RESEARCH ARTICLE OPEN ACCESS

Advanced Simulation Model of Permanent Magnet Synchronous Motor (PMSM)

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Abstract— We are proposing an advanced simulation model of Permanent Magnet Synchronous Motor (PMSM). The developed simulation model is used to implement the vector control scheme of a PMSM drive. In this model, speed and torque as well as the voltages and currents of voltage source inverters components can be effectively monitored and analyzed. The simulation model has been implemented using Matlab and the dynamic response of PMSM drive has been analyzed for constant speed, varying torque and variable speed constant torque operation. Also, the simulation results have been presented. The PMSM block available in the Matlab/Simulink library is used to to validate simulation results . Therefore developed simulation model can be an easy to design tool for the design and development of PMSM drives for different control algorithms and topological variations with reduced computation time and memory size.

Keywords— PMSM,Matlab,Simulink,Inverter

I. INTRODUCTION

For the last twenty years PMSM is a topic of interest and vector control technique is one of the most common closed loop control technique used in a PMSM drive. It also eliminates oscillating flux, torque responses in inverter fed induction motor and synchronous motor drives. There are different types like constant torque angle control, Unity power factor control, and constant mutual air gap

Flux-linkages control, optimum-torque-per-ampere control and flux-weakening control. The choice of these methods depends on mainly on the type of application and the load characteristics. Hence, it is required to perform a simulation study before designing a PMSM drive for choosing the appropriate control algorithm for a particular application.

The advantages of this PMSM is high efficiency, high power factor, high power density, easy maintenance, fast dynamic response. It replaces Induction motor (IM) and Synchronous motor (SM) in several applications because of its advantages.For the last twenty years PMSM is a topic of interest. Vector control technique is one of the most common closed loop control technique used in a PMSM drive. It eliminates oscillating flux, torque responses in inverter fed induction motor and synchronous motor drives.

II. FUNCTIONAL BLOCK DIAGRAM

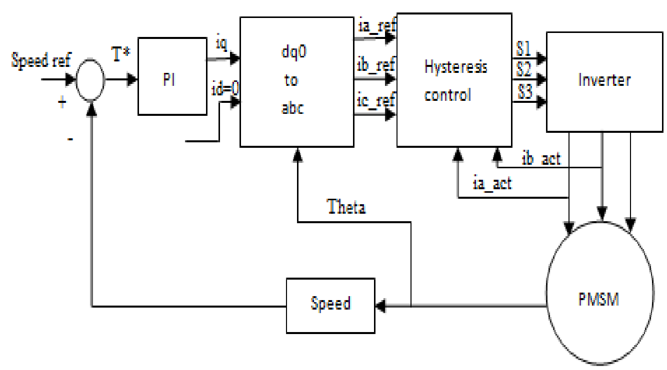

Fig1. Block Diagram of Closed Loop Speed Control of PMSM

For the analysis constant torque method of vector control scheme has been considered. The torque angle is angle between the rotor field and stator current phasor and is maintained at 900 so that flux is kept constant, then the torque is controlled by the stator current magnitude. The error between the reference and actual speed has given as the input to the speed controller, which generates the torque reference and is proportional to Kt iq.

III. METHODOLOGY

The figure 1 shows the methodology of the system. It includes the following steps

1. PMS Motor Parameter Selection
2. PMS Motor Mathematical Modeling
3. Simulink Model Development for Closed Loop Control System
4. Finding Dynamic Response and Stator Current Response
5. Response Comparison
6. Finding Dynamic Response and Stator Current Response
7. Simulink Model Development for Closed Loop Control System
8. PMSM Matlab Library Block Configuration

IV MATHEMATICAL MODEL OF PMSM

The mathematical model of PMSM has been presented in this section to provide a basis for the subsequent sections. The stator and the wound rotor of the PMSM synchronous motor are similar. The permanent magnets used in the PMSM is shown in figure.

