A certain Study on the Performance of Induction Motor Under Abnormal Conditions Using Matrix Converter

A Project Report

Submitted by

SIBILDAS.M - 0920105010

in partial fulfillment for the award of the degree

of

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In

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DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

KUMARAGURU COLLEGE OF TECHNOLOGY

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(An Autonomous Institution Affiliated to Anna University of Technology, Coimbatore.)

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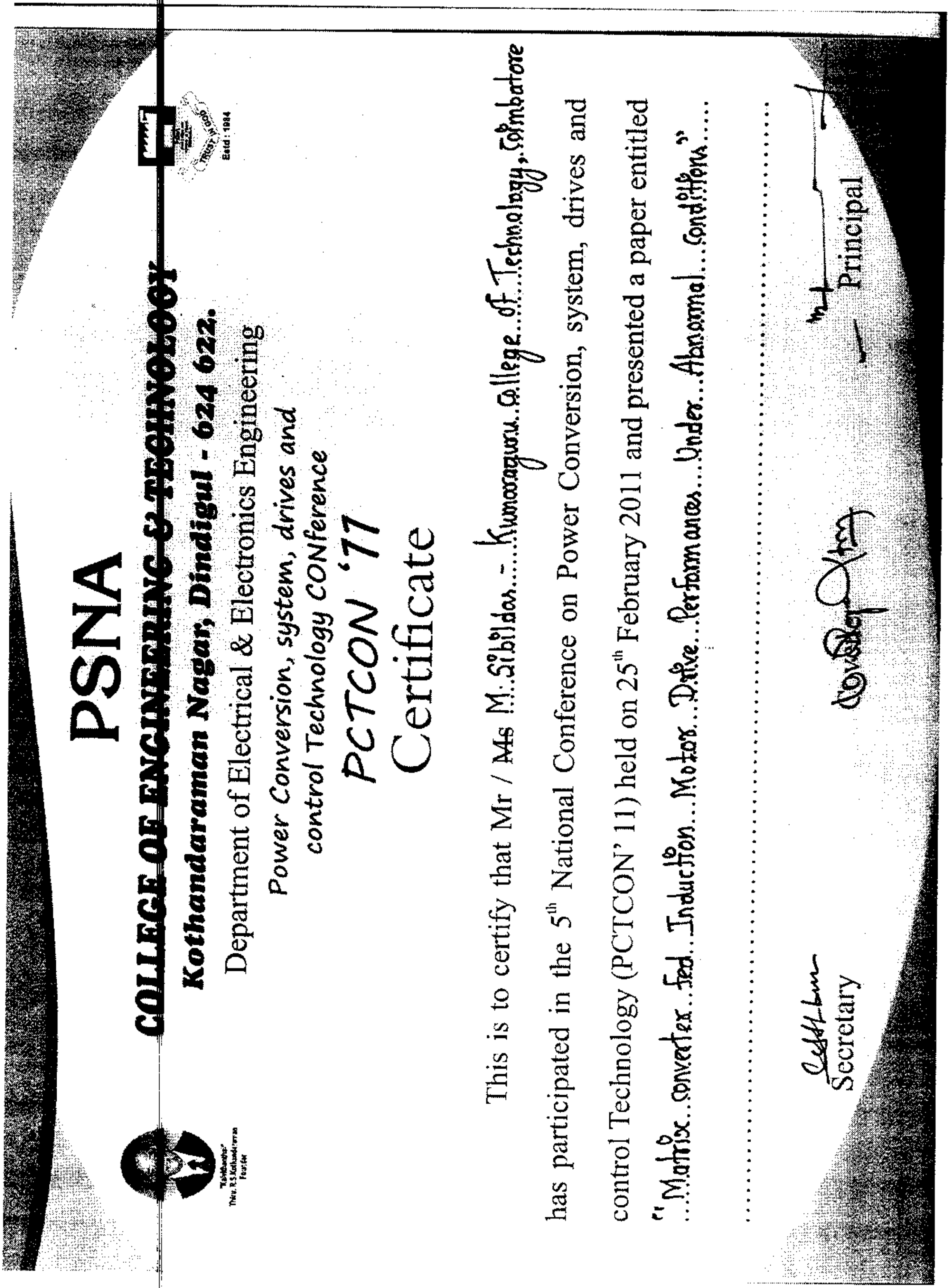

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Dr.R.Mahalakshmi / Prof.K.Premalatha Organising Secretaries	Dr.Rani Thottungal Convener	Dr.S.Ramachandran Principal

ABSTRACT

The matrix converter is a direct frequency conversion device with high input power quality and regeneration capability. As a device without energy storage elements, it has higher power density than PWM inverter devices. The abnormal conditions of input power supply have a great influence on the input/output performance of induction drive. Overheating, line-current unbalance, derating, torque pulsation, and inefficiency etc are the adverse effects of voltage unbalance. The overheating leads to winding insulation degradation. High performance of MC fed induction motor drive could be obtained over a wide operating range, if some compensation techniques are used in abnormal conditions. So, It is necessary to compare the matrix converter fed induction motor with the conventional VSI fed induction motor.

Here initially VSI fed induction motor is simulated for different modulation indices and found the modulation index at which VSI producing less THD. With that THD efficiencies are calculated for different input voltages. The voltage at which the VSI producing highest efficiency is chosen, that voltage is considered as normal voltage. Then the performance of VSI fed induction motor under various abnormal conditions such as over voltage(greater than normal), under voltage(less than normal) and normal voltage condition is performed and are compared with Matrix converter fed induction motor under three conditions. As a prototype single phase matrix converter fed impedance fan is used. The fan is designed to run at three different speeds. For that Main components used here are IGBTs, PIC microcontrollers and driver (25N120) circuit. Hence the performance of VSI fed induction motor was compared with matrix converter fed induction motor and prototype model of single phase matrix converter was done.

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ABBREVIATIONS

VSI	Voltage source inverter
AC	Alternating Current
DC	Direct current
PWM	Pulse Width Modulation
THD	Total Harmonic Distortion
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
I/O	Input/Output
IGBT	Insulated Gate Bipolar Transistor
RMS	Root Mean Square

Chapter 1

INTRODUCTION TO MATRIX CONVERTER

The matrix converter (MC) is a direct frequency conversion device that generates variable magnitude variable frequency output voltage from the ac utility line. It has high power quality (sinusoidal currents with unity power factor) and it is fully regenerative. Fig. 1 shows the basic MC drive structure. Since it does not involve an intermediate dc voltage link and the associated large capacitive filter, an MC drive has higher power density than a pulse-width modulation (PWM) inverter drive. The matrix converter is a forced commutated converter which uses an array of controlled bidirectional switches as the main power elements to create a variable output voltage system with unrestricted frequency. It does not have any dc-link circuit and does not need any large energy storage elements. The key element in a matrix converter is the fully con-trolled four-quadrant bidirectional switch, which allows high-frequency operation.

The introduction of power transistors for implementing the bidirectional switches made the matrix converter topology more attractive. However, the real development of matrix converters starts with the work of Venturini and Alesina published in 1980. They presented the power circuit of the converter as a matrix of bidirectional power switches and they introduced the name "matrix converter." One of their main contributions is the development of a rigorous mathematical analysis to describe the low-frequency behavior of the converter, introducing the "low-frequency modulation matrix" concept. In their modulation method, also known as the direct transfer function approach, the output voltages are obtained by the multiplication of the modulation (also called transfer) matrix with the input voltage. Since the MC is a direct frequency conversion device, the disturbances at the ac utility grid (line) side are immediately reflected to the load side. Line voltage source or impedance unbalances can result in unwanted input/output harmonic currents. Several techniques that reduce the influence of the input voltage unbalance on the load side of the MC drive have been reported.

The matrix converter has several advantages over traditional rectifier-inverter type power frequency converters. It provides sinusoidal input and output waveforms, with minimal higher order harmonics and no sub harmonics; it has inherent bi-directional energy flow capability; the input power factor can be fully controlled. Last but not least, it has minimal energy storage requirements, which allows to get rid of bulky and lifetime- limited energy-storing capacitors. But the matrix converter has also some disadvantages. First of all it has a maximum input output voltage transfer ratio limited to @ 87 % for sinusoidal input and output waveforms. It requires more semiconductor devices than a conventional AC-AC indirect power frequency converter, since no monolithic bi-directional switches exist and consequently discrete unidirectional devices, variously arranged, have to be used for each bi-directional switch. Finally, it is particularly sensitive to the disturbances of the input voltage system.

1.1 THE TOPOLOGY

The matrix converter consists of 9 bi-directional switches that allow any output phase to be connected to any input phase. The circuit scheme is shown in Fig.1.1.The input terminals of the converter are connected to a three phase voltage-fed system, usually the grid, while the output terminal are connected to a three phase current- fed system, like an induction motor might be. The capacitive filter on the voltage- fed side and the inductive filter on the current- fed side represented in the scheme of Fig.2.1 are intrinsically necessary. Their size is inversely proportional to the matrix converter switching frequency. It is worth noting that due to its inherent bi-directionality and symmetry a dual connection might be also feasible for the matrix converter: a current- fed system at the input and a voltage- fed system at the output.

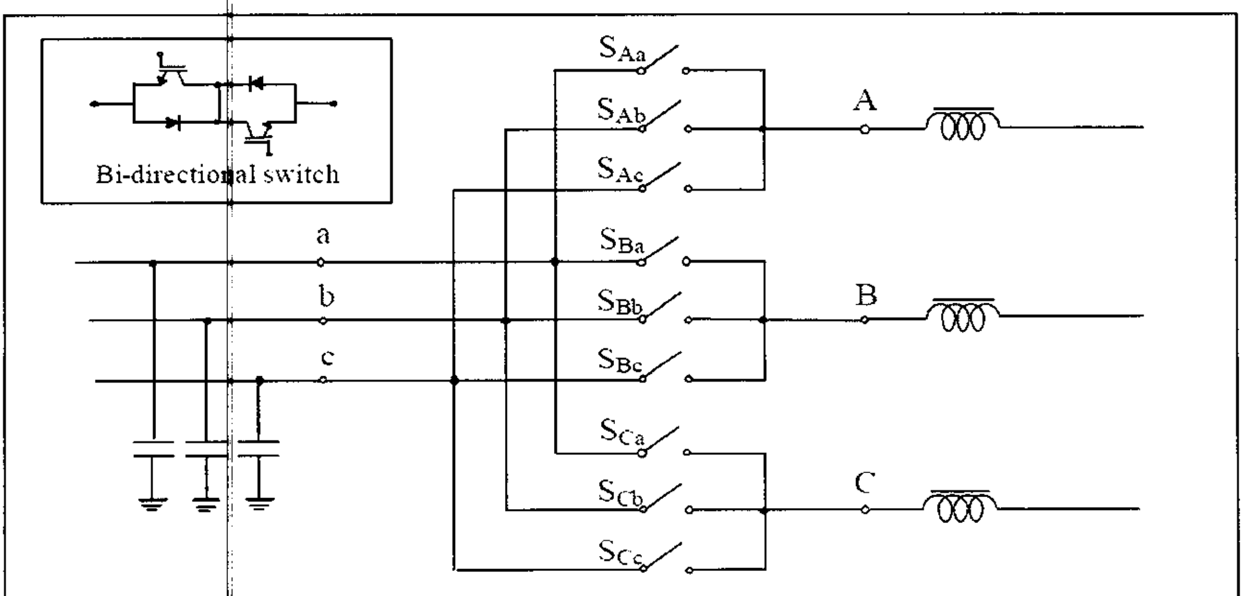


Fig.1.1 Circuit scheme of a three phase to three phase matrix converter. a,b,c are at the input terminals. A, B, C are at the output terminals.

With nine bi-directional switches the matrix converter can theoretically assume 512 (29) different switching states combinations. But not all of them can be usefully employed.

Regardless to the control method used, the choice of the matrix converter switching states combinations (from now on simply matrix converter configurations) to be used must comply with two basic rules. Taking into account that the converter is supplied by a voltage source and usually feeds an inductive load, the input phases should never be short-circuited and the output currents should not be interrupted. From a practical point of view these rules imply that one and only one bi-directional switch per output phase must be switched on at any instant. By this constraint, in a three phase to three phase matrix converter 27 are the permitted switching combinations.

1.2 OUTPUT VOLTAGE COMPARISON OF VSI AND MATRIX CONVERTER

Since no energy storage components are present between the input and output side of the matrix converter, the output voltages have to be generated directly from the input voltages. Each output voltage waveform is synthesized by sequential piecewise sampling of the input voltage waveforms. The sampling rate has to be set much higher than both input and output frequencies, and the duration of each sample is controlled in such a way that the average value of the output waveform within each sample period tracks the desired output waveform. As consequence of the input-output direct connection, at any instant, the output voltages have to fit within the enveloping curve of the input voltage system. Under this constraint, the maximum output voltage the matrix converter can generate without entering the over- modulation range is equal to V*3/2 of the maximum input voltage: this is an intrinsic limit of matrix converter and it holds for any control law . Entering in the over-modulation range, thus accepting a certain amount of distortion in the output voltages and input currents, it is possible to reach higher voltage transfer ratio. In Fig.1.2 the output voltage waveform of a matrix converter is shown and compared to the output waveform of a traditional voltage source inverter (VSI). The output voltage of a VSI can assume only two discrete fixed potential values, those of the positive and negative DC-bus. In the case of the matrix converter the output voltages can assume either input voltage a, b or c and their value is not time-invariant: the effect is a reduction of the switching harmonics.

2. Surges

These are overvoltage that last for more than one cycle. Surges are caused when some heavy electrical load is suddenly switched off. Surges can cause damage in many equipments. In case the overvoltage is very severe, it can slip through the power supply and can blow up the components inside the equipment. A continuous high voltage can damage the power supply itself.

Spikes and surges are generated by the switching off of high power motors and other inductive appliances. All electric motors and transformer generate fields that store energy. When one of these appliances is switched off, the magnetic field collapses and as a result the stored energy having no other place to go, come down the power line as a spike.Relatively small motors like those used in refrigerators, photocopiers and air-conditioners can also lead to spikes of thousands of volts. Spikes and surges damage any equipment on a cumulative nature. When a number of spikes and surges get through, first the component and then the electronic equipments fail. Spikes and surges are the main cause of destruction of the electronic equipments.

Under voltage = can be further divided into three categories, sags, brownout and blackout.

1. Sags

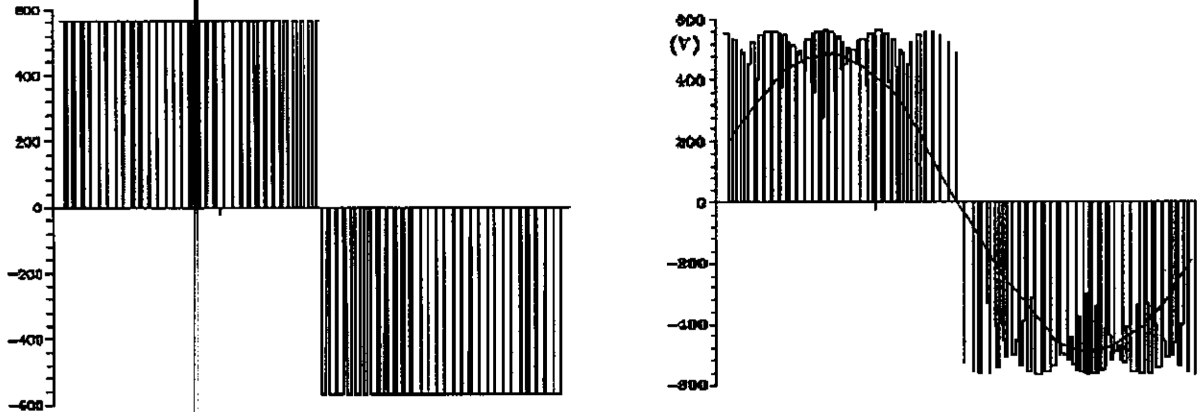
Sags are under voltage that last for more than one cycle. Sags can very badly affect induction motor.

2. Brownout

Brownout is the low voltage condition that can be present even for several hours. This is often created when the power demand exceeds the capacitor of the power generator. Brownout can also cause many problems. Fortunately, high or low voltage problems can be tackled by using some good quality voltage regulators.

3. Blackout

Blackout is the complete no-power condition. Sometime sudden power failure can bring about wastage of time, money and resources. The interrupted process may have to be restarted from some earlier stages or sometimes even the complete work may have to be redone right from the beginning.



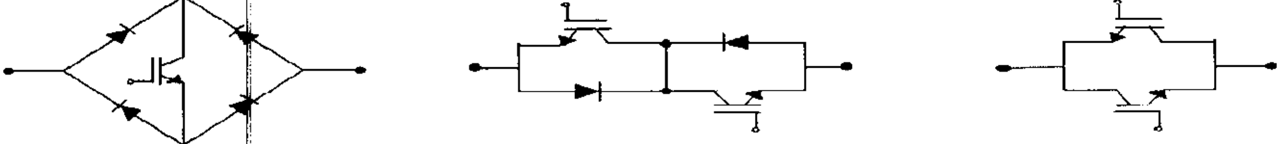
a) VSI   b) Matrix converter

Fig 1.2 Output wave forms generated by VSI and Matrix converter

1.3 BI DIRECTIONAL SWITCH REALIZATION

A first key problem is related to the bi-directional switches realization. By definition, a bidirectional switch is capable of conducting currents and blocking voltages of both polarities, depending on control actual signal. But at present time a true bi-directional switch is still not available on the market and thus it must be realized by the combination of conventional unidirectional semiconductor devices. Fig.1.3 shows different bi-directional switch configurations which have been used in prototype and/or proposed in literature.

Another problem, tightly related to the bi-directional switches implementation, which has represented a main obstacle to the industrial success of the matrix converter, is the commutation problem. The commutation issue basically rises from the absence, in the matrix converters, of static freewheeling paths. As consequence it becomes a difficult task to safely commutate the 20 current from one bi-directional switch to another, since a particular care is required in the timing and synchronisation of the switches command signals.



a) Diode bridge with a single IGBT   b) Two anti-paralleled IGBT with series diodes   c) Two anti-paralleled NPT-IGBT's with reverse blocking capability

Fig.1.3 Possible discrete implementations of a bi-directional switch.

1.4 INDUCTION MOTOR

The AC Asynchronous Motor also named, Induction Motor (IM) is the most widely used electrical motor as it has its own advantages. The main advantage is that the induction motors do not require an electrical connection between the stationary and rotating parts of the motor. Therefore, they do not need any mechanical commutators (brushes), leading to the fact that they are maintenance free motors. Induction motors also have low weight and inertia, high efficiency and high overload capability. Therefore, they are cheaper and more robust, and less prone to failures at high speeds. Furthermore, the motor can work in explosive environments because no sparks are produced.

Because of the highly non-linear and coupled dynamic structure, an induction motor requires more complex schemes than dc motors. When high performance dynamic operation is required, more sophisticated control methods are needed to make the performance of induction motors comparable with dc motors. Recent developments in areas of drive control techniques, fast semiconductor power switches, etc., made induction motors alternatives to dc motors in industry. One of the most widely used induction motor drive control is Direct Torque Control (DTC).

