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Vector Controlled Induction Motor Drive

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Abstract: *An induction motor is a versatile industrial drive. Among the industrial drives used,70% are asynchronous drives. Control of these drives is an important aspect. Vector Control(VC) technique is an excellent control strategy to control torque in an induction motor. It is also called, "Direct Field Orientation (IFO) Asynchronous Drives". These drives are increasingly employed in industry. The performance of VC drives often degrades. Induction motor works on best performance at certain voltage and frequency for certain loads. When the load torque and speed changes. Thus, the efficiency of the induction motor is increased.Due to the dynamics of induction motor (IM) control, which are multivariable, highly nonlinear, and time-varying, as well as the lack of measurements, this is a challenging and complex engineering problem. This work develops and analyzes vector control for three-phase squirrel cage induction motor speed control. The current method forgoes the usage of flux and speed sensors, resulting in a reduction in mechanical cost and robustness. The dynamic control efficiency of motors has substantially improved because to the use of vector control in place of conventional control methods such employing the voltage to frequency ratio as a constant.*

Keywords*:* Field Oriented Control (FOC),PI, Squirrel Cage Induction Motor, Vector Control

I. INTRODUCTION

The drawbacks of DC machines include their higher cost, more rotor inertia, and commentator and brush maintenance issues. Additionally, commentators and brushes restrict machine speed and peak current, create EMI issues, and prevent a machine from operating in hazardous or explosive conditions. Dc machine drive converters and controls, however, are straightforward, and the machine's torque response is quick. The above-mentioned drawbacks of dc machines are not present in ac machines. For applications requiring variable speed, a three-phase induction motor is frequently supplied with variable frequency and variable voltage via a voltage source inverter. To achieve the needed output voltage in the line side of the inverter, an appropriate pulse width modulation (PWM) approach is used.

Due to the numerous ways to regulate the speed and torque of the motor that are currently accessible, the use of three-phase induction machines has significantly increased in industrial applications. Scalar control and vector control procedures make up the two categories of induction motor control techniques. When compared to vector control, scalar control is a rather straightforward method. The scalar control approach is used to regulate the magnitude of the selected quantities.Volts/Hertz constant is the method utilized for the induction motor (IM). Scalar control cannot be used to govern systems with dynamic behaviour, making vector control a more difficult technique. Scalar control's progression was inevitable. The vector control approach uses vector quantities and space phasers to control the desired values. Because identifying the motor's field flux is necessary for implementation, it is also known as field-oriented control.

In this research, a vector control technique implementation of a controller for speed control of an IM has been designed and thoroughly examined. The Field Oriented Control of IM mathematical model is fully developed in this study. The simulation motor is a squirrel cage IM. Asynchronous AC motors are IMs. The squirrel cage motor, which has benefits including mechanical robustness, simplicity of design, and low maintenance requirements, is the most commonly used IM. Pumps and fans, paper and textile mills, propulsion for subways and locomotives, electric and hybrid cars, household appliances, heat pumps and air conditioners, rolling mills, wind generation systems, robotics, etc. are some of these uses.

The industrial variable speed drive system with vector control technology thus uses IM. For speed control, this system needs a speed sensor. However, in particular circumstances, such as motor drives in high-speed drives and hostile

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environments, speed sensors cannot be placed. It also grows pricey and cumbersome. Although the performance is satisfactory at high speeds, it is subpar at extremely low speeds. The majority of methods include parameter adjustment in FOC and rotor flux angle estimation. Any controller can easily be developed in FOC and get close to the desired system response. But if the controlled electrical drives demand high performance, that is, steady state and dynamic tracking capacity to set point changes and capacity to recover from system variances. The performance was subsequently tracked, regulated, and then compared using a traditional PI, fuzzy, and neural controller for such drives. As a result, current research focuses on sensor-less vector control issues that lower costs and boost dependability.

II. DYNAMIC MODEL OF INDUCTION MOTOR

An Induction Motor is typically described in one of three reference frames: an arbitrarily spinning frame, a stationary frame, or a synchronous frame. It is typically more practical to mimic an IM and its converter on a stationary reference frame for transient studies of changeable speed drives. Additionally, due to the zero frame speed, computations with a fixed reference frame are simpler than those with a revolving frame. A synchronously revolving frame that produces constant values of steady-state voltages and currents under balanced conditions is utilized for tiny signal stability analysis.

