International Journal of Computer Science and Electronics Engineering (IJCSEE) Volume 4, Issue 2 (2016) ISSN 2320–4028 (Online)

Design and İmplementation of Permanent Magnet Synchronous Motor Speed Control for Variable Flowrate Moto- Pomp Application

Hasan TUNA[1], and Osman BİLGİN[2]

***Abstract*—**In this study, permanent magnet synchronous motor (PMSM) control algorithm is presented for moto-pomp application. In the experimental study as a control algorithm, space vector control of PMSM is used. In the system, the field oriented control (FOC) is designed using d-q reference frame work model. These procedures, known as Park and Inverse Park transformation, are performed with transformation of the data of motor's feedback components to digital data. Hall sensor is used for speed and position measurement, also for current measurement resistor is used. In the proposed system, 3 phase PWM signals are formed with dsPIC microcontroller. 3 phase sinusoidal voltage is formed through integrated power module which is switched with PWM signals. In feedback, reference information is applied to motor using PI feedback system. So closed loop control system is designed.

***Keywords*—**FOC, PMSM, Park, Clarke, Inverse Park, Space Vector PWM, Hall Sensor, dsPIC.

I. INTRODUCTION

RECENTLY DC and AC motors have replaced by permanent magnet synchronous motors (PMSM). PMSMs have been frequently used in industry, especially in servo systems, because of their superiorities as high efficiency and power factor, high power-weight ratio and torque-inertia ratio, etc. For these reasons, PMSM becomes one of the most important research area. The developing in technology in recent years has accelerated the studies on permanent magnet synchronous motors, especially the studies are focused on Field Oriented Control (FOC) methods. Using vector control method, AC machine control acquires every advantage of DC machine control [1].

Synchronous motors rotate at synchronous speed depending on the number of poles of the motor and voltage frequency. PMSM's consist of three-phase windings on the stator and permanent magnets placed on the rotor. This motor's stator is supplied by alternative current (AC) rotor is supplied by direct current (DC). They have conventional three-phase stator windings but, instead of a field winding, permanent magnets produce field flux. Synchronous machines with electrically excited field winding require brushes and slip rings to transfer current to the rotor. The use of permanent magnets eliminates this requirement thus, problems related to the brushes and slip rings are overcome. Lack of brushes also results in a more robust mechanical construction. Moreover, the copper losses are eliminated therefore; higher efficiency and higher torque/inertia ratio can be achieved. In addition, the stator current component of the magnetization current appearance increases the motor's power factor [2].

In PMSM field is created by permanent magnets. When the stator windings are concentrated, the machine is named as trapezoidal type or brushless dc (BLDC) machine. This machine has a trapezoidal back-emf waveform. When the stator windings are sinusoidally distributed, the back-emf waveform is also sinusoidal and the machine is named as permanent magnet ac (PMAC) machine. This type of PMSM is usually named as servo motor and widely used in high performance servo applications. Recently, permanent magnet synchronous machines (PMSMs) become an important class of high performance ac drives [3].

Field oriented control (FOC) of permanent magnet synchronous motor (PMSM) is one of the widely used methods for the speed control of the motor. The aim of the FOC method is to control the magnetic field and torque by controlling the d and q components of the stator currents or relatively fluxes. With the information of the stator currents and the rotor angle a FOC technique can control the motor torque and the flux in a very effective way. The main advantages of this technique are the fast response and the little torque ripple [4].

II. ELECTRICAL MODEL AND CONTROL STRATEGIES OF PMSM

The basic principle of FOC is to control an ac machine as a separately excited dc motor [5]. Because dc motors control is simple. In DC motors, armature is placed on the rotor and fed through commutator and brushes. FOC is a type of vector control where the field flux, armature mmf and the angle between them are controlled separately. It is based on the vector coordinate transformations. In this method, the motor equations are transformed into a coordinate system which rotates in synchronism with the field flux. It permits separately control of torque and flux quantities by utilizing current control loop with PI controllers like in a dc motor

---

[1] Selcuk University, Dept. Of Electrical and Electronics Engineering, Konya, Turkey

[2] Selcuk University, Assoc. Prof.Dr. Osman BİLGİN, Konya, Turkey.

control [3]. More detailed block diagram for sensorled vector control is given in fig. 1.

