Permanent Magnet Synchronous Motor Voltage Vector Control by Simulation

Ambrish Pati Tripathi,Vikram Singh, Ankush Patidar

Abstract**—** Proposed permanent magnet synchronous motor control based on MATLAB (PMSM) voltage vector control system model of simulation. And take the model for simulation experiment in Matlab/Simulink. The simulation result indicated that the controlling system had a better dynamic response and regulator character of pmsm controlled model. And validate its control algorithm for a theoretical basis that design and debugging permanent magnet synchronous motor control system**.**

Keywords**—**PMSM; The vector controls; Matlab/Simulink; Dtc; Foc; Psm;VSI

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1 INTRODUCTION

Permanent magnet synchronous motors (PMSM) are widely used in low and medium power applications such as computer peripheral equipments, robotics, adjustable speed drives and electric vehicles. The growth in the market of PMSM motor drives has demanded the need of simulation tool capable of handling motor drive simulations. Simulations have helped the process of developing new systems including motor drives, by reducing cost and time. Simulation tools have the capabilities of performing dynamic simulations of motor drives in a visual environment so as to facilitate the development of new systems.

In this work, the simulation of a direct torque control of PMSM is developed using Simulink. The Direct Torque Control is one of the high performance control strategies for AC machine. The DTC scheme has been realized successfully in the Induction Motor drives. The aim of the project is to study the implementation of the Direct Torque Control (DTC) in Permanent Magnet Synchronous Motor (PMSM).

Industry automation is mainly developed around motion control systems in which controlled electric motors play a crucial role as heart of the system. Therefore, the high performance motor control systems contribute, to a great extent, to the desirable performance of automated manufacturing sector by enhancing the production rate and the quality of products. In fact the performance of modern automated systems, defined in terms of swiftness, accuracy, smoothness and efficiency, mainly depends to the motor control strategies. The advancement of control theories, power electronics and microelectronics in connection with new motor designs and materials have contributed largely to the field of electric motor control for high performance systems.

Newly developed permanent magnet synchronous (PMSM) motors with high energy permanent magnet materials particularly provide fast dynamics, efficient operation and very good compatibility with the applications if they are controlled properly. However, the AC motor control including control of PMSM motors is a challenging task due to very fast motor dynamics and highly nonlinear models of the machines.

Therefore, a major part of motor control development consists of deriving motor mathematical models in suitable forms.

Until now most industrial low speed applications have been driven either with DC motors or induction motors with reduction gears. It can be seen clearly that, on the average, DC and synchronous motors have, compared to induction motors, a larger rate of use when the rated power is considered, whereas the rate remains much lower when only the number of used motors is considered. Compared to the induction motor having an equal power the DC and synchronous motor are often expensive and, due to the brushes, require a lot of service and typically also external excitation sources. The problem with induction motors is

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that the slip with a certain torque is about constant. Rotor losses correspond to the relative slip and when the synchronous speed is reduced, the relative slip and thus the losses increase. During the latest decade permanent magnet materials and frequency control techniques have developed rapidly. Permanent magnet synchronous machines (PMSMs) are nowadays used in several pilot applications in paper mills. The machine type is also more and more often used in ship propulsion systems and in direct driven windmills. Lift and hoist applications have pioneered this development and successful mature products are already on the market. As long as the PMSM motors are gaining popularity in industrial and servo applications. electric vehicles are due to its following merits :high torque/inertia ratio, high power density and high efficiency etc. however the dynamic performance of VSI fed PMSM drive system largely depends on the applied current control strategy. The main function of current controller is to force the load current to follow the reference current trajectory in order to minimize the current error. In this paper, hysteresis controller is proposed in the inner loop of vector control of PMSM drive system.

2 DIRECT TORQUE CONTROL

The Direct Torque Control was introduced in the 1980's for Induction Machine for torque and flux control. It was developed for PMSM in 1990's. The DTC is gaining popularity due to its simple control structure and easy implementation.

The principle of Direct Torque Control (DTC) is to directly select voltage vectors according to the difference between reference and actual value of torque and flux linkage.

Torque and flux errors are compared in hysteresis comparators. Depending on the comparators a voltage vector is selected from a table. Advantages of the DTC are low complexity and that it only need to use of one motor parameter, the stator resistance. No pulse width modulation is needed; instead one of the six VSI voltage vectors is applied during the whole sample period. All calculations are done in a stationary reference frame which does not involve the explicit knowledge of rotor position. Still, for a synchronous motor, rotor position must be known at start-up.