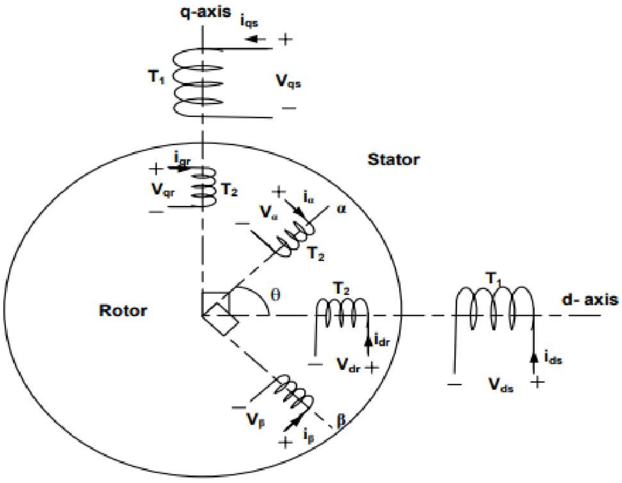


Figure 1. Two-Phase Equivalent Diagram of Induction Motor

Figure. 1 depicts the two-phase equivalent diagram of a three-phase induction motor with windings on the stator and rotor referred to as the d-q axis. The rotor winding is at an angle of r from the stator d-axis, and the windings are spaced apart by 90o. It is expected that the d-axis is leading the q-axis in the rotor's clockwise revolution. The spinning magnetic field will rotate at the supply frequency but counter to the phase sequence of the stator supply if the clockwise phase sequence is d-q. As a result, the rotor is dragged counter clockwise in the direction of the revolving magnetic field in this instance. Figure 1 shows the voltages and currents of the stator and rotor windings.The stator and rotor each have T1 and T2 turns per phase, respectively.The terminal voltages calculated from Figure 1 above are as follows:

$$V_{qs} = R_q i_{qs} + p(L_{qq} i_{qs}) + p(L_{qd} i_{ds}) + p(L_{q\alpha} i_\alpha) + p(L_{qb} i_\beta) \quad (1)$$

$$V_{ds} = p(L_{dq} i_{qs}) + R_d i_{ds} + p(L_{dd} i_{ds}) + p(L_{d\alpha} i_\alpha) + p(L_{qb} i_\beta) \quad (2)$$

$$V_\alpha = p(L_{\alpha q} i_{qs}) + p(L_{\alpha d} i_{ds}) + R_\alpha i_\alpha + p(L_{\alpha\alpha} i_\alpha) + p(L_{\alpha\beta} i_\beta) \quad (3)$$

$$V_\beta = p(L_{\beta q} i_{qs}) + p(L_\beta i_{ds}) + p(L_{\beta\alpha} i_\alpha) + R_\beta i_\beta + p(L_{\beta\beta} i_\beta) \quad (4)$$

The following are the assumptions made in order to simplify the (1) to (4).

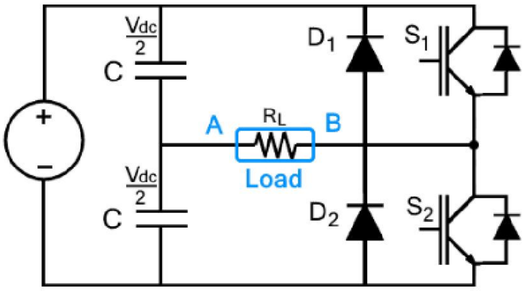
- Uniform air-gap
- Balanced rotor and stator windings with sinusoidal distribution of magneto motive forces (mmf)
- Inductance in rotor position is sinusoidal and
- Saturation and parameter changes are neglected

III. PRINCIPLE OF VECTOR CONTROL

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. If the torque is increased by incrementing the slip or frequency the flux tends to decrease and this flux variation is very slow. The flux decrease is then compensated by the flux control loop, which has a large time constant. This temporary dipping of flux reduces the torque sensitivity with slip and lengthens the response time. The variations in the flux linkages have to be controlled by the magnitude and frequency of the stator and rotor phase currents and their instantaneous phases. Normal scalar control of induction machine aims at controlling the magnitude and frequency of the currents or voltages but not their phase angles.

