Vector Control of Single-Phase Induction Motor Using MATLAB/Simulink

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Abstract: AC inductionmotors offer enviable operational characteristics such as robustness, reliability and ease of control. They are extensively used in various applications ranging from industrial motion control systems to home appliances. However, the use of induction motors at its highest efficiency is a challenging task because of their complex mathematical model and non-linear characteristic during saturation. These factors make the control of induction motor difficult and call for use of a high performance control algorithms such as vector control. In this paper vector control of single phase induction motor is proposed. The speed control loop uses a proportional-integral-derivative regulator to produce the quadrature-axis current reference iq* which controls the motor torque. The motor flux is controlled by the direct-axis current reference id*. The block DQ-AB is used to convert id* and iq* into current references ia*, and ib* for the current regulator. Current and Voltage Measurement blocks provide signals for visualization purpose.

Keywords: single phase induction motor, vector control, PWM technique.

1. INTRODUCTION

Traditionally in fractional and sub-fractional horse power applications, the single-phase induction motor (SPIM) is usually found in several home, office, shopping, farm, and industry appliances such as air conditioning systems, mixers, washers, blowers, compressors, fans, vacuum cleaners, pumps, etc. The main advantage of these motors is their ability to operatefrom a single-phase power supply. Therefore, they can be used wherever a single-phase source is available. There are also other aspects for their popularity: low manufacturing cost, and simplicity. However, compared with three-phase systems, they offer lower efficiency. In many applications it may be desirable to change the speed of the motor, e.g. if we want to control the air-flow of a ventilator.

Then it is useful to use some techniques for varying induction motor (IM) speed. Different inverter topologies for single-phase induction motor drive have been proposed. Commonly, three types of topologies are studied: two-leg, three-leg and four-leg two-phase inverters [4], [5].

The first topology is known as H-bridge voltage inverter with two-legs and a mid-point provide by a capacitive divider. The second is composed of three-legs with the mid-point pro-vided by the common leg. The third possibility has the greatest number of switches, so the losses of the system are in-creased.

The application of power electronic inverters, along with pulse width modulation (PWM), increased the performance of single-phase induction motors. The most widely use PWM techniques are sinusoidal PWM and space vector PWM.Techniques are sinusoidal PWM and space vector PWM. In [7], [8] and some PWM strategies are discussed when applied to a single-phase induction motor drive.

The purpose of this paper is to examine the operation of a single-phase induction motor when operated from a variable frequency power supply under load condition.There is no doubt that most single-phase induction motors (split-phase, capacitor-start, capacitor-run and capacitor-start capacitor-run) usually have a main and auxiliary stator winding asymmetrical and displaced 90 degrees apart from each other. These papers use the model to derive the motor equations and treat the single-phase induction motor, without startup and running capacitor, as an asymmetrical two-phase induction motor. The performance of a single-phase induction motor drive under field oriented control has been analyzed in [1], [2] and [3]. The control method to be applied is the vector control.

II SINGLE PHASE INDUCTION MOTOR

A. Stator of Single Phase Induction Motor

The stator of the single-phase induction motor has laminated stamping to reduce eddy current losses on its periphery. The slots are provided on its stamping to carry stator or main winding. Stampings are made up of silicon steel to reduce the hysteresis losses. When we apply a single phase AC supply to the stator winding, the magnetic field gets produced, and the motor rotates at speed slightly less than the synchronous speed N_s.

Synchronous speed N_s is given by

$$N_s = \frac{120f}{P}$$

Where,

f = supply voltage frequency,

P = No. of poles of the motor.

The construction of the stator of the single-phase induction motor is similar to that of three phase induction motor except there are two dissimilarities in the winding part of the single phase induction motor.

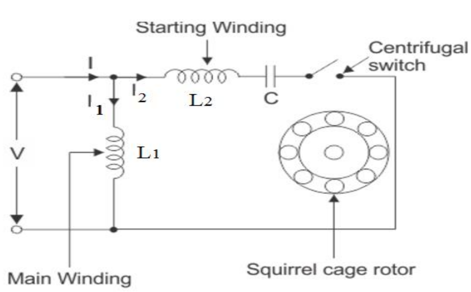

Fig.1

Single Phase Induction Motor

B. Rotor of Single Phase Induction Motor

The construction of the rotor of the single-phase induction motor is similar to the squirrel cage three-phase induction motor. The rotor is cylindrical and has slots all over its periphery. The slots are not made parallel to each other but are a little bit skewed as the skewing prevents magnetic locking of stator and rotor teeth and makes the working of induction motor smoother and quieter, i.e., less noise. The squirrel cage rotor consists of aluminum, brass or copper bars. These aluminum or copper bars are called rotor conductors and placed in the slots on the periphery of the rotor. The copper or aluminum rings permanently short the rotor conductors called the end rings. To provide mechanical strength, these rotor conductors are braced to the end ring and hence form a complete closed circuit resembling a cage and hence got its name as squirrel cage induction motor. As end rings permanently short the bars, the rotor electrical resistance is very small and it is not possible to add external resistance as the bars get permanently shorted. The absence of slip ring and brushes make the construction of single phase induction motor very simple and robust.