1.4.1 Basic Principles of IM

The AC induction motor is a rotating electric machine designed to operate from a three-phase source of alternating voltage. The stator is a classic three phase stator with the winding displaced by 120°. The most common type of induction motor has a squirrel cage rotor in which aluminium conductors or bars are shorted together at both ends of the rotor by cast aluminium end rings. When a set of three phase currents displaced in time from each other by angular intervals of 120° is injected into a stator having a set of three-phase windings displaced in space by 120° electrical, a rotating magnetic field is produced. The interaction of the sinusoidally distributed air gap flux and induced rotor currents produces a torque on the rotor. The rotating magnetic field has an uniform strength and travels at an angular speed equal to its stator frequency. It is assumed that the rotor is at standstill. The rotating magnetic field in the stator induces electromagnetic forces in the rotor windings. As the rotor windings are short-circuited, currents start circulating in them, producing a reaction. As known from Lenz's law, the reaction is to counter the source of the rotor currents, i.e. induced emf in the rotor and in turn, the rotating magnetic field itself. The induced emf will be countered if the difference in the speed of the rotating magnetic field and the rotor becomes zero. The only way to achieve it is for the rotor to run in the same direction as that of stator magnetic field and catch up with it eventually. When the differential speed between the rotor and magnetic field in the stator becomes zero, there is zero emf, and hence zero rotor currents resulting in zero torque production in the motor. Depending on the shaft load, the rotor will settle down to a speed, ω_r, always less than the speed of the rotating magnetic field, called synchronous speed of the machine, ω_s. The speed differential is known as the slip speed, ω_{sl}. The relationship between synchronous speed and stator frequency is given by,

$$\omega_s = 2\pi f_s \text{ rad/sec.}$$

The speed of the stator magnetic field in rpm is given by

$$n_s = 120 * f_s / P.$$

1.5 VOLTAGE IRREGULARITIES

The abnormal conditions of input power supply have a great influence on the input/output performance of induction drive. The problem of voltage unbalanced has attracted special attention amongst electrical engineers dealing with power quality issues in recent past. Overheating, line-current unbalance, de rating, torque pulsation, and inefficiency etc are the adverse effects of voltage unbalance. The overheating leads to winding insulation degradation.

Power problems can be divided into two main category, that is:-

1) Overvoltage
2) Under voltage

Overvoltage can be again divided into two types, spikes and surges.

1. Spikes

A spikes is a very short burst of high voltage which can disrupt the operation of any electronic equipments. Some small spikes are caused by switching equipment, including motor controllers. When lighting strikes the power system, it can cause very large spikes.

The effect on electronic equipments varies with the size and power of the spike. A typical spike may have a fairly high voltage (5000 volts or more). Small spikes usually do not damage the components, but spikes caused by lighting can be much more powerful.

4. Noise

Any signal present on the power line besides the expected alternating current of 50 Hz is called the noise. Noise usually consists of short term over and under voltages. There are several different types of noise. Large electric motors can create powerful electromagnetic fields and may cause EMI problems. Electric motors, which may cause EMI, are found in various kind of equipment-refrigerators, air conditioners, washing machines, furnaces, copier, elevators, machine tools, and so on.

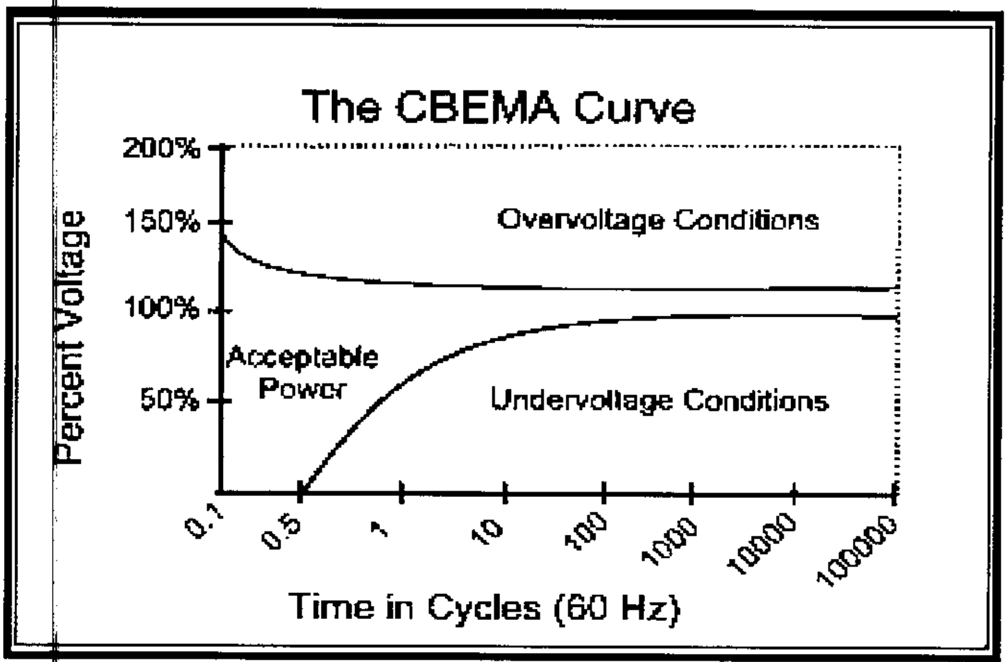


Fig1.4 Voltage irregularities

1.6 LITERATURE SURVEY

The matrix converter (MC) offers possible "all silicon" solution for AC-AC conversion, removing the need for reactive energy storage components used in conventional converter system. Its topology was first described in 1976 by Gyugyi in his paper "Static Power Chargers, Theory, Performance and Application". Previous published studies dealt with three-phase circuit topologies. MC in the three-phase variant is widely researched whilst the Single-Phase Matrix Converter (SPMC) has very little attention whilst offering very wide application.

The Single-phase matrix converter (SPMC) was first realised by Zuckerberger in his paper "Single-phase Matrix Converter". All previous works have focussed attention to direct AC-AC single phase converter and DC chopper but none on inverter as well as rectifier operation.

Investigations on the implementation of the Single phase Matrix Converter as an AC-AC converter subject to passive load conditions was done by Zahirrudin Idris in his paper "Implementation of Single Phase Matrix Converter as a direct AC-AC converter Synthesised using SPWM with passive Load Condition".

Implementation of a new modular AC-AC matrix converter and its control system are described by R.W Ericson in his paper "control and Implementation of a New Modular Matrix Converter". It is capable of both increasing and decreasing the voltage magnitude and frequency, while operating with arbitrary power factors.

1.7 OBJECTIVES OF THE PROJECT

1. A study on the Performances (Speed, Torque, Total Harmonic Distortion) of the 3 phase Induction Motor Drive fed by Matrix Converter under abnormal input voltage conditions and Comparing the performance with the Conventional VSI fed induction motor
2. Hardware implementation of Single phase matrix converter fed by a 230V ac motor.

1.8 ORGANIZATION OF THE REPORT

Chapter 1 deals with the introduction to the project.

Chapter 2 deals with description about VSI fed induction motor and simulation results of three phase fed induction motor

Chapter 3 contains description about Matrix converter fed induction motor, simulation results of three phase matrix converter fed induction motor with comparison to VSI fed induction motor

Chapter 4 prototype model single phase matrix converter fed by a single phase 230V ac motor.

Chapter 5 gives the Conclusion of the Project and the scope for future work.

Chapter 2

VOLTAGE SOURCE INVERTER

The main objective of static power converters is to produce an ac output waveform from a dc power supply. These are the types of waveforms required in adjustable speed drives (ASDs), uninterruptible power supplies (UPS), static var compensators, active filters, flexible ac transmission systems (FACTS), and voltage compensators, which are only a few applications. For sinusoidal ac outputs, the magnitude, frequency, and phase should be controllable.

According to the type of ac output waveform, these topologies can be considered as voltage source inverters (VSIs), where the independently controlled ac output is a voltage waveform. These structures are the most widely used because they naturally behave as voltage sources as required by many industrial applications, such as adjustable speed drives (ASDs), which are the most popular application of inverters. Similarly, these topologies can be found as current source inverters (CSIs), where the independently controlled ac output is a current waveform. These structures are still widely used in medium-voltage industrial applications, where high-quality voltage waveforms are required. Static power converters, specifically inverters, are constructed from power switches and the ac output waveforms are therefore made up of discrete values. This leads to the generation of waveforms that feature fast transitions rather than smooth ones.

For instance, the ac output voltage produced by the VSI of a standard ASD is a three-level waveform (Fig. 1c). Although this waveform is not sinusoidal as expected (Fig. 1b), its fundamental component behaves as such. This behavior should be ensured by a modulating technique that controls the amount of time and the sequence used to switch the power valves on and off. The modulating techniques most used are the carrier-based technique (e.g., sinusoidal pulse width modulation, SPWM), the space-vector (SV) technique, and the selective-harmonic-elimination (SHE) technique.

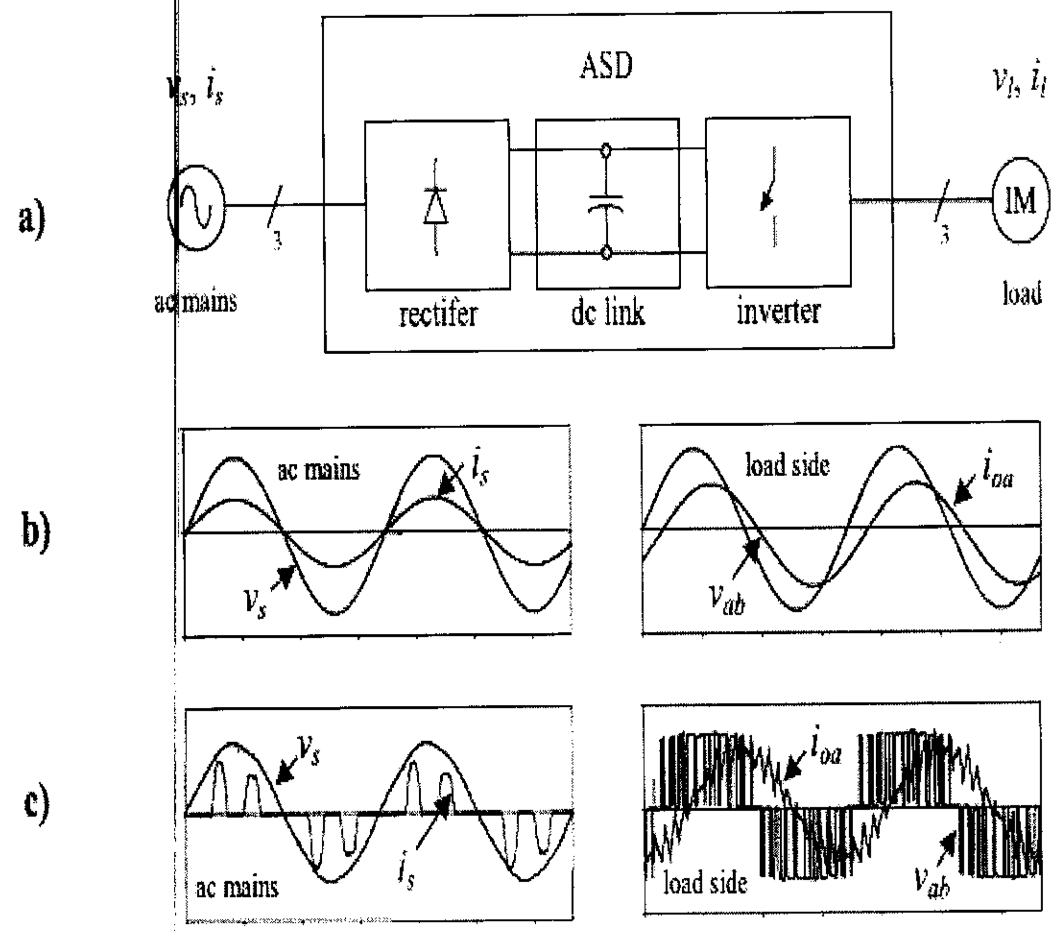


Fig. 2.1: The ac output voltage produced by the VSI of a standard ASD

a) The electrical power conversion topology;

b) The ideal input (ac mains) and output (load) waveforms; and

c) The actual input (ac mains) and output (load) waveforms

2.1. SINGLE-PHASE VOLTAGE SOURCE INVERTERS

Single-phase voltage source inverters (VSIs) can be found as half-bridge and full-bridge topologies. Although the power range they cover is the low one, they are widely used in power supplies, single-phase UPSs, and currently to form elaborate high-power static power topologies, such as for instance, the multicell configurations.

2.1.1 Half-Bridge VSI

Fig below shows the power topology of a half-bridge VSI, where two large capacitors are required to provide a neutral point N, such that each capacitor maintains a constant voltage (Vi)/2. Because the current harmonics injected by the operation of the inverter are low-order harmonics, a set of large capacitors (C+ and C-) is required. It is clear that both switches S+ and S- cannot be ON simultaneously because a short circuit across the dc link voltage source Vi would be produced. There are two defined (states 1 and 2) and one undefined (state 3) switch state as shown in Table 1. In order to avoid the short circuit across the dc bus and the undefined ac output voltage condition, the modulating technique should always ensure that at any instant either the top or the bottom switch of the inverter leg is on.

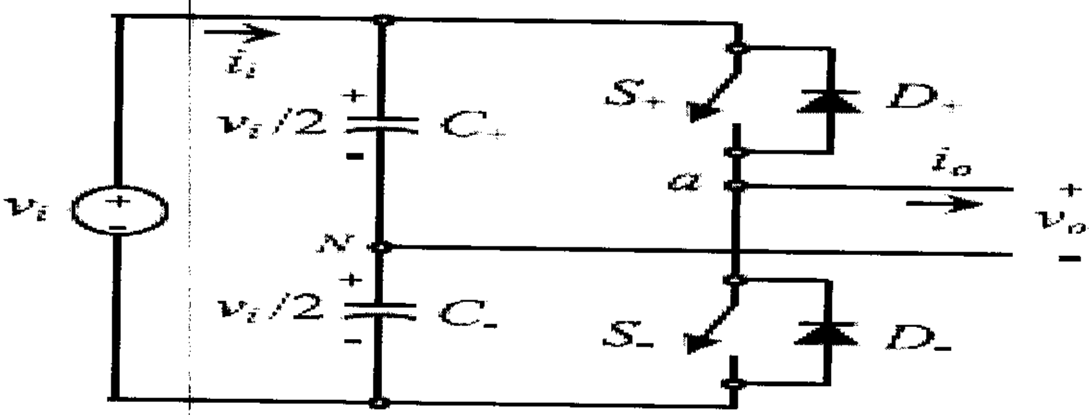


Fig 2.1.1 Single phase half bridge VSI

Tables 2.1.1
Switching states for a half bridge single phase VSI

State	State	v	Components Conducting
+ is on and _ is off	1	v /2	+ if > 0 + if < 0
_ is on and + is off	2	−v /2	_ if > 0 _ if < 0
+ and _ are all off	3	−v /2 v /2	_ if > 0 + if < 0

2.1.2 Full-Bridge VSI

Fig. below shows the power topology of a full-bridge VSI. This inverter is similar to the half-bridge inverter; however, a second leg provides the neutral point to the load. As expected, both switches S1+ and S1- (or S2+ and S2-) cannot be on simultaneously because a short circuit across the dc link voltage source Vi would be produced. There are four defined (states 1, 2, 3, and 4) and one undefined (state 5) switch states as shown in Table 2. The undefined condition should be avoided so as to be always capable of defining the ac output voltage. It can be observed that the ac output voltage can take values up to the dc link value Vi, which is twice that obtained with half-bridge VSI topologies. Several modulating techniques have been developed that are applicable to full-bridge VSIs. Among them are the PWM (bipolar and unipolar) techniques.

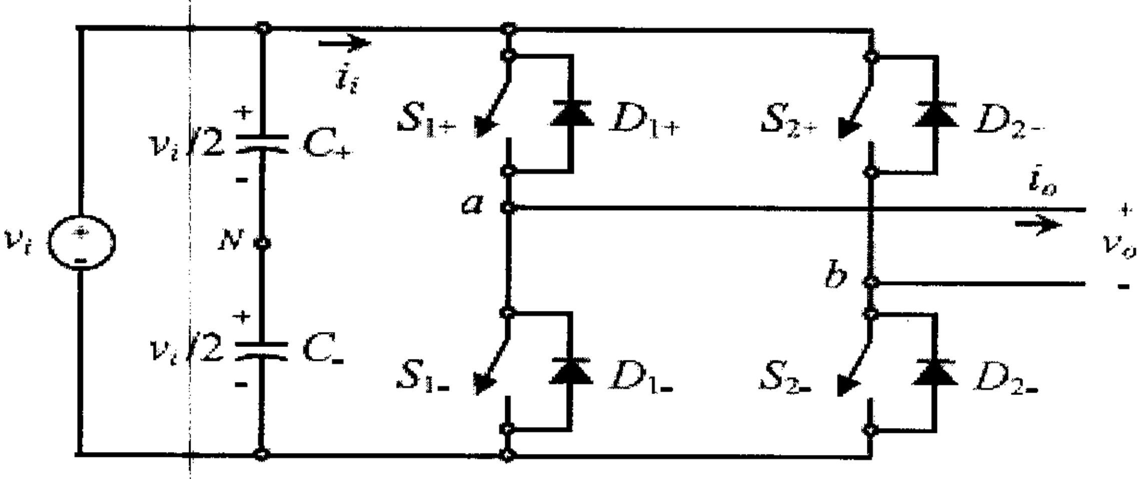


Fig 2.1.2 Single phase full bridge VSI

Tables 2.1.2
Switch states for a full bridge single phase VSI

State	State	v_a	v_b	v	Components Conducting	
$_{1+}$ and $_{2-}$ are on and $_{1-}$ and $_{2+}$ are off	1	$v/2$	$-v/2$	v	$_{1+}$ and $_{2-}$	if >0
					$_{1+}$ and $_{2-}$	if <0
$_{1-}$ and $_{2+}$ are on and $_{1+}$ and $_{2-}$ are off	2	$-v/2$	$v/2$	$-v$	$_{1-}$ and $_{2+}$	if >0
					$_{1-}$ and $_{2+}$	if <0
$_{1+}$ and $_{2+}$ are on and $_{1-}$ and $_{2-}$ are off	3	$v/2$	$v/2$	0	$_{1+}$ and $_{2+}$	if >0
					$_{1+}$ and $_{2+}$	if <0
$_{1-}$ and $_{2-}$ are on and $_{1+}$ and $_{2+}$ are off	4	$-v/2$	$-v/2$	0	$_{1-}$ and $_{2-}$	if >0
					$_{1-}$ and $_{2-}$	if <0
$_{1-}$, $_{2-}$, $_{1+}$, and $_{2+}$ are all off	5	$-v/2$	$v/2$	$-v$	$_{1-}$ and $_{2+}$	if >0
		$v/2$	$-v/2$	v	$_{1+}$ and $_{2-}$	if <0

2.2. THREE PHASE VOLTAGE SOURCE INVERTERS

Single-phase VSIs cover low-range power applications and three-phase VSIs cover the medium- to high-power applications. The main purpose of these topologies is to provide a three-phase voltage source, where the amplitude, phase, and frequency of the voltages should always be controllable. Although most of the applications require sinusoidal voltage waveforms (e.g., ASDs, UPSs, FACTS, VAR compensators), arbitrary voltages are also required in some emerging applications (e.g., active filters, voltage compensators).