Separately excited dc motor drives are simple in control because they independently control flux, which, when maintained constant, contributes to an independent control of torque. This is made possible with separate control of field and armature currents, which, in turn control the field flux and the torque independently. Moreover the dc motor control requires only the control of the field or armature current magnitudes, providing simplicity not possible with an ac machine. In contrast, the induction motor drive requires a coordinated control of stator current magnitudes, frequencies and phase magnitude making it a complex control. As with the dc motor drives, independent control of flux and the torque is possible in ac drives.

IV.INVERTER



The voltage source inverter's schematic is depicted in fig. 6.The torque status output and flux status output are handled by switching logic. The purpose of the best switching logic is to choose the stator voltage vector that will satisfy the outputs for both torque status and flux status.

V. AXES TRANFORMATION

We know that per phase equivalent circuit of the induction motor is valid only in steady state condition. But, it is not that much effective with the transient response of the motor. In transient response condition three phase voltages and currents are not in balance condition. Thus it becomes too much difficult to study the machine performance by analyzing the three phases. In order to reduce this complexity, transformation of axes from 3 – Φ to 2 – Φ is necessary. Another reason for transformation is to analyze any machine of „n‟ number of phases. Thus, an equivalent model of 3 – Φ to 2 – Φ is adopted universally, i.e. „d – q model.

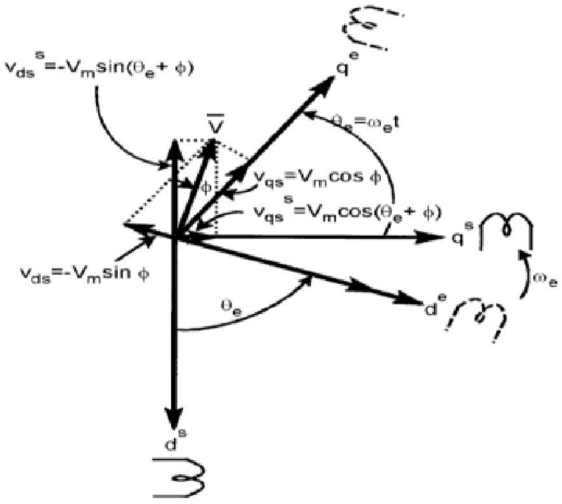


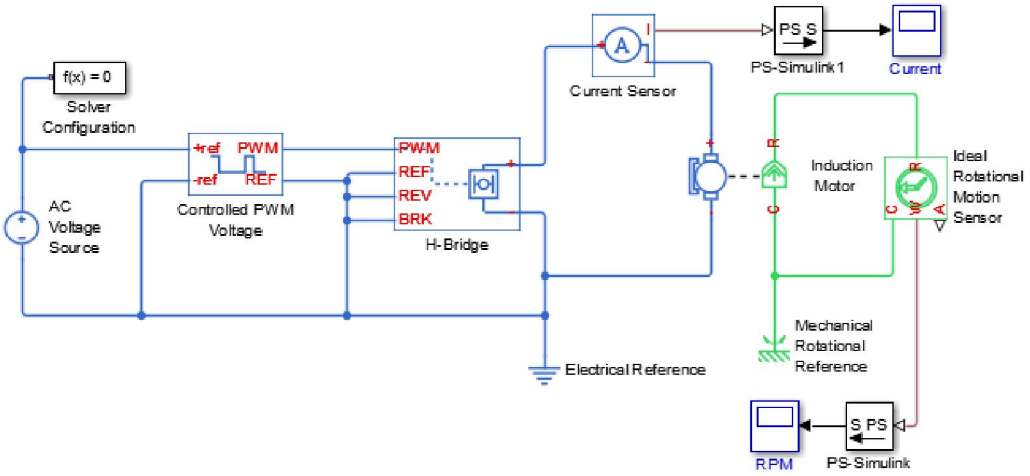
Figure 4. Three-Phase to Two-Phase Transformation

VI. VECTOR CONTROL OF INDUCTION MOTOR

To investigate the many features of induction motor control, Matlab/Simulink simulates the vector control or FOC of the motor. This software enables highly accurate modelling of the real system. It offers an interactive environment for users and a huge selection of numerical algorithms. This section will cover using Simulink blocks to implement vector control of an induction motor. The Simulink diagram of the vector-controlled IM block for simulation is shown in Fig. 7. This system is made up of the Induction Motor Model, the Two Phase to Three Phase transformation block, the Three Phase to Two Phase transformation block, the Flux estimator block, and the Inverter block.

