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Comparative Analysis of PI and PID Controller for PMSM with New Sliding Mode observer

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ABSTRACT: This paper presents the new proportional-integral-derivative controller (PID) for speed, position and torque control of permanent magnet synchronous motor with space vector pulse width modulation and sliding mode observer. PID improves the performance which gives the estimated result of current back emf of the PMSM. PID controller seems to perform better for the expected output. The THD has been analyzed for speed, current and torque. The comparative result has been carried out including PI and PID controllers. MATLAB/SIMULINK software has been used for the simulation purpose.

Keywords: PID, SVPWM, SMO, PMSM, THD

I. INTRODUCTION

Permanent magnet synchronous motor (PMSM) has been used in many applications power electronics, drives, machine tools, modern control theory. Due to high efficiency, high power density, high speed. These applications due the controlling of PMSM speed, torque, position. The vector control can be done by field oriented control (FOC) and direct torque control (DTC). The scalar controlled by voltage and current control. Both process use slide mode observer (SMO) and park transformation for the speed and position control.

The sensor less speed control of PMSM with iterative SMO which used low pass filter. In this paper filter is used current estimation is not properly. Oscillation is occurred [1]. An improved sliding mode observer the sigmoid function used which have boundary condition [2]. Position sensor less PMSM based on sliding mode observer which control the position of rotor and speed the disturbance compare the system output and generate compensating signal [3-4]. SMO with multilevel discontinues control of PMSM where regulate speed and position by phase locked loop which is additional causes delayed response in transient and decrease the control bandwidth [5]. PMSM speed and position estimation by SMO with lyapunov function and stator resistance change with temperature which change the system response with time duration due temperature change of stator and resistance [6]. Sliding mode observer for control of speed and rotor position of PMSM which used the vector control and flux control method where the variable frequency used for the estimation of speed and torque of permanent magnet so the different range of frequency used. The kalman filter which not provide the actual error and limited to error sensitivity. The adaptive kalman filter used for the optimization by the error signal which produce the variance/covariance this produces divergent filters. Due to recursive nature of fitter it is not fully self tuning. [4-5, 7-11].

II. MATHEMATICAL MODEL

A. Conventional PMSM

The PMSM have following assumption

1) the induced EMF is sinusoidal.
2) Eddy currents and hysteresis losses are negligible.
3) Saturation is neglected.

The PMSM is given by the equation

$$\begin{pmatrix} \cdot \\ \cdot \end{pmatrix} = \begin{pmatrix} R_s + \rho L_q & \omega_r L_d \\ -\omega_r L_q & R_s + \rho L_q \end{pmatrix} \left(\; \right) + \begin{pmatrix} \omega_r \\ \rho \end{pmatrix} \quad ..(1)$$

$$T_e = \left(\; \right) (\lambda_d i_q - \lambda_q i_d) \quad ..(2)$$

$$\omega_m = \omega_r \left(\; \right. \quad ..(3)$$

where, ω_r rotor electrical speed and ω_m rotor mechanical speed.

B. Park transformation

The dynamic dq modelling is used for the study transient and steady state of motor. It is done by converting the three phase voltages and current by using the park transformation [5].

Phase voltage variables V_{abc} to V_{dqo}

$$\begin{pmatrix} V_q \\ V_d \\ V_o \end{pmatrix} = \left(\tfrac{2}{3}\right) \begin{pmatrix} \cos\theta & \cos(\theta - 120) & \cos(\theta + 120) \\ \sin\theta & \sin(\theta - 120) & \sin(\theta + 120) \\ \tfrac{1}{2} & \tfrac{1}{2} & \tfrac{1}{2} \end{pmatrix} \left(\; \right) \quad ..(4)$$

Convert V_{dqo} to V_{abc}

$$\begin{pmatrix} V_a \\ V_b \\ V_c \end{pmatrix} = \begin{pmatrix} \cos\theta & \sin\theta & 1 \\ \cos(\theta - 120) & \sin(\theta - 120) & 1 \\ \cos(\theta + 120) & \sin(\theta + 120) & 1 \end{pmatrix} \left(\; \right) \quad ..(5)$$

C. Sliding mode control algorithm

To regulate a dynamic system parameter uncertainties and nonlinearities a controller is used which have two phase, system achieve the desired system behaviour and select feedback gain of controller so system stable.

