ANALYSIS AND SIMULATION OF AC MICRO GRID

Major Project Report

Submitted in Partial Fulfillment of the Requirements for the
Degree of

MASTER OF TECHNOLOGY

IN

ELECTRICAL ENGINEERING
(Electrical Power Systems)

By

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I, **Mr. Harin M. Desai**, (**Roll No:12MEEE06**), give undertaking that the Major Project entitled **"Analysis and Simulation Of AC Micro Grid"** submitted by me, towards the partial fulfillment of the requirement for the degree of Master of Technology in **Electrical Power Systems**, **Electrical Engineering**,under Institute of Technology, Nirma University, Ahmedabad is the original work carried out by me and I give assurance that no attempt of Plagiarism has been made. I understand that in the event of any similarity found subsequently with any published work or any dissertation work elsewhere; it will result in severe disciplinary action.

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This is to certify that the Major Project Report entitled **"Analysis and Simulation of AC Micro Grid"** submitted by **Mr.Harin M. Desai(12MEEE06)** towards the partial fulfillment of the requirements for degree in **Master of Technology (Electrical Engineering)** in the field of **Electrical Power Systems** of Nirma University is the record of work carried out by him under our supervision and guidance. The work submitted has in our opinion reached a level required for being accepted for examination. The results embodied in this major project work to the best of our knowledge have not been submitted to any other University or Institution for award of any degree or diploma.

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Abstract

In India the need to increase the use of renewable energy sources for sustainable energy development is must. Some areas in India are the biggest distribution player and facing a heavy short fall in conventional energy and high distribution and commercial losses. The alternative way to meet the short fall in energy demand is to adopt the Distributed generation with renewable energy technologies especially at the places which have the great potential for renewable energy sources. These sources are going to play important role in economic energy development compared to conventional energy sources if the deployment of micro-grid is done. It allows the the integration of renewable energy generation and provides the quality power in absence of micro-grid. For the use of this micro grid feature the utilization of distributed energy resources has been going on. Here the effort is in developing a small micro grid for a particular area which gets supplied with utilization of renewable energy sources as a separate generation. By integrating this entire small micro grid with distributed generation reliable and sustainable energy development is done. During disturbances, the generation and corresponding loads can separate from the distribution system to isolate the micro grids load from the disturbance (providing UPS services) without harming the transmission grids integrity. This ability to island generation and loads together has a potential to provide a higher local reliability than that provided by the power system as a whole.

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Chapter 1

Introduction

1.1 History

In the countries like India the power shortage problem is very high. And because of this reason many of the regions are still under developed. It is too difficult for the utility to feed this much of region due to heavy load burden.In rural areas like in small villages or towns the power availability is around 7 to 8 hours after that there is a big shortage of energy. Even at some areas there is no electrification at all.Basically the concept of Micro Grid is developed for this kind of areas.In this technology captive generation plants is developed to supply a defined area. Here the generation is made by the available sources over the place.[9]

1.2 Defination

A micro grid is an electrical system that includes multiple loads and distributed energy resources that can be operated in parallel with the broader utility grid or as an electrical island.

Basically micro grid is a system which is developed for supplying power to particular defined area with its own generation sources.

1.3 Types of Micro Grid

1 AC micro grid:-

This can work as the existing micro grids.

2 DC micro grid:-

Some standards must be define to work with this system.

3 Hybrid:-

It is the combination of both AC/DC grid operated to gather according to the nature of load.

1.4 Types of generation for micro grid

Normally any kind of source we can use for power generation but normally used energy forms are

1 Renewable energy (solar, wind).

2 Hydro power generation.

3 Fuel cell, Diesel generator set.

4 Combine heat and power.

5 Energy storage equipment like batteries (as a backup).

1.5 Advantages

1 Reliability of power.

2 Reduce transmission line losses as distance between generation and load is reduced.

3 Efficient use of energy (by providing some features),etc.

1.6 Modes of operation

There are two modes of operation[1]

1 Grid connected mode:-

Here the micro grid is connected with the utility grid on a common bus bar arrangement.

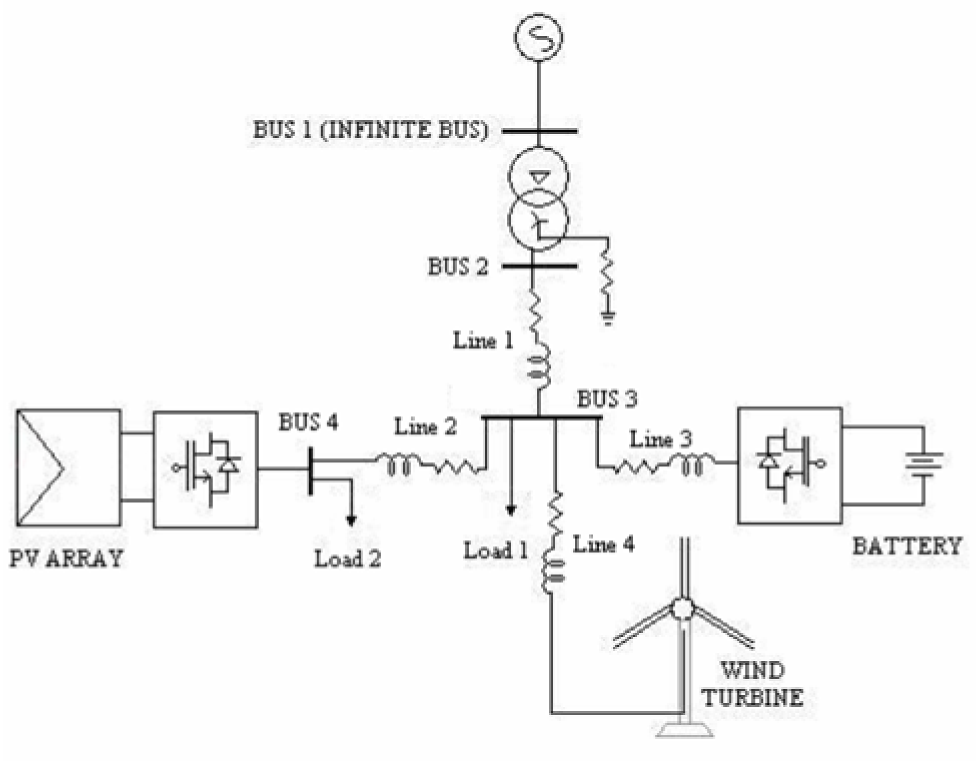

Figure 1.1: Micro grid connected with defined load and state grid overview

The figure shows this mode of operation very well. Here bus 3 is the load bus which is common bus where captive generations as well as utility supply both are inter-faced. In this mode full utilization of captive generation we can make.

2 Islanded mode:-

In this mode the defined micro grid is disconnected from the utility grid and works independently from the state grid.This mode of operation held in case of main supply failure or in case of supply quality mismatch from the standards.

Chapter 2

Litrature Survey

2.1 Distributed Real-Time Simulation Modeling and Analysis of a Micro-Grid with Renewable Energy Sources by Lin-Yu Lu, Jian-Hong H. Liu Student Member, IEEE and Chia-Chi Chu Member, IEEE

This paper is the experiment of a university load (3-phase) at china used on it. Here embedded systems are used to control both complex and normal system. Here hard ware in loop(HIL) is used which is one kind of simulation technique with which we can experiment the real time data. Hence the need to make a hardware to experiment the real time data is reduced so we can save expense used on it.This HIL works on the Opal-RT plate form which is flexible and affordable platform. Here the simulation work is first made up on mat lab Simulink and then it is converted to executable code with compiler and then it will be executed in OPEL-RT plate form. This plate form support interprocessor memory. Here central processing units are used for different operation like one unit can work regarding differential equations, governing system, dynamic behavior of generator etc. And other unit works for network equation to connect generation units with network like synchronizer. Here both the processors are interphase with real time data as stated above.

2.2 A Hybrid AC/DC Micro grid and Its Coordination Control by Xiong Liu, Student Member, IEEE, Peng Wang, Member, IEEE, and Poh Chiang Loh, Member, IEEE

This paper talks about hybrid configuration of Micro grid. Here both ac/dc loads are supplied separately and also with the help of convertors this both source interphase with each other as well as with the state grid. Here main focus is borrowed on micro grid co-ordination control system to tackle the problem of disturbance at load side as well as from generation side. Here some of the control strategies, mathematical modeling are define for the control. Basically the generating sources used here for micro grid are solar and wind. There two modes of operation1.Grid connected 2.Islanded mode.

2.3 Local Smart Micro-grids by Ali Moallem, Student Member, IEEE, Alireza Bakhshai, Senior Member, IEEE, Praveen Jain, Fellow, IEEE

This paper introduces a centralized hierarchical management scheme which controls the multi micro-grid systems with advanced functionalities embedded in a smart grid. Here each micro grid is referred to as a smart local micro grid. Here some of the features are given which make a micro grid to the smart micro grid is

Dynamic islanding

Power quality

Self-healing etc.

This all features main focus is to give uninterrupted and quality power to the load. Here hierarchical management scheme show different level of security. Level 0 and level 1 these levels defined the authorities to the local smart micro grids to operate according to the conditions. There are basically two modes of operation of this system: 1.grid connected 2.islanded (normally it is operating in grid connected mode). Here the whole generated power is given to the utility and all area operations are handled by it. Different control schemes are defined for both modes of operations according to the standard defined by the author.

2.4 Operation and Control of Wind/Fuel Cell Based Hybrid Micro grid in Grid Connected Mode by Vigneysh T, N Kumarappan, Senior Member, IEEE, and Arulraj Department of Electrical Engineering

This paper talks about the hybrid system of AC/DC grid combination. AC power sources and loads are connected to the AC grid whereas DC power sources and loads are connected to the DC grid and both the grids are connected together by a bidirectional converter. Two modes of operation are there as stated in above ref. here normally ac grid is connected to the utility here the source of generation is wind. Dc grid is connecting to the utility when power surplus or shortage is there as it requires the converting operations. Here two generating sources are used fuel cells and wind turbine. Fuel cell output-50KW where wind turbine output-20KW. Here the control scheme (with PQ control) is developed for smooth power exchange between AC/DC. For this controls PI controller is used as a processing unit.

2.5 Smart AC Grid Integrating Dispersed Small Hydropower Sources by R. Magureanu, M. Albu, V. Bostan, A.M. Dumitrescu, G. Dimu, F. Popa and M. Rotaru University Politehnica, Bucharest, Romania

In this paper micro grid is design with the hydro power generator as a main source. The system is developed with two front end convertors, one connected at the generator side and other at grid side. Both are bi-directional convertors. Generator side convertor is used to maintain the frequency to 50hz AC/DC/AC and grid side is used as power factor controller, active harmonic filter, also maintain dc link voltage for that it works as current control rectifier. The hydro is stated as the cleanest source of power generation.

2.6 Electrical India Magazine

This magazine has the article regarding the smart micro grid technology; here they have stated the requirements of this kind of technologies especially stated for Maharashtra rural area villages as the power shortage and power quality is the big issue overt here. The article talks about the micro grid techniques with the energy sources like wind and solar at first. Because at Maharashtra the availability of sun light and availability of wind flow is an ample amount. Also some the state grid burden issues and advantages of this kind of techniques over it are stated. And hence this article is the initiative of my project.

2.7 DC Micro Grid major project report by Ashish P. shah

Its a thesis regarding the same technology. Here the main focus is on DC grid. The generating source defined here is solar. And with this DC output is develop. Here this DC power is used for electrification of the rural village by assuming the whole load as DC. This theory is developed by focusing the DC system advantages over AC.

2.8 The book of power electronics, circuit, devices and application by Muhammad h. Rashid

This book is use full for convertor topology studies. The type of convertors like

1 Buck convertor.

2 Boost convertor.

3 Buck-boost convertor all details are given in this book very well which is of used in this project.

2.9 The book of Power Electronics Essentials Applications by L.Umanand

The book is useful for Boost converter studies and the parameter calculations are done by the equations given in this book.

2.10 The book of Power Electronics by Dr.P.S.Bimbhra

The book is used for the compelete idea of inverter studies. Here all the calculations of inverter are done with the help of this book.

Chapter 3

Fundamental Concept of Micro Grid

3.1 Objective of the project

To make a Distributed generation system for electrification of Rural area (where power availability is less and quality is low) to improve the Reliability and Quality of power. Also to promote the renewable sources with this.

3.2 Methodology

The method is basically called as Distributed Power Generation system. This method is applied only for a particular defind area. Here the energy source used is solar. Generation output voltage is about 230V DC (right now assuming for signal phase) (in case of wind it will be converted AC/DC/AC and directly fed to the load).[2] This solar DC power is than boosted with DC-DC boost converter for required DC output and then converted to AC by an inverter circuitry (here three phase bridge inverter circuit is used) and transferred to the load as well as to state grid .This whole group of modules creates a captive plant for the desire power generation for supplying a defined load. Afterwards this micro grid will be interfaced with the state grid network with the help of controllers to manage import or export of power between state grid and micro grid.In normal operational condition the micro grid network is connected with the state grid network as with this maximum utilization of power from solar is done. Here two modules are planned for protection as well as for smooth operation,

Synchronizer: - This module can synchronize the captive system generation with the state grid.

Operation Control Unit: - To manage the operating conditions weather to operate in grid connected mode or islanded mode.

