© FEB 2018 | IRE Journals | Volume 1 Issue 8 | ISSN: 2456-8880

Vector Field Control of Induction Motor Drive

[1]RAM KISHAN MAHATE, [2]HIMMAT SINGH AHIRWAR
[1, 2] Madhav Institute of Technology & Science Gwalior

Abstract -- Vector control, also called field oriented control (FOC), is a Variable frequency Drive (VFD) control method in which the stator currents of a 3 phase induction motor are identified as two orthogonal components that can be visualized with a vector. The vector control of induction motors is one of the most suitable and popular speed control technique presently used. The vector control technique decouples the two components of stator current space vector: one providing the control of flux and the other providing the control of torque. The two components are defined in the synchronously rotating reference frame. With the help of this control technique the induction motor can replace a separately excited dc motor.

I. INTRODUCTION

Induction machines are largely used in industrial plants and are adequate for almost any kind of environment. Their popularity is due to their high efficiency, reliability, low maintenance. Since the development of the vector control techniques, induction machines based drives became able to deliver the same performance as the traditional direct current machine drives in applications that require torque or speed control. The vector control of ac drives has been widely used in high performance control system. Indirect field oriented control (IFOC) is one of the most effective vector control of induction motor due to the simplicity of designing and construction. In order to obtain the high performance of torque and speed of an IM drive, the rotor flux and torque generating current components of stator current must be decoupled suitably respective to the rotor flux vector like separately excited dc motor. This paper develops a decoupled rotor flux and torque control based on the magnetizing current components. However, this developed control system is valid only for steady state condition. By incorporating PI control system and using space vector modulation technique, the decoupled control system is used to perform in both transient and steady state conditions. In order to perform IFOC of IM drives using SVM it is necessary to measure primary angular frequency, the stator voltages, the stator currents, the magnetizing currents, the rotor fluxes and the rotor speed.

Major improvements in modern industrial processes over the past 50 years can be largely attributed to advances in variable speed motor drives. Prior to the 1950's most factories use DC motors because single phase induction motors could only be operated at one frequency. Now thanks to advances in power electronic devices and the advent of DSP technology fast, reliable and cost effective control of induction motors is now commonplace. In 1997 it was estimated that 67% of electrical energy in the UK was converted to mechanical energy for utilization. AT the same time the motor drive market in Europe was in excess of one billion pounds. The increase in the use of induction motors was largely attributed to major oil and mining companies converting existing diesel and gas powered machinery to run off electricity. Over the past five years however, the area of AC motor control has continued to expand because induction motors are excellent candidates for use in Electric or Hybrid Electric Vehicles. The basic conceptual implementation of vector control is illustrated in the below block diagram.

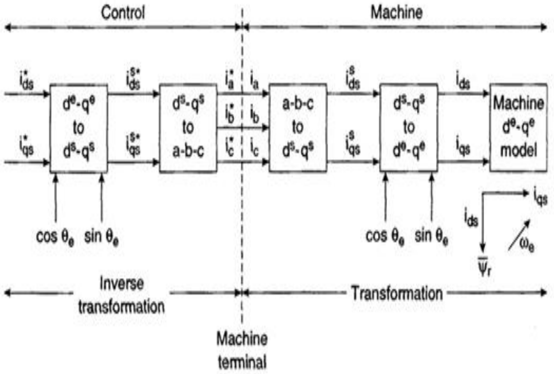

Fig.1. Principle of Vector Control

In this application high performance control schemes are essential. Over the past two decades a great deal of work has been done into techniques such as Field Oriented Control, Direct Torque Control and Space

Vector Pulse Width Modulation. Another emerging area of research involves the application of sensor less control. This differs from conventional methods because it doesn't require mechanical speed or position sensors. Removing these sensors provides a number of advantages such as lower production costs, reduced size and elimination of excess cabling. Sensors less drives are also more suitable for harsh inaccessible environments as they require less maintenance. This undergraduate thesis thoroughly investigated the aforementioned techniques and used them to develop a Field Oriented Control Scheme for use in an Electric Vehicle.

