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Vector Control of PMSM Using Power Electronic Controllers

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ABSTRACT

This paper describes a sensorless field oriented control of permanent magnet synchronous motor (PMSM) using rotor position tracking proportional-integral (PI) controller. With the advent of vector control methods, Permanent magnet synchronous motor (PMSM) can be operated like separately excited dc motor for a high-performance application. This technique can be applied to low and high-speed operations. In this method a loop recovery technique is applied, to boost the bandwidth of PI controller. The design, analysis, simulation of the sensorless method is done using MATLAB R2011a.

Keywords: *Permanent Magnet Synchronous Motor (PMSM) Drive, Proportional-Integral (PI) Controller, Hysteresis PWM Controller.*

1. INTRODUCTION

The first generation back EMF method is proposed to eliminate the Hall Effect sensors. For the method of determining the zero-crossing point of back-EMF via terminal voltages, the filter is required to remove the high switching frequency noise [1].The high-frequency signal injection is needed for this controlling action which is very difficult in practical applications. Recently a new technology is developed which will eliminate the drawbacks of back EMF method. Normally the controlling of the torque of PMSM usually follows either the most popular Direct Torque Control (DTC) or Field Oriented Control (FOC). In this paper, the field oriented control based sensorless method is used.

This control is mainly done using rotor position tracking proportional-integral controller (PI) with low-frequency signal injection. It can be applied to low and high-speed operations. In the existing method, the PWM inverter control method is used which is having a lot of distortion in the output waveforms. The drawback of PWM inverter can be replaced by hysteresis current controller where the motor current i_{abc}* and the vector transformed currents i_{abc} can be taken as input. This hysteresis current controller gives better efficiency, accuracy, and easy control compared to PWM controllers. The main advantage of this system is the simple control algorithm, wide speed range possible without shaft sensor, unity power factor control is possible, increased system efficiency, good speed regulation, reduced the rating of the switching device, a wide range of speed control is possible, low noise [2]. A permanent magnet synchronous motor (PMSM) is a motor that uses permanent magnets to produce the air gap magnetic field rather than using electromagnets [7]. These motors have significant advantages, attracting the interest of researchers and industry for use in many applications [4]-[8]. Permanent magnet synchronous motor has advantages like higher efficiency, high power density and high power factor.

This approach is based on d-axis synchronous current regulator output voltage, which includes the information of rotor position error. A loop recovery technique is applied to the control system. The proposed sensorless control algorithm can accurately determine the speed control and angular position control using mainly sensorless rotor position tracking PI controller. This paper is organized as follows Section II provides the existing control system, Section III gives the proposed sensorless control algorithm. Section IV shows the analysis of sensorless control algorithm using a PI controller. Section V gives the results and discussion of MATLAB SIMULINK simulation waveforms. Section VI gives the conclusion of proposed the system, Section VII gives the Appendix of the proposed system.

2. EXISTING CONTROL SYSTEM

The existing system uses PWM inverter technique for the controlling action. The main drawback of this system is that it is not an accurate and efficient one and also the controlling action is very tedious [3].The basic principle of vector control is to get performance system through controlling flux and torque independently after getting the motor decoupling model through coordinate transformation. Here the vector transformations and their inverse transformations were applied in order to get the exact controlling actions.