VII. MATLAB SIMULATION & RESULTS

1: MODEL AND SIMULATION RESULTS FOR VECTOR CONTROLLED INDUCTION MOTOR DRIVE:



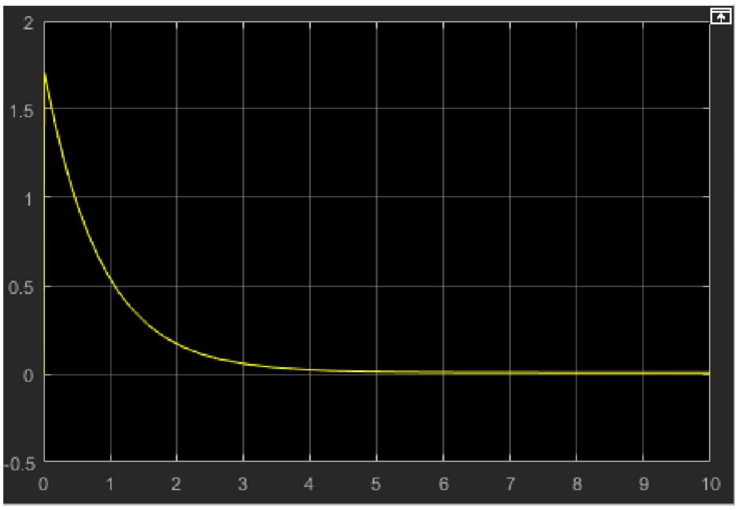


Figure 5: Current Flow

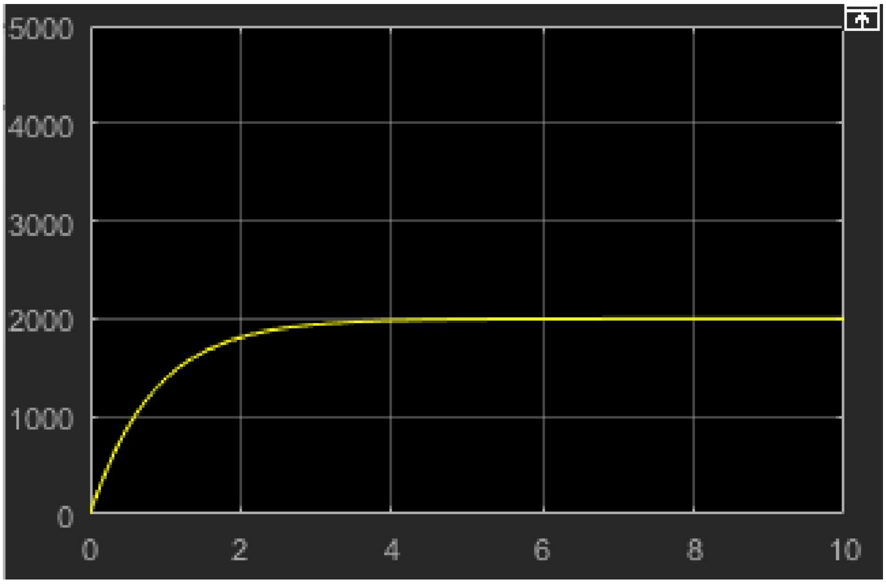


FIGURE 6: Induction Motor Drive RPM

VIII. CONCLUSION

In this paper, we use a vector control technique to create sensor less control of an IM. The details of indirect vector control are provided in this publication. Using MATLAB/SIMULINK, simulation results of vector control of an induction motor (IM) are obtained and displayed. The drive's transient and steady-state performance have been provided based on the study of simulation data. The resulting simulation results are used to make the observations listed below.

1) Dynamic response of the drive is fast.

2) Using vector control, we are estimating the speed which is same as that of the actual speed of an IM.

Thus we can also increase the robustness of the motor as well as response of motor to transient condition/ dynamic loading is achieved.

Open loop V/f control of IM drive with SPWM VSI and SVPWM VSI are compared. It is observed that SVPWM method gives higher performance than SPWM method in terms of THD, fundamental line voltage and speed response. And the performance can be further improved by varying modulation index from low to high value.

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