systems. Hence ensuring the stability of the systems. [12, 13] the adaptive backstepping control was developed depending on the Lyapunov stability theorem for position tracking control of Permanent-magnet synchronous motor (PMSM) using MATLAB/Simulink software. The Simulation results of the adaptive backstepping controller are compared with PI controller results.

2. MATHEMATICAL MODEL OF PMSM:

The PMSM is a synchronous machine with three-phase winding in stator and uses a permanent magnet in rotor separated by air gap. The PMSMs are classified into :(a) Surface Mounted magnets type Fig.1(a), (b) Inset magnets typeFig.1(b) according to the position of magnets on rotor [14, 15].

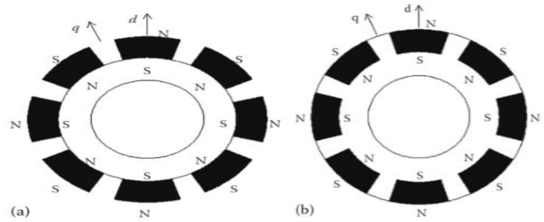

Figure 1. PMSM rotor permanent magnets layout: (a) Surface permanent magnets, (b) Inset permanent magnets

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The mathematical model of PMSM in (d, q) reference frame according to vector control can be expressed as: [3,6].

$$\frac{di_d}{dt}=\frac{-R_s}{L_d}i_d+\frac{PL_q}{L_d}\omega_r i_q+\frac{1}{L_d}u_d \quad (1)$$

$$\frac{di_q}{dt}=\frac{-R_s}{L_q}i_q-\frac{PL_d}{L_q}\omega_r i_d-P\frac{\Phi_f}{L_q}\omega_r+\frac{1}{L_q}u_q \quad (2)$$

$$\frac{d\omega_r}{dt}=\frac{3P\Phi_f}{2J}i_q+\frac{3P}{2J}\left(L_d-L_q\right)i_d i_d-\frac{B}{J}\omega_r-\frac{T_L}{J} \quad (3)$$

$$\frac{d\theta}{dt}=\omega_r \quad (4)$$

With

Rs –Stator resistance.
L_d, L_q - dq-axis inductances.
Φ_f - Permanent-magnet flux linkage.
i_d, i_q -stator currents.
vd, vq -stator voltages.
ω_r- Rotor speed.
θ - Rotor angular position.
J -the moment of inertia.
B -viscous friction coefficient.
p - Number of pole pairs.
T_L -load torque.

3. Controller Design:

The adaptive backstepping controller design is a mix of backstepping algorithm and adaptive Laws. The function of the controller is to track the rotor-desired position in engineering applications. This system can be divided into some sorts of sub-systems, with a self-controller design procedure, which contains several stages with three steps in each one. In the First step, the design is started from the first sub-system. By determining the error between the reference input signal and the actual one. The second step depends on the definition of the Lyapunovcontrol function of the first sub-system. The third step is achieved by calculating the first virtual control, which provides global stability. the first virtual control is considered as a references signal for the second sub-system , the procedures in these steps are repeated until all calculation are fulfilled for all the subsystems .Eventually we get the last virtual control signal, which is the real control input signal of the system .then by calculating the others virtual control laws in a recursive procedure in the same way, until we get the last virtual control which considers as the real control input signal of the system. [16, 17, 18, 19]

The proposed adaptive backstepping controller is described in detail systematically as follows: For height subsystem, we define the position tracking and its time derivative as

$$e_1 = \theta^* - \theta \quad (5)$$

$$\dot{e_1} = \dot{\theta}^* - \dot{\theta} = \dot{\theta}^* - \omega_r \quad (6)$$

Defining a Lyapunov function

$$V_1=\frac{1}{2}{e_1}^2 \quad (7)$$

Differentiating (7) and substituting (5) and (6) in (8)

$$\dot{V_1}=e_1\dot{e_1}=e_1\left(\dot{\theta}^*-\omega_r\right) \quad (8)$$

Adding and subtracting $k_1 e_1$:

$$\dot{V_1}=-k_1{e_1}^2+e_1\left(\dot{\theta}^*-\omega_r+k_1e_1\right) \quad (9)$$

Where:
k_1 Is a positive constant.

