# Solar Powered Field Oriented Control (Vector Control) of PMSM Motor

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## Abstract

Accurate rotor position detection is important for rotor position detection of a sensor less PMSM (Permanent Magnet Synchronous Motor). It is desirable in any kind of machine to use a method which is less dependable on the sensors & complex circuits, so in this paper describes the PMSM control system of variable torque and an axial flux used to field oriented control method. To control the stator current to obtain the desired rotor currents (which cannot be measured directly) be measured with coordinate reference transformation the current can be controlled like Dc value using stander control loops. Rotor position determines plays an important role in the improvement of satisfactory operation of the motor so this is desirable to get the proper information of the rotor position or rotor angle. It is observe that be control the stator current and to be obtain maximum torque is forced to be zero. Also obtain maximum torque and speed which will be able to be used. This paper present the use of field oriented control to drive a PMSM several computer simulation and experimental results are presented. Also with the growing popularity of Electrical Vehicles, a PMSM power train is desirable for Electrical Vehicles & Industrial Applications. Our work describes the control system of an axial flux Permanent Magnet Synchronous Motor for various application alongside the use of renewable energy for powering PMSM with FOC (field Oriented Control).

***Keywords:*** PMSM (Permanent Magnet Synchronous Motor), FOC (field Oriented Control), Space Vector Pulse Width Modulation (SVPWM), Brushless DC (BLDC).

## Introduction

The important role of the permanent magnet synchronous motor to compare other all types of the advanced motor drive. In day to day the demand of these types of motor will be increasing. This motor drives to control the speed which require to attach the drive encoder with shaft and feedbacks supplies. In this motor be used a feedback devices but another higher capacities motor does not tolerate these feedback device because permanent magnet synchronous motor has higher reliability, adjust in any environment, is minimum costs, to take minimum space and minimum weight in advanced motor drives. The traditional control BLDC motor drives the stator in a six step process, which generates oscillation on the produce torque. In six step control a pair of winding is energized until the rotor reaches the next position and then the motor to commute to the next step. Hall sensor determine the rotor position to electronically commute to the motor.

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Advance sensor less algorithm use the back-EMF generation in the stator winding to determine the rotor position. The dynamic response of six step control is not suitable for washing machines, because the load is changing dynamically with in a wash cycle and varies with different loads and selected the wash cycle. In this paper model reference adaptive system based adaptive strategy has been used for speed estimation. With comparison to another method like neural networks, EKF method and sliding mode control method, sensor less BLDC method, Field oriented control method take a minimum and computational time.in the field oriented control method also used the MARS (Model reference Adaptive system) which is completely not dependent on the stator resistance. These system does not fully sensitive of all parameters, means say that is less sensitive. These algorithm is only dependent on q-axis stator inductance. So to minimize the adaptive speed or to estimate the speed be used Popov's criterion method. The validity of the proposed adaptive strategy has been verified by simulation and experiments. The Space Vector Pulse Width Modulation (SVPWM) method is an advanced, computation-intensive PWM method and possibly the best among all the PWM techniques for variable frequency drive application. Because of its superior performance characteristics, it has been finding widespread application in recent years.

## Permanent Magnet Synchronous Motor

Permanent Magnet Synchronous MOTOR (PMSM) is an advanced drive in electrical system. It is a types of drive or machine which is rotating. There are mainly two part in this machine first is stator phase winding and second is rotor permanent magnet. It mainly works on three phase stator winding because these winding produce a rotating magnetic field and this winding energised by three phase ac supply. The other part of this drive is rotor which surface is contain or equipped a high permanent magnet which reason it gives the high-performance in rotor field. Inside these surface is made to ferromagnetic materials like boron, neodymium iron or to erratic the earth magnetic materials all materials found a strong magnetic field. These magnetic field is distribute on rotor surface such as a sine wave form. The rotor surface found a permanent magnetic field which is gives the air gap of the magnetic field on the rotor surface. So this air gap of magnetic field is remain constant. All types of conservative DC motor will be commutate itself and it also used to mechanical commutate but the PMSM does not need this mechanical commutate it will be commutated by the electronics commutation to control the direction of current through the winding. So these PMSM motor armature coil is placed at the stator winding. The armature coil to need to be commutated by the externally. For the externally commutation be take a help of an external switching circuit and inverter topology is used to this purpose.