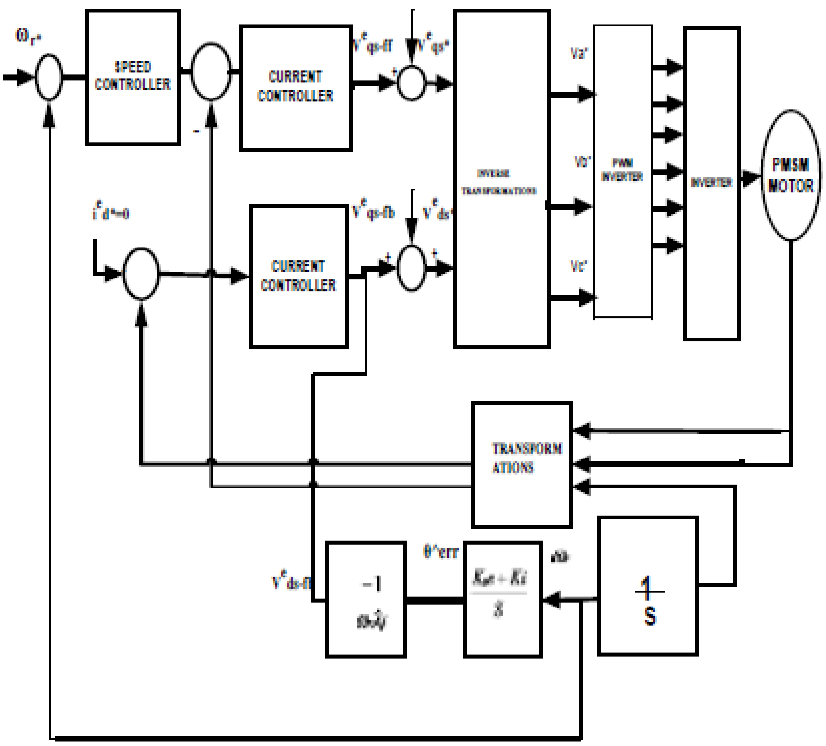

Fig.1 Overall Block Diagram of Existing Sensorless Control System

A. Vector Transformations

The Transformations mainly include Clarke transformations and also their inverse transformations.

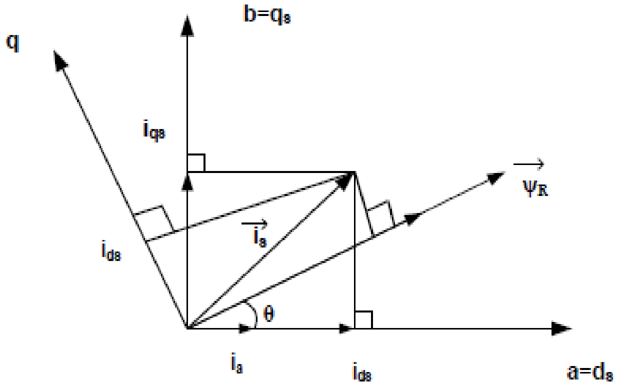

Fig.2 Park Transformations

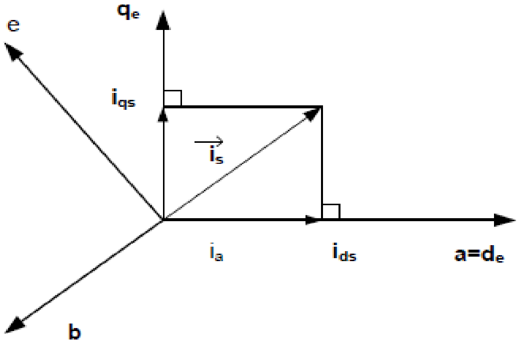

Fig.3 Clarke Vector Transformations

3. PROPOSED SENSORLESS CONTROL ALGORITHM

Here the reference speed and the estimated speed obtained from the sensorless estimator is compared and given to a speed controller. The output of the controller is the reference quadrature axis current which is compared with actual component obtained from the transformations and is given to a current controller. The output is given to inverse transformations. Position error can be controlled to zero by the rotor position tracking PI controller. Thus, an initial starting may fail at standstill, and this control scheme is only available in the high-speed region

