Calculation of total Current harmonic distortion by PWM method for permanent magnet synchronous motors

***Shravani Mathur, **Prof. Vikas Kumar**
*M.Tech scholar, OIST, bhopal
**Asst.Prof.,OIST,Bhopal

Abstract

Adjustable speed drive are becoming a significant load component for power distribution .It involves the use of permanent magnet synchronous motors This paper involves analysis ,control and modeling of permanent magnet synchronous motors and also investigates its effects on Total current harmonic distortion on an adjustable speed by the use of PWM generator and Vector control method .By using Park's transformation ,we can convert three phase system to two phase and then convert it to stationery two axes system (d, q) By varying two vectors of flux and torque,(one on quadrature and other on direct axis) we can control the rotor current and therefore, speed and THD for current and voltage can be calculated. Harmonics are lesser in amplitude and more in frequency as compared to the fundamental.

Index Terms—Adjustable speed drives. Field oriented control, PWM generator, MATLAB/Simulink , PMSM ,three phase stator currents

I. ADJUSTABLE SPEED DRIVES

Adjustable Speed drives are required in many applications. The use of ASDs leads to current harmonics pollution in the power grid and to electromagnetic interference (EMI) with the environment. Power quality and EMI are the constraints on electric induction motor drives. These loads are distributed all over an Electric network Harmonics are undesirable as this interference with power apparatus can result in unacceptable levels of voltage distortion. Harmonic measurements require special equipment, which is quite expensive and not always available. This paper investigates the modeling and control of a synchronous motor for an adjustable speed drive and harmonic analysis was carried out. Using ac drives and ac motors have the advantages of lower maintenance, higher speeds and smaller size. Compared to dc drives, the higher cost of ac drives is in part compensated by a lower ac machine cost because of presence of brushes and commutator in the dc machines. Compared to uncontrolled ac motors, supplied by a power grid, the efficiency of inverter controlled drives can be vastly increased by, e.g. flux optimization

II. Permanent Magnet Synchronous Motors

An electric drive may be operated in one direction of rotation or both directions of rotations depending upon requirements. Per-phase equivalent circuits widely used in steady-state analysis and design of ac machines, are not appropriate to predict the dynamic performance of the motor. A dynamic model is necessary to understand and analyze vector control of ac motor drives. A significant breakthrough was achieved in the analysis of three-phase ac machines through the development of the reference frame theory. The machine model can be transformed to another reference frame to using these techniques. It is possible to simplify the complexity of the mathematical machine model by judicious choice of the reference frame. Initially these techniques were developed for the analysis and simulation of ac machines, but are now being extensively used in the digital control of such machines. The need for compact and accurate machine models is obvious, as digital control techniques are being extended to control current, torque and flux of the ac machines.

Permanent magnet (PM) synchronous motors are widely used in low and mid power applications such as computer peripheral equipments, robotics, adjustable speed drives and electric vehicles.

The growth in the market of PM motor drives has demanded the need of simulation tools capable of handling motor drive simulations. Simulations have helped the process of developing new systems including motor drives, by reducing cost and time. Simulation tools have the capabilities of performing dynamic simulations of motor drives in a visual environment so as to facilitate the development of new systems.

In this work, the simulation of a field oriented controlled PM motor drive system is developed using Simulink. The simulation circuit will include all realistic components of the drive system. This enables the calculation of currents and voltages in different parts of the inverter and motor under transient and steady conditions. The losses in different parts can be calculated facilitating the design of the inverter. A closed loop control system with a PI controller in the speed loop has been designed to operate in constant torque and flux weakening regions. Implementation has been done in Simulink.

A comparative study of hysteresis and PWM control schemes associated with current controllers has been made in terms of harmonic spectrum and total harmonic distortion. Simulation results are given for two speeds of operation, one below rated and another above rated speed A motor of 3Hp,220V, 60Hz,1800 rpm or 188.5 rad/sec is used.