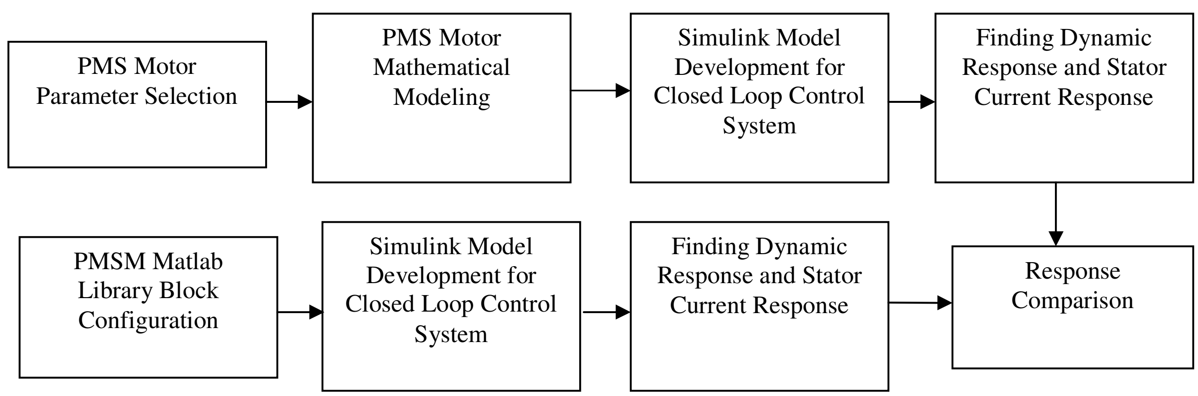

Fig 2: Methodology

The mathematical model of a PMSM is similar to that of the wound rotor SM. The following assumptions are considered while developing the mathematical model.

- There are no field current dynamics
- There is no cage on the rotor

The equivalent circuits of PMSM in d, q axes in rotor reference frame are shown in fig 2 and fig 3 respectively.

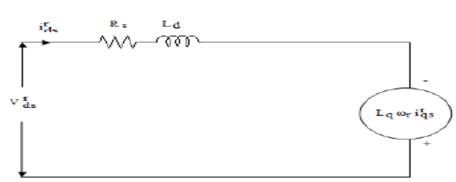

Fig 2 Stator q-axis equivalent circuit

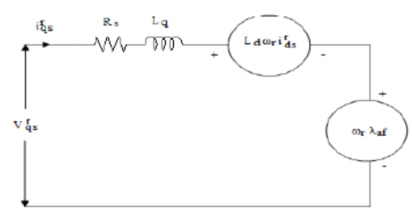

Fig 3 Stator d-axis equivalent circuit

V. ALGORITHMIC DEVELOPMENT AND FLOW CHART

Developed simulation Model of closed loop speed control of PMSM Drive Implemented in Matlab/Simulink

The three phase voltage output of Pulse width modulated (PWM) voltage source inverter (VSI) is given by equations (1) to (3).

Van = Vdc (S1 - S4) (1)

Vbn = Vdc (S3 -S6) (2)

Vcn = Vdc (S5 - S2 (3)

S1 S6 – are three phase inverter switches.

The mathematical model of the PMSM expressed by equations (1) to (3).The developed system simulation model of PMSM drive system in Matlab\simulink is shown in Fig. 4. The subsystem for the mathematical model of PMSM alone is shown in Fig. 5. For this the PMSM block drive in matlab is used .The PM Synchronous Motor Drive (AC6) block represents a classical vector control drive for permanent synchronous motors. The main advantage of this drive is its fast dynamic response. The inherent coupling effect between the torque and flux in the machine is managed through decoupling control, which allows the torque and flux to be controlled independently. However, due to its computation complexity, the implementation of this drive requires fast computing processors or DSPs.

5.2 Hysteresis current controller of VSI

The speed calculation model implemented in Matlab is shown in Fig. 6.

