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Simulation for Vector Control in Permanent Magnet Synchronous Motor under Dynamic Conditions

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ABSTRACT: This paper presents a way to control a 3-phase Permanent Magnet Synchronous motor using the Texas Instruments TMS320F280 digital signal processor (DSP). This processor is part of a new family of DSPs that enable cost-effective design of intelligent controllers for brushless motors. The use of this DSP yields enhanced operations, fewer system components, lower system cost and increased efficiency. The control method presented is field oriented control (FOC). The sinusoidal voltage waveforms are generated by the DSP using the space vector modulation technique. Vector control is done by maintaining the direct axis current “id = 0”.Then by proper servo tuning the error in speed is converted to current reference using PI controller and error in current is converted to voltage reference using P controller which by using PWM generator is given as switching pulses to IGBT inverter converter. It suitably drives the PMSM motor to the exact target.

KEYWORDS*:* Permanent Magnet Synchronous Motor, DSP TMS320F280, Field Oriented Control

I.INTRODUCTION

Compared with other forms of motor, permanent magnet synchronous motor (PMSM) has better dynamic performance,smaller size and higher efficiency. The control method of permanent magnet synchronous motor is mainly divided into two kinds: One is field oriented control and the other is direct torque control.

In FOC we try to maintain the enclosed angle between the two magnets as close as possible to 90 degrees all the time. This would produce the maximum torque between the two magnets, if a torque other than the current value is required we reduce the power of one of the two magnets by changing its magnetizing current appropriately (increase/decrease magnetizing current for increaing/decreasing the resulting torque).

In DTC instead of maintaining the orthogonality between the two magnets, we continually set the enclosed angle appropriately to produce the desired torque, if more torque is desired the angle is pushed towards 90 deg, if less torque is desired the angle is pushed towards zero. Changing the enclosed angle involves controlling voltage instead of current.

Based on MATLAB/Simulink platform, the PMSM vector control simulation system model is built in Simulink. The model has two loops that the outer one is the velocity loop and the current loop is inside. The reference voltage values of the three-phase motor are calculated through the control of speed and stator current from the PMSM, and are sent to the Pulse Width Modulation (PWM) unit, generating three-phase PWM signals needed by voltage inverter in accordance with the rules of the PWM to drive the motor. From the foundation on this,combined with DSP TMS320F28035, a set of model including interrupt control and field oriented control of the motor system is established in Simulink.

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II. PMSM VECTOR CONTROL THEORY

A. THE MAIN IDEA OF VECTOR CONTROL

PMSM is a high order, strong coupling multiply variable system.The various parameters of the motor couple with each other, therefore, make the AC motor control strongly nonlinear.The basic idea of vector control is to make the torque current and exciting current forming in the space of 90 electrical angle degrees in d-q coordinate system through coordinate transformation to achieve decoupling control of stator current.Then AC motor is equivalent to the excitation DC motor. The Fig. 1 shows the structure diagram of vector control system in PMSM.

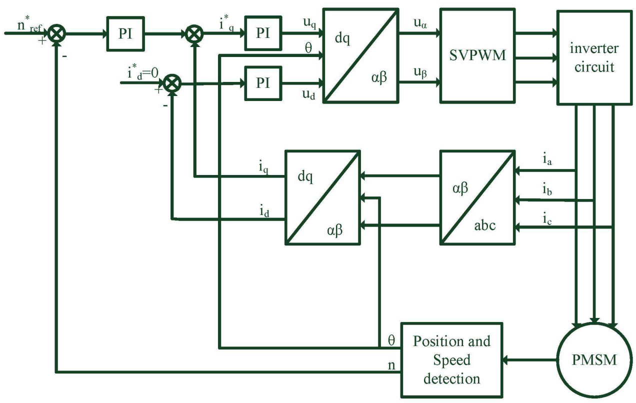

Fig 1 PMSM vector control system block diagram

It is indicated by the Fig. 1 that the vector control system of permanent magnet synchronous motor is composed of several parts: Position and speed detection module, PI regulator of speed loop and current loop, coordinate transformation module, SVPWM module together with the rectifier and inverter module.

