Sensorless Controlling of the Permanent Magnet Synchronous Motor using Space vector Control with Measurement Vector Insertion

Prof. Pooja Agarwal **Prof. Ritesh Diwan**

Abstract: The surface-mounted permanent magnet synchronous motors (SPMSM) are the first preference of the designers for the industrial applications because of its high efficiency and better torque to current ratio. Now as for as the controlling is concern the measurement of speed and rotor positions are generally performed by sensors but the involvement of the sensors increases the cost and reduces the roughness of the motor it also increases the maintenance. Because of these reasons the sensor-less controlling of the motor is a field of intensive and demanding research. In this paper we are presenting the space vector based controlling of the SPMSM which involves the measurement vectors [1] and the presented controlling system. The measurement vector technique reduces the distortion of the measured current hence improves the efficiency of the controlling system.

Keywords: Surface-Mounted Permanent Magnet Synchronous Motors (SPMSM), Sensorless Controlling, Measurement Vector.

1. Introduction

The permanent magnet synchronous motors (PMSM) are gaining applications in many fields such as traction, automobiles, robotics and aerospace technology. The major advantage of using the PMSM over induction motors is that the power density of permanent magnet synchronous motor is higher than one of induction motor with the same ratings due to the no stator power dedicated to the magnetic field production [2]. Other advantage involves the higher efficiency and greater torque to current ratio. Like other motors the PMSM is also required a perfect control mechanism or system. The control of PM synchronous motors requires the knowledge of the rotor magnet axis position (briefly "rotor position"). For this reason they are equipped with some kind of transducer, such as encoders or resolvers, able to provide that information. This additional component involves cost, encumbrance, wiring, alignment procedures, and others tedious disadvantages [3]. Therefore researchers are working for eliminating these sensors or transducers by estimating the position from current and voltages of the motor terminals. The rest of the paper is arranged as that section 2 provides a useful literature descriptions related to same field followed by the space vector controlling and measurement vector explanations in section 3 and 4 respectively. In section 5 the structure of the proposed system is described then the simulated results and conclusion is presented in section 6 and 7 respectively.

2. Related Work

Because of the requirement of such system many researchers has shown their interest and presented their works in different literatures some of them studies during the development of this paper is presented in this section. K. Boughrara, D. Zarko, R. Ibtiouen, O. Touhami,

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and A. Rezzoug [4] presented original numerical Schwarz–Christoffel (SC) transformation to analyze magnetic field originating from permanent magnets and the armature winding currents in a slotted air gap of an inset permanent-magnet synchronous motor. The vector control of PMSM for practical application is described by Milan Brejl & Michal Princ [5], the literature describes the working of PMSM in detail with practical considerations it also presented the real time development circuits with microprocessor. Al Kassem Jebai, Francois Malrait, Philippe Martin and Pierre Rouchon [6] proposed Sensorless position estimation of Permanent-Magnet Synchronous Motors using a saturation model. Their work proposes a clear and original analysis based on second order averaging of how to recover the position information from signal injection; this analysis blends well with a general model of magnetic saturation. They also proposes a simple parametric model of the saturated PMSM, based on an energy function which simply encompasses saturation and cross-saturation effects. The Back EMF Observers base speed and position estimation method is proposed by Marco Tursini, Roberto Petrella and Alessia Scafati [7] their work deals with the self compensation of the intrinsic estimation error in back-EMF based rotor position observers for PM synchronous motors. The self-compensation is based on the analytical calculation of the rotor position estimation error for two types of popular back-EMF observers, such as the standard-linear Luenberger Observer and the non-linear Sliding Mode Observer. Parameters influence on the synchronization process of a PMSM [8] is presented by J. Rais and M. P. Donsión this literature presents the modeling and simulation details with specific parameters.

3. Space Vectors

During normal state, there are eight switching states of inverter which can be expressed as space voltage vector ($S_{A\,,\,B}$ and $_{C}$) such as (0,0,0), (0,0,1), (0,1,0), (0,1,1), (1,0,0), (1, 0,1), (1,1,0) and (1,1,1). S_A = 1 means upper switch of leg A is on while the lower one is off, and vice versa. The same logic is applicable to S_B and $_C$ also. Amongst above eight voltage vectors, (0, 0, 0) and (1, 1, 1) are termed as zero vectors while the other six as active vectors [5]. The switching vectors describe the inverter output voltages as shown in Figure 2.

