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Comparative Study of Scalar and Vector Control of Induction Motor by using PI Controller

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***Abstract*—The major purpose of this paper is to implement and study the scalar and vector control on three phase induction motor drives. In scalar control method stator voltage and frequency ratio kept constant. It is also called V/F control. The scalar method is very simple controlling method as compare to vector control which is more complex. Vector control related to phasor control of induction machine. The VCIM drive includes decoupling of the stator current component which produces torque and flux of induction motor. In this paper, an implementation of speed control of an induction motor (IM) using indirect vector control procedure has been developed and simulated. The comparative study of VCIM and traditional V/F control of IM is done on MATLAB/SIMULINK software. Results show the effectiveness of vector control over scalar control method.**

***Index Terms*— Induction motor, scalar control, vector control, mathematic modeling.**

I. INTRODUCTION

The V/F controlled drives are independent to parameters, easy to use and cost is also low. Scalar control drives provide reasonably inferior efficiency than the other control schemes however they are the easy to implement. In V/F control methods, the stator voltage is adjusted in a part of the deliver frequency, except for low and above base speeds [1]. At the present time, on account of the primary growth in power electronics and micro-computing, the control of AC electric machines has visible tremendous development and the probability for industrial uses [2]. That s why it's popular day by day and the main advantages are low cost, simple construction, reliable and high efficiency. These have additionally proved to be safer than DC motors. The speed control of DC motors may also be implemented in a simple manner, since the torque and flux are decoupled but they've the disadvantage of higher rotor inertia and renovation problems related to commutators and brushes. Due high availability of Thyristors, IGBT, and GTO the speed control of motor become more expensive. Vector control operation similar to separated excited dc machine. In dc motor torque and flux decoupled similar way in vector control happen. 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 chosen.

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

A. Scalar control

In this control only control magnitude of stator voltage and frequency kept constant ratio of them.

Open loop V/F controls: This is most common usable method because of its simplicity, less complexity and these types of motors are widely used in industry. On the hand, induction motors were used with open loop 50Hz energy provides for constant speed applications [1 3]. For adjustable speed drive purposes, frequency control is traditional. Nonetheless, voltage is required to be proportional to frequency in order that the stator flux remains constant if the stator resistance neglected. The power circuit consists of a diode rectifier with a single or three-segment ac supply, filter and voltage-fed inverter. Ideally no feedback indicators are required for this control scheme. Some problems encountered in the operation of this open loop drive are the below:

- The speed of the motor are not able to be controlled exactly, on the starting that the rotor velocity can be less than the synchronous speed and that on this scheme the stator frequency and consequently the synchronous speed is the one control variable.
- The slip speed, being the change between the synchronous speed and the electrical rotor velocity, are not able to be maintained, as the rotor speed isn't measured on this scheme [4 5]. It will lead to operation within the unstable area of the torque-speed characteristics.
- The outcome of the above could make the stator currents exceed the rated current by means of a large quantity for this reason endangering the inverter converter combo.

These problems are to be suppress by way of having an outer loop within the induction motor power, in which the exact rotor speed is compared with its reference value, and the error is processed by way of a controller by and large a PI controller and a limiter is used to obtain the slip-speed under certain value**.**

Closed Loop V/F Control: The foundation of constant V/F speed control of induction motor is to apply a variable magnitude and variable frequency voltage to the motor. Both the voltage supply inverter and present source inverters are used in adjustable speed ac drives [5 6]. The following block diagram suggests the closed loop V/F manage making use of a VSI.

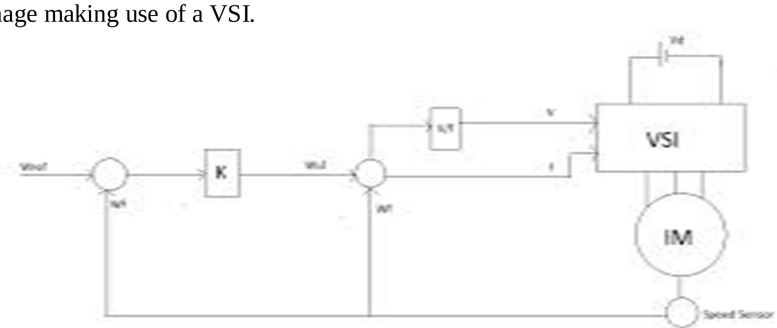

Fig1. Block diagram of closed loop V/F control of induction machine

In this method measure rotor speed by using speed sensor and compare with reference value. The difference between these two values take an error and the error so received is processed in a PI controller and its output sets the inverter frequency.