The PMSM motor is mostly used which place where other motor does not give a sufficient solution. In dynamically changing or variable speed the other method gives oscillation but in the PMSM be used oriented method give a sufficient condition and does not found oscillation in the dynamically changing the variable load. Therefore these motor have sufficient advantage which attract the researchers and industry. The researchers have shown more interest in this field because it gives a enough advantage or result. It also use in many application. In the PMSM motor rotates because the interaction between the two magnetic field of these motor. Which produce the torque. The all permanent magnet motor is provide two magnetic field one magnetic field is twisted by permanent magnet and other is produced by stator coils. In the maximum torque is founded when magnetic vector of the stator is 90 degree of the magnetic vector of the rotor means both magnetic vector is 90 degree to each other. More growth of the permanent magnet synchronous motor (PMSM) is widely used where need high torque/ inertia ratio, higher power density, more efficiency, and easily maintenance, also easily used in CNC machines tools, industrial application and robots so on. To controlling the PMSM system be established a simulation model. For the entire control of the system be used FOC which optimize the entire control. TO attain higher performance a vector control is provided by FOC in the PMSM drive. The vector control is employed in the PMSM. To controlling the stator current and achieve the higher value of torque and flux in this PMSM motor.

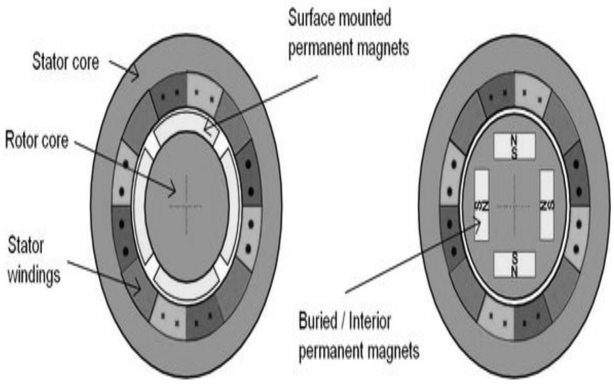



Figure 1.1-Permanent Magnet Synchronous Motor

## FIELD ORIENTED CONTROL (FOC) OF PMSM

Vector control method is also called the Field control method because both are related to each other. Vector control technique is provided by FOC. The main aim of the FOC algorithm is to decompose a stator current into generating magnetic field part and generating torque part. The both component torque and magnetic field is controlled separately after decomposition. The motor controlling structure is sampled compare to separately excited DC motor.

