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VECTOR CONTROL TECHNIQUE OF INDUCTION MOTOR

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Abstract — *Now-a-days induction motor is the main work-horse of the industries. So controlling of induction motor is most precisely required in many high performance applications. Scalar control method gives good steady state response but poor dynamic response. While vector control method gives good steady state as well as dynamic response. This paper applies the pulse width modulation to indirect vector control of an induction machine. A hysteresis current controller is applied for controlling the output voltage of the PWM inverter which is fed the induction machine. To justify the correctness of the system and its feasibility, the simulation method is selected. The model of the system is implemented in MATLAB Simulink software, which is suitable for testing the dynamic simulation of a system.*

Keywords- Vector control, Induction motor, Direct torque control, Field oriented control, Separately excited dc motor.

I. INTRODUCTION

In 1891 at the Frankfurt exhibition, Nikola Tesla first presented a polyphase induction motor. Since then great improvements have been made in the design and performance of the induction motors and numerous types of polyphase and single-phase induction motors have been developed. As a rough estimate nearly 90 percent of the world's AC motors are polyphase induction motors.

The main thing to be understood here is why Induction motors are used in every section or for every action. There are few advantages of using Induction motors which are not provided by any other motor. Some of these advantages of Induction motors are:-

- Cheap: This is the most important thing in current age of competition . If something is costly we immediately start looking for its alternatives. Induction machines are very cheap when compared to synchronous and DC machines. It make them first choice for any operation.
- Robust: induction machines are robust in construction. It is another advantage of using Induction Machine.
- Efficient and Reliable: Induction machines are no doubt very reliable machines and have considerable efficiency.
- Low Maintenance Cost: As construction of induction machine is very simple and hence maintenance is also easy resulting in small maintenance cost.
- High Starting Torque: Starting torque on induction motor is high which make is useful for operations where load is applied before the starting of the motor.

AC induction motor is the most common motor used in industries and mains powered home appliances. It is biggest industrial load, so widely used. Engineers have to know its performance, have to control as per load requirement & protecting induction motor also .

In initial years D.C. motors were widely used in applications where high performance in variable speed was required. Separately excited D.C. motors were extremely used in areas where fast torque was a must. It was considered as a main work horse in the industry. The faster dynamic response of DC motor lies into its being a doubly fed motor and inherent DE-COUPLING facility of independent control of torque and flux in the motor. DC motor had its disadvantage like maintenance, sparking, difficulty in commutation at high current and voltage so it is limited to low power and low speeds. After the invention of the induction motor above mention difficulties was overcome. But it did not have de-coupling facility between torque and flux for controlling. So their dynamic performance was poor. After the invention of static DC controller, DC machines were again widely used for torque and speed control. Then after invention of power electronics components and scalar control method like variable frequency drive (VFD) or slip frequency control, induction motors were widely used again but they didn't have de-coupling facility of torque and flux. So for the de-coupling of torque and flux, vector control introduced for better performance of induction motor application.

Slip frequency control method is well known method for better dynamic performance. This method was widely used in all high performance induction machine drives until field oriented control (FOC) became the industry's standard for AC drives with dynamics close to that of DC motor drives . DTC has emerged over the last decade to become one possible alternative to the well-known Vector Control of Induction Machines. Its main characteristic is the good performance, obtaining results as good as the classical vector control but with several advantages based on its simpler structure and control diagram. Which has simpler construction and working principle and cheaper than FOC . This paper discusses the study about indirect vector control of induction motor.

II. INTRODUCTION OF VECTOR CONTROL (FOC)

Before introduction of vector control of induction motor the methods enjoyed wide acceptability in controlling the speed of the cage induction motor drive are termed as SCALAR (only magnitude), V/f control, voltage control, frequency control, power recovery control etc. all these control methods with cage motor exhibits inferior dynamics performance as compared to separately excited DC motor. So the modern research is carried on introducing and improving VECTOR control which involves both magnetic and phase alignment of quantities .