The standard three-phase VSI topology is shown in Fig. below and the eight valid switch states are given in Table 3. As in single-phase VSIs, the switches of any leg of the inverter (S1 and S4, S3 and S6, or S5 and S2) cannot be switched on simultaneously because this would result in a short circuit across the dc link voltage supply. Similarly, in order to avoid undefined states in the VSI, and thus undefined ac output line voltages, the switches of any leg of the inverter cannot be switched off simultaneously as this will result in voltages that will depend upon the respective line current polarity. Of the eight valid states, two of them (7 and 8 in Table 3) produce zero ac line voltages. In this case, the ac line currents freewheel through either the upper or lower components. The remaining states (1 to 6 in Table 3) produce non-zero ac output voltages. In order to generate a given voltage waveform, the inverter moves from one state to another. Thus the resulting ac output line voltages consist of discrete values of voltages that are Vi , 0, and -Vi for the topology shown in Fig. 4. The selection of the states in order to generate the given waveform is done by the modulating technique that should ensure the use of only the valid states.

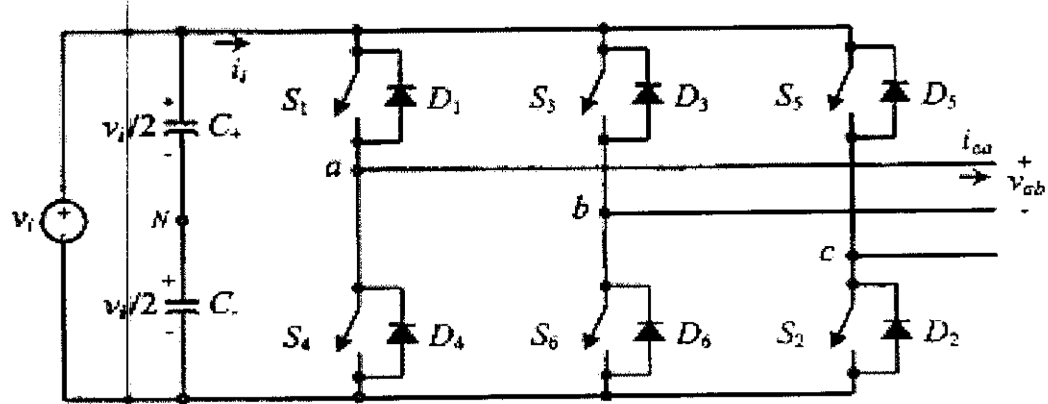


Fig 2.2 Three phase VSI Topology

Table 2.2
Switching states for 3 phase VSI

State	State	v_{ab}	v_b	v_a
1, 2, and 6 are on and 4, 5, and 3 are off	1	v	0	$-v$
2, 3, and 1 are on and 5, 6, and 4 are off	2	0	v	$-v$
3, 4, and 2 are on and 6, 1, and 5 are off	3	$-v$	v	0
4, 5, and 3 are on and 1, 2, and 6 are off	4	$-v$	0	v
5, 6, and 4 are on and 2, 3, and 1 are off	5	0	$-v$	v
6, 1, and 5 are on and 3, 4, and 2 are off	6	v	$-v$	0
1, 3, and 5 are on and 4, 6, and 2 are off	7	0	0	0
4, 6, and 2 are on and 1, 3, and 5 are off	8	0	0	0

2.3 SIMULATION MODEL OF VSI

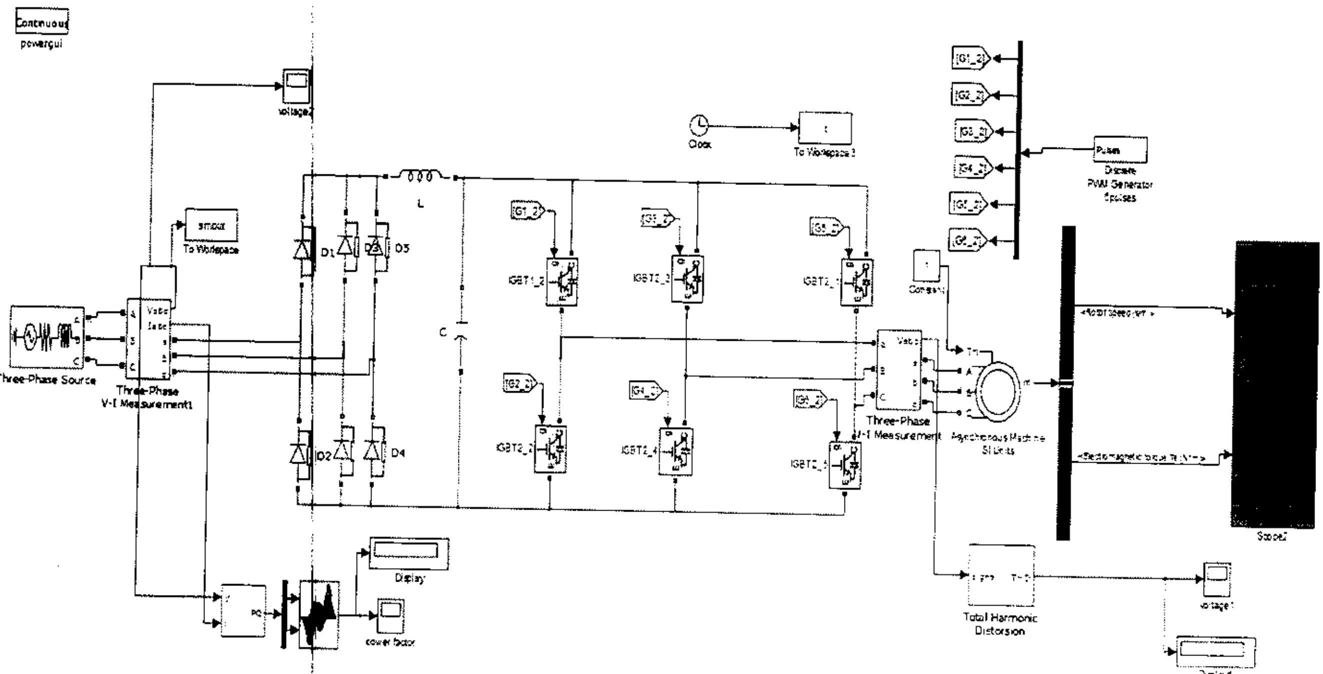


Fig 2.3 Simulation layout for a three phase VSI

The above figure shows the simulation circuit for three phase VSI. Here three phase ac is initially rectified by the uncontrolled rectifier, and then it is filtered by L.C filter and finally inverted by the inverter. The pulses required for the inverter operation is given by the pulse generator. Here Matlab 7.7 version is used for simulation.

2.4 SIMULATION RESULTS

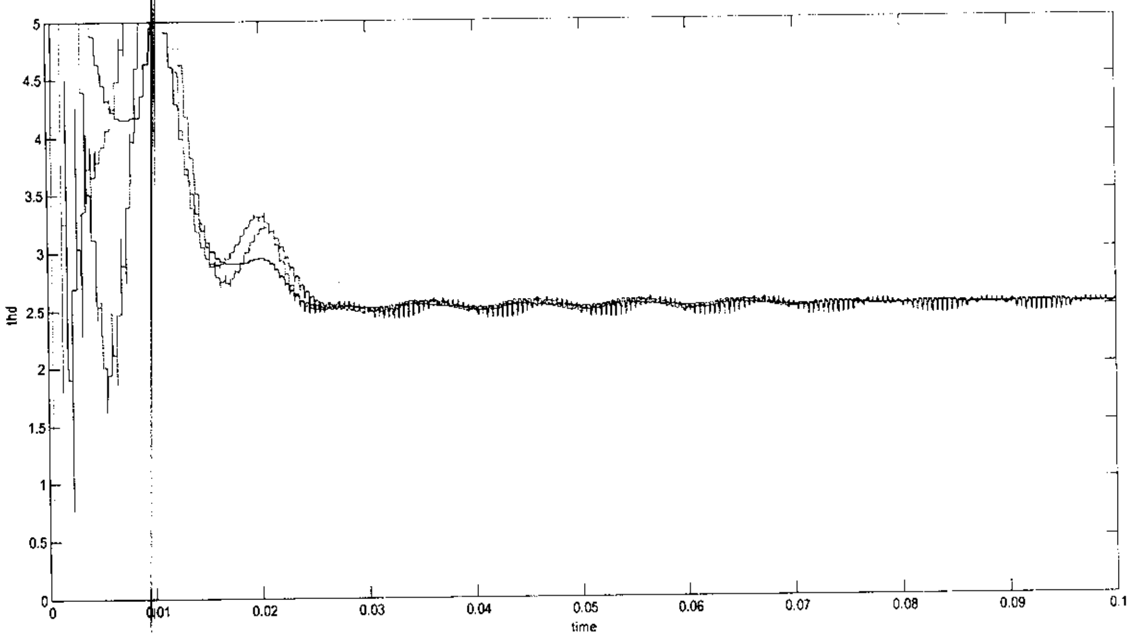


Fig 2.4.1 THD at 0.2 Modulation Index

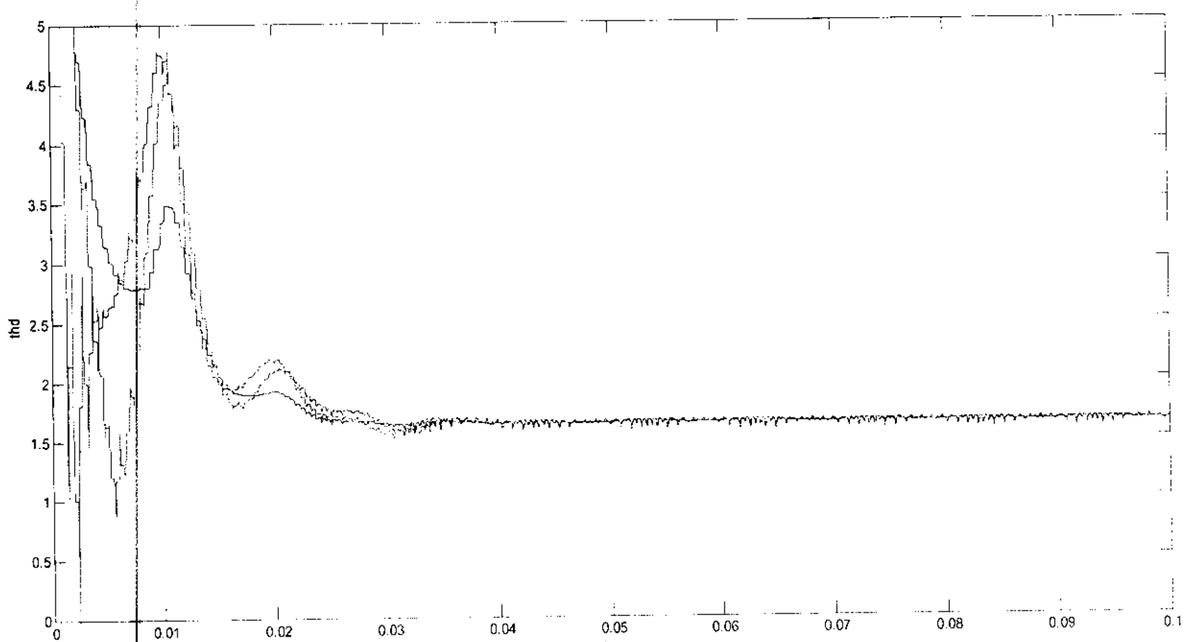


Fig 2.4.2 THD at 0.4 Modulation Index

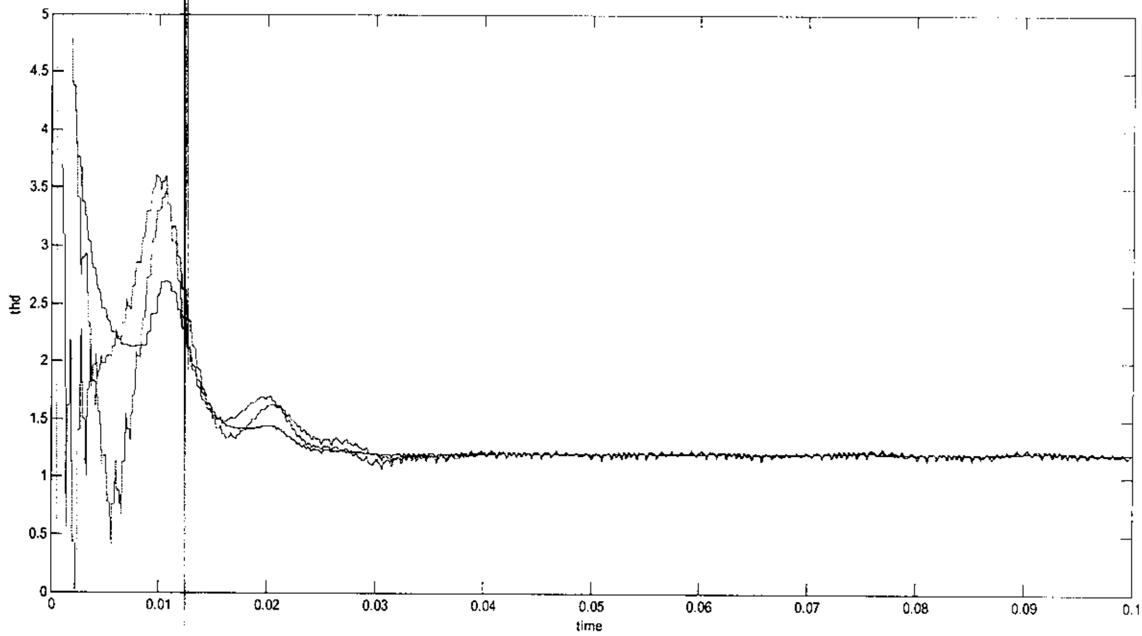


Fig 2.4.3 THD at 0.6 Modulation Index

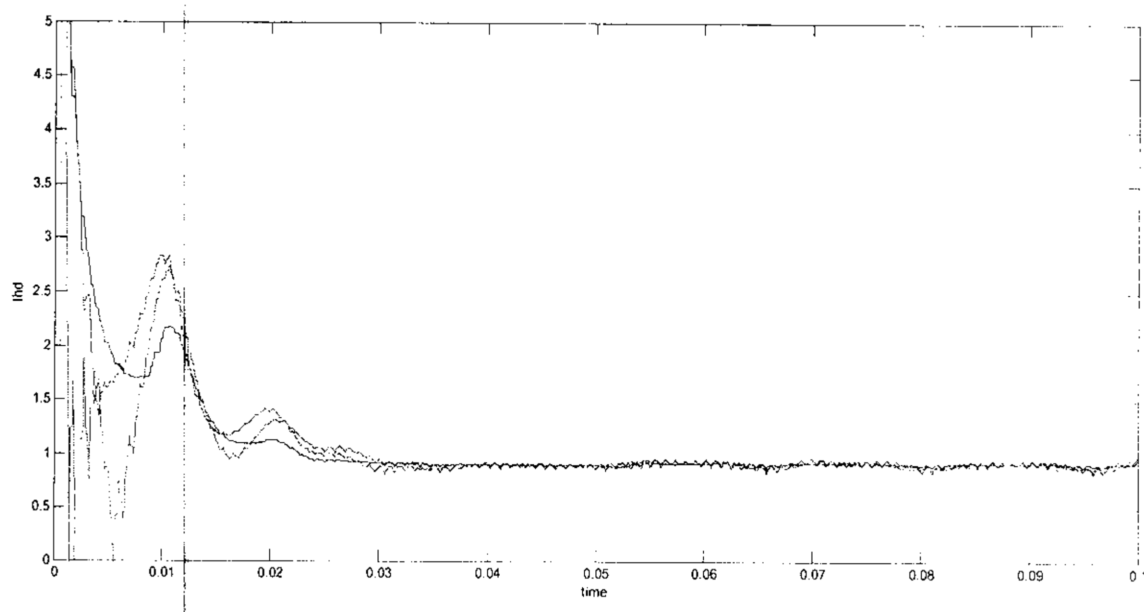


Fig 2.4.4 THD at 0.8 Modulation index

From the above graphs at 0.8 modulation index the total harmonic distortion is less. The below graphs shows the efficiencies of VSI at 0.8 Modulation index.

Table 2.4
Efficiencies for VSI at different input voltage at 0.8 MI

	Input Voltage	Output Voltage	Efficiency
	360	350	97.2
	380	360	94.7
	400	387	96.8
	420	410	97.6
	440	424	96.4

From the above table at 420V input voltage the Voltage Source Inverter have highest efficiency.

2.5 CONCLUSION

The operation of VSI fed induction motor is evaluated by computer simulation using MATLAB/SIMULINK. The system is simulated with various values of modulation indices. The variation of THD with Modulation index and the efficiencies at 0.8 modulation index are noted. It was shown above

Chapter 3

SIMULATION OF MATRIX CONVERTERS

An AC/AC converter converts an AC waveform such as the mains supply, to another AC waveform, where the output voltage and frequency can be set arbitrarily.

AC/AC converters can be categorized into

* Converters with a DC-link.
* Hybrid Matrix Converters.
* Matrix Converters.

For such AC-AC conversion today typically converter systems with a voltage or current DC-link are employed. For the voltage DC-link, the mains coupling could be implemented by a diode bridge. To accomplish braking operation of a motor, a braking resistor must be placed in the DC-link. Alternatively, an anti-parallel thyristor bridge must be provided on the mains side for feeding back energy into the mains. The disadvantages of this solution are the relatively high mains distortion and high reactive power requirements (especially during inverter operation).