Induction motors are widely used in various industries as prime workhorses to produce rotational motions and forces. Generally, variable-speed drives for induction motors require both wide operating range of speed and fast torque response, regardless of load variations. The field oriented control is the most successful in meeting the above requirements. Due to advances in power electronics and microprocessors, variable-speed drives for induction motors using the field oriented control have been widely used in many applications, such as ac servo, electric vehicle drive systems, and so on. Using the field-oriented control, a highly coupled, nonlinear, multivariable induction motor can be simply controlled through linear independent decoupled control of torque and flux, similar to separately excited dc motors. High performance torque control requires fast enough current response for the current regulator to track the reference current. However, due to limitations of voltage and current ratings on the inverter de link, input voltage and current of an induction motor are limited accordingly. Hence, developed torque in the motor should be limited for safe operation under these input constraints. The objective of a variable-speed control system for higher productivity is to track the reference speed as fast as possible. Therefore, under the constraints of input voltage and current, a control scheme which yields the maximum, torque over the entire speed range can be usefully applicable to minimum-time speed control of induction motors. However, most researchers who deal with the speed control of induction motors have not considered the maximum-torque generation scheme.

II. PRINCIPLE OF VECTOR CONTROL

With a vector control, an induction motor can operate as a separately excited dc motor. In a dc machine the develop torque is given by

Td=K*Ia*If

The construction of dc machine is such that field linkage produced by If is perpendicular to the armature flux linkage produced by Ia. these flux vector that are stationary in space are orthogonal or decoupled in nature. As a result a dc motor has fast transient response, however induction motor cannot exhibit the dc machine characteristic if the machine controlled in a synchronously rotating frame (de-dq), where the sinusoidal machine variable appears as dc quantity in steady state. Figure 1.8 shows an inverter fed induction motor with two control current in puts. Ids and Iqs are the direct axis component and quadrature axis component of the stator current respectively in a synchronous rotating reference frame. With vector control Ids is analogous to the field current If and Ids analogous to the armature current Ia of dc motor.

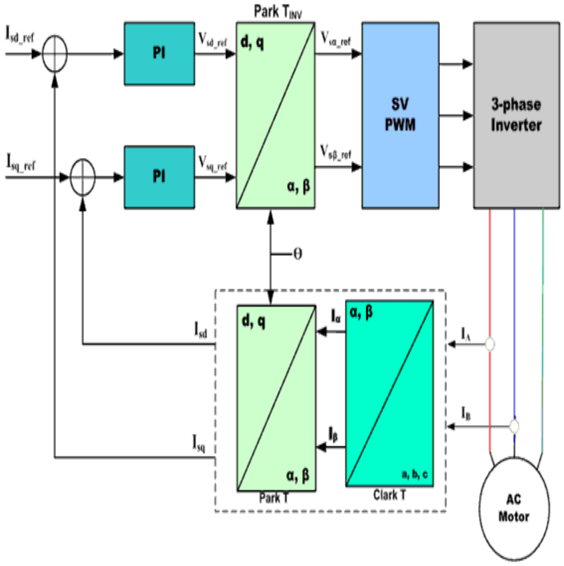

Fig.2. Block Diagram of Vector Control

The electrical DC drive systems are still used in a wide range of industrial applications, although they are less reliable than the AC drives. Their advantage consists in simple and precise command and control structures.

