International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 03 Issue: 03 | Mar-2016 www.irjet.net p-ISSN: 2395-0072

Study of Speed and Torque Characteristics of MATLAB-Simulink Designed PMSM: A Review

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***Abstract*—Permanent Magnet Synchronous Motors (PMSM)are widely used in robotic and industrial applications due to their low inertia, high efficiency and high torque – to -volume ratio. This paper proposes dynamic simulation models of PMSM with the aid of MATLAB – Simulink. The modeling procedures are described and simulation results are presented. These dynamic models capable of predicting the machine's behavior for this machine type. All simulation results are presented for all machine's variable characteristics. The validity of our model here is verified using V/f control, at various frequencies values. These models will be used in future, insensor less speed control.**

Keywords—PM Synchronous Motor, Magnetic flux, speed-toque, MATLAB – Simulink and dynamic modeling

Introduction

Since the last three decades AC machine drives are becoming more popular, especially Induction Motor (IM) and Permanent Magnet Synchronous Motor, but with some special characteristics, the PMSM drives are ready to meet up sophisticated needs such as fast dynamic response, high power factor, and wide operating speed range, as a result, a gradual gain in the use of PMSM drives will surely be witness in the future in low and mid power applications. In a PMSM, the dc field winding of the rotor is replaced by a permanent magnet to produce the air-gap magnetic flux. Having the magnets on the rotor, electrical losses due to field winding of the machine get reduced and the lack of the field losses improves the thermal characteristics of the PM machines and its efficiency. Absence of mechanical components like brushes and slip rings makes the motor lighter, high power to weight ratio for which a higher efficiency and reliability is achieved.

II. MATHEMATICAL MODEL OF PMSM

The mathematical model is similar to that of the wound rotor synchronous motor. As there is no external source connected to the rotor side and variation in the rotor flux with respect to time is negligible, there is no need to include the rotor voltage equations. Rotor reference frame is used to derive the model of the PMSM shown in figure 1 and 2.

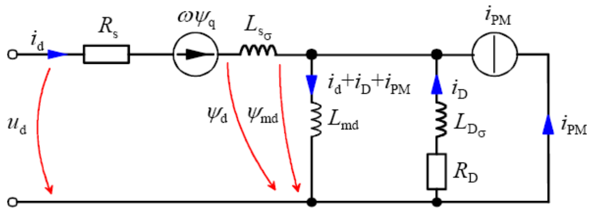

Fig 1. PM equivalent for d-axis

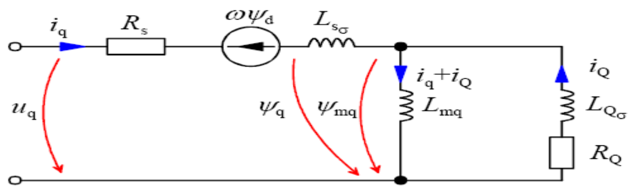

Fig 2. PM equivalent for q-axis

The electrical dynamic equation in terms of phase variables can be written as:

$$v_a = R_a i_a + p\lambda_a (1)$$
$$v_b = R_b i_b + p\lambda_b (2)$$
$$v_c = R_c i_c + p\lambda_c (3)$$

While the flux linkage equations are:

$$\lambda_a = L_{aa} i_a + L_{ab} i_b + L_{ac} i_c + \lambda_{ma} (4)$$
$$\lambda_b = L_{ab} i_a + L_{bb} i_b + L_{bc} i_c + \lambda_{mb} (5)$$
$$\lambda_c = L_{ac} i_a + L_{bc} i_b + L_{cc} i_c + \lambda_{mc} (6)$$

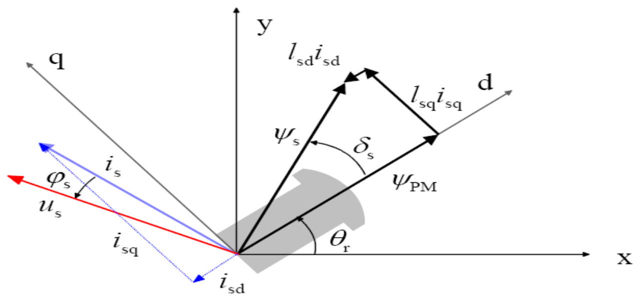

Fig 3. Stator reference axis *x-y*axis & Rotor reference axis *d-q* axis

Considering symmetry of mutual inductances such as Lab = Lba, self inductancesLaa = Lbb =Lcc and flux linkage λma = λmb = λmc = λm. Applying the transformations (1) and (3) to voltages, flux linkages equation (4)-(6), we get a set of simple transformed equations as:

$$v_q = (R_s + L_q p)\, i_q + \omega_r L_d i_d + \omega_r \lambda_m \quad (7)$$

$$v_d = (R_s + L_d p) i_d - \omega_r L_q i_q \quad (8)$$

Ld and Lq are called d and q-axis synchronous inductances, respectively. ωr is motor electrical speed. Each inductance is made up of self inductance (which includes leakage inductance) and contributions from other two phase currents.
The electromagnetic torque Te can be represented as:

$$T_e = (3/2)(P/2)(\lambda_m i_q + (L_d - L_q) i_d i_q) \quad (9)$$

It is apparent from the above equation that the produced torque is composed of two distinct mechanisms. The first term corresponds to the mutual reaction torque occurring between iq and the permanent magnet, while the second term corresponds to the reluctance torque due to the differences in d axis and q-axis reluctance (or inductance). The equation for motor dynamics is:

$$T_e = J p \omega_r + B \omega_r + T_l \quad (10)$$

III.DYNAMIC SIMULATION

This dynamic simulation of PMSM is done with the aid of SIMULINK in MATLAB package.