2.1. What is vector control?

Vector control (VC) mode of operation is defined as a control technique in which two equivalent control signals are produced to control torque and flux in decoupled manner. When three-phase squirrel cage induction motor is operated in VC mode, its response improves considerably and it acts as a better substitute for the separately excited DC motor.
The field and the armature currents respectively can control the flux and torque, independently in the case of DC motors. It is because of this inherent decoupling between the field flux and the armature current, one is able to achieve very good torque dynamics from DC machines. Therefore, achieving good torque dynamics in AC machines is not easy. However, now-a-days, field oriented control or vector control techniques have been employed, which results in good torque dynamics of induction motors.

2.2.Need for vector control

Inverter fed induction motors are increasingly being used for general purpose applications. Varying input voltage (V) to the motor frequency (f) in open loop operation is one of the most popular methods of speed control. This is called scalar control method. In this method, V/f is held constant. As the frequency nearly approaches zero, the magnitude of the stator voltage also tends to zero and the stator resistance absorbs this low voltage. Therefore, at low speeds an auxiliary voltage must be injected for compensating stator resistance drop so that the rated air-gap flux and hence the full load torque is available up to zero speed. Hence, in constant v/f control scheme, the air gap flux may drift as a result, torque sensitivity with slip frequency or stator current will vary. Hence, a speed control scheme with independent control of torque and flux loop is desirable.

In 1971, Blaschke proposed a scheme, which aims at the control of induction motor like a separately excited dc motor, called "Field Oriented Control or Vector Control". In an AC machine, both the phase angle and the modulus of the current must be controlled, or in other words, the current vector must be controlled. This is the reason for the terminology 'Vector Control'. In this scheme, the induction motor is analysed from a synchronously rotating reference frame where all the fundamental ac variables appear to be dc equals. The torque and flux components are identified and controlled independently to achieve good dynamic response. Vector control implies that an ac motor is forced to behave dynamically as a DC motor by the use of feed back control.

Field-oriented control (FOC) or vector control of induction machine achieves decoupled torque and flux dynamics leading to independent control of the torque and flux as for a separately excited DC motor. This is achieved by orthogonal projection of the stator current into a torque-producing component and flux-producing component. This technique is performed by two basic methods. Direct and indirect vector control. FOC can be implemented as indirect (feed-forward) or direct (feedback) depending on the method used for rotor flux identification. The direct FOC determines the orientation of the air-gap flux by use of a hall-effect sensor, search coil or other measurement techniques.

However, using sensors is expensive because special modifications of the motor are required for placing the flux sensors. Furthermore, it is not possible to directly sense the rotor flux. Calculating the rotor flux from a directly sensed signal may result in inaccuracies at low speed due to the dominance of stator resistance voltage drop in the stator voltage equation and inaccuracies due to variations on flux level and temperature.

In case of induction machines, the indirect method is based on reconstruction (estimation) approaches employing terminal quantities such as voltage and currents in a motor model to calculate the flux position. Indirect FOC does not have inherent low-speed problems and is therefore preferred in most applications. There are three possible implementation based on the stator, rotor, or air gap flux orientation. The rotor flux indirect vector control technique is the most widely used due to its simplicity.

III. FOC

FOC methods are attractive but suffer from one major disadvantage. They are sensitive to parameter variations such as rotor time constant and incorrect flux measurement or estimation at low speeds. Consequently, performance deteriorates and a conventional controller such as a PI is unable to maintain satisfactory performance under these conditions.

The Field Orientated Control is based on three major points: the machine current and voltage space vectors, the transformation of a three phase speed and time dependent system into a two co-ordinate time invariant systems and effective Pulse Width Modulation pattern generation.
As shown in fig. 1 construction of DC machine is such that field flux Ψ_f produced by the field current If is perpendicular to the armature flux Ψ_a produced by the armature current Ia. These are decoupled in nature. This means that torque is

individually controlled by the current I_a, without affecting the Ψ_f and we get fast transient response and high torque/ampere ratio with rated Ψ_f.

