ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 2, Issue 6, June 2014

Sensorless Rotor Position Estimation of PMSM by flux linkage method

Gautam Sarvaiya[1], Jignesh Makwana[2], Kunal Bhatt[3]

Student, Department of Electrical Engineering, School of Engineering, RK University, Rajkot, India[1]

Associate Professor, Department of Electrical Engineering, School of Engineering, RK University, Rajkot, India[2]

Assistant Professor, Department of Electrical Engineering, School of Engineering, RK University, Rajkot, India[3]

Abstract: PMSM is very efficient motor and used to control speed or torque in many high performance applications. Field orient control (FOC) method makes this feasible. To implement field orient control technique in drive, accurate rotor position and speed information is required. Cost of drive can be reduced if rotor position information can be obtained without position sensor. In this paper estimation of rotor position is presented by the flux linkage method. Simulation is carried out in Simulink/Matlab and simulation results are presented.

Keywords: PMSM, sensorless, position estimation, FOC, flux linkage.

I. INTRODUCTION

To cop up global warming and non-renewable energy source crisis, mankind has adopted many ways. Use of more and more green energy and energy efficient equipment are most effective solutions for the same. Permanent Magnet Synchronous Motor (PMSM) is very efficient motor with excellent speed and torque control characteristics, which makes it suitable for high performance applications and hence PMSM is replacing other types of motor in speed and position control applications. But high cost of motor and its drive is limiting factor. Field orient control or vector control is widely used to drive the PMSM. For successful implementation of field orient control, accurate information of instantaneous location of rotor position is needed along with speed of rotor. Rotor position and speed information can be obtained by position sensors like resolver, optical encoder. These sensors increase the cost, size and installation complexity of drive [1] [3]. However, sensorless estimation of rotor position and speed is also possible which increase the reliability, and decrease the cost of the drive. Many techniques have been suggested in literature based on the back emf, flux linkage, signal injection and artificial intelligence [4]-[6]. In this paper, first mathematical model of PMSM in stator reference frame is derived and then rotor position estimation is carried out by the flux linkage method.

II. MATHEMATICAL MODEL OF PMSM

Three phase PMSM mathematical model in stator reference frame can be obtained using Clark transformation. The Clark transformation [7] given as

$$\begin{bmatrix} f_{qs}^{s} \\ f_{ds}^{s} \\ f_{0} \end{bmatrix} = \frac{2}{3}\begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & -\frac{\sqrt{3}}{2} & \frac{\sqrt{3}}{2} \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix}\begin{bmatrix} f_{as} \\ f_{bs} \\ f_{cs} \end{bmatrix}$$

Here, f_{as}, f_{bs}, f_{cs} are three phase motor variables like voltage, current or flux linkage and $f_{qs}^{s}, f_{ds}^{s}, f_{0}$ are same machine variable transformed into q and d axes which are orthogonal to each other. The d-axis and q-axis is known as stator reference frame. By use of Clark transformation three phase PMSM can be represented as equivalent two phase machine as shown in Fig. 1 [3] [8].

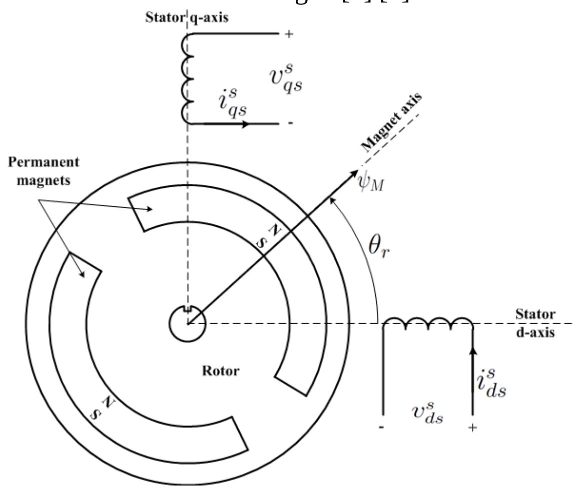

Figure 1: Two phase PMSM

From Figure 1 the two phase voltage can be written as

$$v_{ds}^{s} = R_{ds} i_{ds}^{s} + \frac{d}{dt}\varphi_{ds} \quad (1)$$

$$v_{qs}^{s} = R_{qs} i_{qs}^{s} + \frac{d}{dt}\varphi_{qs} \quad (2)$$

Here, v_{ds}^{s} is stator d-winding voltage, v_{qs}^{s} is stator q-winding supply voltage respectively. i_{ds}^{s} and i_{qs}^{s} are d- and q- winding current in ampere respectively. R_{ds} and R_{qs} is phase d- and q- phase winding resistance in ohm respectively. φ_{ds} and φ_{qs} d-wind and q-winding flux linkages respectively. The construction of PMSM is symmetrical so R_{ds} and R_{qs} are equal. The expression of flux linkage can be written from (1) and (2) as

ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 2, Issue 6, June 2014

$$\varphi_{ds} = \int v_{ds}^{s} - R_s i_{ds}^{s} \quad (3)$$
$$\varphi_{qs} = \int v_{qs}^{s} - R_s i_{qs}^{s} \quad (4)$$

Here, R_s is per phase resistance of stator winding. Figure 2 shows vector diagram of PMSM.

