

CHAPTER ONE

INTRODUCTION

1.1 General Concepts

The history of electrical motors goes back as far as 1820, when Hans Christain Orested discovered the magnetic effect of an electric current. One year later, Michael Faraday discovered the electromagnetic rotation and built the first primitive Direct Current (DC) motor. Faraday went onto discover electromagnetic induction in 1831. Nicola Tesla first developed the poly-phase induction motor in 1886 and by 1890 the simple three-phase motor had been developed. Currently, the main types of electric motors are still the same, DC, Alternating Current (AC) asynchronous and synchronous, all based on Orested, Faraday and Tesla's theories developed and discovered more than a hundred years ago. An electric drive performs the conversion of electrical energy to mechanical energy or vice-versa. The use of drives for motion control is relevant to all aspects of life, such as production plants, home appliances, robots, and transportation of people or goods [1].

Electric drives may run at constant speed or at variable speed. DC motors by their nature allow for a completely decoupled and independent control of the flux-forming field current and the torque forming armature current. Because of this complete separation, very simple and computing time saving control algorithms were developed, which gave the DC motor preferred use especially in high performance drive systems within the early years of the computerized feedback control. However, DC motors have basically two drawbacks, which are the existence of commutators and brushes. These two disadvantages implied not only periodic maintenance but also difficulty to work in dirty and explosive environments [1, 2].

On the other hand, induction motors have been the most widely used and are often viewed as the workhorse of modern industry in fixed speed applications

for reasons of cost, size, weight, reliability, ruggedness, simplicity, efficiency and ease of manufacture. However, because of the involved model high nonlinearities, multivariable, highly coupled, rotor variables are rarely measurable and its parameters vary with operating conditions; these require much more complex methods of control, more expensive and higher rated power converters than DC motors [1, 2]. The development of enabling technologies was slow until the introduction of semiconductor power switches in the 1950's, allowing the development of commercial variable frequency inverters in the 1960's. It then became viable to use variable speed induction motors in some low performance variable speed applications. The search for simple control schemes similar to those used for DC drives, has led to the so-called Vector Control (VC) or Field Oriented Control (FOC) schemes, in which by means of a variable transformation to a rotational frame, it is possible to obtain two current components to produce the torque and the flux respectively. Furthermore, these current components can be independently controlled so as to achieve a decoupled control. By using these techniques, vector controlled induction motors have proved to outperform the DC ones. Since then, the induction motor has replaced the DC motor in many demanding high performance motion control applications, offering many advantages when compared with DC motor. First of all, it is very cheap. Next, it has very compact structure and insensitive to environment. Furthermore, it does not require periodic maintenance like DC motors [3, 4].

Traditionally, there have been two conventional methods which vector control is achieved by them: Direct Vector Control (DVC) and Indirect Vector Control (IVC). Both direct vector control and indirect vector control, has been successfully established in theory and practice. However, the majority of these control strategies requires a perfect knowledge of the motor speed or position of its shaft, hence the use of sensor dedicated to the measure these variables. The sensors include the search coils, coil taps, or Hall Effect sensors. The use of this sensor, nevertheless, implies more electronics, higher

cost, lower reliability, and difficulty in mounting in some cases such as motor drives in harsh environment and high speed drives, increase in weight, increase in size, and increase in electrical susceptibility [3, 4].

To overcome these problems, in recent years, the elimination of these sensors has been considered as an attractive prospect. Therefore, many studies and intensive works have focused on research techniques avoiding the utilization of speed sensor, while maintaining a high level of performance. Indeed these techniques, called sensorless, are a challenge both technically and economically because they provide many advantages the most important being a lower cost, more compact drive system, less maintenance requirements, reducing measurement noise, elimination of the sensor cable, and increased reliability. Various techniques for speed estimation have been suggested such as model reference adaptive system, Luenberger Observer (LO), Kalman Filters (KF), Artificial Intelligence (AI) techniques, and Sliding Mode Observers (SMO). Among different rotor speed estimation techniques, Model Reference Adaptive System (MRAS) schemes are the most common strategies employed due to their relative simplicity and low computational effort [5, 6].

1.2 Problem Statement

In order to implement the vector control technique, the motor speed information is required. Tachogenerators, resolvers or incremental encoders are used to detect the speed. These sensors require careful mounting and alignment and special attention is required with electrical noises. Speed sensor needs additional space for mounting and maintenance and hence increases the cost and the size of the drive system.

1.3 Objectives

The main objectives of this project are listed as follows:

- (1) To study and understand vector control theory briefly.

- (2) To study and understand the various model reference adaptive system speed estimation schemes available with main focus on the rotor flux based model reference adaptive system scheme.
- (3) To study and understand sensorless speed control of induction motor.
- (4) To model and simulate rotor flux based model reference adaptive system speed estimators for induction motor using toolboxes available in MATLAB/SIMULINK.
- (5) To simulate speed sensorless vector control of three phase induction motor using rotor flux based model reference adaptive system technique.

1.4 Methodology

The thesis methodology is undertaken according to these stages:

- (1) Study of the induction motor dynamic equations related to model reference adaptive system speed estimator's structure.
- (2) Construct the model of the three phase induction motor using MATLAB/SIMULINK software.
- (3) Construct the rotor flux based model reference adaptive system using MATLAB/SIMULINK software.
- (4) Examine the estimated and actual rotor speed response under different operation conditions.
- (5) Evaluate performance of rotor flux based model reference adaptive system based on simulation results.

1.5 Thesis Layout

The thesis is presented in five chapters. The scope of each chapter is explained as stated below:

Chapter one gives an introduction to the thesis, including: general concepts, problem statement, objectives, and methodology.

In chapter two available types of electrical motors suitable for high performance control are introduced and compared to the induction motor.

Then the construction and principle operation of induction motors are briefly presented. Furthermore, modelling techniques for induction motor simulation and analysis are presented along with an analysis of the dynamic behaviour. Finally, the various induction motor control methods are briefly reviewed with particular focus given to vector control techniques.

Chapter three gives an overview of speed sensorless estimation strategies available in literature. Model reference adaptive system estimation types are briefly reviewed. Finally, rotor flux based model reference adaptive system estimator for speed estimation of induction motor is described.

Chapter four discusses the simulation results for the rotor flux based model reference adaptive system estimator. Estimator response at different values of speed reference was studied. Analysis and discussion were made to critically evaluate the performance of the rotor flux based model reference adaptive system estimator.

Chapter five draws general conclusions from the thesis and provides suggestions for further research work in this area.