VAR COMPENSATION IN WINDMILL BY USING STATCOM

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BONAFIDE CERTIFICATE

Certified that this project report entitled **"VAR COMPENSATION IN WINDMILL BY USING STATCOM"** is the bonafide work of

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Who carried out the project work under my supervision

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ABSTRACT

The connection of a large wind farm to the electrical grid network is one of the main concerns of the transmission system planners, especially when the strength of the system is relatively low compared to the amount of power delivered by the wind farm. The purpose of this project is to make an analysis of a configuration consisting of a Wind Farm based on conventional Fixed Speed Induction Generator. The generator is magnetized with fixed capacitor banks for unit power factor operation during steady state conditions. To increase the transient stability conditions of the generator a STATCOM is introduced in the system as an active voltage/VAR supporter. The project qualifies the improved short-term voltage and rotor stability performance obtained when a STATCOM is introduced during different types of failure events in the connected power system.

ACKNOWLEDEMENT

It is my bounden duty to thank contribution made by one form or the other by the individuals we hereby acknowledge.

I wish to place on record our deep sense of gratitude and profound thanks to our guide **Prof. K Malarvizhi,** Assistant professor, Electrical and Electronics Engineering Department, on her valuable guidance, constant encouragement, continuous support and co- operation rendered throughout the project.

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LIST OF SYMBOLS AND ABBREVATIONS

NO	SYMBOLS	ABBREVATIONS
1	AC	Alternating Current
2	DC	Direct Current
3	VSC	Voltage Source Converter
4	PCC	Point of Common Coupling
5	Vc	Carrier signal
6	PU	Per Unit
7	Vr	Reference signal
8	Cp	Turbine power co-efficient
9	G	Generator
10	Vs	Source voltages
11	Is	Source current
12	V_{dc}	Voltage across each capacitor
13	V_c	The voltage across the two capacitors
14	V_m	The desired magnitude of the peak terminal voltage
15	V_{tref}	The reference voltage to be maintained at the terminal bus
16	P_{sh}	Amount of power drawn byshuntlink
17	?	Fundamental frequency of the system
18	T	Required time period

CHAPTER - 1
INTRODUCTION

INTRODUCTION

1.1 SYSTEM DESCRIPTION

The working principle of a wind turbine includes the following conversion processes: the rotor extracts the kinetic energy from the wind creating the generator torque and the generator converters this torque into electricity and feeds it into the grid. Presently main turbine type. Squirrel-cage induction generator is the simplest and oldest system consists of a conventional directly grid-coupled squirrel caged induction generator. The slip, and the result rotor speed of the generator as shown in fig 1 , varies with the amount of power generated. The rotor speed variation is small, approximately 1% to 2%, and hence this is normally referred as a constant speed turbine.

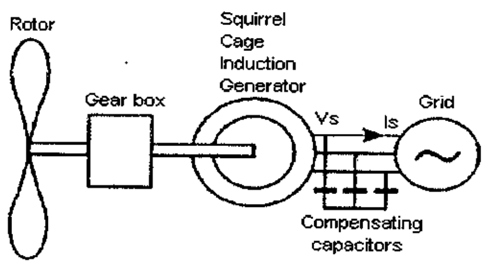


Fig 1. Squirrel-cage induction generator

Squirrel-cage induction generator is still the most commonly used wind turbine (simple and economic solution), this project is concentrated on evaluating the performance of this type of generator. An important operating characteristic of the squirrel cage induction generator is that this type of generator always consumes reactive power, which is undesirable for the transmission system. In the particularly case of large turbines and weak grid, the reactive power consumption of the generator is always fully compensated by capacitors in order to achieve a power factor close to one. Another characteristic of the squirrel-cage induction generators is that, in general, this type of generator tends to slow down voltage restoration after a fault and this can lead to voltage and rotor-speed instability. During a fault, the generator will accelerate due to the unbalance between mechanical power extracted from the wind and electrical power delivered to the grid. When the voltage restores, after the fault is cleared, the generator will consume reactive power, impeding the voltage restoration.

When the voltage does not return quickly enough, the generator continues to accelerate and consumes even larger amount of reactive power. This process eventually leads to voltage and rotor-speed instability if the wind turbine is connected to a weak grid. To prevent these types of instabilities, the more advanced and faster controller STATCOM (this is a voltage-source converter using self-commutated IGBT devices) are included in the system. By having this additional device the voltage stability limit of the system can be enhanced reducing the risk of voltage collapse following a fault in the grid. The connection of STATCOM with the grid at the point of common coupling is shown in fig 2

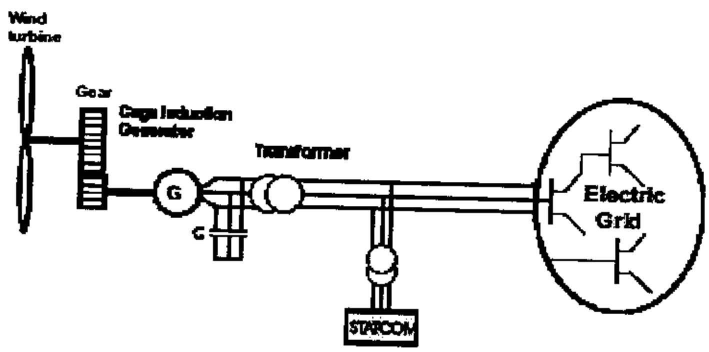


Fig 2 . schematic configuration of the system

This paper will consider the STATCOM as a form for additional voltage and reactive power support. The enhancement of transient voltage and rotor-speed stability is quantified by studying different types of faults in the system.. The impact of the wind generation on the power systems is no longer negligible if high penetration levels are going to be reached. Significant barriers to interconnection are being perceived already with the severe requirements of the new emerged grid codes. Depending on the generator technologies, different solutions are found to support behavior in case of voltage sags. Voltage Source Static Var Compensator such as the STATCOM can be used to regulate voltage as shunt compensator with directly connected asynchronous wind generators.

1.2 PROBLEM STATEMENT

With direct connected asynchronous generators, voltage drop occurs due to reactive power consumption . A voltage source static Var compensator such as STATCOM can be used to regulate voltage as shunt compensator with directly connected asynchronous wind generators. The STATCOM is a power electronics device based on the voltage source converter principle.

The main advantage of STATCOM over thyristor type static Var compensators is that the compensating current does not depend on the voltage level of the connecting point. Before the fault, the STATCOM is controlled to keep the terminal voltage constant. Initial operating condition can be calculated from the induction generator equivalent circuit with terminal voltage at its nominal value .

After fault, the STATCOM will give maximum current, until nominal voltage is reached. When there is no STATCOM control, during the fault, the wind generator accelerates, since it is no longer able to generate enough electromagnetic torque to balance the torque coming from the wind.

1.3 OBJECTIVE

- Analysis of the reactive component of wind generated electrical power in a power generating system.
- The control scheme is to maintain the power balance at the PCC (Point of Common Coupling).
- Finally, the STATCOM is to be designed for balanced system which will regulate the voltage profile of the distribution bus to which it is connected.

1.4 WINDMILL AN OVERVIEW:

The main components of a wind-mill are:

1) Wind Turbine
2) Transmission System
3) Braking System
4) AC Generator

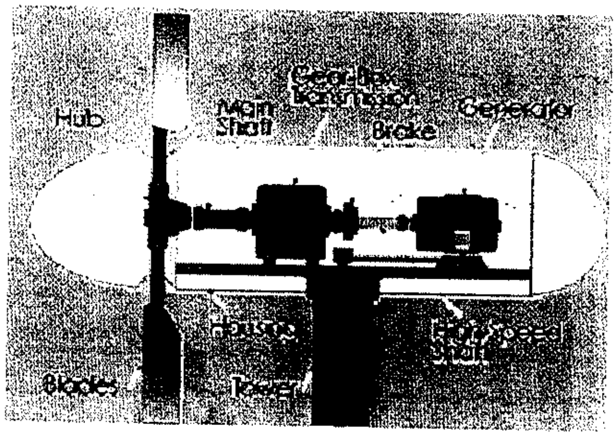


Fig 3: Schematic Diagram of the Wind Mill System

1.4.1 Wind Turbine:

The wind turbine, converts the kinetic energy in the wind to rotational motion by the rotor-typically a three-bladed assembly at the front of the wind turbine. The rotor turns the main shaft, which transfers the motion into the nacelle (the large housing at the top of a wind turbine tower).Inside the nacelle, the slowly rotating shaft enters the gearbox that greatly increases the rotational shaft speed. The output (high speed) shaft is connected to the generator that converts the rotational movement into the electric power at medium voltages.

1.4.2 Transmission System:

Hub- The blades on the wind turbine are bolded to the hub. The hub is casted in a special type of strong iron alloy called SG cast iron. The hub is of conical shape.

Main shaft- The main shaft of the wind turbine is usually forged from hardened and tempered steel. Hardening and tempering is result of forgoing the axle after it has been heated until it is white hot at about 1000 deg. Centigrade.

Gearbox- The Gear box is placed between the main shaft and the Generator. Its function is to increase the slow rotational speed of the rotor blades to the generator rotation speed of 1000 or 1500 rpm. The Gear box has a constant tip speed ratio.

1.4.3 Braking System:

The Braking System works in the principle of centrifugal action that controls the rotor speed through governors. The rotor can be stopped under abrupt conditions by mechanical braking systems. In modern windmills electrical braking system is used instead of mechanical braking system because frequent use of mechanical braking system creates heat stress in the Generator.

1.4.4 AC Generator:

The generator converts the mechanical power of the spinning wind turbine into electricity. Inside the generator, coils of wire are rotated in a magnetic field to produce electricity. Induction generators that produce AC power are generally equipped with features to produce electricity even when the wind speed is fluctuating. In the generator the armature is the coil of wire where the output voltage is generated and the current flows to the load. The portion of generator where the magnetic field is produced is the field .Relative motion between the two is obtained by either spinning the armature within the field or spinning the field with the armature. The power produced by the generator depends on the size and the length of the wires used in the armature, the strength of the magnetic field and the rate of the motion between them.

1.5 OPERATING CHARACTERISTICS OF WIND MILLS:

The wind mills have certain operating characteristics, such as cut-in, rated and cut-out wind speeds.

1.5.1 Cut-in- Speed:

Cut-in speed is the minimum wind speed at which the blades will turn and generate usable power. This wind speed is typically between 10 and 16 kmph.

1.5.2Rated Speed:

The rated speed is the minimum wind speed at which the wind turbine will generate its designated rated power. Rated speed for most machines is in the range of 40 to 55 kmph. At wind speeds between cut-in and rated, the power output from a wind turbine increases as the wind increases.

1.5.3 Cut-out Speed:

At very high wind speeds, typically between 72 and 128 kmph, most wind turbines cease power generation and shut down. The wind speed at which shut down occurs is called the cut-out speed.

1.5.4 Betz Limit:

It is the flow of air over the blades and through the rotor area that makes the wind turbine to function. The theoretical maximum amount of energy in the wind that can be collected by a wind turbine's rotor is approximately 59%. This value is known as the Betz limit.

1.6 WIND POWER CONVERSION:

The function of a wind turbine is to convert the linear motion of the wind energy into rotational energy that can be used to drive a generator. Wind turbines capture the power from the wind by means of aerodynamically designed blades and convert it into rotating mechanical power. The aerodynamic power, P, of a wind turbine is given by:

$$P = 1/2 \; ? \; ? \; R^2 V^3 C_p$$

Where ? is the air density, R is the turbine radius, V is the wind speed and Cp is the turbine power coefficient which represents the power conversion efficiency of a wind turbine. Cp is a function of the tip speed ratio (?) as well as the blade pitch angle (ß) in a pitch controlled wind turbine. ? is defined as the ratio of the tip speed of the turbine blades to wind speed, and given by:

$$? = \frac{R.?}{V}$$

Where ? is the rotational speed of the wind turbine. The Betz limit C_p max, (theoretical) = 16/27=0.529 the maximum theoretically possible rotor power Coefficient.

The Windmill Emulator is shown below:

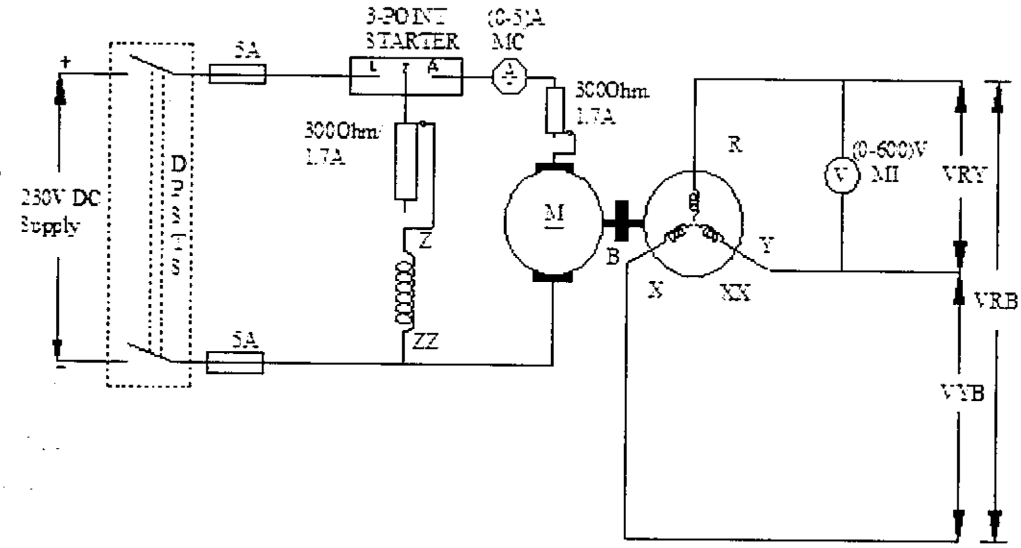


Fig 4 : Circuit Diagram of the Wind Mill Emulator

Name Plate Details:

Motor	Alternator
Voltage: 230 V	Voltage: 400 V
Current: 1.9 A	Current: 4.3 A
Speed: 1500 rpm	Speed: 1500 rpm
Output Power: 2 KW	Output Power: 3 KVA
Excitation: 0.7 A	Excitation: 0.75 A

The Windmill consists of Induction Generator which runs at various speeds proportional to the wind force. A similar model has been developed by coupling a DC motor with a 3-Phase Alternator. The DC motor is made to run at different speeds by using armature speed control .The 3-Phase alternator coupled with DC motor also runs at different speeds. By giving excitation to the field windings the output voltage generated between the lines is measured for various speeds.