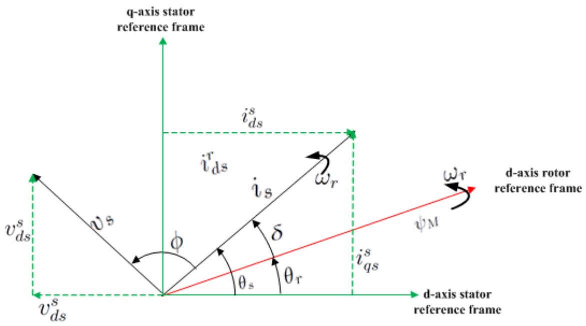

Figure 2: Vector diagram of PMSM

From vector diagram rotor position can be estimated by the estimation of the stator flux linkage and rotor position can be obtained as [2]

$$\theta_r = \frac{\varphi_{qs}}{\varphi_{qs}} \quad (5)$$

Putting (3) and (4) into (5) as

$$\theta_r = \frac{\int v_{ds}^{s} - i_{ds}^{s}}{\int v_{ds}^{s} - i_{ds}^{s}} \quad (6)$$

From (6) it is clear that rotor position can be estimated supply voltage and current.

III. SIMULATION AND RESULT

Simulation is carried out of rotor position estimation by flux linkage method. The result shown in Figure 5 to 6. Results show that estimation follows the actual quantity with acceptable error. From the error shows that error increase with torque.

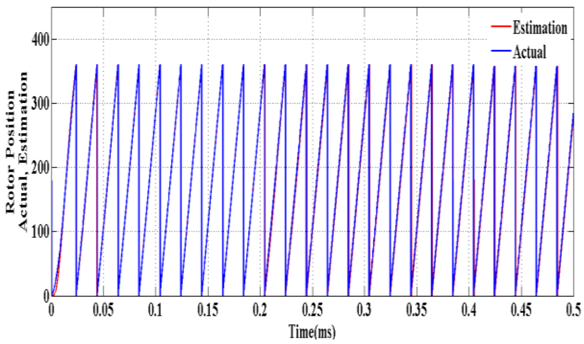

Fig. 3 A Rotor position – Actual and estimated

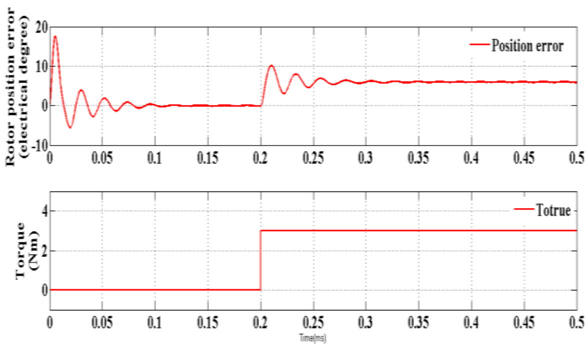

Figure 4: Step change in torque and effect of step change in torque on rotor position estimation

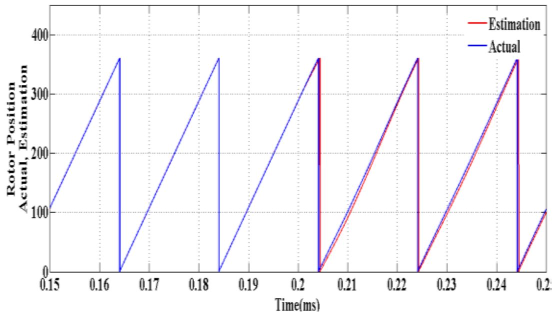

Fig. 5 A Rotor position – Actual and estimated

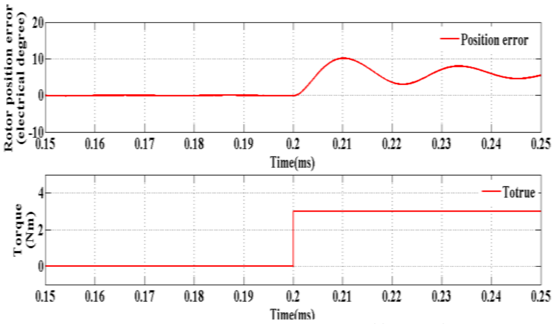

Figure 6: Step change in torque and effect of step change in torque on rotor position estimation

This method includes the integration term. And the estimation of the rotor position is dependent on integration term. It is difficult to set the initial value of the integrator. If the initial value is not properly adjusted then the estimation becomes poor. Also this method is non adaptive method so the parameter variation is not considered.

IV. CONCLUSION

Estimation of the rotor position by flux linkage method is reasonably accurate. Error in estimation increases with the applied load torque. Estimation also takes more time to reach at steady state value after the transition in torque.

REFERENCES

[1] J. F. Gieras, "Permanent Magnet Motro Technology: Design and Application," 3rd ed., FL:CRC Press 2010.
[2] B. K. Bose, "Modern Power Electronics and AC Drives" PHI Publication, New Delhi, 2013.
[3] R. Krishnan, "Electric Motor Drives, Modeling, Analysis and Control," PHI Publication, New Delhi, 2013, pp. 562.
[4] O. Bejak, D. Gerling, "Review of Position Estimation Methods for IPMSM Drives without a Position Sensor, Part I: Nonadaptive Methods," XIX International conference on Electrical Machines – ICEM 2010.
[5] O. Bejak, D. Gerling, "Review of Position Estimation Methods for IPMSM Drives without a Position Sensor, Part II: Adaptive Methods," XIX International conference on Electrical Machines – ICEM 2010.
[6] O. Bejak, D. Gerling, "Review of Position Estimation Methods for IPMSM Drives without a Position Sensor, Part III: Method on Saliency and Signal Injection," International conference on Electrical Machines and Systems (ICEMS), 2010, pp.873–878.
[7] P. C. Krause, Oleg Wasynczuk, S. D. Sudhoff, "Analysis of Electric Machinery and Drive System," 2 ed. Wiley-India, Delhi, 2012, pp. 109-137.
[8] P. Pillay, R. Krishnan, Modeling of Permanent Magnet Motyor Drives, "IEEE transfaction of Industrial Electroncis, Vol. 35, No. 4, Nov. 1988, pp. 537-541.