VECTOR CONTROL TECHNIQUE FOR PERMANENT MAGNET SYNCHRONOUS MOTOR DRIVES USING PI CONTROLLERS

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ABSTRACT

This paper involves a vector control technique of a Permanent Magnet Synchronous motor (PMSM). A Modern research in recent days has been proved that PMSM is the better choice for high performance servo applications when compared to Induction Motors. In this paper, A mathematical model of PMSM has been developed with clarke and park transformations. A DC motor is a linear motor where speed can be controlled only with one parameter. The vector control scheme when applied to the PMSM it presents a linear dynamic motor model as a DC motor with fast response. A speed reference input is given to the PI controllers and the performance of PMSM drive system with different speed reference values is evaluated with the help of MATLAB/SIMULINK and the results are explained very clearly.

Index terms: Vector control, PMSM drives, Clarke Transformation, Park Transformation

1.INTRODUCTION

In the modern research era, Permanent magnet synchronous motors (PMSM) has become a very superior motor in high performance servo applications, because of its properties such as less weight, high efficiency, fast dynamic response, low rotor inertia, high-power factor, high torque inertia ratio and compact structure [3].

Earlier Scalar based control techniques which controls only magnitude are used to control the speed of PMSM and Induction motor drives. Some of the Scalar based control techniques are Voltage control, Rotor Resistance Control and V/F method. But when scalar-based control is used the motor acts as a non-linear motor and has very sluggish and slow response. Scalar Control has high transient time and takes huge time to settle down [8].

Field oriented control (FOC) scheme is used to improve the characteristics of the motor to reduce the order of torque equation [1]. The Implementation of FOC is difficult but the performance is good when compared to other techniques [2]. Hence, Steady state response has better characteristics if FOC is used, Dynamic response is better is characteristics if DTC (Direct Torque Control) is used [4],[5]. Therefore, DTC includes high torque ripples in steady state response. The field-oriented control has two closed loops which are of current and speed.

The concept of PWM inverter used in the paper can also be replaced with a Multi-level DC link inverter with reduced switch count which reduces the number of heatsinks and gate driver circuits [6]. A ten-switch topology UPQC connected for AC machines can also reduce the switching losses [7].

The concept implemented in this paper is vector control of PMSM motor drives for Electric Vehicle applications.

2. MODELING OF PMSM MACHINE:

Dynamic model of PMSM Machine:

Electrical system equations:

Considering a salient pole machine where L_d (Direct axis inductance) is not equal to (Quadrature Axis inductance) L_q

$$V_q = R_s\, i_q + L_q * (dI_q/dt) + L_d\, \omega_r\, I_d + \lambda_f\, \omega_r \text{ -------------(1)}$$

$$V_d = R_s\, i_d + L_d * (dI_d/dt) - L_q\, \omega_r\, I_q \text{ -----------------------(2)}$$

From equations (1) and (2) we get the values of I_q and I_d

$$I_q = \int\{ (V_q / L_q) - (\lambda_f\, \omega_e/L_q) - (\omega_e L_d I_d/L_q) - (R_s I_q/L_q)\}dt\text{—(3)}$$

$$I_d = \int\{ (V_d / L_d) + (\omega_e L_q I_q/L_d) - (R_s I_d/L_d)\}dt\text{-------------------(4)}$$

Equations (3) and (4) which are to be developed in MATLAB environment as shown in figure 1 and 2 respectively.

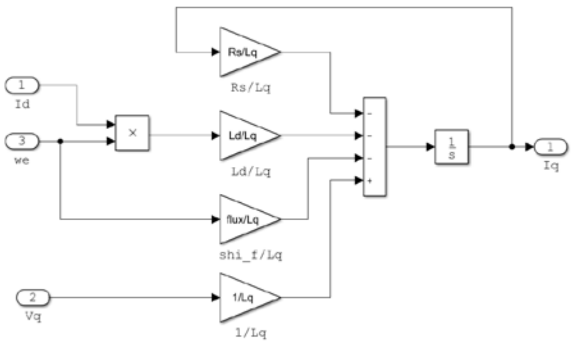

Figure 1: Calculation of I_q(Electrical)

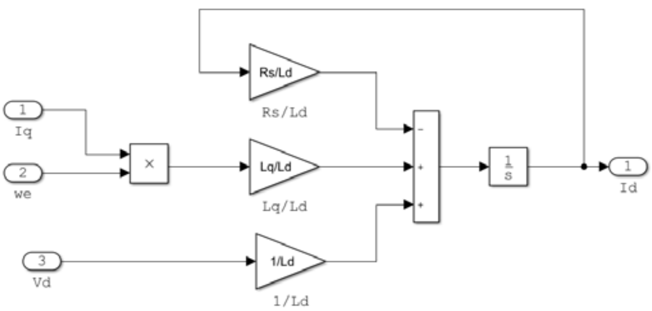

Figure 2: Calculation of I_d (Electrical)

Mechanical system equations:

$$J^* d\omega_m/dt + B^*\omega_m = T_e - T_m \text{ ----(5)}$$

$$\omega_m * P/2 = \omega_m \text{ -------(6)}$$

$$\int\omega_e\, dt = \Theta \text{ ---------(7)}$$

From Equation 5 we get

$$\omega_m = \int(- B\, \omega_m + T_e - T_m) * 1/T\, dt \text{ --------------(8)}$$

Hence from the above equation, the mechanical block of the PMSM is implemented in MATLAB Simulink Environment as shown in figure 3.

