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Study on Vector Speed Control Method of Three Phase Induction Motor

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Abstract: One of the common electric motors used in most applications is induction motor. Induction motor always operates at a speed lower than the synchronous speed. These motors widely used in various industrial applications require precise control over their rotational speed to ensure efficient operation. Various methods exist for achieving speed control. An increasing number of applications in high performing electric drive systems nowadays use squirrel cage induction motors. The paper describes a simplified method for the speed control of a three phase induction motor.

Keywords*:* Speed Control, Field Oriented Control, Direct Vector Control, Indirect Vector Control, Three Phase Induction Motor, Torque Response

I. INTRODUCTION

Induction motors derive their name from the way the rotor magnetic field is created. The rotating stator magnetic field induces currents in the short circuited rotor. These currents produce the rotor magnetic field, which interacts with the stator magnetic field and produces torque, which is the useful mechanical output of the machine.[4].

Induction motor is so common in industry that in many plants no other type of electrical machine can be found. Electrical machines come in a vast range of size and types. Their torque available on the shaft varies from mNm for micromachines to Mnm for large machines.[1].The advancement of variable speed drive technology is praiseworthy and unbelievable in the past few years. Variable frequency drive is a special type of convertible speed drive. AC drive, Variable speed drive, Adjustable frequency drive, inverter drive etc., are the other forms of names of variable frequency drive. [2].

Traditionally, induction motors have been run at a single speed, which was determined by the frequency of the main voltage and the number of poles in the motor .controlling the speed of an induction motor is far more difficult than controlling the speed of a DC motor since there is no linear relationship between the motor current and the resulting torque as there is for a DC motor. [3].The control methods for the induction motor can be divided into two parts: Vector control and scalar control Strategies.

1.1 SPEED OF INDUCTION MOTOR

Speed Of induction motor mainly depends upon frequency and number of poles available. Synchronous speed is directly proportional to the frequency. As the frequency increases speed of the induction motor increases And, also synchronous speed is inversely proportional to the number of poles. As the number of poles increases, speed will decrease. And if we decrease the number of poles the speed will increase.

$$\text{Synchronous Speed} = 120f / P$$

Where,
f=frequency in Hz
P=Number of poles [5].

1.2 VECTOR CONTROL OF INDUCTION MOTOR

Scalar control is simple to implement, but the inherent coupling effect (that is both the flux and the torque are functions of voltage or current and frequency) gives sluggish response and the system is prone to instability because of a high order system effect. Normal Scalar control of induction machine aims at controlling the magnitude and frequency of the currents and voltages but not their phase angles.

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Field oriented control provides a good level of dynamic performance and the motor drive with closed-loop control assures a long term stability of the system. It is also defined as "flux oriented control" or "indirect torque control". This type of control system is of three kinds such as magnetizing flux oriented control, stator flux oriented control, rotor flux control. VFD control method in which the stator currents of a three -phase AC electric motor are identified as two orthogonal components that can be visualized with a vector. One Component defines the magnetic flux of the motor, the other the torque.

Table -1: Difference between Scalar and Vector Control

Control Method Required by the application or process	Motor Scalar Control	Motor Vector Control
Torque Control:		
Resolution	1:1000	1:1000
Non-Linearity	±12%	±12%
Torque Step Rise Time	150ms	10 to 20 ms
Speed Control:		
Resolution	1:20000	1:2000
Speed Range	1:40	1:1000
Static Accuracy	±0.01%	±0.01%
Dynamic Accuracy	3% sec	0.3% sec

II. THE PRINCIPLE OF VECTOR CONTROL

Vector control of induction motors works by decoupling the motor's magnetic flux and torque, allowing each to be controlled independently. The principle is based on the creation of a rotating reference frame aligned with the rotor flux .Thus, motor control is transformed into a linear problem akin to a separately excited DC motor.

