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Scalar control of Permanent Magnet Synchronous motor

Yashvi Parmar[1], Priyanka Patel[2], Nitiksha Pancholi[3], Chand Thakor[4], Unnati Mali[5]

[12345]*Assistant Professor, Dept. of Electrical Engineering, C.G. Patel Institute of Technology, Gujarat, India*

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Abstract – *Permanent Magnet Synchronous Motors (PMSM) are attractive growing for a wide range of industrial drives and servo applications. There are various control strategies of speed control of Permanent Magnet Synchronous Motor. This paper represents scalar control Strategy for speed control of PMSM motor drive. It includes Mathematical model of PMSM, V_{abc} to V_{dq} conversion and simulation of Scalar control strategy.*

Key Words: control strategies, speed control, PMSM, scalar control, simulation

1. INTRODUCTION

Permanent Magnet Synchronous Motors (PMSM) are attractive growing for a wide range of industrial drives and servo applications. Synchronous Motors have to be driven by a Variable Frequency Drive (VFD) to be able to run at different speeds. Control methods for electric motors can be divided into two main categories depending of what quantities they control.

1.1 VARIOUS CONTOL STRATEGIES OF PMSM

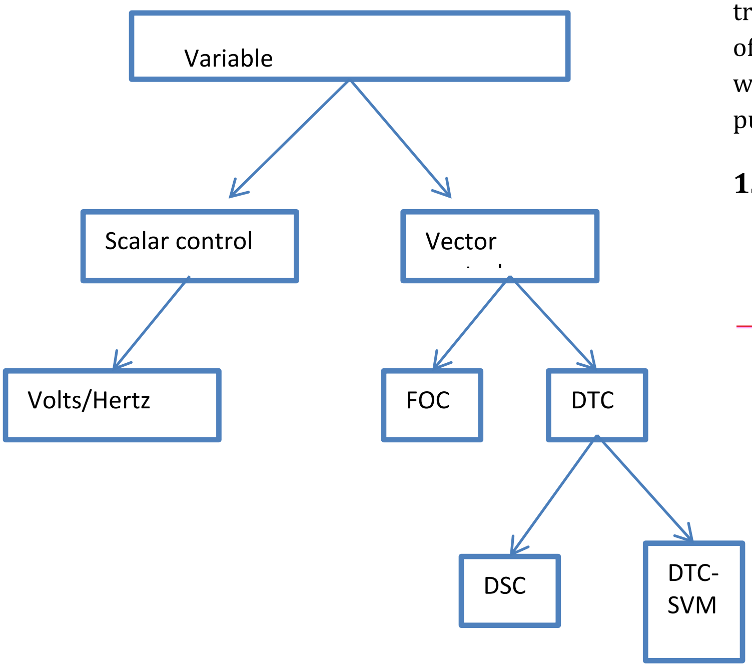


Fig -1: Some common control techniques used for PMSM

1.2 Scalar control

Scalar Control controls only magnitudes. The simplest method to control a PMSM is scalar control, where the relationship between voltage or current and frequency are kept constant through the motors speed range. The frequency is set according to the wanted synchronous speed and the magnitude of the voltage/current is adjusted to keep the ratio between them constant. No control over angles is utilized, hence the name scalar control. The method uses an open-loop control approach without any feedback of motor parameters or its position. This makes the method easy to implement and with low demands on computation power of the control hardware, but its simplicity also comes with some disadvantages. One of them are instability of the drive system after exceeding a certain applied frequency, to overcome this the rotor has to be constructed with damper windings to assure synchronization of the rotor to the electrical frequency. This will limit the number of design choices for the rotor, e.g. the magnets has to be located on the inside of the damper bars. Most PMSM are therefore constructed without damper windings, and they are not suitable for traditional scalar control. Another drawback with the lack of feedback is the systems low dynamic performance, which limits the use of this control method to e.g. fan- and pump-drives.

1.2.1 volt/frequency control

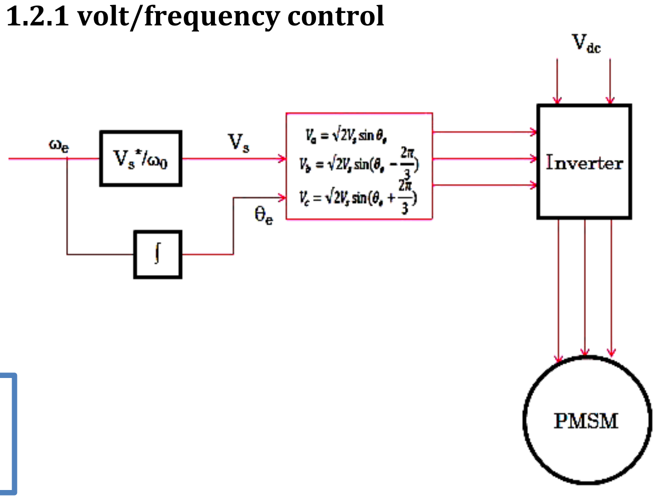


Fig -2: Block diagram of v/f control

Constant volt per hertz control in an open loop is used more often in the squirrel cage IM applications.Using this technique for synchronous motors with permanent magnets offers a big advantage of sensorless control. Information about the angular speed can be estimated indirectly from the frequency of the supply voltage. The principle is based on keeping the stator flux constant at rated value for the motor to develop rated torque/ampere ratio over entire speed range. A sinusoidal voltage PWM algorithm is implemented to increase the amplitude of fundamental voltage .Therefore the dynamic performance is poor, with high overshoot. The signal used in feedback loop is the rotor position needed to control the synchronization between the rotor and the field.

