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# IMPLEMENTATION OF PROTOTYPE SIX PHASE INDUCTION MOTOR AND ITS SPEED CONTROL BY VECTOR CONTROL METHOD

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***ABSTRACT:*** *Multiphase machines are of interest to be applied in electric ship propulsion, where increased power ratings, reliability of operation, redundancy and efficiency are required. The study of modeling and control of multiphase drives is important to realize this application. The main purpose of this thesis was to implement and test control methods for a six-phase induction motor drive. The work focused on continuation and improvement of previous results achieved in the same area of application. The modeling of six-phase induction machine using two different approaches was studied. Based on these approaches, two types of vector control methods were implemented. These are single synchronous frame control and double synchronous frame control. The six-phase induction motor drive was tested for different operating conditions using the two control methods. The motor is normally supplied from two inverters with a split direct current link. The direct current link voltages are kept equal and the two 3-phase groups of the motor share the torque and power equally. Testing the drive during normal operation showed desired control performance using both single synchronous frame control and double synchronous frame control methods.*

***KEYWORDS:*** *Six-phase induction motor, direct current*

## INTRODUCTION

Electric propulsion for ships emerged during the early 20th century. However, propulsion systems driven by diesel engines and gas turbines have been the most widely used. Electric ship propulsion has gained a renewed interest during recent decades because it provides several advantages. Some of these benefits include reduced fuel consumption and maintenance, improved maneuverability, less propulsion noise and vibration, reduced vulnerability to a single system failure and flexibility in location of thruster devices. The increased interest in electric ship propulsion can be mainly attributed to advances in power electronics, digital control systems and electric machine design. These advances have enabled the recently increasing applications of electric motor drives in the marine industry.

Although machines were introduced more than hundred years ago, the research and development in this area appears to be never ending. For machine drive applications, multiphase induction motor could potentially meet the demand for high power electric drive systems which are both rugged and energy efficient. High phase number drives possess several advantages over conventional three phase drives such as reducing the amplitude and increasing the frequency of torque pulsation, reducing rotor harmonic currents, reducing the current per phase without increasing the voltage per phase, lowering the dc link current harmonics, higher reliability and increased power. Multiphase induction motors have found many applications such as electric/hybrid vehicles, aerospace applications, ship propulsion etc.

## STATUS OF VARIABLE SPEED DRIVE

The electrical machine that converts electrical energy into mechanical energy and vice versa, is the workhorse in a drive system the basic function of a variable speed drive is to control the flow of energy from the mains supply to the mechanical system process. Energy is supplied to the mechanical system through the motor shaft. Two physical quantities are associated with the shaft namely torque and speed, in practice either one of them is controlled and referred to as torque control or speed control.

Apart from flexibility of operation at various frequencies, variable frequency drives have an added advantage of energy conservation. Figure 1 show how the power consumption reduces in variable frequency drives as compared to constant speed drives.

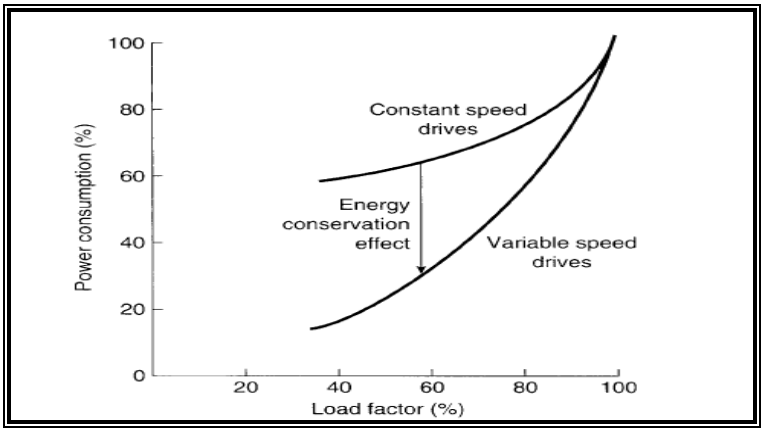


***Fig.1 Energy Saving Characteristics of Variable Frequency Drives***

In the past ac motor drives were mainly used in fixed speed applications. Variable speed applications were dominated by dc drives. Direct current (dc) motor drives were used for speed control because the flux and torque of dc motors can be controlled independently and the electromagnetic torque is linearly proportional to the armature current. Thus desirable speed and position control can be achieved.

But dc motors have disadvantages due to existence of commutator and brushes. Firstly Brushes require periodical maintenance secondly owing to the sparks created by the commentators; dc motors cannot be used in potentially explosive environment. Finally mechanical contacts of commutator and brushes limit high speed operation.

These problems can be overcome by ac motors which have simple and rugged structures. Their small dimensions as compared to dc motors allow ac motors to be designed with substantially higher output rating, low weight and low rotating mass.

Although squirrel cage induction motor was cheaper than dc motor, the converter and control circuit of an induction motor drive was very expensive compared to those for a dc drive Therefore the total cost of an induction motor drive was significantly higher than that of a dc drive.

The fast progress in the development of ac motor drives in the past two decades was mainly due to development of power electronic devices, powerful and inexpensive microprocessors and modern ac motor control technologies. This resulted in reduction in cost of ac drive.