$$U_k = K_{PI} e_k + K_I e_k + \sum_{n=0}^{k-1} e_n$$

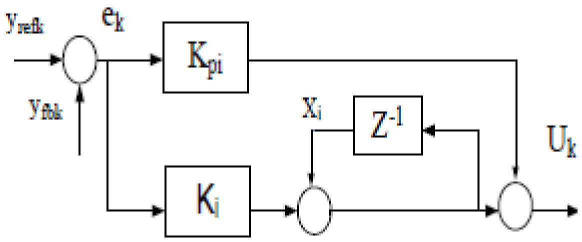

Fig.4 Shows PI Controller Block Diagram

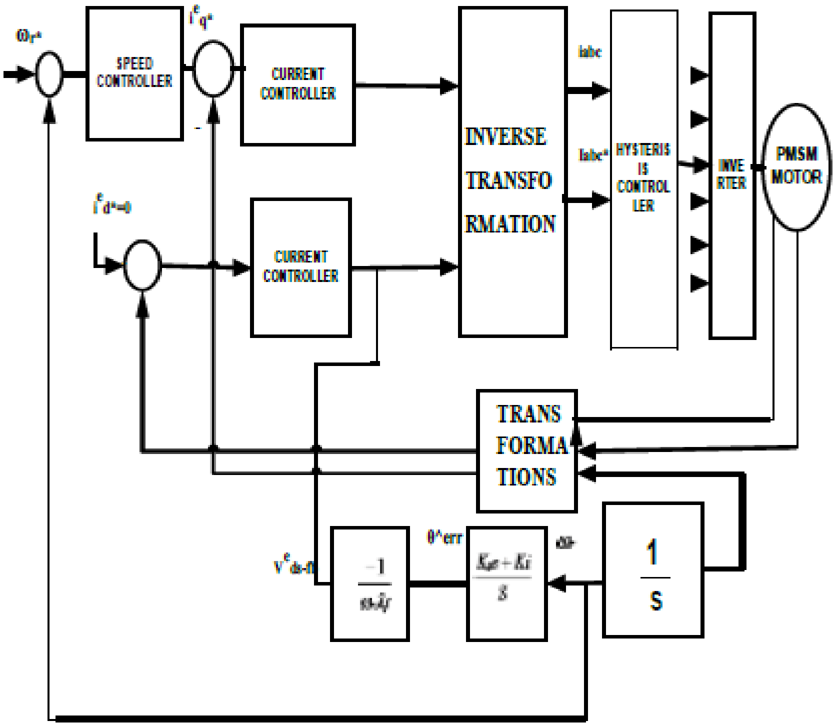

Fig.5 Proposed Sensorless System Block Diagram

To overcome these unwanted starting fails at zero and low speed.[8] instantaneous current values for the A, B, and C phases are generated based on the commanded torque and the actual rotor position. The actual phase currents of the motor are compared with the reference currents i_n*,i_b*, i_c* using three independent comparators. The logic states of the 6 inverter switches are defined depending on the result of the comparison. When the phase current is smaller than (i*-h/2), where h is the hysteresis bandwidth, the output of the comparator becomes 1 and the related phase is connected to higher than (i*+h/2), the output of the comparator becomes 0 and the related phase is connected to the negative rail of the dc bus. Thus the actual motor phase currents are made to track the desired reference within a close band.

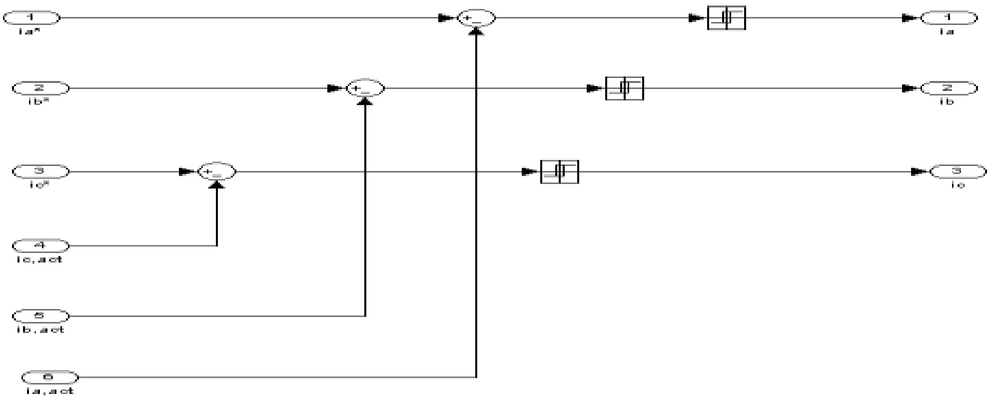

Fig.6 Hysteresis Current Controller

4. RESULTS AND DISCUSSION

The simulation results of actual angular position and estimated angular position without sensor is compared

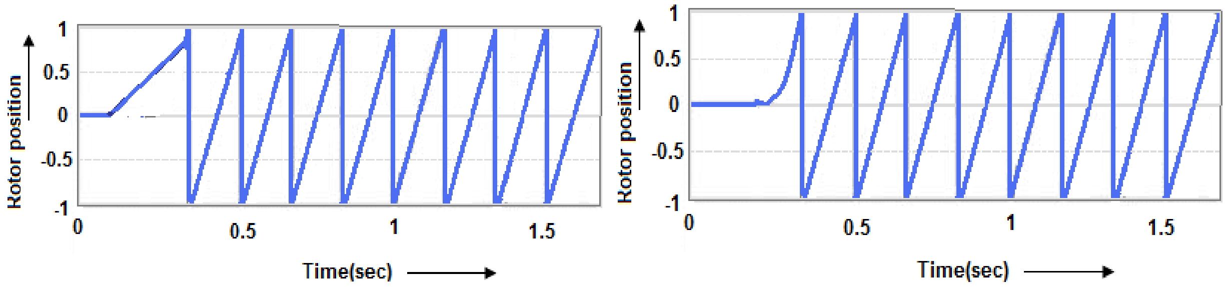

Fig.7 Actual and Estimated Rotor Angular Position for 300 rpm Set Speed using PWM VSI Control