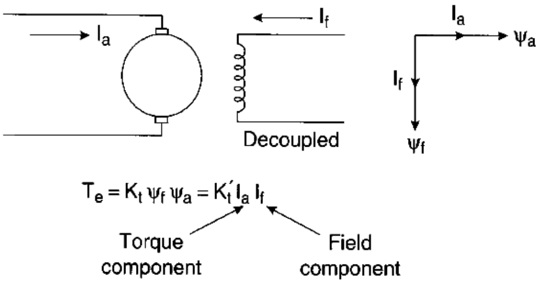

Fig. 1 A Separately excited DC motor

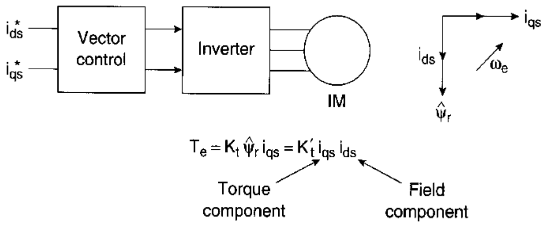

Fig. 2 Vector Control induction motor

As shown in fig. 2, DC machine-like can also be extended to an induction motor if the machine control is considered in a synchronously rotating reference frame (d-q) where the sinusoidal variables appear as DC quantities in steady state.

There are three ways of vector control based on the reference frame in which the stator currents are transformed. They are:
(1) Stator flux oriented control
(2) Magnetizing flux oriented control
(3) Rotor flux oriented control

The goal of FOC (fig. 3) is to maintain the amplitude of the rotor flux linkage at a fixed value, except for field-weakening operation or flux optimization, and only modify a torque-producing current component in order to control the torque of the ac machine. This control strategy is based on projections. Electromagnetic torque is produced by the interaction of stator flux linkages and stator currents (or rotor flux and rotor current), and can be expressed as a complex product of the flux and current space phasors. There are two types of FOC: (1) Direct & (2) Indirect

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3.1. Direct FOC

In direct field-oriented control the rotor flux position is obtained by measuring the air gap flux using sensors or estimated using terminal voltages and currents, which is also known as sensorless direct field oriented control. Knowing the flux position the required phase currents that give the desired flux and torque value can be calculated and forced into the motor stator [5].

3.2.Indirect method

In indirect field-oriented control the 90-degree orientation between the rotor flux and the q-axis component of the stator current is maintained by satisfying the unique slip relationship associated with the d-q currents components in a field-orientation controlled motor. In this method, a feedback of the rotor position is required. Similar to the rotor flux position in direct field-oriented control case the rotor position can be directly obtained from an incremental encoder or estimated using the terminal voltages and currents information which is known as sensor less indirect field-oriented control.
If a voltage vector changes then the stator flux and phase angle between the stator flux and rotor flux vectors changes, then the torque produced will change. Since a two-level inverter is only capable of producing six non-zero voltage vectors and two zero

vectors, it is possible to create a table that determines the voltage vector to apply based on the position of the stator flux and the required changes in stator flux magnitude and torque. This is called the optimal vector selection table. The estimated stator flux magnitude and torque output is compared to the demand values. A voltage vector is then selected that will drive the torque and flux towards the demanded values