The corresponding values of speed and the output voltage obtained from Alternator as an Emulator of the Wind mill is given below:

S.No	Speed (rpm)	Voltage obtained (volts)
1	1500	60
2	1485	58
3	1429	56
4	1381	54
5	1327	52
6	1274	50
7	1239	48
8	975	46
9	914	44
10	889	42
11	828	40
12	768	38

S.No	Speed (rpm)	Voltage obtained (volts)
13	737	36
14	687	34
15	626	32
16	553	30
17	536	26
18	516	24
19	479	22
20	400	20
21	388	18
22	345	16
23	266	14

Table 1 EMF developed for various Speeds

1.7 ORGANIZATION OF THE REPORT

- **Chapter 1** explains the motivation for this project to be undertaken, the brief description of the problem statement, objective, windmill an overview, operating characteristics of wind mills, wind power conversion and the organization of the report.
- **Chapter 2** depicts what STATCOM is all about and its operations with the help of schematic and diagrammatic representations.
- **Chapter 3** is *"Simulation of the system"*. This chapter presents the simulation of the circuit with and without STATCOM connection.
- **Chapter 4** explains the *"Embedded controller"* and how it works in the STATCOM. This chapter also provides the switching scheme of the controller.
- **Chapter 5** gives the block diagram ,hardware photographs and output of the controller.
- **Chapter 6** in this chapter discuss about the result and concludes the works done so far.
- **Appendix – A** program coding for PWM inverter operation
- **Appendix – B** Components

CHAPTER - 2

STATCOM – AN OVERVIEW

STATCOM – An Overview

2.1 INTRODUCTION

This chapter presents the operating principles and applications of highly versatile controller – the STATCOM. This FACTS controller is based on insulated-gate bipolar transistors (IGBTs).

A STATCOM is analogous to an ideal synchronous machine, which generates a balanced set of three sinusoidal voltages- at the fundamental frequency- with controllable amplitude and phase angle. This ideal machine has no inertia, is practically instantaneous, does not significantly alter the existing system impedance, and can internally generate reactive (both capacitive and inductive) power.

2.2 DEFINITION

A distribution shunt-connected reactive power compensation device that is capable of generating and/ or absorbing reactive power in which the output can be varied to control the specific parameters of an electrical power system.

In general a solid state switching converter capable of generating or absorbing independently controllable real and reactive power at its output terminals when it is fed from an energy source or energy- storage device at its input terminals.

A voltage- source converter that, from a given input of DC voltage, produces a set of 3- phase AC output voltages, each in phase with and coupled to the corresponding AC system voltage through a relatively small reactance (which is provided by either an interface reactor or the leakage inductance of a coupling transformer). The DC voltage is provided by an energy storage capacitor.

2.3 PRINCIPLE OF OPERATION

A STATCOM is a controlled reactive power source. It provides the desired reactive power generation and absorption entirely by means of electronic processing of the voltage and current waveforms in the **voltage source converter (VSC).** A single-line STATCOM power circuit is shown in the Fig.5 where a VSC is connected to a utility bus through magnetic coupling.

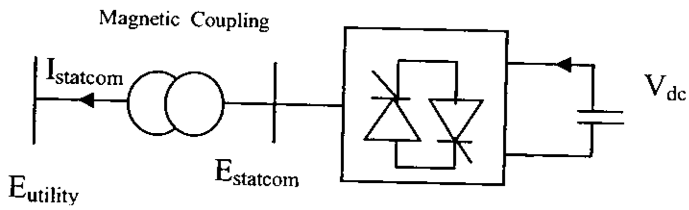


Fig.5 .VSC connected to the AC network through a shunt transformer

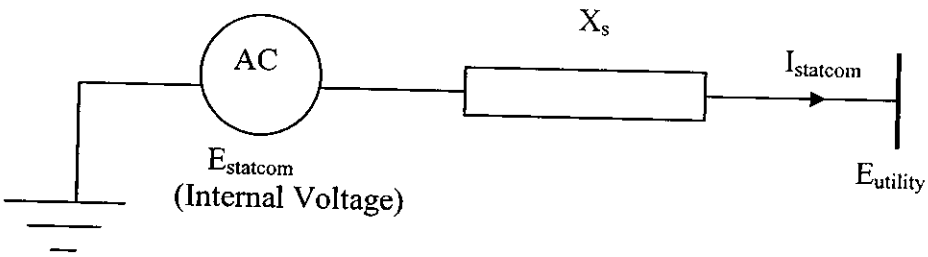


Fig.6 .Shunt connected variable solid state voltage source.

In Fig.6, a STATCOM is seen as an adjustable voltage source behind a reactance i.e., the capacitor banks and shunt reactors are not needed for reactive power generation and absorption, thereby giving the STATCOM a compact design, or small footprint, as well as low noise and low magnitude impact.

The exchange of reactive power between the converter and the AC systems can be controlled by varying the amplitude of the 3-phase output voltage Es, of the converter as illustrated in the Fig .7. That is if the amplitude of the output voltage is increased beyond that of the utility bus voltage, Ei, then the current flows through the reactance from the converter to the AC system and the converter generates capacitive- reactive

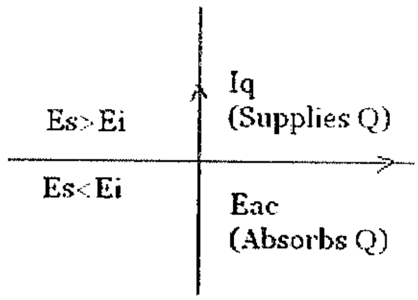


Fig.7 Reactive power exchange between converter and AC system

power for the AC system. If the amplitude of the output voltage is decreased below the utility bus voltage, then the current flows from the AC system to the converter and the converter absorbs inductive- reactive power from the AC system. If the output voltage equals the AC system voltage, the reactive power exchange becomes zero, in which case the STATCOM is said to be in floating state.

Adjusting the phase shift between the converter output voltage and the AC input voltage can similarly control the real power exchange between the converter and the AC system. In other words, the converter can supply real power to the AC system from the DC energy storage if the converter output voltage is made to lead the AC system voltage. On the other hand, it can absorb real power from the AC system for the DC system if its voltage lags behind the AC system voltage.

A STATCOM provides the desired reactive power by exchanging the instantaneous reactive power among the phases of the system. The mechanism by which the converter internally generates and/ or absorbs the reactive power can be understood by considering the relationship between the output and input powers of the converter. The converter switches the DC input circuit directly to the AC output circuit. Thus the net instantaneous power at the AC output terminals must always be equal to the net instantaneous power at the DC input terminals (neglecting the losses).

If it is assumed that the converter is operated to supply only the reactive power output, the real power provided by the DC source as the input to the converter must be zero. Furthermore, because the reactive power at zero frequency (DC) is by definition zero, the DC source supplies no reactive power as the input to the converter and thus clearly plays no part in generation of reactive output power by the converter. In other words, the converter simply interconnects the three output terminals so that the reactive output currents can freely flow among them. If the terminals of the AC systems are regarded in this context, the converter establishes a circulating reactive power exchange among the phases. However, the real power that the converter exchanges at its AC terminals with the AC system must, of course, be supplied to absorbed from its DC terminals by the DC capacitor.

Although the reactive power is generated internally by the converter switches action, a DC capacitor must still be connected across the input terminals of the converter. The primary for the capacitor is to provide a circulating current path and acts as a voltage source. The magnitude of the capacitor is chosen so that the DC voltage across its terminals remains fairly constant to prevent it from contributing to the ripples in the DC current. The VSC output voltage is in the form of a staircase wave into which smooth sinusoidal current from the AC system is drawn, resulting in the slight fluctuations in the output power of the converter. Depending on the converter configuration employed, it is possible to calculate the minimum capacitance required to meet the system requirements, such as ripple limits on the DC voltage and the rated reactive power support needed by the AC system.

The VSC has the same rated current capability when it operates with the capacitive or inductive reactive current. Therefore, a VSC having certain MVA rating gives the STATCOM twice the dynamic range in MVAR (this also contribute to a compact design). A DC capacitor bank is used for the operation of the VSC. The reactive power of a STATCOM is produced by means of power electronic equipment of the voltage source converter type. The VSC may be a 2-level or 3-level type, depending on the required power output and voltage. A number of VSCs are combined in a multi-pulse connection to form a STATCOM. In the steady state, the VSCs operate with fundamental frequency switching to minimize converter losses. However, during transient conditions caused by the line faults, a pulse width modulated (PWM) mode is used to prevent the fault current from entering the VSCs. In this way, the STATCOM is able to withstand transients on the AC side.

CHAPTER – 3

SIMULATION

SIMULATION

3.1 SIMULATION BLOCK OF WINDMILL

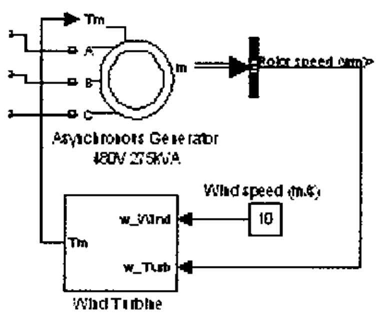


Fig .8 simulation block of windmill

Figure shows the simulation circuit of the windmill . It consists of asynchronous generator with rating of 275 kVA ,480 V .A wind turbine is coupled to the induction generator and generator will rotate the same speed of the turbine. In simulation we consider the wind speed of 10 m/sec for a small time period. The roter speed of the motor will compare to the wind speed and corresponding torque will produce. This torque will feed to the induction generator and generator will produce a three phase balanced output.

The balanced output voltage is fed to the grid. The generator is magnetized with fixed capacitor banks for unit power factor operation during steady state conditions. When ever a fault or load change occurs in the grid, induction generator will absorb the reactive power. At that time the output voltage of the generator will reduce to a lower value.

3.2 SIMULATION BLOCK OF STATCOM

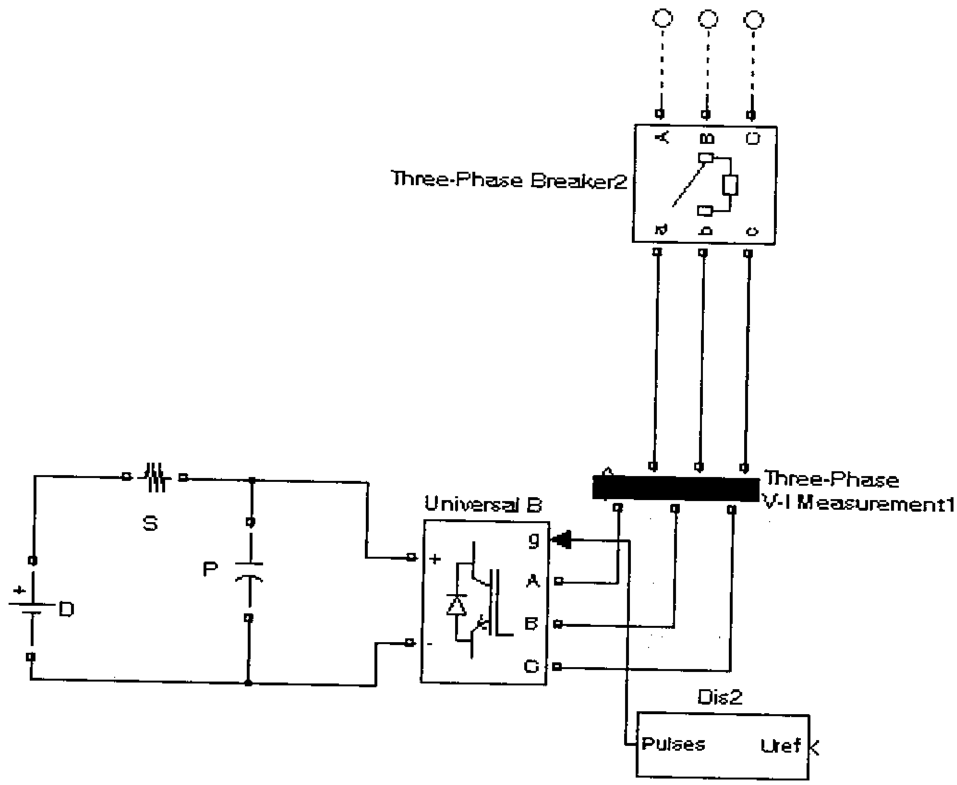


Fig . 9 Simulation Block of STATCOM

This block implements a bridge of selected power electronics devices. A series RC snubber are connected are parallel with each switch devices. The main STATCOM block is a universal bridge circuit of IGBT. It act as a voltage source converter. It convert ac to dc and vice versa. The main function of STATCOM is to compensate the reactive power absorb by the wind generator whenever a fault occur in the grid. It will inject reactive power to the grid.

3.3 DESCRIPTION

A 100-Mvar STATCOM regulates voltage on a three-bus 135-kV system. The 48-pulse STATCOM uses a Voltage-Sourced Converter (VSC) built of four 12-pulse three-level IGBT inverters. Look inside the STATCOM block to see how the VSC inverter is built. The four sets of three-phase voltages obtained at the output of the four three-level inverters are applied to the secondary windings of four phase-shifting transformers (-15 deg., -7.5 deg., 7.5 deg., +7.5 deg. phase shifts).

The fundamental components of voltages obtained on the 135 kV side of the transformers are added in phase by the serial connection of primary windings.

During steady-state operation the STATCOM control system keeps the fundamental component of the VSC voltage in phase with the system voltage. If the voltage generated by the VSC is higher (or lower) than the system voltage, the STATCOM generates (or absorbs) reactive power. The amount of reactive power depends on the VSC voltage magnitude and on the transformer leakage reactances. The fundamental component of VSC voltage is controlled by varying the DC bus voltage. In order to vary the DC voltage, and therefore the reactive power, the VSC voltage angle (alpha) which is normally kept close to zero is temporarily phase shifted. This VSC voltage lag or lead produces a temporary flow of active power which results in an increase or decrease of capacitor voltages.

