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A REVIEW ON INDUCTION MOTOR SPEED CONTROL METHODS

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Abstract
The applications of induction motors in various fields are increasing day by day because of the robustness and low maintenance cost. Maximum of these applications not only need fast response but also need intelligent speed control. To achieve high efficiency and maximum torque, speed control is the main concern of the induction motor. This paper introduces different classifications of speed control of an induction motor. Different characteristics of each speed control method will be described including performance, maintenance cost and area of applications. Finally based on different relative advantages and disadvantages comparison will be made among different types of speed control of induction motor as each type of control will be suitable for various applications.

Keywords— Induction motor, speed control, fuzzy logic controller, torque control

I. INTRODUCTION

The use of induction motors are increasing day by day significantly in various fields including industrial, residential applications [1-2].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 form of names of variable frequency drive [7]. Various kinds of operations and different multispeed functions are executed by regulating the speed of motor. Previously the variable speed drive faced many limitations such as poor efficiencies, unstable speed control, large space consumptions etc. by the development of power electronics these problems are overcome gradually [3].

The necessity of induction motors in various fields need to be understood first. The advantages provided by induction motors making a huge difference compare to other electrical motor. Some the advantages are describe below:

- The induction motors are very cheap compare to dc motors or synchronous motors
- The robust construction of induction motors makes it more preferable than any other motors
- The percentage of reliability and efficiency of induction motors is undoubtedly better than any other motors
- Induction motors maintenance cost are very low because of its simple construction

In industrial sectors three phase induction motor is heavily used because of ruggedness and reliability. For heavier load consumption, single phase induction motor is used such as fan in household equipment. It is widely used in industrial appliances instead of dc machines because it can achieve a fast torque response [3-5]. Torque response is very sensitive to flux and easily manipulated by variation of parameters. Identify accurate parameters are very important to achieve the desired performance.

II. SPEED CONTROL

Synchronous speed and rated speed are the two speed terms basically used in induction motor. Synchronous speed is defined with the speed in which motor's magnetic field rotates. It is one kind of motor theoretical speed where the fact consider that there is no load and bearing friction is ignored [3, 6]. Synchronous speed of a motor depends on two factors. One is magnetic pole of stator and another is supply frequency. The synchronous speed is described by in Eq. 1,

$$Ns = \frac{120f}{p} \qquad (1)$$

Where,
f = Frequency in Hz
p= Number of poles

The rotor speed and the rotating magnetic field speed of an induction motor are two different things. The rotor synchronous speed is always higher than the rotor actual speed and the percentage difference between the between these two speeds is known as slip of the motor [5-6].

$$S = \frac{Ns - Nr}{Nr} \qquad (2)$$

Where,
Ns = Synchronous speed

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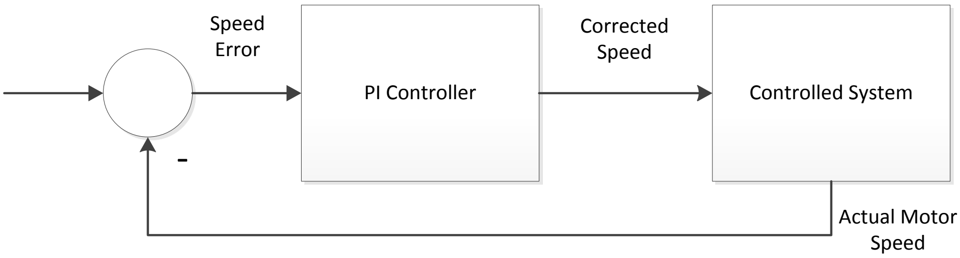

Fig. 1. Basic figure of closed loop scalar control method

Nr = Rotor speed

$$Ns \propto \frac{f}{p} \quad (3)$$

Equation 3 states that induction motor synchronous speed is directly equivalent to supply frequency and inversely equivalent to number of stator poles. The best possible way to control the speed of an induction motor by changing the supply frequency because the number of stator poles is fixed by design.

III. CONTROL PLATFORMS

Different induction motor speed control techniques applied in modern era are categorized in three following classifications:

A. Scalar Control (v/f Control)

The most used scheme for speed control of induction motor is by varying supply frequency. This scheme provides results with wide speed range and starting performance.

In this type of control, an inverter with PWM control is used to generate variable frequencies. The main motor is fed with these frequencies. To get constant torque for smooth operation, the v/f relation keeps constant [7]. As a result the flux of the motor remains constant and the torque is not dependent on the supplied frequencies. Since the flux is maintained constant, the toque developed depends only on the slip speed. This type of control also known as scalar control. The open loop v/f method is widely used in the industry because of its low cost, easy implementations and immunity to feedback error signals.