B. VECTOR CONTROL COORDINATE TRANSFORMATION

In the ABC coordinate system, the spatial position of the three-phase stator windings is 120 degrees of the mechanical angle.The three-phase sinusoidal current feeding into three phase windings connected to each other by 120 degrees electrical angle will produce a magnetic field rotating with the same intensity, which is the actual driving magnetic field of motor.However, to generate such a magnetic field does not necessarily require three-phase winding. The two-phase current perpendicular to each other can also make the composite magnetic field with two-phase sinusoidal current different from 90 degrees electrical angle in the α-β coordinate system. This field has the same characteristics as the three-phase rotating magnetic field mentioned above.

C. PRINCIPLES OF SVPWM TECHNIQUE

SVPWM means a special switch trigger sequences and pulse width combinations of three-phase voltage source inverter in AC induction motor and PMSM, which will generate three sinusoidal current waveforms with 120 degrees electrical angle differing from each other. A three-phase voltage type PWM inverter is shown in Fig. 2. The aim of vector control strategy based on SVPWM technique is to obtain a circular magnetic field through the combination of different width voltage pulse sequences. We see from the Fig. 2 that there are six power switches.

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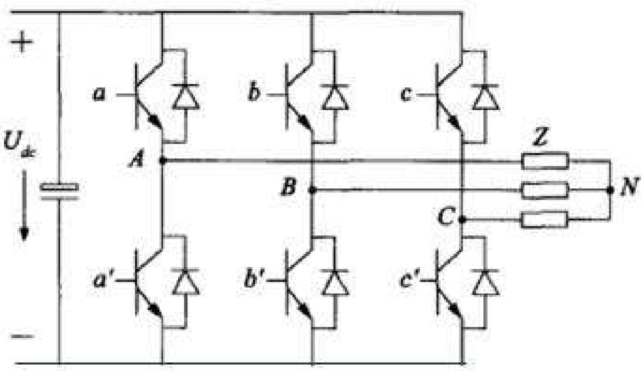

Fig. 2 Circuit of three-phase voltage inverter

III. 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 = 12Kw, DC voltage Vdc = 300V, Stator winding resistance Rs = 1.08Ω, d axis winding inductance Ld 8.5e-3H, q axis winding inductance Lq = 8.5e-3H, the rotor magnetic flux λm = 0.175Wb, moment of inertia J = 0.0008Kg*m^2, the pole number P = 8, magnetic flux density B = 0.00038818Wb/m^2, reference speed = 3000rpm. Set the total simulation time t = 0.2s

