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Comparative Analysis of scalar & vector control of Induction motor through Modeling & Simulation

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Abstract: The main objective is implementation of scalar & vector control of three phase induction motor drives. Scalar control as the name indicates is due to magnitude variation of control variable only disregards any coupling effect in the induction machine. The scalar control is very simple method for controlling the speed of induction motor compared to the vector control which is more complex. Vector control is completely mathematical model on control of torque and speed of a three-phase indirect vector controlled induction motor drive. In this paper, an implementation of speed control of an induction motor (IM) using indirect vector control method has been developed and simulated. The comparative study of VCIM and conventional v/f control of IM is done this work. The VCIM drive involves decoupling of the stator current component which produces torque and flux of induction motor. It is seen that it provides smooth speed control and compared to v/f control. Finally comprise the result of scalar and vector control technique.

Keywords: Induction Motor, Mathematical Modeling, Electric Machine Simulation, Scalar & Vector Control.

I. INTRODUCTION

Nowadays, as a consequence of the important progress in power electronics and micro-computing, the control of AC electric machines has seen considerable development and the possibility for industrial application [1]. The reason for its day by day increasing popularity can be primarily attributed to its robust construction robustness, relatively low cost, reliability and efficiency, is the object of several research works. These have also proved to be more reliable than DC motors. Apart from these advantages, they have some unfavorable features like their time varying and non-linear dynamics. Speed control is one of the various application imposed constraints for the choice of a motor. Variable speed application can be dominated by dc drives. The speed control of DC motors can be carried out in a simple way, since the torque and flux are decoupled but they have the disadvantage of higher rotor inertia and maintenance problems associated with commentators and brushes.

The huge availability of Thyristors, IGBT and GTO in recent years the speed control of induction motor is becoming in expensive, so now a day it is increasingly replacing the DC motors in high performance electrical motor drives. However the technique of vector control or field oriented control (FOC) based on the rotor field orientation applied to the IM provides the decoupling between the torque and flux in a similar way to DC machine.

In this paper comparative study between the conventional scalar control and vector control is done. For the scalar control closed loop v/f control and indirect field oriented vector control (IFOC) are selected.

II. OVER VIEW OF DIFFERENT CONTROLLING SCHEMES FOR SPEED CONTROL OF 3-PHASE IM

A. Scalar Control

The name scalar control indicates the variation of control variables magnitude only and disregards the coupling effect in the machine. For example, the voltage of an induction machine can be controlled to control the flux, and frequency or slip can be controlled to control the torque. However, flux and torque are components of frequency and voltage respectively. In Scalar control both the magnitude and phase alignment of vector quantities are controlled. Scalar controlled drives give somewhat poor performance, but they are easy to implement. Scalar controlled drives have been widely used in industrial sector. However, their importance has diminished recently because of the better performance of vector-controlled drives which is demanded in many applications.

For improvement of quality many industrial applications require variable speed and constant speed control. Several techniques have been developed to control Alternating Current (AC) power. The operation of induction motors in the constant volts per hertz (V/f) mode has been known for many decadal periods, and its principle is well understood. With the introduction of PWM inverters, the constant V/f control became popular. Since the introduction of vector theory almost all research has been concentrated in this area, and little has been published about constant V/f operation. Its practical application at low frequency is still challenging, due to the manipulate of the stator resistance and the necessary rotor slip to produce torque. In addition,

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the nonlinear behavior of the modern pulse width modulated voltage-source inverter (PWMVSI) in the low voltage range makes it difficult to use constant V/f drives at frequencies below 3 Hz.[2].

B. Vector control or field oriented control

Blaschke in 1972 has introduced the principle of field orientation to realize dc motor characteristics in an induction motor derive. By this control technique the induction machine can be controlled like a separately excited dc motor. Because of dc machine-like performance, vector control is also known as decoupling, orthogonal, or trans vector control [3]. Vector control is applicable to both induction and synchronous motor drives. In DC machine the field flux is perpendicular to the armature flux. Being orthogonal, these two fluxes produce no interaction with each other. Adjusting the field current can therefore control the DC machine flux, and the torque can be controlled independently of flux by adjusting the armature current [4]. An AC machine is not so simple because of the interactions between the stator and the rotor fields, whose orientations are not perfect and vary with the operating conditions. We can obtain DC machinelike performance in holding a fixed and orthogonal orientation between the field and armature fields. In an AC machine by orienting the stator current with respect to the rotor flux so as to attain independently controlled flux and torque. Such a control scheme is called flux-oriented control or vector control. Vector control is applicable to both induction and synchronous motor drives application.