3.3.1 Simulation Of The System Without fault & STATCOM

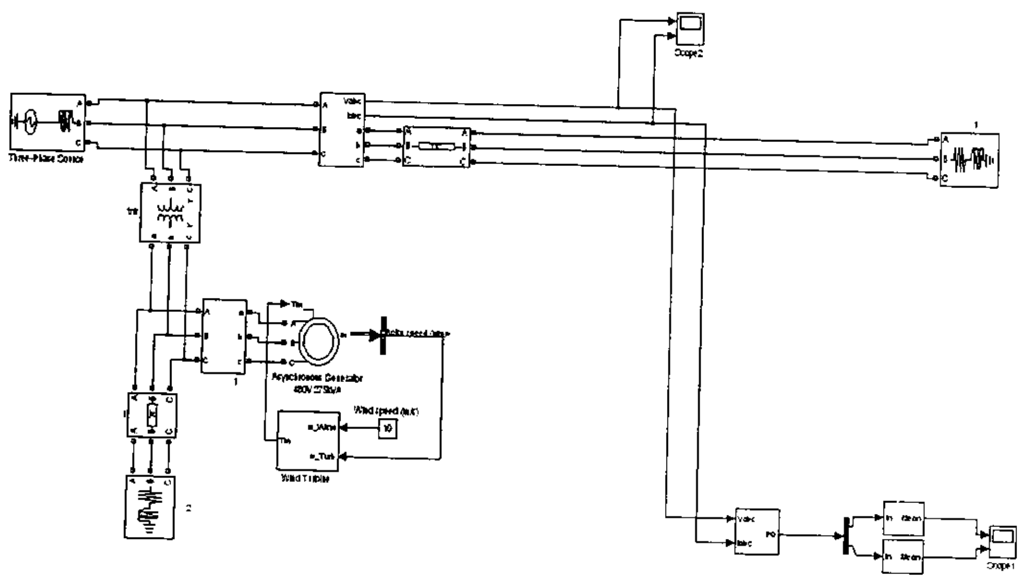


Fig .10 Simulation of the system without STATCOM

One of the three voltage sources used in the 135 kV system equivalents can be be varied in order to observe the STATCOM dynamic response to changes in system voltage. Open the "Programmable Voltage Source" menu and look at the sequence of voltage steps which are programmed.

3.3.2 Voltage Waveform of grid Without fault & STATCOM

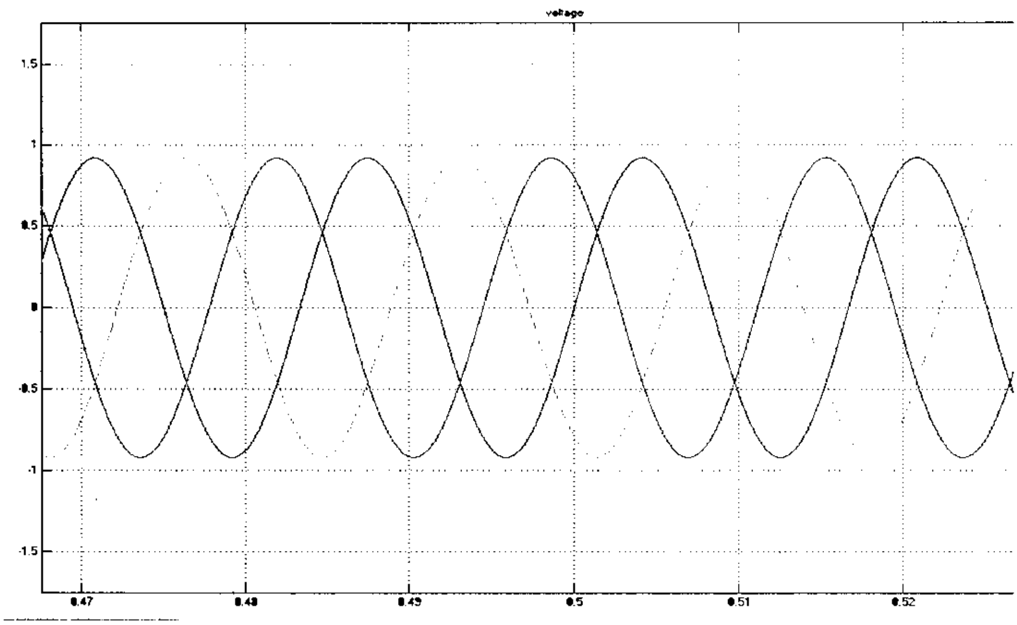


Fig . 11 voltage and current waveform without fault& STATCOM

3.3.3 Active And Reactive Power Without fault & STATCOM

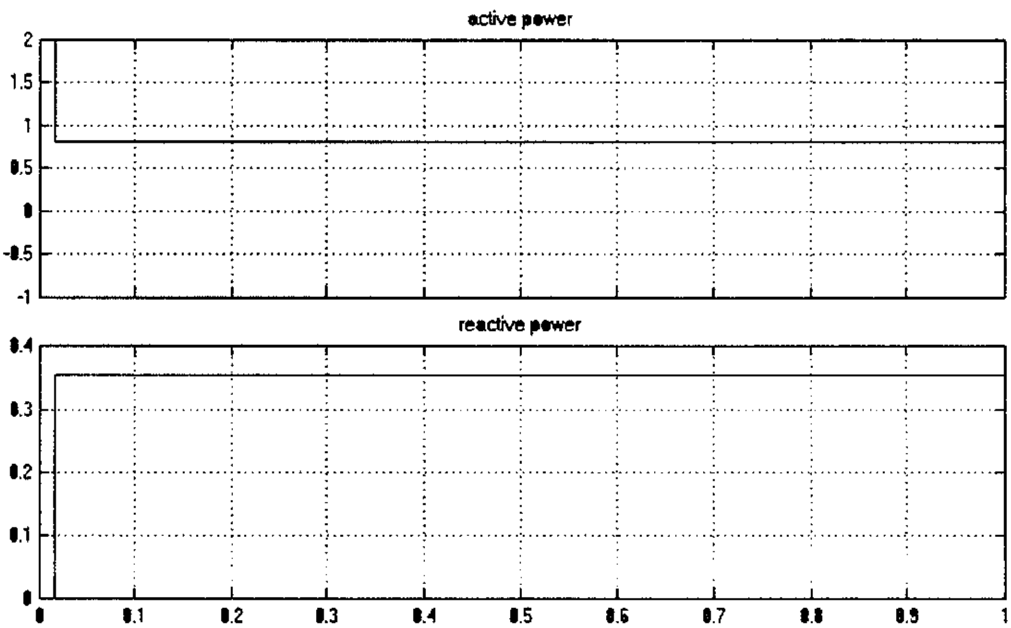


Fig . 12 active and reactive power without fault & STATCOM

3.3.4 Simulation Of The System With STATCOM without fault

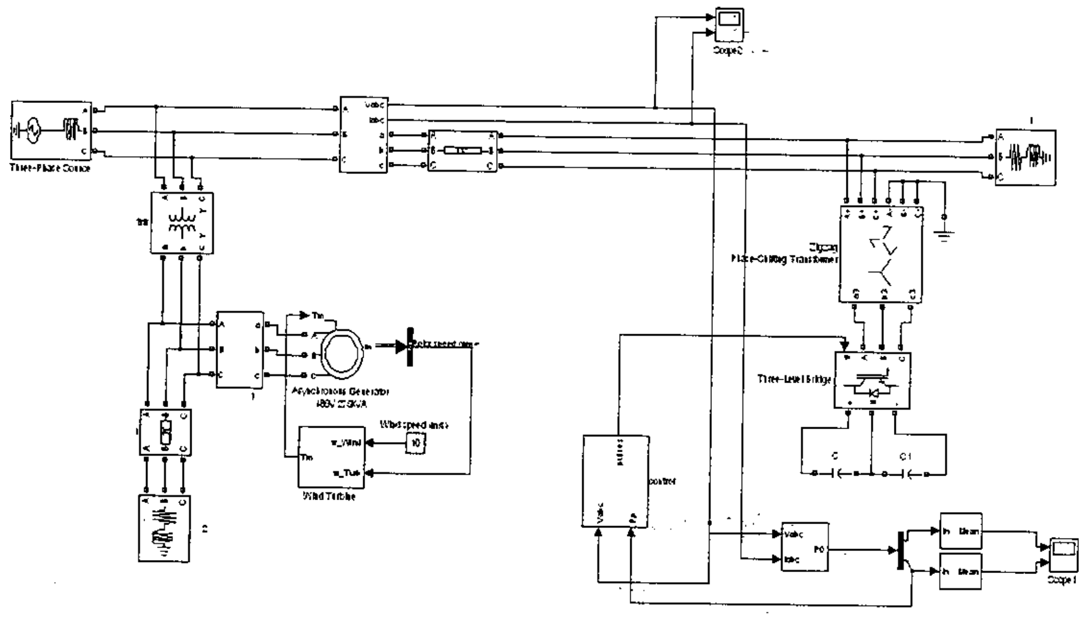


Fig 13 Simulation Of The System With STATCOM without fault

3.3.5 Voltage Waveform of grid With STATCOM without fault

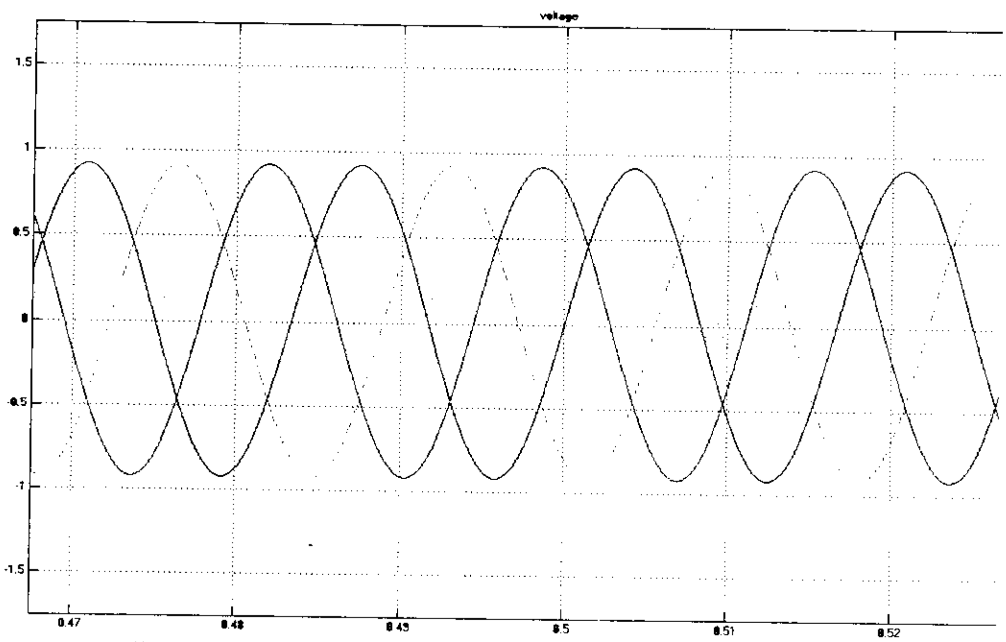


Fig .14 Voltage Waveform of grid With STATCOM without fault

3.3.6 Active And Reactive Power With STATCOM without fault

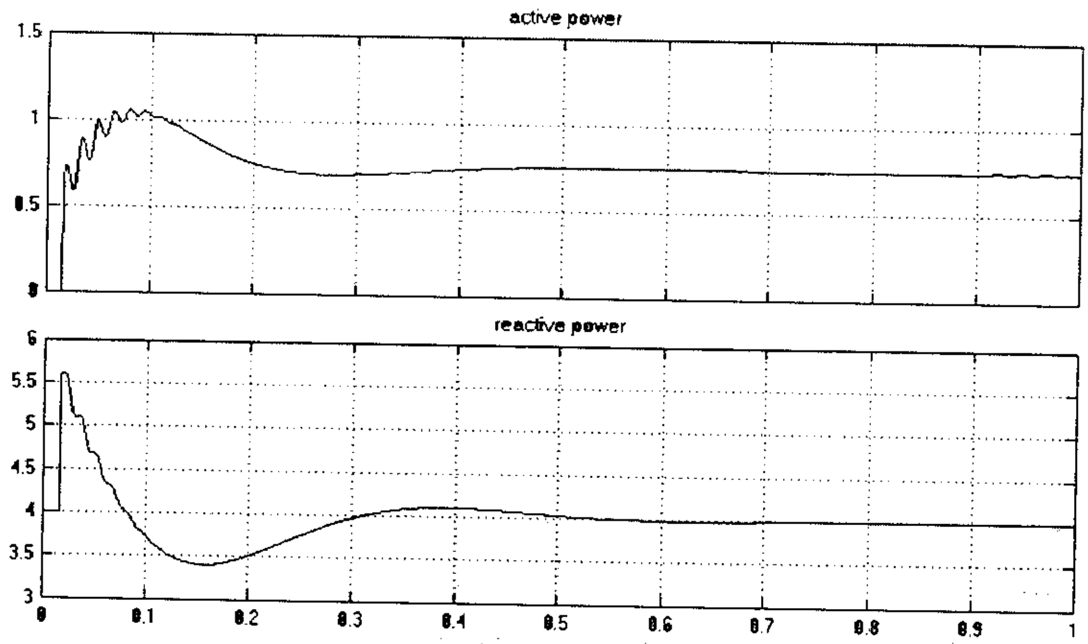


Fig .15 Active And Reactive Power With STATCOM without fault

3.4 DYNAMIC RESPONSE OF THE STATCOM

Run the simulation and observe waveforms on the STATCOM scope block. The STATCOM is in voltage control mode and its reference voltage is set to Vref=1.0 pu. The voltage droop of the regulator is 0.03 pu/100 VA.Therefore when the STATCOM operating point changes from fully capacitive (+100 Mvar) to fully inductive (-100 Mvar) the STATCOM voltage varies between 1-0.03=0.97 pu and 1+0.03=1.03 pu.