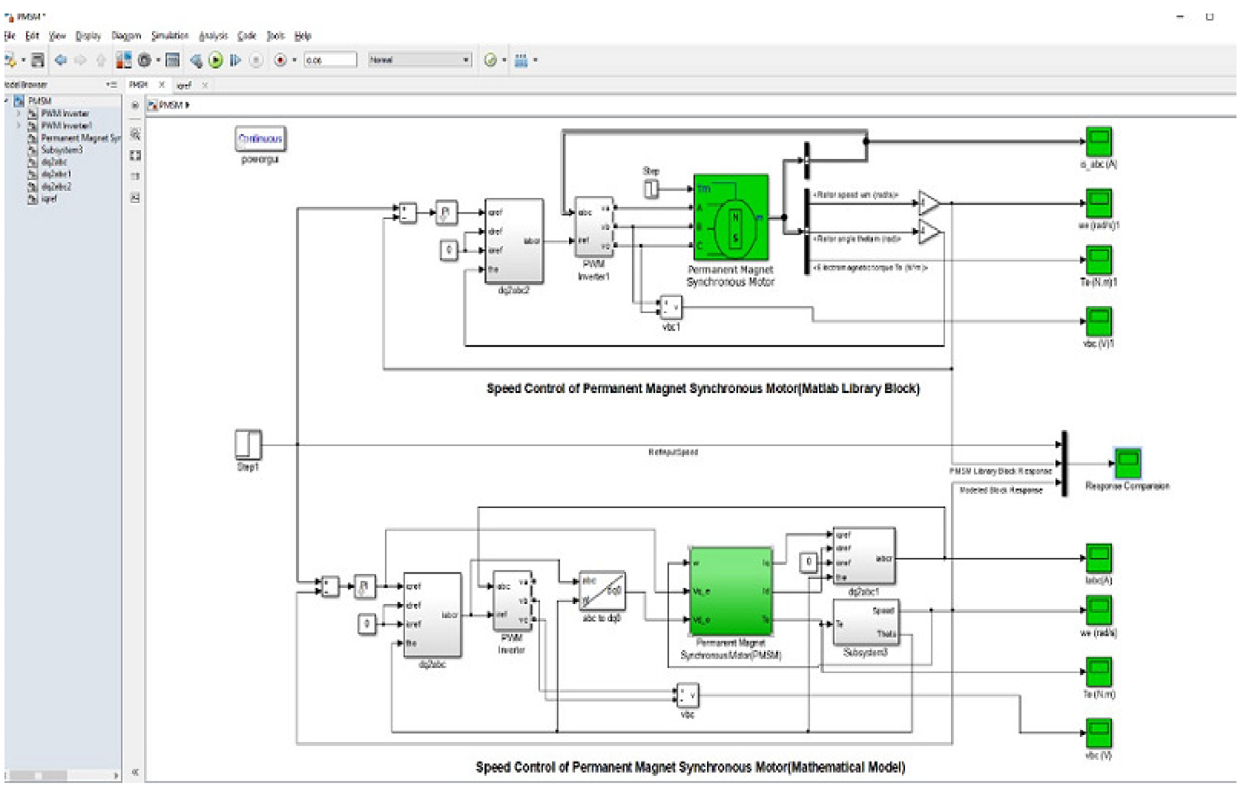

Fig 4 - Developed simulation Model of closed loop PMSM drive implemented in Matlab