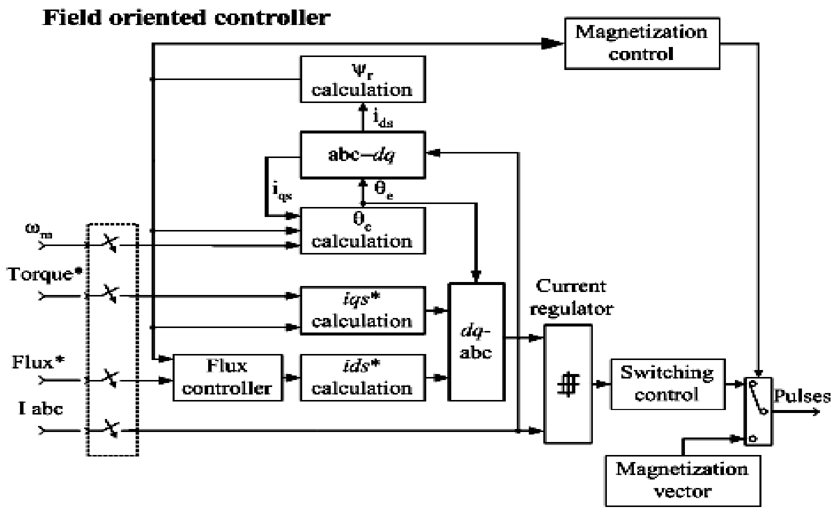
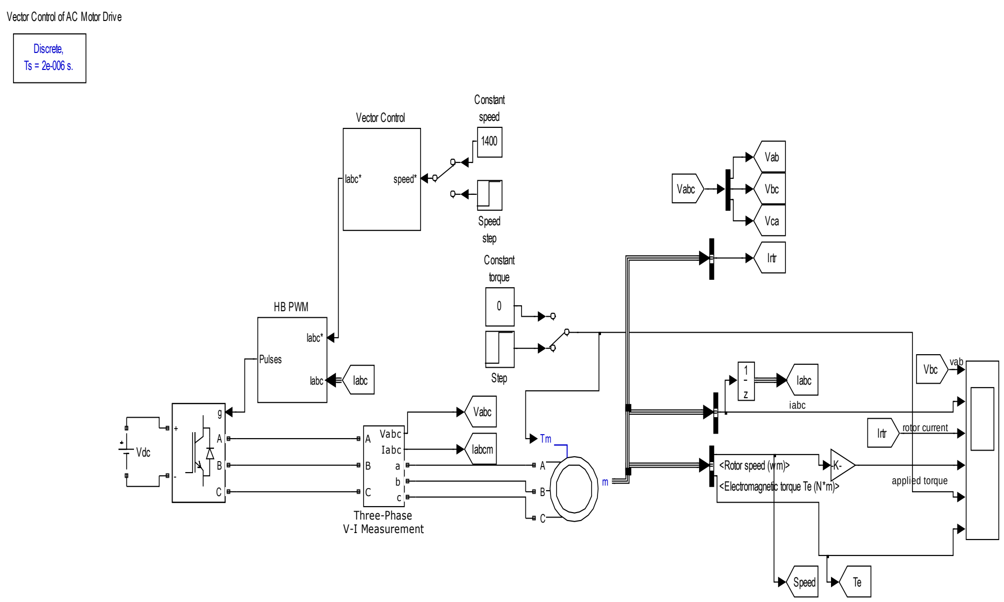


Fig. 3 Basic block diagram of FOC

This shows the torque produced is dependent on the stator flux magnitude, rotor flux magnitude, and the phase angle between the stator and rotor flux vectors.

