

# Matlab-based Permanent Magnet Synchronous Motor Vector Control Simulation

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**Abstract**—Proposed permanent magnet synchronous motor based on MATLAB (PMSM) vector control system model of simulation. And take the model for simulation experiment in Matlab / Simulink environment. The simulation result indicated that the controlling system had a better dynamic response and regulator character. 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

## I. FOREWORD

Compared with other forms of motor, permanent magnet synchronous motor (PMSM) has better dynamic performance, smaller size and higher efficiency. In recent years, with the rapid development of electric power electronics technical, rare earth permanent magnetic materials and the increasingly sophisticated research in permanent magnet motor. PMSM is widely used in national defense, agriculture and daily life.<sup>[1]</sup>

PMSM is a multivariable, nonlinear and high coupling system. The output torque and stator current present a complicated function relation. Magnetic field can be decoupled to get a good control performance: It was no slip frequency current, less affected by the rotor parameters, easier to implement vector control. Therefore, the model of PMSM vector control has become a widespread concern.

This paper analyzes the mathematical model of permanent magnet synchronous motor based on the use of powerful simulation with Matlab modeling capabilities. In the Matlab / Simulink to create a simulation model of PMSM control system can be provide effective means and tools for analysis and design of the servo control system.

## II. PMSM MATHEMATICAL MODEL

### A. Basic Model

The permanent magnet synchronous motor mainly from stator and rotor two part constitute. Three-phase stator windings produce a rotating magnetic field through the three-phase AC. Rotor is usually equipped with high-performance permanent magnet in surface or inside of ferromagnetic materials. Such as neodymium iron boron or rare earth magnetic materials to obtain a strong magnetic field, etc. And the rotor magnetic field to distribute for the sine or look like a sine wave form. The interaction between the stator and rotor magnetic field generated torque when the stator three-phase inverter with access to electricity generated in the motor rotating magnetic field. Then the

torque push synchronization of the rotor to the stator magnetic field rotation speed to achieve the purpose of frequency control. In order to facilitate analysis, the motor to make the following assumptions: the stator winding three-phase symmetrical, uniform air gap, ignoring the end effect; neglected magnetic saturation and iron loss ,magnetic circuit is linear; converter provides an ideal three-phase power, ignoring higher harmonics ; ignore the rotor shaft friction.

Motor voltage balance equation is given by:

$$\begin{bmatrix} U_a \\ U_b \\ U_c \end{bmatrix} = \begin{bmatrix} R & 0 & 0 \\ 0 & R & 0 \\ 0 & 0 & R \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} d\psi_a/dt \\ d\psi_b/dt \\ d\psi_c/dt \end{bmatrix} \quad (1.1)$$

Motor flux balance equation is given by:

$$\begin{bmatrix} \psi_a \\ \psi_b \\ \psi_c \end{bmatrix} = \begin{bmatrix} \cos 0^\circ & \cos 120^\circ & \cos 240^\circ \\ \cos 240^\circ & \cos 0^\circ & \cos 120^\circ \\ \cos 120^\circ & \cos 240^\circ & \cos 0^\circ \end{bmatrix} \begin{bmatrix} L & 0 & 0 \\ 0 & L & 0 \\ 0 & 0 & L \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} \psi_{fr} \cos \theta \\ \psi_{fr} \cos(\theta - 120^\circ) \\ \psi_{fr} \cos(\theta - 240^\circ) \end{bmatrix} \quad (1.2)$$

Torque expression is given by:

$$T_e = \lambda \begin{bmatrix} i_a & i_b & i_c \end{bmatrix} \frac{d}{d\theta} \begin{bmatrix} \psi_{fr} \cos \theta \\ \psi_{fr} \cos(\theta - 120^\circ) \\ \psi_{fr} \cos(\theta - 240^\circ) \end{bmatrix} \quad (1.3)$$

Equation of motion for the motor is given by:

$$J \frac{d\omega}{dt} = T_e - T_l \quad (1.4)$$

Type of  $U_a, U_b, U_c$  for the three-phase stator winding voltage.  $i_a, i_b, i_c$  for the three-phase stator winding current.  $\psi_a, \psi_b, \psi_c$  for the three-phase stator winding flux.  $R, L, \psi_{fr}$  are the stator windings of each phase of resistance, inductance, the equivalent rotor field flux.  $T_l$  is load torque.  $\lambda, J, \omega$  are the motor pole number, rotor inertia, the rotor electrical angular velocity.

The AC permanent magnet synchronous motor is a multi-variable coupled and nonlinear time-varying system in last type. Direct use of traditional linear control theory can not achieve effective control of it. Therefore, it must be possible to transform and simplify the use of classical control theory regulator design.



#### IV. DIRECT POSITION DETECTION of PMSM SIMULINK BASED SIMULATION MODEL

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 Simpowersystems own model of parts library. Speed and position information from the measurement module Machines Measurement Demux direct feedback. Use  $i_d = 0$  control method to control the speed and dq-axis current with PI control.