3.3 Block Diagram

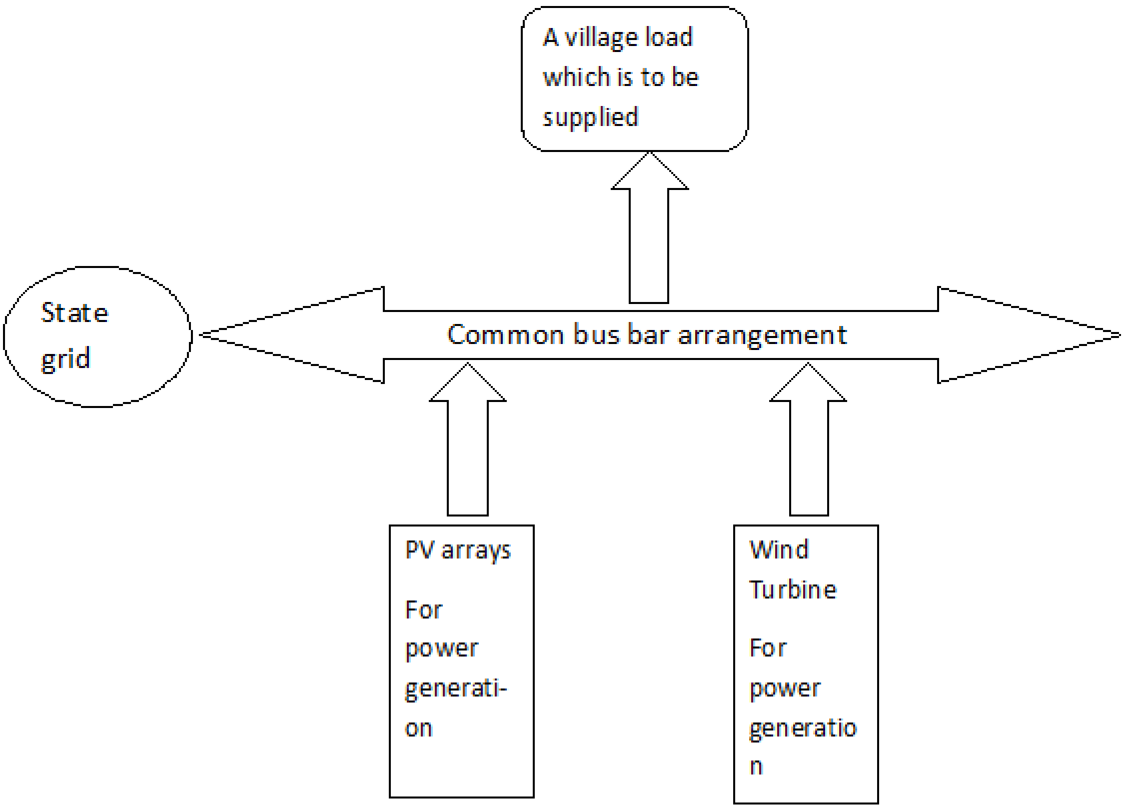

Figure 3.1: Overall block diagram of the system

3.4 Solar Cell and its mathamatical modeling

PV cell is basically a semiconductor diode. This semiconductor diode has got a P-N junction which is exposed to light. When it gets illuminated by sunlight it generates electric power. PV cell are made of various semiconductor materials. But mono-crystalline silicon and poly-crystalline silicon are mainly used for commercial purpose.

3.4.1 Equivelent Circuit of solar cell

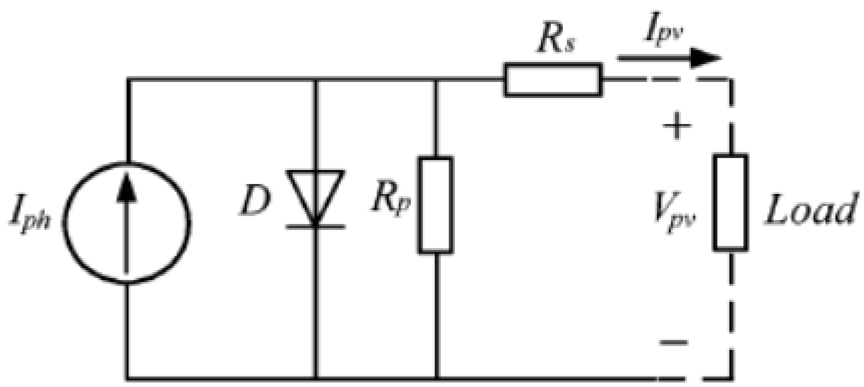

Figure 3.2: Equivelent circuit of solar cell

3.4.2 Solar cell Characteristic

The characteristics are as shown in figure 3.3

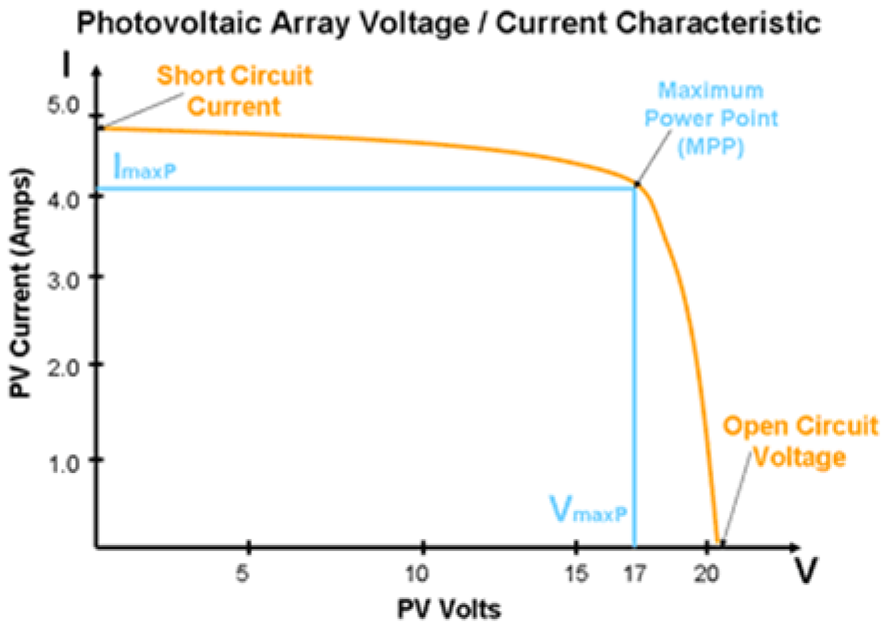

Figure 3.3: Solar cell characteristic

3.4.3 The current output of the PV panel is modeled by the following Three equations:-

$I_p v = \eta_p I_p h - \eta_p I_{sat} * [\exp(\frac{q}{A*k*T})(\frac{V_p v}{\eta_s + I_p v * R_s}) - 1]$.........(1)

$I_p h = (I_{sso} + k_i(T - T_r)) * \frac{S}{1000}$...(2)

$I_{sat} = I_{rr}(\frac{T}{T_r})^3 exp((\frac{qE_{gap}}{kA}).(\frac{1}{T_r} - \frac{1}{T}))$............(3)

Table I: Parameters for photovoltaic panel

Symbol	Description	Value
V_{oc}	Rated open circuit voltage	403V
I_{ph}	Photocurrent	
I_{sat}	Module reverse saturation current	
q	electron charge	$1.602 * 10^{-19}C$
A	Ideality factor	1.50
k	Boltzman constant	$1.38 * 10^{-}23J/K$
R_s	series resistance of a PV cell	
R_p	parallal resistance of a PV cell	
I_{sso}	short circuit current	3.27A
k_i	SC current tempature coefficient	$1.7e^{-3}$
T_r	Referance Temprature	301.18
I_{rr}	reverce saturation current at T_r	$2.0793e^{-6}A$
E_{gap}	energy of the band gap for silicon	1.1eV
η_p	number of cells in parallal	40
η_s	number of cells in series	900
S	solar radiation level	$0 - 1000w/m^2$
T	surface temprature of the PV	350K

Parameter's Detail:- The Details are as per table I.Here the values are just taken for reference.

3.5 Wind Turbine Induction Generator(WTG)

Modeling of Wind Turbine Generator Power output from a WTG is determined by the equation given below,

$P_m = 0.5\rho A C_p(\beta, \lambda) V_w^3$

where

ρ = Air density,

A = Rotor swept area,in m^2

V_w = Wind speed,in m/s^2*and*

$C_p(\lambda, \beta)$ = Power co-efficient,

which is the function of Tip speed ratio λ and pitch angle β.

3.6 DC/DC Boost Converter

Figure depicts a step-up/boost converter. It consists of DC input voltage source V_s. Boost inductor L, Controlled switch S (Mosfet), diode D, filter capacitor C, and load resistance R.

When the switch S is in the on state, the current in the inductor increases linearly and the diode D is off at that time. When the switch S is turned off, the energy stored in the inductor is released through the diode to the output RC circuit.As shown in the figure the current supplied to the output RC circuit is discontinuous. Thus, a larger filter capacitor is required in comparison to that in the boost-derived converters to limit the output voltage ripple. The filter capacitor must provide the output DC current to the load when the diode D is off.

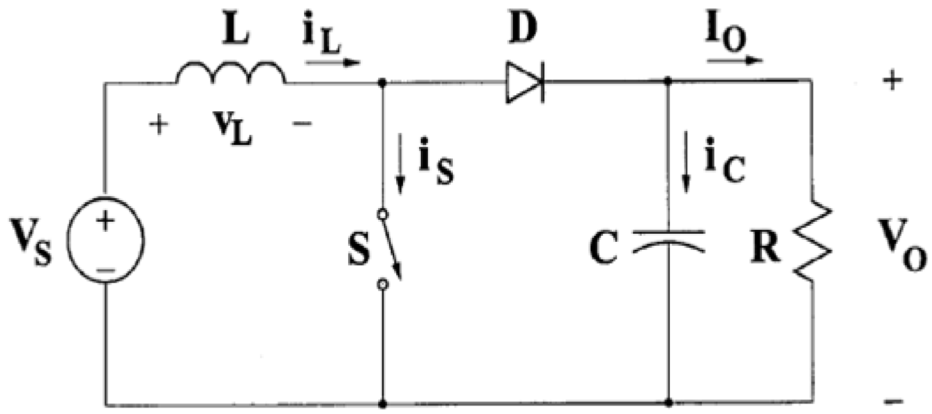

Figure 3.4: Boost converter circuit

The calculations of different parameters are done as per the equations given below.[10]

By referring the figure

$$(V_i)DT_s + (V_i - V_0)(1 - D)T_s = 0.........(1)$$

By simplifying equation 1, one obtains

$$V_0 = \frac{V_i}{1-D}............(2)$$

To obtain input output current relationship,

$$V_i I_m = V_0 I_0................(3)$$

Here the value of inductor L is calculated on the basis of the amount of current ripple.Δi_L that the designer would like to allow for a given application.The switching frequency f_s is a design choice. From this $T_s = \frac{1}{f_s}$ is obtain.Δi_L is also a design choice.Common choice of Δi_L is 10% of I_{in}.The output power P_0 is known from the converter specification. From the knowledge of P_0 and V_0, I_0 is calculated .I_{in} can be estimated or measured from the voltage source. Here it is solar photovoltaic module or this can be estimated as per the given load. The only unknown L can then be calculated as,

$$L = V_i \frac{D}{\Delta i_L f_s} \text{.............(4)}$$

To regulate Vo with variation in V_{in} , the value of D should be varied.

Thus if V_{imax} is the maximum input voltage swing then D_{min} will be the corresponding minimum duty cycle to obtain a specified V_o.

If V_{imin} is the minimum input voltage swing, then D_{max} will be the corresponding maximum duty cycle to obtain the specified V_o.

Thus for a regulated V_o.

$$V_0 = \frac{V_{imax}}{1-D_{min}} = \frac{V_{imin}}{1-D_{max}} \text{..............(5)}$$

Here,

V_0 = required output voltage from the boost converter.

V_{imax} V_{imin} = the minimum and maximum input voltage variations Of the DC voltage source (solar module).

D=the duty ratio required for switching.

Hence

$$D_{min} = 1 - (\frac{V_{imax}}{V_{imin}})(1 - D_{max}) \text{...........(6)}$$

The inductor value should be calculated with a appropriate duty ratio for a particular input voltage swing. Thus,

$$L = \frac{V_{imax} D_{min}}{\Delta i_L f_s} \text{....................(7)}$$

For capacitor value calculation,

we know that,

$$\Delta Q = C \Delta V_0 = I_0 D T_s = \frac{I_0 D}{f_s} \text{...............(8)}$$

$$C = \frac{I_0 D}{\Delta V_0 f_s} \text{.............(9)}$$

3.6.1 Modifications

The calculated parameter value from these boost converter equations gives the minimum limits.Parameter value should not be less than these calculated values, it may be equal or greater, we can vary according to the load.When this boost converter with the calculated values connect to the load it generates tremendously high ripples in the system. Which needs to be reduce at any how to maintain the quality of output power and hence to reduce these distortions and to get the expected results two techniques we can adopt:-

1 PWM technique with PI controller tuning.

2 By adjusting the capacitor, inductor and duty ratio as per the requirements.

PI controllers has some limitations above certain voltage levels as it cannot balance the ripples and hence we can use the second technique with which we can easily maintain or control the ripples for the desire output.
Here by increasing the value of L C we can get the desired output. For this system high increase in capacitor value and small increase in inductor value is required. The improved boost converter output wave forms are as shown in fig 4.8

3.7 Inverter

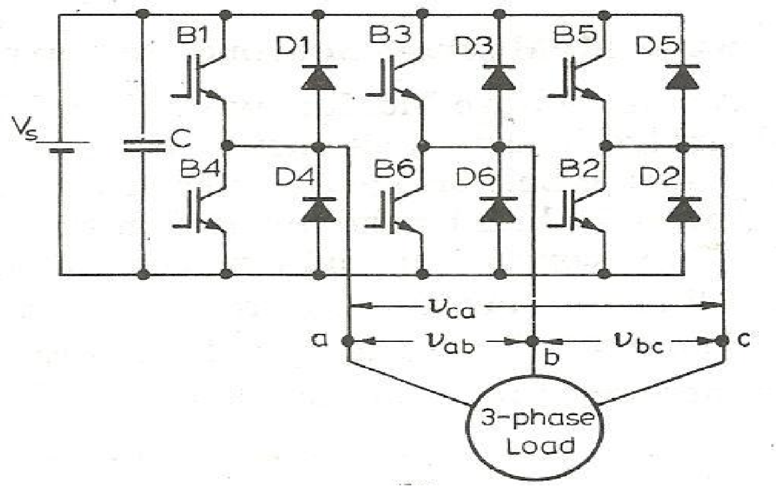

Figure 3.5: Three phase bridge inverter using IGBT

A basic three phase inverter is a six step bridge inverter. It uses a minimum of six thyristors. In inverter terminology, a step is defined as a change in the firing from one thyristor to the next thyristor in proper sequence.For one cycle of 360°, each step would be of 60° interval for a six-step inverter.This means thyristors would be gated at regular intervals of 60° in proper sequence so that a 3-phase AC voltage is synthesized at the output terminal of a six-step inverter.Fig 3.5 shows the power circuit diagram of three phase bridge inverter using six thyristors. For three phase circuit IGBTs are used in place of thyristors.The three phase load is assumed to be star connected. In fig 3.5 the thyristors are numbered in the sequence in which they are triggered to obtain voltages V_{AB},V_{BC},V_{CA} at the output terminals A,B,C which are further used here as phase R,Y,B as per indian standards.

The Output V_{rms} voltage is measured by the equation:-

$V_{rms} = \frac{4V_s * \cos\frac{\pi}{6}}{\sqrt{2}\pi}$

Thyristor conduction patterns used is Sinusoidal pulse width modulation (SPWM).[10]

3.7.1 Sinusoidal Pulse width modulation (SPWM) technique

In this method several pulses per half cycle are used. In SPWM, the pulse width is sinusoidal function of the angular position of the pulse in a cycle as shown in fig.3.6.