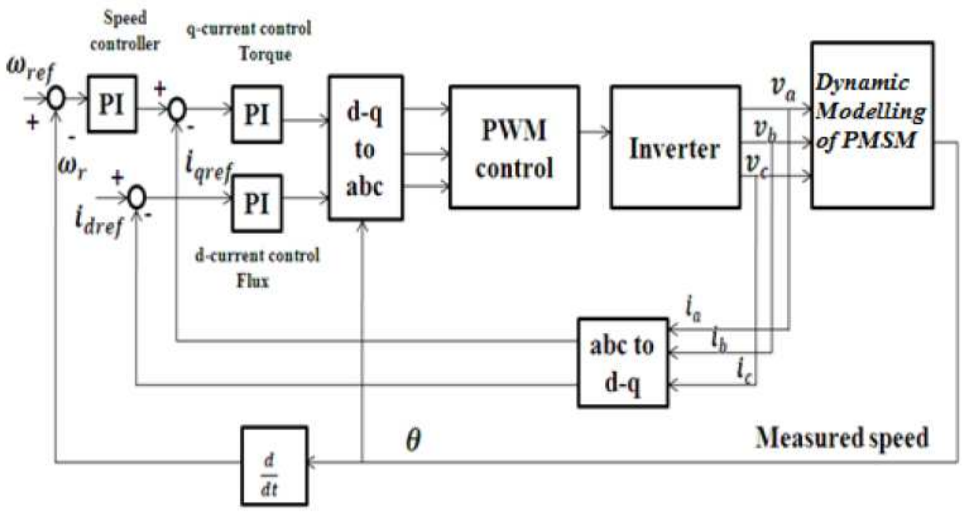



**Figure 1.2 Block diagram of FOC of PMSM**

FOC is advanced algorithm which can handle the dynamic load changing. Its offer the greatest cost benefit in the appliance. When used induction motors at its highest efficiency be is a challenging task, because of their complex mathematical model and non-linear characteristics during saturation. So these factor make the control of induction motor difficult so be use of high performance control algorithm such as vector control. Field oriented control in which control of torque and speed are directly based on the electromagnetic state of the motor, Similar to dc motor. It is the first technology to control the real motor control variables of torque and flux with decoupling between the stator current components (magnetizing flux, and torque). In the torque generating component of the stator flux can be controlled independently. The magnetizing state of the motor can be maintained at the appropriate level when decoupled control at low speed and the torque can be controlled to regulate the speed. Among all the techniques of variable frequency, variable speed drive application PWM method is the best technique because it greater performance characteristics. It is also finding in wide spread application in past years. But field oriented is also a mathematical advanced technology in this application.

## Sensor less BLDC Motor

An improved direct back EMF detection method which is used further in the rotor position detection of a sensor less brushless dc (BLDC) motor. It is desirable in any kind of machine to use a method which is less dependable on the sensors and complex circuits, sensor less method is used to commutate and trigger the inverter connected to BLDC motor. Hall Effect signals gives the information of the operations in the BLDC motor. Hall Effect signals are used for the gate pulses for the inverter. To get the improvement of satisfactory operation to determine the rotor position is a big role. We also say that to be want a good or improvement result then to rotor position is very important. So it is also desired to get a proper information of the angle of rotor and rotor position. We define the rotor position by the Zero crossing detection of back EMF. By old method calculating the back EMF of the BLDC is created a virtual neutral point. So be used a complimentary method which does not provide a neutral point. This method is also provide a wide range of speed which does not operate these motor. So conditioning circuit is provided a rectifying the back EMF at very low speed. In stand still condition be determine the actual rotor position. The field oriented method is also determine the rotor position to use a mathematically transform reference method.

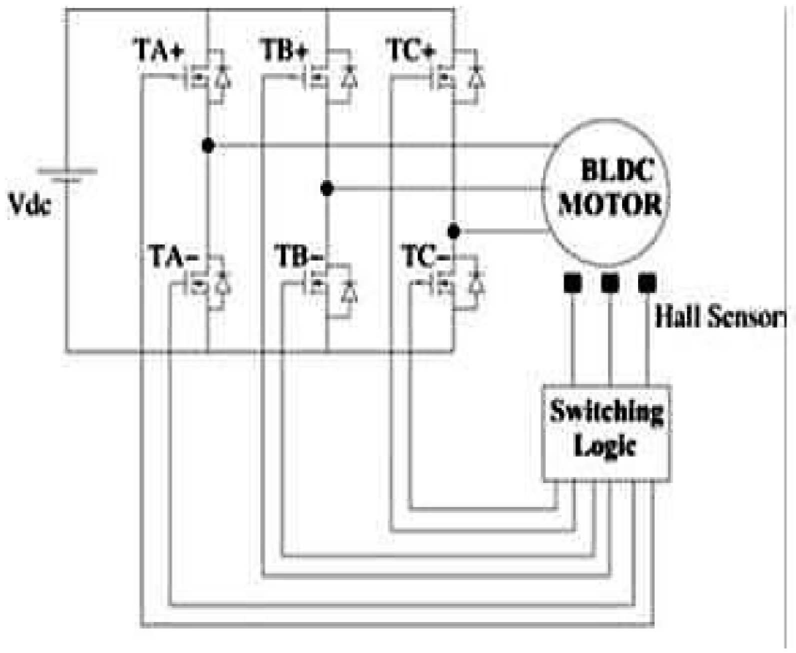



**Fig.1.3 Schematic diagram of a BLDC Motor**

The Hall Effect sensor is also a method to determine the BLDC motor drive system position information. The output of this method is determine the actual position of the BLDC motor. There are many method is use to determine the rotor position of the

BLDC motor. In which some method is indirectly sensing the back EMF from the three motor voltage terminals of three phase motor which indirectly define the rotor position information. For the position of rotor in BLDCM there are two control method is used first is square wave control method and second is sinusoidal current control method. There are different between both control method when be observe the accuracy of the position information. In the sensor less BLDC motor "Back EMF ZCD" technique is more important to determine the rotor position information of the BLDC motor. The Back EMF energized by the voltage divider connected with the low pass filters and comparator circuits. When this Back EMF is send to zero crossing detector circuit a positional pulse used for rotor position detection is obtained. To compare of my thesis work is same to determine the rotor position but as a different method be applied a coordinate transformation reference in FOC. But in this thesis PMSM motor is applied a FOC control method to determine the rotor position information. And give the supply of these motor by a renewable resources without use a battery. We save the some cost of the total energy coasting. In the thesis simulation also provide an optional supplies.

