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DIRECT TORQUE CONTROL OF INDUCTION MOTOR USING FUZZY LOGIC

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ABSTRACT

This paper presents of induction motors has increased tremendously since the day of its invention. They are being used as actuators in various industrial processes, robotics, house appliances (generally single phase) and other similar applications. The reason for its day by day increasing popularity can be primarily attributed to its robust construction, simplicity in design and cost effectiveness. These have also proved to be more reliable than DC motors. Apart from these advantages, they have some unfavorable features like their time varying and non-linear dynamics. Speed control is one of the various application imposed constraints for the choice of a motor. Hence, in the last few years various methods for the speed control have been developed

KEYWORDS: Micro Grid Protection, Earthling Systems, Fault Current, Touch Voltage, Micro Sources and Inverters.

INTRODUCTION

The induction motor finds its place amongst more than 85% of industrial motors as well as in its single-phase form in various domestic usages. Markedly a constant-speed motor with shunt characteristic, speed drops only by a few percent from no-load to full load. Hence in the past, induction motors have been used primarily in constant speed applications. Traditional methodologies employing speed control have either been high-priced or very inefficient, unlike the dc motor in which the presence of commutator and brushes require recurrent maintenance make dc motor drives improper for use in hazardous and polluted environments. On the other hand, owing to the simple, rugged, cheaper, smaller and subsequently lighter build of induction motor drives (particularly squirrel-cage type), they are designed for fans, blowers, cranes, traction, conveyers, etc. in spite of finding stiff competition from dc drives for such applications.

2.2.1 Principle of rotating magnetic field

When a three phase voltage is applied to the stator winding, a rotating magnetic field is produced. It is called a rotating field since its poles do not remain in a fixed position on the stator but go on shifting their positions surrounding the stator. The magnitude of this field is constant and equal to 1.5ϕm, where ϕm is the maximum flux due to any phase. On energizing the three phase stator from a three phase supply, a rotating magnetic field sets up round the stator which rotates at synchronous speed ns. This field passes through the air-gap and cuts the stationary rotor conductors. Owing to the relative speed between the rotating flux and the static rotor, electromotive forces are induced in the rotor conductors. For the reason that the rotor circuit is short-circuited, currents start flowing in the rotor conductors. Again, these conductors are placed in the magnetic field produced by the stator. As a result, mechanical force acts on the rotor conductors. A torque, produced as a result of this force, tends to move the rotor in the same direction as the rotating field. This is justified by Lenz law, according to which the direction of rotor currents will be such that they have a tendency to oppose the cause producing them. Now, the relative speed between the rotating field and the standstill rotor conductors is the cause generating the rotor currents. Thus to reduce this speed, the rotor starts running in the same direction as that of stator field and tries to catch it. Clearly, the rotor speed N is always less than the stator field speed's‟.

2. Speed Control of Induction Motors

The speed control of induction motors involves more complexity than the control of dc motor, especially if comparable accuracy is desired. The main reason for the same can be attributed tot he complexity of the mathematical model of the induction machine, as well as the complicated power converters supplying this motor. Variable speed induction motor drives employ various control algorithms.

2.1 Speed Regulation as a Means of Controlling a Process

Let us consider the process of driving to work. Driving at the highest possible speed would probably cause an accident. And driving at a single speed that will be safe for every portion of the route will take long to reach to the destination. Hence adjusting the speed which goes well with the route minimizes the time to accomplish the objective of the process within limits of reliable operation. The process control benefits that may be provided by an adjustable speed drive are as follows

1. Smoother operation.
2. Acceleration control as an added incentive.
3. Varying operating speed for each process.
4. Compensates for fluctuating process parameters.
5. Permits slow operation for setup purpose.
6. Allows accurate positioning.
7. Provides torque control.