Initially the programmable voltage source is set at 1.0491 pu, resulting in a 1.0 pu voltage at SVC terminals when the STATCOM is out of service. As the reference voltage Vref is set to 1.0 pu, the STATCOM is initially floating (zero current). The DC voltage is 19.3 kV. At t=0.1s, voltage is suddenly decreased by 4.5 % (0.955 pu of nominal voltage). The SVC reacts by generating reactive power (Q=+70 Mvar) in order to keep voltage at 0.979 pu. The 95% settling time is approximately 47 ms. At this point the DC voltage has increasded to 20.4 kV. Then, at t=0.2 s the source voltage is increased to1.045 pu of its nominal value.

3.4.1 Simulation Of The System With Fault & Without STATCOM

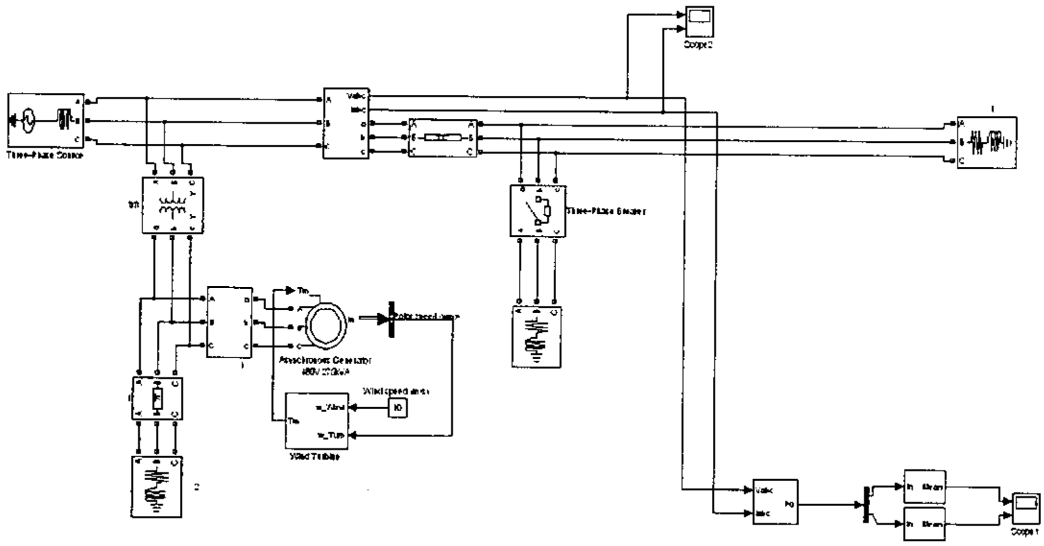


Fig . 16 Simulation of the system with fault without STATCOM

3.4.2 Voltage Waveform of grid With fault without STATCOM

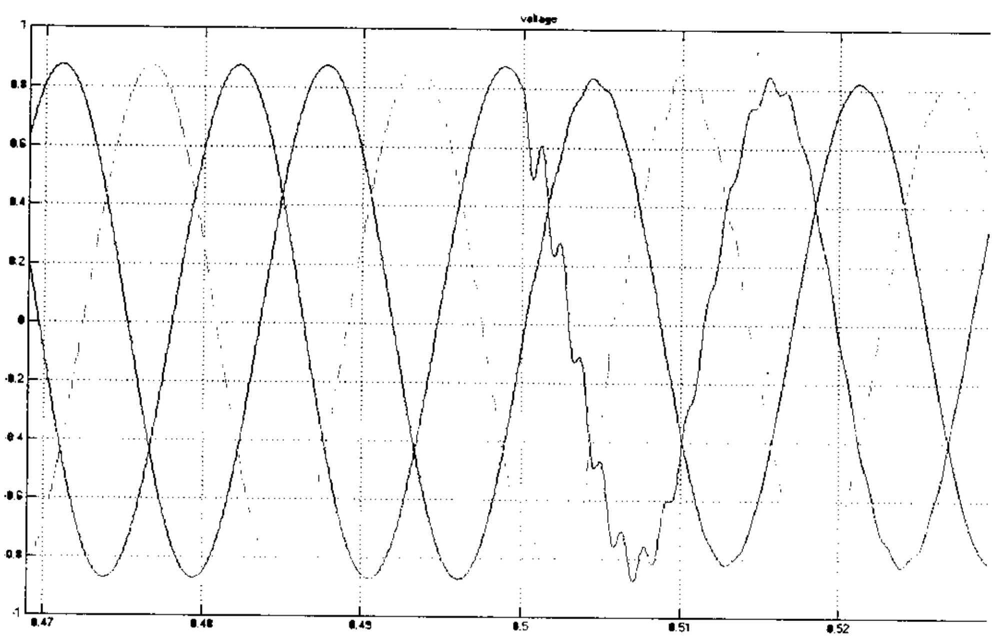


Fig .17 Voltage Waveform of grid With fault without STATCOM

3.4.3 Active And Reactive Power With fault without STATCOM

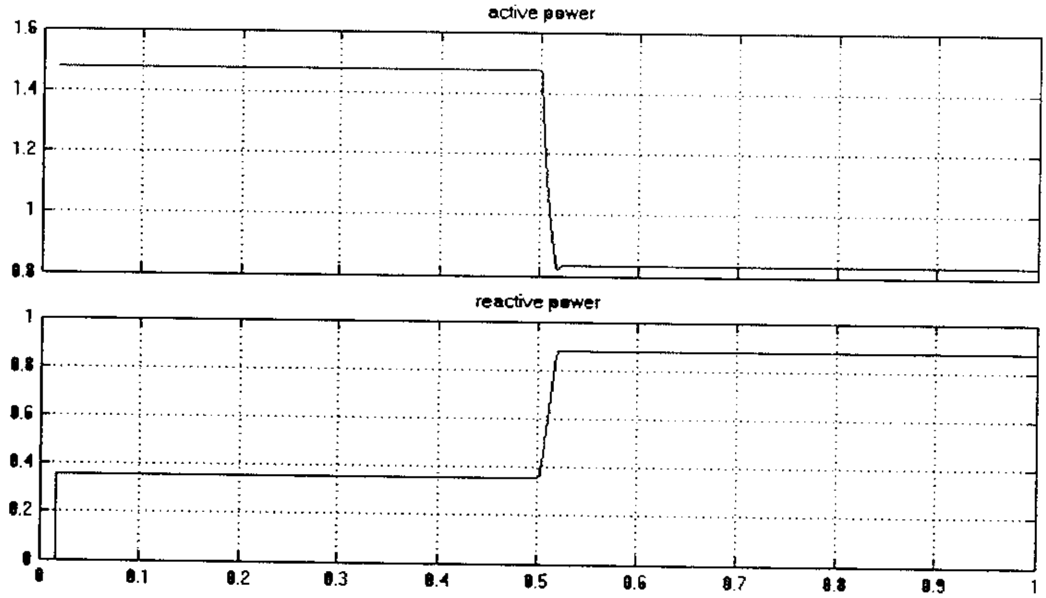


Fig .18 Active And Reactive Power With fault without STATCOM

Observe on the first trace showing the STATCOM primary voltage and current that the current is changing from capacitive to inductive in approximately one cycle. Finally, at t=0.3 s the source voltage in set back to its nominal value and the STATCOM operating point comes back to zero Mvar.

3.4.4 Simulation Of The System With Fault & STATCOM

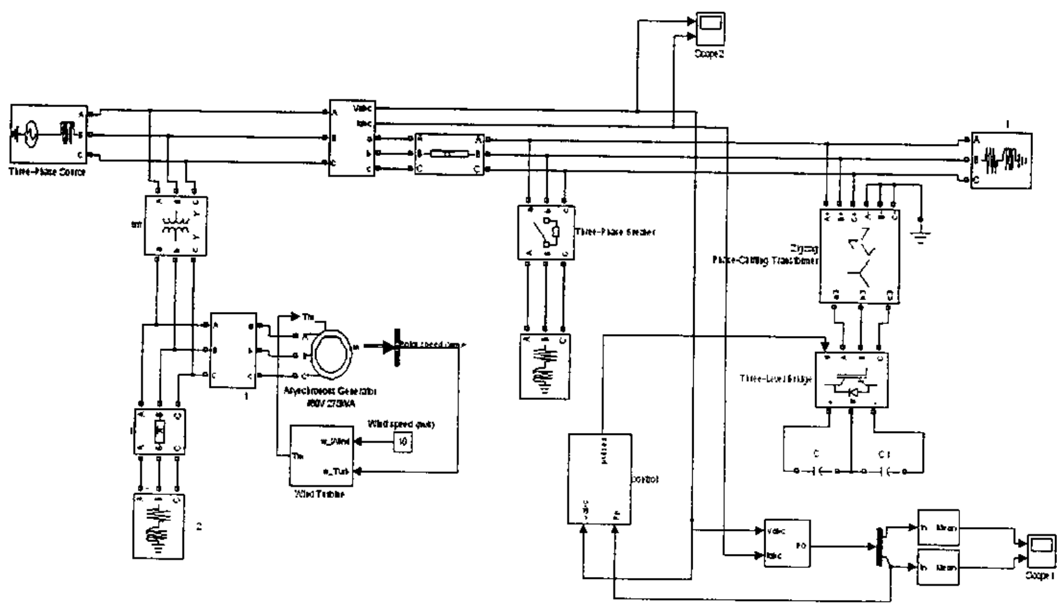


Fig . 19 Simulation Of The System With Fault & STATCOM

3.4.5 Voltage Waveform With fault & STATCOM

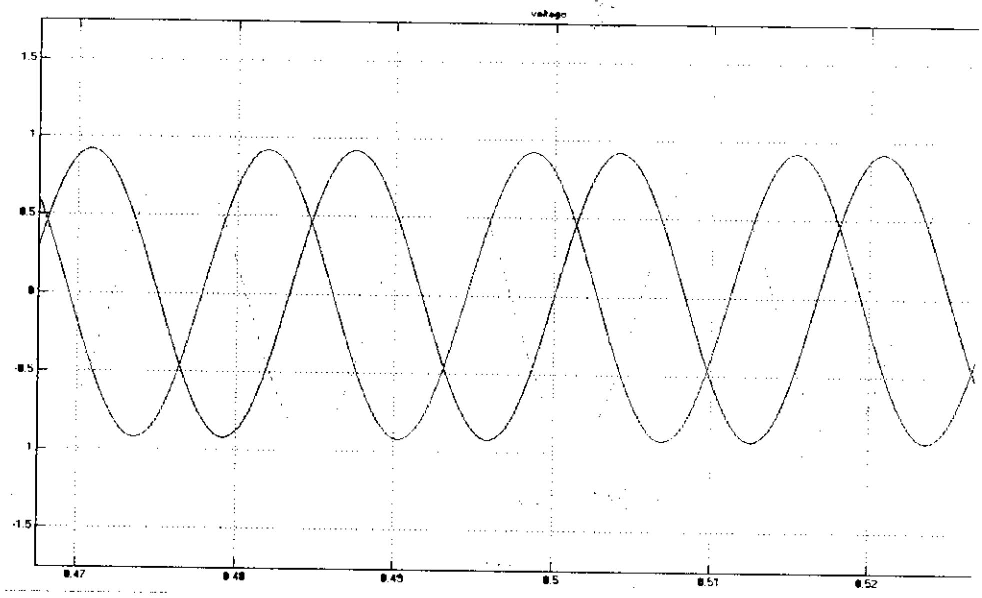


Fig . 20 voltage waveform with fault & STATCOM

3.4.6 Active And Reactive Power Waveform With fault & STATCOM

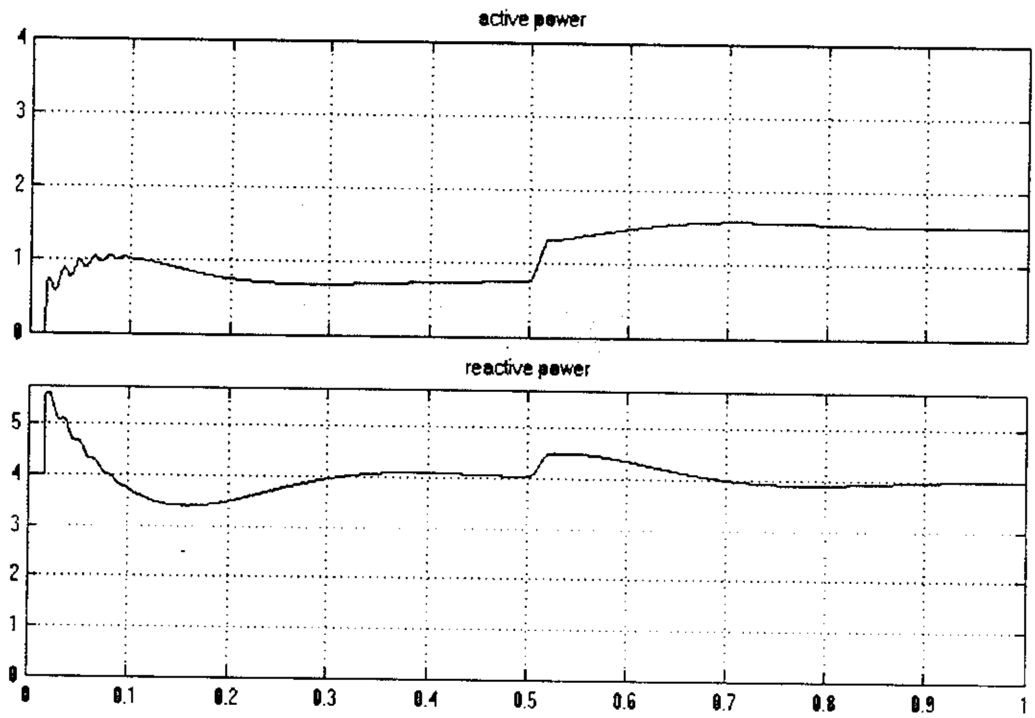


Fig . 21 active and reactive power waveform with STATCOM

If you look inside the "Signals and Scopes" subsystem you will have access to other control signals. Notice the transient changes on alpha angle when the DC voltage is increased or decreased in order to vary reactive power. The steady state value of alpha (0.5 degrees) is the phase shift required to maintain a small active power flow compensating transformer and converter losses.

