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SPEED CONTROL OF THREE PHASE MOTOR USING FUZZY LOGIC CONTROLLER

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Abstract- The dynamic performance of an electrical drive must be very good so that the response to the changing speed and the torque is fast. This requirement can be fulfilled by using the fuzzy logic control of the electrical drive. The advantage of using fuzzy logic control is that it does not require complex mathematical modeling of the motor. By just knowing the behavior of the motor the control signals is manipulated to obtain the desired response characteristics of the motor. In this paper a fuzzy logic technique is proposed which is very simple and easy to implement in the actual scenario. Various methods to implement the fuzzy logic control are also proposed.

Fuzzy logic controller based speed control of a three phase induction motor. The system is modeled in a MATLAB Simulink and the result is being compared with the conventional PI controller. Constant v/f control scheme is being implemented in the scheme. The controller is designed such that it can reduce the error between rotor speed and reference speed as fast as possible. The performance of the controller with the change in reference speed is simulated and the dynamic performance of the motor is observed. Result show that the dynamic performance of the induction motor is improved. Along with that result shows that the system is not much affected to the disturbance occurring in the system. The induction motor attains adaptability to the system disturbances which proves to be very useful for the robust performance of the motor.

Index Terms- Fuzzy logic controller, MATLAB, Simulink, V/F control, three phase induction motor, speed control.

1. INTRODUCTION

Electric drives play an important role in the field of power electronics; since they are used in a wide range of applications. In this context, it is important to match the correct drive to the application in accordance with its requirements. In the recent decades, a huge step had been taken in power semiconductors and microprocessors development. As a result, modern drive system technology had changed dramatically, and accordingly more studies were done on electric drive systems to fulfil the various needs of different applications.

The continuous improvements in power electronics field made it easier to develop modern switch-mode inverters based on high speed power transistors, like MOSFET and IGBT. Such inverters are able to adjust the speed of induction motor more efficiently than before. Using power transistors has the advantage of making electric drives lighter and less cost than old styles that used DC motors. Furthermore, the switching schemes, mainly PWM, improved the performance of modern electric drives, and several PWM techniques had been proposed with different advantages and drawbacks. On the other hand, induction motors became the most widely used in industrial drive applications due to their advantages over other motors. [4] Some of these advantages are: ruggedness, lower rotor inertia, absence of commutator and brushes, besides the lower price and smaller size. There are various methods of speed control in the literature like pole changing method, rotor resistance control, stator voltage control, slip control, constant V/f control, variable V/f control etc.

In the recent years the fuzzy logic controlling is a great interest among the researchers. As in the classical controlling scheme it is needed to have a mathematical model of the system. The fuzzy controlling doesn't need the mathematical model of the system. [3]

In addition to that it makes the control simple and reliable. In the fuzzy controlling in induction motor is also increasing day by day. Researchers continuously try to use fuzzy controlling for induction motors as induction motors are the widely used motors in the industries because of its various advantages like self starting capability, rugged construction, and maintenance free operation, economical and reliable.[15] Induction motor possesses many advantages but it also have some disadvantages that its speed controlling is very much complex. It is best suitable for the constant speed loads but it is not suitable for variable speed loads. To overcome these disadvantages various works are going on about the speed controlling of the induction motor. In the fuzzy controlling scheme the control signals are manipulated accordingly in real time so that not only speed but other parameters like flux, torque and stator currents can also be controlled.

1.1 Objective

The principle aim of the proposed study is to design a simple speed controlling of the induction motor. The controlling is designed in such a manner that the mathematical modeling of the induction motor is not required and it should improve the dynamic performance of the induction motor. Along with that motor should be able to withstand the load disturbances occurring in the system and stability should not be affected. The motor torque should adjust itself with the load so as to cope up with the disturbances occurring in the system. Briefly the aim of the control system design is to increase dynamic performance and robustness of the three phase induction motor.

1.2 Problem Statement

Into days world the ever increasing usage of the three phase induction motor and its many benefits it is desired to improve the performance of the three phase induction motor and use it in the best possible ways and in as much applications as possible. In literature three are many ways for obtaining the desired performance .Out of the different methods many of the methods require the mathematical modeling of the three phase induction motor which is not accurate and some methods dost require mathematical modeling but the controlling methods are complex which increases complexities and cost of the control circuit. In the proposed research a very simple control concept is proposed which improves the dynamic performance as well as the robustness nature of the induction motor.