Figure 1 shows the basic diagram of closed-loop v/f control method. The closed-loop v/f control method provides more precision result to control the speed and torque. To obtain the desired torque, a slip control loop is used in closed loop method because the slip is proportional to the induction motor torque [7-8]. The difference is decreased to zero by the PI controller, so that motor will achieve desired speed. Uncontrolled magnetic flux is the main disadvantages of this system [8].

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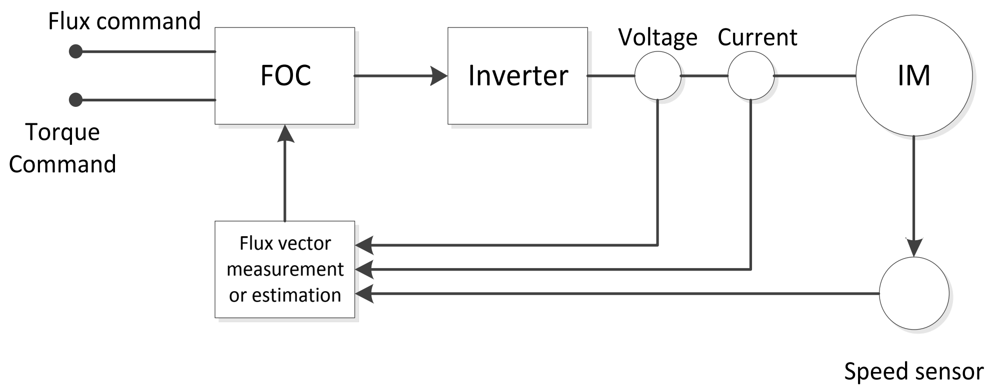

Fig. 2. Direct Vector Control

B. Vector Control

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 are of three kinds such as magnetizing flux oriented control, stator flux oriented control, rotor flux control. Induction motors are extensively used in different sophisticated commercial and process applications which require high performances [9]. To achieve those high performance, the speed of the motor need to maintain a specific reference trajectory regardless of any parameter modifications, unbalanced load and model uncertainties.

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 [9-11]. The flux measurement process also add more extra equipment cost and the measurement is not accurate. That is why vector control technique is not very adequate technique for speed control. 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 rotor.

C. Direct Torque Control (DTC)

The DTC method is obtained from the basic fact of the fallacy in between the actual reference values and the estimated torque and flux values. The inverter states can be directly controlled within a prefixed band limit to reduce the torque and flux errors [8-10]. This control method is a new technique for speed refinement of Induction motor by using adjustable frequency converter. Different parameter like mutual inductance, stator resistance, co-efficiency of saturation etch are prerequisite of this control method.

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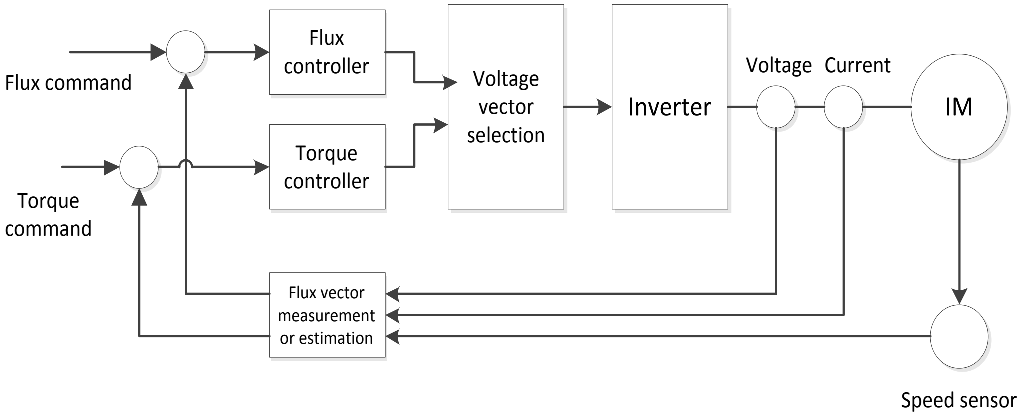

Fig. 3. Indirect Vector Control

Field orientation is obtained without speed if the rotor or position feedback using developed motor hypothesis to compute the motor torque without using modulation. Motor torque and magnetizing flux are the main controlling variables in this technique that's why it is called direct torque control method. Fast response time, eradication of feedback devices, diminish mechanical fiasco are the main advantages of DTC method [11]. There are many also disadvantages like higher torque, ripple flux, comparator hysteresis

Figure 4 shows the basic construction of direct torque control method. In DTC method, stator flux is manipulated in such way that required torque is obtained. This is accomplished by selecting the combination of an invert switch that drives the stator vector. The appropriate modification is imposing the correct voltages to the windings directly.