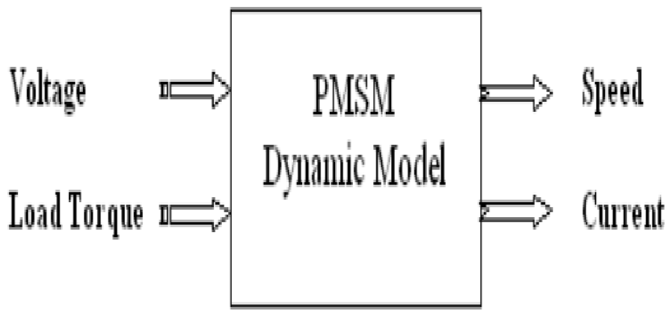

Fig 5. PMSM Model Block

Fig.5, presents a block for the PMSM inwhich, the voltage and load torque are considered as inputs, with the speed and current as outputs.

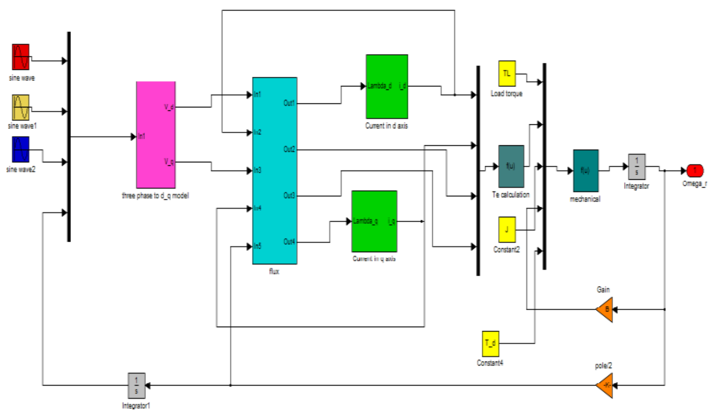

Fig 6.Dynamic Model ofPermanent Magnet Synchronous Motor

IV.MODEL SIMULATION RESULTS

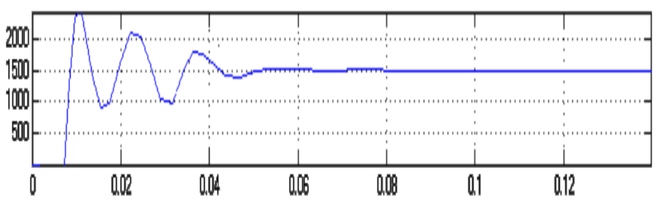

Fig.7. speed-timewith core loss

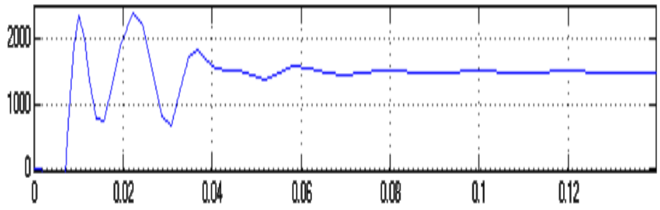

Fig.8. speed-timewithoutcore loss

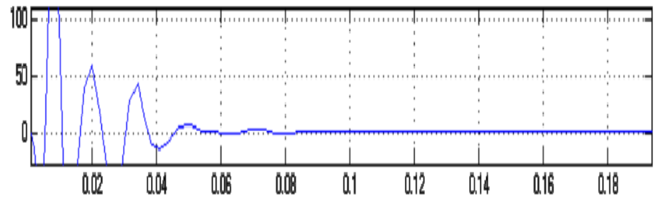

Fig.9. Torque-timecharacteristics with core loss

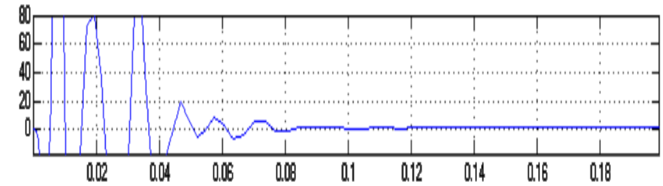

Fig.10. Torque-timecharacteristics withoutcore loss

Conclusion

A detailed Simulink model for a PMSM drive system affirms on the validity of simulink in matlab environment to be used for electrical machines dynamic modeling. This is mainly proposes simulation dynamic model for Permanent Magnet Synchronous Motor (PMSM), with the aid of MATLAB – Simulink. The modeling procedures are described and simulation results are presented. It is notified that, the dynamic model capable of predicting the machine's behavior for this machine type models are developed by coupling electrical equations and mechanical equations of the PMSM. All simulation results are presented for all machine's variable characteristics. The validity of our model here is verified using V/f control, at various frequencies values and also vector control method can verify the speed-torque characteristics of PMSM.

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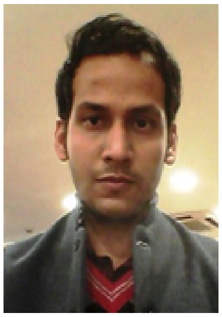

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