An AC/AC converter with approximately sinusoidal input currents and bidirectional power flow can be realized by coupling a PWM rectifier and a PWM inverter to the DC-link. The DC-link quantity is then impressed by an energy storage element that is common to both stages, which is a capacitor C for the voltage DC-link or an inductor L for the current DC-link. The PWM rectifier is controlled in a way that a sinusoidal mains current is drawn, which is in phase or anti-phase (for energy feedback) with the corresponding mains phase voltage. figure 2.10 shows the matrix converter

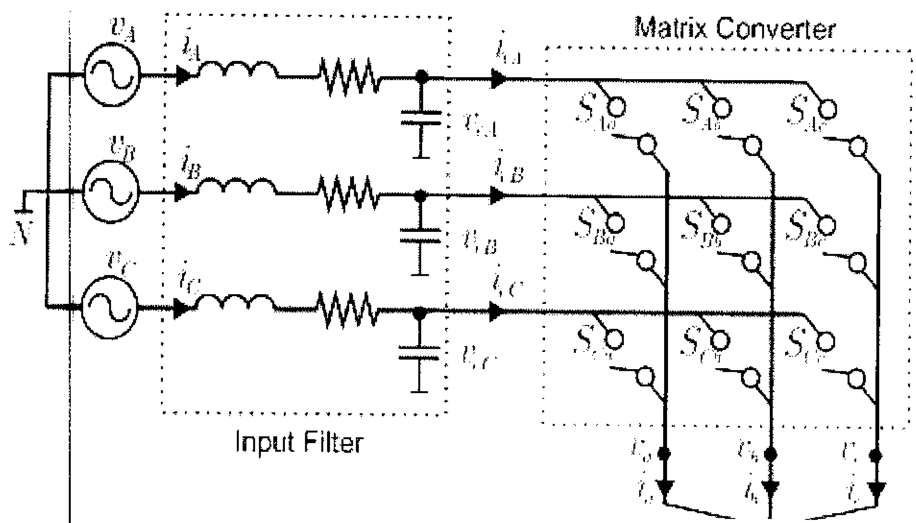


Fig 3.1 Matrix Converter

Due to the DC-link storage element, there is the advantage that both converter stages are to a large extent decoupled for control purposes. Furthermore, a constant, mains independent input quantity exists for the PWM inverter stage, which results in high utilization of the converter's power capability. On the other hand, the DC-link energy storage element has a relatively large physical volume, and when electrolytic capacitors are used, in the case of a voltage DC-link, there is potentially a reduced system lifetime. In order to achieve higher power density and reliability, it is makes sense to consider Matrix Converters that achieve three-phase AC/AC conversion without any intermediate energy storage element. Conventional Direct Matrix Converters perform voltage and current conversion in one single stage. There is the alternative option of indirect energy conversion by employing the Indirect Matrix Converter or the Sparse Matrix Converter which was invented by Prof. Johann W. Kolar from the ETH Zurich. As with the DC-link based systems, separate stages are provided for voltage and current conversion, but the DC-link has no intermediate storage element. Generally, by employing matrix converters, the storage element in the DC-link is eliminated at the cost of a larger number of semiconductors. Matrix Converters are often seen as a future concept for variable speed drives technology, but despite intensive research over the decades they have until now only achieved low industrial penetration. The reason for this could be the higher complexity in modulation and analysis effort.

The advantages of the MC are:

a) Four quadrant operation and, therefore, it is inherently bidirectional. Thanks to bidirectional switches, the MC can deliver or take power from the grid, with a direct and instantaneous conversion between input and output of the converter (conventional AC/AC converters use two conversion steps with an intermediate DC link).

b) Although the MC uses a high number of switches, there is a tendency in the market towards a price reduction of silicon components, and this problem will be minimized in a foreseeable future. The high number of switches means a higher distribution of the thermal stress in the switches.

c) The MC can operate in high and low pressure environments, and at high temperatures, such as space and submarine applications where the use of electrolytic capacitors is restricted. In this sense, the MC is a good candidate for the connection of tidal energy power stations.

d) The power losses of the MC may be considerable reduced using semi-soft commutation strategies. For this reason, high switching frequencies can be used, highly reducing the size of filters and auxiliary equipment. High operating frequencies mean high order harmonics, which are less harmful for the grid. All this makes the MC more efficient than a "rectifier-inverter" approach.

e) Using appropriate modulation strategies, it is possible to achieve sinusoidal currents at the grid and sinusoidal voltages at the load, with an unity power factor with any type of load.

The MC is a very promising technology that may contribute to the development of power electronics, but nowadays, several technological barriers must be superseded in order to extend its use in real commercial applications. Some of the challenges are:

a) Protection of the converter is a complex task, because there is no way to store energy.

b) The MC is very sensitive to voltage dips and distortions in the grid, because the power conversion has no intermediate steps. There are some strategies to reduce this effect, such as load stored energy recovery or improved modulation strategies, anyway this is an open research field.

c) The MC has a limited voltage transfer ratio of 0.86. This voltage transfer ratio may be increased with a higher harmonic content at the load.

d) The high number of power switches in a MC means a higher connection complexity, control, thermal management, etc. Thus, the development of Intelligent Power Modules (IPM) or Power Electronics Building Blocks (PEBB), integrating the power switches with the gate control circuits, increases the reliability and the efficiency of the converter, and makes the design task easier. The development of new silicon switches, such as RB-IGBT, will further improve these aspects.

Table 3.1
Comparison of different power converters

	'Inverter-Rectifier' converter	Multilevel converter	Matrix converter
Capacitors	Large sized capacitors, reduced lifetime	Small capacitors but in large numbers	No high capacitors
Temperature	Very sensitive	High influence in behavior	Less influence in behavior
Switching loss	High	High	Low
Control	Simple	Very complex	Complex
Power quality	Poor	Acceptable	Good

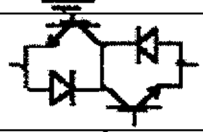
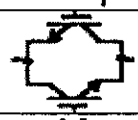
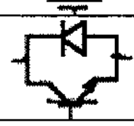
3.1 SWITCHING TABLE

Table 3.1.1
Allowed Switching States

#	SAa	SBa	SCa	SAb	SBb	SCb	SAc	SBc	SCc
1	1	0	0	0	1	0	0	0	1
2	1	0	0	0	0	1	0	1	0
3	0	1	0	1	0	0	0	0	1
4	0	1	0	0	0	1	1	0	0
5	0	0	1	1	0	0	0	1	0
6	0	0	1	0	1	0	1	0	0
7	1	0	0	0	0	1	0	0	1
8	0	1	0	0	0	1	0	0	1
9	0	1	0	1	0	0	1	0	0
10	0	0	1	1	0	0	1	0	0
11	0	0	1	0	1	0	0	1	0
12	1	0	0	0	1	0	0	1	0
13	0	0	1	1	0	0	0	0	1
14	0	0	1	0	1	0	0	0	1
15	1	0	0	0	1	0	1	0	0
16	1	0	0	0	0	1	1	0	0
17	0	1	0	0	0	1	0	1	0
18	0	1	0	1	0	0	0	1	0
19	0	0	1	0	0	1	1	0	0
20	0	0	1	0	0	1	0	1	0
21	1	0	0	1	0	0	0	1	0
22	1	0	0	1	0	0	0	0	1
23	0	1	0	0	1	0	0	0	1
24	0	1	0	0	1	0	1	0	0
25	1	0	0	1	0	0	1	0	0
26	0	1	0	0	1	0	0	1	0
27	0	0	1	0	0	1	0	0	1

Table 3.1.1 shows the possible switching combination that can achieved in matrix converter for save operation. Table 3.1.2 shows the different way of making an unidirectional device into an bi-directional device, connection scheme shown in variant 1 is selected for the hardware connection due to the presents of internal diodes

Table 3.1.2
Switching Configuration of A Matrix Converter

	Variant	Switching Configuration	Driver	Switches/ Diodes/Total
Matrix Converter	1.		9	18/18/36
	2.		9	18/18/36
	3.		6	18/0/18
DC – Voltage –Link Converter			7	12/12/24

3.2 SIMULATION MODELS

Simulation model of three phase matrix converter fed induction motor given in fig 3.2.1. Here in matrix converter nine switches are used. In each switch there will be two IGBTS. The switch connection shown in fig 3.2.2. The control system and switching logic used are used in figure 3.2.3 and 3.2.4.

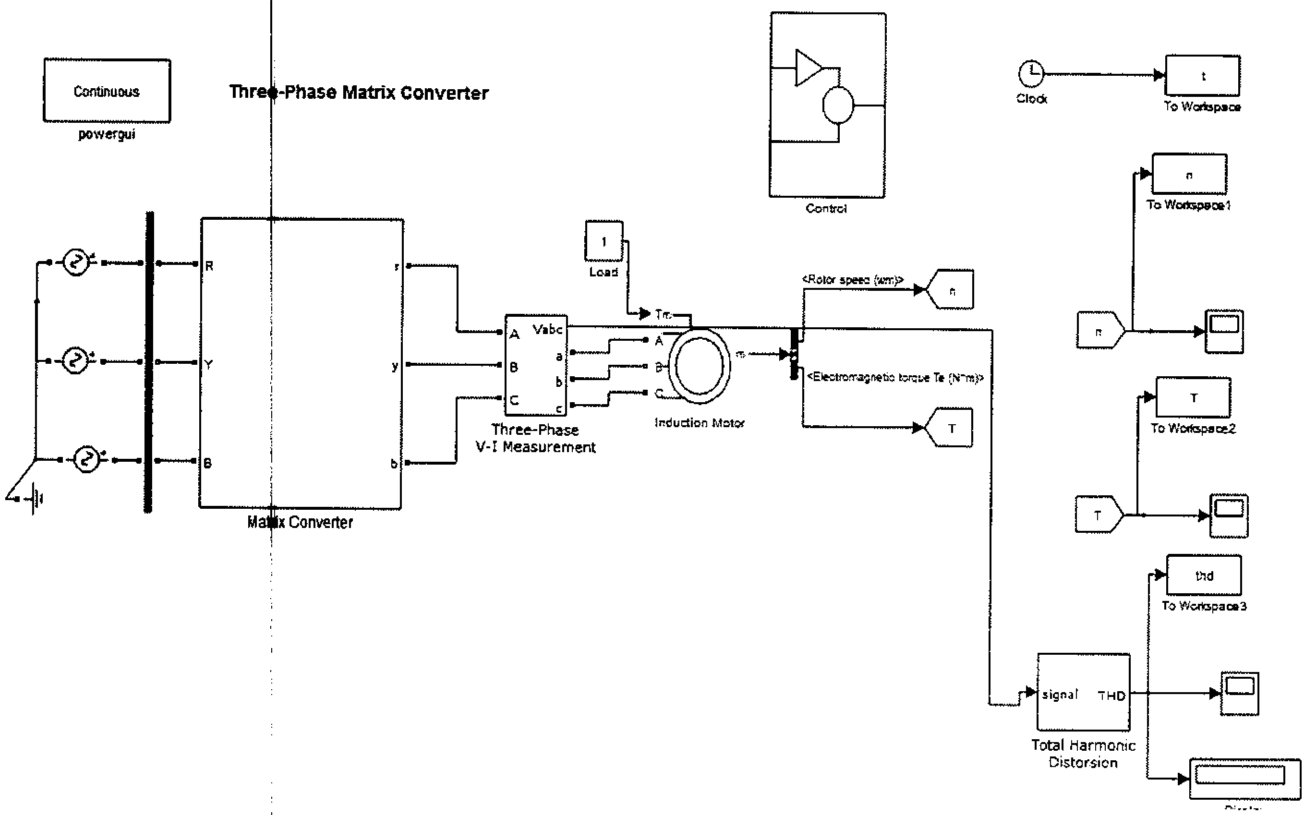


Figure 3.2.1 Simulation model of three phase Matrix converter

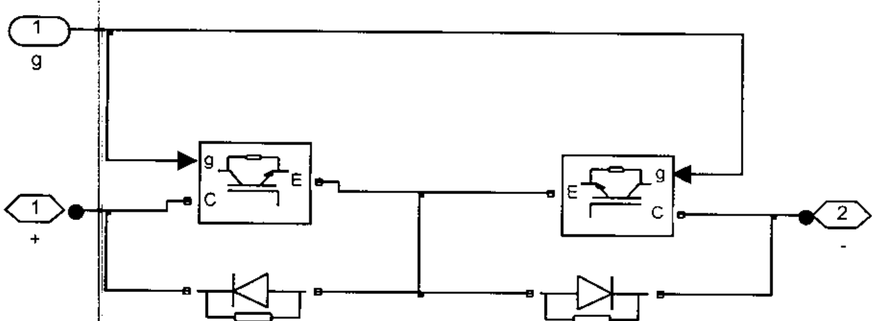


Figure 3.2.2 Switch connection

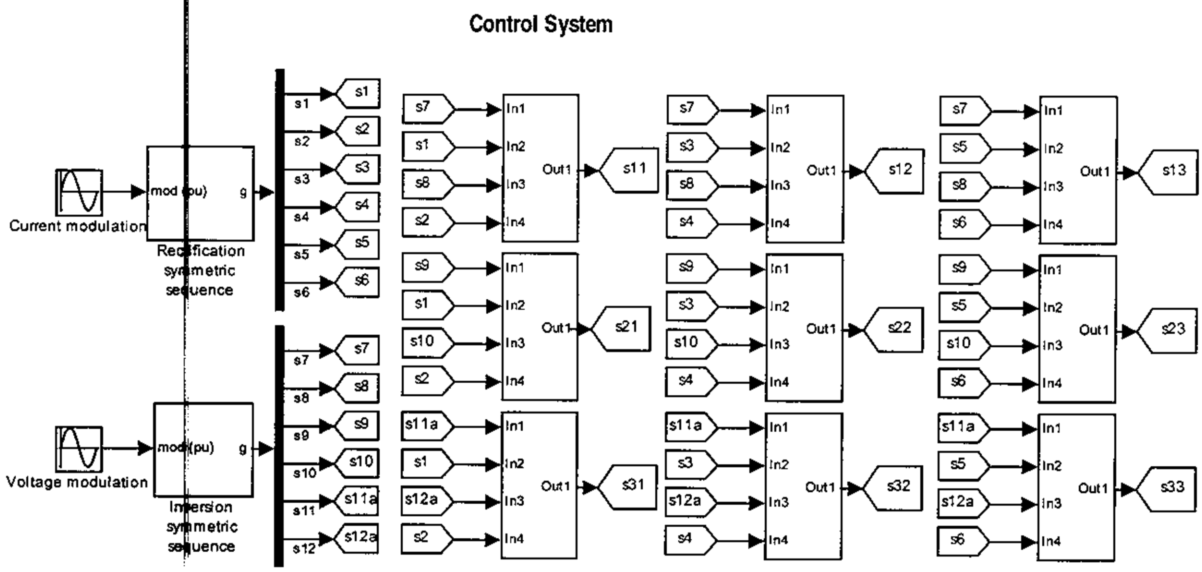


Figure 3.2.3 Control system

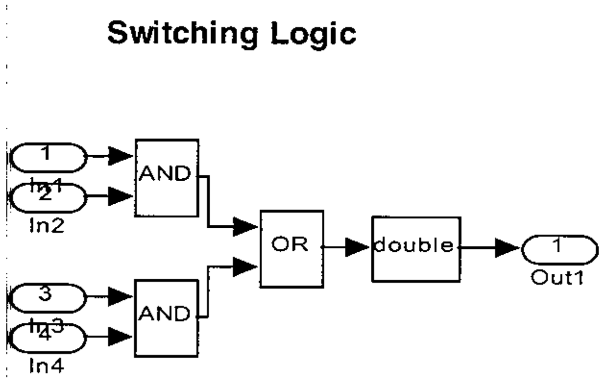


Figure 3.2.4 Switching logic

3.3 SIMULATION RESULTS

From the simulation of VSI fed induction motor, at 420V supply voltage it has highest efficiency. So 420V taken as normal supply voltage. Then the simulation is done for Matrix converter fed Induction motor and result is compared with VSI fed induction motor. That is, Matrix converter and VSI fed induction motor are simulated for speed, Total harmonic distortion and Torque and the result are compared. For under voltage condition considered 400V and 440V as Over Voltage. Then simulation is done for Speed, Total Harmonic distortion and torque, and then results are compared.

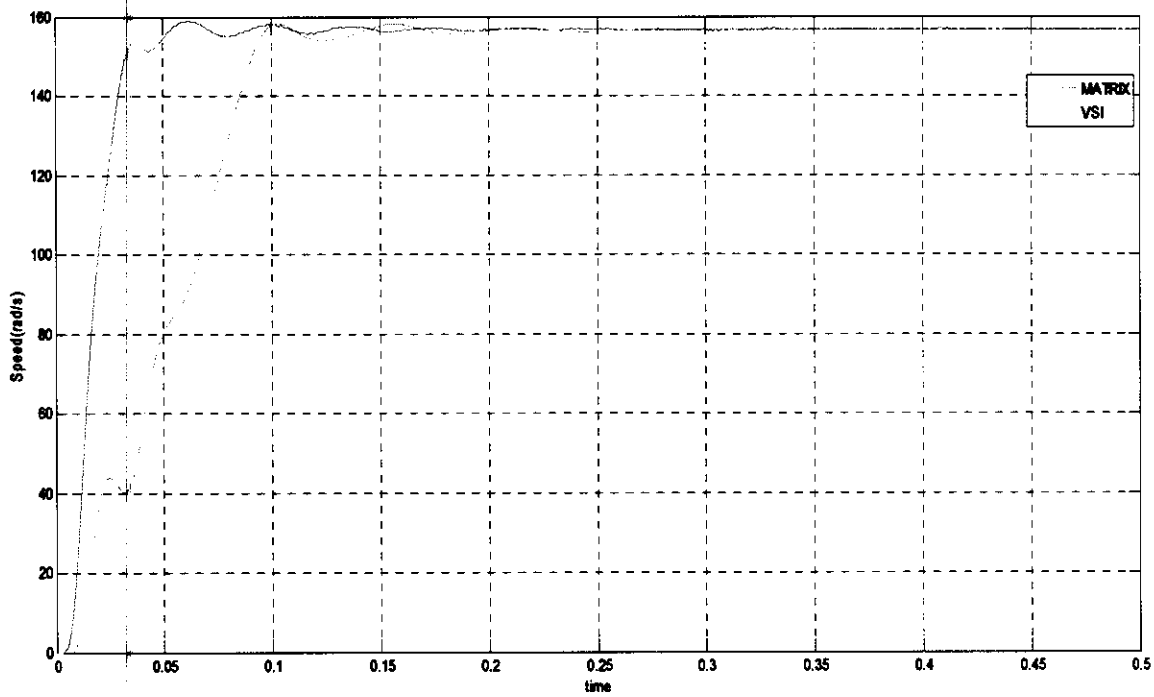


Figure 3.3.1 Speed of VSI and Matrix converter fed induction motor 420V (normal)