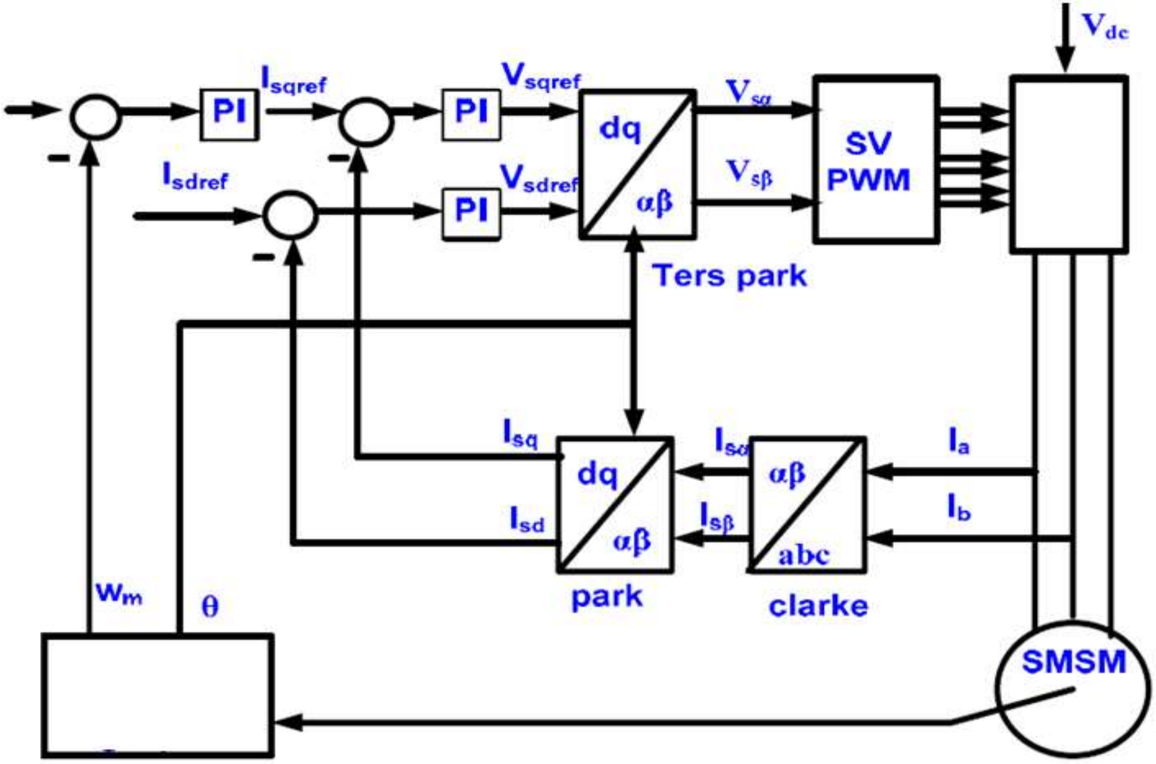


Fig. 1: Detailed block diagram of sensorled vector control

This method requires position information of rotor for park and inverse park transformation. FOC is the basic method for obtaining the position of the rotor flux. In synchronous machines, the rotor speed is equal to the speed of rotor flux. So in terms of θ (rotor flux position) is measured by the sum of the rotor speed. If there is a fault at position of the rotor, i_{sd} and I_{sq} axis will not work symmetrically. That is while wrong values are obtained from the flux and torque.

In Clarke transformation, three-phase currents in stationary reference frame are converted into the equivalent two-phase currents (α and β) in stationary reference frame. $I_{s\alpha}$ and $I_{s\beta}$ are ac currents, and $I_{s\alpha}$ leads $I_{s\beta}$ by 90°. Commutator (Park) transformation converts I_α and I_β currents in stationary frame to the currents I_d and I_q into the synchronously rotating frame. Inverse Park transformation converts $V_{s\alpha ref}$ and $V_{s\beta ref}$ voltages in synchronous frame to the voltages $V_{s\alpha}$ and $V_{s\beta}$ in stationary frame. After all space vector PWM technique is used stationary frame voltages. More detailed information is given in fig. 2 [6].