III. FIELD ORIENTED CONTROL

AC Induction motors offer enviable operational characteristics such as robustness, reliability and ease of control. They are extensively used in various applications ranging from industrial motion control systems to home appliances. However, the use of induction motors at its highest efficiency is a challenging task because of their complex mathematical model and non-linear characteristic during saturation. These factors make the control of induction motor difficult and call for the use of a high performance control algorithms such as vector control.

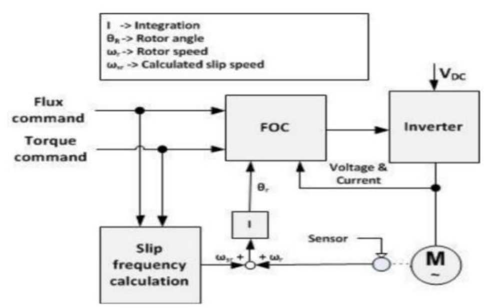

Fig.2.a Simplified indirectFOC

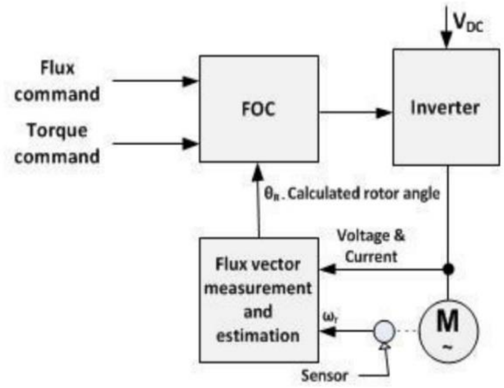

Fig.2.b Simplified direct FOC

i. Introduction of Field Oriented Control

Scalar control such as the "V/Hz" strategy has its limitations in terms of performance. The scalar control method for induction motors generates oscillations on the produced torque. Hence to achieve better dynamic performance, a more superior control scheme is needed for Induction Motor. With the mathematical processing capabilities offered by the micro-controllers, digital signal processors and FGPA, advanced control strategies can be implemented to decouple the torque generation and the magnetization functions in an AC induction motor. This **decoupled torque** and **magnetization flux** is commonly called rotor

ii.Flux Oriented Control (FOC).

Field Oriented Control describes the way in which the control of torque and speed are directly based on the electromagnetic state of the motor, similar to a DC motor. FOC 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), the torque producing component of the stator flux can be controlled independently. Decoupled control, at low speeds, the magnetization state of motor can be maintained at the appropriate level, and the torque can be controlled to regulate the speed. "FOC has been solely developed for high-performance motor applications which can operate smoothly over the wide speed range, can produce full torque at zero speed, and is capable of quick acceleration and deceleration."

iii.Working Principle of Field Oriented Control

Thefield oriented control consists of controlling the stator currents represented by a vector. This control is based on projections that transform a three phase time and speed dependent system into a two coordinate (d and q frame) time invariant system. These transformations and projections lead to a structure similar to that of a DC machine control. FOC machines need two constants as input references: the torque component (aligned with theq coordinate) and the flux component (aligned with d coordinate).

The three-phase voltages, currents and fluxes of AC-motors can be analyzed in terms of complex space vectors. If we take i_a, i_b, i_c as instantaneous currents in the stator phases, then the stator current vector is defined as follow:

$$\vec{i}_s = i_a + i_b e^{j2\pi/3} + i_c e^{j4\pi/3}$$

Where, (a, b, c) are the axes of three phase system.

This current space vector represents the three phase sinusoidal system. It needs to be transformed into a two time invariant coordinate system. This transformation can be divided into two steps:

(a, b, c) → (α, β) (the Clarke transformation), which gives outputs of two coordinate time variant system.

(a, β) → (d, q) (the Park transformation), which gives outputs of two coordinate time invariant system.