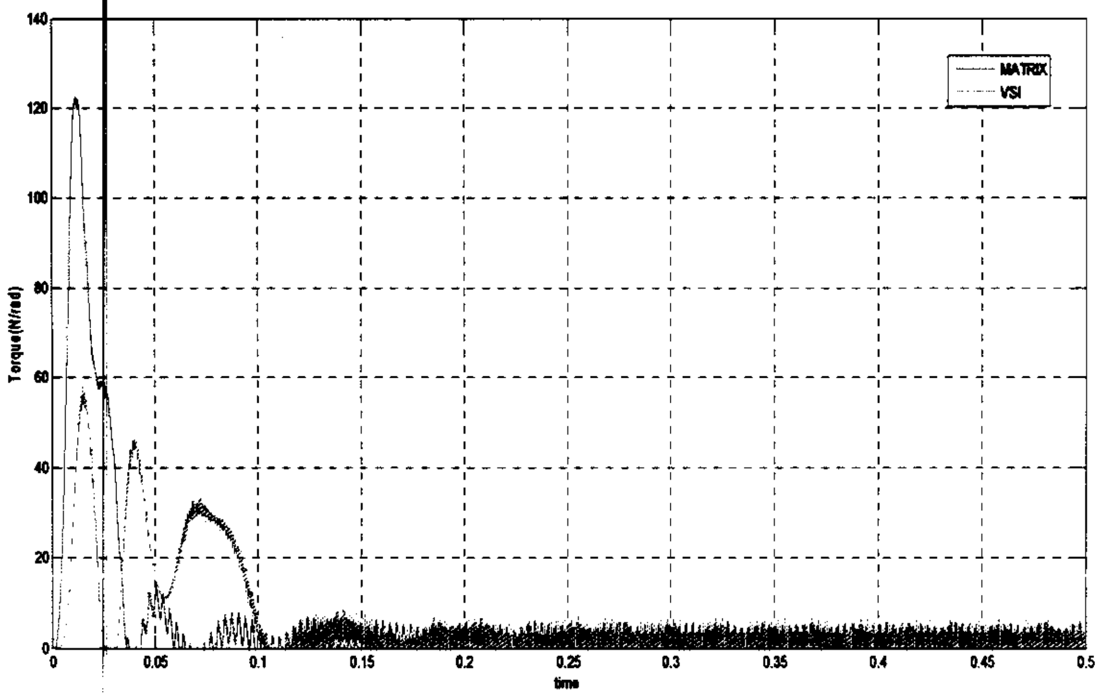


Figure 3.3.2 Torque of VSI and Matrix converter fed induction motor 420V (normal)

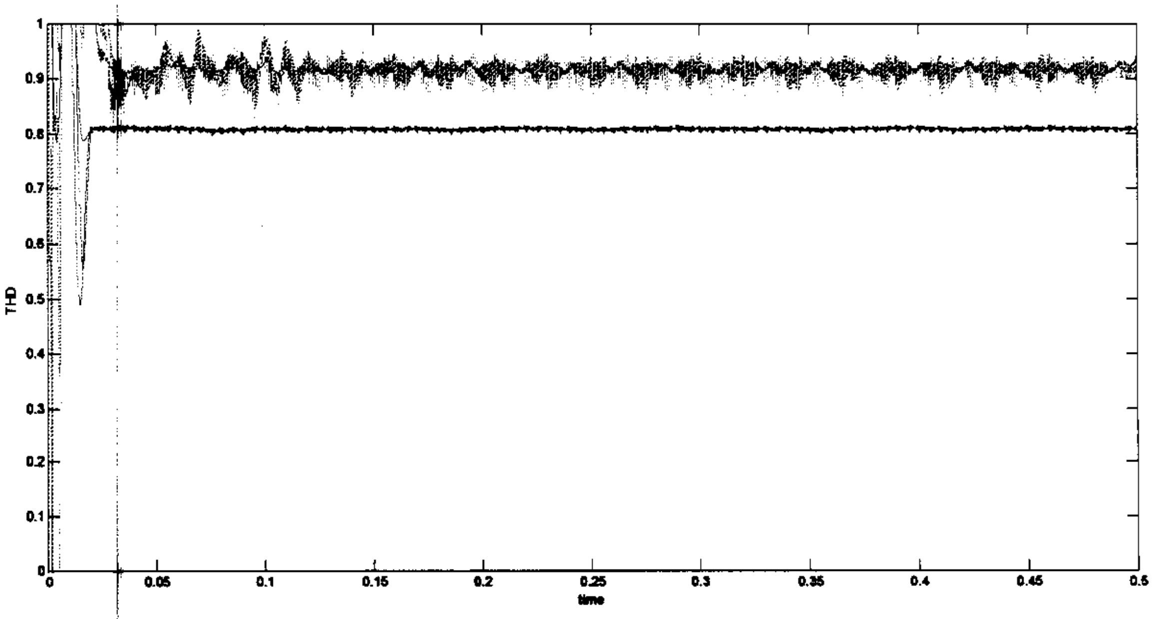


Figure 3.3.3 THD(numerical) of VSI and Matrix converter fed induction motor at 420V (normal)

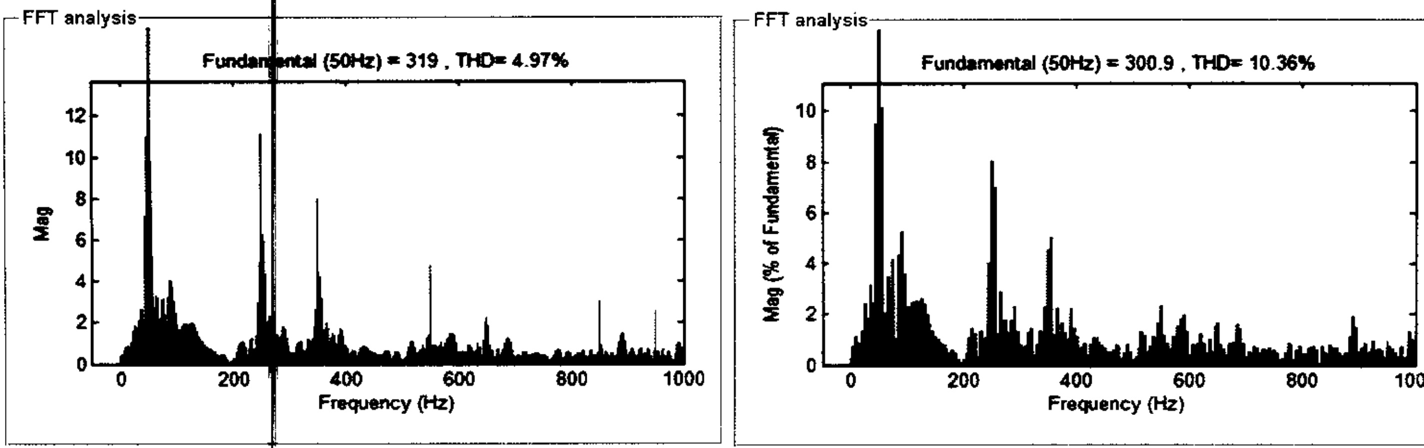


Figure 3.3.4 THD comparison of VSI and Matrix converter fed Induction motor at 420V

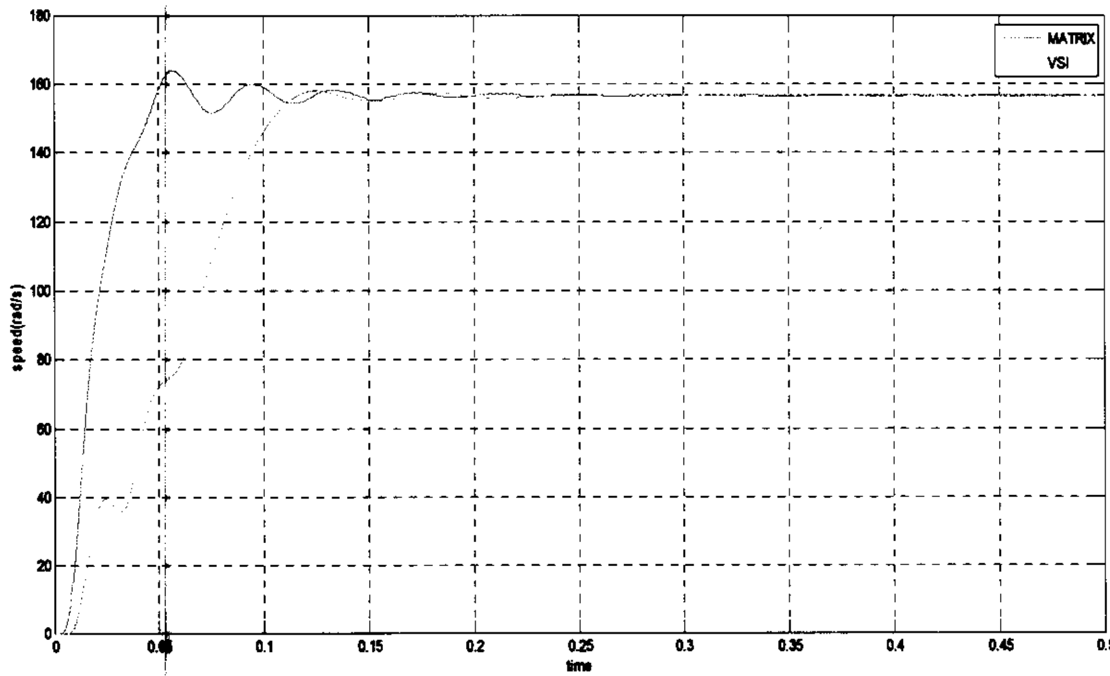


Figure 3.3.5 Speed of VSI and Matrix converter fed induction motor 400V (Under)

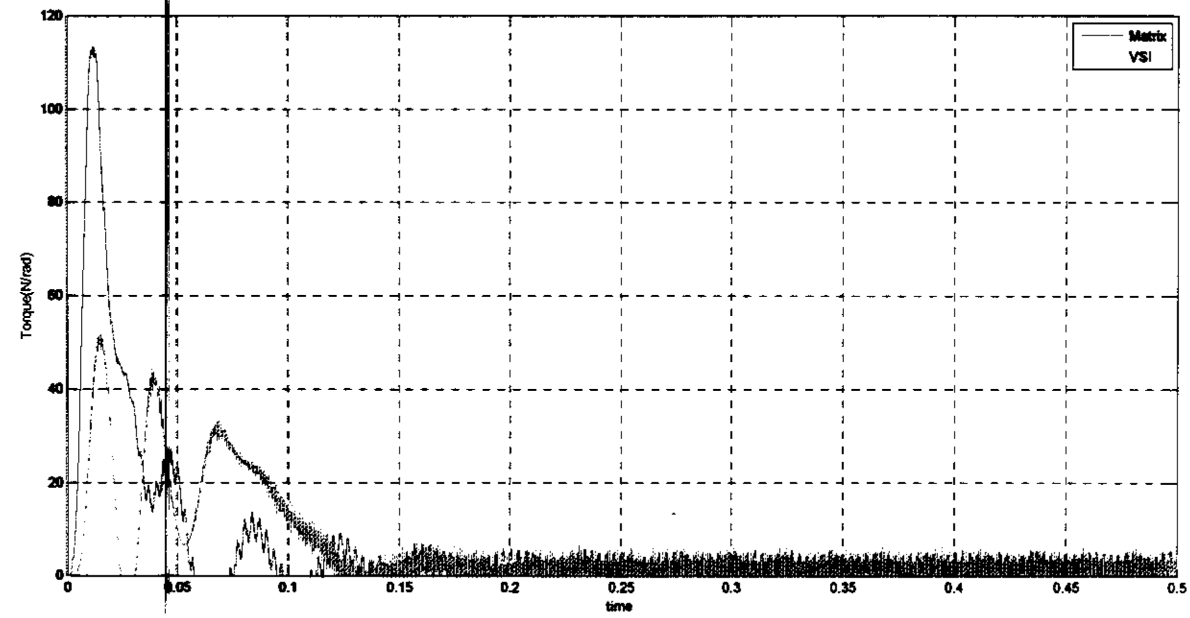


Figure 3.3.6 Torque of VSI and Matrix converter fed induction motor 400V (Under)

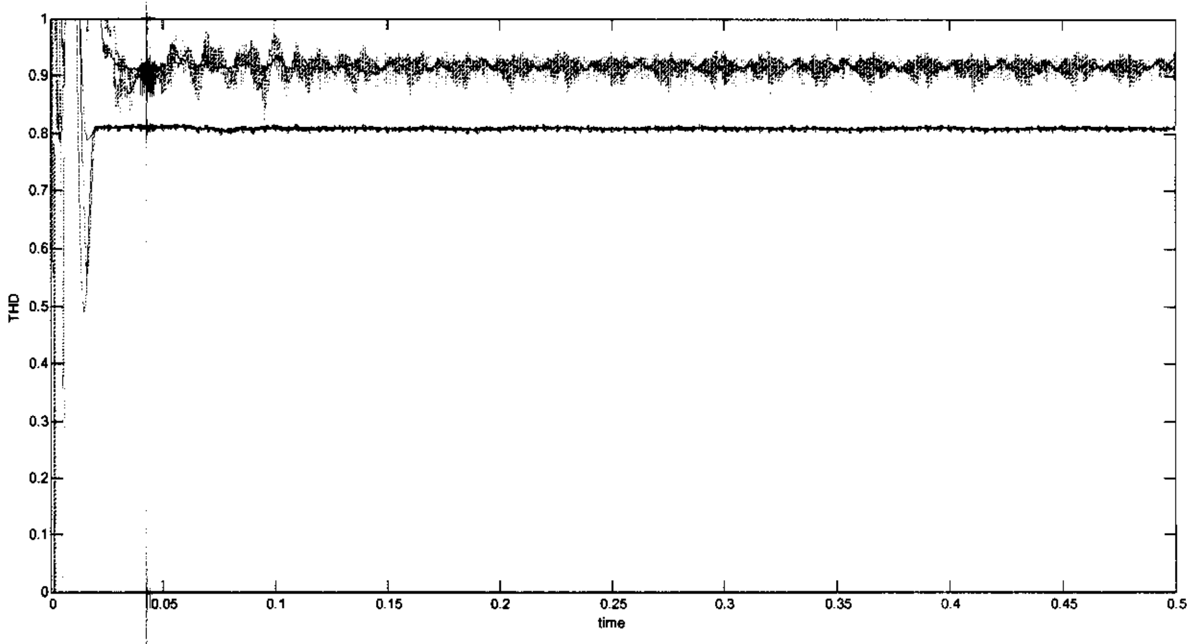
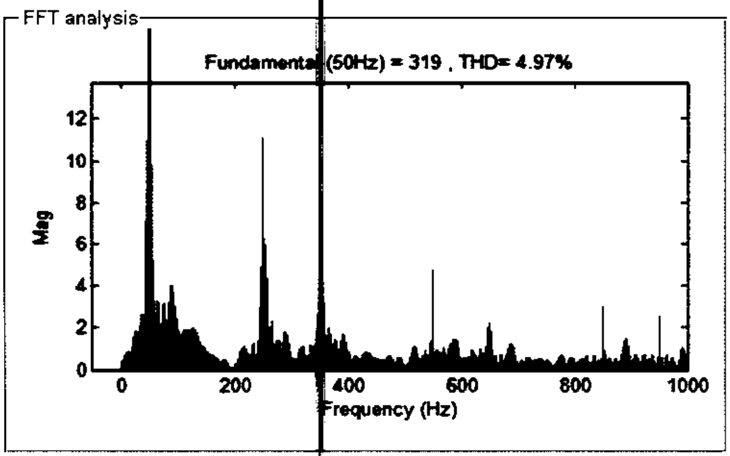


Figure 3.3.7 THD(numerical) of VSI and Matrix converter fed induction motor at 400V (under)



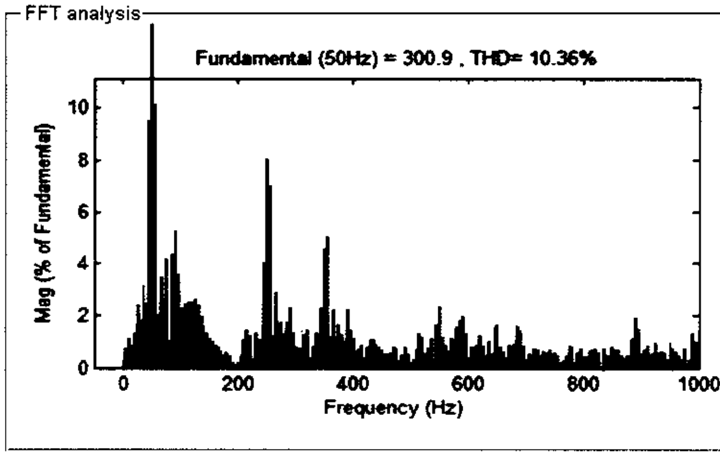


Figure 3.3.8 THD comparison of VSI and Matrix converter fed Induction motor at 400V

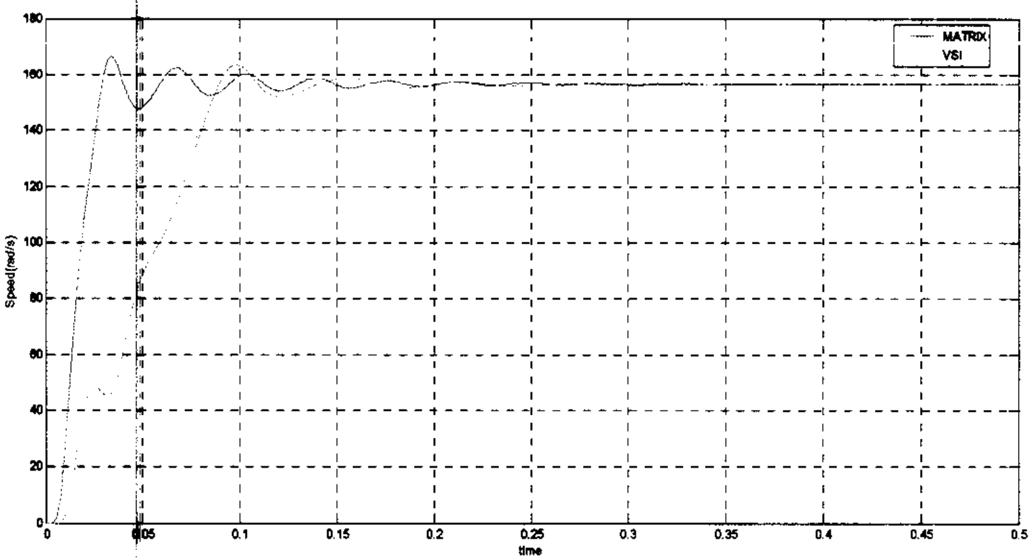


Figure 3.3.9 Speed of VSI and Matrix converter fed induction motor 440V (over)

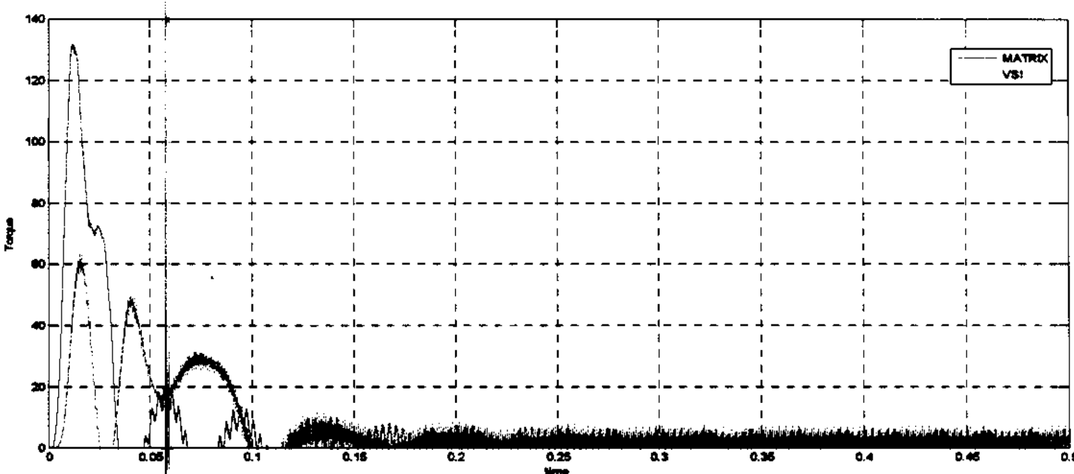


Figure 3.3.10 Torque of VSI and Matrix converter fed induction motor 440V (Over)