The DTC hence require low computational power when implemented digitally. The system possess good dynamic performance but shows quite poor performance in steady-state since the crude voltage selection criteria give rise to high ripple levels in stator current, flux linkage and torque. Its simplicity makes it possible to execute every computational cycle in a short time period and use a high sample frequency. For every doubling in sample frequency, the ripple will approximately halve. The problem is that the power switches used in the inverter impose a limit for the maximum sample frequency.

It can be summarized as A scalar control technique called Volts/hertz control being among the simplest control methods. It is used where exact torque and flux control is not essential but where control speed is desirable, like when several motors are driven in parallel by a single inverter.

Vector control is used where high performance torque and flux control is needed. Vector control can be implementing by using FOC or DTC technique. DTC technique is simple, robust and offer good dynamic performance. FOC technique gives the best performance in terms of ripples level but requires more processor power and are more complicated to implement.

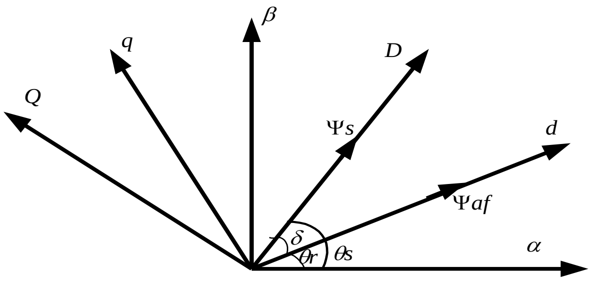

Fig. 1 Stator and rotor flux linkage in coordinate system

The dq coordinate and is fixed on the rotor rotational coordinate is fixed on the rotor rotational coordinate and the positive direction of d is the direction of rotor flux. The xy coordinate is fixed on the stator rotational coordinate and the positive direction of x is direction of stator flux linkage .The angle between stator flux and rotor flux is defined as load angle when the stator resistance is neglected. So the relations of flux linkage, voltage and electromagnetic torque of PMSM are described as follows.

$$V_d = R_s i_d + \frac{d\Psi_d}{dt} - \omega_r \Psi_q$$

$$V_q = R_s i_q + \frac{d\Psi_q}{dt} - \omega_r \Psi_d$$

$$\Psi_s = L_s i_s + \Psi_{af} e^{j\theta_r}$$

$$\Psi_q = L_q i_q$$

$$T_e = \frac{3}{2} P[\Psi_d i_q - \Psi_q i_d]$$

$$T_e = T_L + B\omega_r + J\frac{d\omega_r}{dt}$$

Where ϕd and ϕq are the stator flux linkages, ud and uq are phase voltages, id and iq are currents, Ld and Lq are inductances in the rotational d-q coordinate respectively. and Rs, ω,ϕf, Te, Np,δ,θ and p are stator resistance, angular velocity, permanent rotor flux linkage, electromagnetic torque, pairs of poles, load angle, rotor position and differential operator respectively.

According to the classical theory of electrical machines, the PMSM drive system is equivalent to that of the dc motor when a decupling control is possible known as vector control .The vector control decouples the torque component and flux producing current in the motor through its stator excitation by applying instantaneous space vector theory. The vector control of the PMSM is derived from its dynamic dq model. considering the currents as inputs. the phase currents are given by

$$I_a=I_m \sin(\omega rt+\delta)$$

$$I_b=I_m\sin(\omega rt+\delta-2\pi/3)$$

$$I_c=I_m\sin(\omega rt+\delta+2\pi/3)$$

Where δ is the angle between the rotor field and stator .
The currents assigned above are the stator currents that must be transformed to the rotor reference frame with the rotor speed ωr. using park's transformation the q and d axis currents are constants in the rotor reference frame .since δ is a constant for a given load torque. solving by using park's transformation,