2.2 Types of Speed Control

2.2.1 Scalar Control

The induction motor draws the rated current and delivers the rated torque at the base speed. When the load is increased (over-rated load), while running at base speed, the speed drops and the slip increases. The motor can take up to 2.5 times the rated torque with around 20% drop in the speed. Any further increase of load on the shaft can stall the motor. The torque developed by the motor is directly proportional to the magnetic field produced by the stator. So, the voltage applied to the stator is directly proportional to the product of stator flux and angular velocity. This makes the flux produced by the stator proportional to the ratio of applied voltage and frequency of supply. By varying the frequency, the speed of the motor can be varied. Therefore, by varying the voltage and frequency by the same ratio, flux and hence, the torque can be kept constant throughout the speed range. Stator Voltage (V) ∝ [Stator Flux (Φ)] x [Angular Velocity (ω)]

$V \propto \Phi * 2 \Pi F \quad \Phi \propto V/F$

This makes constant Volts/hertz the most common speed control of an induction motor. Fig 1 shows the relation between the voltage and torque versus frequency. It demonstrates torque voltage and frequency being increased up to the base speed. At base speed, the voltage and frequency reach the rated values as listed in the nameplate. The motor can be driven beyond base speed by increasing the frequency further. However, the voltage applied cannot be increased beyond the rated voltage.

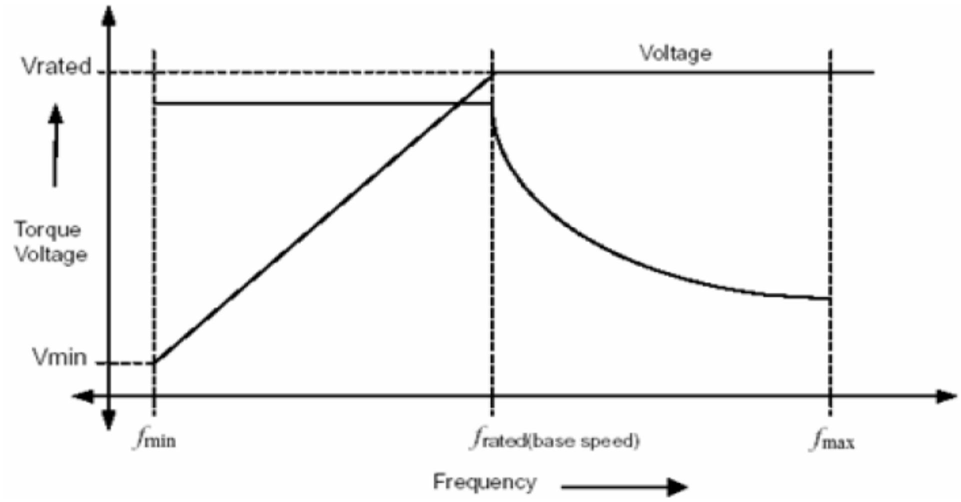

Fig 1: Speed Torque Characteristics with V/f Control.

Therefore, only the frequency can be increased, which results in the field weakening and the torque available being reduced. Above base speed, the factors governing torque become complex, since friction and windage losses increase significantly at higher speeds. Hence, the torque curve becomes nonlinear with respect to speed or frequency.

2.2.2 Vector Control

AC motors, particularly the squirrel-cage induction motor (SCIM), enjoy several inherent advantages like simplicity, reliability, low cost and virtually maintenance-free electrical drives. However, for high dynamic performance, their control remains a challenging problem because they exhibit significant non-linearity and many of the parameters vary with the operating conditions. Field orientation control or IVC of an induction machine achieves decoupled torque and flux dynamics leading to independent control of the torque and flux. Fig.2. shows block diagram of speed control system using vector control.

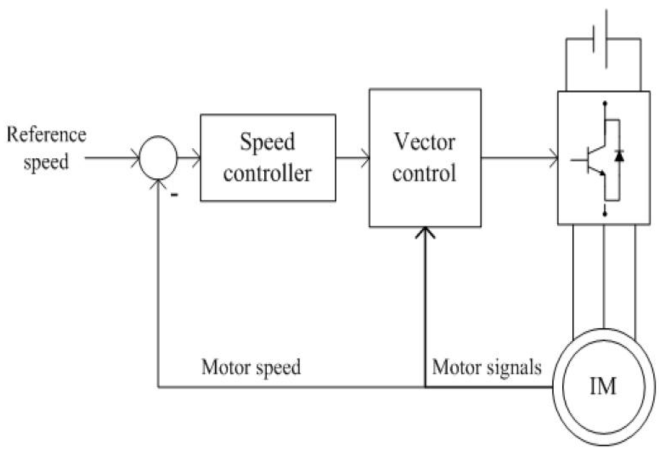

Fig. 2: Vector control of induction motor.