CHAPTER - 4

EMBEDDED CONTROLLER

4.1 PIC 16F877 MICROCONTROLLER TO DRIVE SINGLE PHASE PWM INVERTER:

In this part of the single phase PWM Inverter port B and port C Timer 0 and TRISB registers are initialized. The PWM pulses are generated from RB4, RB5, RB6, and RB7 of port B. By adjusting the time delay generated from the microcontroller suitable triggering pulses are given to the power MOSFET to get turn ON and turn OFF.

For this adjustment of the time delay embedded C codes are written in the microcontroller .This embedded C is compiled in MPLAB IDE. The debugger used is In- Circuit Debugger ICD 2.

4.2 DRIVER CIRCUIT FOR SINGLE PHASE PWM INVERTER:

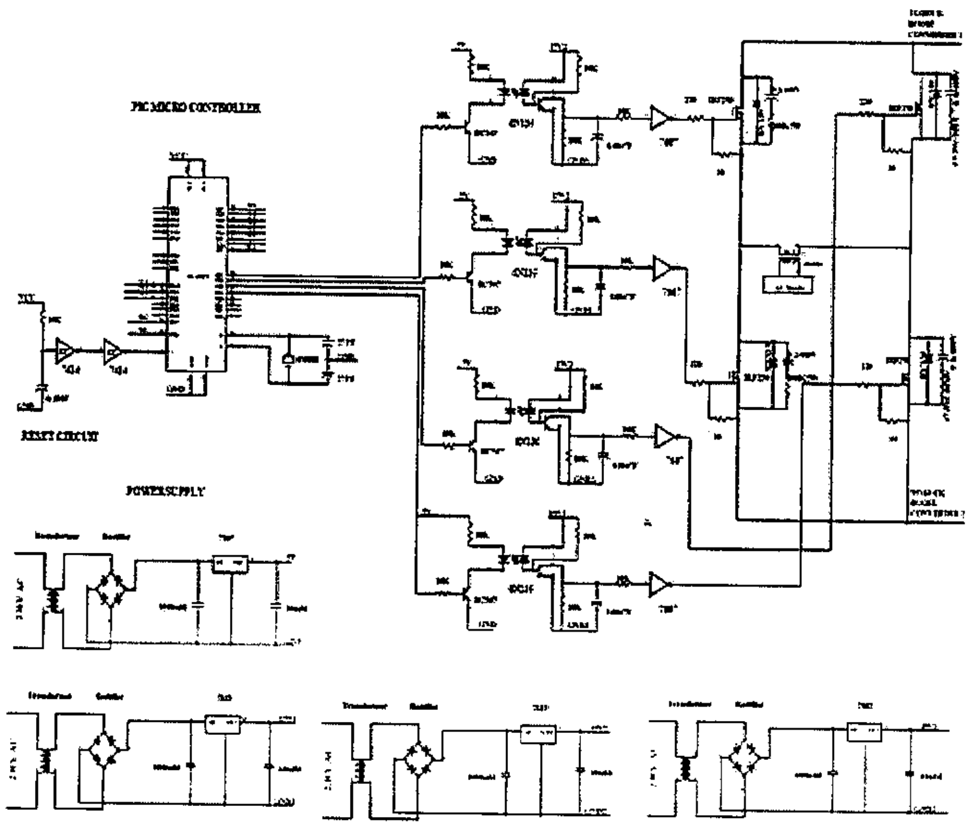


Fig .22 Circuit Diagram to drive power MOSFET'S of PWM Inverter

4.3 DRIVER CIRCUIT OPERATION FOR SINGLE PHASE PWM INVERTER:

In order to give triggering pulse to the power MOSFET'S for single phase PWM Inverter, the triggering pulse are generated from PB4, PB5, PB6 and PB7 of port B. These output pins drive the transistor BC 547. Depending on the output voltage (Logic 0 or Logic 1) the transistor gets turn ON and turn OFF. The voltage thus obtained is isolated by using optocoupler MCT2XXX .The purpose of the isolation is to give constant output voltage to drive the power MOSFET'S so that the variation in the input voltage will not affect the output voltage .Thus the isolated output voltage now drives the other transistor BC 547 and gives the triggering pulse to the power MOSFETS.

4.4 SINGLE PHASE PWM INVERTER:

In this project a fixed DC input voltage from the output of the Buck-Boost Converter is given to the Inverter and a controlled AC voltage is obtained at the output by adjusting the ON and OFF period of the power MOSFET's. The PWM technique has the following advantages:

- The output voltage control in this method can be obtained without any additional components
- The lower order harmonic can be minimized along with the output voltage control.

The pulse width modulation techniques can be classified mainly as:

(a) Single Pulse Width Modulation

(b) Multiple Pulse Width Modulation

(c) Sinusoidal Pulse Width Modulation

4.5 SINGLE PULSE WIDTH MODULATION:

The output voltage from the single phase PWM Inverter is shown below .It consists of a pulse of width 2d located symmetrically about ? /2 and the another pulse located symmetrically about 3 ? /2 .The range of pulse width varies from 0 to ? (0<2d< ?) .The output voltage is controlled by the pulse width of 2d.The shape of the output voltage is a quasi-square wave.

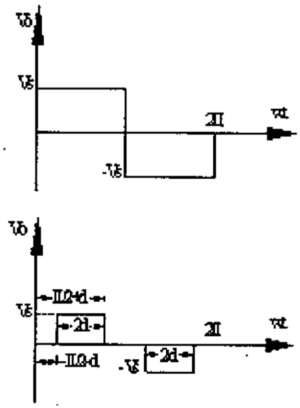


Fig.23 Single Phase PWM Output

4.6 MULTIPLE PULSE WIDTH MODULATION:

The Multiple Pulse Width Modulation uses two symmetric pulses per half cycle. The symmetrical modulated wave form is shown below:

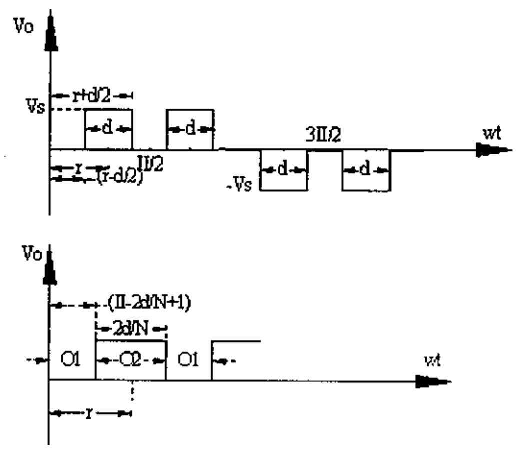


Fig . 24 Symmetrical modulated wave for Multiple Pulse Width Modulation

This symmetric modulated wave can be generated by comparing an adjustable square voltage wave Vr of frequency $?_c$ as shown in below:

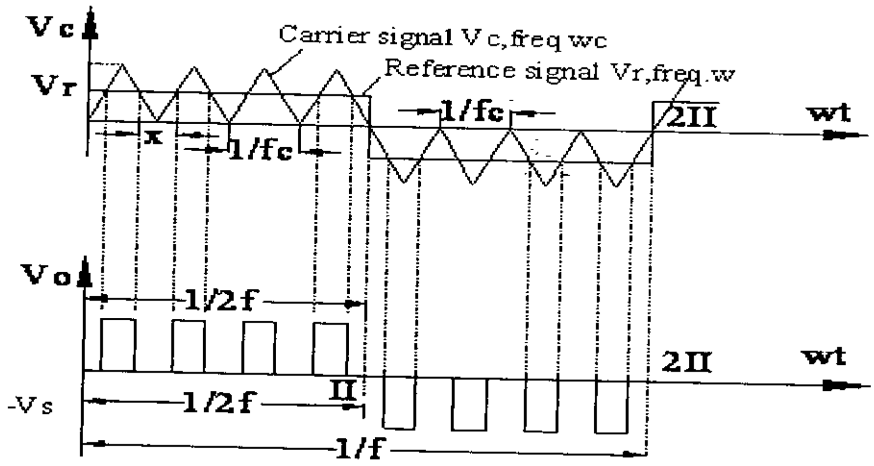


Fig . 25 Output Voltage waveform with Multiple Pulse Width Modulation

The firing pulse for the power MOSFET is given by the intersection of carrier and reference signal .The firing pulses so generated turn ON the MOSFET so that the output voltage is available during the interval triangular modulating wave exceeds the square modulating wave.

4.7 SINUSOIDAL PULSE WIDTH MODULATION:

In this modulation, several pulses per half cycle are used. In Multiple Pulse Width Modulation, the pulse width is equal for all pulses whereas in Sinusoidal PWM the pulse width is a sinusoidal function of the angular position of the pulse given in the cycle.For releasing sine PWM, a higher frequency triangular wave is compared Vc is compared with the sinusoidal reference wave Vr of desired frequency. The value of Vr/Vc is called Modulation Index and it controls the harmonic content of the output waveform. The intersection of Vc and Vr determines the switching instant and commutation of the modulated pulse. The below diagram shows the Sinusoidal PWM:

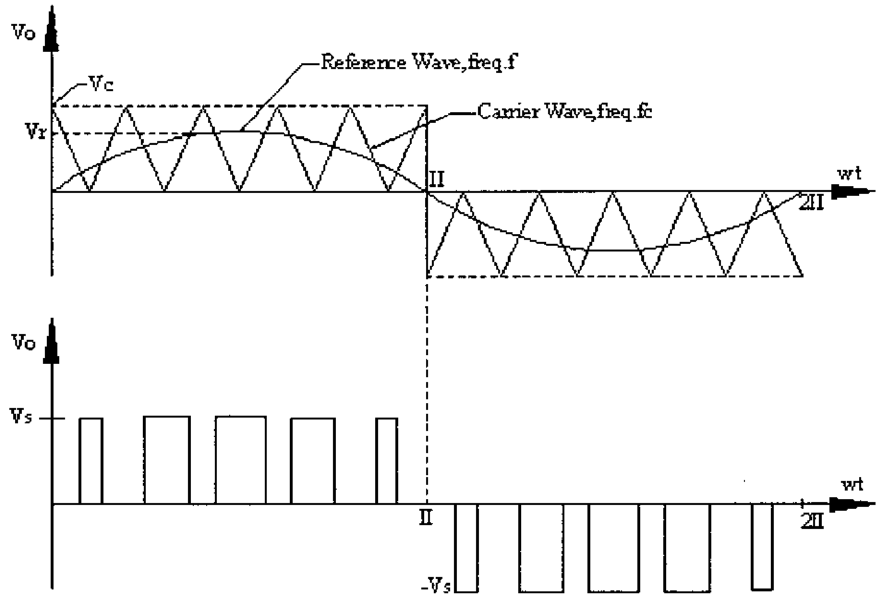


Fig . 26 Output Voltage waveform with Sinusoidal Pulse Width Modulation

CHAPTER – 5

HARDWARE SET UP

5.1 BLOCK DIAGRAM

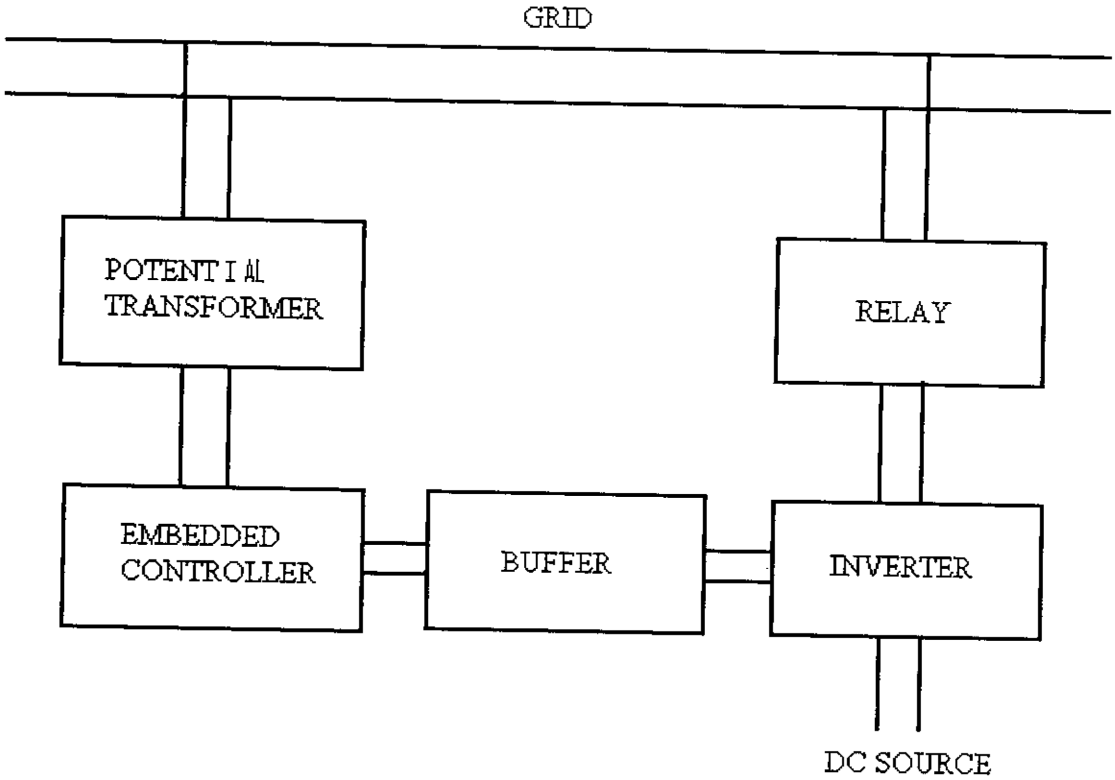


Fig . 27 Block Diagram of Hardware

Fig . 28 shows the block diagram of the hardware setup. The potential transformer step down the grid voltage 5 V, this 5 V Ac supply is rectified and given to the PIC controller. If there is any change grid voltage PIC controller produce the triggering signal to the MOSFET. The MOSFET shunt inverter convert the 12 V dc from the DC source to AC Voltage. The PIC controller only controls the output voltage of the shunt inverter. There is a relay connected to the output side of the shunt inverter, that relay will activate, when the grid voltage is below the rated value. Whenever a fault or load change occurs the induction generator will absorb the reactive power from the grid that is why the grid voltage will reduce, at that time the shunt inverter will inject the reactive power to grid and try to maintain the grid voltage to its rated value. This closed loop control will controls the grid voltage as constant whenever a fault or load changes occurs in the grid.