The cage induction motor drive with vector or field oriented control offers a high level of dynamics performance and the closed-loop control associated with this derive provides the long term stability of the system. Induction Motor drives are used in a numbers of industrial and process control applications requiring high performances. In high performance drive systems, the motor speed should closely follow a specified reference trajectory prevailing any load disturbances, parameter variations, and model uncertainties. In order to achieve high performance, field-oriented control of induction motor (IM) drive is employed. However, the controller design of such a system plays a crucial role in system performance. The decoupling characteristics of vector-controlled IM are adversely affected by the parameter changes in the motor. So the vector control is also known as an independent or decoupled control [5].

There are essentially two general methods of vector control:

C. Direct Vector control or Feedback method

In direct field oriented control strategy rotor flux vector is either measured by using a flux sensor mounted in air gap or mathematically by using the voltage equations starting from the electrical machine parameters.

D. Indirect Vector control or Feed-forward method

In indirect vector control strategy rotor flux vector is estimated using the field oriented equations (current model) requiring a rotor speed measurement.IFOC is more popular than DFOC due to implementation simplicity and become the industrial standard. In the IFOC method the rotor flux angle and thus the unit vector $\cos\theta e$ and $\sin\theta_e$ are indirectly obtained by simulation of the rotor speed and slip frequency. The IFOC and DFOC except the rotor angle is generated in an indirect manner using the measured speed ω_r and the slip speed ω_s.

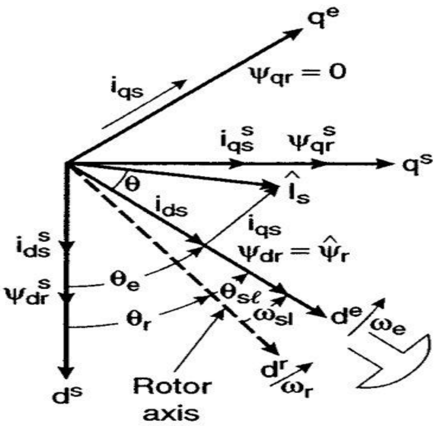

Figure 1.Phasor diagram indirect vector control method of induction motor

E. Proportional – Integral (PI) Control

In this paper complete mathematical model of FOC Induction motor is described and simulated in MATLAB for studies a 50 HP (37KW) induction motor has been considered .The performance of FOC drive with proportional plus integral (PI) controller are presented and analyzed. One common linear control strategy is proportional-integral (PI) control. The PI control law is given below:

$$T = k_p e(t) + k_i \int e(t).dt \;\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Its output is the updating in PI controller gains (k_p and k_i) based on a set of rules to maintain excellent control performance even in the presence of parameter variation and drive nonlinear parameters. The use of PI controllers for speed control of induction machine drives is characterized by an overshoot during tracking mode and an inferior load disturbance rejection. At starting mode the high value of the error is amplified across the PI controller stimulate high variations in the command torque. If the gains of the controller exceed a certain value, the variations in the command torque become high and unstable the system. To overcome this problem we propose the use of a limiter ahead of the PI controller [11].This limiter causes the speed error to be maintained within the saturation limits and stimulating, when appropriately chosen, smooth variations in the command torque even when the PI controller gains are very high.

The motor reaches the reference speed rapidly and without overshoot, step commands are tracked with almost zero steady state error and negligible overshoot, load disturbances are rapidly rejected and variations of some of the motor parameters are fairly well dealt with.

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III. MATLAB SIMULATION CLOSED LOOP V/F SPEED CONTROL METHOD USING PI CONTROLLER

A. *Machine parameters*

In order to start simulating the system, the parameters must be known. They can be either
Calculated or measured as in this investigation. The parameters of the motor, used for simulation are given as follows:

Voltage (V) = 220
Frequency (Hz) =50
Stator resistance (ohm) = 0.087
Stator leakage inductance [H] = 0.8e-3
Rotor resistance (ohm)= 0.228
Rotor leakage inductance [H]= 0.8e-3
Magnetizing inductance [H]= 0.8e-3
Magnetizing inductance [H]= 0.8e-3
Number of poles=4
Proportional gain (Kp) = 100
Integral gain (Ki) =5200