The function$\dot{V_1}$should be negative according to Lyapunovtheory to ensure the system's stability. The desired speed for position control, which is indicated by the stabilizing function (virtual control) from (9), are represented as follows:

$$\dot{\theta}^*-\omega_r+k_1e_1=0 \quad (10)$$

$$\omega_r^* = \dot{\theta}^* + k_1 e_1 \quad (11)$$

The tracking error for the speed reference signal ω_r^* is:

$$e_2 = \omega_r^* - \omega_r \quad (12)$$

Substituting (11) in (12)

$$e_2 = \dot{\theta}^* + k_1e_1 - \omega_r \quad (13)$$

Substituting (6) in (13)

$$e_2 = k_1 e_1 + \dot{e_1} \quad (14)$$

By using (14) the position error dynamics can be given as

$$\dot{e_1} = -k_1e_1 + e_2 \quad (15)$$

Dynamic Speed error is expressed as

$$\dot{e_2} = \dot{\omega_r^*} - \dot{\omega_r} \quad (16)$$

$$\dot{e_2} = \left(\theta^{(2)*}+k_1\dot{e}_1\right)-\left(\frac{3P\Phi_f}{2J}i_q+\frac{3P}{2J}\left(L_d-L_q\right)i_d i_q-\frac{B}{J}\omega_r-\frac{T_L}{J}\right) \quad (17)$$

Let,

$$A=\frac{3P\Phi_f}{2J},\ B=\frac{3P}{2J}\left(L_d-L_q\right),\qquad C=\frac{T_L}{J},\ D=\frac{B}{J} \quad (18)$$

Thus, (17) can be expressed as

$$\dot{e_2} = k_1\dot{e}_1 + \theta^{(2)*} - (Ai_q + Bi_d i_q - C - \omega_r D)$$

$$\dot{e_2} = k_1(-k_1e_1+e_2) + \theta^{(2)*} - Ai_q - Bi_d i_q + C + \omega_r D$$

$$\dot{e_2} = -{k_1}^2e_1 + k_1e_2 + \theta^{(2)*} - Ai_q - Bi_d i_q + C + \omega_r D \quad (19)$$

Defining a new Lyapunov function

$$\mathrm{V}_2=\frac{1}{2}{\mathrm{e}_1}^2+\frac{1}{2}{\mathrm{e}_2}^2 \quad (20)$$

Differentiating (20)

$$\dot{V_2}=e_1\dot{e}_1+e_2\dot{e}_2 \quad (21)$$

Substituting (15) and (19) in (21)

$$\dot{V_2}=e_1(-k_1e_1+e_2)+e_2(-{k_1}^2e_1+k_1e_2+\theta^{(2)*}-Ai_q-Bi_d i_q+C+\omega_r D) \quad (22)$$

Adding and subtracting k_2e_2

$$\dot{V_2}=-k_1{e_1}^2-k_2{e_2}^2+e_2\left[\left(1-{k_1}^2\right)e_1+k_1e_2+k_2e_2+\theta^{(2)*}-Ai_q-Bi_d i_q+C\omega_r D\right] \quad (23)$$

To give the Eq. (23) a negative value, the third term should be eliminated, and this is accomplished by defining reference currents i_d^* and i_q^* for the state variables i_d and $i_q$respectively

$$[(1-k_1{}^2)e_1 + (k_1+k_2)e_2 + \theta^{(2)*} - Ai_q - Bi_d i_q + C + \omega_r D] = 0 \quad (24)$$

$$i_d{}^* = 0 \quad (25)$$

$$i_q{}^* = \frac{1}{A}[(1-k_1{}^2)e_1 + (k_1+k_2)e_2 + \theta^{(2)*} + C + \omega_r D] \quad (26)$$

Then, (23) becomes

$$\dot{V_2} = -k_1 e_1{}^2 - k_2 e_2{}^2 \quad (27)$$

Wherek_1,k_2 are positive design constants, the Eq. (27) is given a negative value when the backstepping gains $k_1$and $k_2$have high values which ensures stability. The system parameters can change according to the variation of working conditions, which affect the controller's performance. The position and speed control performance of PMSM system is sensitive to slight deviations in the mechanical parameters because the nonlinear decoupling control is dependent on those parameters. Therefore, it is required to reflect the parametric uncertainties in the mechanical system model equations to compensate the external disturbances and achieve adaptive backstepping control. Hence the parameters C and D in Eq. (24) and (26) are considered variables ($\hat{C}.\hat{D}$) and not constant values. Therefore, Eq. (26) is presented as:

$$\hat{\imath}_q{}^* = \frac{1}{A}[(1-k_1{}^2)e_1 + (k_1+k_2)e_2 + \theta^{(2)*} + \hat{C} + \omega_r \hat{D}] \quad (28)$$