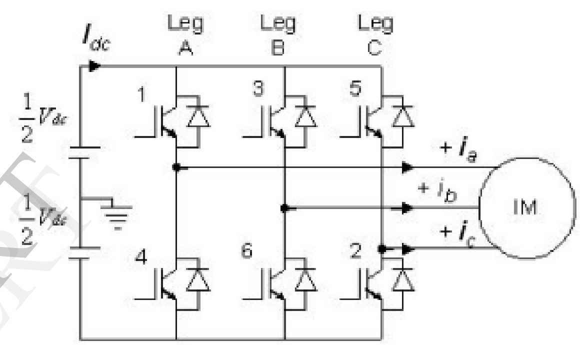

Figure 1: Voltage source inverter-induction motor drive.

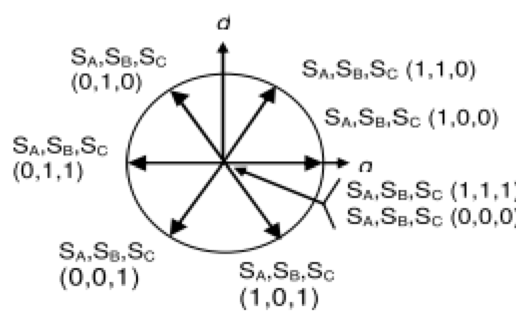

Figure 3: Voltage vectors and space sectors [5].

4. Measurement Vector Insertion Method (MVIM)

A new single current sensing algorithm is proposed in [1] for achieving high-quality phase current reconstruction and regulation using a dc link current sensor. The proposed method effectively overcomes the problem created by the un-measurable intervals figure 3.

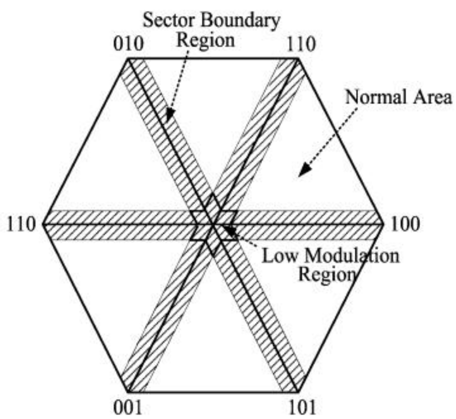

Figure 3: Un-measurable areas (shaded) in the inverter output voltage space vector plane along sector boundaries.

The new concept introduces a special switching sequence whenever the reference voltage vector falls into one of the un-measurable regions to insure that all three phase currents are measurable. In the first switching interval , the PWM algorithm generates a reference voltage vector according to basic SVPWM operation. During the second switching interval the new method introduces three special measurement vectors as shown in Fig. 4 and 5, so that all three phase currents can be sequentially measured during this interval.

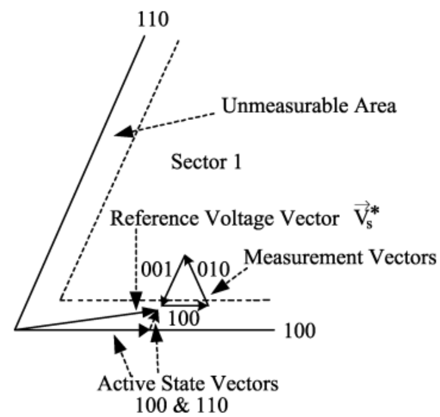

Figure 4: Basic concept of MVIM.

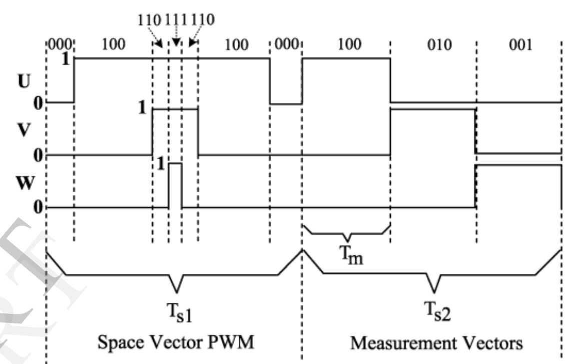

Figure 5: Example of PWM timing waveforms for basic MVIM algorithm for reference vector in vicinity of (100) active voltage vector with $T_{s1} = T_{s2}$.