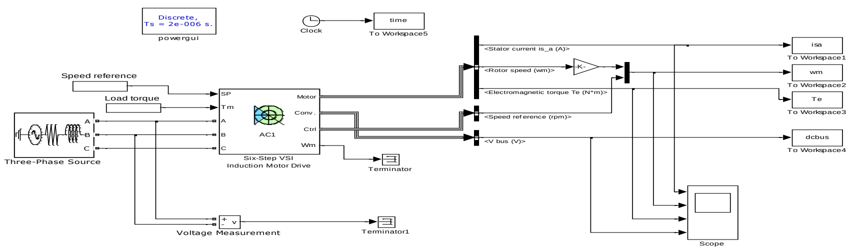

Figure2. Simulink Model of close loop V/f speed control using PI controller

IV. MATLAB SIMULATION OF VCIM BASED OF PI CONTROLLER

Machine parameters

The parameters of the motor, used for simulation are as shown in follows:

Voltage (V) = 220
Frequency (Hz) =50
Inertia =0.089
Stator resistance (ohm)=0.087
Stator leakage inductance (H)=0.08e-3
Rotor resistance (ohm)=0.228
Rotor leakage inductance (H)=0.8e-3
Magnetizing inductance (H)=34.7e-3
Proportional gain (K_p) = 0.5
Integral gain (K_i) = 30
Derivative gain (K_d) =0