The system equation

$X(t) = Ax(t) + Bu(t)$ ..(5)

Where A and B are n*n and n*l matrices, and the measured y(t) is related

$y(t) = Cx(t),$ ..(6)

where c is n*1 matrices for estimation of system

$X\hat{}(t) = Ax\hat{}(t) + Bu(t)$ ..(7)

Where X^ is the estimate of actual X. A, B and u(t) is matrices of PMSM. So the estimator obtains the optimal result for the speed and current of PMSM. To speed up the estimation process and give the difference between measured and estimated output and correct the model continuously this is lubenberger observer

$\dot{x}\hat{}(t) = Ax\hat{}(t) + Bu(t) + m(y(t)- y\hat{}(t))$ ..(8)

Where m is n*1gain constant matrix.

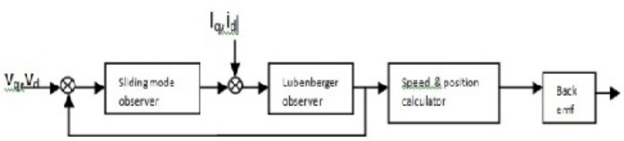

Fig.1. Sliding mode observer with lubenberger observer.

The state error is given by $\dot{e}(t) = x(t)-x\hat{}(t)$

The estimation error $\dot{e}(t)$ converges to zero and remains, independent of any known i/p function u(t) on the system and its effect on the x(t).

D. PID mode controller

The combination of proportional, integral, derivative is most power full but complex controller is used for virtually any process.

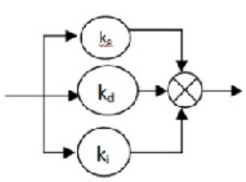

Fig. 2. PID controller.

The PID expression is given by

$P=K_p e_p + k_p k_i \int dt + k_p k_d$ ..(9)

where k_p, k_i, k_d Proportional, integral, derivative constant. The PID controller gives the better result than PI and PD controller.

E. Total harmonic distortion

A nonlinear system produces harmonics of an input signal for the devices. The output waveform is not exact replica of system; distortion occurred often referred harmonic distortion (HD).

The system produces harmonics consisting of sine wave with frequencies which are multiples of fundamental signals. Total harmonic distortion (THD) is measured in terms of the wave.THD is given by

$$THD = \frac{\sqrt{E_2^4 + E_3^4 + E_4^4 + E_4^4 + E_5^4 + \cdots E_n^4}}{E_1} \quad ..(1$$

Where E^2_2...... E^2_n is representing the amplitude of nth harmonic and represent the amplitude of fundamental.

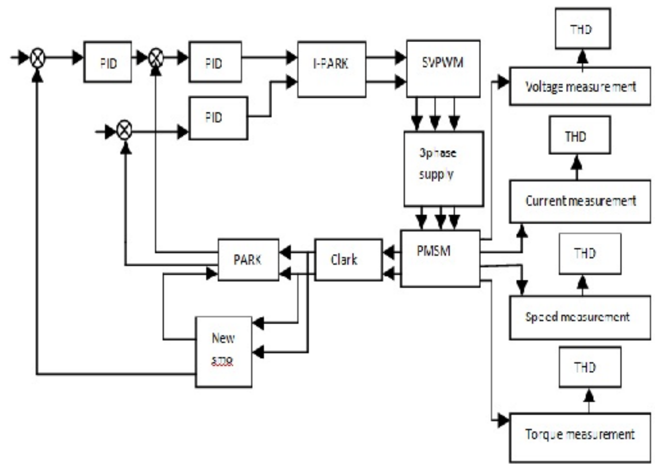

Fig.3. Block diagram of overall system.

Fig. 3 shows block diagram of PMSM wich consist of new sliding mode observer which used the lubenberger observer, proportional-integral-derivative (PID) controller control the speed, current and total harmonic distortion measure the distortion of the different output waveform. the conventional space vector pulse width modulation, park transformation, inverse park transformation and clark transformation which convert the voltage to d, q axis and from d, q axis.