2. Simulation of scalar control

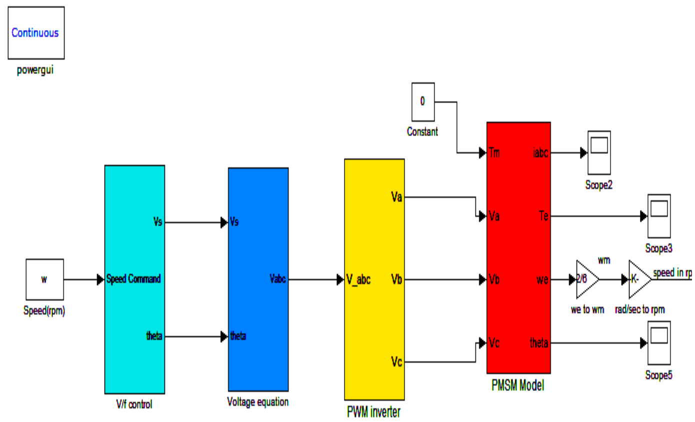


Fig -3: Simulink model

In V/f control, supply voltage is calculated from speed command and theta is obtained by integrating speed command. Then using Sinepwm method three voltages V_a, V_b, V_c are generated.

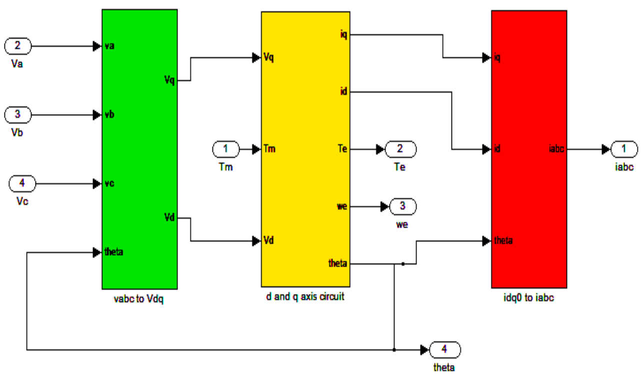


Fig -4: subsystem of PMSM Model

Equations used in simulation are:

V_{abc} to V_{dq} conversion

$$\begin{bmatrix} V_{qs}{}^{r} \\ V_{ds}{}^{r} \end{bmatrix} = \frac{2}{3}\begin{bmatrix} \cos\omega_r t & \cos\left(\omega_r t - \frac{2\pi}{3}\right) & \cos\left(\omega_r t + \frac{2\pi}{3}\right) \\ \sin\omega_r t & \sin\left(\omega_r t - \frac{2\pi}{3}\right) & \sin\left(\omega_r t + \frac{2\pi}{3}\right) \end{bmatrix}\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

$$V_q = R_s i_q + \omega_r (L_d i_d + \lambda_f) + \rho L_q i_q$$

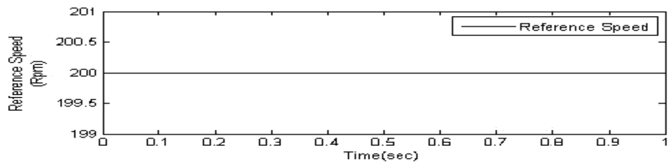
$$V_d = R_s i_d - \omega_r L_q i_q + \rho (L_d i_d + \lambda_f)$$

$$T_e = \frac{3}{4} P(\lambda_f i_q + (L_d - L_q) i_q i_d)$$

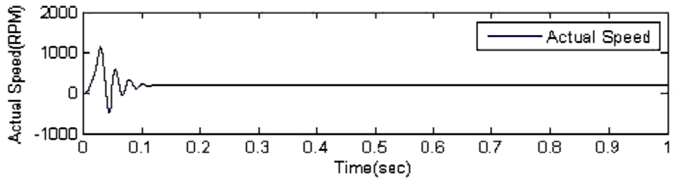
$$\omega_m = \int \left(\frac{T_e - T_L - B\omega_m}{J} \right) dt$$