The AC drives, sometimes more expensive but far more reliable, require complex modern control techniques. The design of a control system is realised in two important steps:

1. The drive system has to be converted into a mathematical model, in order to accomplish the analysis and the evaluation of the system.
2. The imposed response of the drive system is obtained through an optimal regulator, when external perturbations are present. The induction motors are relatively cheap and rugged machines because their construction is realised without slip rings or commutators. These advantages have determined an important development of the electrical drives, with induction machine as the execution element, for all related aspects: starting, braking, speed reversal, speed change, etc. The dynamic operation of the induction machine drive system has an important role on the overall performance of the system of which it is a part. There are two fundamental directions for the induction motor control:

- Analogue: direct measurement of the machine parameters (mainly the rotor speed), which are compared to the reference signals through closed control loops;
- Digital: estimation of the machine parameters in the sensor less control schemes (without measuring the rotor speed), with the following implementation methodologies:

- Slip frequency calculation method;
- Speed estimation using state equation;
- Estimation based on slot space harmonic voltages;
- Flux estimation and flux vector control;
- Direct control of torque and flux;
- Observer-based speed sensorless control;
- Model reference adaptive systems;
- Kalman filtering techniques;
- Sensor less control with parameter adaptation;
- Neural network based sensor less control;
- Fuzzy-logic based sensor less control.

Another classification of the control techniques for the induction machine is made by Holtz (1998) from the point of view of the controlled signal:

a) SCALAR CONTROL:

a.1 Voltage/frequency (or v/f) control;

a.2 Stator current control and slip frequency control. These techniques are mainly implemented through direct measurement of the machine parameters.

b) VECTOR CONTROL:

b.1 Field orientation control (FOC): b.1.1. Indirect method; b.1.2. Direct method;

b.2 Direct torque and stator flux vector control. These techniques are realized both in analogue version (direct measurements) and digital version (estimation techniques)

The development of accurate system models is fundamental to each stage in the design, analysis and control of all electrical machines. The level of precision required of these models depends entirely on the design stage under consideration. In particular, the mathematical description used in machine design requires very fine tolerance levels as stated by Nabae et al. (1980) and Murata et al (1990). However, in the development of suitable models for control purposes, it is possible to make certain assumptions that considerably simplify the resulting machine model. Nonetheless, these models must incorporate the essential elements of both the electromagnetic and the mechanical systems for both steady state and transient operating conditions (Nowotny and Lipo - 1996). Additionally, since modern electric machines are invariably fed from switching power conversion stages, the developed motor models should be valid for arbitrary applied voltage and current waveforms. This work presents suitable models for use in digital current control of the induction motors. In addition, the limits of the validity of these models are summarized and, in some cases, the models are extended to account for some non-idealities of the machine. Usually, the following assumptions are made (Lorenz et al. 1994):

- No magnetic saturation, i.e. machine inductance is not affected by current level.
- No saliency effects i.e. machine inductance are not functions of position.
- Negligible spatial mmf harmonics i.e. stator windings are arranged to produce

  Sinusoidal mmf distributions.
- The effects of the stator slots may be neglected.
- There is no fringing of the magnetic circuit.
- The magnetic field intensity is constant and radially directed across the air-gap.
- Eddy current and hysteresis effects are negligible.

III. SIMULATION RESULT

Parameter of the Induction motor are

Vsrated = 415
Israted = 7.2
f = 50
P = 4
Rs = 1.557
Rr = 2.62
Ls = 195e-3
Lr = 195e-3
Lo = 177e-3
Lls = Ls-Lo
Llr = Lr-Lo
J = 0.1
B = 0.0161
Tm = J/B
Isd = (1.414*0.4*Israted)
Kw = 10
Tw = 1
Tr = Ls/Rs

The simulation performance of DFOC IMD is tested under 1440 rpm forward motoring mode with a load torque. In this paper a review is proposed for vector control of induction motor drive. The control scheme used here is ‘field oriented control’. The ‘field oriented control’ is classified as ‘Direct Field Oriented Control’ (DFOC) and ‘Indirect Field Oriented Control’ (IFOC). The FOC method has an attractive feature but it suffers with some drawbacks, such as; requirement of co-ordinate transformations, current controllers, and sensitive to parameter variations, PWM modulators, switching frequency, and rotor position measurement and control tuning loops. These drawbacks of FOC schemes are minimized with the new control strategy i.e., IFOC scheme, which is introduced by Isao Takahashi and Toshihiko Noguchi, in the mid 1980’s he performance of control strategy is tested and compared based on MATLAB/Simulink environment under different operating conditions..

