CHAPTER 1

INTRODUCTION

A brief review of the recent advances that has led to the rapid development of the power electronic drives and its applications in the industrial field is presented in this chapter. Finally, the chapter concludes with a brief outline about the various contributions proposed in this thesis along with the necessity for selecting the simulation tools.

1.1 BACKGROUND ABOUT INDUSTRIAL DRIVES AND ITS APPLICATIONS

Oersted discovered the effects of magnetism due to the passage of electric current through a piece of wire. This concept laid the foundation theory for the development of various types of electrical machines, which began in the early 1800s. Oersted's invention further led to the discovery of the electromagnetic induction effect by Michael Faraday in 1831 and developed the world's first DC machine. Again, in 1883, another scientist, Tesla, designed and developed an AC synchronous machine. The AC asynchronous motor is called as induction motor, and it is the today's most popular electrical motor. Throughout the world, the electrical drives business is worth more than USD 10 billion per annum.

Induction motors are used worldwide as the work-horse in most of the industrial applications. Such motors are widespread because they are robust, easily installed, controlled and adaptable for many processes. Indeed, in the industrialized countries, approximately 70% of the entire electrical power available is consumed by AC drives, whereas most of them are IMs.

Induction motors play a vital role in the industrial sector, especially in the field of electric drives and control **[1]**. Without proper control of speed, it is virtually impossible to achieve the desired task for a specific application. General-purpose applications of induction motors include control of pumps, conveyors, machine tools, centrifugal machines, presses, elevators and packaging equipments. On the other hand, applications in hazardous locations include control of petrochemical and natural gas plants, whereas severe environment applications for induction motors include the control of grain elevators, shredders and equipment for coal plants.

Advantages of IM over other electric machines includes the structural simplicity, robustness, ruggedness, durability, reliability, low cost, low weight and inertia, less failure rates and virtually maintenance-free electrical drives. IMs do not require any type of connection between the stator and the rotor. Unlike that of the DC motors, IM does not require any commutator-brushes, which make it a very good entity to be used in explosive situations as sparks are not produced. Thus, these machines could be categorized as maintenance-free machines and cost-effective. The above-mentioned advantages show the superiority of the usage of IM over other types of electrical motors in various industrial applications. Hence, it becomes a perfect rotational energy conversion machine for variable speed applications.

Induction motor drives find numerous applications in modern-day automation. Speed control in industrial drives can serve several purposes. The variable frequency drive or variable speed drive can control the RPM of a motor, which drives a fan, pump, conveyor belt or other machine. In our work, we concentrate on the speed control of IMs using some sophisticated control techniques. The advantage of using speed controllers for speed control of electric drives is that, the speed of the machine can be matched to the set value and if deviated from the set value due to any disturbances, it can be automatically brought back to the set value using feedback loops in the designed controller.

The advancements in power electronics and PWM technique during the last three decades wrapped up the modern control of motor drives. Over the last fifteen years, major improvements in motor drive stability and efficiency were made. This was due to significant progress in all relevant fields, as follows:

1. The invention of highly efficient and fully controllable power semiconductor switches such as, MOSFET, SCR, IGBT, etc.

2. The new topologies such as four-leg, resonant and soft-switching converters.
3. The invention of new AC machine control strategies such as FOC theory and SVPM techniques.
4. Optimized control solutions and their analysis, such as PID, hysteresis, adaptive and FLC strategies, ANN, genetic algorithms and hybrid control, etc.

A variable voltage is required because the motor impedance reduces at low frequencies and consequently the current has to be limited by reducing the supply voltages. Hence, considerable research could be done in this area. The aim was to find even simpler methods of speed control of IMs. Historically, number of controllers has been developed by various researchers. To name a few of the controllers developed by them include the scalar, vector, field acceleration and hybrid controllers. They can be discussed as follows:

1.1.1. Scalar Controllers: These are the simplest controllers, based on the voltage–frequency concept. A constant relation between 'v' and 'f' is imposed in this type of scalar control, which can be considered as the simplest open loop type control (without feedback). Scalar controllers are not very accurate and do not yield good results in the control of speed, flux, torque, etc. This is because the torque and flux are not controlled directly.