III. SIMULATION RESULT

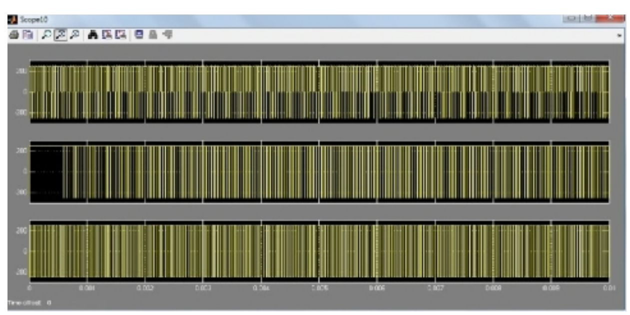

Fig. 4. Voltage result of PI a, b and c.

This figure shows the result of a, b and c phase voltage of PMSM with PI controller which have the - 250 to +250 volts peak to peak value.

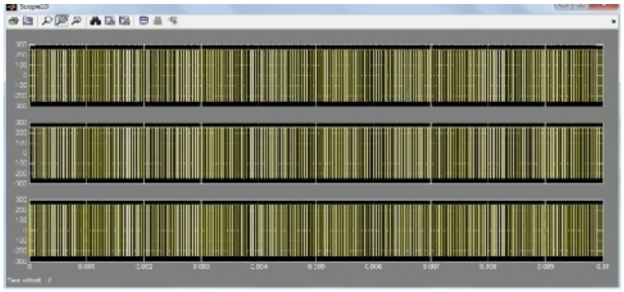

Fig.5. Voltage result of PID a,b and c.

This shows the peak to peak -250 to +250 volts of PMSM a, b and c phase voltage result with the PID controller.

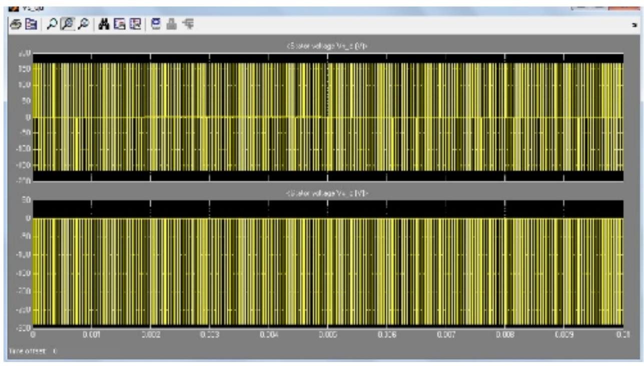

Fig.6. Voltage result of PI in d-q axis.

The result of PMSM of d-q axis with PI controller -175 to +175 volts peak to peak.

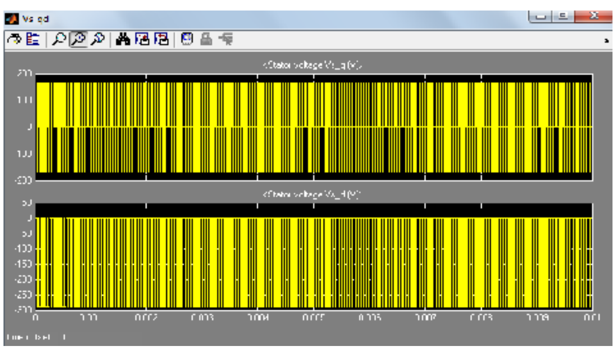

Fig.7. Voltage result of PID in d-q axis.

This shows the result of voltage of permanent magnet Synchronous motor with PID controller which have -175 to +175 volts peak to peak.

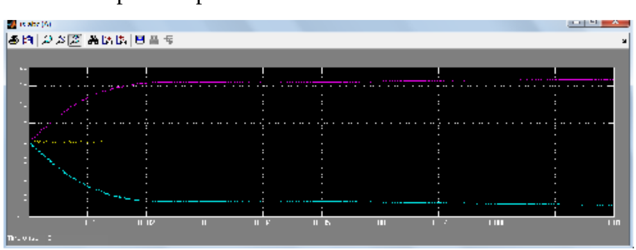

Fig.8. Current result of a,b,c PI.

This figure shows the result of a, b and c phase current which have 0 volts minimum and 16 volts maximum it takes 0.002 sec to reach its maximum value.