This method enhances the dynamic response of the motor, achieving better control over speed, torque, and position. The decoupling of torque and flux control also eliminates the mutual influence between them, yielding superior performance.[6]

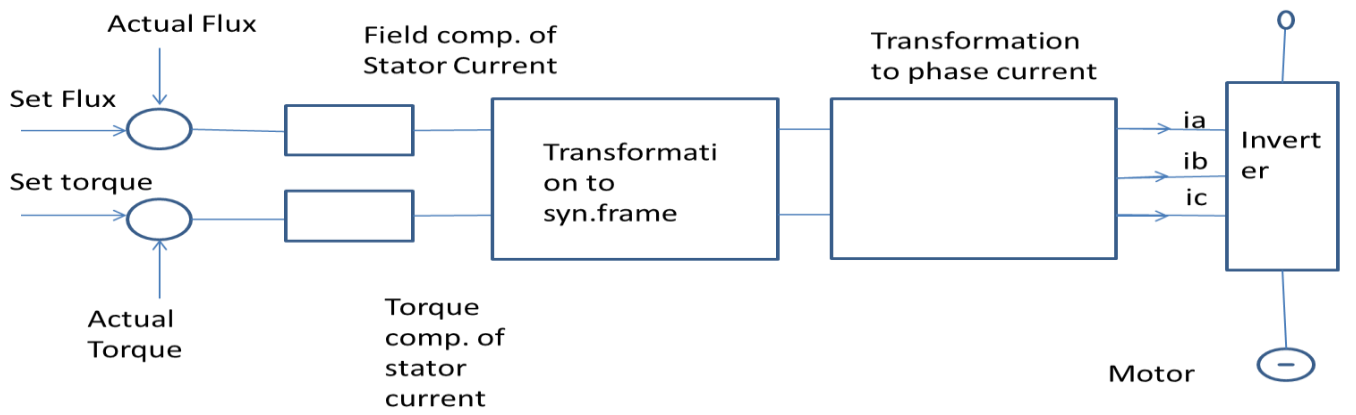

Fig-1 Implementation of field oriented control

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- **COMPONENTS OF VECTOR CONTROLLED INDUCTION MOTOR**

Vector controlled induction motor systems typically comprise the following elements:

- Induction Motor: The primary component that converts electrical energy into Mechanical energy.
- Vector Controller: A device that controls the Motor's speed and torque separately.
- Encoder: An essential component used to measure the rotor's position and speed.
- Power Inverter: This component converts DC power into AC power for the motor.

III. CLASSIFICATION OF VECTOR CONTROLLED INDUCTION MOTOR

1) Direct Vector Control
2) Indirect Vector Control

The basic schemes of indirect and direct methods of vector control are shown in figures below. Direct Vector control method is related to the unit vector originated from the stator flux. These vector signals are calculated directly or assumption from the stator voltage and current signals. The components of stator flux are calculated from the stator quantities. To Obtain rotor field angle information rotor speed is not required in this scheme. Indirect vector control method is most common and more reliable method than direct vector control method. In this method the unit vectors and rotor field angles are measured indirectly by summation of slip frequency and speed of the motor. [2]

3.1 DIRECT VECTOR CONTROL

The Direct Method of Vector control method which was originally proposed by BLASCHKE is as shown in fig 2 . This technique utilizes direct sensing of the air gap flux vector by using one of the measured techniques