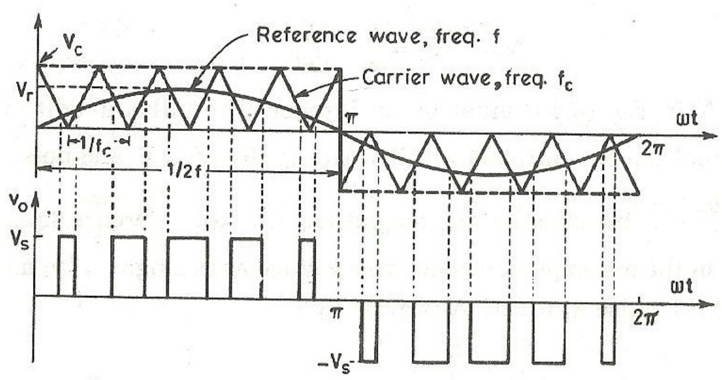

Figure 3.6: Graphical representation of SPWM technique

In this technique a high frequency triangular carrier wave v_c is compared with a sinusoidal reference wave v_r of the desire frequency. The desire frequency is set as per the switching device you have used for inverter. The interaction of v_c and v_r waves determines the switching instants and commutation of the modulated pulse. In fig 3.6. V_c is the peak value of triangular carrier wave and V_r that of the reference, or modulating, signal.
The carrier and reference waves are mixed in a comparator as shown in the fig.3.7. block dia.

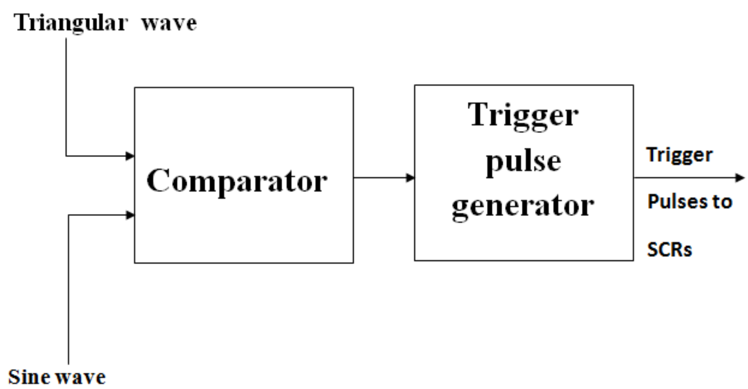

Figure 3.7: Block Diagram of SPWM

Here whenever sinusoidal wave has magnitude higher than the carrier wave the comparator gives output high, or else it will be low.
The following is the equation for calculating no.of pulses per half cycle:
$N = \frac{f_c}{2f}$

If zero of the triangle wave coincides with zero of the reference wave than there are $(N-1)$ pulses per half cycle. As shown in fig 3.8 the equation for no of pulses in this case is $((\frac{f_c}{2f} - 1))$.

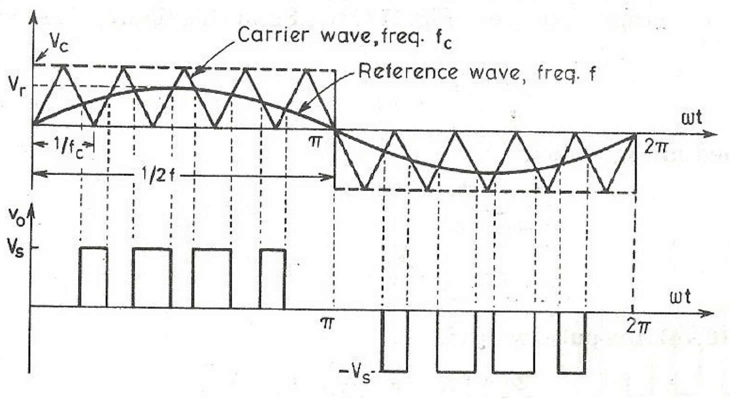

Figure 3.8: Graphical representation of SPWM if sin and triangle coincide at zero

3.7.2 Modulation Index

The ratio of $\frac{V_r}{V_c}$ is known as modulation index (MI). It can control the magnitude of the fundamental component of the output voltage as well as controls the harmonic contents of the output voltage waveforms.

Harmonic analysis of the technique

1 For MI less than one, the higher order harmonics are create as by increasing the number the number of pulses per half cycle, the order of dominant harmonic frequency can be raised which can then be filtered out easily and hence we can say with order of harmonics increase the filtering requirements are minimized.

2 For MI greater than one, lower order harmonics are create, also pulse width is no longer a sinusoidal function.

3.7.3 Advantages

1 Power loss in the switching devices is very low .When a switch is off there is practically no current, and when it is on there is almost no voltage drop across the switch.

2 Power loss, being the product of voltage and current, is thus in both cases close to zero.PWM also works well with digital controls which is because of their on/off nature.

3 Can easily set the needed duty cycle.

4 Cheap to make.

5 Low power consumption.

6 Can utilize very high frequency.

7 Energy efficient when use to convert voltages.

8 High power handling capability.

9 Efficiency up to 90%.

The OutPut waveforms of the SPWM inverter are as shown in fig 4.12 to fig 4.20

By observing the system it is found that by using SPWM technique still the desired smooth wave form is not achieved, some of the distortion in voltage and current wave forms are there which are called noteches of switching harmonics. And hence it needs to be filtered out. The solution for doing this is PI controller[6]. The is known as proportional integral control technique.

3.7.4 PI controller

It is known as Proportional Integral control scheme.It will control the output voltage with the specified limit defined in the form of proportional gain K_p and integral gain K_i. PI controller will eliminate forced oscillations and steady state error.

The PI controller integrates the error between the feedback and reference current to generate a variable voltage which is then fed into the pulse-width modulator to produce the switching gate signal for the converter.

PI controller has some advantages as given below:

1 Constant switching frequency;

2 Closed-loop control;

3 Good dynamic regulation;

4 Low acoustic noise.

3.7.5 Block diagram of PI controller

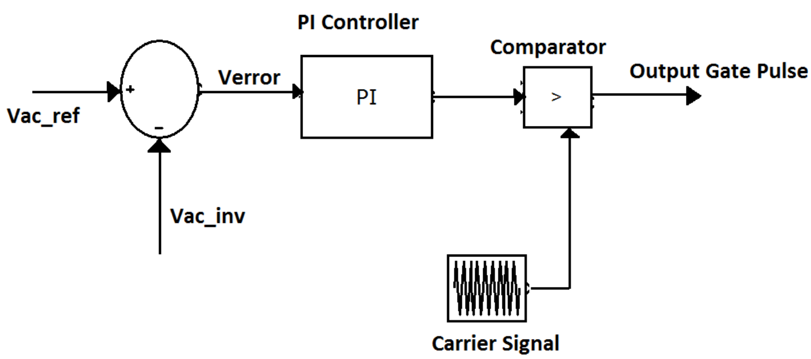

Figure 3.9: Block diagram of PI controller

The block dia. is as shown in fig.3.9. Here three phase 180° degree conduction mode inverter is taken as a reference.The reference three phase signal will be compared with the feed back signal and accordingly error per phase will be generated.This error will get minimised with the help of PI controller unit (all three phases need idividual PI controller unit).This reduced error signal is compared with the carrier signal to generate pulses which will be given to the IGBTs of the inverter circuitry for required controlled output.
The improved wave forms after inserting PI controller is as shown in fig 4.21 to fir 4.29

3.8 Distribution State Grid Model

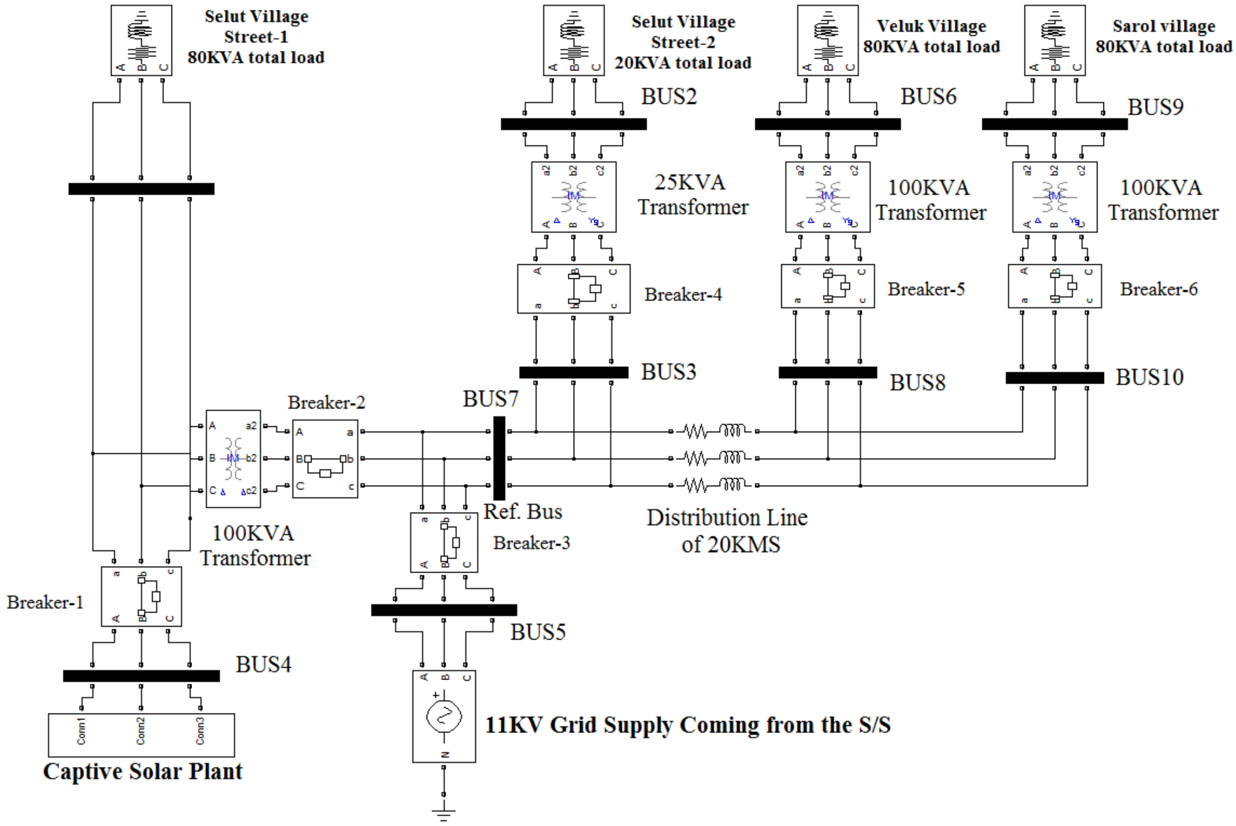

Figure 3.10: Distribution State Grid Model

3.8.1 Definition

It is basically a network of synchronized power providers and consumers connected by distribution lines and operated by one or more control centers.

3.8.2 The overall structure of State Grid Model

The overall structure of State Grid Model is shown in the figure 3.9. It is the distribution network model. Total load area design is 260KVA which is assumed to supply

with two units G1 and G2.
Here G1 is the captive solar plant and G2 is the state grid supply coming from the GETCO substation. The total rated load of the whole network is taken from the DGVCL of rander rural subdivision, Surat. The feeder is of 11KV masma feeder.
The total load distribution details are as shown below:-
Total 3 villages are considered here,
Selut with two transformers of 100KVA and 25KVA.
Veluk with single transformer of 100KVA.
Sarol with single transformer of 100KVA.
80% of each transformer is the load of that village.
As shown in figure3.10 the network has 2 generator buses and 5 load buses and 1 slack bus.
The generator buses(PV) are: - BUS4 and BUS5
The load buses(PQ) are: - BUS1, BUS2, BUS3, BUS6, BUS8, BUS9, BUS10
And slack bus: - BUS7
The whole network (Generator units and load) is connected with 3-phase distributed line.
The type of line: - Distributed overhead line,
Distance: - 20KM
Type of conductor: - ACSR (panther)
The network has four different load areas connected with each other through switching devices.The load areas are defined as shown above out of which first 80KVA load is design to supply with the captive plant which is of 80KVA rated capacity. The captive plant and the load connected with it this whole system is known as a micro grid.
Two units G1, G2 are the power supply units of the whole network out of which G2 is supplying to the network and G1 is the captive plant which is going to get connected in the network. This means 260KVA load is supplied with G2 from the initials and the G1 captive plant (solar based) is get connected or interphase next. In normal case the the micro defined load is connected with state grid network with other load areas and captive plant supplies to the state grid with this maximum utilization of

power is possible.
The actual idea of this captive plant interphase is to improve the reliability of the defined 80KVA load out of the total load.In any case if the other power supply get turned off or fluctuations are observed in the state grid network G1 and the 80KVA defined load is get separated and operate independently as a micro grid network until the network get reinstall. In normal case the captive plant G1 has to connect to the modeled grid network as the whole plant is interconnected. And hence for this reason two modules have to be constructed for the plant to get interphase with the network.
The techniques are:-

1 Synchronizer.

2 Operation control unit.

3.9 Design of Synchronizer:-

It is the automated control unit which can make synchronization operation to connect the captive plant with the rest of the grid.

3.9.1 Basics:

To connect any of the generation device with the rest of the live grid synchronization is the must process to follow. To maintain the stability of the whole system.
When a generator is to be paralleled with the Supply Utility Grid the voltages on either side of the paralleling circuit breaker must be matched (synchronized).
To synchronize the generator set and the Grid voltages,four different Parameters of the generator set voltage across the open paralleling circuit breaker must be controlled:-

1 Voltage magnitudes

2 Frequency of the voltages

3 Phase angle between the voltages

4 Phase sequence

The ideal conditions for the operation are:

1 Voltage magnitude

For safe paralleling, a maximum voltage magnitude difference of 0.5 percent is recommended.

2 Frequency

For safe paralleling, a maximum frequency difference of 0.5Hz is recommended.

3 Phase angel

For safe paralleling, a maximum phase angle difference of 10 degrees is recommended.

4 Phase sequence

Here out of all phase angel control is very much important aspect as it can maintain power transfer of the system.

3.9.2 Process:-

As shown in the figure 3.10. the synchronization is done between two buses BUS4 and BUS1. Here BUS4 is PV bus and BUS1 is PQ bus. As stated above for synchronization, phase angle, voltage, frequency and phase sequence have to maintain. Frequency voltage are measured and maintained by the system control device,Phase sequenece can be directly measured.The main concern of the synchronizer is to measure and maintain the phase angel to connect the captive plant to the system.The following are the equations with which we can measure and control the phase angel of the system.

Phase angle calculation :-

The whole calculations are done according to BUS1

The real power transfer formula:-

$P = \frac{V_1 V_2 \sin\delta}{X_L}$

Here,

P= Real power of the network

X=Reactance of the line

V1, V2=Voltages of the buses BUS4 and BUS1

δ = Angle difference between two buses.