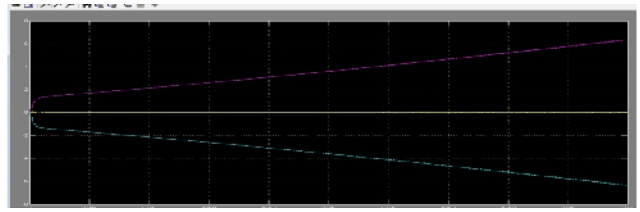

Fig.9. Current result a,b,c PID.

The result of PMSM with PID controller current increase continuously with time.

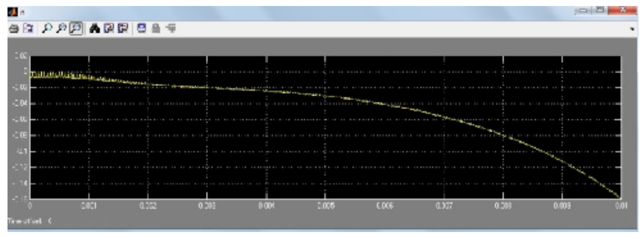

Fig.10. Rotor speed result of PI.

This figure shows the speed result of PMSM with PI which Decrease with the time.

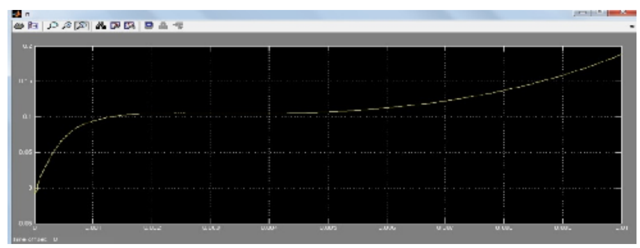

Fig.11. Rotor speed result of PID.

The rotor speed of PMSM with PID controller increase so this is better than the PI controller which speeds got zero after some times.

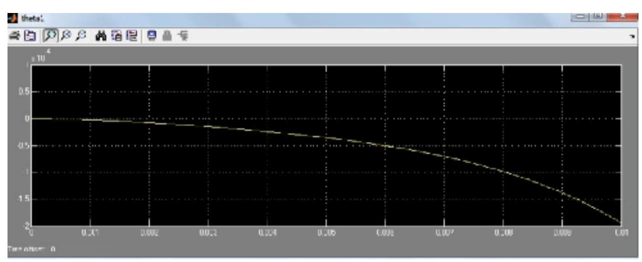

Fig.12. Stator angle of PI.

This figure shows the result of Stator angle of PMSM with PI controller slowly decrease. This figure shows the result of motor with PID controller where the stator angle increases this give the better performance than the PI controller.

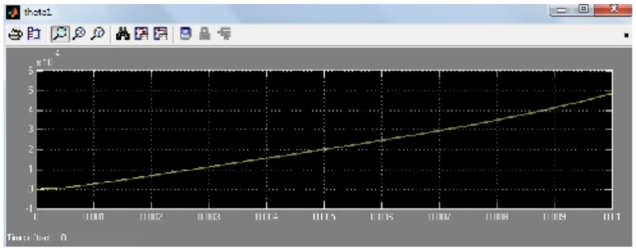

Fig.13. Stator angle of PID.

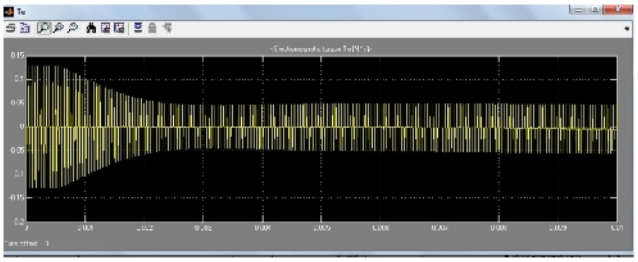

Fig.14. Torque result of PI.

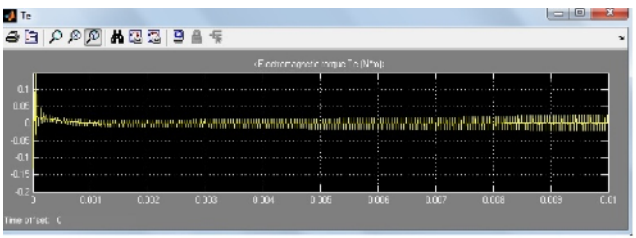

Fig.15. Torque result of PID.