Vector control is a technique which allows the induction motor to act like a Separately excited DC machine with decoupled control of torque and flux, making it possible to operate the induction motor as a high-performance four-quadrant servo drive. The principle of vector control was devised by Hassel and Blacked and was developed by Leonard. In separately excited DC machine with a constant field excitation, torque is directly proportional to armature current. The orthogonal relationship between air gap flux and torque is independent of the speed of rotation so that the torque of the DC machine is proportional to the product of the flux and armature current. If the magnetic saturation is ignored, field flux is proportional to field current and is unaffected by armature current because of the orthogonal orientation of the stator and rotor fields.

Therefore, direct control of armature current gives direct control of motor torque and fast response, because motor torque can be altered as rapidly as armature current can be altered. The vector control technique provides a similar control strategy for the induction motor. The idea behind vector control is that the stator current of the induction motor is decomposed into orthogonal components as a magnetization component (flux producing) and a torque component. These components are controlled individually. In order to obtain high dynamic performance of the induction motor, the magnetizing current component is maintained at its rated level while the torque should be controlled through the torque component for the stator current.

3. Direct Torque Control

Direct torque control (DTC) is one method used in variable frequency drives to control the torque (and thus finally the speed) of three-phase AC electric motors. This involves calculating an estimate of the motor's magnetic flux and torque based on the measured voltage and current of the motor. Stator flux linkage is estimated by integrating the stator voltages. Torque is estimated as a cross product of estimated stator flux linkage vector and measured motor current vector. The estimated flux magnitude and torque are then compared with their reference values. If either the estimated flux or torque deviates from the reference more than allowed tolerance, the transistors of the variable frequency drive are turned off and on in such a way that the flux and torque errors will return in their tolerant bands as fast as possible.

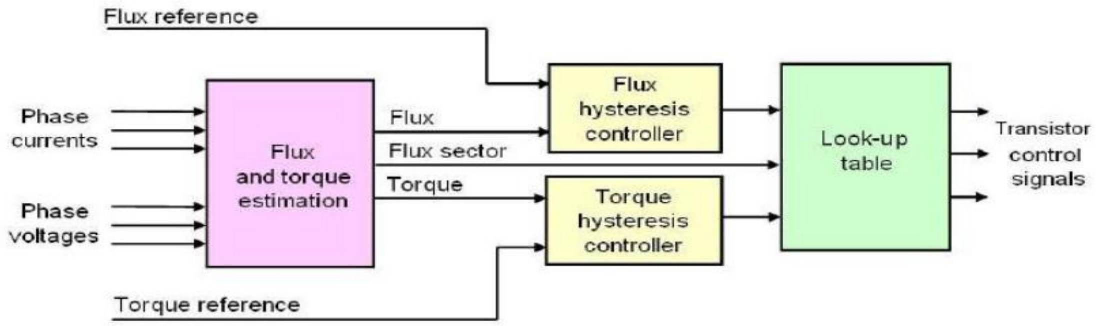

Fig. 3: Block diagramof DTC.

3.1 Direct Torque Control Principle

Direct Torque Control (DTC) is an optimized AC drives control principle where inverter switching directly controls the motor variables: flux and torque. The measured input values to the DTC control are motor current and voltage. The voltage is defined from the DC-bus voltage and inverter switch positions. The voltage and current signals are inputs to an accurate motor model which produces an exact actual value of stator flux and torque every 25 microseconds. Motor torque and flux two-level comparators compare the actual values to the reference values produced by torque and flux reference controllers. The outputs from these two-level controllers are updated every 25 microseconds and they indicate whether the torque or flux has to be varied. Depending on the outputs from the two-level controllers, the switching logic directly determines the optimum inverter switch positions. Therefore every single voltage pulse is determined separately at "atomic level". The inverter switch positions again determine the motor voltage and current, which in turn influence the motor torque and flux and the control loop is closed.