5.2 FLOW CHART OF THE MICROCONTROLLER OPERATION IN PWM INVERTER:

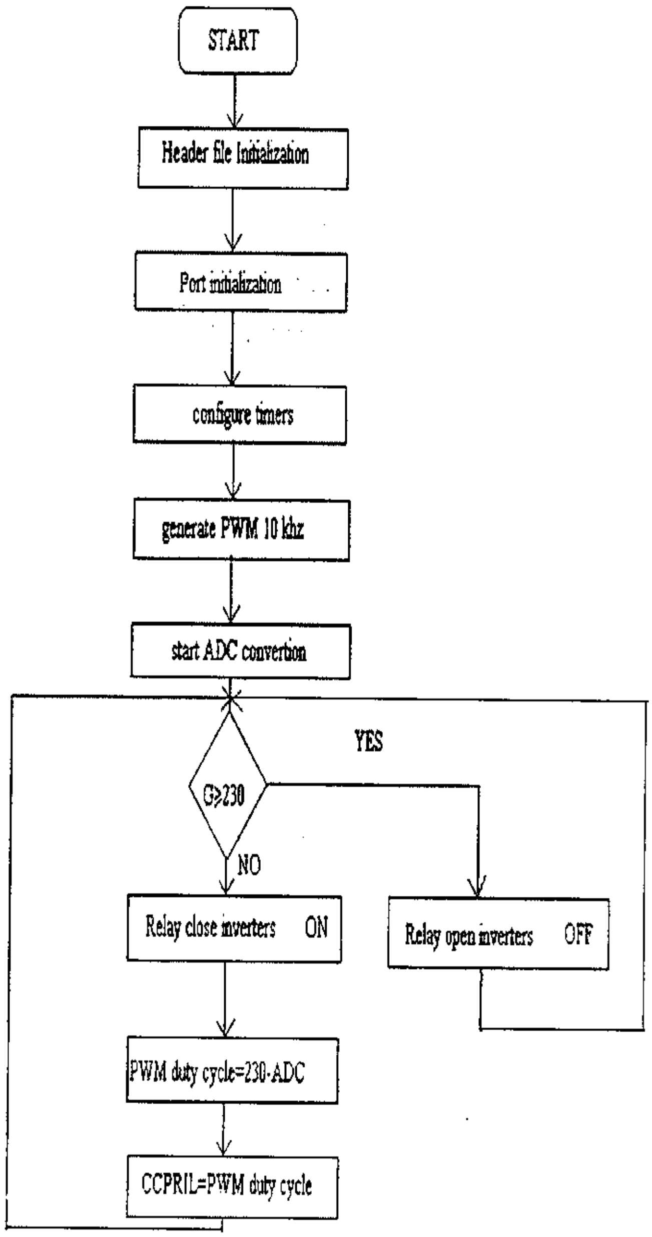


Fig . 28 Flow Chart for PWM Inverter Operation

5.3 HARDWARE PHOTOGRAPHS:

.The power MOSFET used for PWM Inverter is IRF TO220 which has voltage rating and current ratings as 500V, 8A respectively.

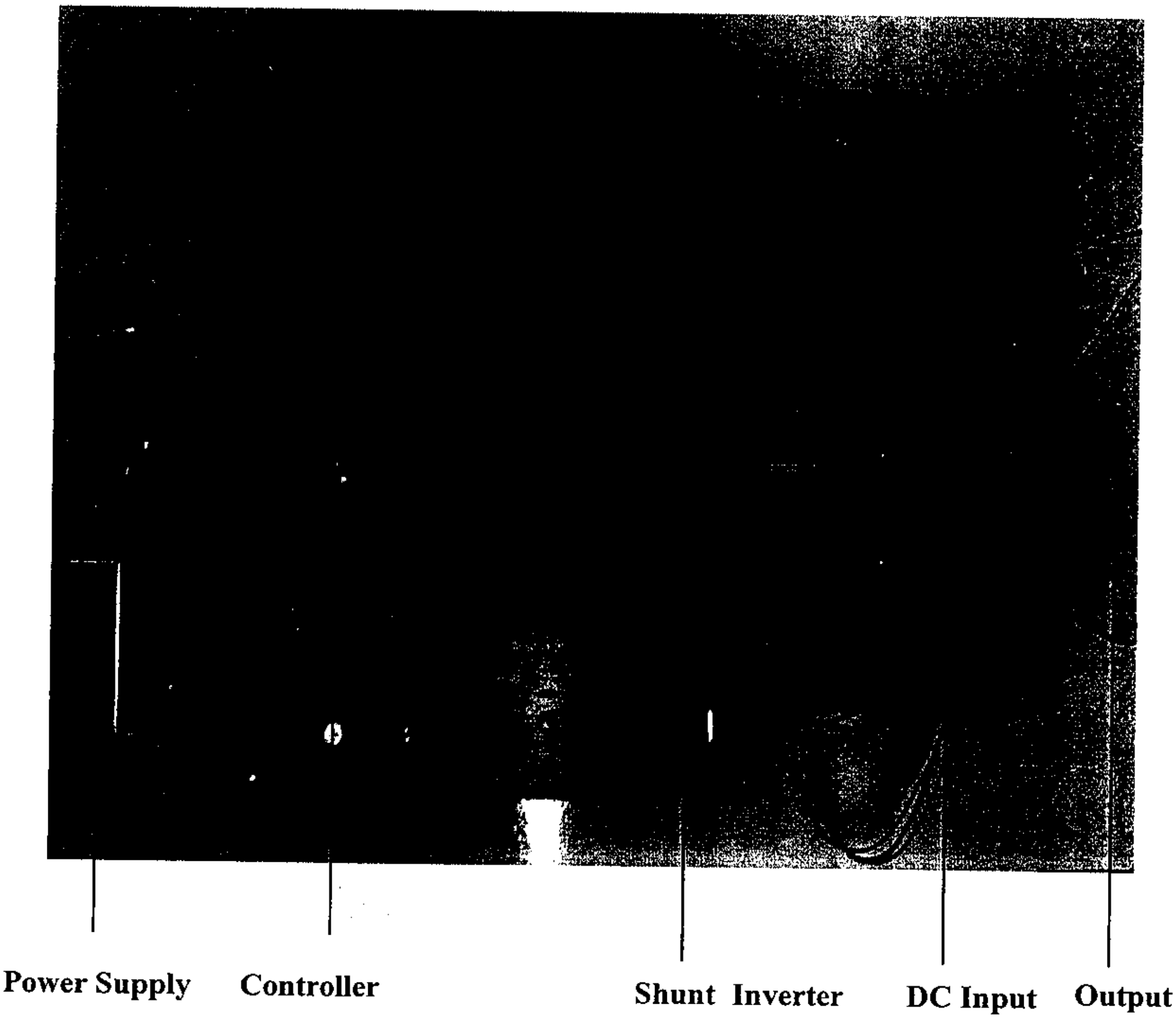


Fig .29 Shunt inverter hardware setup

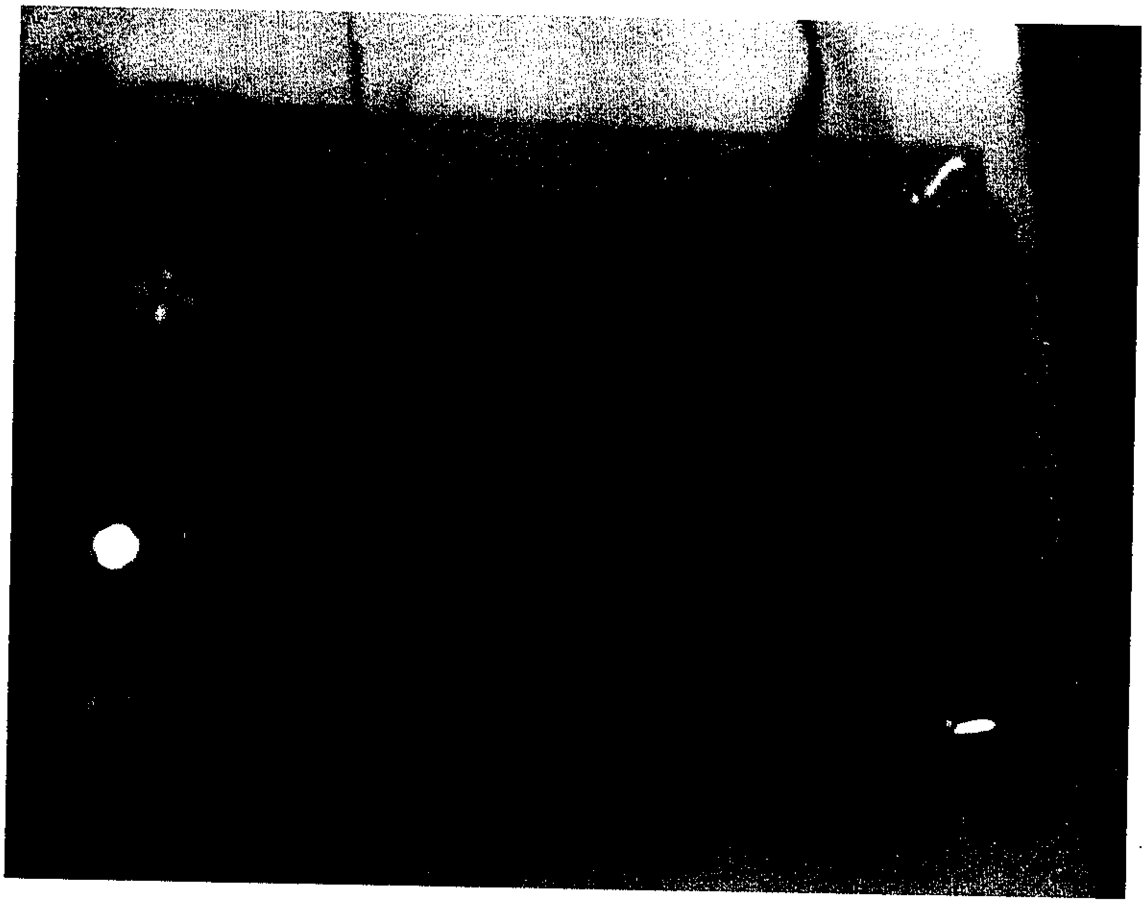


Fig . 30 PIC Microcontroller hardware setup

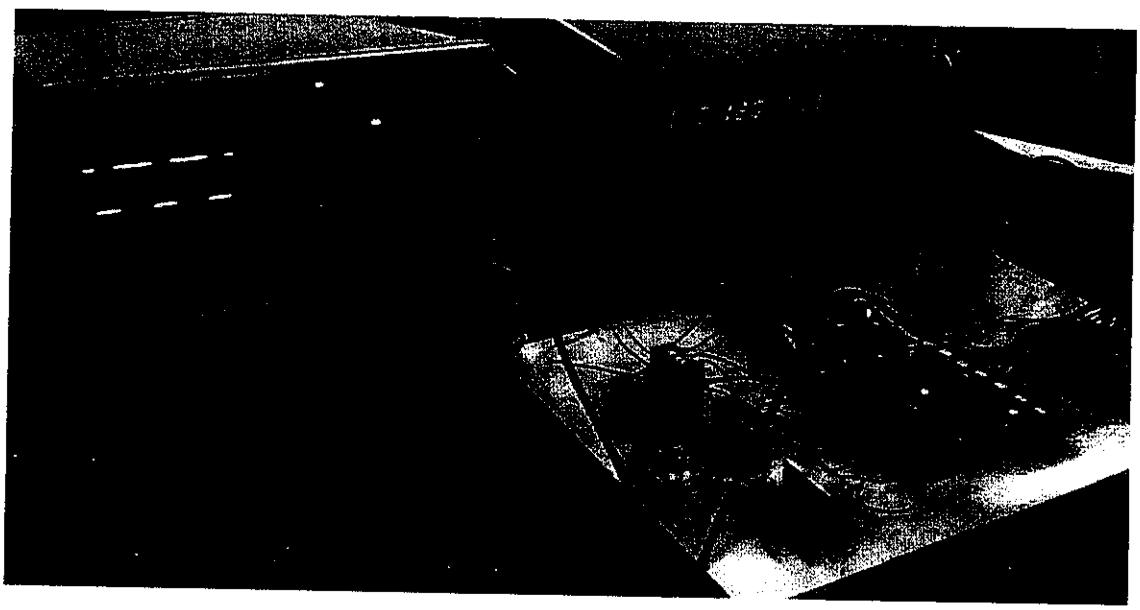
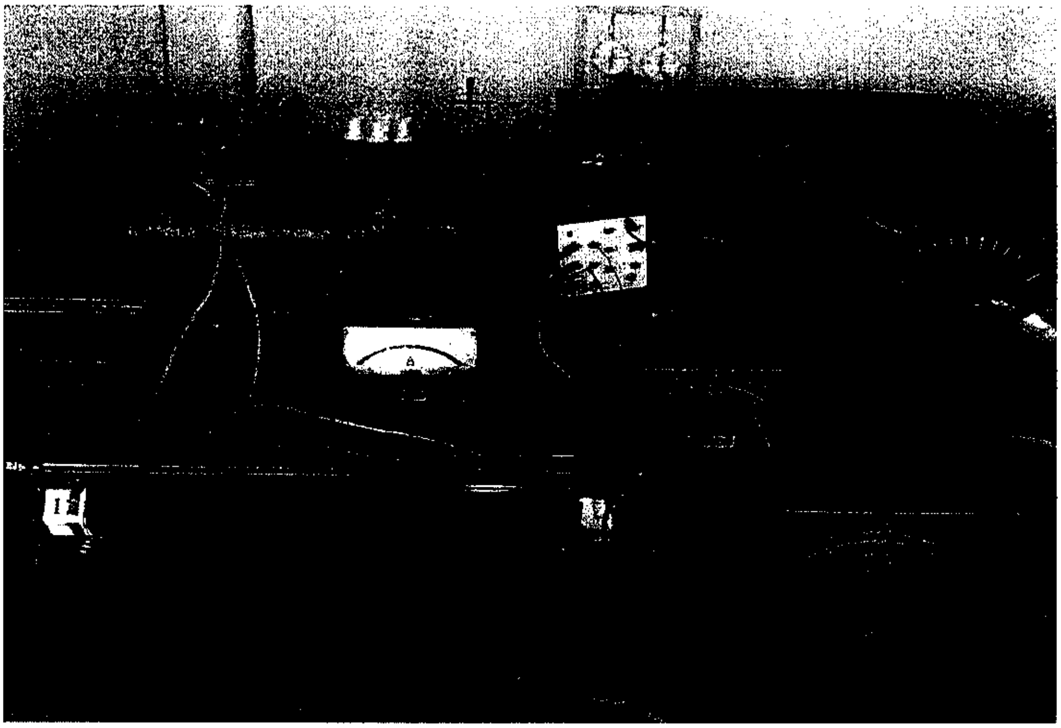