2. TECHNICAL BACKGROUND

2.1 Working of Induction Motor: The principle of operation of the induction machine is based on the generation of a rotating magnetic field. The rotor receives power due to Induction from stator rather than direct conduction of electrical power. When three phase voltage is applied to the stator winding a rotating magnetic field of constant magnitude is produced which rotates at synchronous speed. [19] This rotating field is produced by the contributions of space-displaced phase windings carrying appropriate time displaced currents. These currents are time displaced by 1200 electrical degrees.

According to Faraday's law an EMF induced in any circuit is due to the rate of change of magnetic flux linkage through the circuit. As the rotor winding in an induction motor are short circuited through an external resistance and it cuts the stator rotating magnetic field, an EMF is induced in the rotor circuit and due to this EMF a current flows through the rotor conductor.[15]

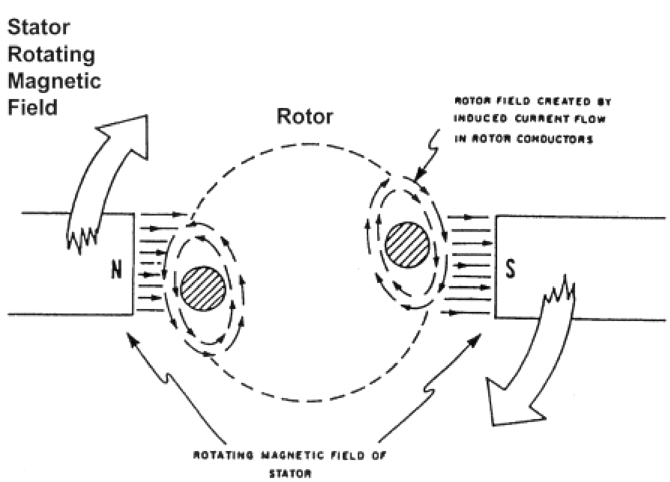

Fig 2.1 rotating magnetic field

Here the relative velocity between the rotating flux and static rotor conductor is the cause of electric current generation, hence per Lenz's law rotor will rotate in the direction to reduce the cause i.e. the relative velocity.

2.2 Speed control techniques of the induction motor

The speed control of induction motor is more complicated than that of dc motor, especially when, comparable accuracy is desired. [10] The main reason for this can be attributed to the complexity of the mathematical model of the induction machine, as well as the non-linear power converters supplying this motor.

2.2.1 Types Of speed control:

Mathematically, the relation between the speed of an induction motor and the synchronous speed (speed of rotating flux) can be stated as:

Nr = (1-s) Ns;   Ns = (120f)/p

Where, Nr is the rotor speed Ns is the synchronous speed.

s is the slip

f is the supply frequency as speed is a function of frequency and no. of poles, speed can be varied by varying these parameters.

Different ways of controlling speed of induction motor are:

1. Changing no. of poles
2. Stator voltage control
3. Rotor resistance control
4. Slip power recovery scheme, and
5. Constant V/f control

2.2.2 V/f Control Overview:

Induction motor speed variation can be easily achieved for a short range by either stator voltage control or rotor resistance control. But at low speed it result in low efficiency. The most efficient scheme for speed control of induction motor is by varying supply frequency. This results in scheme with wide speed range but also improves the starting performance.

The v/f ratio is kept constant, when the machine is operating at speed below base speed, so that flux remains constant. Maximum torque remains constant in this case. At frequency less than rated frequency, the torque capability decrease and this drop in torque has to be compensated by increasing the applied voltage.