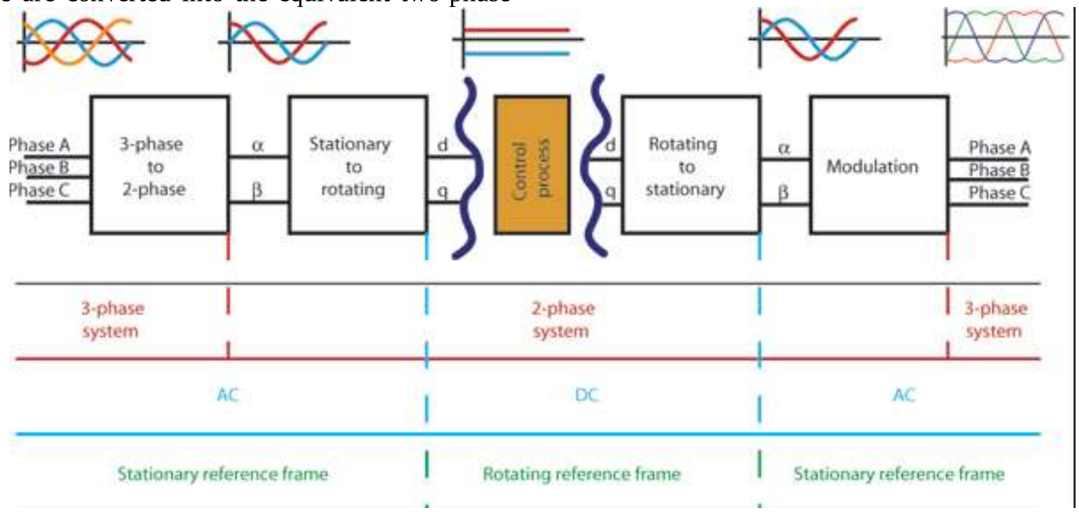


Fig. 2: Basic principle of field-oriented control [8]

Three-phase ac machine speed and position control require three-phase ac supply with adjustable amplitude and frequency. Therefore, the ac power line cannot be directly used. For this purpose, power converters have been developed. Among the modern power converters, voltage-source inverters are the most widely used circuits in these applications. This inverter is a circuit that converts the dc voltage into ac voltage with adjustable amplitude and frequency. By employing basic vectors, the desired voltage space vector can be generated with the following objectives,

- ✓ maximum utilization of the dc-link,
- ✓ maximum possible linear operation,
- ✓ minimum switching loss,
- ✓ minimum ripple in the phase currents
- ✓ constant switching frequency. [7]

Operation of PMSMs requires position sensors in the rotor shaft when operated without damper winding. The need of knowing the rotor position requires the development of devices for position measurement. There are five main devices for the measurement of position, the potentiometer, linear variable differential transformer, optical encoder, hall-effect sensors and resolvers.

III. EXPERIMENTAL STUDY

In this study, 10-pin, 24V, 3-phase PMSM is used. In this operation, field oriented control (FOC) is performed by means of the motor control. Single phase voltage ($220V_{AC}$) is converted to $24V_{DC}$ and 15 V_{DC} for processing purpose. This voltage power module is applied to convert input voltage by using PWM switching to sinusoidal voltage. In fig. 3, experimental study design is shown in detailed.

The power module (AS- IPM PS11035) current is measured, from 0.1Ω resistor. Since its value is millivolt level, current is amplified by opamp. That is while more accurate data is transferred to the microprocessor. Motor rated current measured in mV voltage on resistance is applied to adc.