Since i_d and i_q are considered as manipulating variables for position control, their error functions are given by

$$e_3 = \hat{\imath}_q{}^* - i_q \quad (29)$$

$$e_4 = \hat{\imath}_d{}^* - i_d \quad (30)$$

Using Eq. (29) and (30), dynamicspeed error (19) can be rewritten as

$$\dot{e_2} = -k_1{}^2 e_1 + k_1 e_2 + \theta^{(2)*} - A(\hat{\imath}_q{}^* - e_3) - Bi_q(\hat{\imath}_d{}^* - e_4) + C + \omega_r D$$

$$\dot{e_2} = -k_1{}^2 e_1 + k_1 e_2 + \theta^{(2)*} - Ae_3 - Bi_q e_4 + C + \omega_r D - A\hat{\imath}_q{}^*$$

$$\dot{e_2} = -k_1{}^2 e_1 + k_1 e_2 + \theta^{(2)*} - Ae_3 - Bi_q e_4 + C + \omega_r D - A\frac{1}{A}[(1-k_1{}^2)e_1 + (k_1+k_2)e_2 + \theta^{(2)*} + \hat{C} + \omega_r \hat{D}] \quad (31)$$

$$\dot{e_2} = -e_1 - k_2 e_2 + Ae_3 + Bi_q e_4 - \tilde{C} - \tilde{D}\omega_r \quad (32)$$

Where:

$\tilde{C} = \hat{C} - C$

$\tilde{D} = \hat{D} - D$

Thus, dynamic current error is given

$$\dot{e_3} = \dot{\hat{\imath}}_q{}^* - \dot{i_q} \quad (33)$$

$$\dot{e_3} = \frac{1}{A}[(1-k_1{}^2)\dot{e}_1 + (k_1+k_2)\dot{e}_2 + \theta^{(3)*} + \dot{\hat{C}} + \dot{\hat{D}}\omega_r + \hat{D}\dot{\omega_r}] - \dot{i_q}$$

$$\dot{e_3} = \frac{1}{A}[(1-k_1{}^2)(-k_1 e_1 + e_2) + (k_1+k_2)(-e_1 - k_2 e_2 + Ae_3 + Bi_q e_4 - \tilde{C} - \tilde{D}\omega_r) + \theta^{(3)*} + \dot{\hat{C}} + \dot{\hat{D}}\omega_r + \hat{D}(Ai_q + Bi_d i_q - \hat{C} - \hat{D}\omega_r)] + \frac{R_s}{L_q} i_q + \frac{PL_d}{L_q}\omega_r i_d + P\frac{\Phi_f}{L_q} - \frac{1}{L_q} u_q \quad (34)$$

$$\dot{e}_4 = \dot{\hat{\imath}}_d{}^* - \dot{i_d} \quad (35)$$

$$\dot{e}_4 = 0 - \left[-\frac{R_s}{L_d} i_d + \frac{PL_q}{L_d}\omega_r i_q + \frac{1}{L_d} u_d\right] \quad (36)$$

$$= \frac{R_s}{L_d} i_d - \frac{PL_q}{L_d}\omega_r i_q - \frac{1}{L_d} u_d \quad (37)$$

The final Lyapunov function is given by

$$V_3 = \frac{1}{2}\left(e_1{}^2 + e_2{}^2 + e_3{}^2 + e_4{}^2 + \frac{1}{\gamma_1}\tilde{C}^2 + \frac{1}{\gamma_2}\tilde{D}^2\right) \quad (38)$$

Differentiating (38)

$$\dot{V_3} = \left(e_1\dot{e_1} + e_2\dot{e_2} + e_3\dot{e_3} + e_4\dot{e_4} + \frac{1}{\gamma_1}\tilde{C}\dot{\tilde{C}} + \frac{1}{\gamma_2}\tilde{D}\dot{\tilde{D}}\right) \quad (39)$$

Where:

$\gamma 1, \gamma 2$ are positive adaptation gains

Substituting alldynamic error in (39)