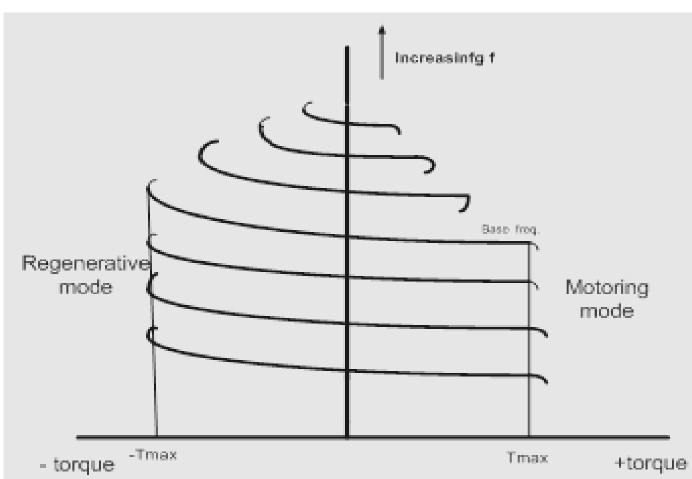

Fig 2.2 motor torque vs frequency characteristics of three phase induction motor

3.2.3 Constant V/F control

The base speed of the induction motor is proportional to the supply frequency and no. of poles of induction motor. As the no. of poles are fixed during the design, the best way to control the speed of induction motor by varying supply frequency. The electromagnetic torque developed by the induction motor is directly proportional to the ratio of the applied voltage and the frequency. [12] So, the torque developed can be kept constant throughout the speed range, by varying the voltage and the frequency and keeping their ratio constant. This is what V/F control does.

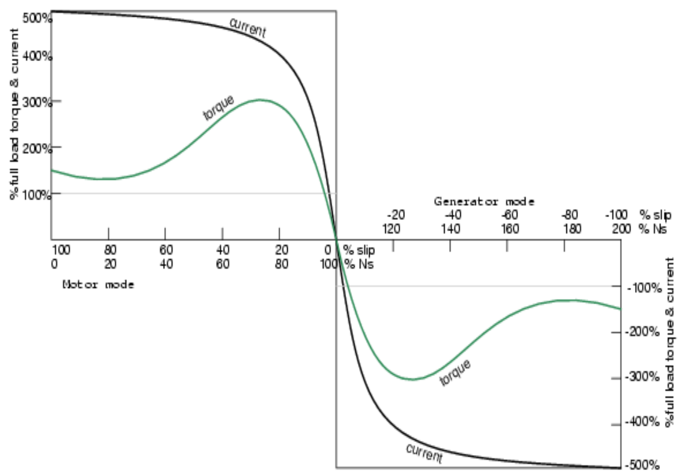

Fig 2.3 complete torque speed characteristics

3. PROPOSED METHODOLOGY

3.1 Fuzzy logic control

Fuzzy logic is a technique to inculcate human-like thinking into a control system. So the main purpose of designing fuzzy controller is to embody the human intelligence or human like thinking in the controller to control the process parameters. Fuzzy controller basically contains four essential segments. [19]

3.1.1 Designing fuzzy logic controller

The block diagram to control the speed of the induction motor is shown in fig. no. 3.1

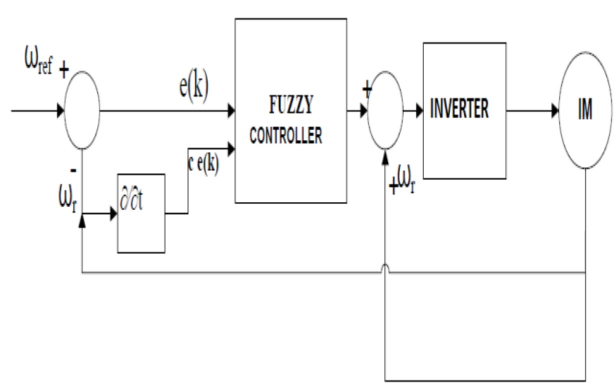

Fig 3.1 Block diagram of fuzzy logic controlled induction motor drive

As shown in the block diagram 3.1, the motor speed is taken as the feedback element. The motor speed is compared with the reference speed and the error signal e(k) is obtained. The difference of error signal and unit change in error signal gives the change in error signal ce(k). The signals e(k) and ce(k) is given as the input to the fuzzy logic controller. [20]The inputs are fuzzified in the fuzzy logic controller and proper rules are set. Then according to the rules output is obtained which is then

Defuzzified to obtain the control signal. The control signal is then used to modify the output frequency and voltage of the inverter to obtain the desired speed.