Here the values of P, V1 and V2 are directly measured from the network the value of reactance X is not possible to measure directly

For Reactance calculation X:-

Z of the system is measured by the equation

$Z = \frac{V}{I}$

Here R and L values are assumed for the ideal condition

And hence

By, $Z^2 = R^2 + X_l^2$

We get, $X_L = \sqrt{Z^2 - R^2}$

Whenever current or voltage of the line changes Z changes but R remains constant so that with the above equation X will get continuously measured.
And hence,

$\delta = \arcsin \frac{PX}{V_1 V_2}$

With this equation we can get the phase angle of the line, the ideal value of δ should be $30°$.
Maximum allowed value of delta is $90°$.So normally δ should be within $30°$ to $90°$ as above$90°$ the system is out of phase and below $30°$ it power transfer is low.

3.9.3 Flowchart

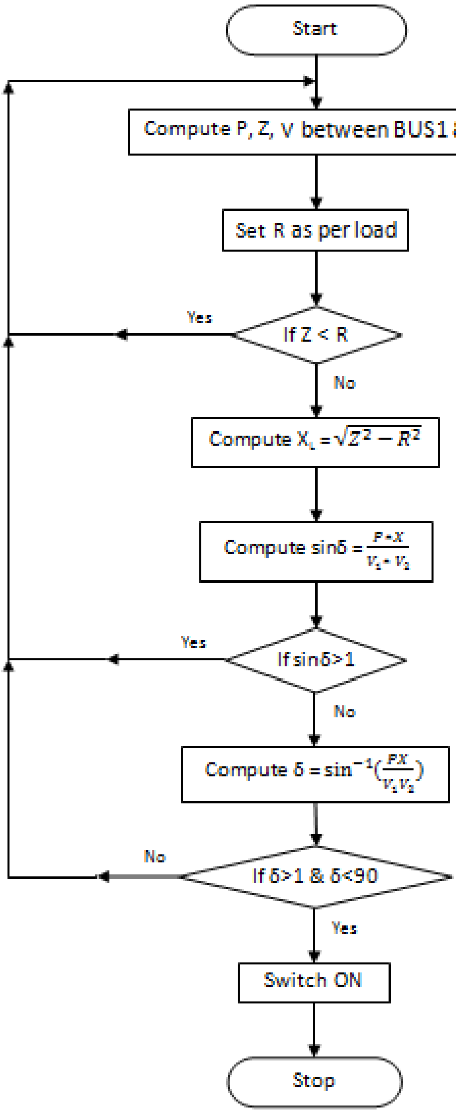

Figure 3.11: Process dia. of synchroniser

3.10 Operation Control Unit

This unit is the heart of the micro grid operation. It can be known as protection device too it can work with two modes of operation,

1 Grid connected mode

2 Islanded mode

This unit is design to maintain reliability of power for define load.
In grid connected mode the whole system micro grid and rest of the network is interconnected and in islanded mode the micro grid will get separated from the network.

3.10.1 Basics of Operation

This unit will sense the value of voltage, current and frequency and if disturbance any disturbance can measure like fluctuation in voltage ,current and frequency than it will operate and isolate the micro grid from the rest and when fluctuation are over or within the range the restoration will occur. The operation unit work by switching between buses BUS4 and BUS7.
Here voltage and current are directly measured from the circuit network but f is measured according to equation.
$X_L = 2\Pi f L$
Here X is measured from the equation
$X_L = \sqrt{Z^2 - R^2}$
And hence $f = \sqrt{\frac{Z^2 - R^2}{2}}$
Here the frequecy calculations have some limitations as normaly 1%(0.5) variation in frequency is allowed but with this calculations very less variations is allowed so it will be the future scope.

3.10.2 Flow Chart

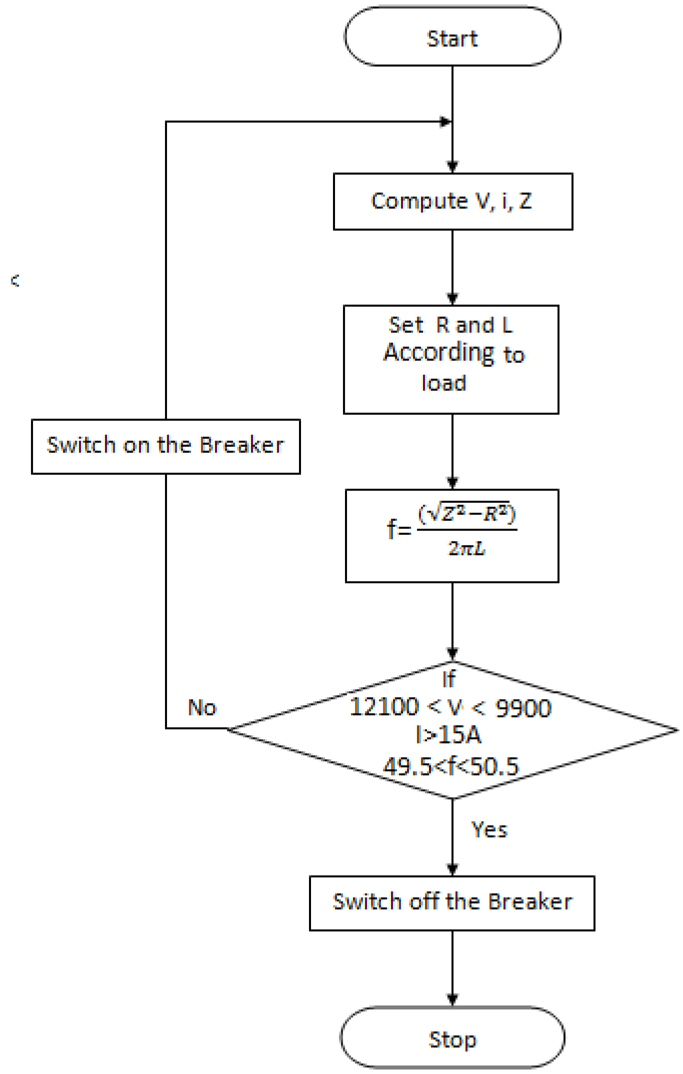

Figure 3.12: Process dia. of operation control

Chapter 4

MATLAB simulations and results

4.1 Solar cell simulation

4.1.1 Simulation Circuitary

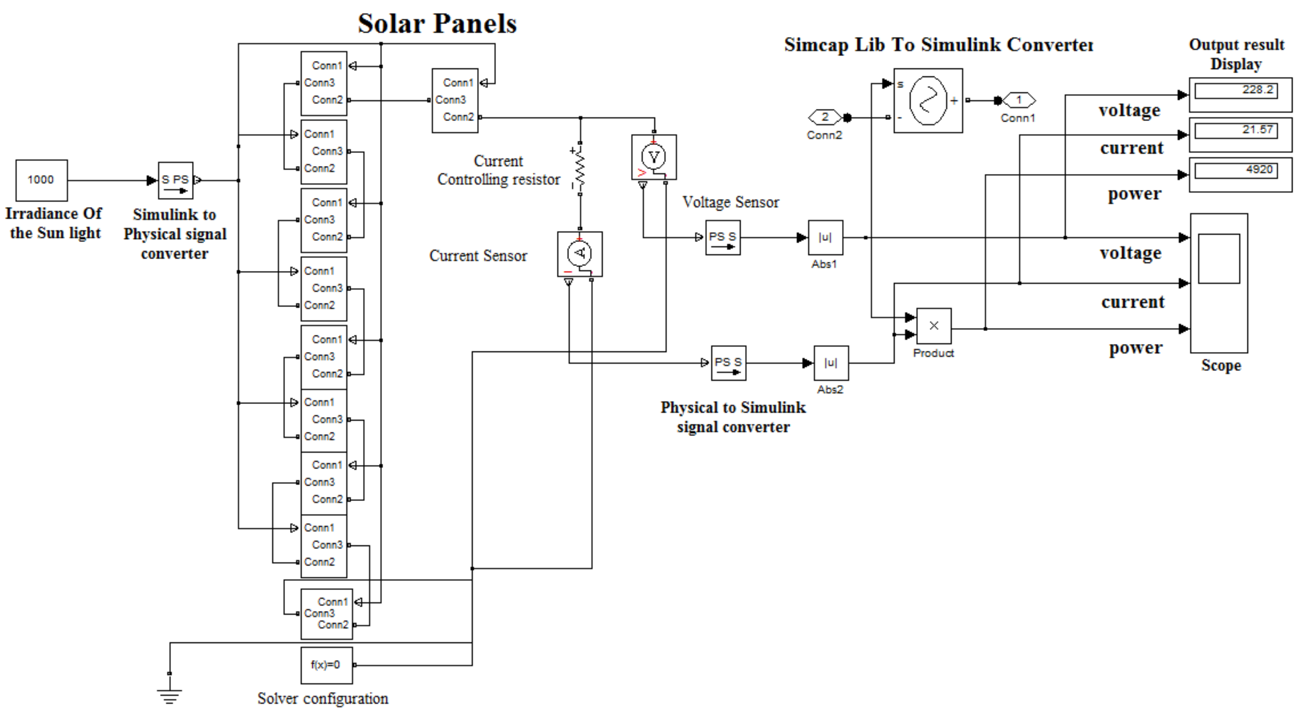

Figure 4.1: Solarcell simulation circuit

The circuit shows the solar cell simulation for 230 V DC output. Here the details of solar cell and its ratings are as per table I.The solar radiation is right now assume constant, sps(simulation to physical signal) and psp (physical to simulation signal) convertors are used. Here solar cell works with the physical signal and hence simulation irradience signal are converted to physical signal and provided to solar penal and output of cell will be again converted to simulink signal to show the result. Abs is the block to show the absolute values of the signal. Voltage and Current sensors are used accordingly to mesure output voltage and current of the cell.The resistor used is to limit the current flowing through the circuit,it is of small value.The solver configuration is used for proper grounding of the system The power generation output with this simulation circuit is around 4.92KW. Here it is assumed right now that the power factor of the system is 0.9. The target is to reach upto 80KVA three phase load.

Table I: Solar cell parameter data

Parameters	Value
Total no of cells	756
Total no of cells per modules	72 cells ,90 cells in last two
Total no of modules	10
Open circuit voltage per cell	0.6V
Short circuit current per cell	21.73A
Irradiance used for measurement	$1000w/m^2$
Quality factor	1.5
Series Resistance	$5.1e-3$ ohm
Energy gap	1.11ev
Reference cell temperature	25° C
Total generated output voltage	228.2V
Total power generated	4.920KW

Parameter's Details :-The simulation data are shown in table I

4.2 Solar cell out put for 3-phase

The output of solar cell as shown in fig. 4.2,4.3,4.4

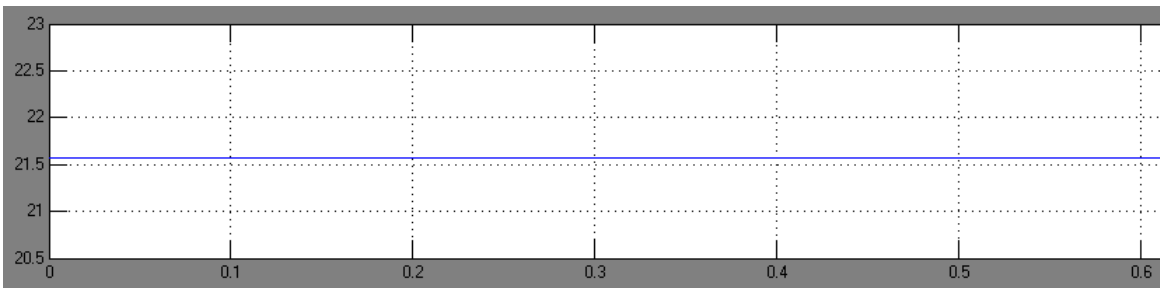

Figure 4.2: Solar cell current waveform

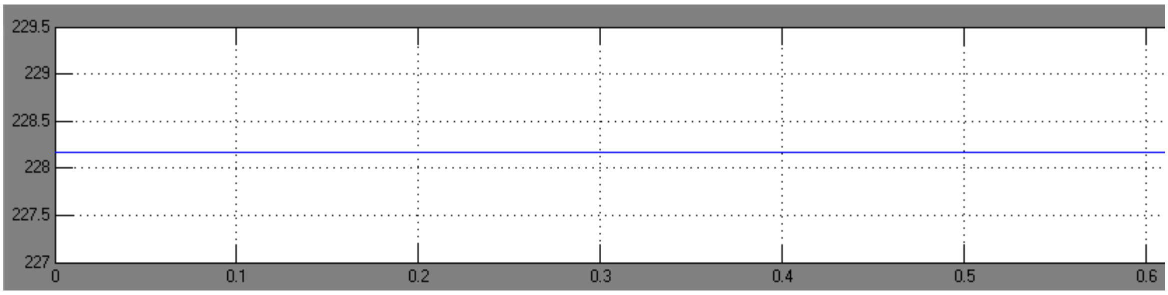

Figure 4.3: Solar cell voltage waveform

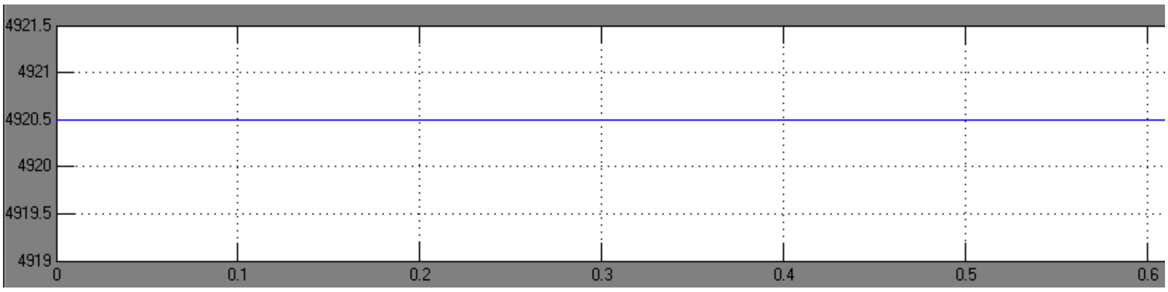

Figure 4.4: Solarcell power output

4.3 Boost-Covertors

4.3.1 Converter circuitery

The converter circuitery is as shown in fig 4.5.Here Mosfet is used for high frequency operation.With high frequency required voltage boost can be achived easily.