$$\dot{V_3} = \Big(e_1(-k_1 e_1 + e_2) + e_2(-e_1 - k_2 e_2 + Ae_3 + Bi_q e_4 - \tilde{C} - \tilde{D}\omega_r) + e_3\Big\{\frac{1}{A}\Big[(1-k_1{}^2)(k_1+k_2)(-e_1 - k_2 e_2 + Ae_3 + Bi_q e_4) - (k_1+k_2)(\tilde{C} + \tilde{D}\omega_r) + \dot{\hat{C}} + \dot{\hat{D}}\omega_r + \hat{D}Ai_q + \hat{D}Bi_d i_q - \hat{D}\hat{C} - \hat{D}^2\omega_r\Big] + \frac{R_s}{L_q} i_q + \frac{PL_d}{L_q}\omega_r i_d + P\frac{\Phi_f}{L_q} - \frac{1}{L_q} u_q\Big\} + e_4\Big\{\frac{R_s}{L_d} i_d - \frac{PL_q}{L_d}\omega_r i_q - \frac{1}{L_d} u_d\Big\} + \frac{1}{\gamma_1}\tilde{C}\dot{\tilde{C}} + \frac{1}{\gamma_2}\tilde{D}\dot{\tilde{D}}\Big) \quad (40)$$

$$
\begin{aligned}
\dot{V}_3 = & -k_1{e_1}^2 - k_2{e_2}^2 - k_3{e_3}^2 - k_4{e_4}^2 + Ae_2e_3 \\
& + Be_2e_4i_q \\
& + e_3\left\{\frac{1}{A}\Big[\left(1-{k_1}^2\right)(\,k_1+k_2)\big(-e_1\right. \\
& - k_2e_2 + Ae_3 + Bi_qe_4\big) \\
& - (\,k_1+k_2)\big(\tilde{C}+\tilde{D}\omega_r\big) + \dot{\hat{C}} + \dot{\hat{D}}\omega_r \\
& + \hat{D}Ai_q + \hat{D}Bi_di_q - \hat{D}\hat{C} - \hat{D}^2\omega_r\Big] \\
& + \frac{R_s}{L_q}i_q + \frac{PL_d}{L_q}\omega_r i_d + P\frac{\Phi_f}{L_q} - \frac{1}{L_q}u_q \\
& \left. + k_3e_3\right\} \\
& + e_4\left\{\frac{R_s}{L_d}i_d - \frac{PL_q}{L_d}\omega_r i_q - \frac{1}{L_d}u_d\right. \\
& \left. + k_4e_4\right\} - \big(\tilde{C}+\tilde{D}\omega_r\big)e_2 \\
& - e_3\frac{1}{A}(\,k_1+k_2)\big(\tilde{C}+\tilde{D}\omega_r\big) + \frac{1}{\gamma_1}\tilde{C}\dot{\hat{C}} \\
& + \frac{1}{\gamma_2}\tilde{D}\dot{\hat{D}} \qquad (41)
\end{aligned}
$$

Rearranging (41):

$$
\begin{aligned}
\dot{V}_3 = & -k_1{e_1}^2 - k_2{e_2}^2 - k_3{e_3}^2 - k_4{e_4}^2 - Ae_2e_3 \\
& + \tilde{C}\left\{\frac{1}{\gamma_1}\dot{\hat{C}} - e_2 - \frac{1}{A}(\,k_1+k_2)e_3\right\} \\
& + \tilde{D}\left\{\frac{1}{\gamma_2}\dot{\hat{D}} - e_2\omega_r\right. \\
& \left. - \frac{1}{A}(\,k_1+k_2)e_3\omega_r\right\} \\
& + e_3\left\{\frac{1}{A}\Big[\left(1-{k_1}^2\right)(-k_1e_1+e_2)\right. \\
& + (\,k_1+k_2)(-e_1-k_2e_2+Ae_3) \\
& +\ \theta^{(3)*} + \dot{\hat{C}} + \dot{\hat{D}}\omega_r + \hat{D}Ai_q + \hat{D}Bi_di_q \\
& - \hat{D}\hat{C} - \hat{D}^2\omega_r\Big] + \frac{R_s}{L_q}i_q + \frac{PL_d}{L_q}\omega_r i_d \\
& \left. + P\frac{\Phi_f}{L_q} - \frac{1}{L_q}u_q + k_3e_3\right\} \\
& + e_4\left\{Be_2i_q + B\frac{i_qe_3}{A}(\,k_1+k_2)\right. \\
& + \frac{R_s}{L_d}i_d - \frac{PL_q}{L_d}\omega_r i_q - \frac{1}{L_d}u_d \\
& \left. + k_4e_4\right\} \qquad (42)
\end{aligned}
$$

The system's stability is accomplished when $\dot{V}_3 \to 0$ this condition is ensured as the positive terms of Eq. (42) decreasing to zero. Hence, the parameter adaptation laws are given by $\dot{\hat{C}} = \gamma_1\left(e_2 + \frac{1}{A}(\,k_1+k_2)e_3\right)$ (43)

$$
\dot{\hat{D}} = \gamma_2\left(e_2\omega_r + \frac{1}{A}(\,k_1+k_2)e_3\omega_r\right) \qquad (44)
$$