III. Detailed Modeling of PMSM

Detailed modeling of PM motor drive system is required for proper simulation of the system. The d-q model has been developed on rotor reference frame At any time t, the rotating rotor d-axis makes an angle θr with the fixed stator phase axis and rotating stator mmf makes an angle α with the rotor d-axis. Stator mmf rotates at the same speed as that of rotor

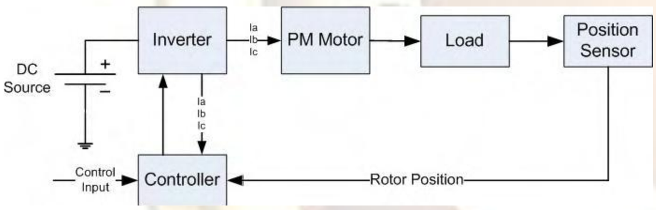


Fig. depicts self control permanent magnet motors

Field Oriented Control of PM Motors

The PMSM control is equivalent to that of the dc motor by a decoupling control known as field oriented control or vector control. The vector control separates the torque component of current and flux channels in the motor through its stator excitation.
The vector control of the PM synchronous motor is derived from its dynamic model.
Considering the currents as inputs, the three currents are:

$ia = Im \sin(\omega rt + \alpha)$

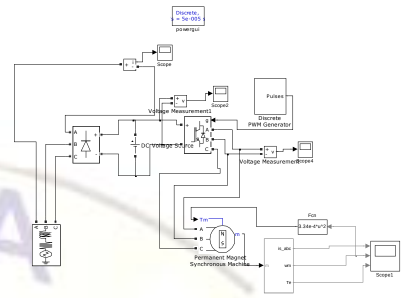
ib =Im sin (wt+α -2pi/3)

ic=Im sin(wt+α-4pi/3)

Constant torque operation

Constant torque control strategy is derived from field oriented control, where the maximum possible torque is desired at all times like the dc motor. This is performed by making the torque producing current iq equal to the supply current Im. That results in selecting the α angle to be 90 º degrees

Fig.1 Matlab simulink of PWM generator fed permanent magnet synchronousmotor



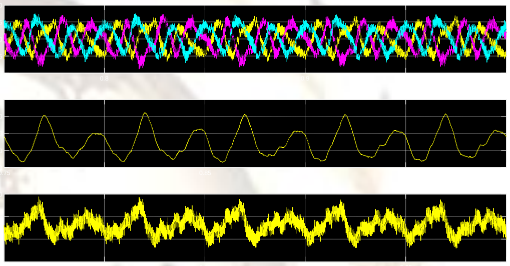


Fig.1.a waveforms of harmonic component of stator current,speed,mechanical torque

Fig.2 Matlab simulink by Field oriented control

IV. Mathematical Equations

These are the instantaneous values of three phase stator currents displaced by 120 degree each

$\Psi_{rd}=L_m\, i_{sd}/1+sTr$

Where Lm =Mutual inductance
Isd =direct axis stator current
s =Laplace Transform
Tr =Rotor Time costant, Lr/Rr

$Tm = 3/2Lm/Lrz_p\ \Psi_{rd}\, i_{sq}$

Where Lr= Rotor resistance
Zp =number of pole pairs
I sq= quadrature axis stator current
Tm = motor torque

V. DRIVE SYSTEM SIMULATION IN SIMULINK

This chapter describes different tools available for electrical and electronic systems simulation and then justification is given for selecting Simulink for the PMSM system.

Block by block an explanation is given for Simulink simulation of the drive system.

Distortion Index

The most commonly used index for measuring the harmonic content of a waveform is the total harmonic distortion (THD). It is a measure of the effective value of a waveform and may be applied to either voltage or current.

Total harmonic distortion is the contribution of all the harmonic frequency currents to the fundamental. Just as waveforms can be added to produce distorted waves, distorted waves may be decomposed into fundamental and harmonic components.

Total Current Harmonic Distortion (THDi)

The THDi is a measure of the effective value of the harmonic components of a distorted waveform. This index can be calculated for either voltage or current. The following equation gives THD for current.

where Ih is the rms value of harmonic component h of the current. The THD provides a good idea of how much extra heat will be realized when a distorted voltage is applied across a resistive load. Likewise, it can give an indication of the additional losses caused by the current flowing through a conductor.