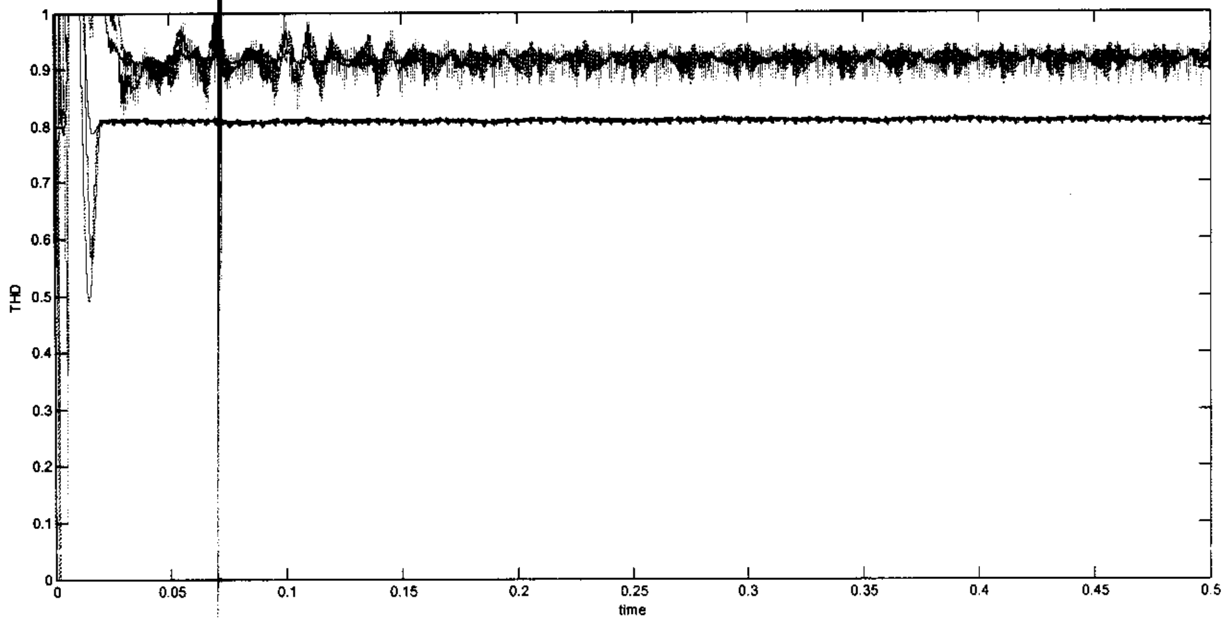


Figure 3.3.11 THD(numerical) of VSI and Matrix converter fed induction motor at 440V (Over)

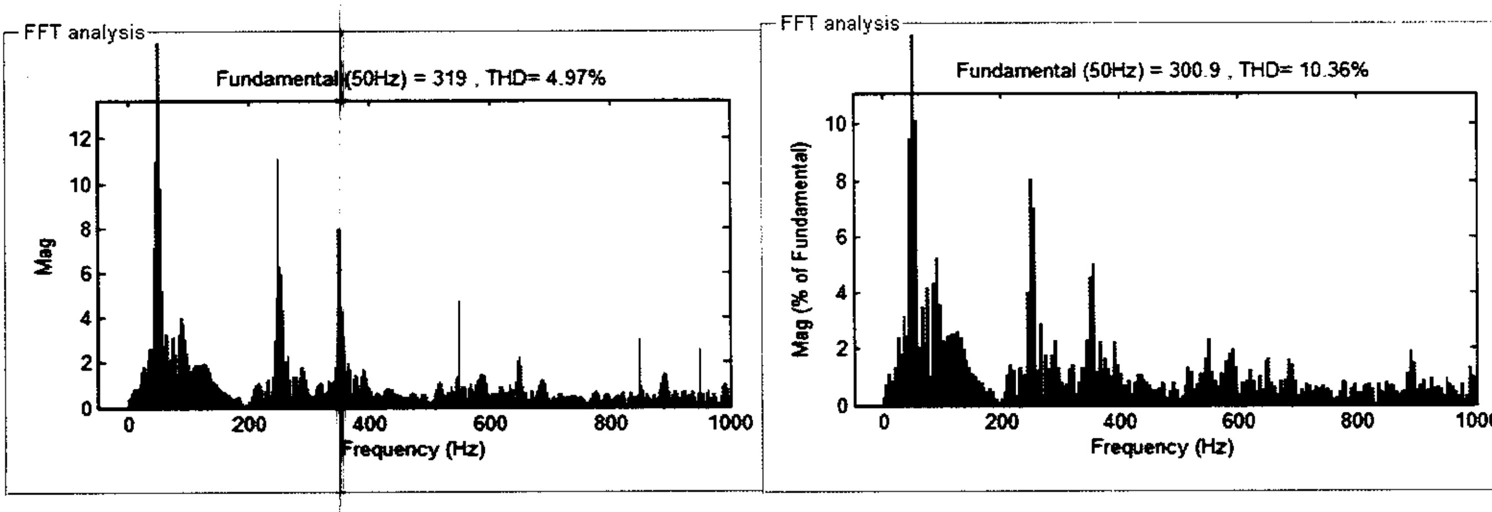


Figure 3.3.12 THD comparison of VSI and Matrix converter fed Induction motor at 440V

3.4 COMPARISON OF SIMULATION RESULTS

Table 3.3.1
Comparison of VSI and Matrix converter fed Induction motor at 400V

DESCRIPTION	MATRIX CONVERTER	VSI
Transient Period	0.05	0.13
Torque	110	50
Total harmonic distortion	4.97%	10.36%

Table 3.3.2
Comparison of VSI and Matrix converter fed Induction motor at 420V

DESCRIPTION	MATRIX CONVERTER	VSI
Transient Period	0.04	0.1
Torque	121	51
Total harmonic distortion	4.97%	10.36%

Table 3.3.3
Comparison of VSI and Matrix converter fed Induction motor at 440V

DESCRIPTION	MATRIX CONVERTER	VSI
Transient Period	0.03	0.09
Torque	130	61
Total harmonic distortion	4.97%	10.36%

From the above tables Transient period and the Total harmonic distortion are less in Matrix converter fed induction motor comparing to VSI fed induction motor and also Torque is higher in Matrix converter fed induction motor. Hence Performance of Matrix converter fed induction motor is better than VSI fed induction motor.

3.5 CONCLUSION

The operation of Matrix converter fed induction motor is evaluated by computer simulation using MATLAB/SIMULINK 7.7. The system is simulated for Speed, Torque and Total harmonic distortion and the result is compared with VSI fed induction motor under various voltage conditions. Also tabulation is done at Normal voltage, under voltage and over voltage for both VSI and Matrix converter fed induction motor.

Chapter 4

MATRIX CONVERTER HARDWARE MODEL AND RESULTS

A prototype model of matrix converter has been designed and implemented. The matrix converter designed for single phase supply and it has been designed to perform the conversion of frequency form 50Hz to 50Hz, 50/3Hz to 50Hz & 50/3Hz to 50Hz. Matrix converter is developed using MOSFET switches which is connected anti-parallel to each other. The change of frequency is achieved by getting a feed forward loop from the input, thus the zero crossing of input supply is detected and firing angle is calculated by the controller accordingly.

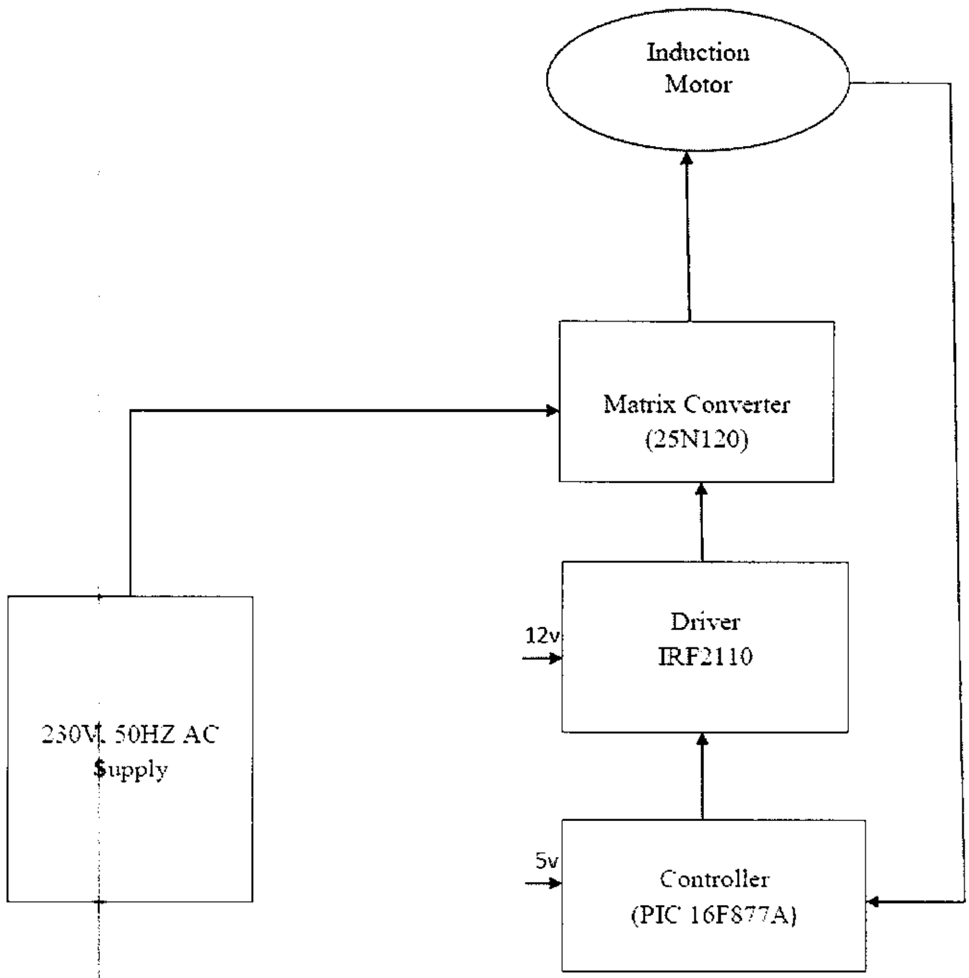


Fig 4.1 Block diagram of Matrix Converter

4.1 BLOCK DIAGRAM DESCRIPTION

The entire system is divided into the following subsystems for the easiness of understanding.

- Single Phase Matrix Converter.
- 12/220V Single Phase Transformer
- Isolation Transformer
- Power supply circuit
- PIC 16f877A
- Driver circuit
- Optocoupler
- AC motor
- Resistors and Capacitors

The figure. 4.1 shows the experimental setup used in this project. The 1-ph supply is given through the 220/0-12V transformer. 8 IGBTS switches which are connected antiparallel forms, the Matrix circuit incorporating the rectifier and inverter operations. The output of matrix converter is fed to the impedance fan, which is generally used for cooling purpse. Driver circuits are provided through ICs IRS 2110. Optocoupler are provided between the power circuit and the signal level circuit for isolation. The switching pulses are generated by the PIC microcontroller. The pulses are generated such that to run the fan at three different speeds 50Hz, 50/2 Hz and 50/3 Hz.

4.1.1 Power Supply Unit

The Ac voltage, typically 220V rms, is connected to a transformer, which steps that ac voltage down to the level of the desired dc output. A diode rectifier then provides a full-wave rectified voltage that is initially filtered by a simple capacitor filter to produce a dc voltage. This resulting dc voltage usually has some ripple or ac voltage variation.

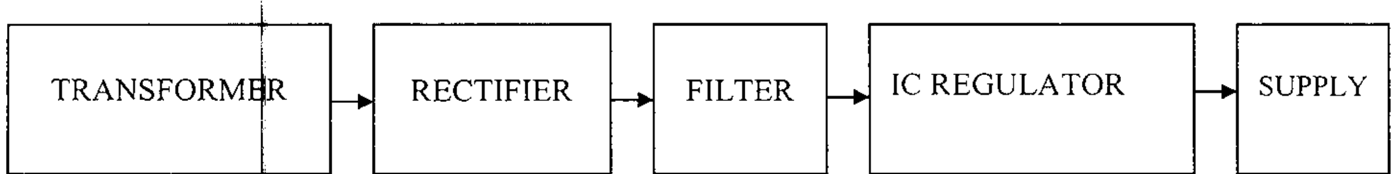


Fig 4.1.1.a Block diagram of power supply

A regulator circuit removes the ripples and also remains the same dc value even if the input dc voltage varies, or the load connected to the output dc voltage changes. This voltage regulation is usually obtained using one of the popular voltage regulator IC units. The power circuit diagram & layout are shown in figure 4.1.2 &4.1.3

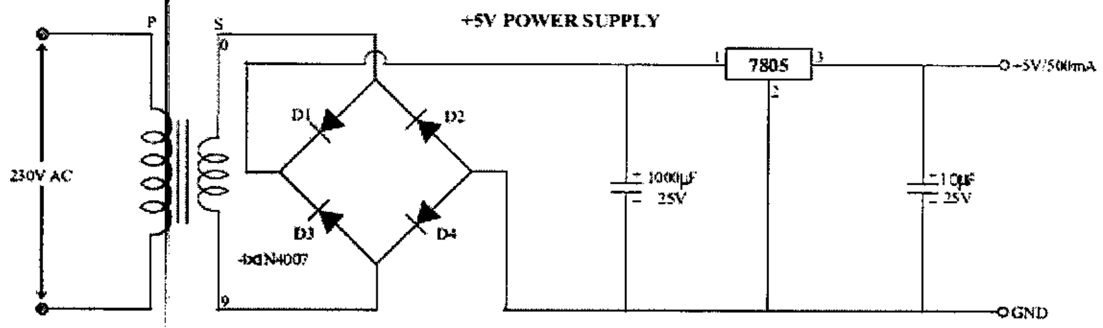


Fig 4.1.1.b Power Supply Circuit

The AC voltage, typically 230Vrms, is connected to a transformer, which steps that ac voltage down to the level for the desired dc output. A diode rectifier then provides a full wave rectified voltage that is initially filtered by a simple capacitor filter to produce a dc voltage. This resulting DC voltage usually has some ripple or ac voltage variation. A regulator circuit can use this DC input to provide a dc voltage that not only has much less ripple voltage but also remains the same dc value even if the input dc voltage changes. This voltage regulation is usually obtained using one of a number of popular voltage regulator IC units.

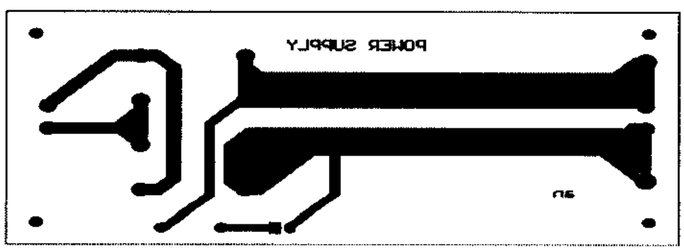


Fig 4.1.1.c Power Supply

4.1.2 Single Phase Matrix Converter

The single phase Matrix converter with bidirectional MOSFETs are arranged which are capable of blocking voltage and current in both directions. Of the eight MOSFET switches, four of them will work during the rectification mode and the remaining four will work during the inversion mode of operation. The schematics and layout is shown in figure below.

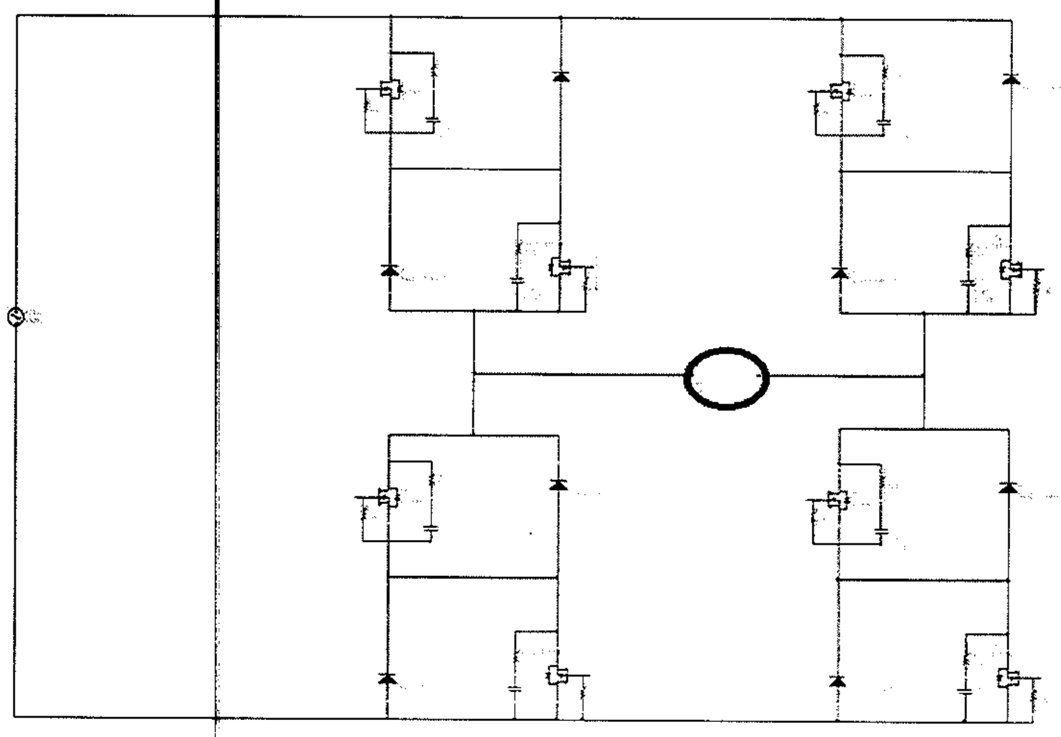


Fig 4.1.2.a Single phase Matrix converter Circuit

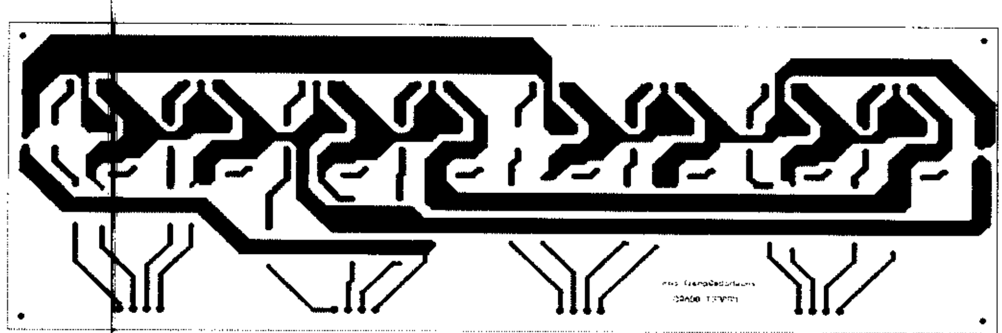


Fig 4.1.2.b Power Module Board

Advantages of MOSFET

- IGBT provides much better system reliability.
- IGBT provides fast switching speed
- Overload and peak current handling capacity is high
- IGBTs have better temperature stability
- Drain-source conduction threshold voltage is absent which eliminates electrical noise.