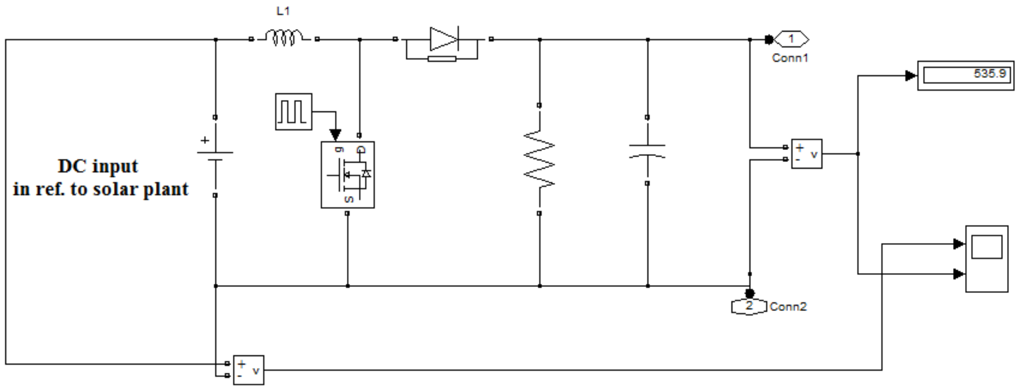

Figure 4.5: Boost converter

Table II: Boost converter simulation data

Parameters	Value
Dc input voltage source	228.4V
Dc output voltage	532.255V
Inductor	0.060708H
Capacitor	$3500 * 10^-6$ μf
Resistor	100
Type of switch	MOSFET
Pulse generator	Amplitude = 1 Time period = $3.3 * 10\hat{-}5$ secs Pulse width =60.50% Phase delay = 0 secs

Parameter's Details:- The simulation data are as shown in table II.

4.3.2 Boost Converter input waveform

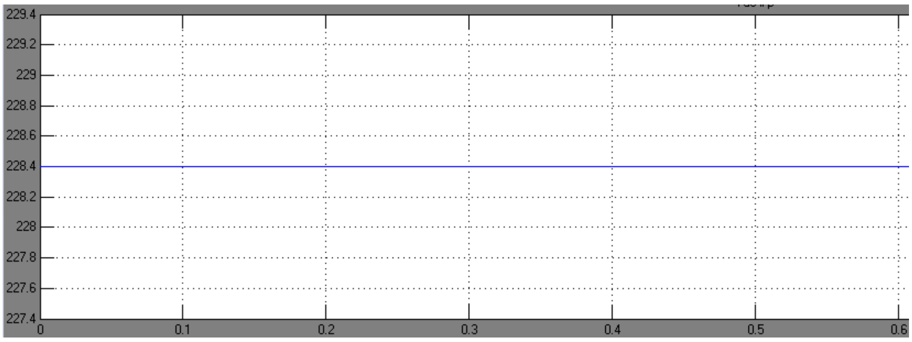

Figure 4.6: Boost converter input of 228.4V

4.3.3 Boost Converter Output waveforms at no load connections

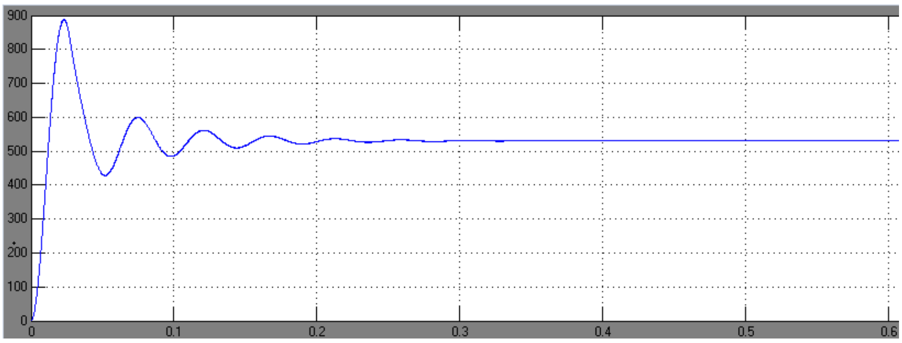

Figure 4.7: Boost converter output of 532.255V at noload without ripples

4.3.4 Boost Converter output waveforms with load connections

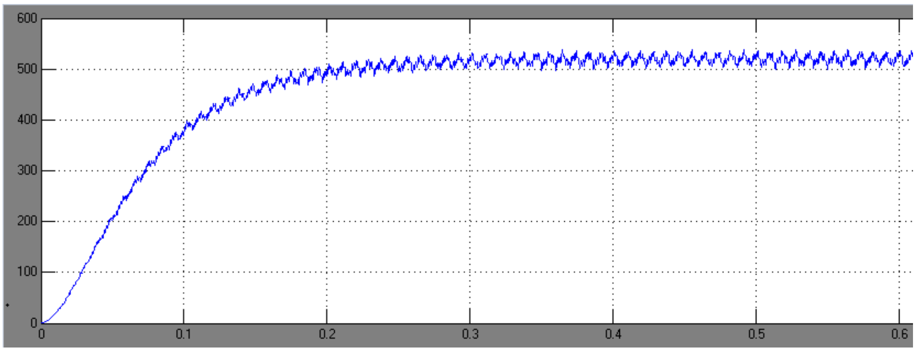

Figure 4.8: Improved boost converter output of 532.255V at full load

4.4 Inverter

4.4.1 Circuit diagram

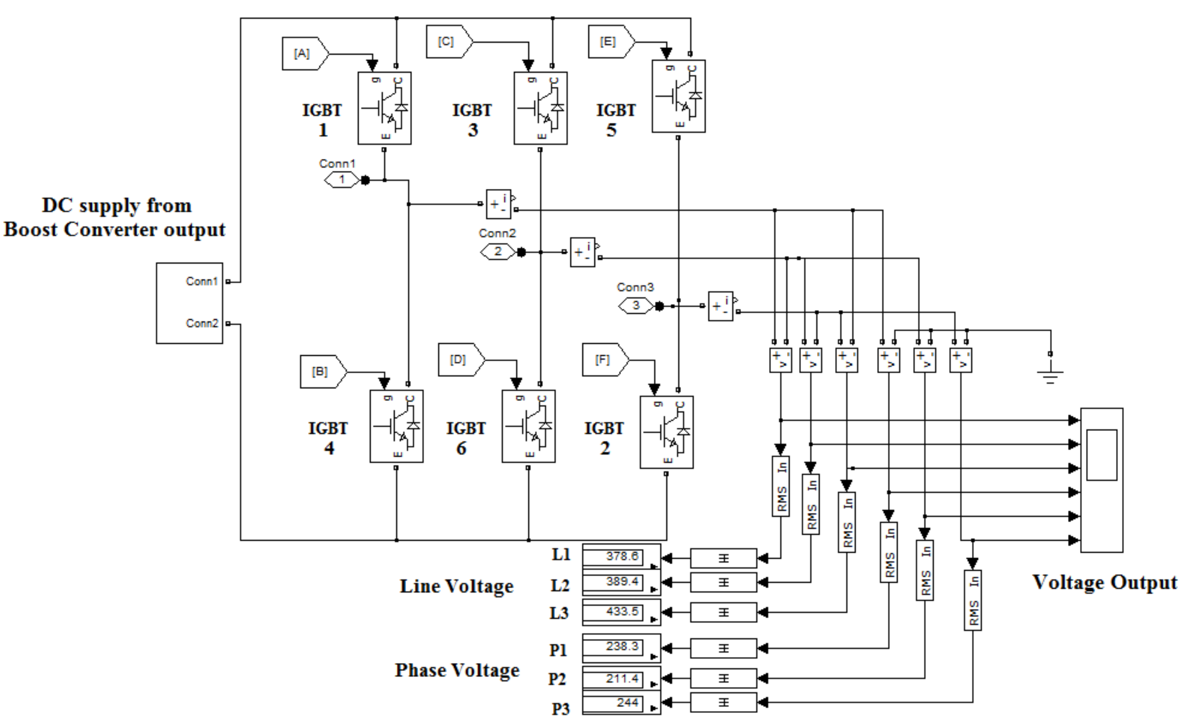

Figure 4.9: Full bridge Inverter circuit with IGBT switches

Table III: Simulation data of inverter

Parameters	value
Input voltage V_s	532.255 (DC)
Output maximum line to line voltage V_m	532.255V(AC)
Output r.m.s line to line V_{rms} voltage	415V(AC)
Output r.m.s line to ground voltage	230V
Output maximum line current at full load I_m	157.39A
Output r.m.s line current I_{rms}	111.29A
Type of switch	IGBT
Type of load	3-phase RL series
Total Load S	80KVA
Active(P) and Reactive power(Q)	P=72000KW Q=34871.19KVAR

Parameter's Details:- The simulation data are as shown in Table III

4.4.2 Gate driver circuit based on SPWM technique

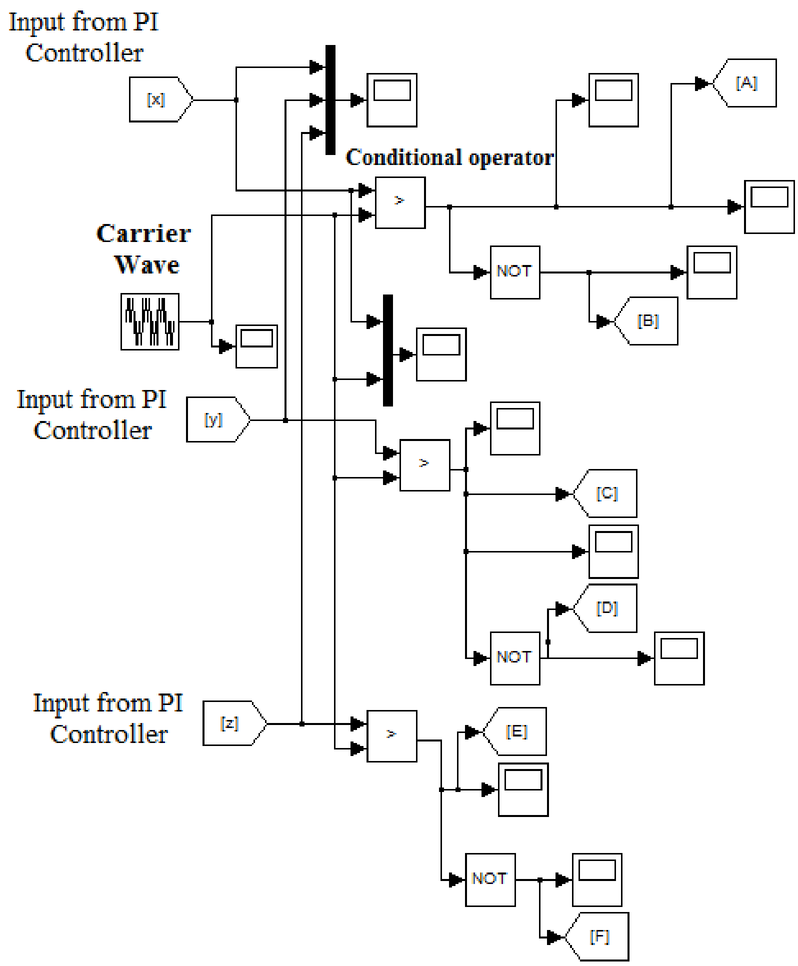

Figure 4.10: Gate driver circuit

Here carrier frequency selected is 30KHZ as IGBT is capable enough to work with this high frequency.As the frequency is high we get more modified or improved results.The carrier amplitude is 1.25.

4.4.3 PI controller circuit

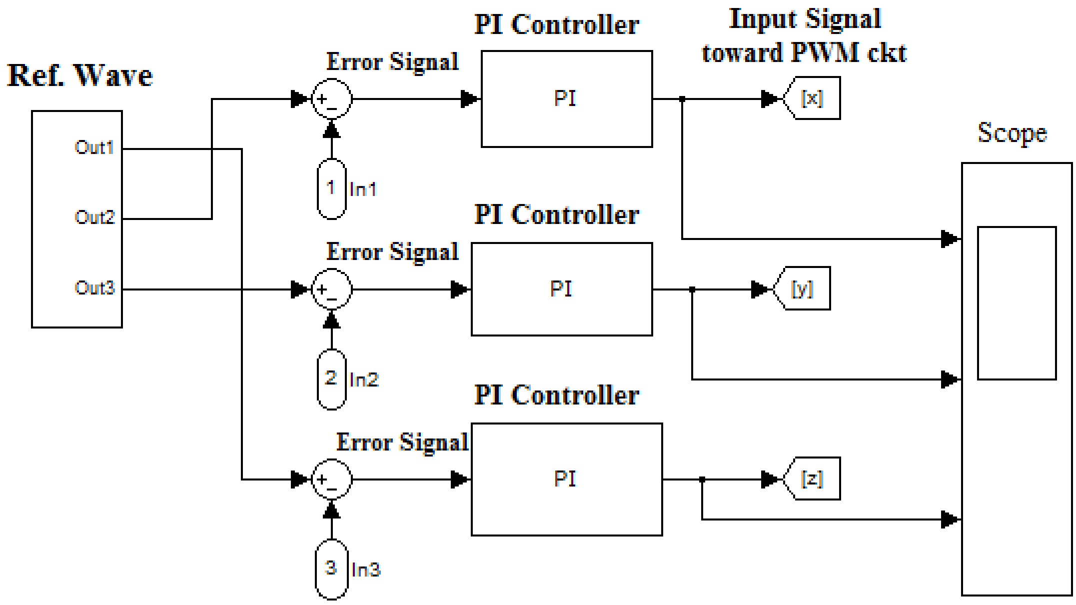

Figure 4.11: PI cotroller module

Here feedback is taken from BUS1 which is shown in fig 3.9,This will compare with reference and accordingly error signal will be generated ,this will be tuned with PI controller which gives time bound signal by redusing the error,this modified signal will again gothrough the SPWM technique and according to that controlled pulses will be generated.

Here the values of proportional and integral gains taken are $K_p = 0.0045$ and $K_i = 3$,The outputlimits are bound within the range [Upper Lower]=[1.13 -1.13].