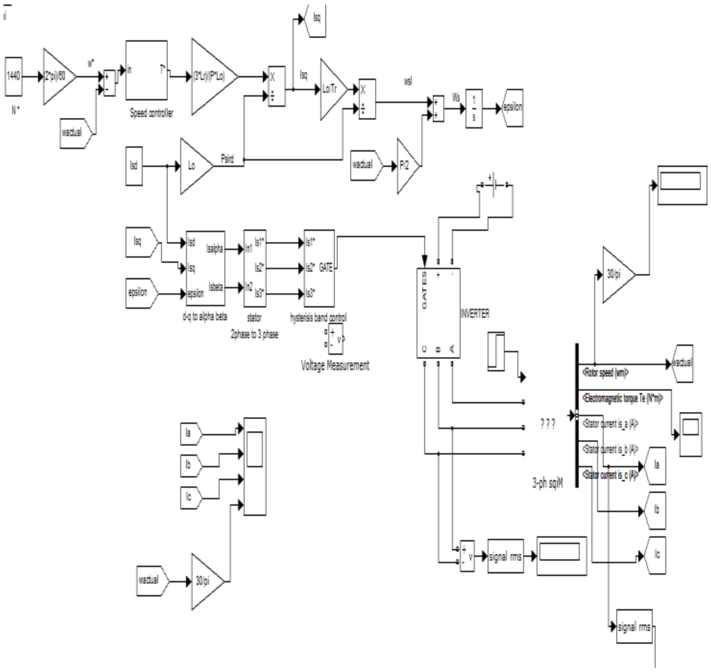

Fig.3 Simulation of Vector field control of Induction Motor

IV. SIMULATION RESULTS

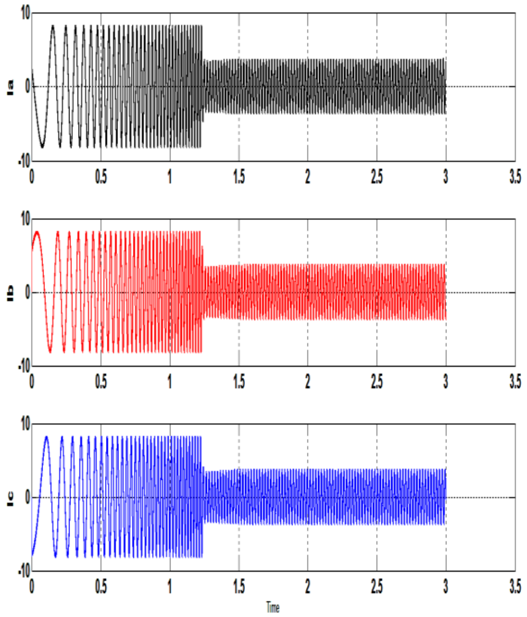

Fig.4 Phase Current

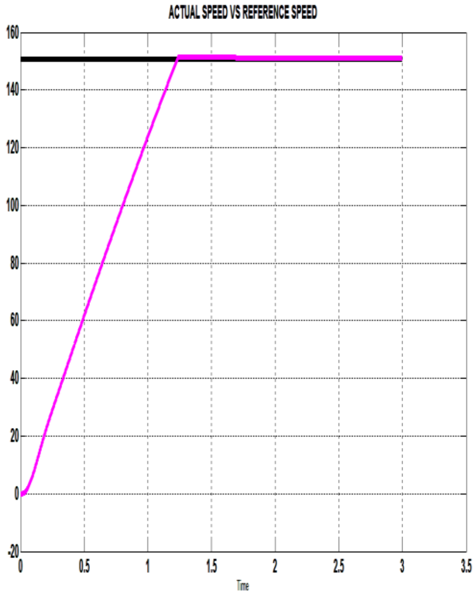

Fig.5 Reference and Actual Speed

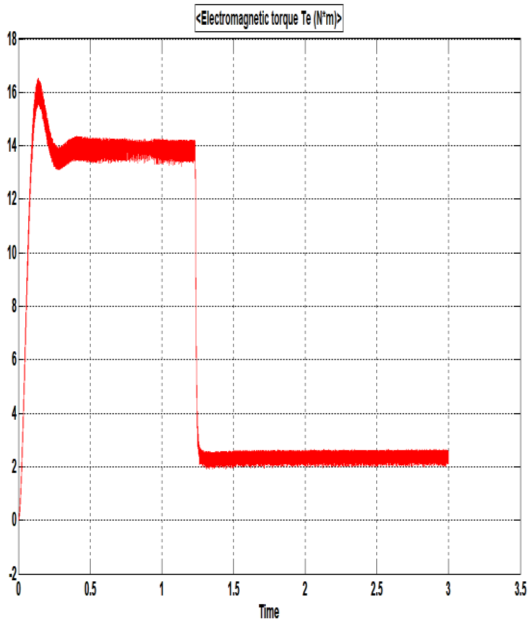

Fig.6. Electromagnetic Torque

Figure 4 shows the three phase stator current which is sinusoidal in nature .Figure 5 shows comparison od reference speed and actual speed and the speed error is almost zero and motor attains speed of 1440 rpm within 3 sec. Figure 5 shows electromagnetic torque of Induction motor.

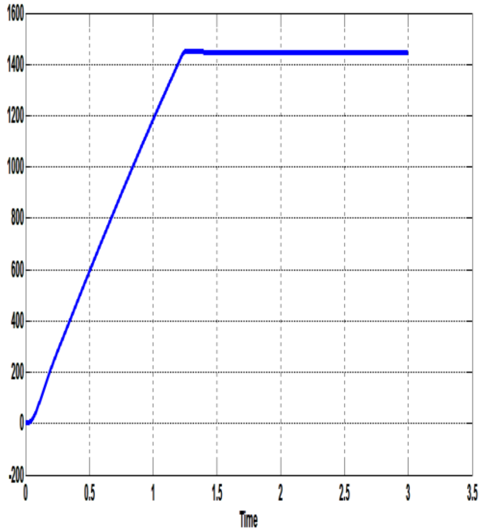

Fig.7 Reference and Actual Speed

V. CONCLUSION

Fast response of vector control make it better than other method of speed control of induction motor, By using this method we attend maximum response in minimum time .By result analysis change in load torque speed attend reference speed in minimum time, by comprise with scalar control method this method is fast accurate and control variable speed of induction motor. We can control speed by varying parameters of motor, load torque, load limit value. Its sharp and accurate function of flux and speed control.