A. SIMULINK FOR STEP SPEED REFERENCE AND DIRECT CURRENT (Id)=0A:
:

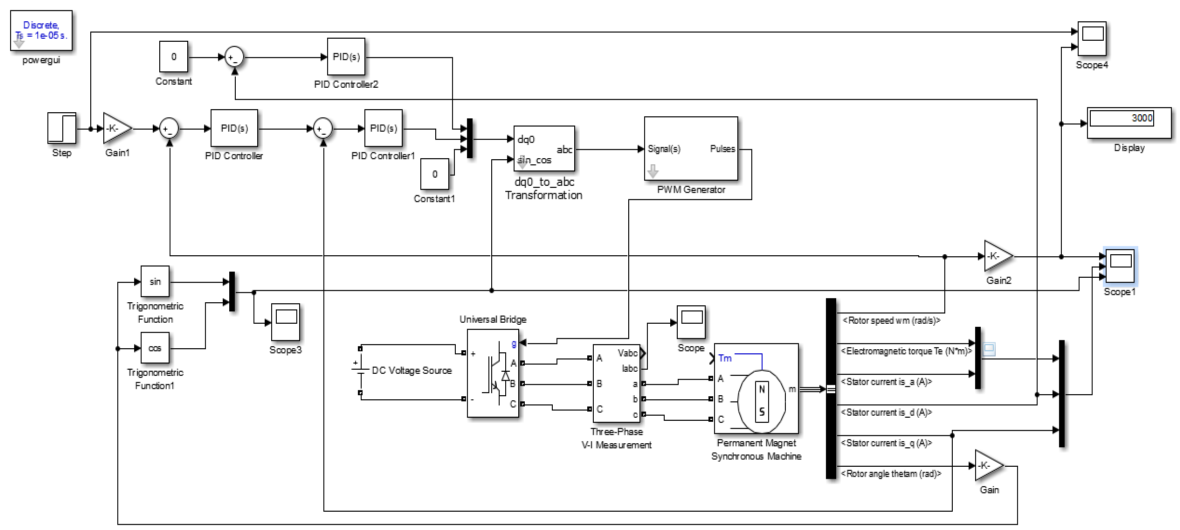

Fig.3 Simulation model for Vector control of PMSM

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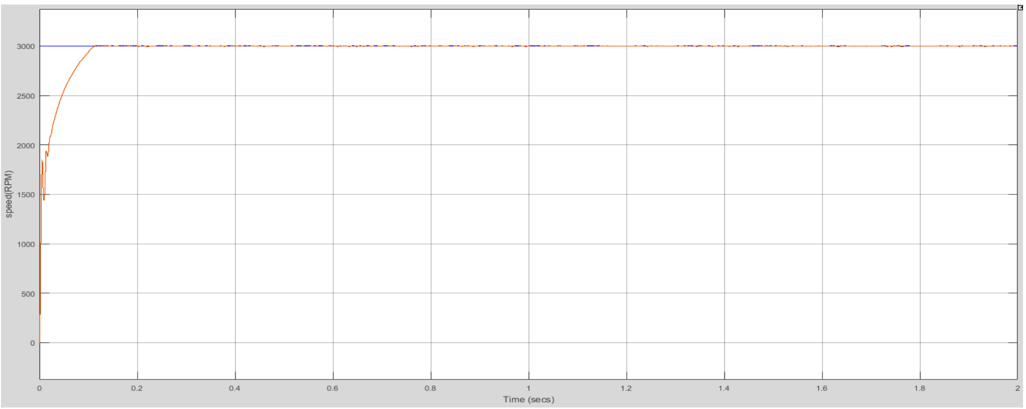

Fig.4 Speed response curve

Fig 4 shows that for Id=0 and for reference speed of 3000 rpm the PMSM motor synchronizes with the reference speed in less than 0.2 seconds.

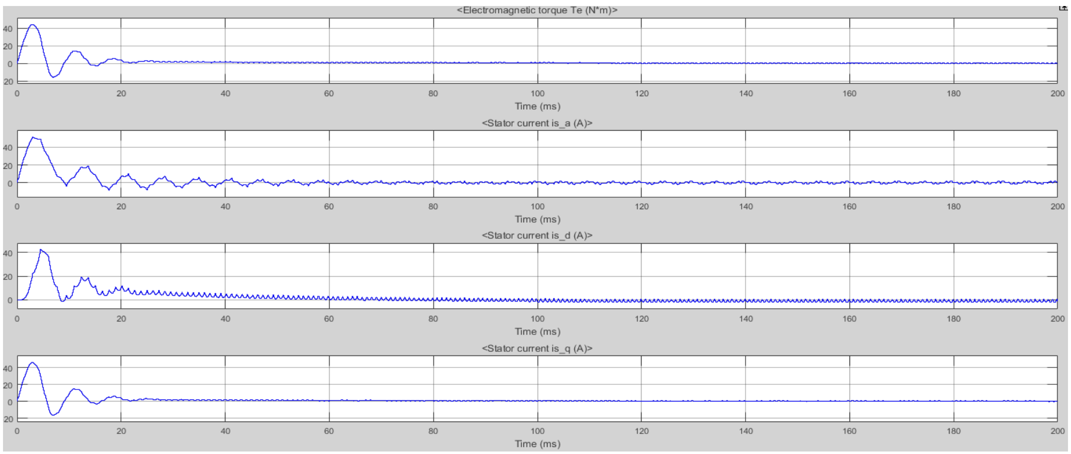

Fig 5 Torque and Currents response curve

Fig 5 shows the waveforms for electromagnetic torque (Te), phase current(ia),direct axis current(id) and quadrature axis current(iq) are shown.From the waveforms we can see that the torque (Te) and quadrature axis current (iq) are proportional to each other.