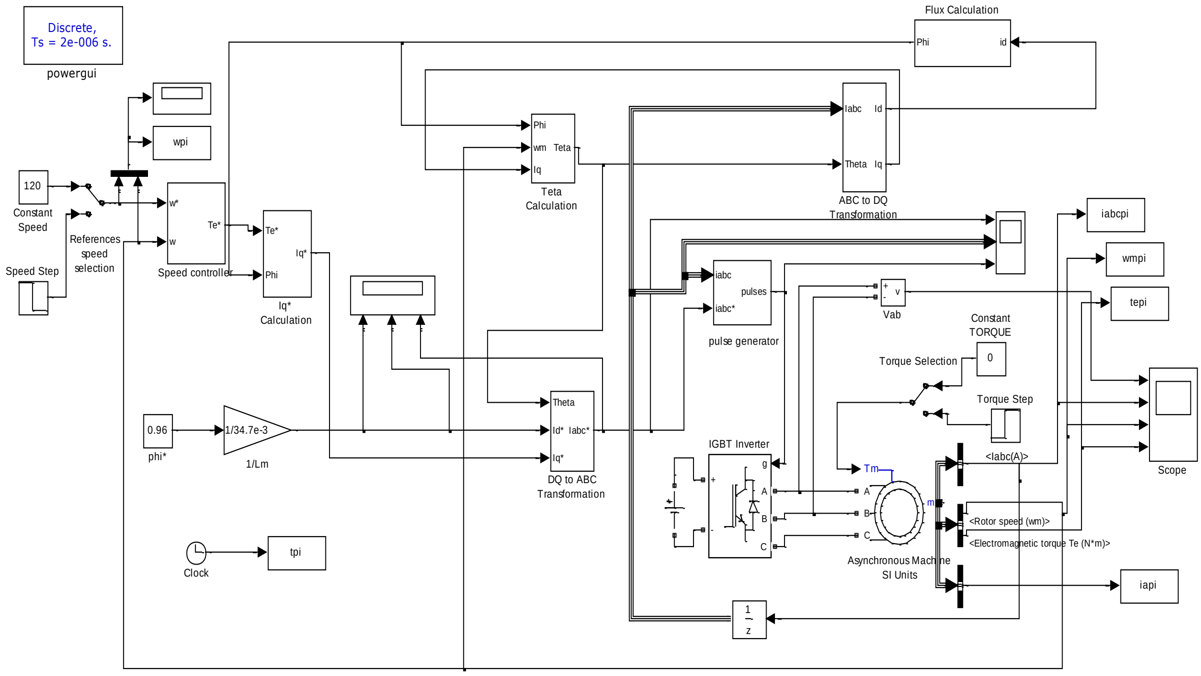

Figure 3. **S**imulink Model of indirect vector Control using P-I controller

V. SIMULATION RESULTS

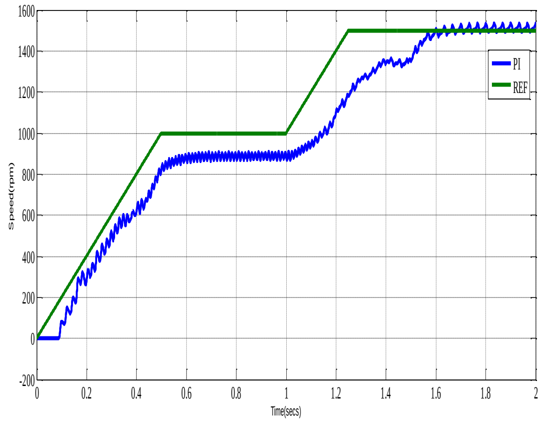

Figure 4. Speed Response of V/f control of IM

The results show that with increase in voltage the speed varies in all load conditions at all frequencies.

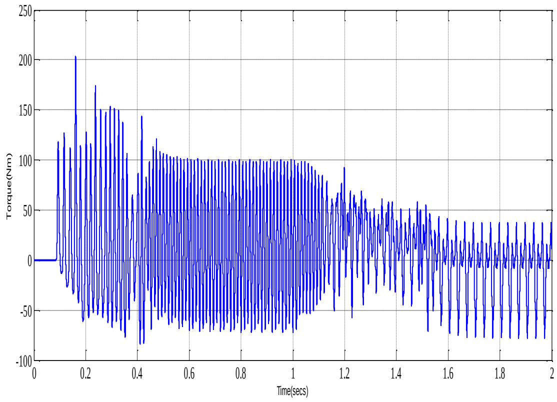

Figure 5. Torque Response of V/f control of IM

It is shown those large torques are obtainable even in low speed ranges, with almost no steady state error in speed.

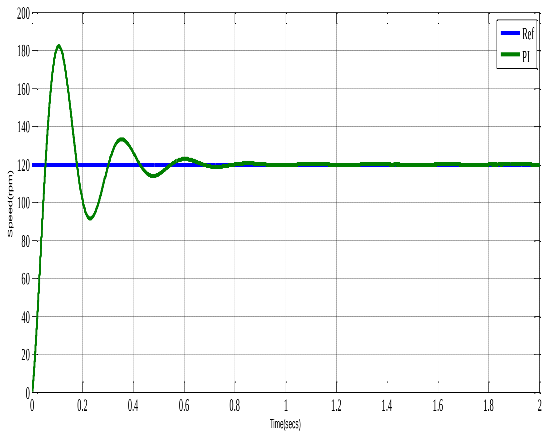

Figure 6. Speed Response of VCIM

Above figure shows the speed response for the motor with different load torque (T,) when the reference speed is120 (rad sec) while keeping the voltage-frequency ratio (V/f) constant.

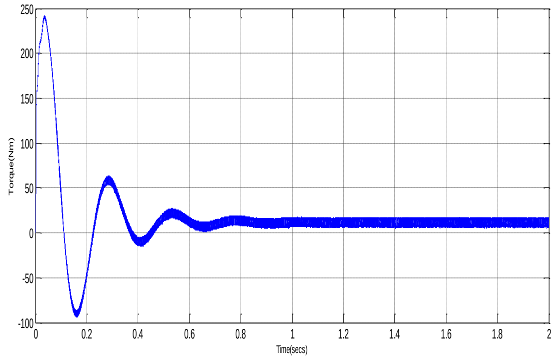

Figure 7. Torque Response of VCIM
This torque response reflects the ripples are less

VI. CONCLUSION AND FUTURE SCOPE

Both the control methods have advantages and disadvantages.

Scalar control is cheap and well implementable method because of these advantages and simplicity, many applications in the industry operate with this control technique. On the other hand it is not satisfactory for the control of drives with fast dynamic behavior, since it gives slow response to transients' .It is a low performance control, but it is a stable control technique. The field oriented control method operates with fast responses. So it satisfies the requirements of dynamic drives method to handle transients. The only disadvantage is its complexity.

Both the VCIM and V/f control of induction motor uses PI controller, which is an excellent controller for linear systems. It reduces the steady state error and provides a smooth tracking with the command signal. But if the system is influenced by uncertainties, which usually composed of unpredictable variations in the machine parameters external load disturbances and modeled and non-linear dynamics, it is very hard or impossible to design the control structure based conventional PI controllers. To provide better control in the presence of such uncertainites. PI controller can be replaced by other robust control techniques, such as optimal control, Variable structure control, Adaptive, Fuzzy and neural control.

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BIOGRAPHIES

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