B. Vector control or field oriented control

Vector control, also called field-oriented control (FOC), is a variable-frequency drive (VFD) control method where the stator currents of a three-phase AC machine are divided as two orthogonal components that can be visualized with a vector. One component defines the magnetic flux of the machine, the other the torque. The control system of the drive calculates from the flux and torque references given by the drive's speed control the corresponding current component references. Typically proportional-integral (PI) controllers are used to keep the measured current components at their reference values. The pulse-width modulation of the variable-frequency drive defines the transistor switching according to the stator voltage references that are the output of the PI current controllers [10]. Vector control induction motor can be control like separately excited dc motor. Vector control is suitable for both induction and synchronous machine drives. In DC machine the field flux is perpendicular to the armature flux. Being orthogonal, these two fluxes produce no interaction with each and other. By adjusting the field current can control the DC machine flux, and the torque may also be control independently of flux by using adjusting the armature current [1]. An AC machine shouldn't be so simple considering that of the interactions between the stator and the rotor Fields, whose orientations usually are not ideal and vary with the running conditions. We are able to obtain DC machine like efficiency in protecting a constant and orthogonal orientation between the field and armature fields. In an AC machine device by orienting the stator current with respect to the rotor flux so that you can attain independently controlled flux and torque [7]. Vector control is suitable to each induction and synchronous motor drives. The cage induction motor drive with vector control presents a high stage of dynamics efficiency and the closed-loop control associated with this derive presents the long term stability of the system. Induction Motor drives are used in a numbers of commercial and procedure control functions requiring excessive performances. In high performance pressure methods, the motor speed will have to intently follow a distinct reference trajectory prevailing any load disturbances, parameter variants, and mannequin uncertainties. With a view to achieve excessive performance, field-oriented control of induction motor (IM) drive is employed. Nonetheless, the controller design of this type of procedure performs a critical role in approach efficiency. The decoupling characteristics of vector controlled IM are adversely affected with the parameter changes in the motor. So the vector control is also known as an unbiased or decoupled control [8].

Direct vector control or feedback control: In direct field oriented control method rotor flux vector is either measured by using utilizing a flux sensor established in air gap or mathematically with the aid of using the voltage equations starting from the electrical computer parameters.

Indirect Vector control or Feed-forward method: In indirect vector control technique rotor flux vector is estimated making use of the Field oriented equations (present model) requiring a rotor speed measurement .IFOC is more wide spread than DFOC as a result of implementation simplicity and become the commercial uses. Within the IFOC procedure the rotor flux angle and as a consequence the unit vector $\cos Q$and $sinQe$ are indirectly acquired by way of simulation of the rotor speed and slip frequency. The IFOC and DFOC besides the rotor angle are generated in an indirect method using the measured speed $\dot{w}_r$ and the slip speed w_s.

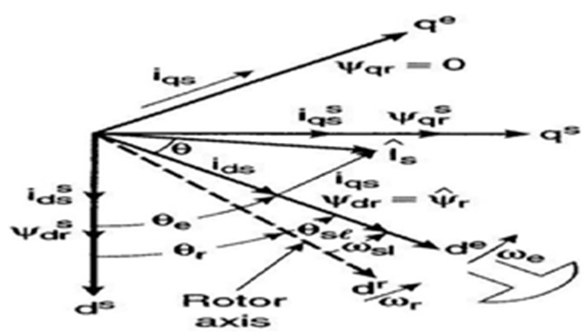

Fig 2. Vector Control Rotor & Stator Flux dq Axis

$$Hds = RsIds + D\Psi ds \qquad \text{(i)}$$
$$Hqs = RsIqs + D\Psi qs \qquad \text{(ii)}$$
$$Hdr = RrIdr + wr\,\Psi dr + D\Psi dr \qquad \text{(iii)}$$
$$Hqr = RrIqr - wr\,\Psi qr + D\Psi qr \qquad \text{(iv)}$$
$$\Psi ds = \int (Hds - RsIds) \qquad \text{(v)}$$
$$\Psi qs = \int (Hqs - RsIqs) \qquad \text{(vi)}$$
$$ET = \frac{3}{2} p\, \Psi dsIqs - \Psi qs\, Ids \qquad \text{(vii)}$$

Where , Hds = stator d axis voltage , Hqs = stator q axis voltage, Hdr = rotor d axis voltage, Hqr = rotor q axis voltage, Ψds = stator d axis flux, Ψqs = stator q axis flux, E_T = Electromagnetic torque.