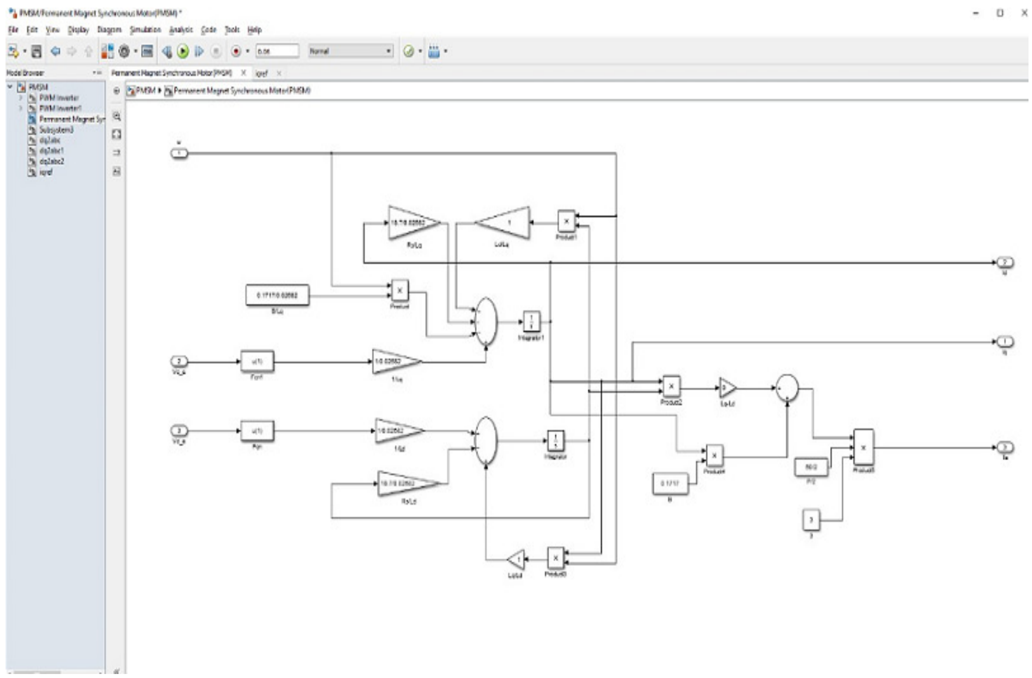

Fig. 5.Mathematical Model of PMSM implemented in Matlab

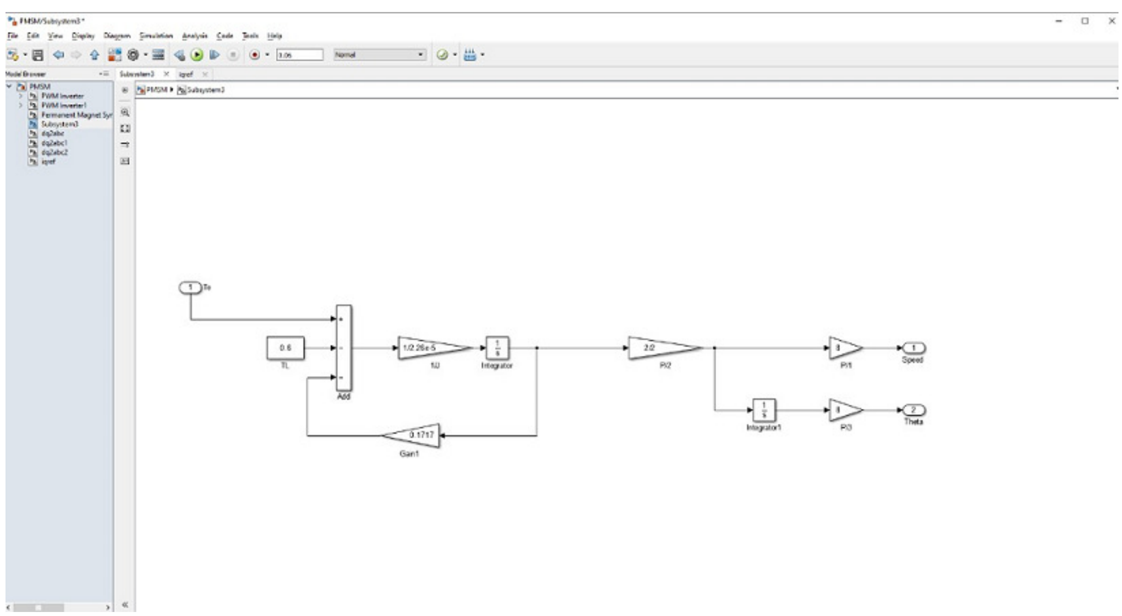

Fig. 6. Speed Calculation Model

VI EXPERIMENTAL RESULT

The different cases considered for simulation are 1. Constant speed varying torque and 2.varying speed constant torque. The motor parameters used are; Rs 18.7Ω = ; Ld&Lq 0.02682H = ; J = 2.26e -5kgm2 ; F = 1.349e-5Nm/rad/s; P = 2; F = 50HZ; Vdc 300V; = B = 0.1717V/rad/s; For constant speed operation, the reference speed is set as 3000 rpm and the load torque varied from 0.6N-m to 0.8N-m at 0.25sec. Fig. 8 shows the starting current response of the developed system simulation model and the circuit simulation model respectively, which has oscillations during starting but reaches steady state within negligible time. Fig 9 shows the simulation results of the developed model and the circuit simulation model respectively which includes, speed and torque response along with rotor position angle. For constant torque operation the load torque is kept at 0.8 Nm and the reference speed is varied from 1500rpm to 3000rpm at 0.25 sec. The simulation results of the developed system simulation model and the circuit simulation model is shown in fig 10. It can be observed from fig 8 to fig 10, the simulation results of the developed system simulation model and the circuit simulation model well coincides with each other, which shows the accuracy of the developed model.