## Basic Model for Field Oriented Control

Stator phase currents are measured. These measured current are fed into the Clark transformation block. The output of the Clark transform are entitled isα and isβ. These two component of the current enter into park transformation Block that provide the current in the d, q reference frame. The isd and isq components are contrasted to the references. Isd (the flux reference) and isq (the torque reference). At this instant, the control structure has an advantage it can be used to control either synchronous or induction machines by simply changing the flux reference and tracking rotor flux position.

In PMSM the rotor flux is fixed determined by the magnets so there is no need to create one. Therefore while controlling a PMSM, isdref should be equal to zero. But in the induction motors need a rotor flux creating in order to operate, the flux reference must not be equal to zero. The output of the PI controllers are Vsdref and Vsqref. They are applied to the inverse Park transformation block. Both Park transformation need the rotor flux position. Hence rotor flux position is essence of FOC.

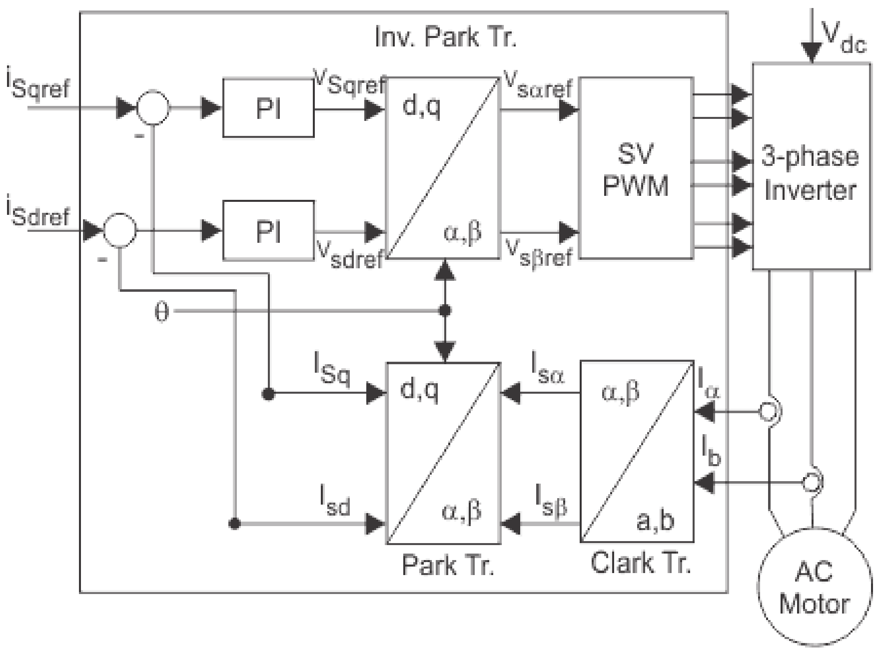



Figure 1.4 Simplified FOC block diagram

The evaluation of the rotor flux position is different in case of synchronous motor. The motor speed is equal to the rotor flux speed. Then rotor flux position is directly determined by position sensor or by interaction of rotor speed. In case of asynchronous motor the rotor speed is not equal to the rotor flux speed. Because of slip therefore a particular method is used to evaluate rotor flux position (θ). This method utilise current model, which needs two equation of the induction motor model in d, q rotating reference frame. It also torque is can be controlled directly because flux component and torque component are independent. Main aim of this paper use the field oriented control consisting of controlling the stator current represented by a vector. This control is based on projection that (transformation a three phase time and speed dependent system) into a two coordinate (d and q frame) time invariant system. These transformation and projection lead to structure similar to that of a dc machine control.