B. SIMULINK FOR DIRECT CURRENT (Id)=5A:

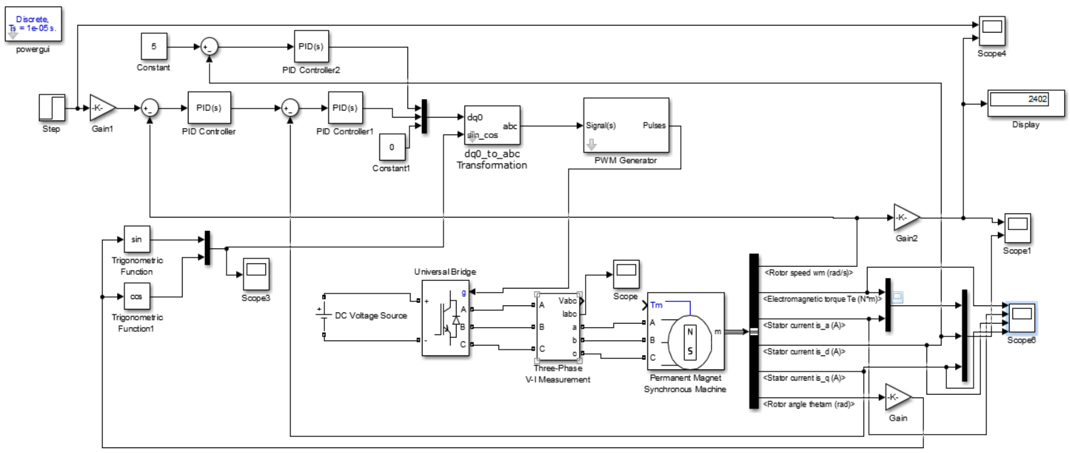

Fig. 6 Simulation model for Vector control of PMSM with id=5A

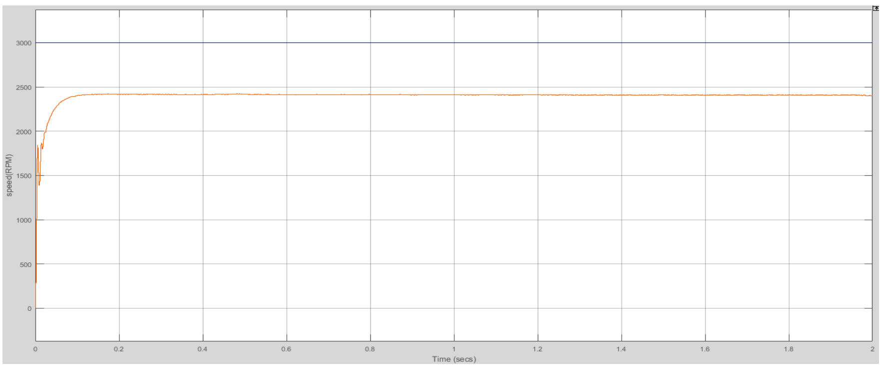

Fig.7 Speed response curve

Fig 7 shows that when the direct axis current is given a value, the PMSM motor does not synchronize with the reference speed.

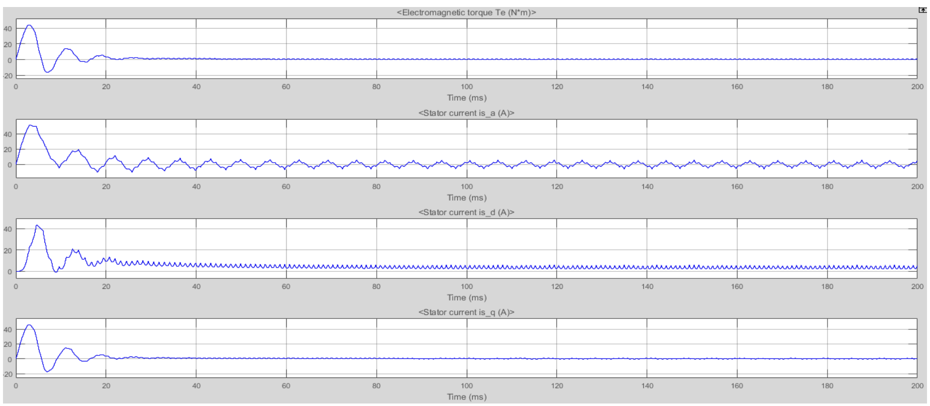

Fig. 8. Torque and Currents response curve

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Fig 8 shows that the torque and quadrature axis currents are similar as they depend on each other and after producing the required torque the Iq becomes zero.