Fig .31 Complete circuit hardware setup



5.4 HARDWARE RESULTS:

The PWM pulse generated from the Microcontroller is generated is given below .The output voltage is 5V (1 divisions and 5V /division)

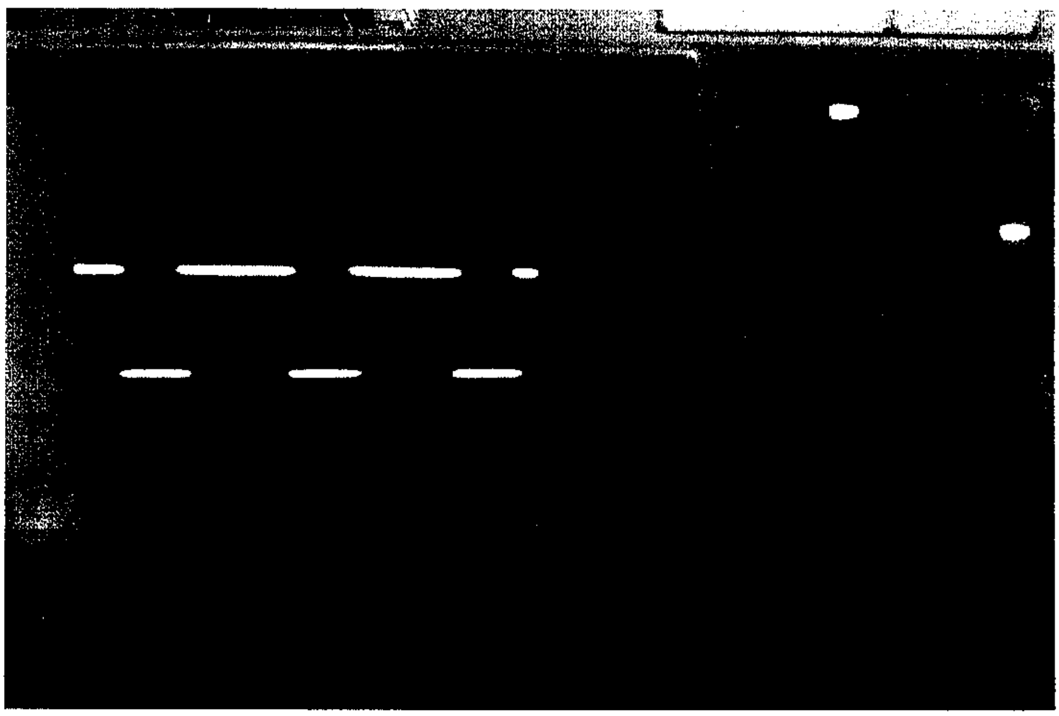


Fig . 32 Hardware Results

CHAPTER - 6

RESULT ANALYSIS & CONCLUSION

6.1 RESULT ANALYSIS

This study has analyzed the transient stability limits of a wind farm with squirrel-cage induction generators. It has been demonstrated that the squirrel-cage induction generators used in constant-speed turbines can lead to voltage and rotor instability. During the fault, they accelerate because of the unbalance between mechanical power extracted from the wind and electrical power supplied to grid. When the voltage restores, they consume much reactive power, making it difficult the voltage restoration. When the voltage does not return quickly enough, the wind turbine continues to accelerate and consumes even higher amount of reactive power. This process may eventually lead to voltage and rotor speed instability.

The study has demonstrated that an additional active voltage/VAR support produced by a STATCOM can significantly improve the recovery of wind turbines from the fault since this device can make a faster restoration of the voltage, improving the stability limit conditions of the induction generators. The level of support that the STATCOM can provide depends on the rating of this device. This is due to the following facts: first, in general, the power electronics used in STATCOM is very sensitive to over currents caused during voltages drops. Hence, during fault conditions the STATCOM has limited capability to support the wind farm. Second, the normal design of a STATCOM does not include overload current capability. This means that the support that a STATCOM can provide during the post-fault condition is limited to its nominal current level. Some grid companies are presently prescribing requirements for the connection of wind farms in their grid, such as that the wind turbines should be able to withstand voltage drop of certain magnitudes and duration. The necessary rating of the STATCOM needs to be determined in order to meet those requirements. A STATCOM has been considered in the study as a possible means to improve the voltage and rotor-speed instability of induction generator.

6.2 CONCLUSION

It is found in the simulation results that under short circuit conditions the STATCOM can provide a major increase in the transient stability margin of power systems that integrate wind generation. The fault duration is increased from 20 ms with only fixed capacitors to 186 ms with the STATCOM. Results of the experiments performed in the lab set-up of 7.5 kW confirm the increased transient stability margin as a result of the use of a suitably rated STATCOM. In this paper we could not provide a quantitative transient margin, but the experimental results provide a clear qualitative verification of transient margin increase compared to the system without the STATCOM support. The STATCOM is an optimum candidate for providing ride through in wind farms equipped with asynchronous generators directly connected to the grid.

In addition, considering that wind turbines generators will trip when they detect a 30% voltage drop, it can be said that the STATCOM provides with a clear capability of handling ride through for an 80% voltage drop. The extent of this handling capability will depend on the power system configuration and rating of the device itself.. In the electrical system analyzed in this paper, in spite of the additional cost of power electronics converters and control, with the new grid codes, the achievement of ride through capability is of relevance. Therefore, investment in a STATCOM will certainly be justified in the scenario presented in this paper.

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[10].R. Mohan Mathur, Rajiv.K Varma, *"Thyristor based FACTS controllers for electrical transmission systems"*, Wiley IEEE press.

APENDIX – A

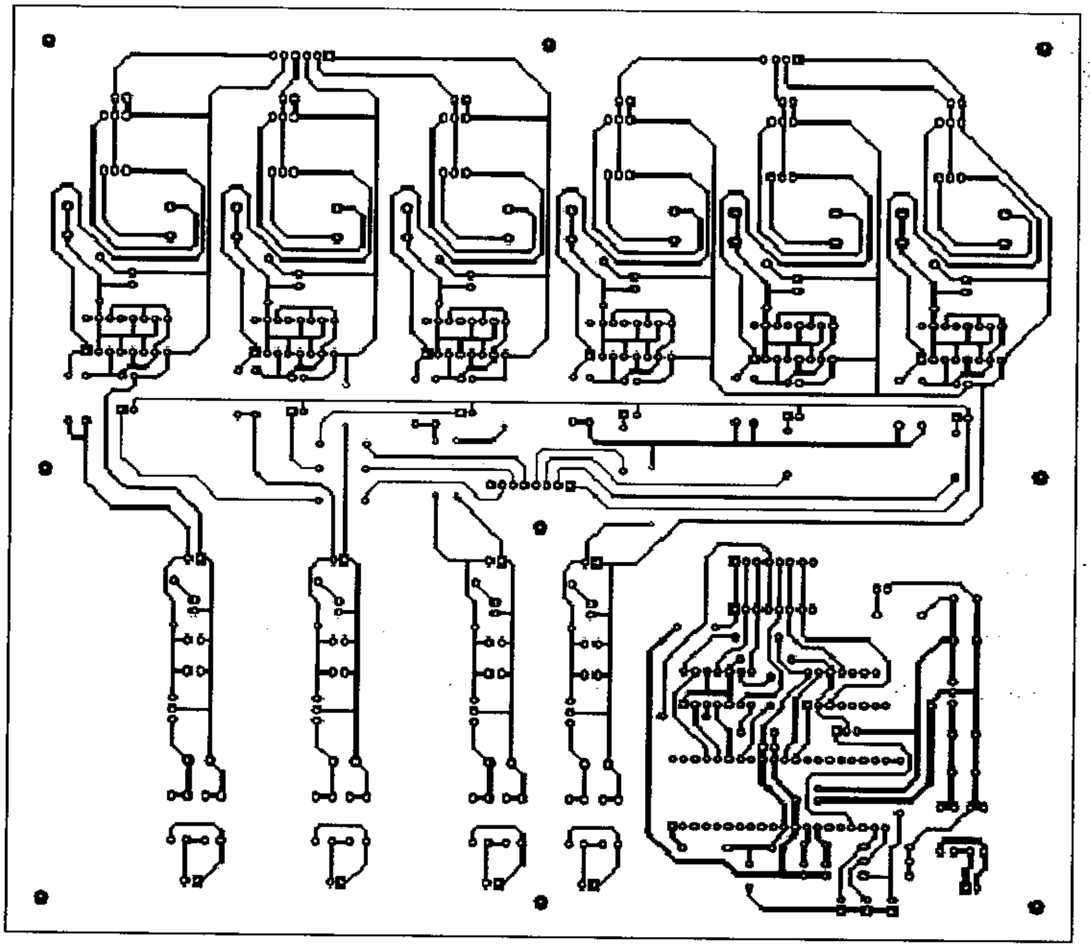
PROGRAM CODING FOR PWM INVERTER OPERATION:

```
#include<pic.h>

unsigned char count=0,d_cycle,set_f[5]={0};
unsigned int ADRES=0;

#define S1 RD6
#define S2 RB4
#define S3 RD7
#define S4 RB3
#define S5 RB2
#define S6 RB1

#define RELAY1 RB5
#define RELAY2 RB6
#define RELAY3 RB7

__CONFIG(WDTDIS & XT & PWRTEN & BOREN & LVPDIS);
void main()
{
        ADCON1=0X8E;
        TRISA=0X01;
        TRISB=0;
        TRISC=0;
        TRISD=0;

//      PORTA=0;
        PORTB=0;
        PORTC=0;
        PORTD=0;

        T1CON=0X01;         //timer1
        TMR1H=0XF2;
        TMR1L=0XFB;

//      TMR1H=0XFF;
//      TMR1L=0XC8;

        T2CON=0X04;         //pwm
        PR2=99;
        CCP1CON=0X0C;
        CCPR1L=d_cycle=50;
```

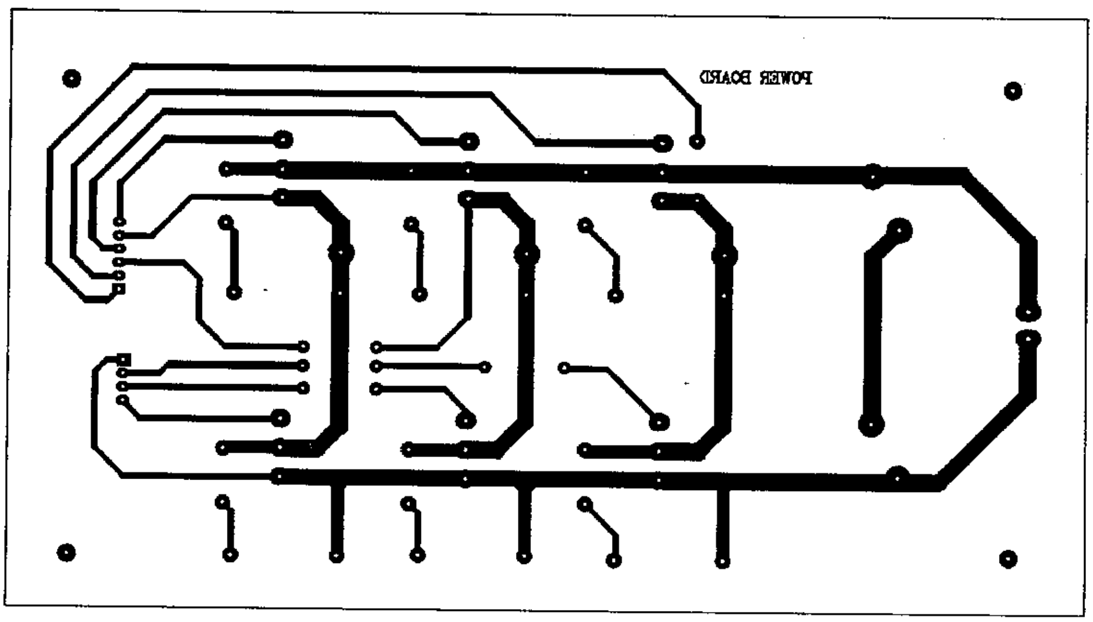
```
        S1=1;
        S6=1;

        GIE=PEIE=TMR1IE=1;

        while(1)
        {
                ADCON0=0X81;
                delay();
                ADGO=1;
                delay();
                while(ADGO);
                ADRES=ADRESH*256+ADRESL;

                ADRES=ADRES/2;


                if(ADRES<230)
                {
                        RELAY1=RELAY2=RELAY3=1;
                        d_cycle=230-ADRES;
                        if(d_cycle>100)
                                d_cycle=100;


                }
                else
                {
                        RELAY1=RELAY2=RELAY3=1;
                        d_cycle=0;
                }
                CCPR1L=d_cycle;

                delay1();
        }

}
delay()
{
        unsigned char i;
        for(i=0;i<=100;i++);
}
delay1()
{
        unsigned int i;
        for(i=0;i<50000;i++);
}


void interrupt isr()
```

```
{
        if(TMR1IF==1)
        {
                TMR1IF=0;
                TMR1H=0XF2;
                TMR1L=0XFB;
//              TMR1H=0XFF;
//              TMR1L=0XC8;

                count++;
                if(count==1)
                {
                        S2=1;
                        S6=0;
                }
                if(count==2)
                {
                        S1=0;
                        S3=1;
                }
                if(count==3)
                {
                        S2=0;
                        S4=1;
                }
                if(count==4)
                {
                        S3=0;
                        S5=1;
                }
                if(count==5)
                {
                        S6=1;
                        S4=0;
                }
                if(count==6)
                {
                        count=0;
                        S5=0;
                        S1=1;
                }
        }
}
```