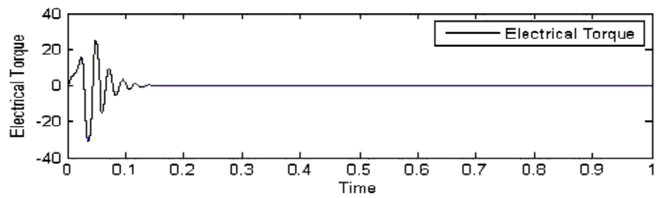
3. Simulation Results

- **For speed=200 RPM**

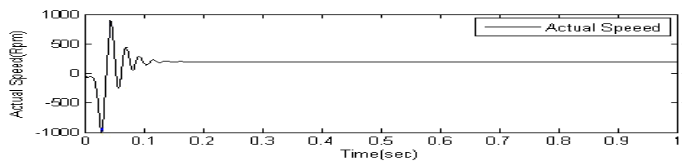


➢ **With T_L=0 N.m**





➢ **With T_L=3 N.m**



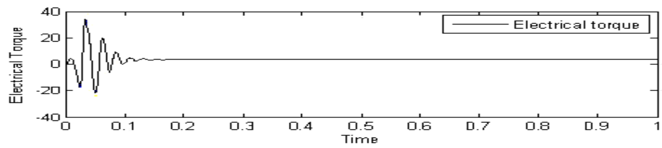
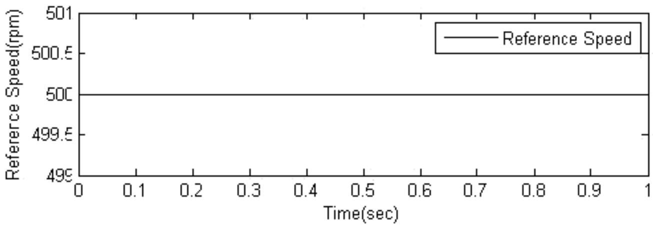


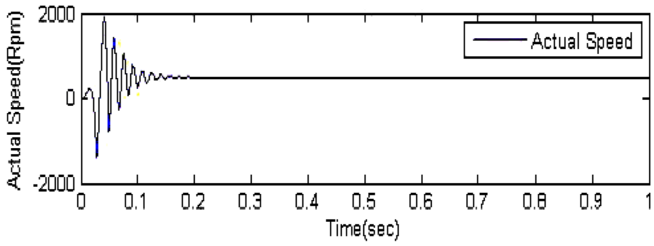
Fig -5: Simulation results for 200 rpm speed at no load and with load torque

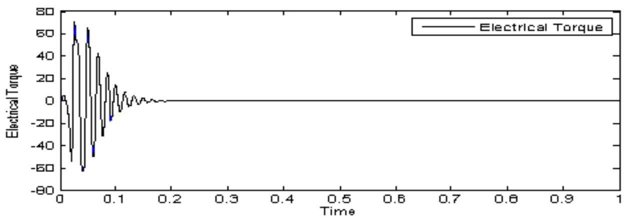
In this case the commanded speed is set at 200 RPM and load Torque is varied. At No load Torque, the speed is settled at 120 ms. At T_L= 3 N.m, the speed is settled at 140 ms and the steady state speed is same as the set speed. In this case the torque is variable so when there is a change in load torque the speed is also changed for that instant.

- **For speed=500 RPM**

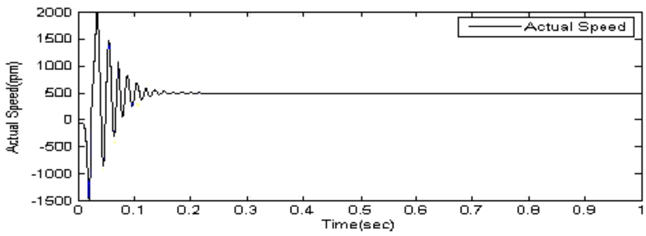


- **With T_L=0 N.m**





- **With T_L=3 N.m**



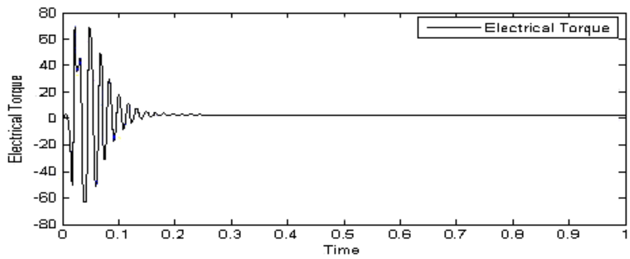


Fig -6: Simulation results for 500 rpm speed at no load and with load torque

In this case the commanded speed is set at 500 RPM and load Torque is varied. At No load Torque, the speed is settled at 190 ms. At T_L= 3 N.m, the speed is settled at 210 ms.

Table -1: Parameters of PMSM

Rated output power	1500 Wat
Magnetic flux linkage	0.154 web
Poles	3
Stator resistance	1.4 Ω
q-axis inductance	0.0058 H
d-axis inductance	0.0066 H
Inertia	0.00176 $KG.M^2$
friction coefficient	0.00038 N.M.S/ rad

4. CONCLUSIONS

Scalar control brings an advantage of sensorless control. Simulation results show the effect of load torque on speed. As load torque varies, speed also varies. When speed reaches at its rated speed after settle down of torque.

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