3.2 Simulation diagram

The simulation of the proposed scheme is done in the MATLAB simulation fig 3.2 shows the simulation model of the proposed work

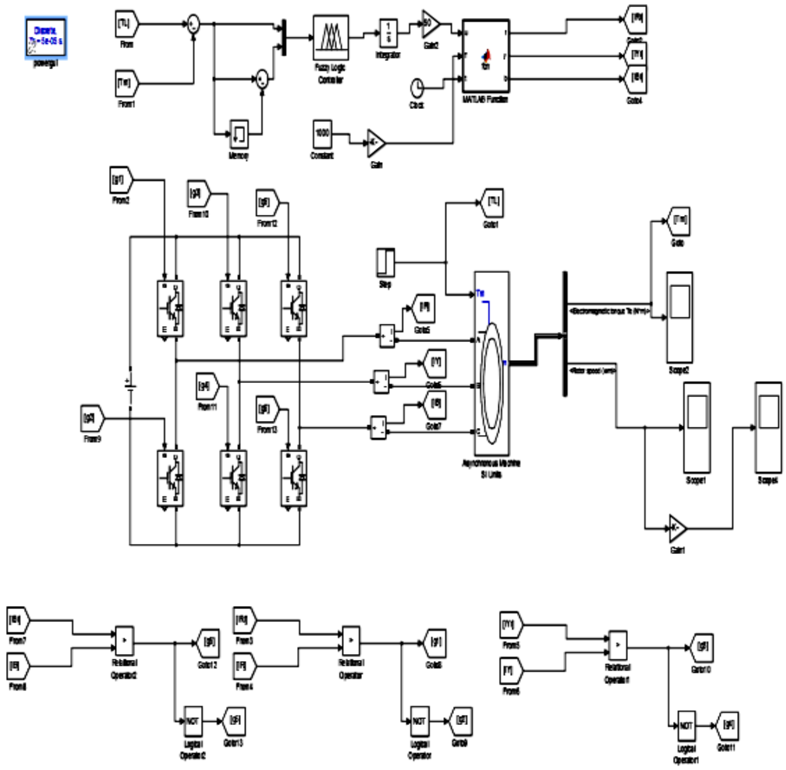

Fig 3.2 simulation diagram

As shown the induction motor is fed through the inverter. The input to the inverter is assumed to be a stiff dc source. The motor output speed is taken as a feedback it is compared with the reference speed which can be changed accordingly. The error and change in error input is given to the fuzzy logic controller whose output modifies the control signal according to the need. According to the control signal a three phase reference current waves are generated which acts as a reference current waves and that reference current waves are tracked by suitable gate pulse of the inverter. Here hysteresis current control scheme is utilized to track the reference current.

To simulate the effect of the disturbance in the speed of induction motor the load torque in a motor is varied the fig 3.3 describes the variation of load torque with time.

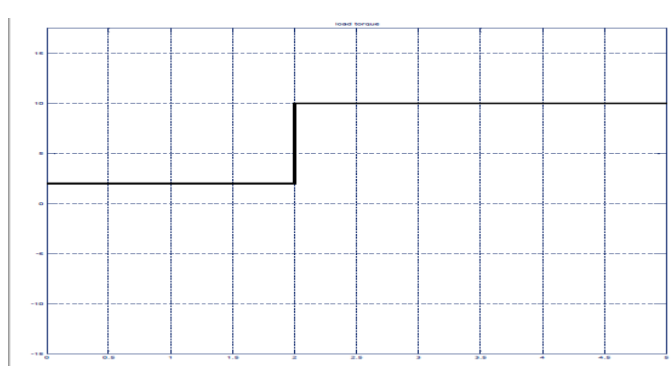

Fig 3.3 variation of the load torque with time

Fig 3.4, fig 3.5 and fig 3.6 describes the fuzzification of the error signal, change in error signal and output variable of the fuzzy logic controller respectively