The Fig. 14 shows the result of torque with PI controller and Fig. 15 with PID controller give the fast response of torque than the PI so the speed of rotor gets maximum speed in small time duration.

IV. CONCLUSIONS

In this paper new sliding mode observer is proposed with lubenberger observer and new PID controller in place of PI controller to improve the angle, current and voltage of permanent magnet synchronous motor. The total harmonic distortion is also calculated. In this paper the comparison of PI and PID controller have done which response is show in the result of different response voltage, current, speed and torque. Result of PID controller is better than the PI controller.

REFERENCES

[1]. Kye-lyong kang, Jang-Mok kim, Keun-Bae Hwang and Kyung-Hoon Kim, "Sensor less Control of PMSM in High Speed Range with Iterative Sliding Mode Observer", *Nineteenth Annual IEEE Applied Power Electronics Conference and Exposition, 2004 (APEC '04).* P.no: 1111 – 1116, vol. **2**, ISBN: 0-7803-8269-2.

[2]. K. Paponpen and M. Konghirum "An Improved sliding mode observer for speed sensor less vector control drive system" Power Electronics and Motion Control Conference, 2006. IPEMC 2006. CES/IEEE 5th international p.no 1–5, vol: **2**, isbn:1-4244-0448-7.

[3]. Song Chi and Longya Xu, "Position sensor less control of pmsm on a novel sliding mode observer over wide speed range" *Power Electronics and Motion Control Conference, 2006. IPEMC 2006. CES/IEEE 5th International,* Vol. **3**, P.no 1 – 7, ISBN:1-4244-0448-7.

[4]. S. Chi, Z.czhang and L Xu, "A novel sliding mode observer with adaptive feedback gain for pmsm sensor less vector control." *Power Electronics Specialists Conference, 2007. PESC 2007. IEEE,* P.no 2579 – 2585, ISBN: 978-1-4244-0654-8,

[5]. S.Chi and Jinsheng sun, " A novel sliding mode observer with multilevel discontinuous control for position sensor less pmsm drives". *Applied Power Electronics conference and Exposition, 2008. APEC 2008 Twenty-Third Annual IEEE,* P.no-127 – 131, ISSN :1048-2334.

[6]. Vasilios C. Ilioudis and Nikolaos I. Margaris, "pmsm sensor less speed estimation based on sliding mode observer." *Power Electronics Specialists Conference, 2008. PESC 2008. IEEE,* P.no-2838 – 2843, ISBN: 978-1-4244-1667-7.

[7]. Dong Jiang,Zhengming Zhao and Fei Wang,"A sliding mode observer for pmsm speed and rotor position considering saliency." *Power Electronics Specialists Conference, 2008. PESC 2008. IEEE,* P.no.-809 – 814, ISBN: 978-1-4244-1667-7.

[8]. Lu wenqi, Hu Yuwen, Haung Wenxin, Chu Jianbo, Du Xuyang and yang jianfei, "Sensorless control of permanent magnet synchronous machine based on a novel sliding mode observer." Vehicle Power and Propulsion Conference, 2008. VPPC '08. *IEEE,* P.no-1–4, ISBN: 978-1-4244-1848-0,E-ISBN :978-1-4244-1849-7.

[9]. Vasilios C.Ilioudis and I.Margaris, "Speed and position estimation technique for pmsm based on modified machine model.". *Optimization of Electrical and Electronic Equipment (OPTIM), 2010 12th International Conference on,* P.no:407 – 415, ISBN: 978-1-4244-7019-8.

[10]. Vasilios C.Ilioudis, "Flux weaking method for sensor less PMSM control using torque decoupling technique." Sensorless Control for Electrical Drives (SLED), 2010 First Symp. on, P.no:32-39 ISBN: 978-1-4244-7035-8,

[11]. Chen wei, chen yankun, Li hongfeng and song zhanfeng "Sensorless control of permanent magnet synchronous motor on a novel sliding mode observer." *Power Electronics and Motion Control Conference (IPEMC), 2012 7th International,* Volume: **4,** P.no:2582 – 2586, ISBN:978-1-4577-2085-7.