Wave forms of inverter without the use of PI controller:-

4.4.4 Line to Line voltage wave forms of inverter :-

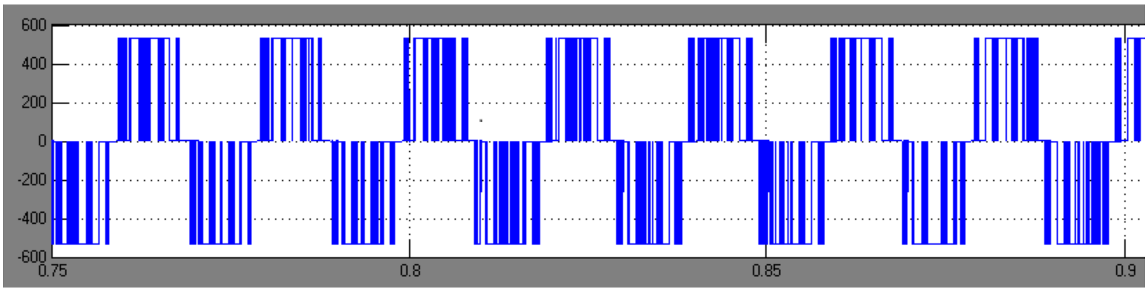

Figure 4.12: Output 415V AC line to line V_{rms} voltage of an inverter for phase RY

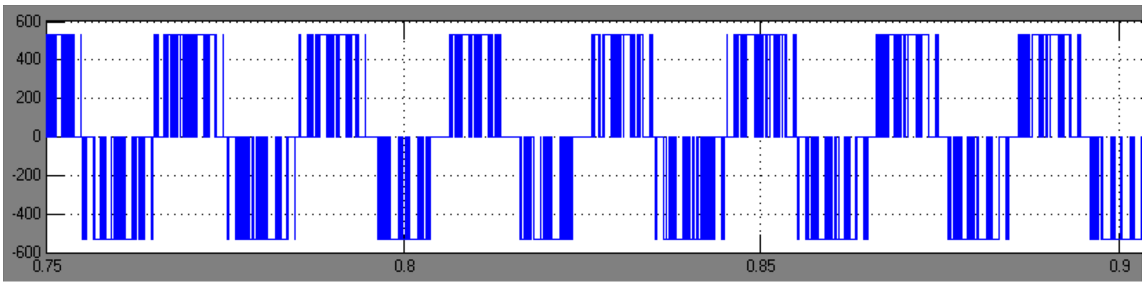

Figure 4.13: Output 415V AC line to line V_{rms} voltage of an inverter for phase YB

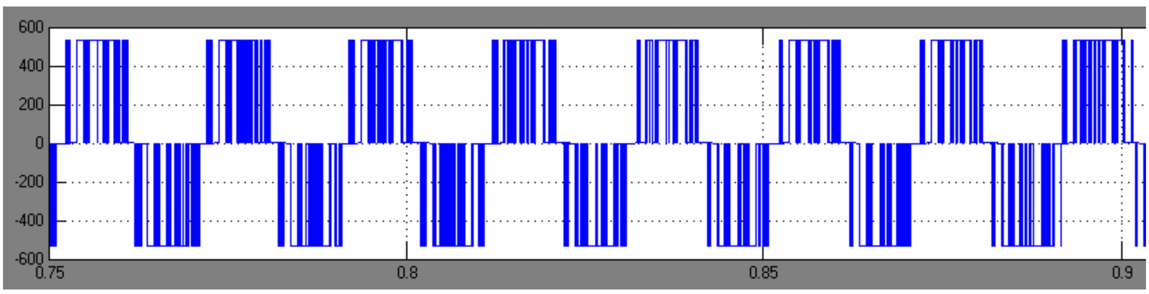

Figure 4.14: Output 415V AC line to line V_{rms} voltage of an inverter for phase BR

4.4.5 Line to Ground voltage wave forms of inverter :-

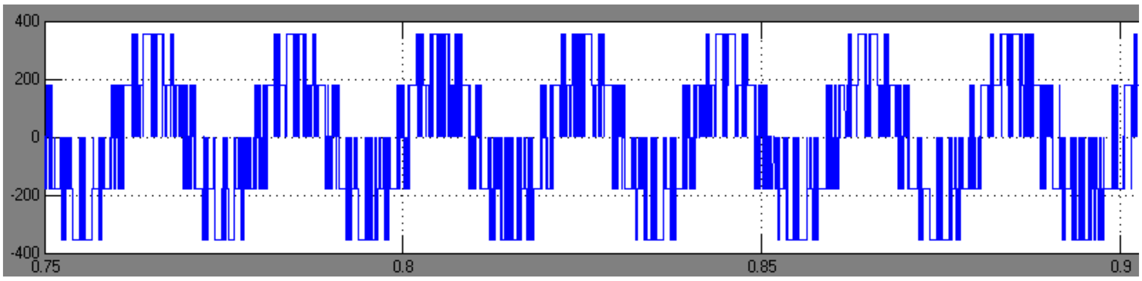

Figure 4.15: Output 230V AC line to ground V_{rms}voltage of phase R

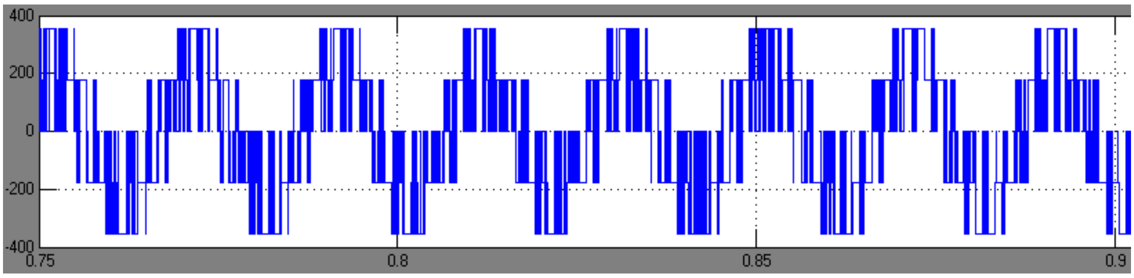

Figure 4.16: Output 230V AC line to ground V_{rms} voltage of phase Y

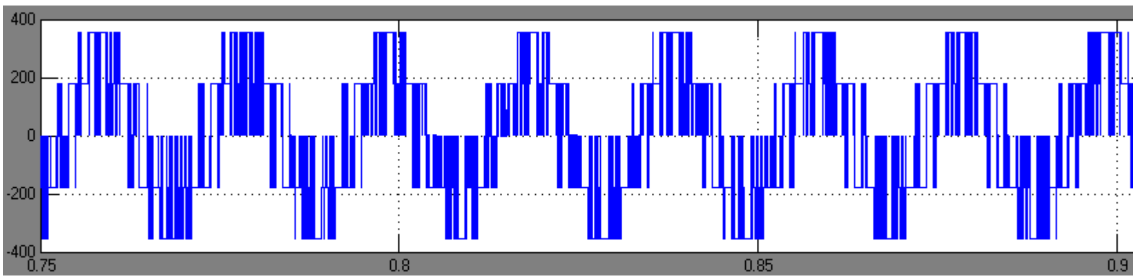

Figure 4.17: Output 230V AC line to groud V_{rms} voltage of phase B

4.4.6 Line current waveforms of an inverter

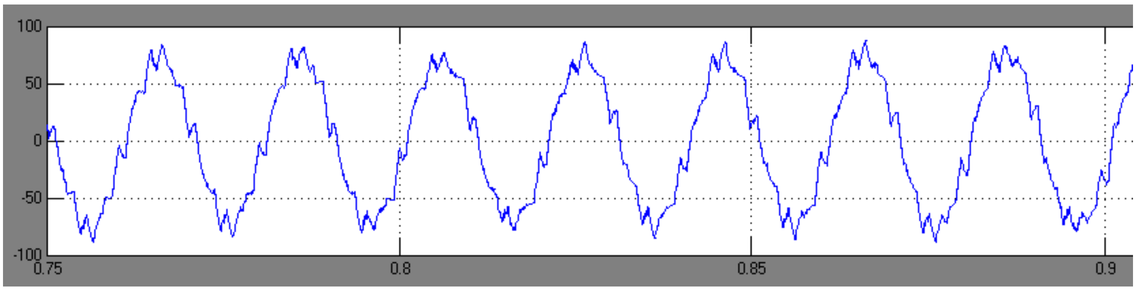

Figure 4.18: Output AC current wave form for Phase R

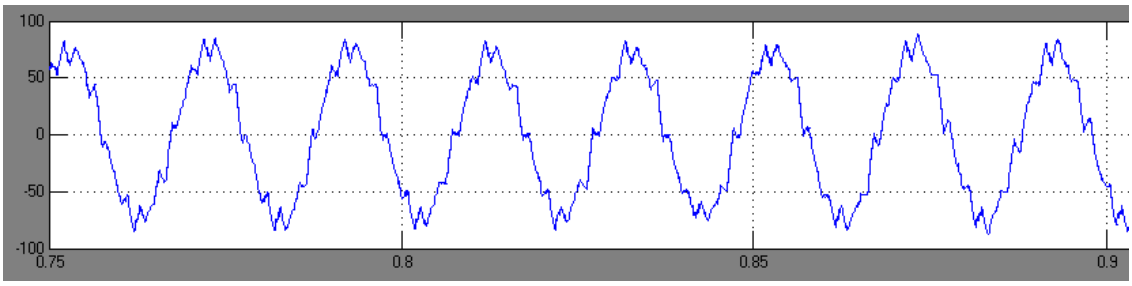

Figure 4.19: Output AC current wave form for Phase Y

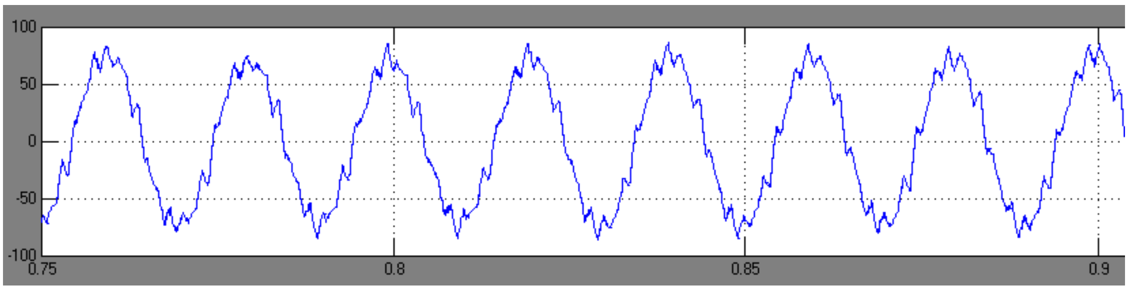

Figure 4.20: Output AC current wave form for Phase B

Wave forms of inverter with the use of PI controller

4.4.7 Line to Line Voltage wave forms of Inverter :-

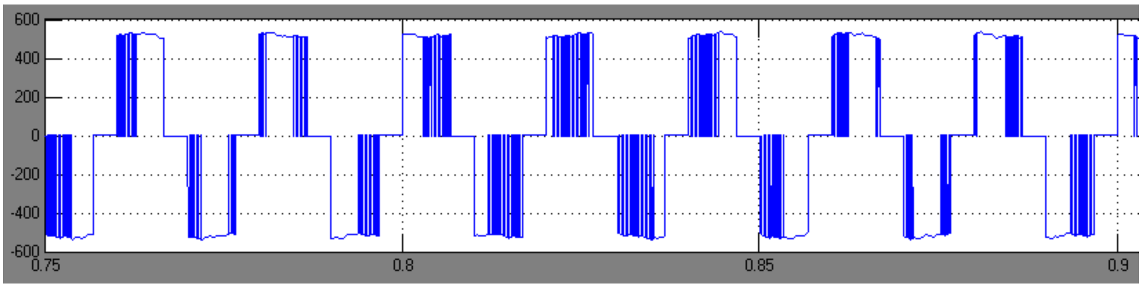

Figure 4.21: Output 415V AC Line to Line V_{rms} voltage of an inverter for phase RY

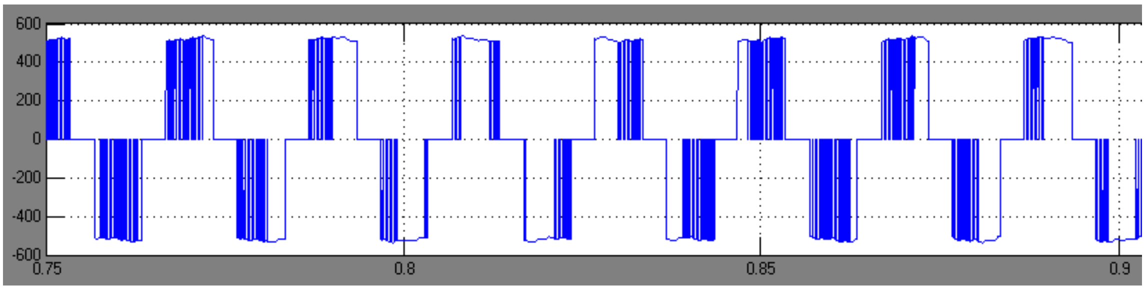

Figure 4.22: Output 415V AC Line to Line V_{rms} voltage of an inverter for phase YB

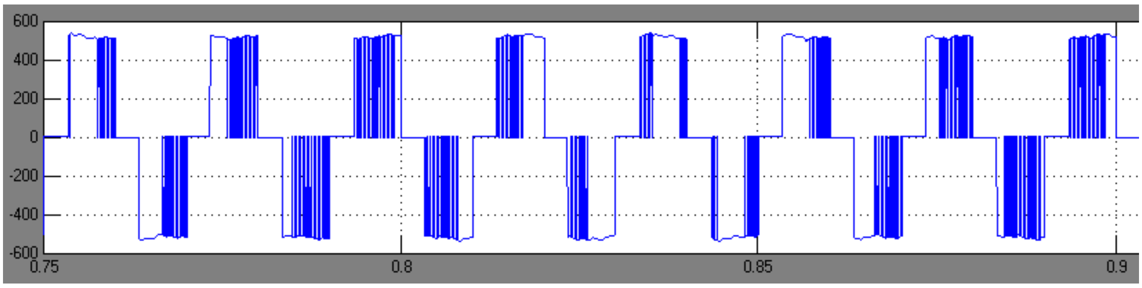

Figure 4.23: Output 415V AC Line to Line V_{rms} voltage of an inverter for phase BR