A group of three active space vectors consisting of [100], [010], and [001] can be utilized for the measurement vectors, or, alter-natively, a second group of active space vectors [110], [011], and [101] can be applied. This new algorithm will be referred to as the measurement vector insertion method (MVIM).

5. Proposed Method

The proposed system is divided in two parts in first part we estimates the phase currents using single current sensor at the dc link only and by using the space vector method with measurement vectors insertion. And then the equation [1] is used to estimate the rotor position and speed

In this method, the flux linkage is estimated from measured voltages and currents and then the position is predicted by use of polynomial curve fitting [9]. The fundamental idea is to take the voltage equation of the machine,

$$V = Ri + \frac{d\psi}{dt}$$

$$\psi = \int_0^t (V - Ri)dt$$

Where, V is the input voltage, i is the current, R is the resistance, and ψ is the flux linkage, respectively. Based on the initial position, machine parameters, and relationship between the flux linkage and rotor position, the rotor position can be estimated. At the very beginning of the integration the initial flux linkage has to be known precisely to estimate the next step flux linkages. This means that the rotor has to be at a known position at the start [14, 16, and 20]. Last equation (20) written in α-β coordinates depends on the terminal voltage and the stator current. Using the α-β frame the equation for the rotor angle can be written as follows:

$$\theta = \tan^{-1}\left(\frac{\psi_{\alpha s} - Li_{\alpha s}}{\psi_{\beta s} - Li_{\beta s}}\right)$$

where L is the winding inductance.

The actual rotor angle using the d-q frame can be calculated with:

$$\theta = \tan^{-1}\left(\frac{\psi_{ds}}{\psi_{qs}}\right)$$

Then the estimated θ is differentiated to get the speed of the rotor.

6. Simulation Results

We simulated the proposed model shown in figure 6 with the parameters shown in Table 1.

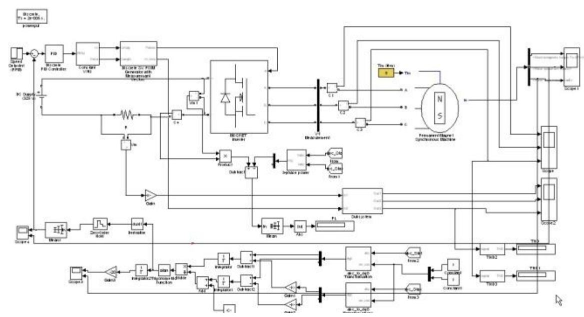

Figure 6: Simulink Model of the Simulated system.

Tablet 1: Parameters of the simulated Modal

Parameter Name	Value
DC Link Voltage	300 V
Rated Torque	33.9 Nm
Rated Speed	2200 RPM
Stator Inductance	0.00153 H
Stator Resistance	0.129 ohm
Flux by Magnet	0.1821 Wb

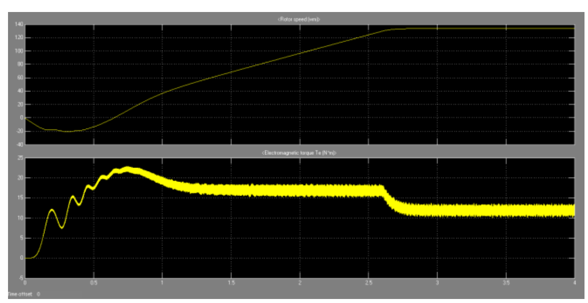

Figure 7: speed and torque of the motor it takes about 0.1 seconds to regulate the speed.

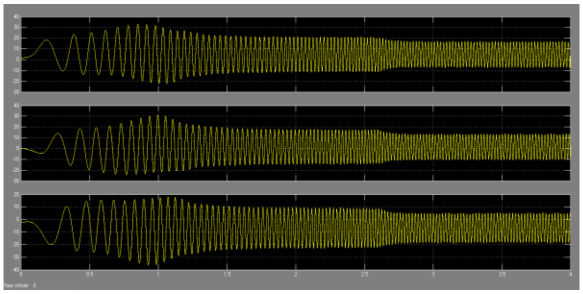

Figure 8: Measured current waveform by measurement vector insertion it shows that the waveforms are almost sine waves hence no distortion present.

7. Conclusion

The simulation result shows that the proposed Space vectored controlling with the measurement vectors insertion gives great controlling as well as the system need only one current sensor which makes it robust the other advantage of the proposed method that it can be applied to any type of PMSM without much modification.

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