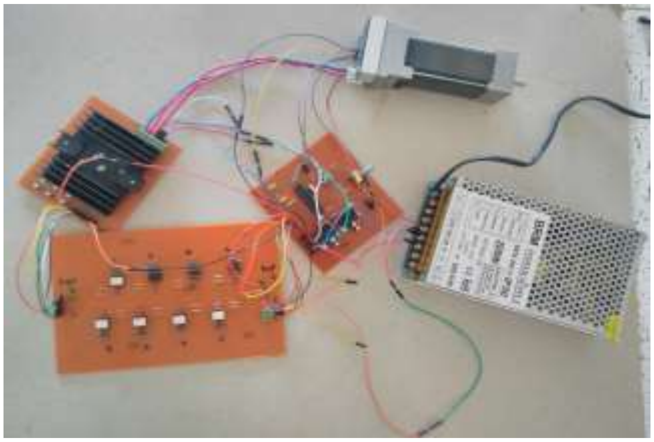


Fig. 3: Experimental study design

Trigger output signals are produced by dsPİC. They are isolated from power circuit by opto coupler. The purpose of optical isolator circuit is to provide isolation between the power circuit and the control circuit. PWM signals generated from microprocessor are applied to the power module. This integrated circuit is shown in fig. 6.

During the motor operation interference destroy pwm signal, to prevent this bad effect integral 6N137 is used. The transfer of data is shown by led. Opto coupler circuit in this study is shown in fig.4.

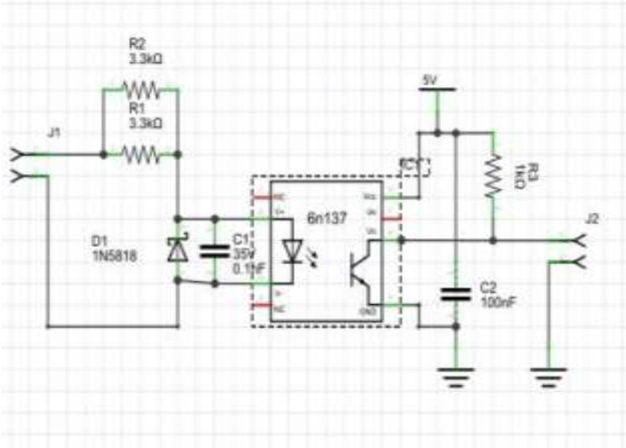
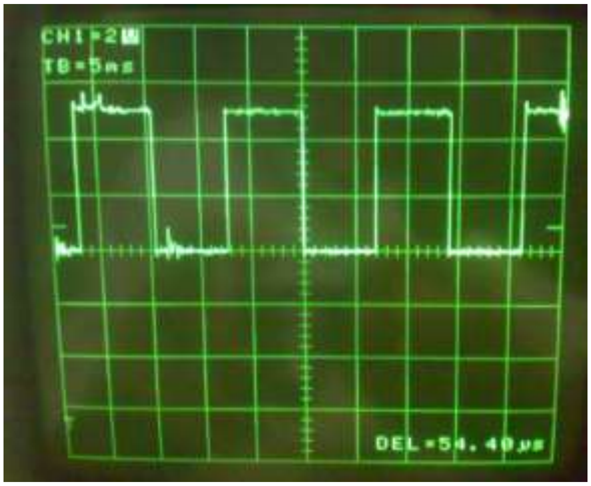


Fig. 4: Opto coupler circuit in study design

Hall Effect sensors provide the portion of information needed to synchronize the motor excitation with rotor position in order to produce constant torque. The rotor magnets are used as triggers the hall sensors. Three hall sensors are placed 120 degrees around the stator frame. Their digital signals are used to sense the rotor position. In fig. 5, hall effect sensors output signals are shown.



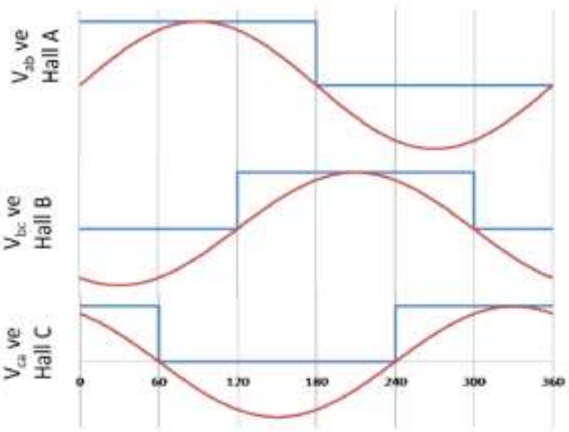


Fig. 5: Hall Effect sensors output signal

We determined the PWM frequency as 20 kHz according to the simulations of the inverter circuit with motor model and this modulation frequency is satisfactory for motor driver systems. The sinusoidal voltage between the motor phases signal is shown in fig. 7.