PCB DESIGN



POWER BOARD



APENDIX – B

PIC16F87XA

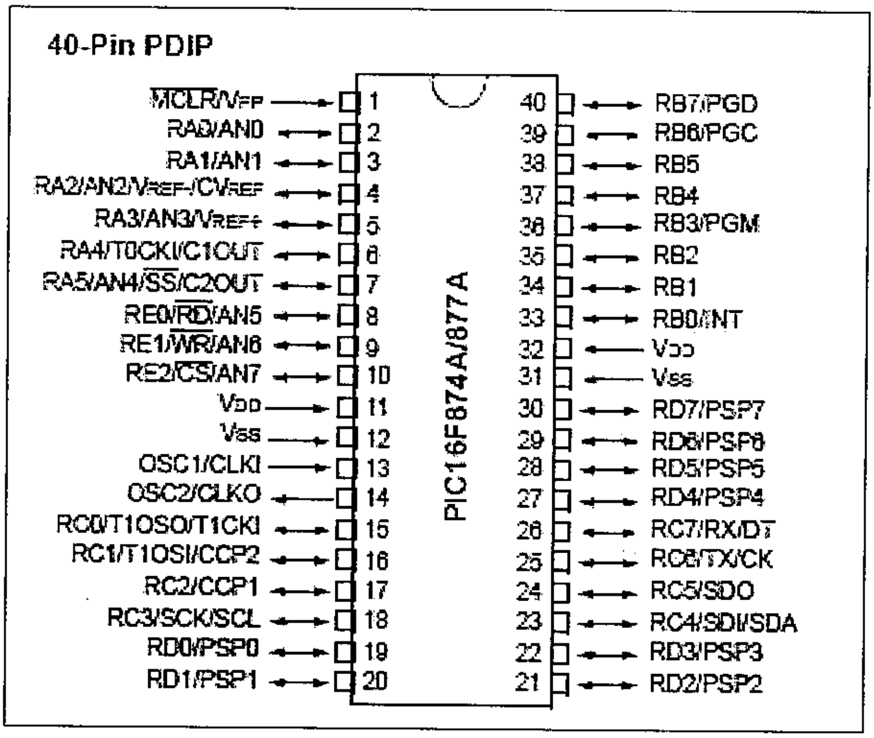


Fig .33 pin diagram of PIC16F87XA

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 other 28-pin or 40/44-pin PIC16CXXX and PIC16FXXX microcontrollers

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
- ☞ 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)

Analog Features:

- 10-bit, up to 8-channel Analog-to-Digital Converter (A/D)
- Brown-out Reset (BOR)
- Analog Comparator module with:
- Two analog comparators
- Programmable on-chip voltage reference (VREF) module
- Programmable input multiplexing from device inputs and internal voltage
  reference
- Comparator outputs are externally accessible

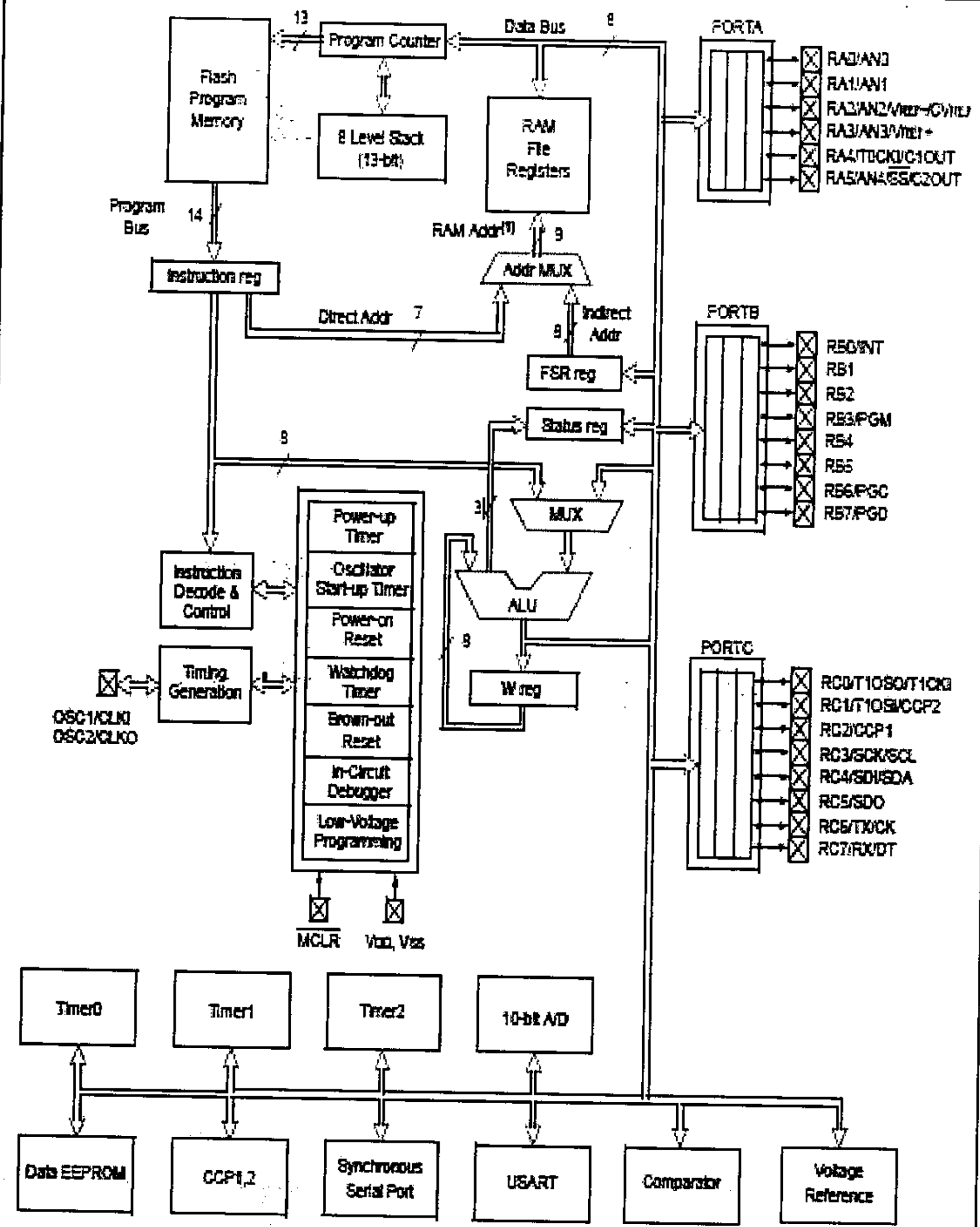
Special Microcontroller Features:

- 100,000 erase/write cycle Enhanced Flash program memory typical
- 1,000,000 erase/write cycle Data EEPROM
  memory typical

- Data EEPROM Retention > 40 years
- Self-reprogrammable under software control
- In-Circuit Serial Programming™ (ICSP™) via two pins
- Single-supply 5V In-Circuit Serial Programming
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code protection
- Power saving Sleep mode
- Selectable oscillator options

CMOS Technology:

- Low-power, high-speed Flash/EEPROM technology
- Fully static design
- Wide operating voltage range (2.0V to 5.5V)
- Commercial and Industrial temperature ranges
- Low power consumption



Device	Program Flash	Data Memory	Data EEPROM
PIC16F873A	4K words	192 Bytes	128 Bytes
PIC16F876A	8K words	368 Bytes	256 Bytes

Note 1: Higher order bits are from the Status register.

Fig . 34 PIC16F873A Block Diagram

COMPONENTS

IRF840B/IRFS840B

500V N-Channel MOSFET

General Description

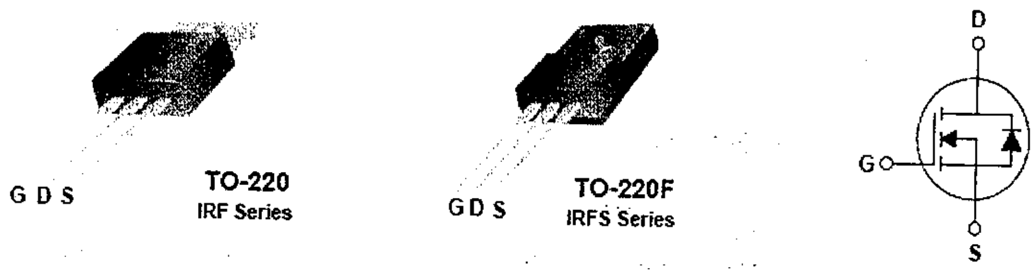


Fig . 35 500V N-Channel MOSFET

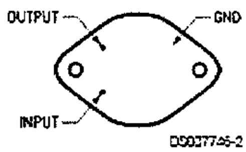
These N-Channel enhancement mode power field effect transistors are produced using Fairchild's proprietary, planar, DMOS technology. This advanced technology has been especially tailored to minimize on-state resistance, provide superior switching performance, and withstand high energy pulse in the avalanche and commutation mode. These devices are well suited for high efficiency switch mode power supplies, power factor correction and electronic lamp ballasts based on half bridge.

Features

- 8.0A, 500V, RDS(on) = 0.8O @VGS = 10 V
- Low gate charge (typical 41 nC)
- Low Crss (typical 35 pF)
- Fast switching
- 100% avalanche tested
- Improved dv/dt capability

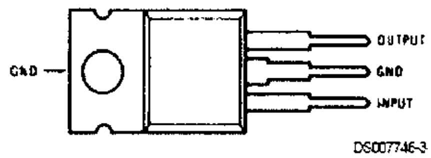
SERIES VOLTAGE REGULATORS

Metal Can Package
TO-3 (K)
Aluminum



Bottom View
Order Number LM7805CK,
LM7812CK or LM7815CK
See NS Package Number KC02A

Plastic Package
TO-220 (T)



Top View
Order Number LM7805CT,
LM7812CT or LM7815CT
See NS Package Number T03B

Fig . 36 series voltage regulators

The LM78XX series of three terminal regulators is available with several fixed output voltages making them useful in a wide range of applications. One of these is local on card regulation, eliminating the distribution problems associated with single point regulation. The voltages available allow these regulators to be used in logic systems, instrumentation, HiFi, and other solid state electronic equipment. Although designed primarily as fixed voltage regulators these devices can be used with external components to obtain adjustable voltages and currents. The LM78XX series is available in an aluminum TO-3 package which will allow over 1.0A load current if adequate heat sinking is provided. Current limiting is included to limit the peak output current to a safe value. Safe area protection for the output transistor is provided to limit internal power dissipation. If internal power dissipation becomes too high for the heat sinking provided, the thermal shutdown circuit takes over preventing the IC from overheating. Considerable effort was expanded to make the LM78XX series of regulators easy to use and minimize the number of external components. It is not necessary to bypass the output, although this does improve transient response. Input bypassing is needed only if the regulator is located far from the filter capacitor of the power supply. For output voltage other than 5V, 12V and 15V the LM117 series provides an output voltage range from 1.2V to 57V.

Features

- Output current in excess of 1A
- Internal thermal overload protection

- No external components required
- Output transistor safe area protection
- Internal short circuit current limit
- Available in the aluminum TO-3 package

Voltage Range

- LM7805C 5V
- LM7812C 12V
- LM7815C 15V

DUAL OPERATIONAL AMPLIFIER

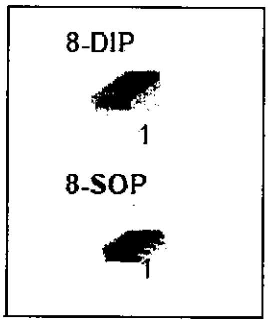


Fig . 37 Dual operational amplifier

Features

- Internally Frequency Compensated for Unity Gain
- Large DC Voltage Gain: 100dB
- Wide Power Supply Range:
- LM258/LM258A, LM358/LM358A: 3V~32V (or ±1.5V ~ 16V) LM2904 : 3V~26V
- Input Common Mode Voltage Range Includes Ground
- Large Output Voltage Swing: 0V DC to Vcc -1.5V DC
- Power Drain Suitable for Battery Operation.

Description

The LM2904,LM358/LM358A, LM258/LM258A consist of two independent, high gain, internally frequency compensated operational amplifiers which were designed specifically to operate from a single power supply over a wide range of voltage. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage. Application areas include transducer amplifier, DC gain blocks and all the conventional OP-AMP circuits which now can be easily implemented in single power supply systems.

PHOTOTRANSISTOR OPTOCOUPLERS

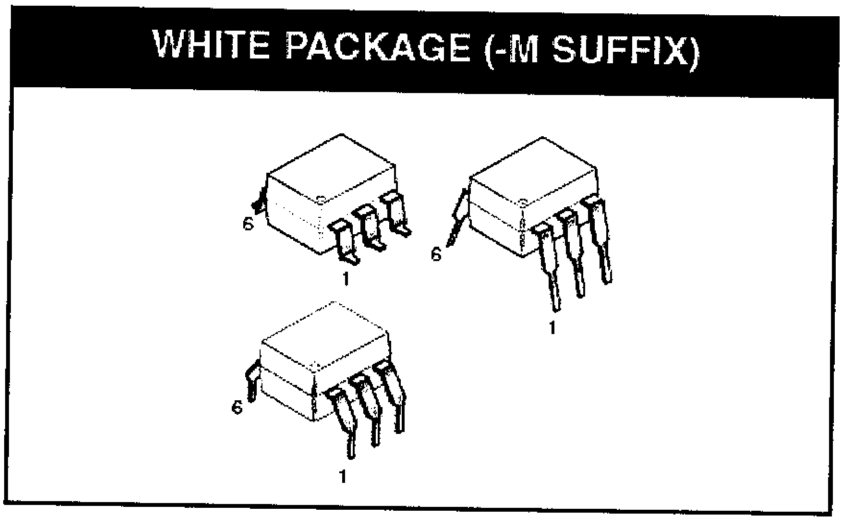


Fig . 38 Phototransistor optocouplers

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.

Applications

- Power supply regulators
- Digital logic inputs
- Microprocessor inputs

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