III. PROPORTIONAL – INTREGRAL (PI) CONTROL

In this paper, the Induction motor model for FOC and scalar control is described. The two system models are simulated in MATLAB for studies a 3 HP induction motor. The system behavior for scalar and FOC drive with PI controller are viewed and analyzed. The PI control law is given by the simple equation (VIII).

$$U = k_p e(t) + k_i \int e(t).dt \qquad \text{(VIII)}$$

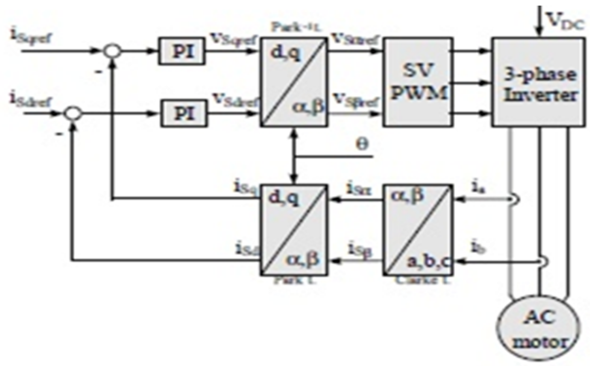

Fig 3. Scheme of FOC for AC- Motor

The output of PI controller is simple depends on the value of k_p and k_i . These values can be found by using Zeigler-Nichols tuning formula. The PI controllers works during tracking the speed and is characterized by way of an overshoot also it shows the inferior performance for load disturbance rejection in case of scalar control.

