POWER MANAGEMENT OF DISTRIBUTED GENERATION IN MICRO GRID

A Dissertation submitted in fulfillment of the requirements for the award of Degree
Of

MASTER OF ENGINEERING
IN
POWER SYSTEMS

Submitted by

Taranpreet Singh
Regd. No. 801542023

Under the Guidance of
Dr. Amrita Sinha
Assistant Professor, EIED

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Electrical and Instrumentation Engineering Department
Thapar University, Patiala

(Declared as Deemed-to-be-University u/s 3 of the UGC Act., 1956)

Post Bag No. 32, Patiala – 147004
Punjab (India)

DECLARATION

I hereby certify that work which is being presented in dissertation entitled **"POWER MANAGEMENT OF DISTRIBUTED GENERATION IN THE MICRO GRID"** in partial fulfillment of the requirements for the award of degree of **Master of Engineering in Power System** at Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of **Dr. Amrita Sinha, Assistant Professor(EIED).** The matter embodies in this dissertation has not been submitted for the award of any degree to any other university.

Date

Taranpreet singh

Reg .no 801542023

It is certified that above statement made by the candidate is correct and true to best of my knowledge.

1/8/17

Dr.Amrita Sinha
Assistant
Professor(EIED)
Thapar University, Patiala

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Taranpreet Singh

Taranpreet Singh

Reg.No. 801542023

Email Id: Taranpreetsingh61@gmail.com

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ABSTRACT

Power management in micro grid including distributed generation consisting of solar, wind, diesel generator and utility system to provide uninterrupted supply to the load has been presented in this dissertation. Modeling of micro sources has been developed from mathematical model of solar, wind power plant and diesel generator. The optimal control system has been developed into the simulation model for power management with variation in generation. The MPPT control has been used for tapping maximum power from the solar energy system. A power control algorithm sharing the generating power from the different micro sources has been developed. It also helps in control of active power and synchronization of micro sources with grid. A complete model of micro grid with different micro sources solar - wind - diesel - utility has been considered for controlled output power according to load demand using Matlab/Simulink software. The priority of the control algorithm has been to use the power generated by the renewable sources first, and then from the main grid connected to conventional sources. To maintain the uninterrupted supply to critical loads the diesel generator has been used as backup.

CHAPTER-1.
INTRODUCTION

1.1 MICRO GRID SYSTEM

Managing the electrical power of the micro grid is a complex task with rapid increase in population the demand of load has also been elevated. In order to fulfill these demands the conventional resources are largely exploited. Hence to overcome this issue, the use of non- conventional resources is an attractive solution to this problem Our main purpose is to provide energy to the system in an efficient and reliable way. Use of coal and fossil fuels powered power plant produce harmful gases that have a adverse effect on the environment and lead to problem like global warming. Microgrid consumes less fuel and causes less pollution [16].