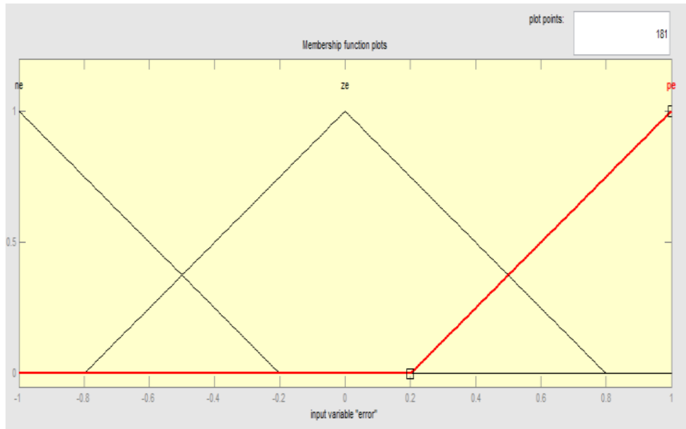

Fig 3.4 fuzzified error signal

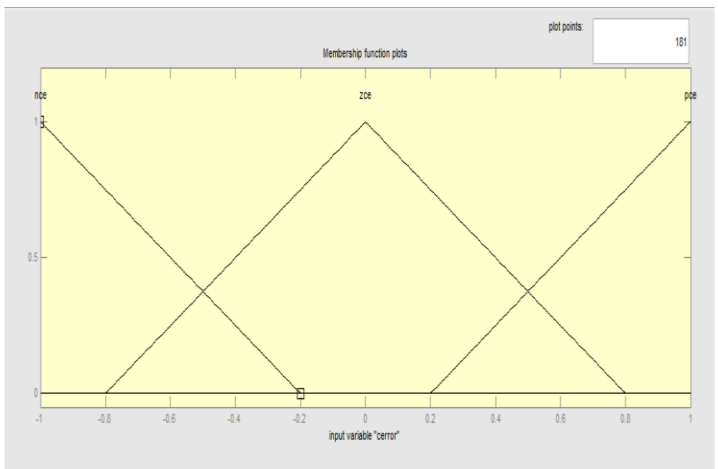

Fig 3.5 fuzzified change in error signal

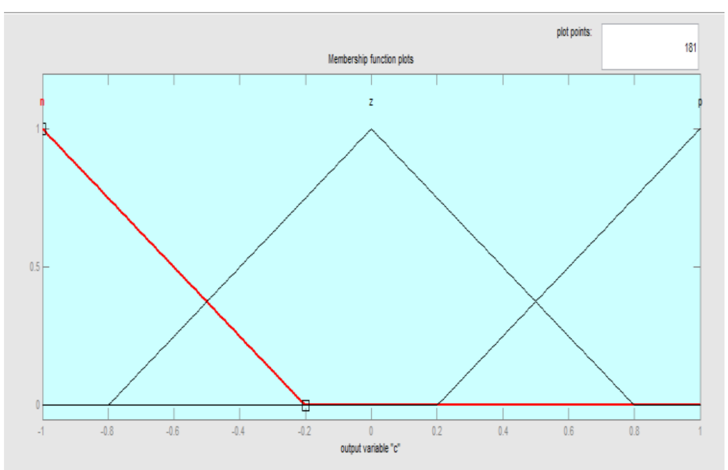

Fig 3.6 fuzzified output variable

Fig 3.7 describes the rules that are made to obtain the output variable and fig 3.8 describes the surface view of the rules

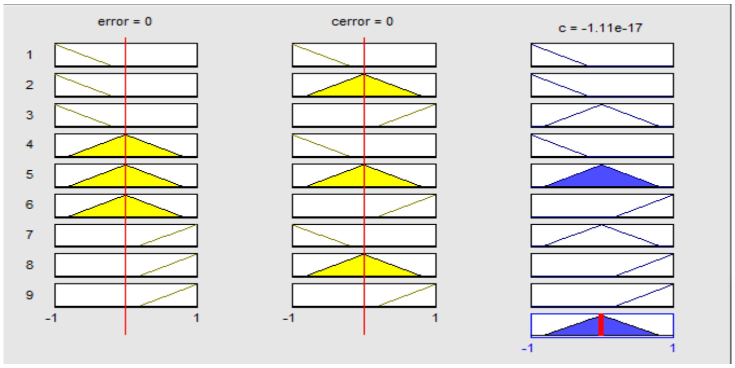

Fig 3.7 rule viewer plot

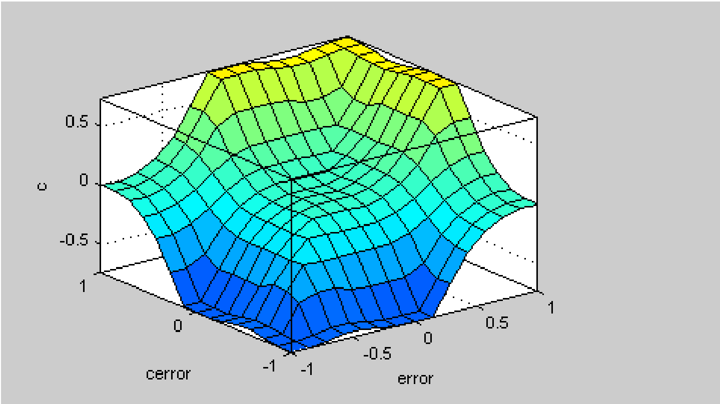

Fig 3.8 surface rule viewer plot

3.3 Summary: This chapter describes the proposed controlling scheme for the speed control of the three phase induction motor. Simulation diagram shows how the proposed methodology is being tested and various plots shows how the problems are being simulated so that the proposed scheme is being tested for various problems that are being associated with the three phase induction motor. In this chapter also the scheme of fuzzy logic control is illustrated.