4.4.8 Line to Ground voltage wave forms of Inverter :-

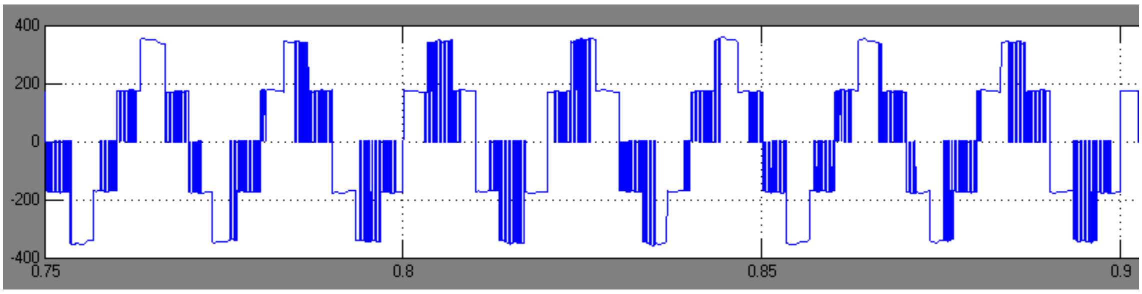

Figure 4.24: Output 230V AC Line to ground V_{rms}voltage of phase R

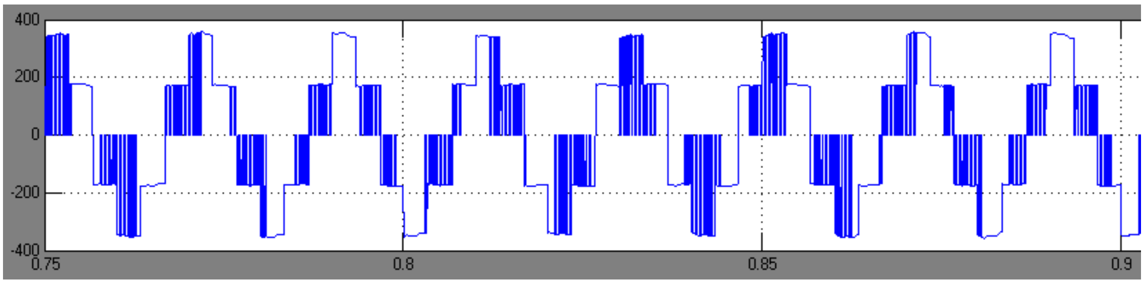

Figure 4.25: Output 230V AC Line to ground V_{rms} voltage of phase Y

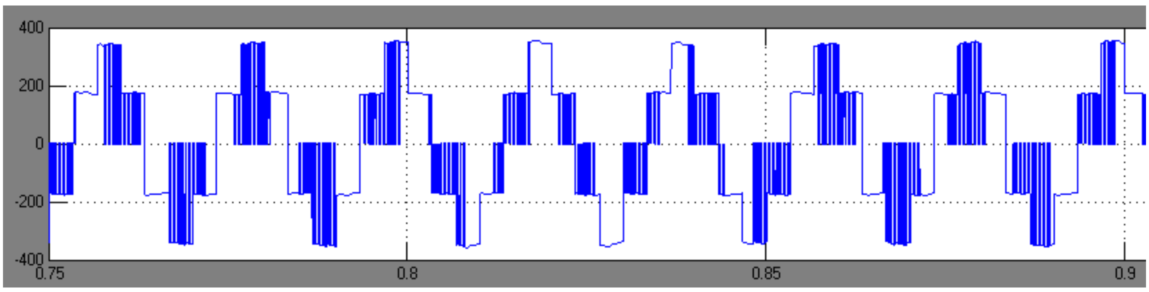

Figure 4.26: Output 230V AC Line to groud V_{rms} voltage of phase B

4.4.9 Line current waveforms of an inverter:-

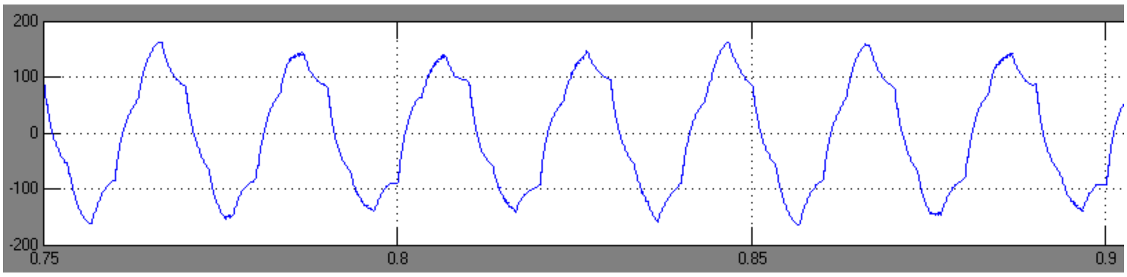

Figure 4.27: Output AC current wave form for Phase R

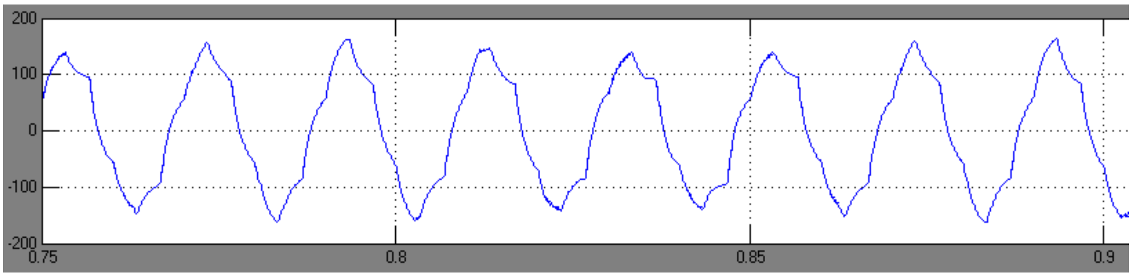

Figure 4.28: Output AC current wave form for Phase Y

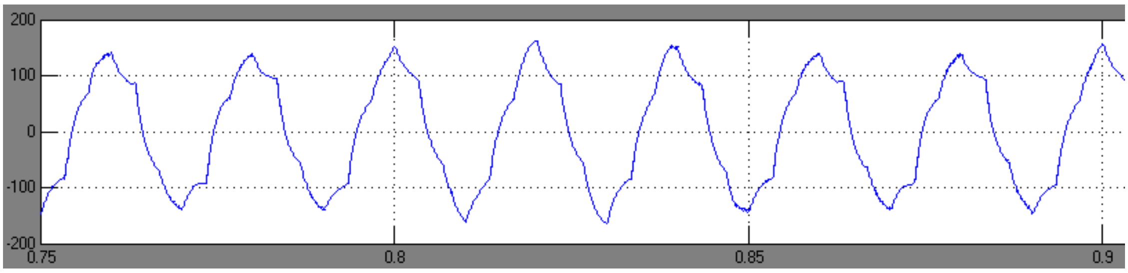

Figure 4.29: Output AC current wave form for Phase B

4.5 Distribution State Grid Model

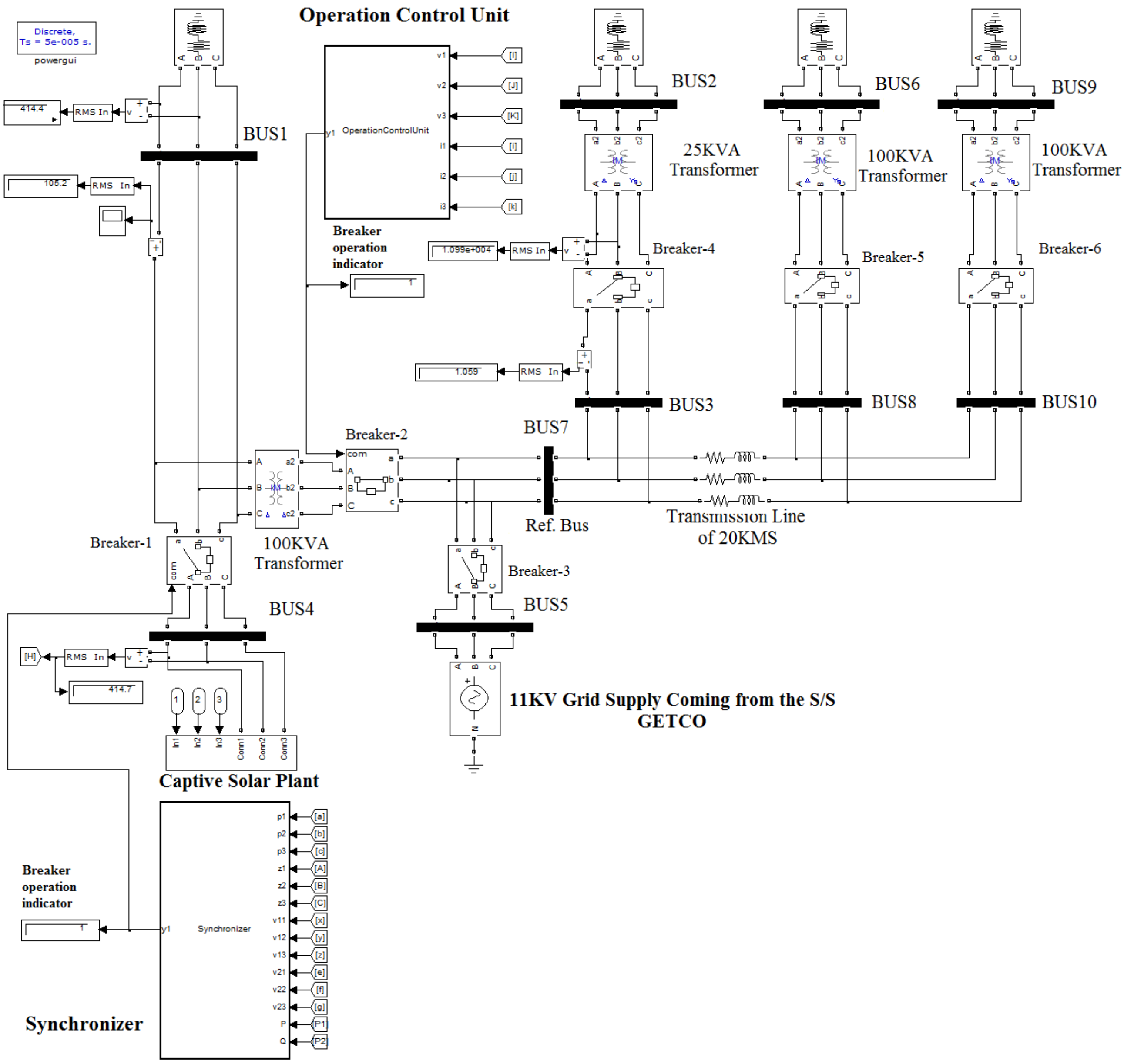

Figure 4.30: Grid Network Model

Here all the loads are interconnected in normal operation.

All the tables shown below gives the network details

TableIV **shows the details of generators and buses**

TableV **shows the details of Distribution lines**

TableVI **shows the details of load**

Table IV: Network Elements Details

Elements	Details
Total No Of powersupply units	3(G1,G2) G1 = Captive Generation G2 = S/S supply
Total Connected Load	260KVA
No of Buses	10-Bus 7-Load buses(PQ) 2-generator buses (PV) 1-Slack Bus
PQ Buses	BUS1,BUS2,BUS3,BUS6,BUS8,BUS9,BUS10
PV Buses	BUS4,BUS5,BUS6
Bus	B7
Total No. of Breakers	6

Table V: Line details

Parameters	Values
Type	R-L distributed parameter
Total length	20KMS
R	2.5 OHM/KM
L	0.025 H/KM

Table VI: Details of Load

Name of village	Selut
Parameters	Values
Load Type	3-phase series R-L
Nominial Voltage(line to line)	415 V_{rms}
Frequancy	50Hz
Total Load	100KVA
$Steert-1$ Load	80KVA
Active Power P1	72KW
Reactive Power Q1	34871.19KVAR
Street-2 Load	20KVA
Active Power P2	18 KW
Reactive Power Q2	8.7177 KVAR
Name of village	Veluk
Load Type	3-phase series R-L
Nominial Voltage	415 V_{rms}
Frequancy	50Hz
Total Load	80KVA
Active Power P	72KW
Reactive Power Q	34.87KVAR
Name of village	Sarol
Load Type	3-phase series R-L
Nominial Voltage	415 V_{rms}
Frequancy	50Hz
Total Load	80KVA
Active Power P	72KW
Reactive Power Q	34.87KVAR

4.6 Output Results :-

4.6.1 Output results of BUS7 as a reference bus of the network

Parameters	Values
Active power	P7=231KW
Reactive power	Q7= 17KVAR
Voltage V7	11000V
Current I7	8.55A
Total Impedance of the network	73.27 ohm