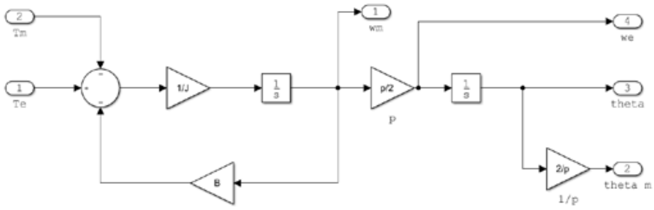

Figure 3: Mechanical model of PMSM

3. PROPOSED CIRCUIT DIAGRAM:

The proposed circuit is simulated in MATLAB Simulink 9.3 and the brief model is as shown in figure 4.

Referring to the figure 4, there are blocks namely torque estimator, flux linkage estimator and Voltage estimator which are implemented separately in MATLAB/SIMULINK environment.

The closed loop operation can be explained from the figure 4, where the speed of the machine is fed back to the voltage estimator circuit using PI controllers. The stator currents I_a I_b and I_c are fed back through the torque estimators and flux linkage estimator blocks,

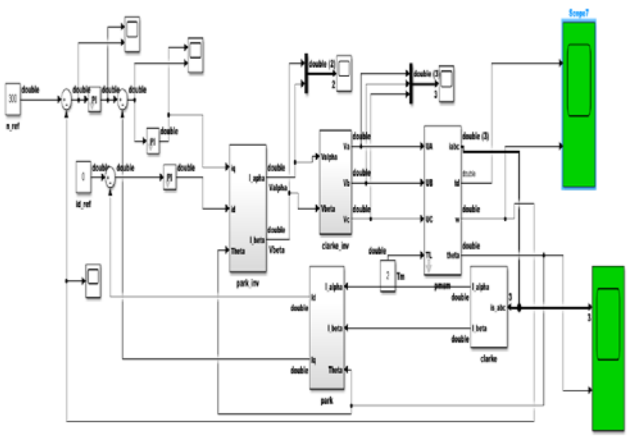

Figure 4: Proposed Circuit Diagram of PMSM Control

The detailed circuit of Clarke transformation is shown in the figure 5.

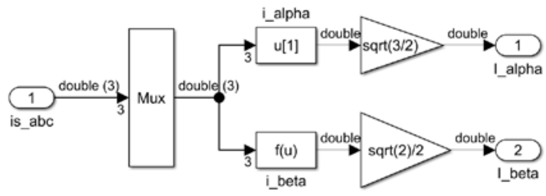

Figure 5: Clarke Transformation

The detailed circuit of park transformation is shown in the figure 6.

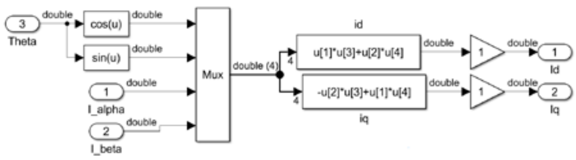

Figure 6: Flux Linkage estimator block

4. SIMULATION RESULTS:

The torque and speed curves for the speed reference value 300 are shown in figure 7.

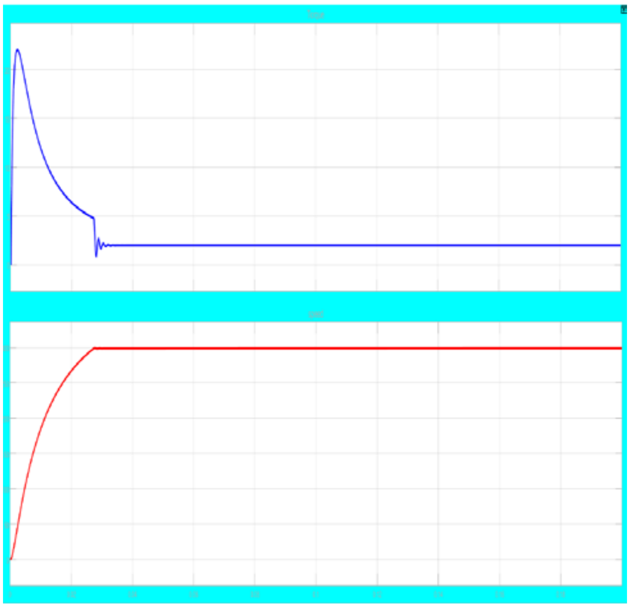

Figure 7: Torque and Speed of the PMSM machine with w_{ref} = 300

The variation of three phase output currents and rotor angle theta is shown in figure 8.