Control voltages are defined as

$$
\begin{aligned}
{v_q}^* = L_q & \left\{k_3e_3 + \frac{1}{A}\Big[\left(1-{k_1}^2\right)(-k_1e_1+e_2)\right. \\
& + (\,k_1+k_2)(-e_1-k_2e_2+Ae_3) \\
& +\ \theta^{(3)*} + \dot{\hat{C}} + \dot{\hat{D}}\omega_r + \hat{D}Ai_q + \hat{D}Bi_di_q \\
& - \hat{D}\hat{C} - \hat{D}^2\omega_r\Big] + \frac{R_s}{L_q}i_q + \frac{PL_d}{L_q}\omega_r i_d \\
& \left. + P\frac{\Phi_f}{L_q}\omega_r\right\} \qquad (45)
\end{aligned}
$$

$$
\begin{aligned}
{v_d}^* = L_d & \left\{k_4e_4 + Bi_q\left[e_2 + \frac{e_3}{A}(\,k_1+k_2)\right] + + \frac{R_s}{L_d}i_d\right. \\
& \left. - \frac{PL_q}{L_d}\omega_r i_q\right\} \qquad (46)
\end{aligned}
$$

Substituting (43)-(46) into (42)

$$
\dot{V}_3 = -k_1{e_1}^2 - k_2{e_2}^2 - k_3{e_3}^2 - k_4{e_4}^2 + Ae_2e_3 \qquad (47)
$$

The system is considered stable when the backstepping gains k_2 andk$_3$ have high values and then$\dot{V}_3$ is a negative definite.

4. EXPERIMENTAL RESULTS:

The structure diagram of adaptive backstepping control of PMSM is shown in Fig (2). The rotor position and the three-phase currents are measured by sensors. That are used as feedback signals for the controller. The position error signal is acquired by comparing the actual position signal with the reference Position signal. The adaptive backstepping control uses position error signal, current and voltages signals and parameter adaptation laws (43),(44) to determine the control voltages which present the actual control inputs. However these signals are in (d-q) reference frame, thus they must be transformed into the three-reference frame to give the inverter voltages, which supply and drive the PMSM motor.

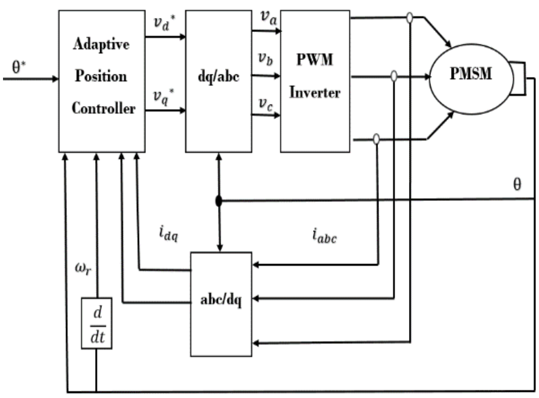

Figure 2. Block diagram of the Adaptive backstepping controller for position Control of PMSM Drive.

The nominal parameters of PMSM motor that using in the simulation in this paper are given in the **Table 1**

The adaptive backstepping control gains are selected as k1 =200, k2 =60, k3=95, k4 =950, γ_1=0.02, γ_2=0.005.

Table 1.PMSM PARAMETERS [20]

PMSM parameters	Nominal values (unit)
$\boldsymbol{StatorresistanceR_s}$	0.02 (Ω)
$\mathbf{d-axis\ inductance}\ \boldsymbol{L_d}$	$1.25(mH)$
$\mathbf{q-axis\ inductance}\ \boldsymbol{L_q}$	$1.25(mH)$
$\boldsymbol{polepairsP}$	4
$\boldsymbol{MotorinertiaJ}$	$0.089(Kg.m^2)$
$\boldsymbol{FrictioncoefficientB}$	$0.005(N.m.\frac{sec}{rad})$
$\boldsymbol{Ratedpower}$	$40\ KW$
$\boldsymbol{Ratedvoltage}$	$380(V)$
$\boldsymbol{Ratedcurrent}$	$70\ (A)$
$\mathbf{Magnetic\ flux\ constant}\boldsymbol{\Phi_f}$	$0.381(V.\frac{sec}{rad})$

We studied the performance of the proposed control, in these two cases:

Case 1: A sine-wave trajectory is taken as reference position signal θ^*=10sin (2t) rad and the load torque of $T_l = 10\ N.M$ is suddenly applied at $t = 1.5\ s$, the simulation results are given in fig (3-5). Fig (3) shows the curve of position reference and actual position response, zooming in fig (4), the blue line represents the position reference signal and the red line represents actual position signal. It can be observed from the figures that the adaptive backstepping controller has a Good tracking effect, as it shows the actual position signal tracks the reference position signal closely. It can be noted from fig.5 that the speed returns to its reference value after a short period of slight deviation whenever a load is added.