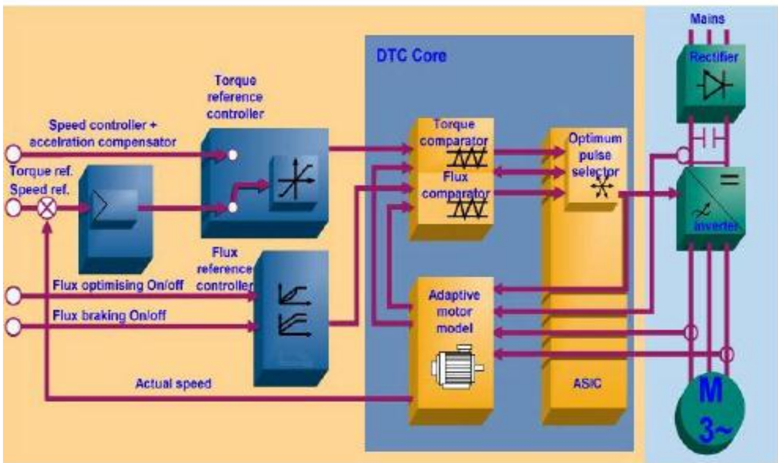

Fig. 4: Functional block diagram for DTC of induction motor.

3.2 Stator Flux Control

The IM equations, in a stator reference frame, are defined by: where Rs and Rr are the stator and rotor resistances. Ls and Lr are the mutual stator and rotor inductances. The stator flux is estimated from the measure of stator current and voltage and their transformation in the subspace. So The stator flux module and the linkage phase are given by So, the variation of the stator flux is directly proportional to the stator voltage, thus the control is carried out by varying the stator flux vector by selecting a suitable voltage vector with the inverter. A two level hysteresis comparator could be used for the control of the stator flux.

3.4 Direct Torque Control with Three-Level Inverter

The basic functional blocks used to implement the DTC scheme are represented in Figure. The instantaneous values of the stator flux and torque are calculated from stator variable by using a closed loop estimator. Stator flux and torque can be controlled directly and independently by properly selecting the inverter switching configuration.

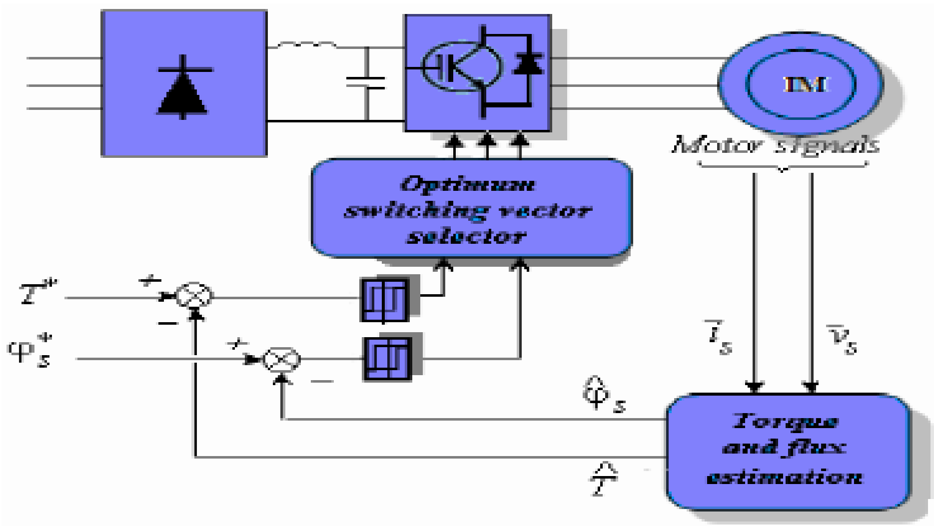

Fig. 5: DTC scheme for AC motor with three level inverter.