VI. Simulation Tools

Study of electric motor drives needs the proper selection of a simulation tool. Their complex models need computing tools capable of performing dynamic simulations. Today with the growth in computational power there is a wide selection of software titles available for electrical simulations such as ACSL, ESL, EASY5, and PSCSP are for general systems and SPICE2, EMTP, and ATOSEC5 for simulating electrical and electronic circuits. IESE and SABER are examples of general-purpose electrical network simulation programs that have provisions for handling user-defined modules. SIMULINK® is a toolbox extension of the MATLAB program. It is a program for simulating dynamic systems

Simulink has the advantages of being capable of complex dynamic system simulations, graphical environment with visual real time programming and broad selection of tool boxes The simulation environment of Simulink has a high flexibility and expandability which allows the possibility of development of a set of functions for a detailed analysis of the electrical drive . Its graphical interface allows selection of functional blocks, their placement on a worksheet, selection of their functional parameters interactively ,and description of signal flow by connecting their data lines using a mouse device.

Tables and figures

Phase	PWM Inverter(%)	
A	20.89	
B	21.40	
C	23.77	

Vector controlled ASD

By evaluation of the harmonic distortion spectra of PWM inverter fed ASD and Vector controlled ASD it is clear that harmonic distortion is very less in vector control rather in PWM scheme

The following table gives the total current harmonic distortion levels for all the phases A, B and C for PWM inverter fed permanent magnet synchronous motors.

VII. Conclusion

The issue of power quality has become more apparent due to the ever increasing number of non-linear loads. The low frequency harmonic current produced by these loads can cause damage to the power system equipment. Adjustable speed drive (ASD) is becoming a significant load component for power distribution.

Designing of these loads to reduce the problems arising from harmonic pollution is done in this paper. This paper involves simulation of ASD such that power quality is significantly improved by reducing the harmonics to a significant level

Simulation Results

The system built in Simulink for a PMSM drive system has been tested with the two current control methods, Hysteresis and PWM, at the constant torque and flux-weakening regions of operation. The parameters were taken from reference . IGBT (Insulated gate Bipolar Junction Transistor) parameters of the inverter are given inAppendix1.The motor is operated with constant torque up to its rated speed and beyond that rated speed flux-weakening mode is adopted. Simulation results are given at electrical speeds of 188.5 radians per second (31 Hz) and 600 radians per second (95

Hz). The above speeds represent below and above rated speed of the motor.

REFERENCES

[1] M.Farhney ,"Design Considerations when Applying various ASD topologies to meet H armonic Compilance", Paper No. PCIC - 2010- 15 Copyright material IEEE.

[2] Mukhtar Ahmed,"High Performance AC drives: Modeling, Analysis and Control", Springer Publications, London, 2010.

[3] Yu Yu; Yang Zhao;" H armonic and Interharmonic currents generated by the VSI fed Adjustable Speed Drives", IEEE International Conference IPMEC'09, 2009, pp. 2464-2467.

[4] Li Zhang," Power Converter Circuits", Marcel Dekker Inc., New York, 2004.

[5] Sumitha Mohan, Henry GCuldner Ralf Briest Henrik Wolf Dresden University of Technology , “Analysis and control aspects of harmonic distortion in the front-end threephase four-wire PWM boost rectffier “EPE 2005 - Ditsdcn

[6] “Simulation Study of AC Motor Speed Sensorless Vector Control System Based on SVPWM “ JIN Hui, ZHAO Yue-ling College of Electric Engineering Liaoning University of Technology ,*Jinzhou, China*, 2009 Ninth International Conference on Hybrid Intelligent Systems

[7]” A Proof of Concept Study of Predictive Current Control for VSI-Driven Asymmetrical Dual Three-Phase AC Machines Federico Barrero, *Senior Member, IEEE*, Manuel R. Arahal, *Member, IEEE*,

[8] “Pulse Multiplication in AC–DC Converters for Harmonic Mitigation in Vector-Controlled Induction Motor Drives “,Bhim Singh, *Senior Member, IEEE*, G. Bhuvaneswari, *Senior Member, IEEE*,

[9] Motores Sinchrones de Imanes Permanents, Manuel Pérez Donsión, Manuel A. Fernandéz Ferro, 1990Universidade de Santiago de Compostela

[10] Elektrické pohony pro dynamicky náročné aplikace, Martin Diblík, 2006 Technická univerzita v Liberci

[11] Permanent Magnet Synchronous Machine Model for Real-time SimulationA. B. Dehkordi, A. M. Gole, T. L. Maguire 2005, International Conference on Power System Transients in Montreal

[12] Direct Torque Controlof a Permanent Magnet Synchronous Motor,David Ocen, 2005 Stockholm