4. RESULTS AND DISCUSSIONS

Fig 4.1 shows the variation of rotor speed with time. It is seen that the motor quickly settles to the reference speed by adjusting the reference current of the inverter. The settling time here is around 2.5 sec. It is also seen in the intermediate time when there is a load disturbance then there is slight variation in the motor speed but the motor quickly adjusts itself to the steady state value.

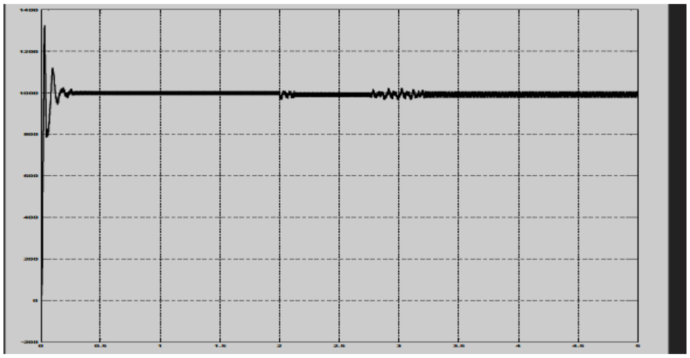

Fig 4.1 speed time curve of the three phase induction motor

Fig 4.2 describes the variation of motor torque with time. Initially motor torque is less but at the time when load increases the motor torque increases so as the cope up with the load and maintains stability.

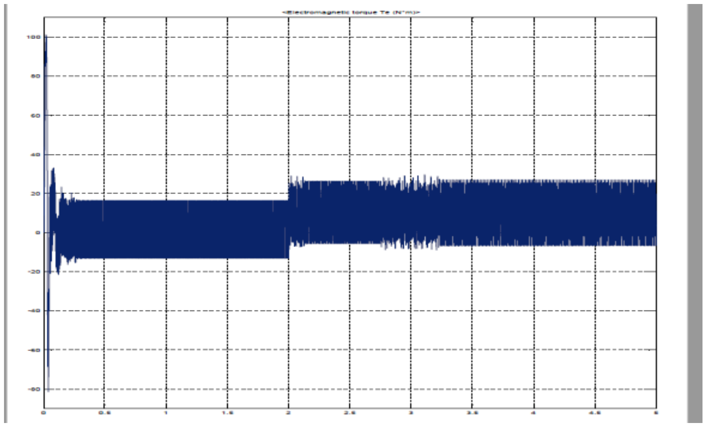

Fig 4.2 variation of motor torque with time

From the various result obtained it is evident that the proposed methodology to control the speed of the three phase induction motor is highly dynamic and simple in application. Along with that this control scheme is highly robust that is it is not very much affected by the disturbances occurring in the system. As the complexity in controlling is not very much as the mathematical modeling of the system is not required hence it is simple to be applied and the system is highly adaptable.

5. CONCLUSIONS

The fuzzy conntroller provides a very good result for speed controlling of a three phase induction motor. From the various results obtained following observations is obtained :

1 By using the fuzzy logic in controlling there is no need of mathematical mnodelling of the induction motor.
2 With varying speed the induction motor adjusts itself very quickly this shows that the dynamic performance of the induction motor is incresed.
3 When the disturbance is simulated by varying the load it is seen that the induction motor adjusts its electromagnetic torque very quickly so as to maintain the desired speed this shows that the robustness of the induction motor is incresed.
4 As far as controlling is considered the controlling scheme is very much simple and easy to be implemented.

6. FUTURE SCOPE

Induction motors are the most widely used motors as it has so much benefits and its maintenance cost is very less. Generally induction motors are used for constant speed applications. By using the proposed methodology induction motors can prove to be useful for variable speed drives as well. With the advent of fast computers and microcontrollers implementing the fuzzy control becomes very much easy and economical. So by using this technology in future cheap induction motor drives will be available for variable speed applications.

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