C.SIMULINK FOR MULTIPLE STEP REFERENCE INPUTS AND DIRECT CURRENT (Id)=0A:

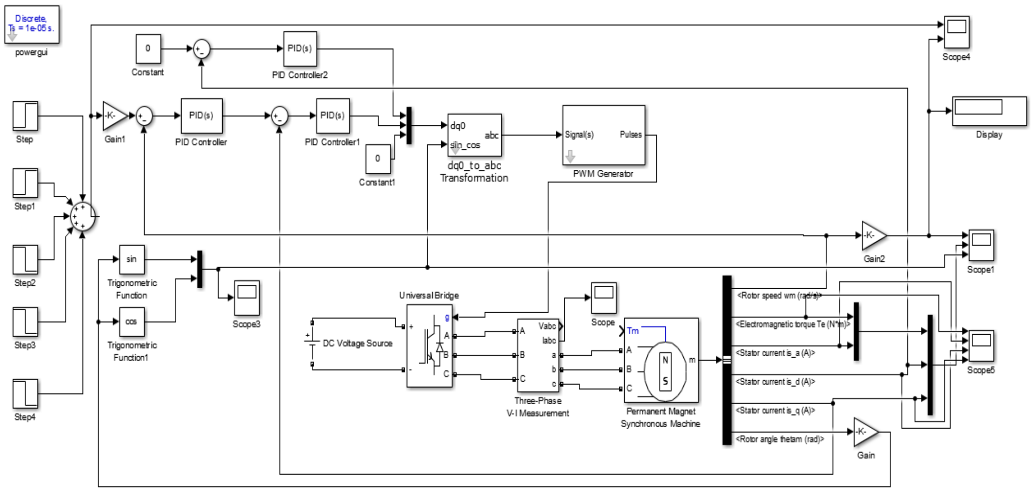

Fig. 9. Simulation model for Vector control of PMSM with id=0A with multiple references

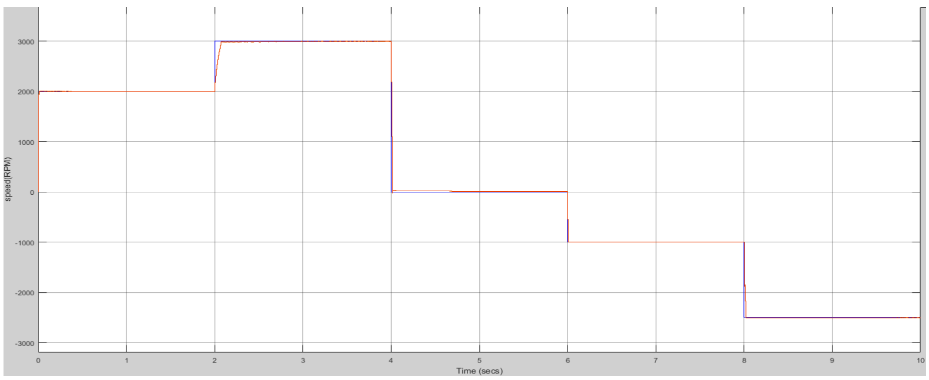

Fig 10.Speed response curve

Fig 10 shows that though the reference speed changes for about every two seconds the PMSM motor synchronizes exactly in a time less than 0.2 seconds.

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D: FOR SPEED 0 TO 2000 RPM:

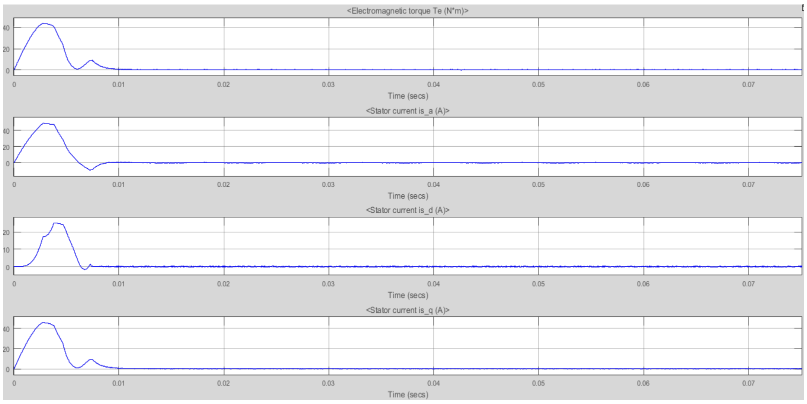

Fig. 11. Torque and Currents response curve

E: FOR SPEED 2000 TO 3000 RPM:

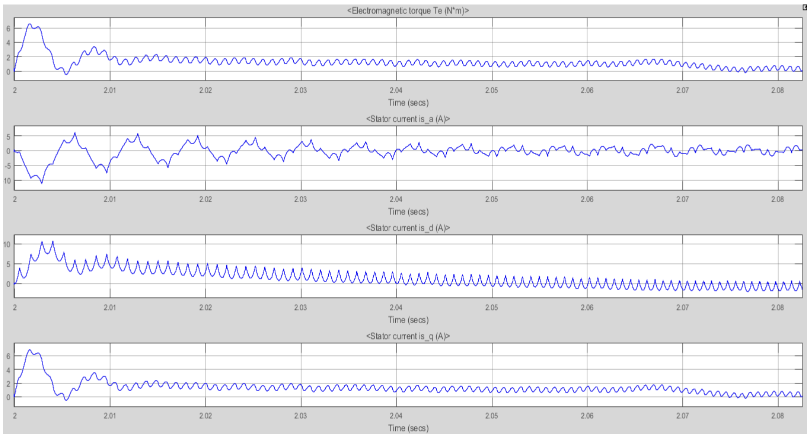

Fig. 12. Torque and Currents response curve

F: FOR SPEED 0 TO -1000 RPM:

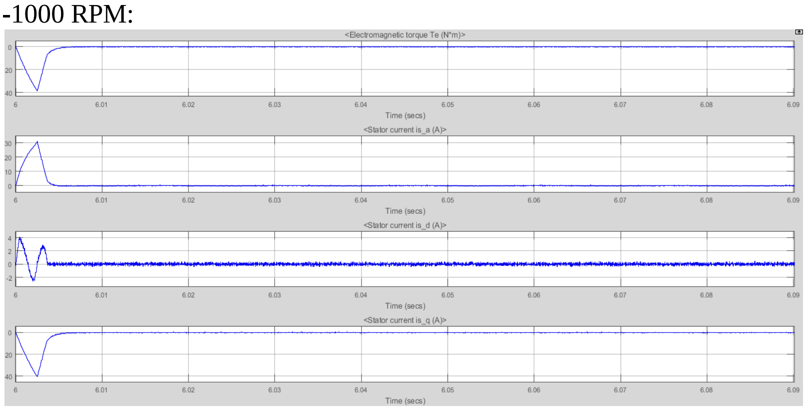

Fig. 13. Torque and Currents response curve

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G: FOR SPEED -1000 TO -2500 RPM:

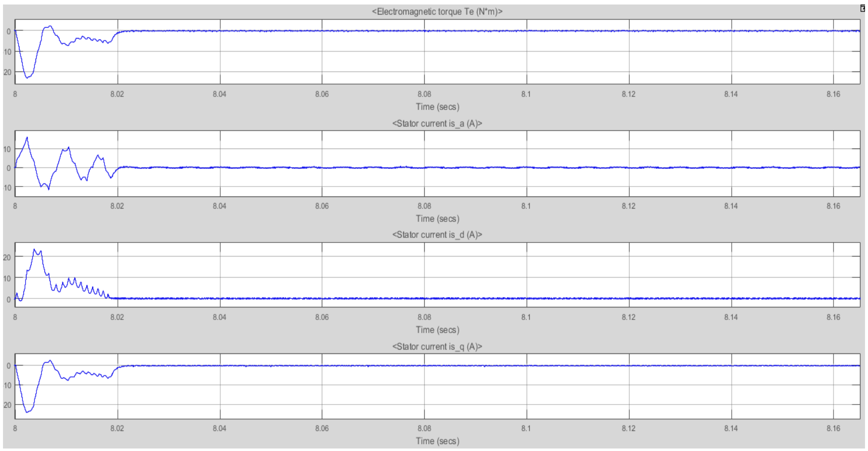

Fig. 14. Torque and Currents response curve

IV.CONCLUSION:

This paper verified the performance of PMSM simulation based on vector control in MATLAB/Simulink.The strategy of the model system is “id = 0”. Firstly,we build a set of control system with the existing PMSM and inverter module provided by Simulink Library. The simulation results show that the control model has good performance. The current can respond quickly and the fluctuation period of the speed is short when the torque is suddenly changed, which proves to be a stable software simulation model.Then the simulink is done with direct axis current (id=5A) and analysed that the reference speed is not attained.Then the simulink is sone for variable speed torque conditions and analysed that the PMSM motor synchronizes for each variable speed very quickly when direct axis current (id)=0.

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