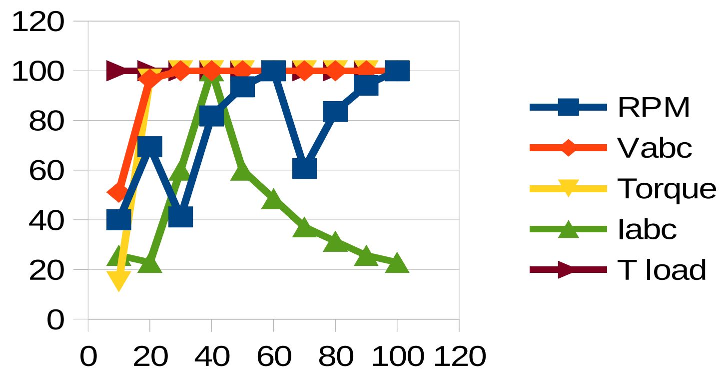
## Results

Mode 1: Speed Source Enable: False

In this mode we disable the speed selection by the user and we run the motor with fix reference speed. And we have obtained the following results.

| Time | RPM | Vabc | Torque | Iabc | T load |
|---|---|---|---|---|---|
| 10 | 40 | 51.13 | 15.13 | 25.71 | 100 |
| 20 | 69.41 | 96.59 | 96.56 | 22.85 | 100 |
| 30 | 41.17 | 100 | 100 | 60 | 100 |
| 40 | 81.76 | 100 | 100 | 100 | 100 |
| 50 | 93.52 | 100 | 100 | 60 | 100 |
| 60 | 100 | 100 | 100 | 48.57 | 100 |
| 70 | 60.58 | 100 | 100 | 37.14 | 100 |
| 80 | 83.53 | 100 | 100 | 31.42 | 100 |
| 90 | 94.11 | 100 | 100 | 25.71 | 100 |
| 100 | 100 | 100 | 100 | 22.85 | 100 |

Table 1.1-Mode 1 Consulted results. (All are in percentage



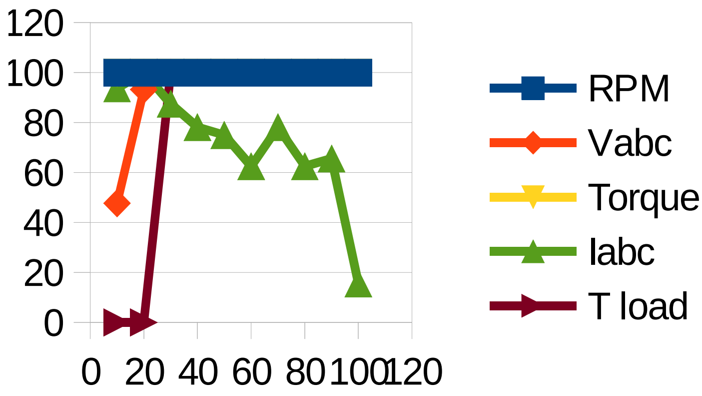

Graph 1.1-Mode 1 consulted

Mode 2: Speed Source Enabled: True

In this mode we enable the variable speed selection to the motor the allow the user to run motor a desired speed/RPM. In this mode we have obtained following results.

| Time | RPM | Vabc | Torque | Iabc | T load |
|---|---|---|---|---|---|
| 10 | 100 | 47.72 | 99.89 | 93.75 | 0 |
| 20 | 100 | 93.18 | 99.94 | 100 | 0 |
| 30 | 100 | 100 | 100 | 87.5 | 100 |
| 40 | 100 | 100 | 100 | 78.12 | 100 |
| 50 | 100 | 100 | 100 | 75 | 100 |
| 60 | 100 | 100 | 100 | 62.5 | 100 |
| 70 | 100 | 100 | 100 | 78.12 | 100 |
| 80 | 100 | 100 | 100 | 62.5 | 100 |
| 90 | 100 | 100 | 100 | 65.62 | 100 |
| 100 | 100 | 100 | 100 | 15.62 | 100 |

Table 1.2-Mode 2 consolated results




Graph 5.2-Mode 2 consolated results

## Conclusions

We have presented the simulations & experimental results of the Grid Solar Hybrid Powered Field Oriented Control of an axial Flux Permanent Magnet Synchronous Motor (PMSM).

Several tests were performed, in Mat lab simulation, with various speed & load constrains, in order to obtain experimental results. The experimental results have shown that the FOC presents a fast response to torque reference variations, both with load & no-load torque conditions. Also it has been observed reliable Renewable Energy operation of PMSM with solar combination (FOC) is a promising technology.

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