IV. SIMULATION DIAGRAM



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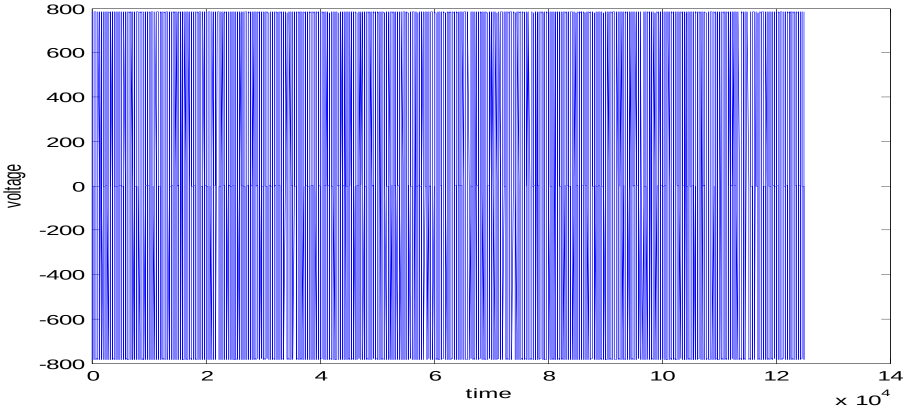
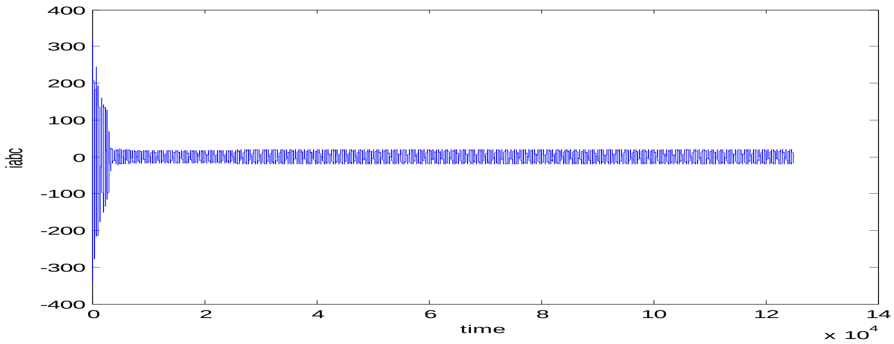
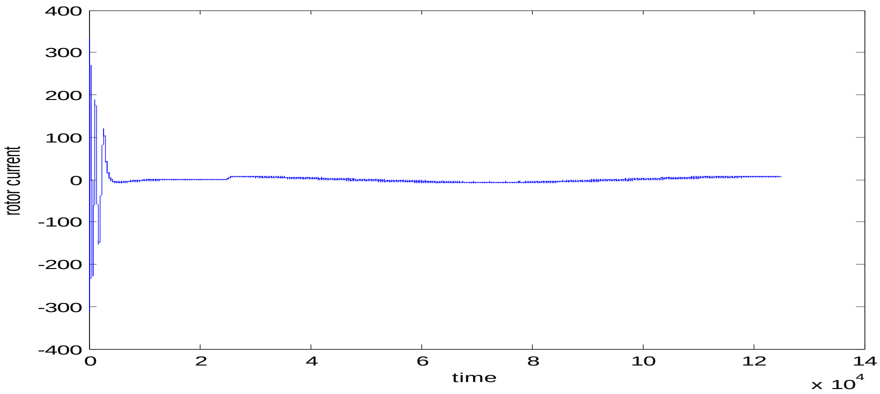
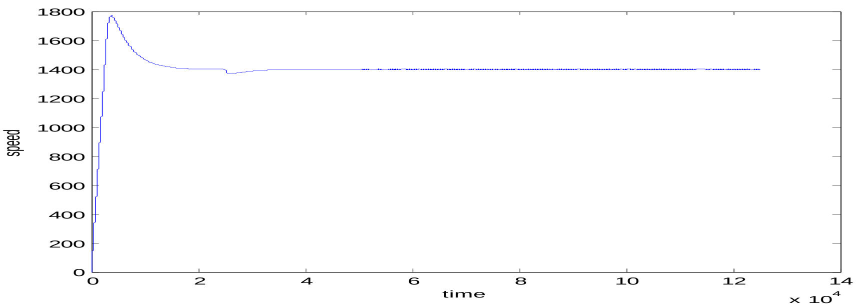
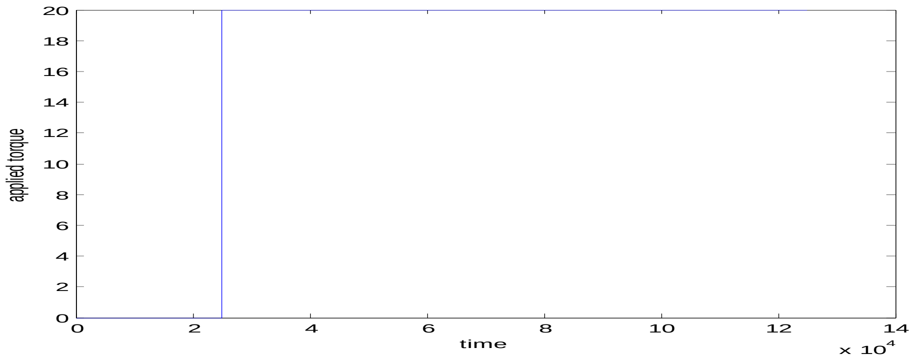
V. SIMULATION RESULTS