3.5 Stator Flux and Electromagnetic Torque

The calculated magnitude of stator flux and electric torque are compared with their reference values in their corresponding hysteresis comparators as are shown in Fig 3.4. Finally, the outputs of the comparators with the number of sector at which the stator flux space vector is located are fed to a switching table to select an appropriate inverter voltage vector.

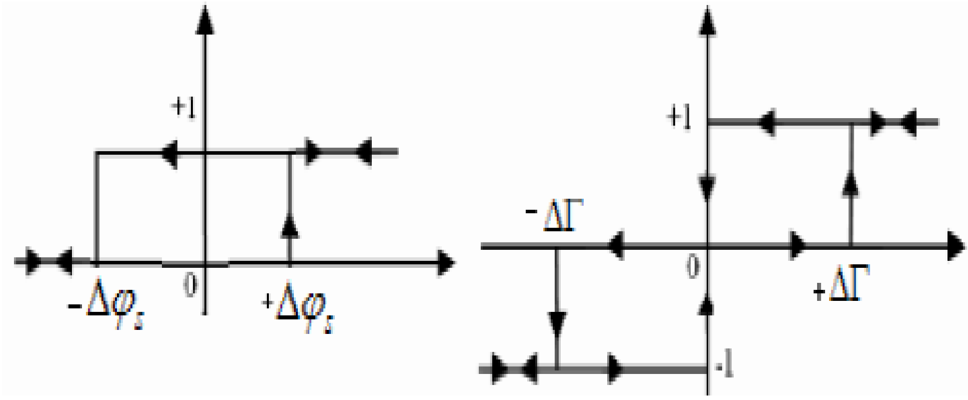

Fig. 6: Stator flux and torque hysteresis comparator.

The selected voltage vector will be applied to the induction motor at the end of the sample time.

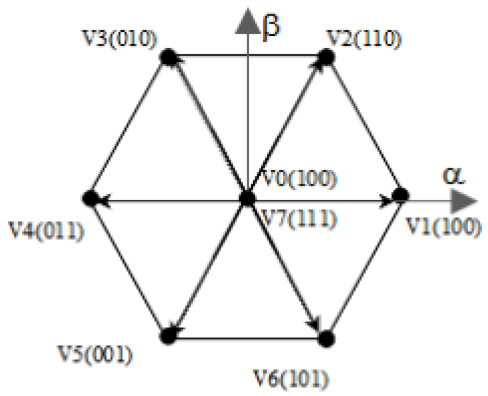

Fig. 7: Partition of d-q plane into six angular vectors.

Neglecting the stator resistance, implies that the end of the stator flux vector will move in the direction of the applied voltage vector, as shown in Fig 5. Is the initial stator flux linkage at the instant of switching. To select the voltage vectors for controlling the amplitude of the stator flux linkage, the voltage vector plane is divided into six regions, as shown in Fig 6. In each region, two adjacent voltage vectors, which give the minimum switching frequency, are selected to increase or decrease the amplitude of, respectively. For instance, vectors and are selected to increase and decrease the amplitude of when is in region one and is rotating in a counter-clockwise direction. In this way, can be controlled at the required value by selecting the proper voltage vectors. Fig 7 shows how the voltage vectors are selected for keeping within a hysteresis band when is rotating in the counter clockwise direction.