$$I_q=Im \sin \delta$$
$$I_d=Im \cos \delta$$

From the above equations electromagnetic torque is obtained by

$$T_e = \frac{3}{2}P[\Psi_d i_q - \Psi_q i_d]$$

3 PMSM VECTOR CONTROLTHEORY

Vector control is actually control of phase and amplitude for a motor stator voltage or current vector at the same time. The motor torque will depend on the stator current space vector is = id + jiq. When the permanent magnet flux and the direct excitation, cross-axis inductance is confirmed. In other words, control id and iq that can control the motor torque. Current id as excitation current, on the id of the control, in practical application there are three kinds of general circumstances, this paper use id = 0 of the control strategy. Permanent magnet rotor according to the location of the different permanent magnet synchronous motor can be divided into: the surface and inside buried. The tile-shaped magnet was generally and in the outer surface of the rotor iron core in the surface permanent magnet synchronous motor (SPM SM). This important feature of the motor is that straight axis and cross axis for the main inductance is equal (L d = L q). And within the interior permanent magnet synchronous motor (IPMSM) of the permanent magnets in the rotor inside the stator magnet in vitro surface and inner circle core made of ferromagnetic material between the pole shoe can protect the permanent magnets. This important feature of permanent magnet motor is direct, cross-axis of the main inductance is not equal to (L d ≠ L q). For surface-type PMSM, as L d = L q, this style incorporated into the electromagnetic torque equation. Torque equation can be obtained equation (2.10) that only related to the electromagnetic torque and the q axis current iq. So let id = 0, through control the iq, you can achieve maximum torque control in the surface type PM SM vector control. Figure 2shows a vector control strategy block diagram with the use of id = 0.

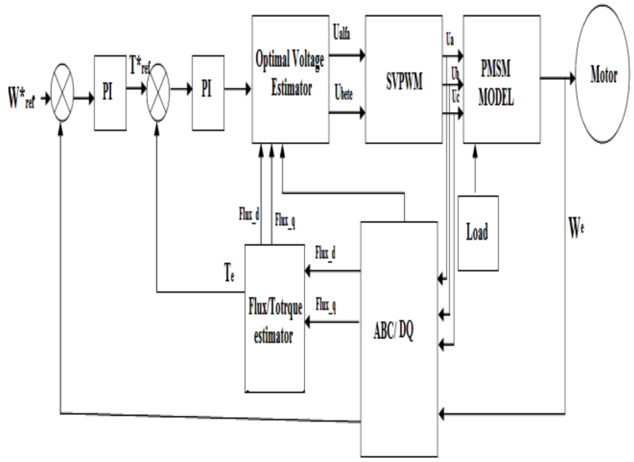

Fig. 2 PMSM vector control system block diagram

4 SIMULINK BASED SIMULATION MODEL OF PMSM

Figure 3 is a model for sensorless vector control, which is called this simulation platform. Permanent magnet motor and inverter models used directly in the Simulink side Simpower systems own model of parts library. Speed and position information from the measurement module Machines Measurement Demux direct feedback. Use id = O control method to control the speed and dq-axis current with PI control.

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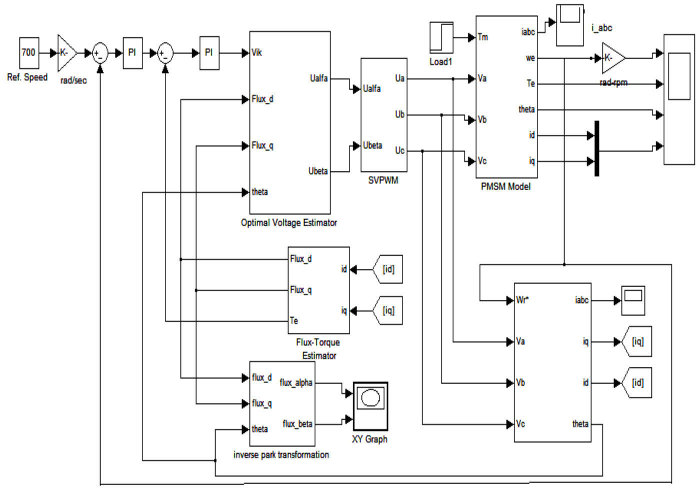

Fig. 3 Simulink based simulation model of PMSM

5 SIMULATION RESULTS

According to the proposed vector control of PMSM simulation model, run in Matlab, using the motor parameters in bellow are as follows: electrical power P = 2kw, DC voltage Udc = 310V, stator windings resistance Rs =1.4 Ω, d-phase winding inductance Ld = .0036e-3H,

, the pole number p = 6, magnetic flux density B = 0. Set the total simulation time t = 0.2 s, for the sudden increase in torque test. No load start, t = 0.1s when the additional load Tm = 5N.m, speed is 700 r / min. Waveforms as follows:

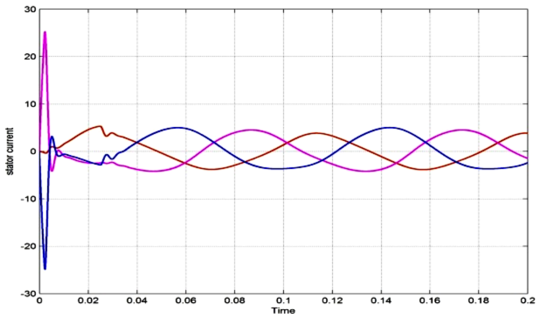

Fig. 4 Simulation Result for Current Response Curve

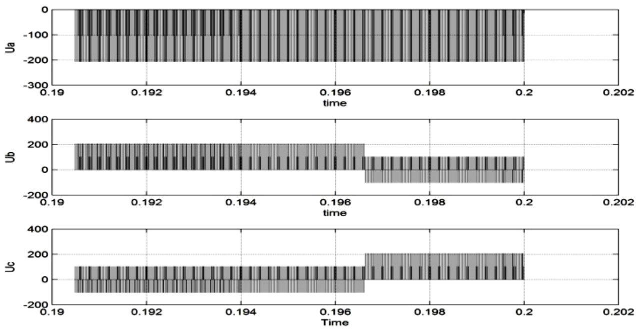

Fig. 5 Simulation Result for SVM Inverter Voltage Ua,Ub and Uc

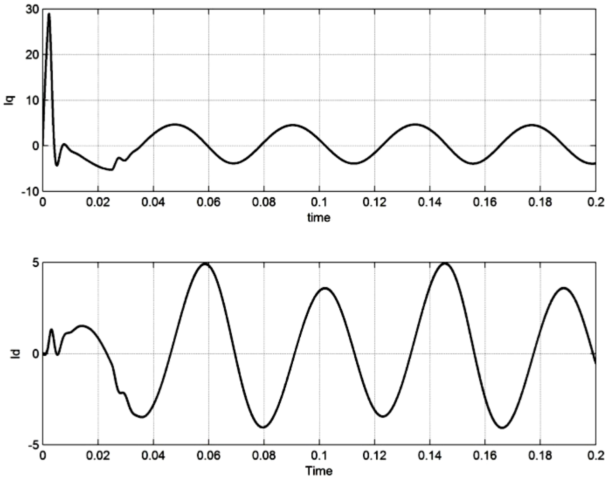

Fig. 6 Simulation Result for Direct Current and Quaderature current

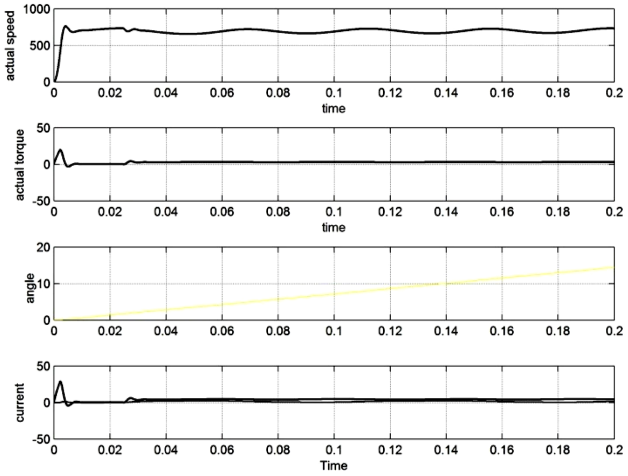

Fig. 7 Simulation Result for Torque, speed, load angle and Current

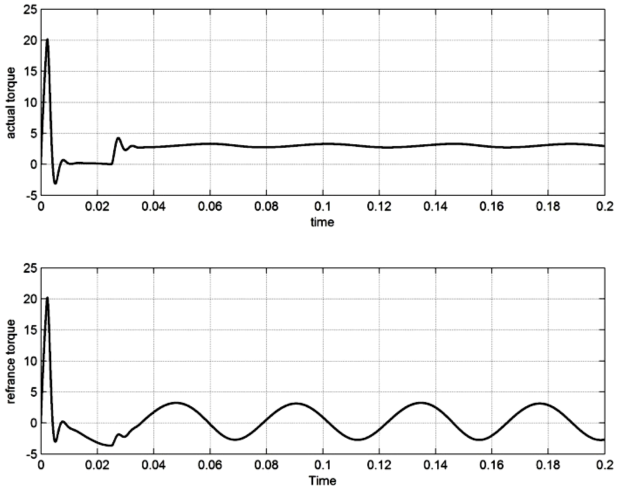

Fig. 8 Simulation Result for Actual Torque and Reference Torque

6 CONCLUSION

In this paper, Simulink based simulation of PMSM vector control system modelling. Simulation results show that The system can run smoothly, has good static and dynamic Characteristics. Experiment and validate id = 0 is a good control algorithm. It provides an effective means and tools for analysis and design of PMSM control system provides. And provides a guideline of designing and debugging for Practical PMSM system.

APPENDIX

S No.	Parameter	Values
1	P	6
2	R_s	1.4
3	L_d	0.0036
4	L_q	0.0058
5	L_{amaf}	0.152
6	B	0.000388
7	J	0.00176
8	V_{dc}	310
9	W_{r_ref}	700

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