A. Simulation Results

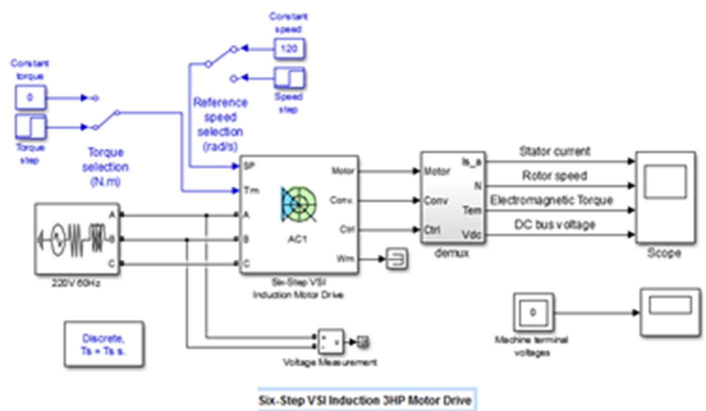

Fig 4. Simulink Diagram of V/F Control of IM

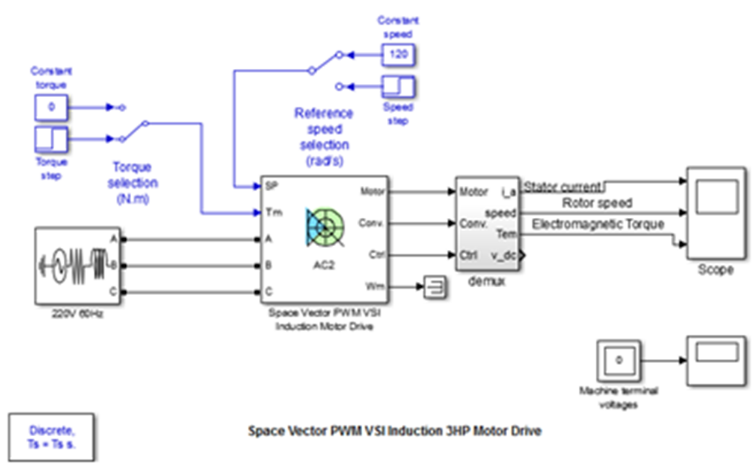

Fig 5. Simulink Diagram of Vector Control of IM

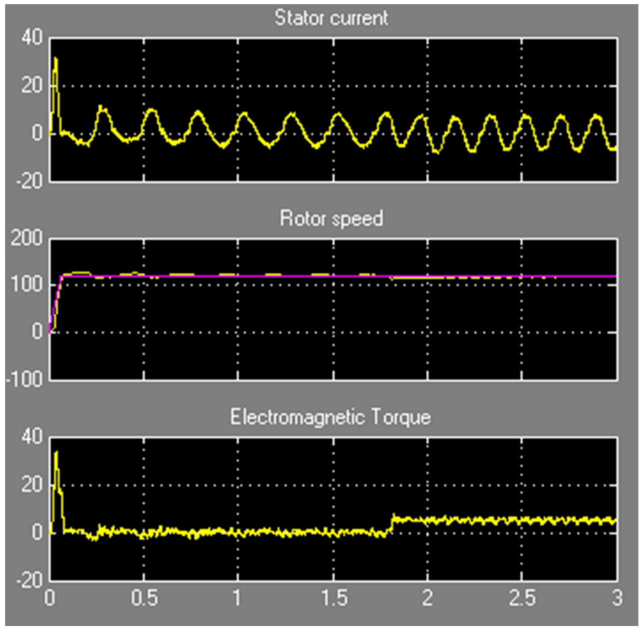

Fig 6. Vector Control

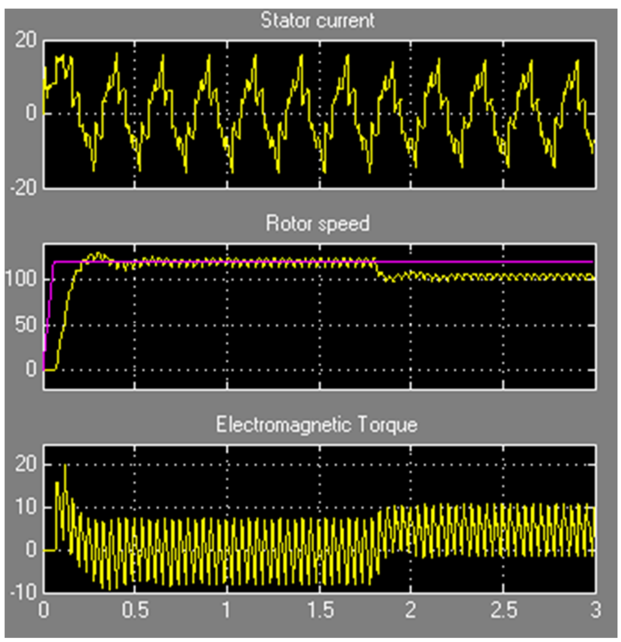

Fig 7. Scalar Control

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
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 (KP) = 1.2
Integral gain (Ki) = 20
The results shows that, when a speed reference step from 0 to 120 rpm is applied at t = 0t, the speed set point doesn't go instantaneously at 120 rpm but follows the acceleration ramp as shown in fig 6 and fig 7. The motor reaches steady state at t = 0.2s in vector control and in scalar control motor take more time for reaching steady state (t = 0.4).
At t = 1.8 s, a load torque of 5 Nm is applied on the motor's shaft. It is observed that a speed decrease and electromagnetic torque increase. When electromagnetic torque = load torque follow constant path and after some time speed also follow reference speed. In vector it follow approx reference value (fig 6) but in scalar control (fig 7) rotor speed very far from reference speed.
The induction motor is fed by a voltage source inverter, which is built using the Universal Bridge Block. The DC bus voltage is produced by a thyristor rectifier and regulated using a PI controller in order to maintain constant volts per hertz ratio. The motor drives a mechanical load characterized by inertia J, friction coefficient B, and load torque T_L.
From above result can say vector control is better than scalar control .In V/F control rotor losses stability during transient and dynamic however vector control behavior good in both conditions as compare scalar control**.**

IV. Conclusion and Future Scope

Both the control approaches have advantages and negative aspects.
Scalar control is low-cost and well implementable process considering the fact that of those benefits and ease, many functions in the enterprise function with this control method. On the other hand it isn't enough for the control of drives with speedy dynamic behavior, when you consider that it gives gradual response to transients .It's a low performance control, however it's a steady control procedure. The field oriented control approach operates with fast responses. So it satisfies the specifications of dynamic drives method to control transients. The only drawback is its complexity.
Both the VCIM and V/F control of induction motor uses PI controller, which is a good controller for linear techniques. It reduces the constant state error and presents a soft tracking with the command signal. But if the procedure is influenced by using uncertainties, which normally composed of unpredictable variants in the machine parameters external load disturbances and modeled and non-linear dynamics, it is vitally tough or unattainable to design the controller constitution established conventional PI controllers. PI controller can be replaced by other powerful controller procedures, Adaptive, Fuzzy and neural control.

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