The (a, b, c) → (α, β) Projection (Clarke transformation)

Three-phase quantities either voltages or currents, varying in time along the axes a, b, and c can be mathematically transformed into two-phase voltages or currents, varying in time along the axes α and β by the following transformation matrix:

$$i_{\alpha\beta o} = 2/3 * \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix}$$

IV SIMULATIONRESULTS

The simulation. Observe on the scope the motor currents, voltage, speed, and torque during the starting. Double click on the two Manual Switch blocks to switch from the constant w_{ref}=1500 rpm and TL blocks to the Step blocks. (Reference speed w_{ref} changed from 1500 to 750 rpm at t = 2 s and load torque changed from 0 to 1 N.m at t= 1s). Restart the simulation and observe the drive response to successive changes in speed reference and load torque.

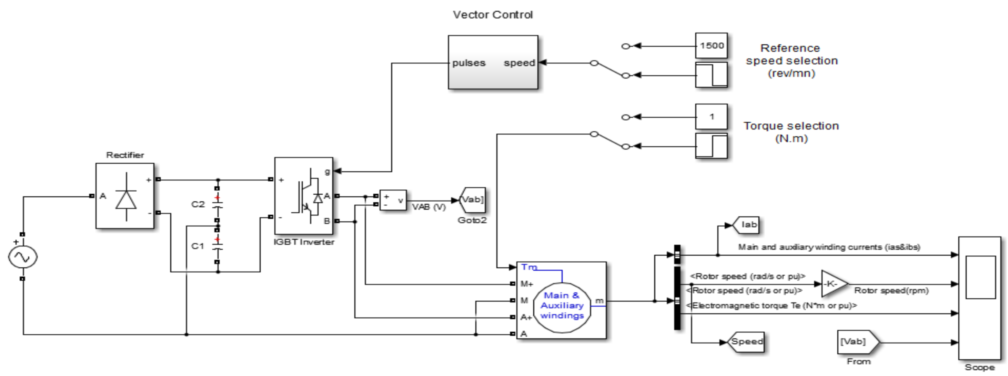

Fig.3 Block diagram of Vector control of single phase induction motor

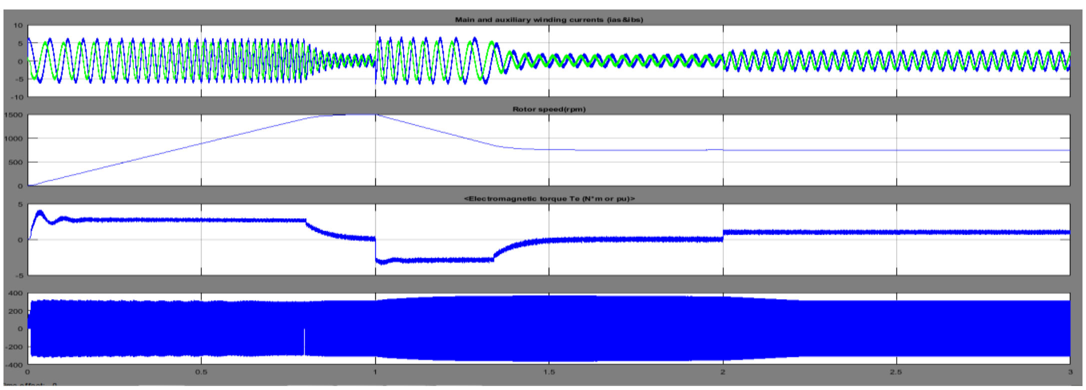

Fig.4 Vector control of single phase induction motor

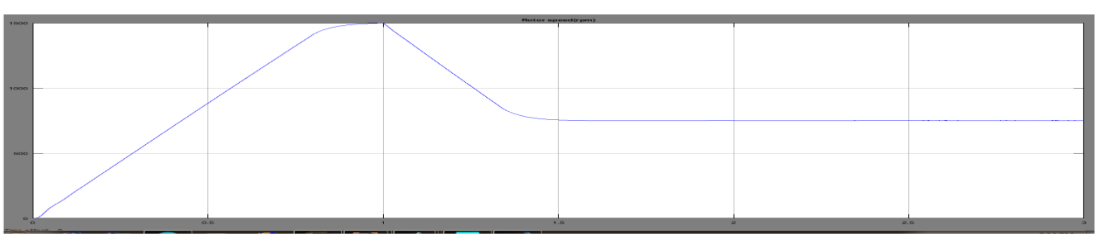

Fig.5 The actual and reference motorspeed

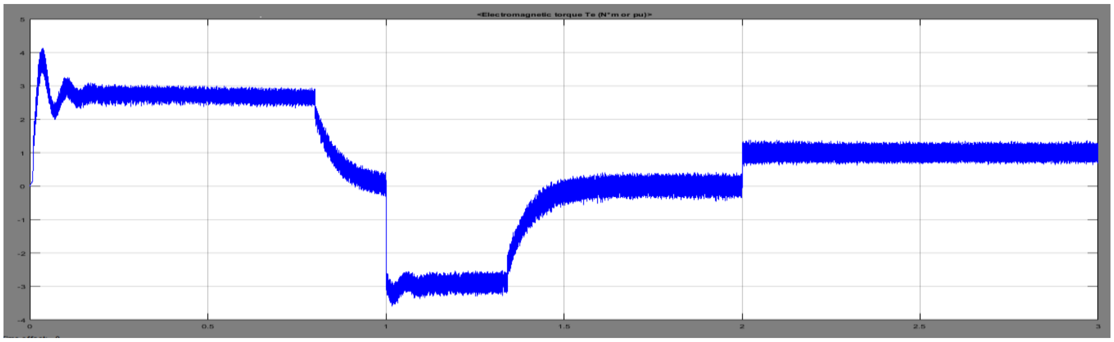

Fig.6 Electromagnetic motor torque

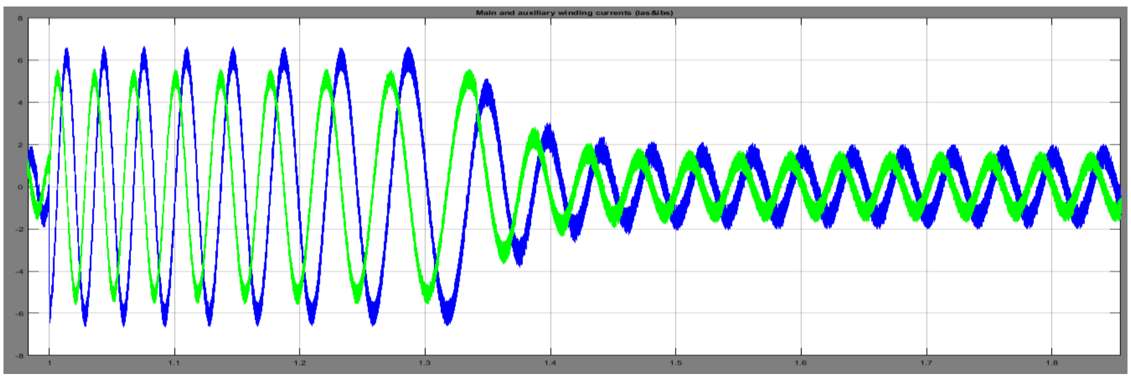

Fig.7 Main and auxiliary currents of the motor

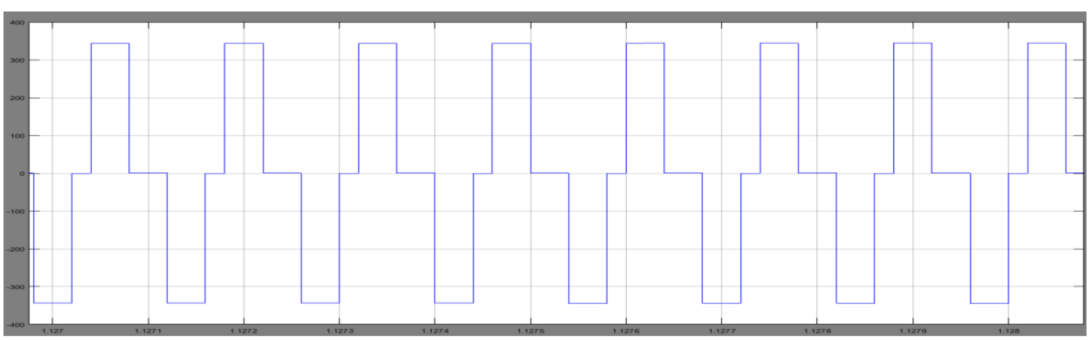

Fig.8 Voltage

V. CONCLUSION

In this paper Vector control for single phase induction motor presented and successfully implemented and the result observed on the MATLAB Simulink environment, speed control is achieved without the use of any sensor for any single phase induction machine field oriented control technique is one of the best techniques for the speed control. It allows the decoupled control of the motor flux and electromagnetic torque. After decoupling, the induction motor can be controlled as a DC motor and the electromagnetic torque and current can be control independently. As the overall performance of the induction machine is directly related to the performance of current control.Therefore, decoupling of the control scheme is acquired by the compensation of the coupling effect between q-axis and d-axis current dynamics. This current control makes the system more efficient and energy saving. From the simulation result for the various parameters it was observed that there is very less current spikes for the different set of speed and applied voltage and the spikes are almost at the same level for the sets of speed and supplied voltage although the settling time is varying for all speed and itwas conclude that the system is robust toparameter variation and gives the alternates for the conventional way of speed control of induction motor.

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