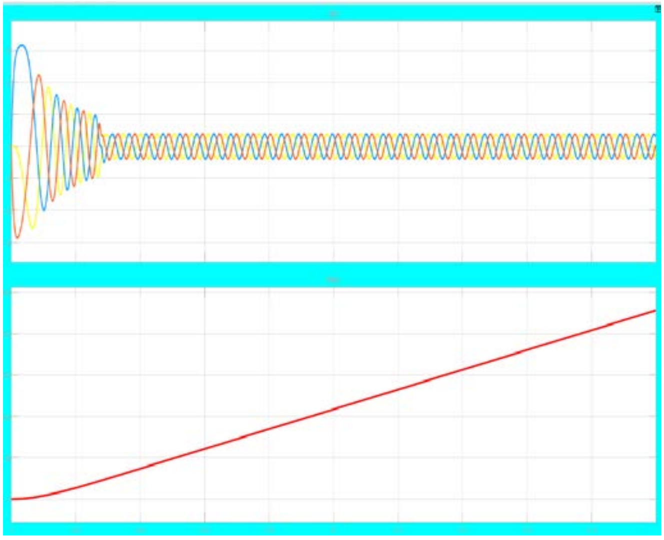

Figure 8: Iabc and rotor angle.

The torque and speed curves for the speed reference value 400 are shown in figure 8.

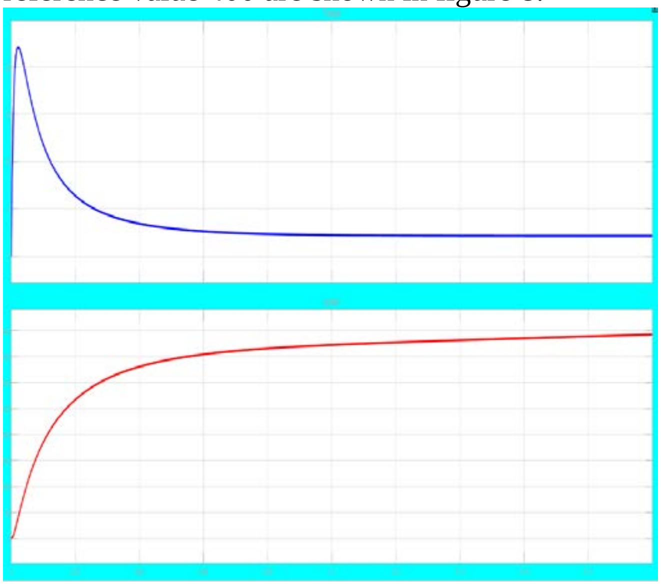

Figure 8: Torque and Speed of the PMSM machine with w_{ref} = 400

Conclusion:

In this paper, a vector control of PMSM motor drive using PI controllers is presented. The torque-speed characteristics of PMSM is studied by varying the reference speed value and the feedback loops. The FOC technique has two feedback loops for current and speed. The entire system is developed and simulated in MATLAB/SIMULINK and results are vividly presented.

REFERENCES:

1. R. K. Sharma, V. Sanadhya, L. Behera and S. Bhattacharya, "Vector control of a permanent magnet synchronous motor," 2008 Annual IEEE India Conference, 2008, pp. 81-86, doi:

10.1109/INDCON.2008.4768805.

2. M. M. Negm, S. A. Leithy, H. Dopa and A. Kamel, "Vector control for a three-phase induction motor based on optimal regulator theory," Proceedings of IEEE. AFRICON '96, 1996, pp. 654-660 vol.2, doi: 10.1109/AFRCON.1996.562965.
3. V. M. Bida, D. V. Samokhvalov and F. S. Al-Mahturi, "PMSM vector control techniques — A survey," 2018 IEEE Conference of Russian Young Researchers in Electrical and Electronic Engineering (EIConRus), 2018, pp. 577-581, doi: 10.1109/EIConRus.2018.8317164.
4. T. Zhang, B. Liu and H. Zhang, "Direct torque control of permanent magnet synchronous motor," Proceedings of the 29th Chinese Control Conference, 2010, pp. 3358-3361.
5. Direct self control for high dynamics performance of inverter feed a.c. machines," *ETZ Archiv*., vol. 7, no. 7, pp. 211–218, 1985.
6. K. B. Kumar, A. Bhanuchandar and C. Mahesh, "A Novel Control Scheme for Symmetric Seven Level Reduced Device Count Multi-Level DC Link (MLDCL) Inverter," 2021 International Conference on Sustainable Energy and Future Electric Transportation (SEFET), 2021, pp. 1-4, doi: 10.1109/SeFet48154.2021.9375714.
7. Kumar, Kasoju Bharath, Dongari Vamshy, and Mahesh Chanda. "A Novel Three phase Three Wire UPQC (Unified Power Quality Conditioner) Configuration using Ten Switch Topology for linear RL loads." IJITEE, Volume 10, Issue 4 DOI: 10.35940/ijitee.D8458.0210421
8. Y. N. Dementyev, N. V. Kojain, A. D. Bragin and L. S. Udut, "Control system with sinusoidal PWM three-phase inverter with a frequency scalar control of induction motor," 2015 International Siberian Conference on Control and Communications (SIBCON), 2015, pp. 1-6, doi: 10.1109/SIBCON.2015.7147008.