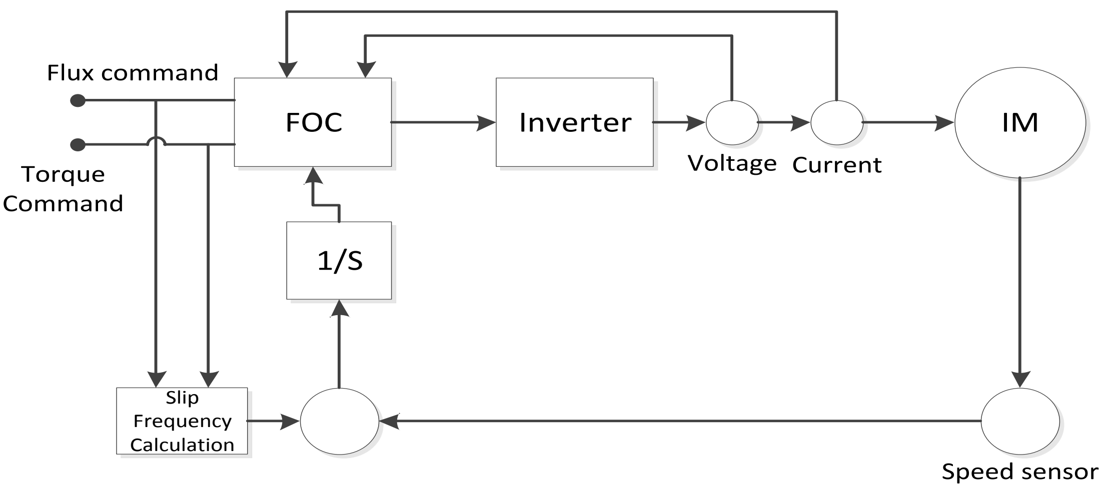

Fig. 4. Direct Torque Control Technique

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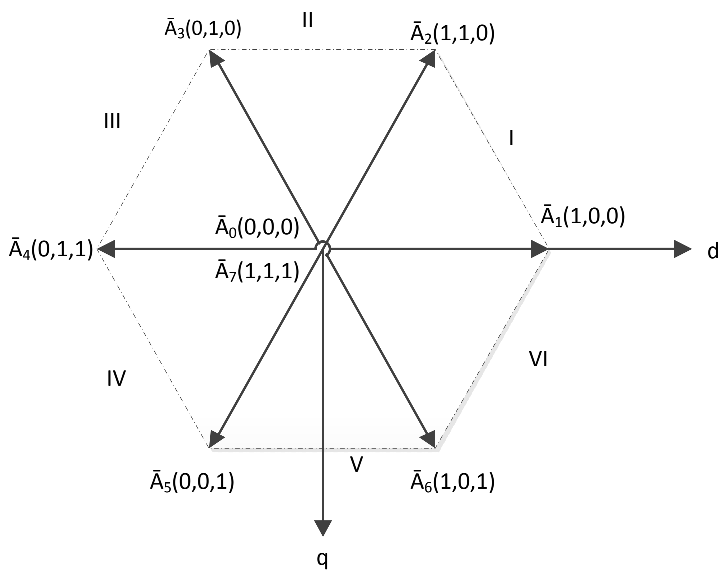

Fig. 5. Voltage space vector exported by inverter

- **Space Vector Modulation**

The method to establish the accurate stator flux is in form of selecting right inverter condition. Rotor flux state is categorized into six various positions. The stator flux modulus and torque is obtained by condemn on peripheral elements respectively of the liaison space vector on its locus. These elements are directly symmetrical to the components of the same voltage space vector in same direction.

Figure 5 describes the probable stator flux locus and its various positions depending on voltage source inverter(VSI) conditions[5].The probable locus is categorized into six various positions signaled by is continuous line. Only 8 distinguish states is assumed in voltage source inverter (VSI). Among them six states give a result of non-zero outputs which is recognized as non-zero switching states. Rest of states produce zero outputs. The vectors are numbered from A1 to A6 and the sectors are labeled from 1-6.

- **Fuzzy Logic Controller (FLC)**

Fuzzy logic controller is a modern method to think like human into the control scheme. FLC is normally designed to imitate human thinking. Fuzzy linguistic description is primarily used to control the process systems as fuzzy logic controller [12, 13].