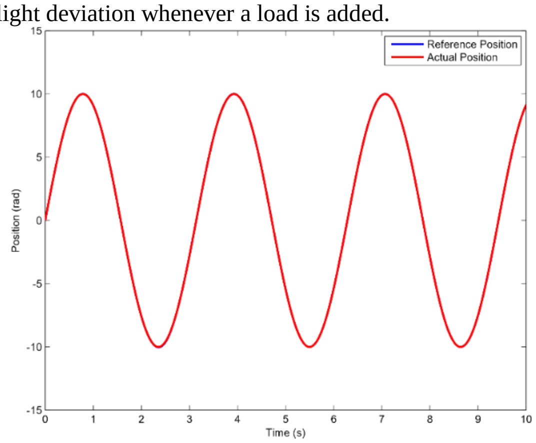

Figure 3. Position Tracking Curve.

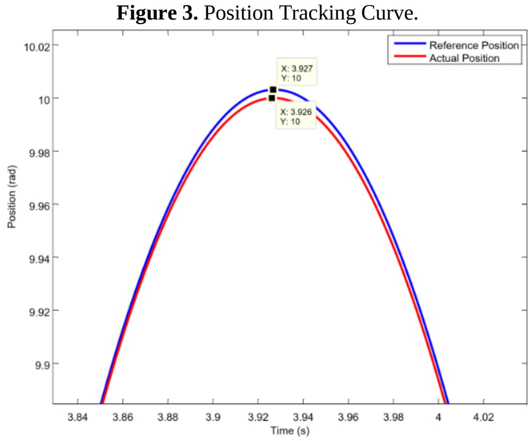

Figure 4. Zoom in on Position Tracking Curve

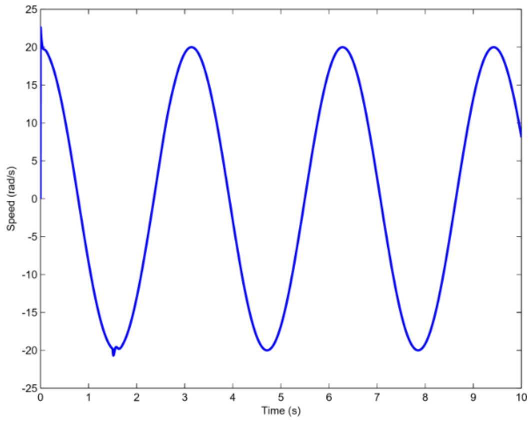

Figure 5. Speed Curve.

Case 2: A triangular -wave trajectory is taken as reference position signal and the load torque of $T_l = 10\ N.M$ is suddenly applied at $t = 1.5\ s$, the simulation results are given in Fig 7(a)-(e).and compared with the simulation results of the convention control (PI) for PMSM drive Fig. 6(a)-(e). The gain values of (PI) controller, which is used for the simulation, are selected as, Speed controller Kp =0.6835 and Ki=0.27 and Current controllers Kp=0.25 and Ki=0.8, position controller K=15.Fig. (a) Shows the comparative simulation results between backstepping controller and conventional controller with triangular position reference. The measured position tracks the reference signal closely by using adaptive backstepping control with driving system. While there is a deviation in the reference position tracking using conventional controller (PI) in driving system, as shown.Figure (b) shows the speed curves of both the driving systems with the same triangular -position reference signal. According to the figure, the proposed controller has high fast response with small stability error at marginal changes for (1 ms) compared with the conventional controller. Figure (c) shows the q-axis current component of both the driving systems with the triangular -position reference signal. According to the figure, the fast transient state occurs, then the q-axis current component returns to a value that achieves the demanded load torque. In contrast, the driving system with conventional controller has large fluctuations in the transient state period, which can cause damage in the driving system. According to vector control technique, the d-axis current component (id) is regulated quite to zero. Both conventional and backstepping controllers could achieve the main control condition, as show in figure (d).According to figures, the response curves of the adaptive backstepping controller have a smaller steady-state error than the PI controller. The proposed controller is featured by fast response and has a shorter settling time than the PI controller has. By selecting positive values for the backstepping gains, the stability of the system is achieved depending on the Lyapunov Stability Theory which is not achieved by selecting the parameter of the PI controller. As a result, the proposed controller has a better performance than the traditional controller does.