4. Hardware Implementation

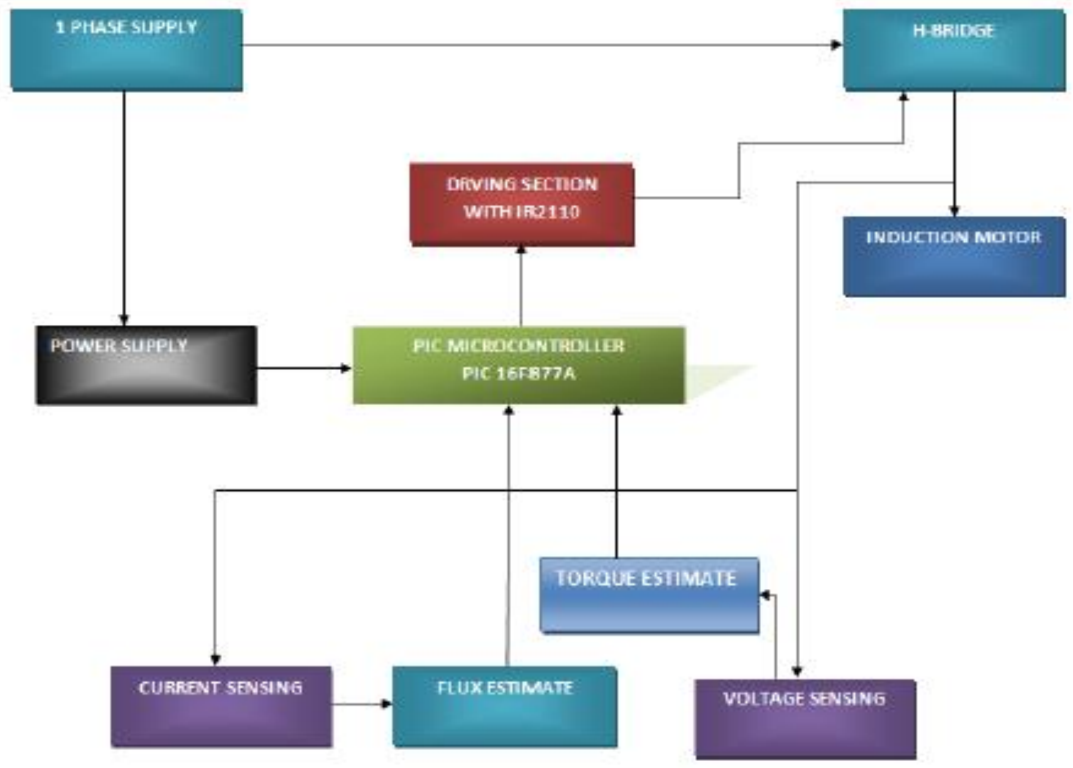

Fig. 8: Functional block diagram.

4.1 Power Supply System

A power supply is a device that supplies electrical energy to one or more electric loads. The term is most commonly applied to devices that convert one form of electrical energy to another, though it may also refer to devices that convert another form of energy (e.g., mechanical, chemical, solar) to electrical energy. A regulated power supply is one that controls the output voltage or current to a specific value; the controlled value is held nearly constant despite variations in either load current or the voltage supplied by the power supply's energy source. Every power supply must obtain the energy it supplies to its load, as well as any energy it consumes while performing that task, from an energy source. A power supply may be implemented as a discrete, stand-alone device or as an integral device that is hardwired to its load. In the latter case, for example, low voltage DC power supplies are commonly integrated with their loads in devices such as computers and household electronics.