Figure 4.31: Result data with ref. to BUS7

4.6.2 Result display of BUS7

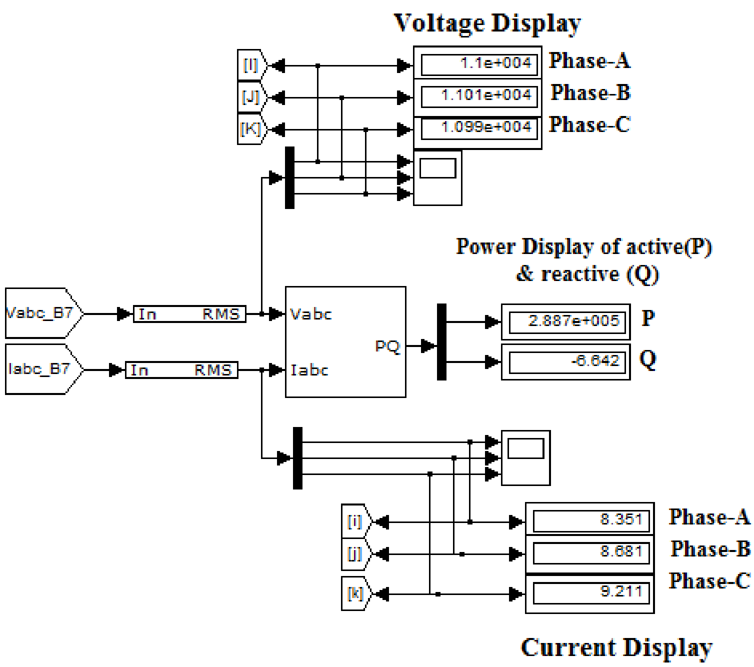

Figure 4.32: Simulation output result displays of BUS7

Similarly results of other buses are as shown in fig4.33 and 4.34

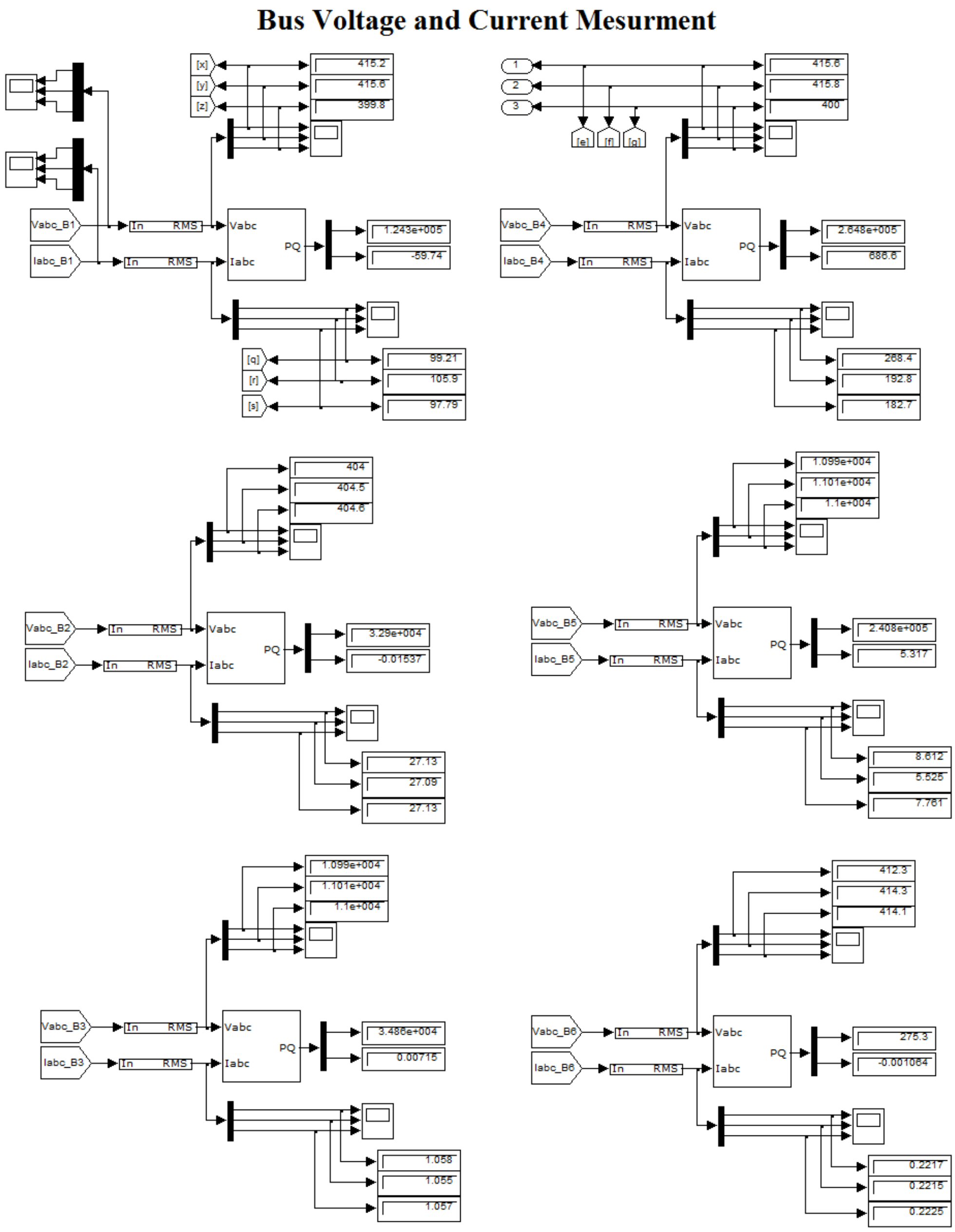

Figure 4.33: Simulation output result displays

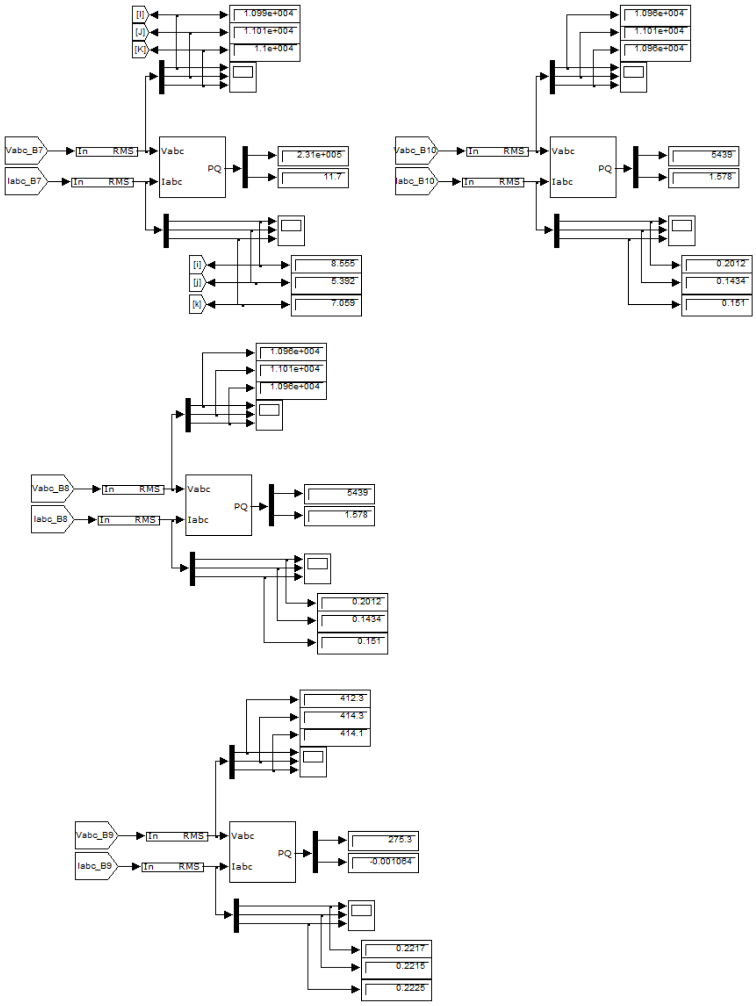

Figure 4.34: Simulation output result displays

4.7 Synchroniser

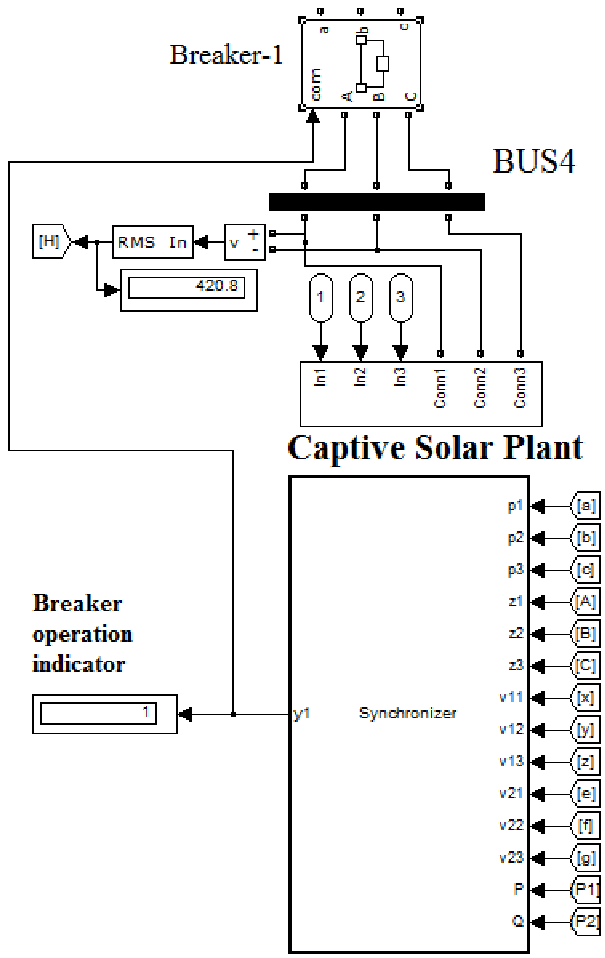

Figure 4.35: Synchroniserunit

The figure shows the synchroniser unit which is having some programming function-designs,this programming is based on the flow chart shown in fig.3.8.It will synchronised the captive plant with the grid when all the synchronization conditions are statisfied.

4.8 Operation Control Unit

The figure shows the Operation control unit which decides the operating states of the sytem whether to operate with grid connected mode or islanded mode.

The unit is having some programming function-designs,this programming is based on the flow chart shwon in fig 3.9

4.8.1 Operation of normal condition-Grid connected mode

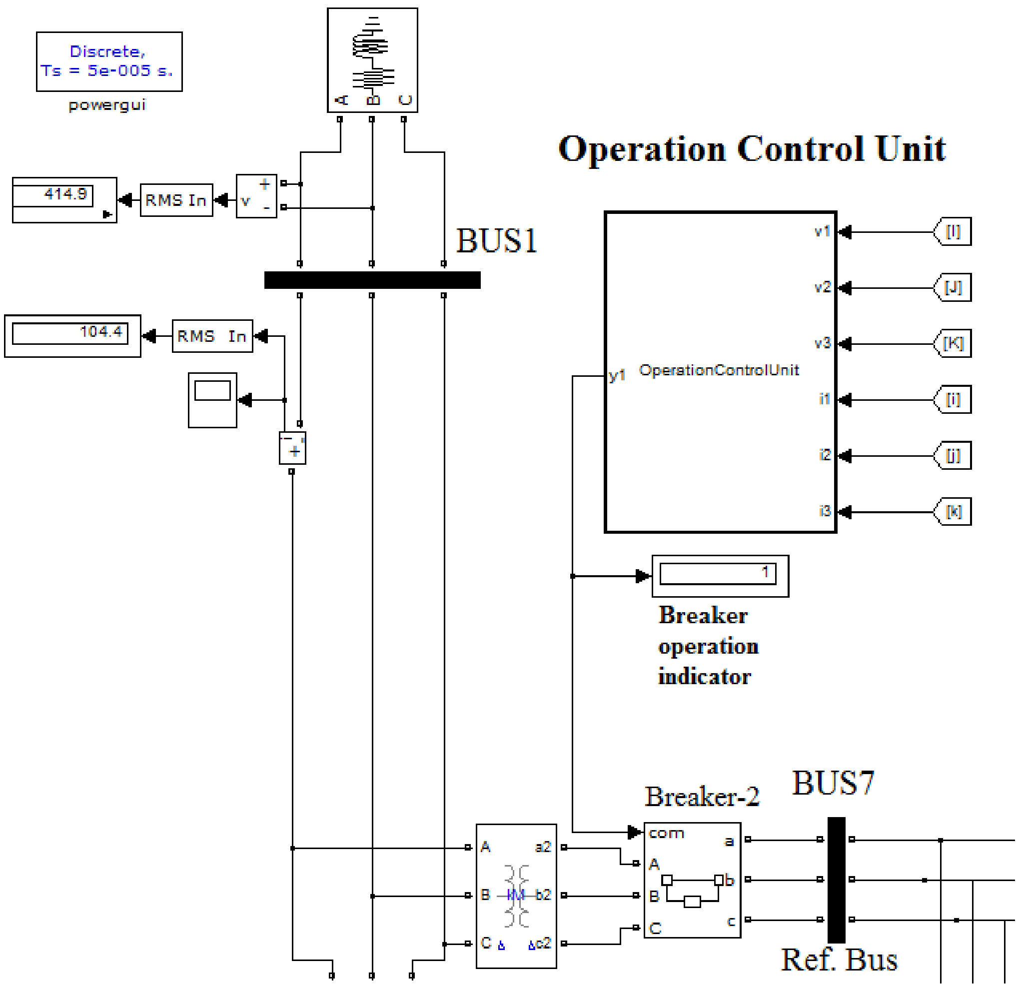

Figure 4.36: Operation control unit at grid connected mode of operation

The breaker indicator is 1 it means the state grid is interfaced with the micro grid network hence it is the normal operational condition of the network

4.8.2 Operation at abnormal condition of grid-Islanded mode

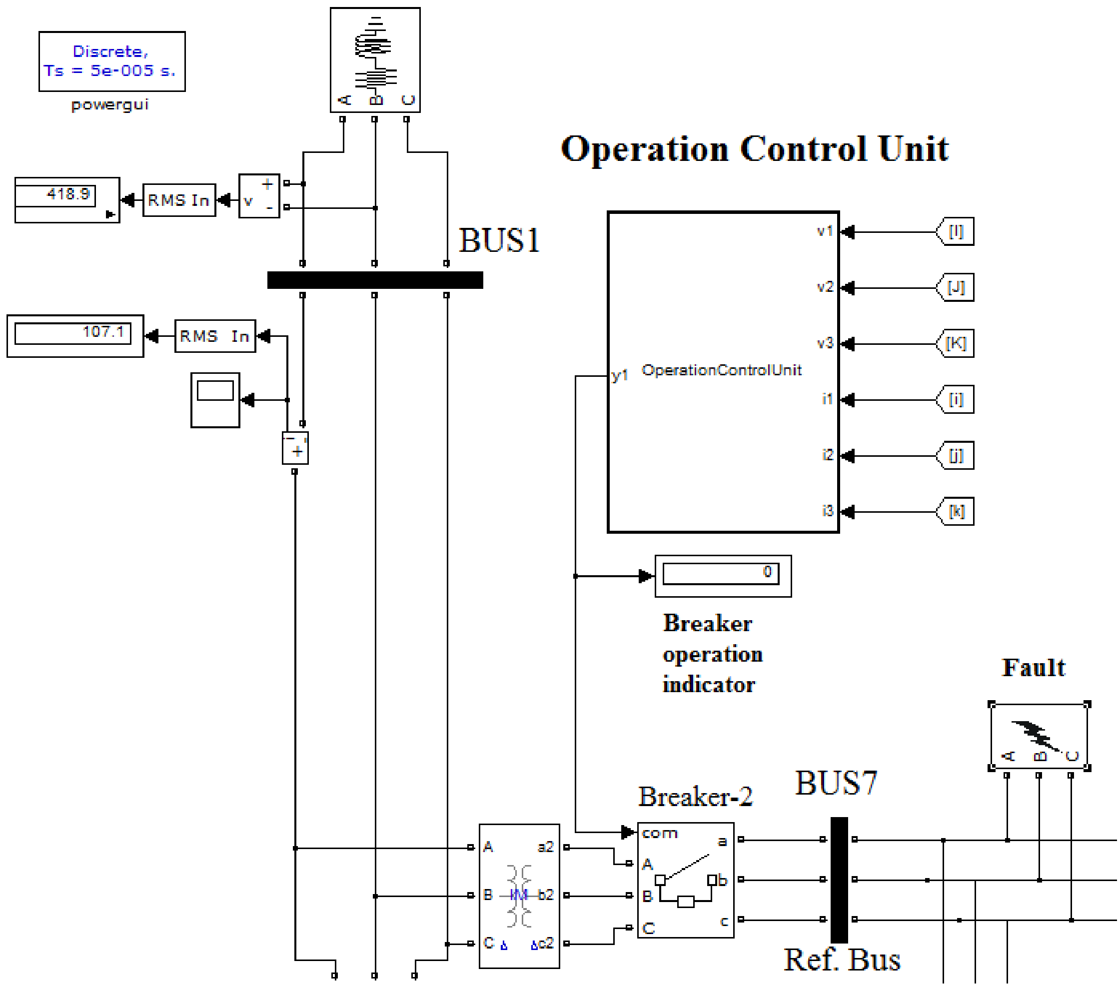

Figure 4.37: Operation control unit at abnormal grid conditions

The breaker indicator is 0 this means the state grid is under abnormal condition or having fault and hence micro grid will get islanded from the rest of the network.

Chapter 5

Conclusion and Future Scope

5.1 Conclusion

With this technique maximum utilization of solar generation is possible also the micro grid can be protected from the other network in case of abnormalities with the help of control units. With SPWM technique controlled power generation is being achieved with proper voltage and current profile.Further this technique improves the accuracy of the system by reducing line and switching losses(notches).And it is done by reducing the error between required and generated voltage with PI controllers since the gains of PI controllers play an important role in stability and steady state control of the system. And with all this schemes improve power quality (for captive plant), availability and reliability for the defined micro grid networ is achived.

5.2 Future Scope

1 Wind energy network and a battery backup system can be devloped to Improve the relaibility of the system during the nights.

2 The idea of frequency calculation which is given in section 3.10.1 for operation control unit can controll frequency upto certain range.This can be improved by taking some modified mathamatical steps.

3 A GSM based modules can be added to the system with which we can continuously analysed the system globally.

4 Reactive power compansation device can be added at mirogrid load side, which will helpfull to the system specially in case of islanded mode.

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