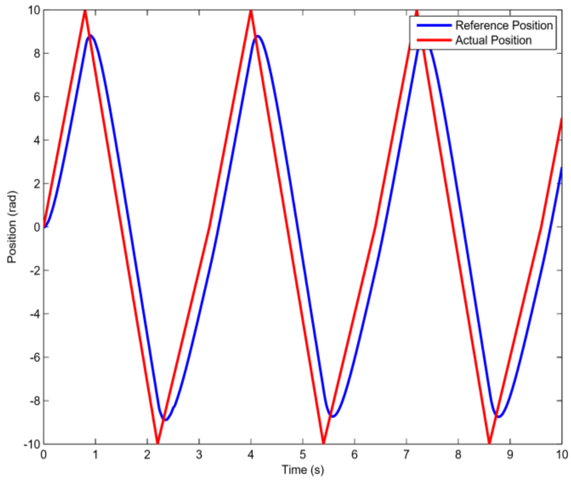

Figure 6 (a). Position Tracking Curve under control of PI controller.

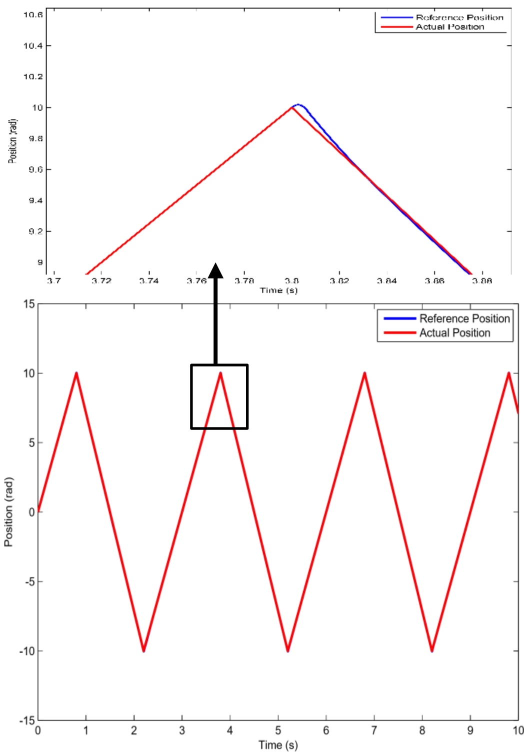

Figure 7(a). Position Tracking Curve under control of Adaptive Back stepping controller.