IGBTs are able to operate in hazardous radiation environments. Here FGA25N120AN is used.

4.1.3 Pulse Generating Circuit

PIC16F877A microcontroller is used as the pulse generating circuit and Driver circuit is used to remove the harmonics, buffer and filter the PWM signal. PIC16F877A is a 40 pin; CMOS flash microcontroller with A/D controller. pin configuration and layout is shown in figure below

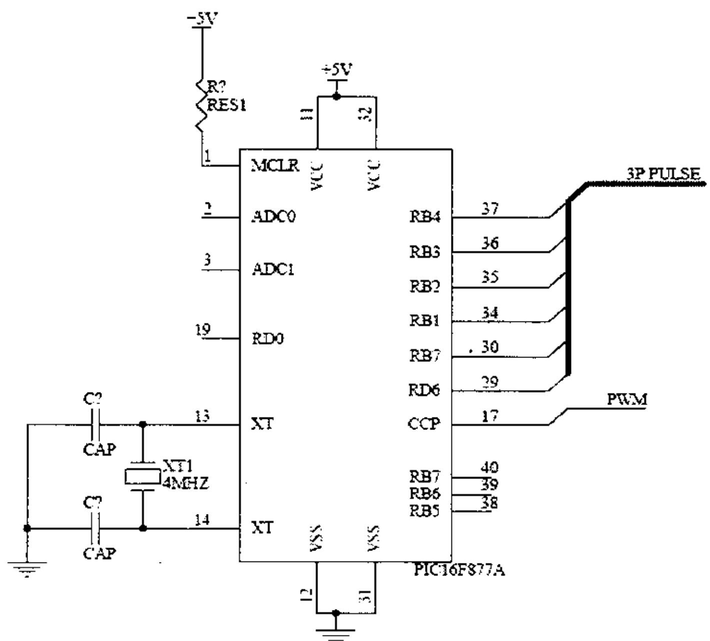


Fig 4.1.3 a Pin configuration of PIC16F877A

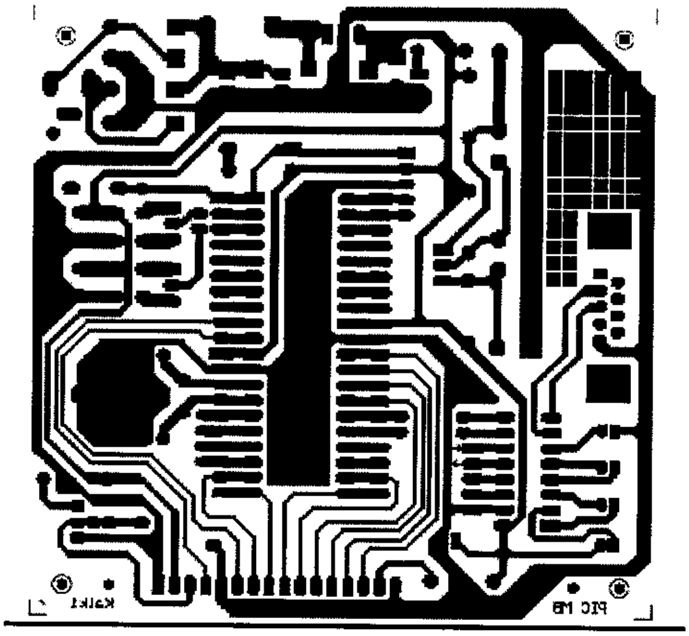


Fig 4.1.3.b Mother Board

Features of PIC16F877A

High-Performance RISC CPU

- Only 35 single word instructions to learn
- All instructions are 1 µs (@4MHz) except for program branches which are 2 cycles
- Operating speed: DC - 20MHz clock input.

Peripheral Features:

- Two 8-bit timer/counter (TMR0, TMR2) with 8-bit programmable prescaler.
- 12.5 ns resolution for PWM mode.
- Two Capture/Compare PWM (CCP) Module.
- Brown-out detection circuitry for brown-out Reset (BOR).

Special Micro controller Features

- Power-On Reset
- Power-up Timer (PWRT) and Oscillator Start-Up Timer (OST)
- Selectable oscillator options.
- Watchdog timer (WDT) with its own on-chip RC oscillator for reliable operation.
- Self-reprogrammable under software control.
- Power saving Sleep mode.

4.1.4 Driver Circuit

The driver circuit consists of the integrated chip IR2110, diodes, resistor at a dc voltage of +12V. the schematics is shown in figure below.

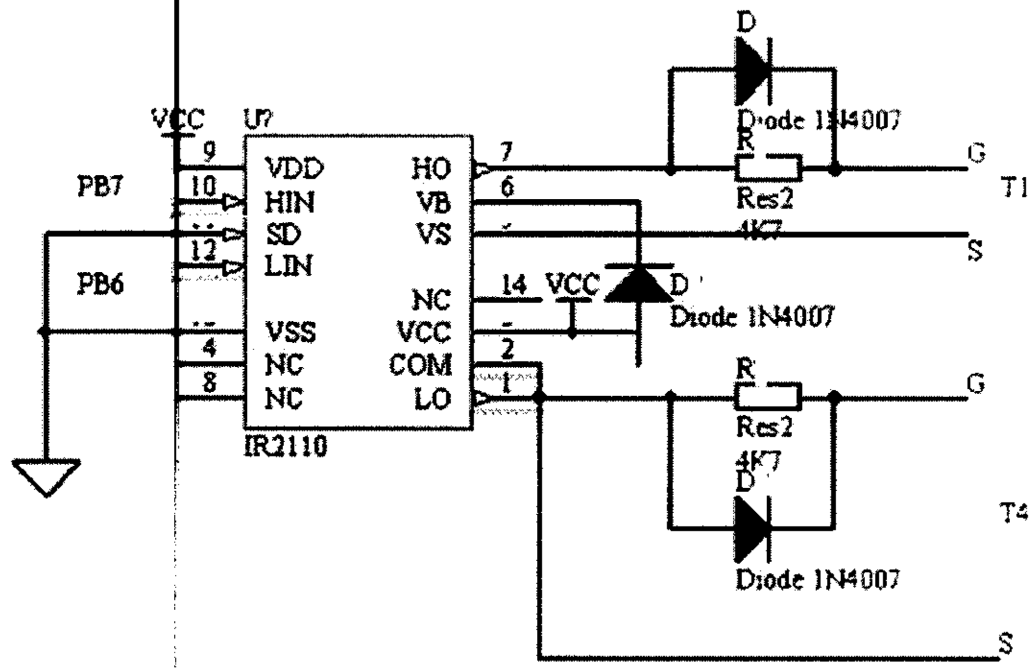


Fig 4.1.4 driver circuit

4.1.5 Optocoupler:

Optocoupler is also termed as optoisolator. Optoisolator a device which contains a optical emitter, such as an LED, neon bulb, or incandescent bulb, and an optical receiving element, such as a resistor that changes resistance with variations in light intensity, or a transistor, diode, or other device that conducts differently when in the presence of light. These devices are used to isolate the control voltage from the controlled circuit. Figure 3.10 shows the pin configuration of Optocoupler

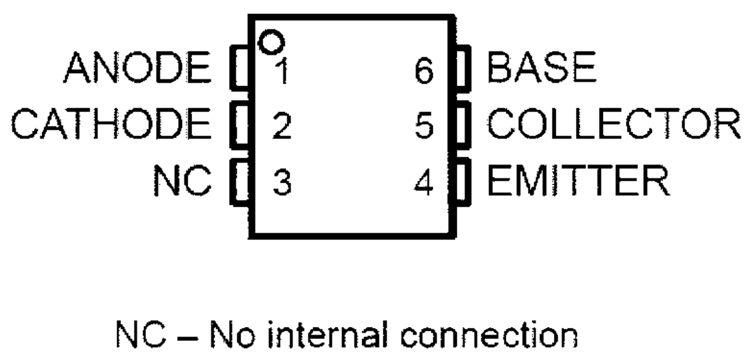


Fig. 4.1.5 MCT2E OPTOCOUPLER

- Gallium Arsenide Diode Infrared Source Optically Coupled to a Silicon npn Phototransistor
- High Direct-Current Transfer Ratio
- Base Lead Provided for Conventional Transistor Biasing
- High-Voltage Electrical Isolation . . .
- 1.5-kV, or 3.55-kV Rating
- Plastic Dual-In-Line Package
- High-Speed Switching:

4.2 HARDWARE MODEL AND RESULTS

The fabricated hardware model is as shown in fig. below. Here output of matrix converter is connected to a impedance fan, which was generally using for cooling purpose. Here the impendence fan is running at three different speed corresponding to 50HZ, 50/2HZ and 50/3 HZ frequencies and the switching signals for that different speed is given in fig 4.3,fig 4.4 and fig 4.5

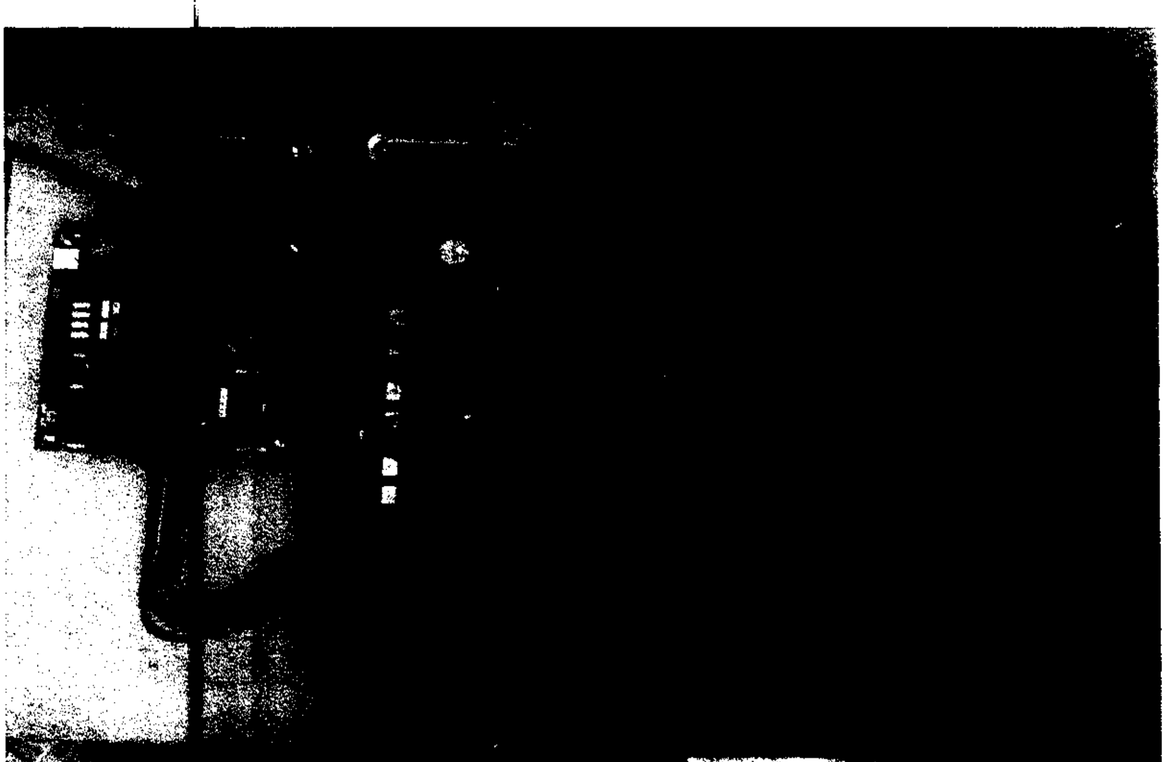


Fig.4.2 Prototype photo

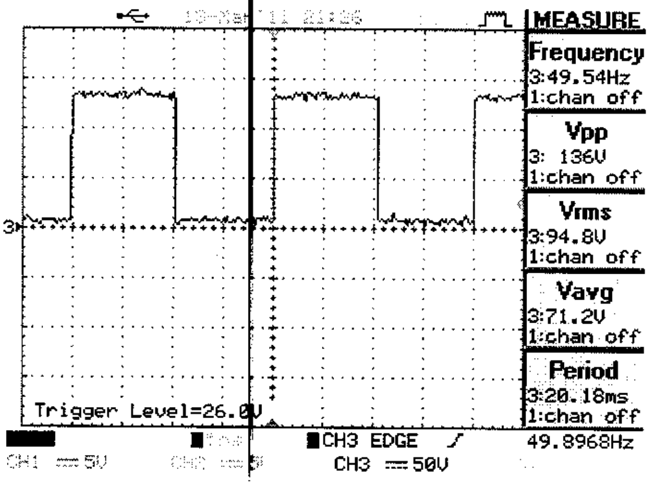


Fig.4.3 Switching signal for IGBTS at 50HZ

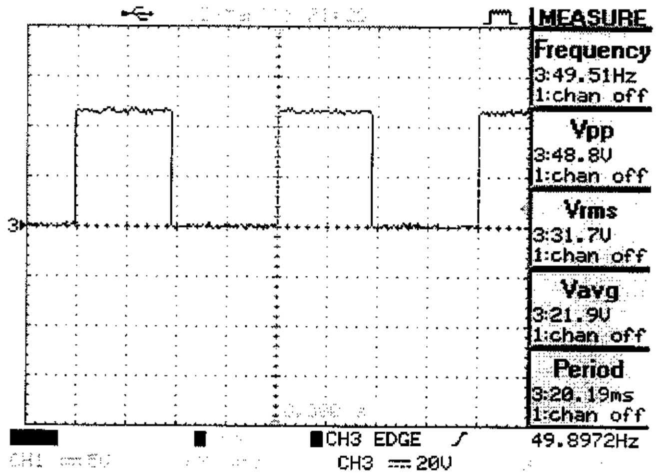


Fig.4.4 Switching signal for IGBTS at 50/2 HZ

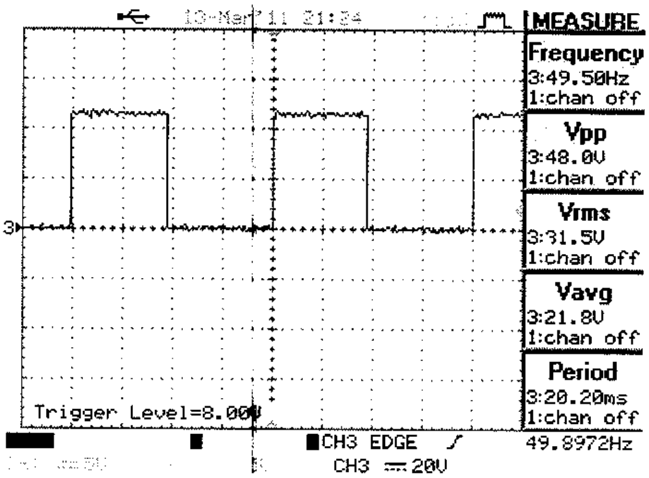


Fig.4.5 switching signal for IGBTS at 50/3 HZ

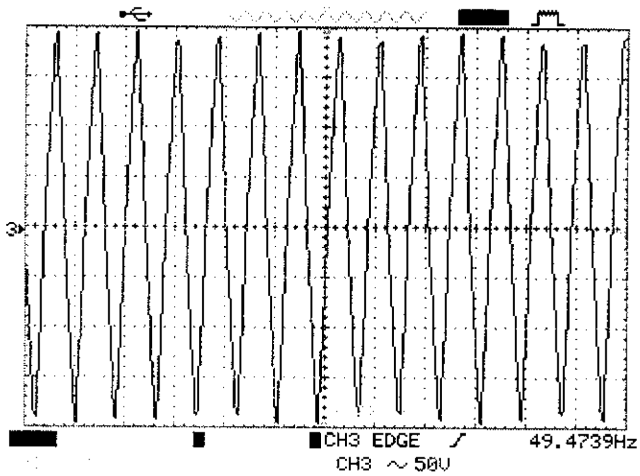


Fig 4.6 Output voltage waveform

5.3 CONCLUSION

The single phase matrix converter fed impendence fan is run at three different speed corresponding to 50HZ, 50/2HZ and 50/3HZ and the corresponding output was taken.

Chapter 5

CONCLUSION AND FUTURE SCOPE

5.1 CONCLUSION

Simulation is done for various values of modulation indexes at different values of input voltage for VSI fed induction motor. From that simulation results the modulation index at which VSI producing lowest THD is found. Then the efficiencies are calculated for different input voltages at that modulation index. From that, input voltage at which VSI producing highest efficiency is chose. Then Matrix converter fed induction motor is simulated at normal input voltage, under voltage and over voltage conditions. Then results are compared with VSI fed induction motor. From the simulation results,

- The transient period taken by the Matrix converter fed Induction motor is less than VSI fed induction Motor.
- The torque is higher for the Matrix converter fed induction motor.
- Also the Total Harmonic Distortion is less in Matrix converter fed . . Induction Motor.

Hence the performance of Matrix converter fed induction motor is better than VSI fed induction motor.

5.2 FUTURE SCOPE

High performance of MC fed induction motor drive could be obtained over a wide operating range, if some compensation techniques are used in abnormal conditions. So, research on compensation strategy of matrix converter is one of the further extensions of present work.