The ac variable speed drive has experienced two major control strategies namely scalar control and vector control.

Scalar control is used in low cost, low performance variable speed drives. This method does not guarantee good dynamic performance because transient states of motor are not considered in the control algorithm. Though some efforts were made to improve the scalar-control performance, the result is still unsatisfactory. So the vector control was introduced by Hasse and Blashke in order to achieve performance comparable to dc drives. Main advantage of vector control is that good dynamic performance of the drive is obtained.

## REVIEW OF LITERATURE

In order to frame research problem, extensive study of the Multiphase induction motors and their related problems was carried out. Three-phase induction machines are today a standard for industrial electrical drives. Cost, reliability, robustness and maintenance free operation are among the reasons these machines are replacing dc drive systems. The development of power electronics and signal processing systems has eliminated one of the greatest disadvantages of such ac systems, which is the issue of control. With modern techniques of field oriented vector control, the task of variable speed control of induction machines is no longer a disadvantage, the need to increase system performance, particularly when facing limits on the power ratings of power supplies and semiconductors, motivates the use of increased phase number, and encourages new PWM techniques, new machine design criteria and the use of harmonic current and flux components. In a multi-phase system, assumed to be a system that comprises more than the conventional three phases, the machine output power can be divided into two or more solid state inverters that could each be kept within prescribed power limits, also, having additional phases to control mean additional degrees of freedom available for further improvements in the drive system.

Variable-speed AC motor drives with more than three phases (multi-phase drives) have several advantages when compared to the standard three-phase realizations. The current stress of the semiconductor devices decreases proportionally with the phase number, torque ripple is reduced, rotor harmonic currents are smaller, power per rms ampere ratio is higher for the same machine volume and harmonic content of the DC link current for VSI fed drives is reduced. Other advantages include an improvement in the noise characteristics and a reduction in the stator copper loss, leading to improved efficiency. Further advantages are related to the higher reliability at the system level, since a multi-phase drive can operate with an asymmetrical winding structure in the case of loss of one or more inverter legs/machine phase. Applications of multi-phase induction motor drives are mainly related to the high-power/high-current applications.

The choice of asymmetrical (30° displacement between two three-phase windings) rather than symmetrical (60° displacement between two three-phase windings) six phase configuration was in the early days of the multiphase induction motor drives dictated by the need to eliminate the 6th harmonic of the torque ripple, caused by the 5th and the 7th harmonics of the stator current.

Output Torque of multiphase induction motors is much higher than that of conventional three phase Induction Motor. Emil Levi [2006] provides a review of the recent developments in the area of multiphase induction motor control. In this paper Vector control and direct torque control (DTC) are addressed and utilization of the additional degrees of freedom that exist in multiphase machines for differing purposes is described (higher stator current harmonic injection for torque enhancement and control of a group of series-connected multiphase motors supplied from a single multiphase VSI).

## RESEARCH OBJECTIVE

To achieve these goals, following research objectives are set:

1. To design practicable, techno economically competent, six phase, and star connected Induction motor.
2. To avoid complexity of design and control, this innovative design should not need any third harmonic current injection and Special current waveforms for torque improvement.
3. To carry out mathematical modeling of the designed six phase induction motor for vector control.
4. To carry out simulation of Multi-motor vector control in Matlab and compare the same with three phase induction motor.
5. To carry out simulation of vector control of six phase induction motor in Matlab. Compare the same with three phase induction motor.
6. To test the developed prototype six phase induction motor first with three phase supply and then with six phase supply.
7. To use two three phase Space Vector Pulse Width Modulation (SVPWM) inverters for six phase supply after thorough study.
8. To run the developed prototype motor using two numbers of three phase SVPWM inverters suitable as per the motor rating.
9. To develop control algorithm, Sensor less vector control is to be studied in detail and then implemented for control.

10. Field Protected Gate Array (FPGA) technique of sensor less vector control is to be studied and implemented. FPGA is a silicon chip containing an array of configurable logic. A system of FPGA chip is more reliable as they do not need any control software.
11. To compare motor performance with other high power available motor technologies and equivalent three phase Induction Motor.

## SCOPE OF RESEARCH

1. From the above research objectives the scope of the research is derived as to design practicable, techno economically competent, six phases, star connected Induction motor. To avoid complexity of design and control, this innovative design should not need any third harmonic current injection and Special current waveforms for torque improvement.
2. To carry out mathematical modeling of the designed six phase induction motor for vector control. To carry out simulation of Multi-motor vector control in Matlab and compare the same with three phase induction motor. And to carry out simulation of vector control of six phases induction motor in Matlab. Compare the same with three phase induction motor.
3. To test the developed prototype six phase induction motor first with three phase supply and then with six phase supply.
4. To use two three phase Space Vector Pulse Width Modulation (SVPWM) inverters for six phase supply and to run the developed prototype motor using two numbers of three phase SVPWM inverters suitable as per the motor rating.
5. To develop control algorithm, Sensor less vector control is to be studied in detail and then implemented for control. Field Protected Gate Array (FPGA) technique of sensor less vector control is to be studied and implemented. FPGA is a silicon chip containing an array of configurable logic. A system of FPGA chip is more reliable as they do not need any control software.

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