REFERENCES

[1] Xu, D. W. Novotny, "Selection of the flux reference for induction machine drives in the field weakening region," IEEE Trans. on Ind. App. Vol 28, No 6, Nov. -Dec. 1992, pp. 1353 1358.

[2] S.H.Kim, S.K. Sul, "Maximum torque control of an induction machine in the field weakening region," IEEE Trans. on. Ind. Appl., Jul./Aug. 1995, vol.3 1, No.4, pp. 787-794.

[3] G. Griva, F. Profumo, M. Abrate, A. Tenconi, D. Berruti, "Wide speed range DTC drive performance with new flux weakening control," Conf. Rec. PESC'98, vol. 2, pp. 1599 1604, 17 22 May 1998, Fukuoka, Japan.

[4] D. Casadei, F. Profumo, G. Serra, A. Tani, L. Zarri, "Performance analysis of a speed-sensorless induction motor drive based on a constantswitching-frequency DTC scheme," IEEE Trans. on Ind. App., Vol. 39, NO. 2, March/April 2003, pp. 476-484.

[5] H. Grotstollen, J.Wiesing, "Torque capability and control of a saturated induction motor over a wide range of flux weakening," IEEE Trans. on Ind. Elec., vol. 42, no. 4, Aug. 1995, pp. 374-381.