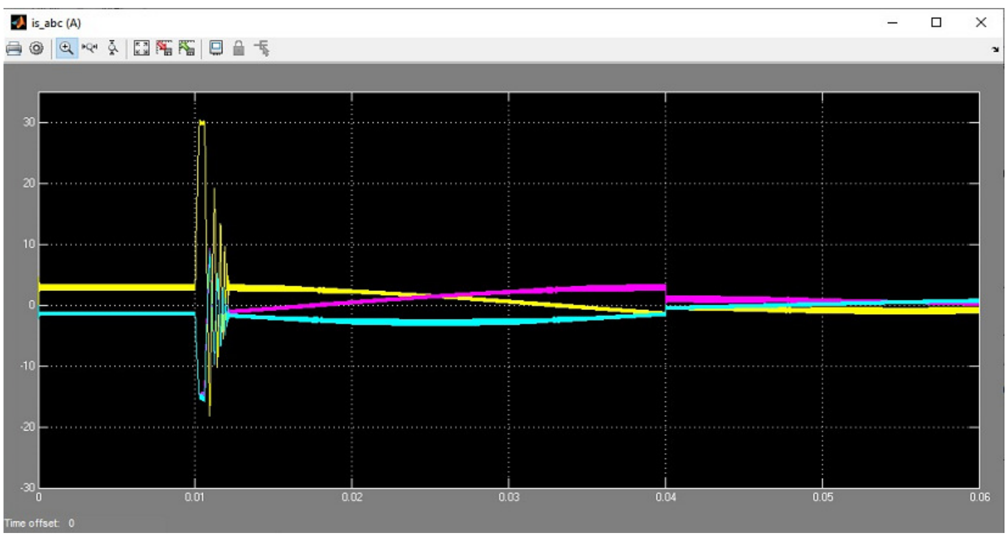

Fig. 8. Stator Current Response

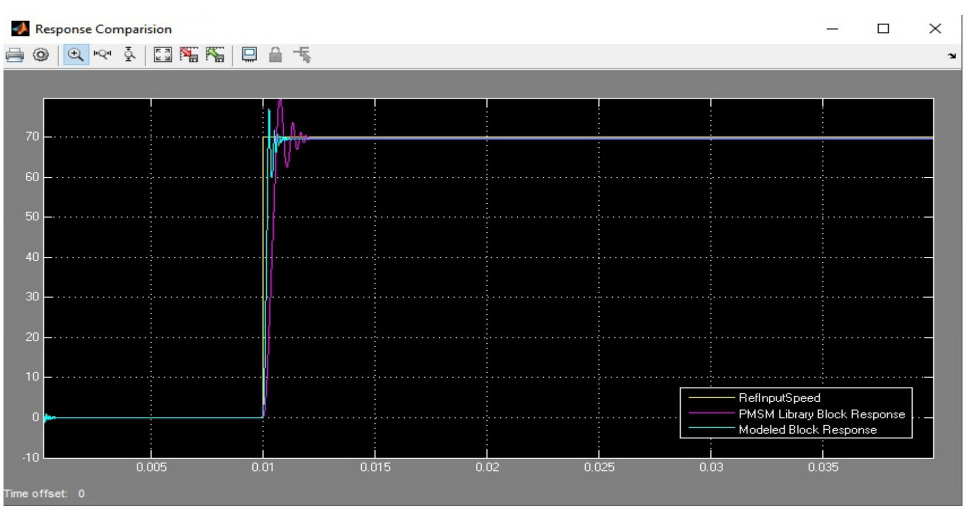

Fig 9 Response Comparison

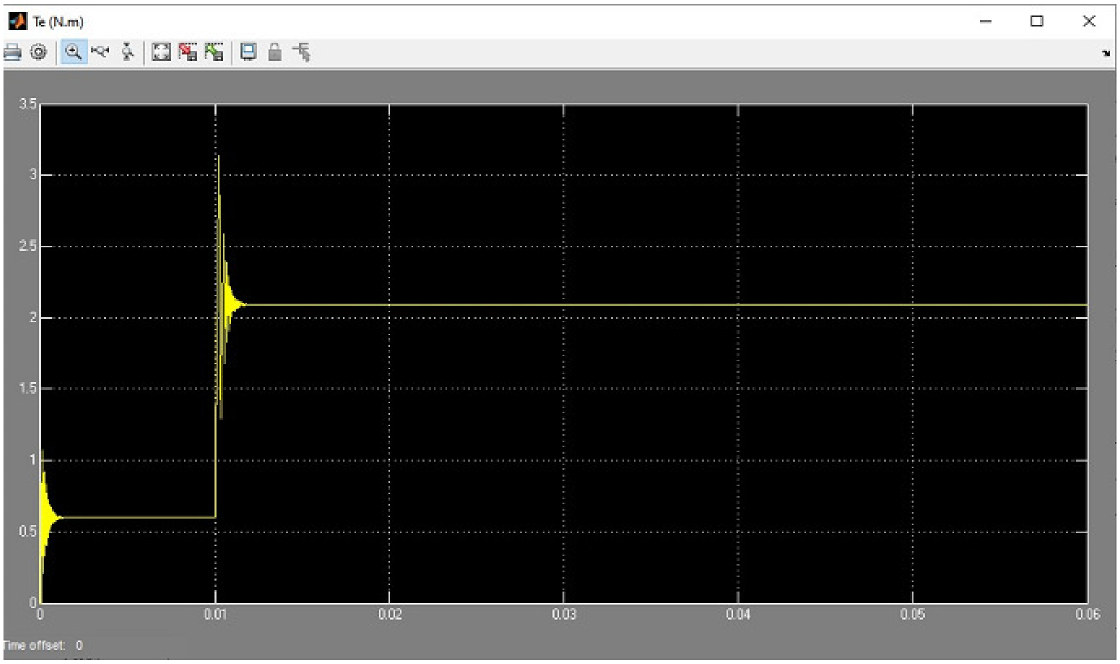

Fig. 10. Motor torque response

CONCLUSION:

1. Mathematical modeling and designing of PMSM block in Simulink is done.
2. Designed closed loop control system for speed control of PMSM in Simulink.
3. Designed circuit simulation Model for Matlab library PMSM block.
4. Validated speed control results of Proposed PMSM block with Matlab Simulink library PMSM block with following two conditions for both,
   a. Constant Speed and Varying Torque
   b. Varying Speed and Constant Torque
5. And simulate the model successfully.

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