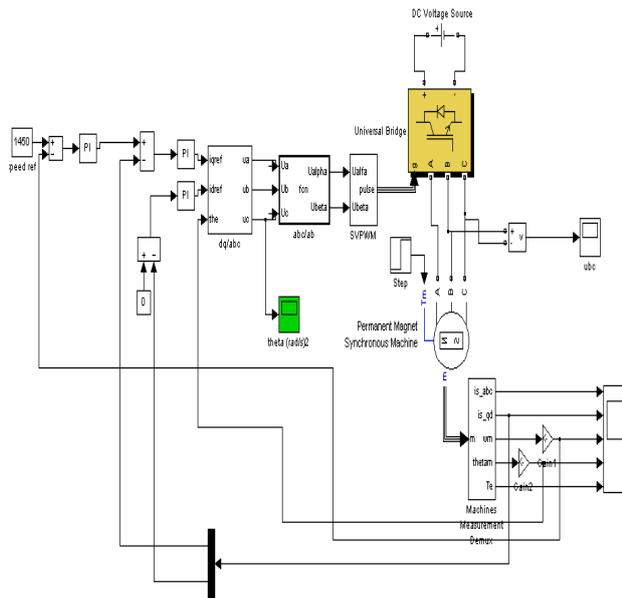


Figure 3. Simulation Model of permanent magnet synchronous motor

#### V. SIMULATION RESULTS

According to the proposed vector control of PMSM simulation model, run in Matlab, using the motor parameters are as follows: electrical power  $P = 2\text{kw}$ , DC voltage  $U_{dc} = 550\text{V}$ , stator windings resistance  $R_s = 2.875\Omega$ , d-phase winding inductance  $L_d = 8.5 \text{e-}3\text{H}$ , d-axis winding inductance  $L_d = 805\text{e-}3\text{H}$ , the rotor magnetic flux  $\Psi_f = 0.175 \text{Wb}$ , moment of inertia  $J = 0.8 \text{e-}3 \text{kg} \cdot \text{m}^2$ , the pole number  $p = 4$ , magnetic flux density  $B = 0$ . Set the total simulation time  $t = 0.2 \text{s}$ , for the sudden increase in torque test.

No load start,  $t = 0.1\text{s}$  when the additional load  $T_m = 5\text{N.m}$ , speed is  $2000 \text{r/min}$ . Waveforms as follows:

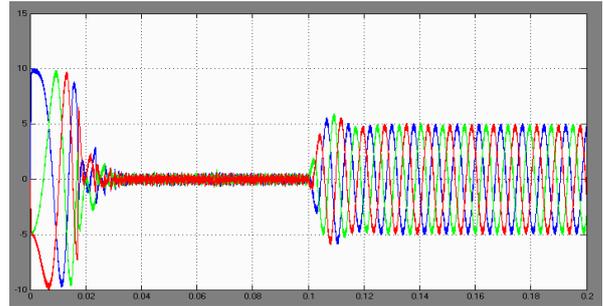


Figure 4. Current response curve

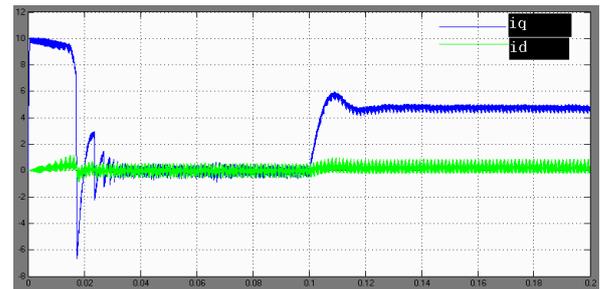


Figure 5. dq axis current waveform

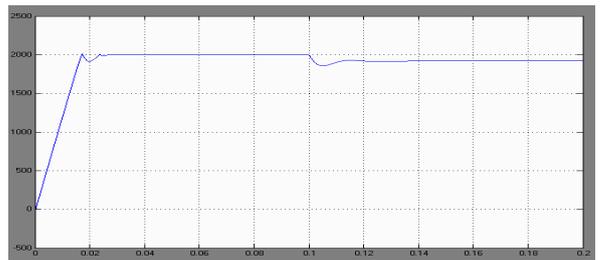


Figure 6. Speed response curves

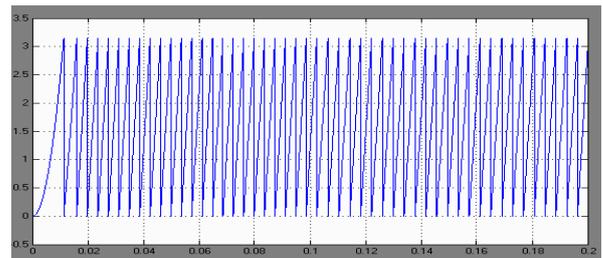


Figure 7. Rotor position waveform

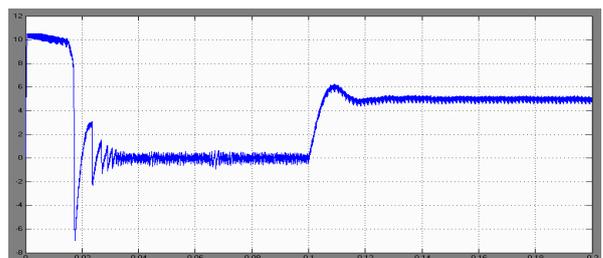


Figure 8. Electromagnetic torque waveform

Sudden increase in torque when the speed becomes 2000 r / min (Fig. 4 to Fig. 8). Then you can see the current, torque response time is very short and very small fluctuations in speed. We can see steady speed when in stable operation with load and stator phase current maintain to a good sinusoidal. This implies that the system has a good anti-interference ability.

## VI. CONCLUSION

In this paper, Simulink-based simulation of PMSM vector control system modeling. Simulation results show that the system can run smoothly, has good static and dynamic characteristics. Experiment and validate  $i_d = 0$  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.

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