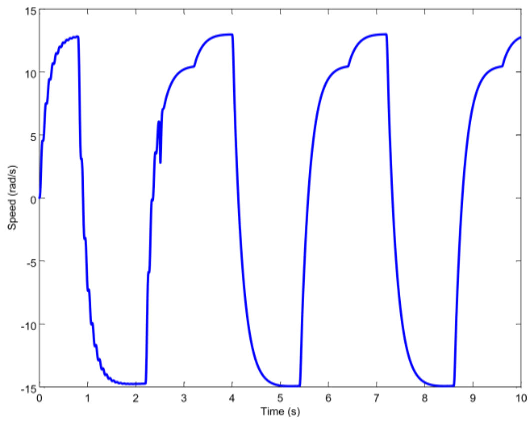

Figure6(b). Speed curve under controlof PI controller

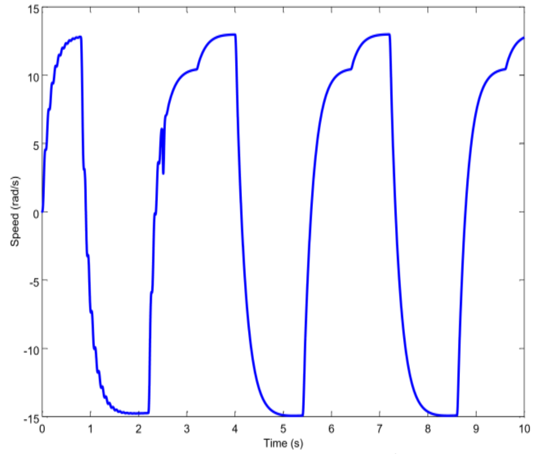

Figure 6 (b) .Speed curve under control of PI controller

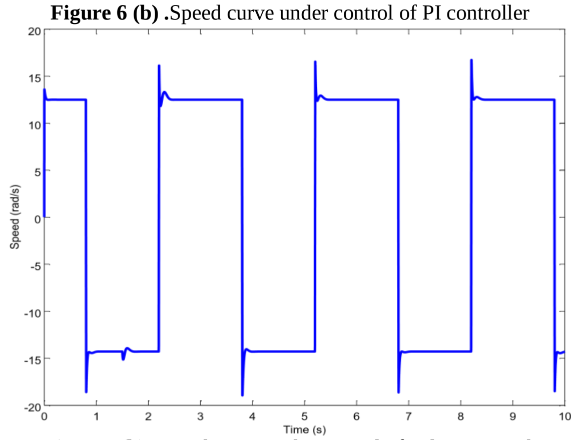

Figure 7(b). Speed curve under control of Adaptive Back stepping controller.

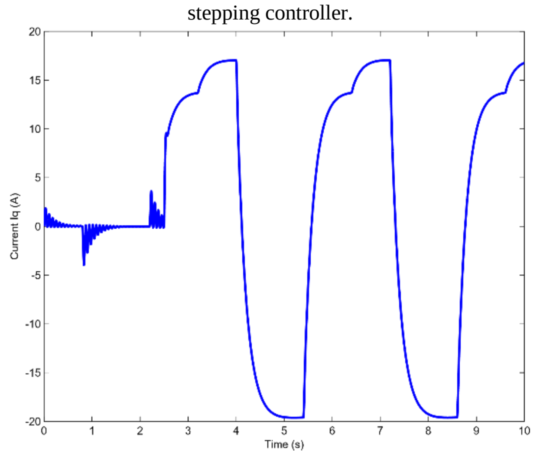

Figure6(c). Q-axis current response curve under control of PI controller.

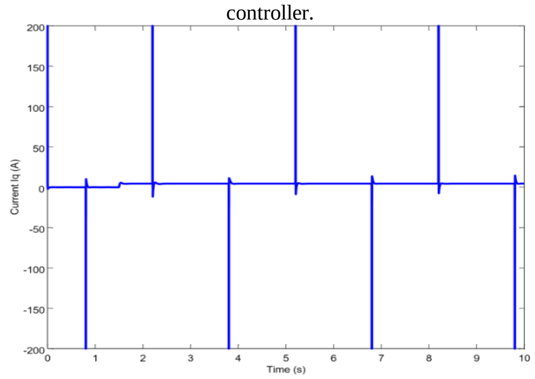

Figure 7(c). Q-axis current response curve under control of Adaptive Back stepping controller.

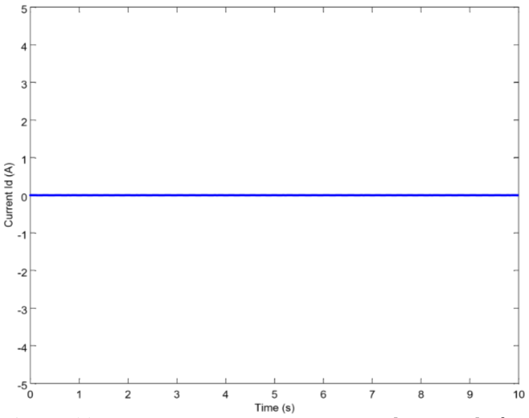

Figure6(c). D-axis current response curve under control of PI controller.

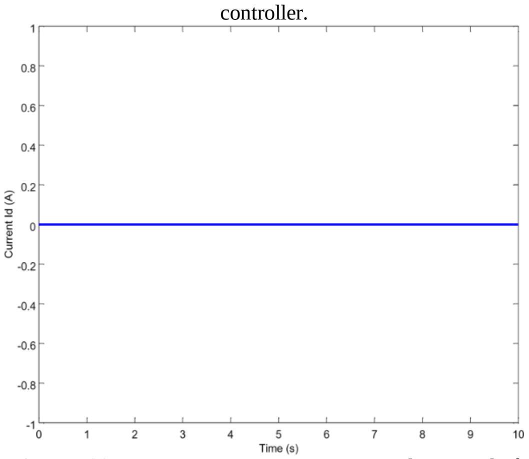

Figure 7(c). D-axis current response curve under control of Adaptive Back stepping controller.

5. Conclusion:

In this paper, an adaptive backstepping controller has been proposed for the control of a PMSM drive system. This controller can overcome the performance problems of the drive system with the traditional controller (PID). In addition, it estimates the varying mechanical system parameters, such as load torque and inertia. The simulation results show that using the proposed controller can ensure the rotor position tracking the reference curves precisely, and achieved fast response.

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