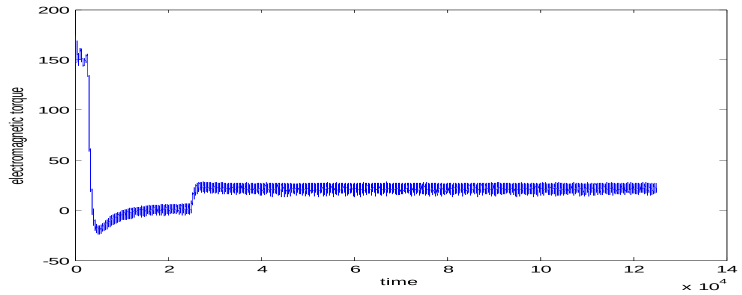












Advantages of Field Oriented Control

1) Improved torque response.
2) Torque control at low frequencies and low speed.
3) Dynamic speed accuracy.
4) Reduction in size of motor, cost and power consumption.
5) Four quadrant operation.
6) Short-term overload capability.

VI. CONCLUSIONS

This paper has introduced a survey on Induction motor speed control. Three phase induction motor is controlled with an efficient technique called field oriented control. The FOC helps in controlling the torque and provides better speed regulation. Hence by using this FOC technique has improved the motor performance and efficiency and speed control of the Induction motor is obtained in an accurate manner.

REFERENCES:

[1]. P. K. Mukherjee & S. Chakravorti, "Electrical machines"
[2]. Joachim Böcker, Member, IEEE ,"State of the Art of Induction Motor Control", Shashidhar Mathapati, University Paderborn, Warburger Str. 100, D-33098 Paderborn, Germany
[3]. Technical guide no 1, "Direct Torque Control, The world's most advanced AC drive technology", ABB
[4]. Punya Jain and Abhishek Vyas, " Simulation of vector controlled induction motor drive using MATLAB", B. E. thesis of B.E. Electrical, Faculty of Technology and Engineering, The maharaja Sayajirao University, Baroda
[5]. R.Krishnan, (2005), "Electric motor drives- modeling, analysis and control", Prentice- Hall, India
[6].Texas Instruments Europe, "Field Orientated Control of 3-Phase AC-Motors", Literature Number: BPRA073, February 1998
[7]. Peter Vas, "Sensorless Vector and Direct Torque Control," Oxford Science Publications, NY, 1990
[8]. Doki, S., Sangwongwanich, S. and Okuma, S. "Implementation of speed sensorless field oriented vector control using adaptive sliding observer." IEEE-IECON, San Diego, pp. 453-458, 1992.
[9].Kubota, H. and Matsuse, K. "Speed sensorless field oriented control of induction machines." IEEE IECON, Bologna, Italy, pp. 1611-1615, 1994.
[10].Schauder, C. "Adaptive speed identification for vector control of induction motors without rotational transducers." IEEE Transactions on Industrial Applications, vol. 28, pp. 1054-1061, 1992.
[11].Tajima, H. and Hori, Y. "Speed sensorless field-orientation control of the induction machine." IEEE Transactions on Industry Applications, vol. 29, pp. 175-180, 1993
[12].Tamai, S., Sugimoto, H. and Yano, M. "Speed sensorless vector control of induction motor with model reference adaptive system." IEEE Industrial Applications Society Annual Meeting, Atlanta, pp. 189-195, 1987.