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Appendix

A) CODING:

```
/*****                     Matrix Converter Coding

#include<pic.h>
#include<lcdg.h>
void forw();
void rec();
#define  sw1 RC0

#define  sw2 RC1
#define  sw3 RC2
#define  sw4 RC3
#define  l1 RB0
#define  l2 RB2
#define  l3 RB1
#define  l4 RB3
#define  N RC7
#define  P RC6

unsigned int T,D,i,one,ten,hun,tho,temp1,d=1;

void mc_init();
void disp();
```

```
void main()
{
        mc_init();
        //lcd_init();
        delay(500);

        delay(5000);

        delay(1000);   // Start OFF Delay for device to get into transient

        do
        {
                if(RC0==0)
                {
                        delay(5000);
                        do
                        {
                                while(!P);
                                if(P==1)
                                {       delay(10);
```

```
RB0=RB1=RB2=RB3=RD0=RD1=RD2=RD3=0;
                    delay(10);
                    RB1=RB0=1;
                    delay(1000);
                    //while(P);

RB0=RB1=RB2=RB3=RD0=RD1=RD2=RD3=0;
                    delay(10);
                }
                while(!N);

                {   delay(10);

RB0=RB1=RB2=RB3=RD0=RD1=RD2=RD3=0;
    RB0=RB1=RB2=RB3=RD4=RD5=RD6=RD7=0;
                    delay(10);
                    RD0=RD1=1;
                    delay(1000);
                    //while(N);

RB0=RB1=RB2=RB3=RD0=RD1=RD2=RD3=0;
    RB0=RB1=RB2=RB3=RD4=RD5=RD6=RD7=0;
                    delay(10);
                }
            }while(1);
        }
```

```
do
{
if(RA0==1)
{



RB1=RB2=0;
RB0=RB3=1;
DELAY(100); //        240

RB0=RB1=RB2=RB3=0;
DELAY(100); //        20

RB0=RB3=0;
RB1=RB2=1;
DELAY(100);

RB0=RB1=RB2=RB3=0;
DELAY(100);

}
}while(RA0==0);
```

```
while(RA1==1)
{

RD6=RD5=0;
RD4=RD7=1;
                DELAY(100);

RD7=RD6=RD5=RD4=0;
                DELAY(100);

RD4=RD7=0;
RD6=RD5=1;
                DELAY(100);

RD7=RD6=RD5=RD4=0;
                DELAY(100);

}

rb0=1;          //+ve
delay(5);
```

```
                rb2=1;
                delay(100);

                /******/

        rb0=0;
        delay(5);

                rb2=0;
                delay(10);

                /*****************************/

        RB1=1;                  //-ve
        delay(5);

                RB3=1;
                delay(100);

                /******/

        RB1=0;
        delay(5);

                RB3=0;
                delay(10);
```

```
RD7=1;                  //+ve
delay(5);

          RD5=1;
          delay(100);

          /******/

RD7=0;
delay(5);
          RD5=0;
          delay(100);

          /*****************************/

RD6=1;                  //-ve
delay(5);

          RD4=1;
          delay(100);

          /******/
```

```
RD6=0;
delay(5);
RD4=0;
delay(100);

}
while(1);

}

void mc_init()
{
TRISB=0x00;
TRISC=0xFF;
TRISD=0x00;
TRISE=0x00;
TRISA=0xFF;
ADCON1=0X06;
GIE=1;
PEIE=1;
PORTA=0XFF;
PORTB=0X00;
PORTD=0X00;
```

```
			PORTC=0X00;
			PORTE=0x00;
			}


unsigned int take_adc(unsigned char);

void lcd_init(void);
void lcd_command(unsigned char);
void lcd_data(unsigned char);
void print_line(unsigned char const*,unsigned char);
void delay(unsigned long);
unsigned int adresult;

unsigned int take_adc(unsigned char channel)
{
unsigned char adh,adl,de=10,ad_temp;

ad_temp=ADCON1;
//ADCON0=channel;	//0x85;
ADCON1=0x80;
ADCS1=1;
ADCS0=0;
switch(channel)
{
case 0:				CHS2=0;
```

```
            CHS1=0;
            CHS0=0;
            break;
case 1:     CHS2=0;
            CHS1=0;
            CHS0=1;
            break;
case 2:     CHS2=0;
            CHS1=1;
            CHS0=0;
            break;
case 3:     CHS2=0;
            CHS1=1;
            CHS0=1;
            break;
case 4:     CHS2=1;
            CHS1=0;
            CHS0=0;
            break;
case 5:     CHS2=1;
            CHS1=0;
            CHS0=1;
            break;
```

```
case 6:                     CHS2=1;

                                    CHS1=1;
                                    CHS0=0;
                                    break;
case 7:                     CHS2=1;

                                    CHS1=1;
                                    CHS0=1;
                                    break;
}
ADGO=ADON=1;
while(de--);
while(ADGO);
 adh=ADRESH;
 adl=ADRESL;
 adresult=(0|adh);
 adresult=adresult<<8;
 adresult=adresult|adl;
 ADCON1=ad_temp;
 return(adresult);
}

void delay(unsigned long del_del)
{
while(del_del--);
}
```

B) DATA SHEETS:

FAIRCHILD
SEMICONDUCTOR®

1N4001-1N4007

1N4001 - 1N4007

Features

- Low forward voltage drop.
- High surge current capability.

DO-41
COLOR BAND DENOTES CATHODE

General Purpose Rectifiers

Absolute Maximum Ratings*

T_A = 25°C unless otherwise noted

Symbol	Parameter	Value							Units
		4001	4002	4003	4004	4005	4006	4007	
V_{RRM}	Peak Repetitive Reverse Voltage	50	100	200	400	600	800	1000	V
$I_{F(AV)}$	Average Rectified Forward Current, .375 " lead length @ T_A = 75°C	1.0							A
I_{FSM}	Non-repetitive Peak Forward Surge Current 8.3 ms Single Half-Sine-Wave	30							A
T_{stg}	Storage Temperature Range	-55 to +175							°C
T_J	Operating Junction Temperature	-55 to +175							°C

*These ratings are limiting values above which the serviceability of any semiconductor device may be impaired.

Thermal Characteristics

Symbol	Parameter	Value	Units
P_D	Power Dissipation	3.0	W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	50	°C/W

Electrical Characteristics

T_A = 25°C unless otherwise noted

Symbol	Parameter	Device							Units
		4001	4002	4003	4004	4005	4006	4007	
V_F	Forward Voltage @ 1.0 A	1.1							V
I_{rr}	Maximum Full Load Reverse Current, Full Cycle T_A = 75°C	30							µA
I_R	Reverse Current @ rated V_R T_A = 25°C T_A = 100°C	5.0 500							µA µA
C_T	Total Capacitance V_R = 4.0 V, f = 1.0 MHz	15							pF

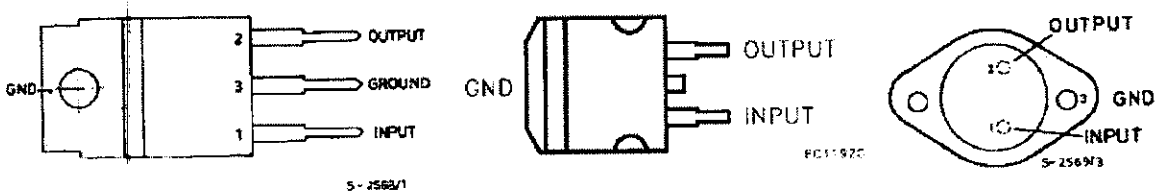
ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Value	Unit
V_i	DC Input Voltage (for V_O = 5 to 18V) (for V_O = 20, 24V)	35 40	V V
I_o	Output Current	Internally limited	
P_{tot}	Power Dissipation	Internally limited	
T_{op}	Operating Junction Temperature Range (for **L7800**) (for **L7800C**)	-55 to 150 0 to 150	°C °C
T_{stg}	Storage Temperature Range	-65 to 150	°C

THERMAL DATA

Symbol	Parameter		D²PAK	TO-220	TO-220FP	TO-3	Unit
$R_{thj-case}$	Thermal Resistance Junction-case	Max	3	3	5	4	°C/W
$R_{thj-amb}$	Thermal Resistance Junction-ambient	Max	62.5	50	60	35	°C/W

CONNECTION DIAGRAM AND ORDERING NUMBERS (top view)



TO-220 & TO-220FP

D²PAK

TO-3

Type	TO-220	D²PAK (*)	TO-220FP	TO-3	Output Voltage
L7805				L7805T	5V
L7805C	L7805CV	L7805CD2T	L7805CP	L7805CT	5V
L7852C	L7852CV	L7852CD2T	L7852CP	L7852CT	5.2V
L7806				L7806T	6V
L7806C	L7806CV	L7806CD2T	L7806CP	L7806CT	6V
L7808				L7808T	8V
L7808C	L7808CV	L7808CD2T	L7808CP	L7808CT	8V
L7885C	L7885CV	L7885CD2T	L7885CP	L7885CT	8.5V
L7809C	L7809CV	L7809CD2T	L7809CP	L7809CT	9V
L7812				L7812T	12V
L7812C	L7812CV	L7812CD2T	L7812CP	L7812CT	12V
L7815				L7815T	15V
L7815C	L7815CV	L7815CD2T	L7815CP	L7815CT	15V
L7818				L7818T	18V
L7818C	L7818CV	L7818CD2T	L7818CP	L7818CT	18V
L7820				L7820T	20V
L7820C	L7820CV	L7820CD2T	L7820CP	L7820CT	20V
L7824				L7824T	24V
L7824C	L7824CV	L7824CD2T	L7824CP	L7824CT	24V

(*) AVAILABLE IN TAPE AND REEL WITH "-TR" SUFFIX

FAIRCHILD
SEMICONDUCTOR®

IGBT

FGA25N120AN

General Description

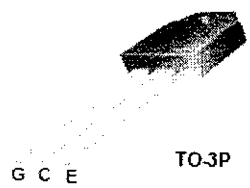
Employing NPT technology, Fairchild's AN series of IGBTs provides low conduction and switching losses. The AN series offers an solution for application such as induction heating (IH), motor control, general purpose inverters and uninterruptible power supplies (UPS).

Features

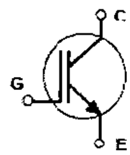
- High speed switching
- Low saturation voltage : $V_{CE(sat)}$ = 2.5 V @ I_C = 25A
- High input impedance

Applications

Induction Heating, UPS, AC & DC motor controls and general purpose inverters.



TO-3P



Absolute Maximum Ratings T_C = 25°C unless otherwise noted

Symbol	Description		FGA25N120AN	Units
V_{CES}	Collector-Emitter Voltage		1200	V
V_{GES}	Gate-Emitter Voltage		± 20	V
I_C	Collector Current	@ T_C = 25°C	40	A
	Collector Current	@ T_C = 100°C	25	A
$I_{CM (1)}$	Pulsed Collector Current		75	A
P_D	Maximum Power Dissipation	@ T_C = 25°C	310	W
	Maximum Power Dissipation	@ T_C = 100°C	125	W
T_J	Operating Junction Temperature		-55 to +150	°C
T_{stg}	Storage Temperature Range		-55 to +150	°C
T_L	Maximum Lead Temp. for soldering Purposes, 1/8" from case for 5 seconds		300	°C

Notes :
(1) Repetitive rating : Pulse width limited by max. junction temperature

Thermal Characteristics

Symbol	Parameter	Typ.	Max.	Units
$R_{\theta JC}$	Thermal Resistance, Junction-to-Case	--	0.4	°C/W
$R_{\theta JA}$	Thermal Resistance, Junction-to-Ambient	--	40	°C/W

MICROCHIP

PIC16F87X

28/40-Pin 8-Bit CMOS FLASH Microcontrollers

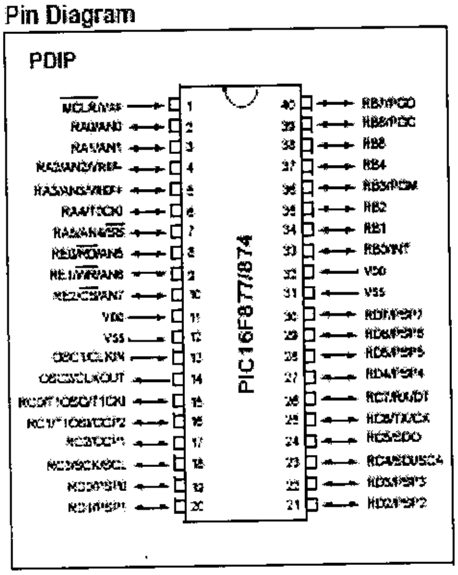
Devices Included in this Data Sheet:

- PIC16F873
- PIC16F874
- PIC16F876
- PIC16F877

Microcontroller Core Features:

- High performance RISC CPU
- Only 35 single word instructions to learn
- All single cycle instructions except for program branches which are two cycle
- Operating speed: DC - 20 MHz clock input
  DC - 200 ns instruction cycle
- Up to 8K x 14 words of FLASH Program Memory,
  Up to 368 x 8 bytes of Data Memory (RAM)
  Up to 256 x 8 bytes of EEPROM Data Memory
- Pinout compatible to the PIC16C73B/74B/76/77
- Interrupt capability (up to 14 sources)
- Eight level deep hardware stack
- Direct, indirect and relative addressing modes
- Power-on Reset (POR)
- Power-up Timer (PWRT) and Oscillator Start-up Timer (OST)
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code protection
- Power saving SLEEP mode
- Selectable oscillator options
- Low power, high speed CMOS FLASH/EEPROM technology
- Fully static design
- In-Circuit Serial Programming™ (ICSP) via two pins
- Single 5V In-Circuit Serial Programming capability
- In-Circuit Debugging via two pins
- Processor read/write access to program memory
- Wide operating voltage range: 2.0V to 5.5V
- High Sink/Source Current: 25 mA
- Commercial, Industrial and Extended temperature ranges
- Low-power consumption:
  - < 0.6 mA typical @ 3V, 4 MHz
  - 20 µA typical @ 3V, 32 kHz
  - < 1 µA typical standby current

Pin Diagram



Peripheral Features:

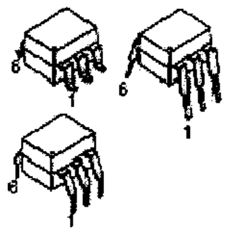
- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during SLEEP via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules
  - Capture is 16-bit, max. resolution is 12.5 ns
  - Compare is 16-bit, max. resolution is 200 ns
  - PWM max. resolution is 10-bit
- 10-bit multi-channel Analog-to-Digital converter
- Synchronous Serial Port (SSP) with SPI™ (Master mode) and I²C™ (Master/Slave)
- Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI) with 9-bit address detection
- Parallel Slave Port (PSP) 8-bits wide, with external RD, WR and CS controls (40/44-pin only)
- Brown-out detection circuitry for Brown-out Reset (BOR)

FAIRCHILD
SEMICONDUCTOR®

PHOTOTRANSISTOR OPTOCOUPLERS

MCT2 MCT2200	MCT2E MCT2201	MCT210 MCT2202	MCT271

WHITE PACKAGE (-M SUFFIX)



BLACK PACKAGE (NO -M SUFFIX)

DESCRIPTION

The MCT2XXX series optoisolators consist of a gallium arsenide infrared emitting diode driving a silicon phototransistor in a 6-pin dual in-line package.

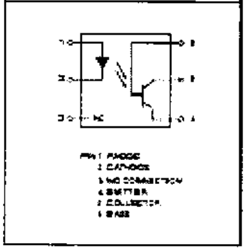
FEATURES

- UL recognized (File # E90700)
- VDE recognized (File # 94766)
  - Add option V for white package (e.g., MCT2V-M)
  - Add option 300 for black package (e.g., MCT2.300)
- MCT2 and MCT2E are also available in white package by specifying -M suffix, eg. MCT2-M

APPLICATIONS

- Power supply regulators
- Digital logic inputs
- Microprocessor inputs

SCHEMATIC



Data Sheet January 2002

8A, 500V, 0.850 Ohm, N-Channel Power MOSFET

This N-Channel enhancement mode silicon gate power field effect transistor is an advanced power MOSFET designed, tested, and guaranteed to withstand a specified level of energy in the breakdown avalanche mode of operation. All of these power MOSFETs are designed for applications such as switching regulators, switching converters, motor drivers, relay drivers, and drivers for high power bipolar switching transistors requiring high speed and low gate drive power. These types can be operated directly from integrated circuits.

Formerly developmental type TA17425.

Ordering Information

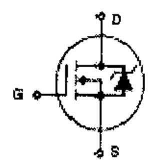
PART NUMBER	PACKAGE	BRAND
IRF840	TO-220AB	IRF840

NOTE: When ordering, include the entire part number.

Features

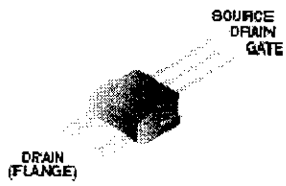
- 8A, 500V
- $r_{DS(ON)} = 0.850\Omega$
- Single Pulse Avalanche Energy Rated
- SOA is Power Dissipation Limited
- Nanosecond Switching Speeds
- Linear Transfer Characteristics
- High Input Impedance
- Related Literature
  - TB334 "Guidelines for Soldering Surface Mount Components to PC Boards"

Symbol



Packaging

JEDEC TO-220AB
TOP VIEW



International
IOR Rectifier

Data Sheet No. PD60147 Rev.T

IR2110(S)/IR2113(S) & (PbF)

HIGH AND LOW SIDE DRIVER

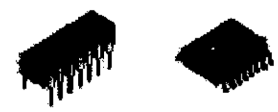
Features

- Floating channel designed for bootstrap operation
  Fully operational to +500V or +600V
  Tolerant to negative transient voltage
  dV/dt immune
- Gate drive supply range from 10 to 20V
- Undervoltage lockout for both channels
- 3.3V logic compatible
  Separate logic supply range from 3.3V to 20V
  Logic and power ground ±5V offset
- CMOS Schmitt-triggered inputs with pull-down
- Cycle by cycle edge-triggered shutdown logic
- Matched propagation delay for both channels
- Outputs in phase with inputs
- Also available LEAD-FREE

Product Summary

V_{OFFSET}	(IR2110)	500V max.
	(IR2113)	600V max.
I_O+/-		2A / 2A
V_{OUT}		10 - 20V
$t_{on/off}$ (typ.)		120 & 94 ns
Delay Matching	(IR2110)	10 ns max.
	(IR2113)	20ns max.

Packages

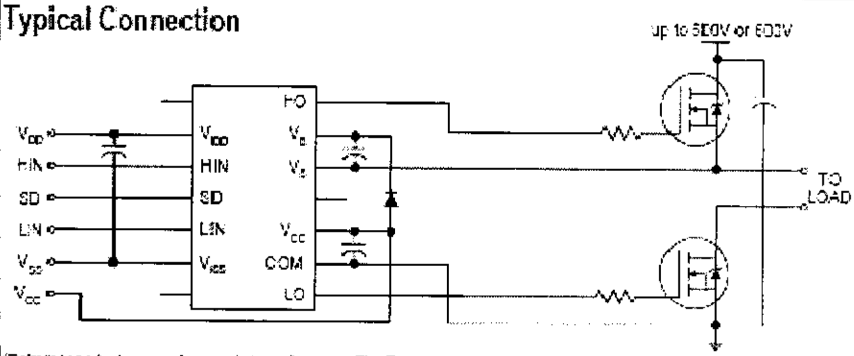

14-Lead PDIP
IR2110/IR2113

16-Lead SOIC
IR2110S/IR2113S

Description

The IR2110/IR2113 are high voltage, high speed power MOSFET and IGBT drivers with independent high and low side referenced output channels. Proprietary HVIC and latch immune CMOS technologies enable ruggedized monolithic construction. Logic inputs are compatible with standard CMOS or LSTTL output, down to 3.3V logic. The output drivers feature a high pulse current buffer stage designed for minimum driver cross-conduction. Propagation delays are matched to simplify use in high frequency applications. The floating channel can be used to drive an N-channel power MOSFET or IGBT in the high side configuration which operates up to 500 or 600 volts.

Typical Connection



(Refer to Lead Assignments for correct pin configuration). This/These diagram(s) show electrical connections only. Please refer to our Application Notes and DesignTips for proper circuit board layout.