Powerex Application Specific IPMs (ASIPMs) are inteligent power modules that integrate power devices, gate drive and protection circuitry in a compact package for use in small inverter applications up to 20kHz. ASIPM modül used in this study is shown in fig. 6.

Fig. 6: ASIPM modül in study design

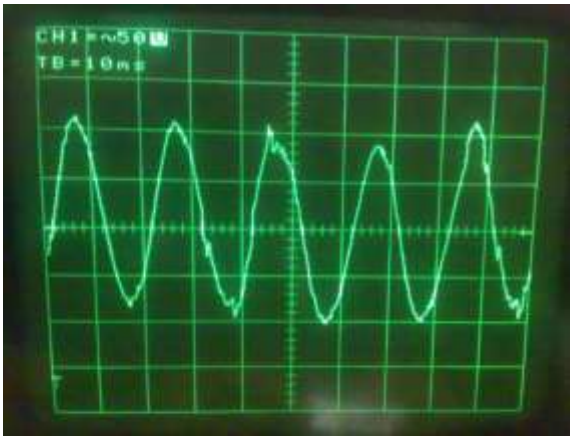


Fig. 7: The sinusoidal voltage between the motor phases

IV. CONCLUSION

The focus of this paper is to apply field oriented control technique of PMSM motor to drive pomps. According to need of liquid automatically adjust the speed of PMSM. The dsPIC is well suited for closed-loop control of PMSM. The main advantage of this circuit is that; speed control can be achieved by using the Field Oriented Control where two currents responsible for torque and field are separately resolved and controlled. The space vector PWM technique is used in the creation of vector to control the power modules. Current and position controllers are implemented to dsPİC. Motor speed is controlled according to analog signal that produced by pump controller.

ACKNOWLEDGMENT

Firstly, I would like to thank my supervisor **Assoc. Prof. Dr. Osman BİLGİN**, for his guidance, understanding and patience. Throughout the preparation of this thesis, he provided encouragement, sound advice, and lots of good ideas.

I would like to show my gratitude to colleagues, who supported this work in both technical and moral aspects.

I would like to thank my family for all their help during my thesis.

REFERENCES

[1] Ünal, S., 2008, Sensorless position estimation of permanent magnet synchronous motors using artificial neural networks, PhD thesis, pp. XV Fırat University, Elazığ, Turkey, 2009.

[2] Uygur, S., “Vector control of PMSM in washing machine application,” Master’s thesis, Istanbul Technical University, pp. 14-16, FEBRUARY 2012.

[3] Sharma, R. K. Sanadhya, V. Behera L. and Bhattacharya S., 2008, Vector Control of a Permanent Magnet Synchronous Motor, India Conference, INDICON 2008. Annual IEEE ,1, 11-13, 81– 86.

[4] Sakarya, H., 2008, Design and İmplementation of field oriented control driver system for permanent magnet synchronous motor, Master’s thesis, Selçuk University, Konya, Turkey, 2009.

[5] Permanent Magnet Synchronous Motor Control, High-performance and power-efficient motor control, Beyond Bits Motor Control Edition.

[6] Karakaş, S., “An FPGA based BLDC motor control system,” Master’s thesis, Middle East Technical University, pp. 36-64, FEBRUARY 2011.

[7] Ajangnay, M.O., 2010, “Optimal PID controller parameters for vector control of induction motors, International Symposium on Power Electronics Electrical Drives Automation and Motion SPEEDAM 14-16 June 2010 Pisa 959-965.

[8] Wilson, D., “Electric power steering: one good turn deserves another,” June 30, 2005.