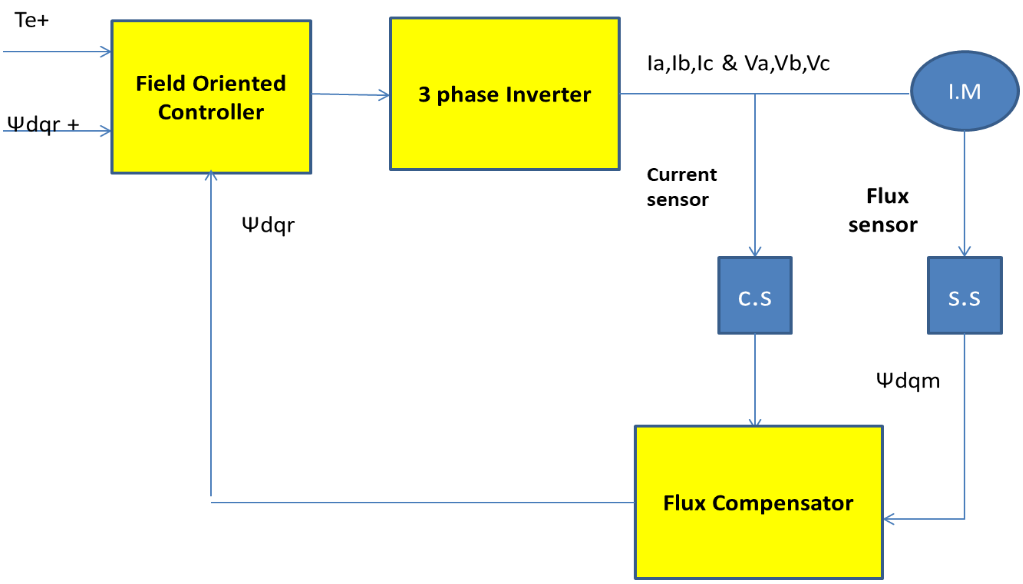

Fig-2 Direct Flux Oriented Control of Three Phase Induction Motor

The measured air gap flux signal is feedback to the control and used to decouple the torque producing component of stator current from the producing component. Since this method uses feedback control and direct sensing of the regulated variable, it is essentially insensitive to variations. [7]

3.2 INDIRECT VECTOR CONTROL

Indirect vector control scheme is simpler to implement than the direct field orientation method .Hence there is increasing popularity towards the indirect field orientation method. The indirect method of field orientation was originally proposed by HASSE as shown in fig.3. This method avoids the requirement of flux acquisition (sensing devices)by using known motor parameters to compute the appropriate motor slip frequency to obtain the desired flux position.

On the other hand ,the rotor flux is estimated from the stator current vector, voltage vector and or rotor speed, and then this estimate is in effect, fed forward to the flux and torque controllers.

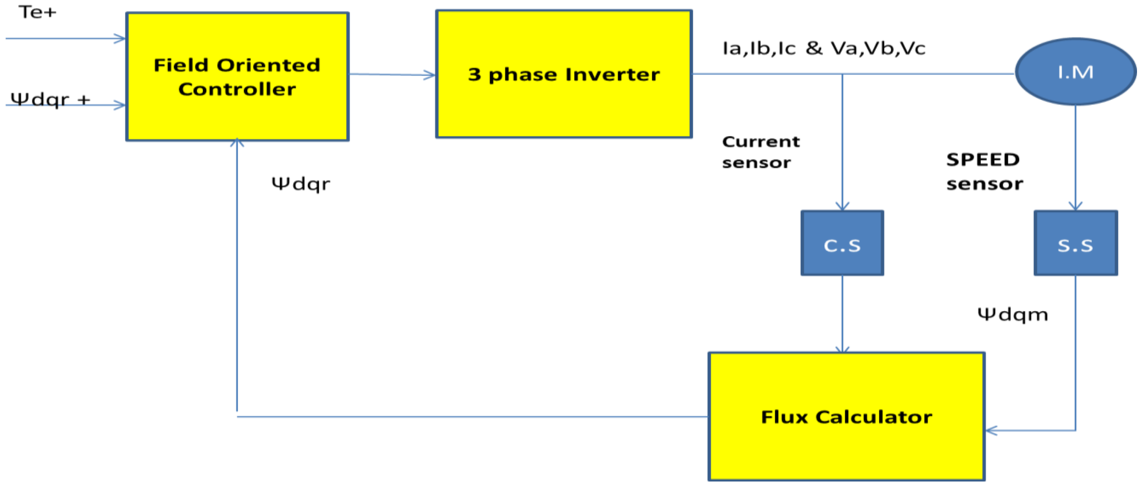

Fig-3 Indirect Flux Oriented Control of Three Phase Induction Motor.

3.3 ADVANTAGES OF INDIRECT VECTOR CONTROL METHOD

1) The sensors are eliminated
2) The dynamic performance of the indirect vector control is better than the direct vector control
3) The cost is less

3.4 ADVANTAGES OF DIRECT VECTOR CONTROL METHOD

1) Improved torque response.
2) Torque controls a low frequency and low speed.
3) Dynamic speed accuracy
4) Reduction in power consumption
5) Short term overload capability

IV. CONCLUSIONS

This paper examines the different types in the field oriented control of induction motors including the principles, classification (direct and indirect field orientation control).Due to the number of disadvantages of direct vector control method such as requiring so many sensors which become a tedious work as well as costlier , poor flux sensing at lower speed also persists. From this it is clear that the indirect vector control techniques supersede the direct vector control and is more used .Hence the indirect vector control method is more adapted technique.

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