1.1.2. Vector Controllers: These controllers can be used for controlling a number of parameters such as flux, speed, torque, etc. Separate feedback control loops could be made use of in the control of the above parameters, thus providing a better control than the scalar ones. The vector control technique, which is also known as FOC allows a SCIM to drive with better dynamic performance. The FOC technique decouples stator current into two components, one providing air-gap flux and other providing the torque. The flux and torque are independently controlled and also other characteristics are linearized.

1.1.3. Field Acceleration Control: The stator current's phase and amplitude are kept constant in this type of control as a result of which electromagnetic transients are avoided, thus safeguarding the equipment from damages.

1.2 REVIEW OF SIMULATION CONCEPTS

The control of any real-time system is not possible directly in modern-day automation. First, the mathematical model of the system is developed followed by the controller model. Off-line programming concept is used to evaluate the performance of the designed system using some sophisticated software tools Matlab. Once the entire system is working well off-line, i.e., in the simulation, it is transformed into the reality stage using interfacing devices. This is one of the essential steps required in building the mathematical model.

Furthermore, this model can be used along with some advanced graphic simulators to test the developed system off-line and then implement it in real time, thus validating the experimentation with the simulation.

There are various approaches to creating the simulation models of power electronic drives **[2]**. One of the methods is the development of Simulink models in Matlab/Simulink environment. This modeling can be based on a modular approach, wherein each module can be modeled at any level of complexity, while maintaining full compatibility of the modules. Besides the obvious advantages of modular modeling, the main benefits of the simulation approach are as follows:

- It allows change in the complexity of the models without changing the system description.
- It allows mixed-level modeling using the interface modules.
- It also allows development of sub-systems so that the overall developed Simulink model looks compact.
- Once the model has been simulated along with the controller in the Simulink environment, the characteristics can be studied, tuned to the requirements and then can move forward to the implementation stage.

By using the Matlab/Simulink and its library, sub-systems can be developed so that the overall model becomes compact and thus increases the speed of the computations. The computer simulation models that could be developed using Matlab/Simulink can also be used for transient analysis of AC and DC machines. Using the Simulink software, each block of model can be connected and modified suiting to the specification. Some limit condition can also be inserted in the function blocks. In addition, there are many tool boxes of signal processing, neural network, fuzzy logic, identification and control in the Simulink library **[3] [4]**.

The various advantages of modeling in the Simulink environment discussed above have led us to select the same in our research work for the speed control of IM's.

1.3 PLAN OF INVESTIGATION

This thesis examines the design of various types of controllers using the concept of PI, Mamdani-Fuzzy logic, Takagi–Sugeno FL and ANFIS strategies for controlling the duty cycle for the inverter with SVPWM technique to control terminal voltage of the IM drive which aims at controlling various parameters of the Induction motor, especially speed, which is considered as the main parameter. The thesis has been organized in the following sequence.

Chapter 1 presents the general introduction to the industrial drives and its applications. Review of the simulation concepts in the design, development and control of industrial drives is followed next. Finally, the outline of the thesis work is presented.

A brief review of the work (literature survey) carried out by various authors so far and related to the research considered in this thesis is presented in Chapter 2.

Chapter 3 presents the mathematical modeling of the induction motor, starting from the so-called SVPWM technique, as this forms the basis of the mathematical modeling of IMs along with the d–q dynamic model, Kron's dynamic model and the Stanley dynamic model. Kron's mathematical model is used in our work to develop the controllers using various strategies in the subsequent chapters.

Chapter 4 presents a Simulink-based novel design of a Proportional-Integral (PI) controller to control various parameters of the IM, viz., speed, voltage, torque, etc.

The design of a Matlab/Simulink model-based fuzzy logic control scheme (Mamdani-Fuzzy logic) for control of the speed of an IM using the SVPWM concept is discussed in Chapter 5.

In Chapter 6, the design of the controllers based on the Takagi–Sugeno control strategy for the speed control of IM drive is depicted along with the simulation results.

Chapter 7 presents the design of an adaptive neuro-fuzzy (ANFIS) inference scheme for the IM plant to control its various parameters, such as speed, torque, flux, current, etc.

In Chapter 8, comparative analysis of the results of the four developed types of controllers, viz., PI, Mamdani-Fuzzy logic, Takagi–Sugeno FL and ANFIS, is presented along with discussions and justifications for the best control method.

Chapter 9 highlights the significant contributions of the work performed in this thesis and concludes the thesis along with the scope for future work in this exciting research area.