[6] R. J. Kerkman, T. M. Rowan, D. Leggate, "Indirect field-oriented control of an induction motor in the field-weakening region," IEEE Trans. on Ind. Applications, Vol. 28, No. 4, July!/ August 1992, pp. 850 857.

[7] E. Levi, M. Wang, "A speed estimator for high performance sensorless control of induction motors in the field weakening region," IEEE Trans. on Pow~er Electronics, Vol.17, No. 3, May 2002, pp. 365-378.

[8] M.S. Huang, "Improved field-weakening control for IFO induction motor," IEEE Trans. on Aer. and Elect. Sys., Vol.39, No. 2, Apr. 2003, pp. 647-658.

[9] M.Ho Shin, D.S. Hyun, S. B. Cho, "Maximum torque control of statorflux-oriented induction machine drive in the field-weakening region," IEEE Trans. on Ind. App., Vol. 38, No. 1, Jan./Feb. 2002, pp. 117 121.

[10] D. Casadei, G. Serra, A. Tani, L. Zarri, "A Robust method for flux weakening operation of DTC induction motor drive with on-line estimation of the break-down torque," EPE 2005, Dresden, Germany, Sept. I11 14, 2005, IEEE Cat. Num. 05EX1I132C, pp.1 1I0.

[11] T.S. Kwon, M.H. Shin, D.S. Hyun, "Speed sensorless stator flux-oriented control of induction motor in the field weakening region using Luenberger observer," IEEE Trans. on Pow. El., Vol. 20, No. 4, July 2005, pp. 864-869.

[12] A. Biinte, H. Grotstollen, P. Krafka, "Field weakening of induction motors in a very wide region with regard to parameter uncertainties," PESC 96, Vol. 1, 26-27 June 96, pp. 944-950.

[13] C. Caruana, G.M. Asher, M. Sumner, Performance of high frequency signal injection techniques for zero-lowfrequency vector control induction machines under sensorless conditions, IEEE Trans. Ind. Electron. Vol. 53, 2006, pp. 225–238.

[14] S. I. Rojas, J. Moreno, G. Espinosa-Perez, Global observability analysis of sensorless induction motors, Automatica, vol. 40, 2004, 1079–1085.

[15] H.M. Kojabadi, Simulation and experimental studies of model reference adaptive system for sensorless induction motor drive, Simulat. Model. Practice Theory, vol. 13, 2005, pp. 451–464.

[16] M. Rashed, A.F. Stronach, A stable back-emf MRASbased sensorless low speed induction motor drive insensitive to stator resistance variation, IEE Proc. Electric Power Appl., Vol. 151, 2004, 685–693.

[17] Gadoue S. M., Giaouris D., Finch J. W., ‘MRAS sensorless vector control of an induction motor using new sliding-mode and fuzzy-logic adaptation mechanisms’, IEEE Trans. Energy Conversion, 2010, Vol. 25, No. 2, pp. 394–402.

[18] S. Maiti, C. Chakraborty, Y. Hori, M.C. Ta, Model reference adaptive controller-based rotor resistance and speed estimation techniques for vector controlled induction motor drive utilizing reactive power, IEEE Trans. Ind. Electron., Vol. 55, 2008, pp. 594–601.

[19] H.M. Kojabadi, Active power and MRAS based rotor resistance identification of an IM drive, Simulat. Model. Practice Theory, vol. 17, 2009, pp. 376–389.

[20] C. Schauder, Adaptive speed identification for vector control of induction motors without rotational transducers, IEEE Trans. Ind. Appl., Vol. 28, 1992, pp. 1054–1061.

[21] Slotine J. J. E, W. Li, ‘Applied Nonliner Control’, Prentice hall, 1991. [13] Y. Luo and W. Chen, “Sensorless stator field orientation controlled induction motor drive with a fuzzy speed controller,” Computer and Mathematics with Appl., Vol. 64, 2012, pp. 1206–1216.