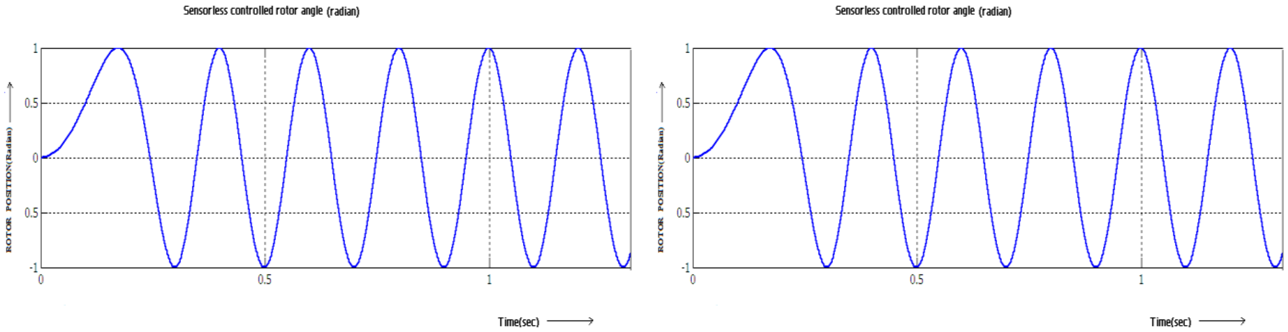

Fig.8 Actual and Estimated Rotor Angular Position for 300 rpm Set Speed using Hysteresis Current Controller

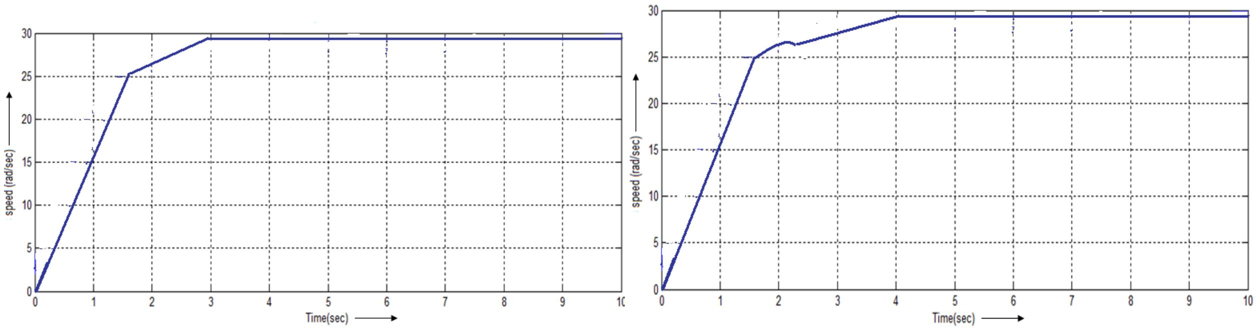

Fig.9 Actual and Estimated Rotor Angular Position for 300 rpm Set Speed using PWM VSI Control

From the fig.8, fig.9.fig.10, fig.11it has inferred that rotor angle estimated without the sensor is tracking almost the actual rotor angle both in PWM VSI inverter and Hysteresis current controllers. By proper tuning of the sensorless controlled PI controller mainly Ziegler-Nichols tuning the speed waveforms are obtained as shown. The comparative result of rotor speed of PMSM motor with sensors and without sensors was performed using MATLAB versionR 2011b.

5. CONCLUSION

Sensorless control of PMSM motor drive using rotor position tracking PI controller have been simulated using MATLAB and the results have been presented. In this paper, the speed and rotor position is simulated using PWM VSI control and hysteresis current control and compared. From the waveforms, it is inferred that the hysteresis controller output waveforms give better performance. The simulated results have shown that the speed and rotor position of PMSM motor can be controlled without sensors and the values remain the same as that with sensors. The results obtained from Sensorless speed control of PMSM demonstrate that the system is less cost compared to sensor control and also good dynamic performance is obtained. In this system, it is easy to determine the possible operating range with the desired bandwidth and perform the vector control even at low speed. Obtained results confirm the effectiveness of the proposed scheme under heavy load conditions. In this proposed method only speed and angular position of PMSM motor controlled without sensors and using only rotor position tracking PI controller. In the future implementation of another good tuning of PI can result in much better performance in this sensorless control area since they are cost-effective and also having good dynamic performance.

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