4.2 PIC 16F887 Microcontroller

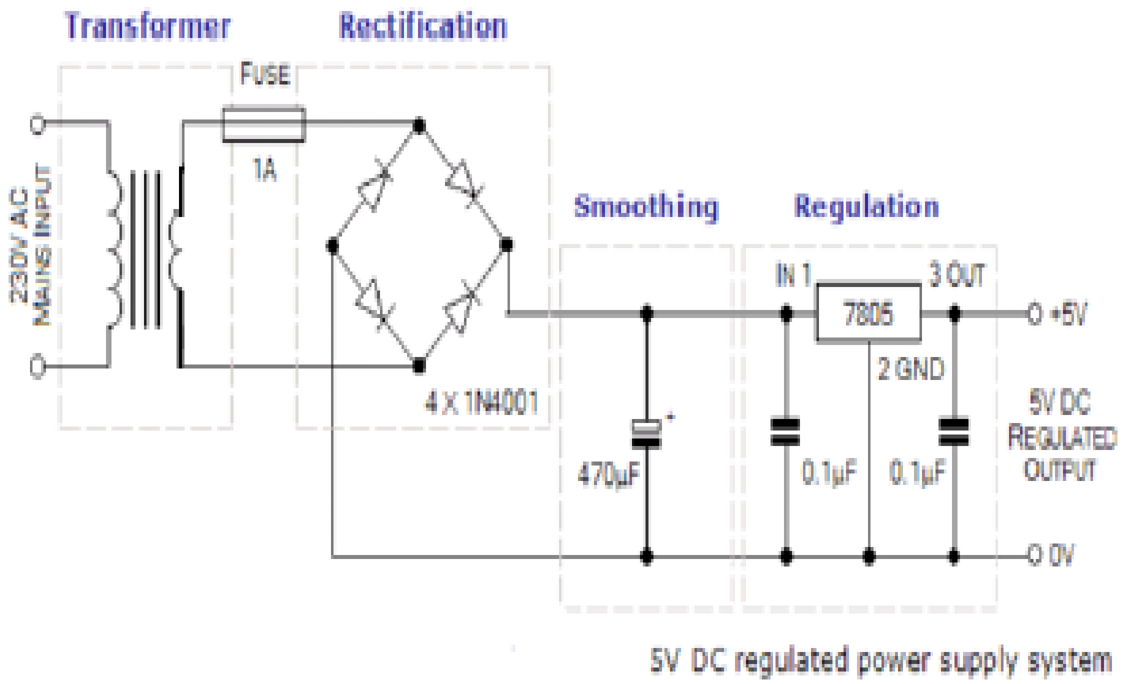

Fig. 9: Power supply circuit for PIC 16F877.

The PIC16F887 having 40pins and 5 ports. In this PIC microcontroller the first pin is connected with the master clear circuit, it is used for the clear purpose. For this circuit we will provide +5v supply. For this project we won"t use port A and port E. 11th and 12th pin for the purpose of VSS and VDD. For RF we will provide +5v supply. In power supply circuit first the step down transformer will provide 12v AC supply. Then this alternating current converted into direct current with the help of bridge rectifier. At last with the help of particular rectified IC we can get particular voltage level.

4.3 Working

The torque and stator flux of the induction motor is estimated and compared with the reference values independently. The torque and flux errors produced are given as input to the fuzzy logic controller where the linguistic inputs are processed as per the fuzzy rules table and crisp output is produced. The controlled output can be applied as a firing signals to the inverter through IR2110 (Driver IC) and Optocoupler.TheOpto isolation of signals is necessary as the control signals from the controller is digital one where as the firing signals to be applied to inverter should be analog one. Thus torque and flux of the induction motor is controlled effectively.

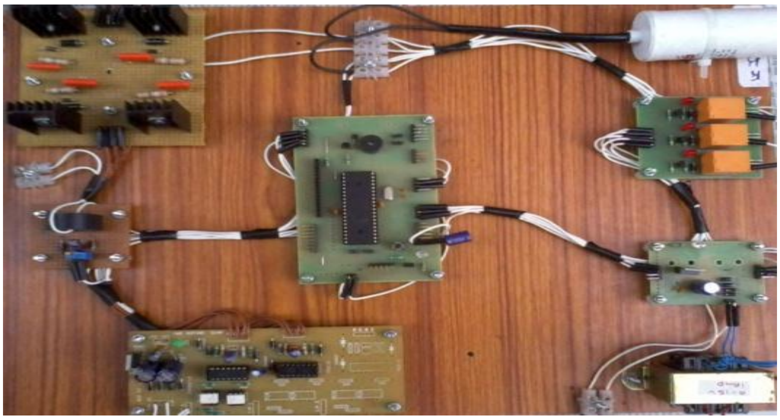

Fig. 10: Hardware setup.

5. CONCLUSION

In this paper, we present a kind of fuzzy torque control system for induction motor based on fuzzy control technique. The simulation results suggest that FLDTC of induction machine can achieve precise control of the stator flux and torque. Compared to conventional DTC, presented method is easily implemented, and the steady performances of ripples of both torque and flux are considerably improved. The main improvements shown are: • Reduction of torque and current ripples.• No flux droppings caused by sector changes circular trajectory.• Fast torque response. • Zero-steady-state torque and flux.

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