FLC is a special type of design controller for industry with complex work functions and high non-linearity process. In a motor control system, the task of FLC is to diversify linguistic control rules into control method rely on speculative information or expert wisdom. FLC system is very beneficial for induction motor because any distinguish mathematical prototype of the induction

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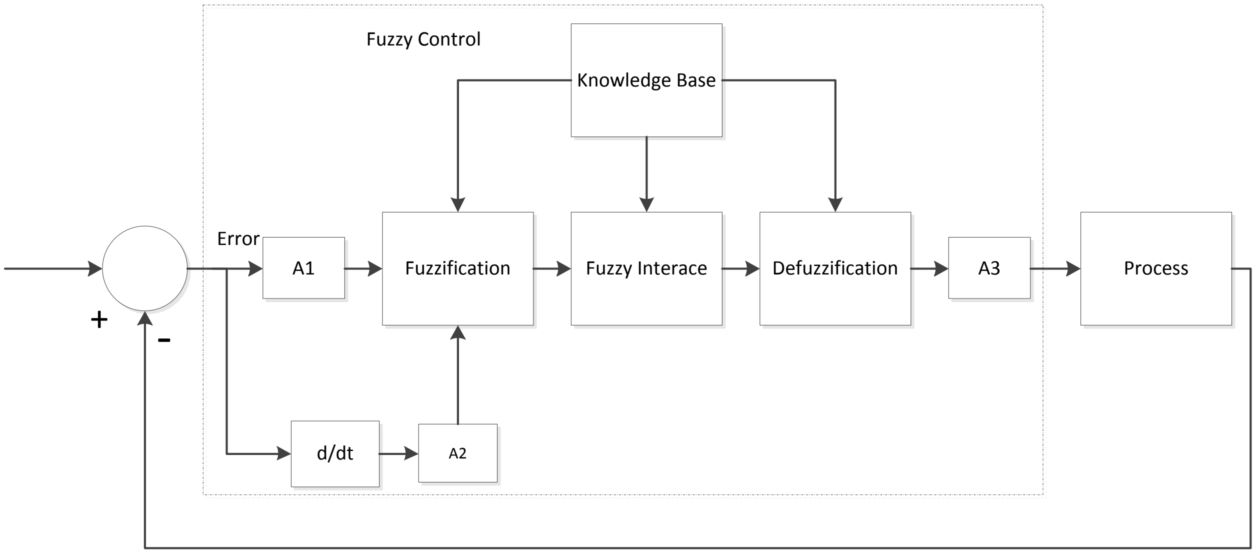

Fig. 6. Structure of fuzzy control.

motor or any other closed-loop system is not required [10]. The control rules of FLC is a fixed set usually proved from expertise scientists. Input and output variables is associated with membership function (MF) which is generally predetermined on a common universe of discourse.
Figure 6 describes the structure of the fuzzy logic controller.The success rate of FLC design depends on various points like scaling factors of proper selection of output and input, tuning other control parameters etc. this kind of system is gone through many trial and error ways to get the possible best performance [12, 13]. The structure shows four functions, each one materialized by block [13].

- Initially fuzzification interface transforms the crisp error and its displacement into various fuzzy variables. After that linguistic labels are being mapped from these variables. The range of the membership functions are described within -1 to 1. Each label is defined in various notations such as : negative big(nb), negative medium(nm), negative small(ns), zero(ze), positive small (ps), positive medium(pm) and positive big(pb). The variable values are very symmetrical to the membership functions so that maximum 7X7=49 rules can be created in the rules table.

- Fuzzy inference function is used as a set of If-then rules to gain good control over the system. This rules contain subsets definition, membership functions and universe discourse.

- Fuzzy inference module is the main part of fuzzy control system. Its function is to formulate the mapping from input to output using logic. This mapping provide a hypothesis from which conclusions can be determined or various patterns can be understand. This involves all the elements that are explained in If-Then rules, membership functions, and logical operations.

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- The interface that transforms the culmination of the fuzzy inference into actual inputs for the system is called defuzzification. Basically defuzzification produces a significant result in crisp logic based on corresponding membership functions and fuzzy sets.

IV. CONCLUSION

This paper reviewed the genesis and advancement of speed control techniques and its performance analysis on induction motor. First the basic principle of speed control are attentively reviewed and made comparison. Later different modern techniques are shown and the development are methodically reviewed. Finally it has been concluded that by applying modern intelligent method like fuzzy logic improve motor dynamic performance, reduce ripple torque and stator flux.

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