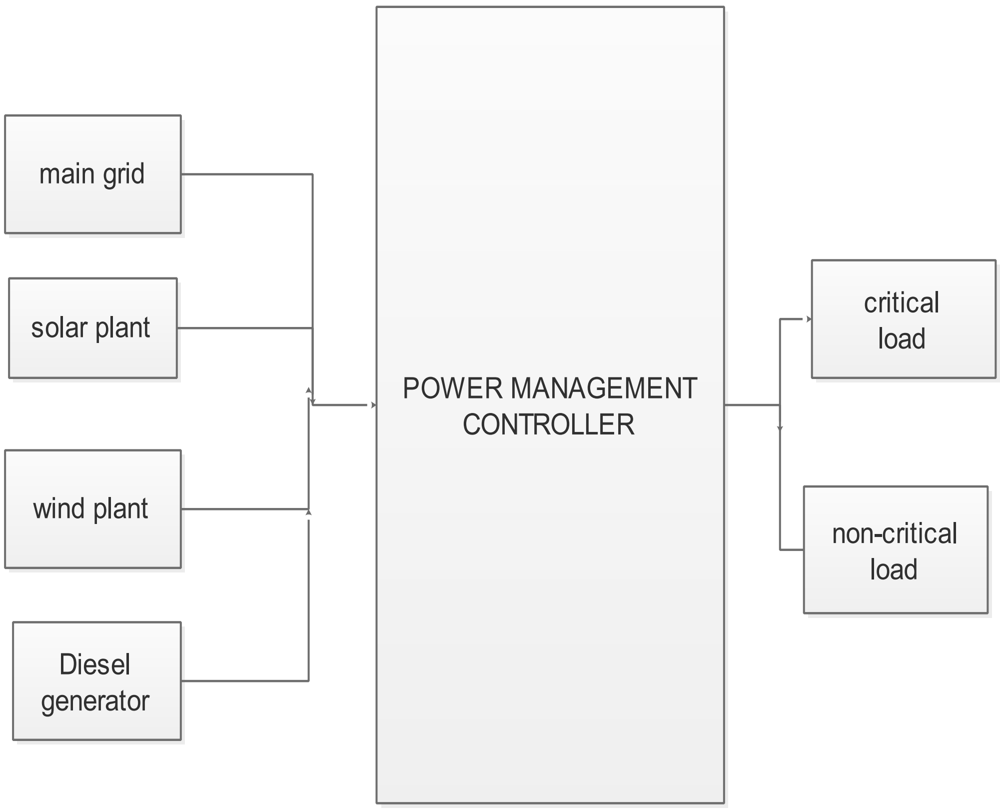

Figure:1-1 Block diagram of microgrid

A microgrid is a bunch of distributed energy sources (micro-sources) and interconnected loads without lined electrical constraints that can operate as a single governable load. The block diagram of microgrid is as shown in Figure 1.1. The main grid and microgrid are connected through a common point of coupling, but can be separated from main grid in case of disturbances or fault. Hence, a microgrid provides localized power solution. Microgrids have a variety of energy sources such as micro turbines, wind turbines, fuel cells, and solar (PV) systems along with storage devices making the system highly efficient to supply continuous local loads. Thelocal loads can be classified into two groups i.e. the critical load and non-critical load, based on the need to prevent power outages. Critical loads are defined as loads that requires apply without interruption while non-critical loads can be shut down if there are disturbances in the main grid. Microgrids can allow extra power from the local generators to be sent to the utility grid. The main purpose of the microgrid is to avoid power outages that impact critical loads. A microgrid has higher efficiency as compared to conventional grid that has higher losses. [15]

Micro grid electricity structure is a highly integrated power based grid. It is combined with the DG'S and devices that measure supply and demand of power and Advanced computer based devices are used for its control and operation of demand The installation of micro sources ensures power quality of the system and hence helps to complete the customer requirement. The micro grid system is based on renewable energy resources that are used for the generation of power.

Micro grid concept has been used in distributed generation [6] for solving problems of synchronization for individual distributed generations. The micro grid is designed for different voltage level such as per source of generation. The distributed generation in micro grid can be controlled in different ways.

1. Islanded operation**:** In this mode, the microgrid works autonomously disconnected from the main grid and generates enough power to supply all critical loads. If the power generated by the microgrid in totality is more than the critical load then few non-critical loads can be also connected till the supply and load demand meets. [15]
2. Grid connected operation: In this mode, the microgrid is connected to the main grid. The microgrid will support the main grid (utility) by either importing or exporting power based on the total generation of the local distributed generators. The microgrid has to be synchronized with the main grid with all the feeders connected.

In the micro grid the concept (CERTS) of control of active power is a different technique. There are different configurations to control the power flow in distributed generation. Mainly power flow control modes are

- Unit power flow (UPC): In this mode the voltage and the power of all the micro sources are regulated, controlled and synchronized with the main grid at the connection points to the feeder. This power control has been accomplished by measuring the instantaneous power with the help of the voltage at the connection point and the current infused by the micro source. [1] The instantaneous power and predefined power is compared. Here the increased load will be fed by the utility, since the micro sources inject constant power regardless of the load variation. When the microgrid operates in islanded mode then the droop control method assures that the voltages and frequencies of all micro sources are the same in order maintain system stability. As any difference in voltage magnitudes leads to circulation of high reactive current between the units and any deviation in frequency results in active power absorption by some units. [15]
- Feeder flow control (FFC): The feeder of the micro-source is monitored by each unit and when the load increases, the output power of micro source increases such that the power in the feeder is constant. Thus, the output of the micro sources depends on the load variation and will increase whenever the load increases making it fully controllable load. The droop controller takes over when the microgrid shifts to islanded mode. [1]

1.2 Background of micro grid

The incorporation of renewable resources with the microgrid is increasing day by day to slim down the emission of harmful gases and utilization of diminishing fossil fuels. This has also elevated the efficacy and reliability of the system. The perception of micro grid is a way out the difficulty due to paucity of fossil fuel in the future [4]

The name grid has been used for a power system to sustain the operations like Electricity Generation, transmission, distribution and control of electric power. The nonrenewable resources are used for the distributed generation that is distributes huge amount of generated power by the large power plants and mostly power fed by the fossil fuels to automatic load control center. The electric power distribution and control is based on power demand and generation of electric power. Micro grid (MG) is also called smart grid (SG) or intelligent grid. MG is used for the two way power flow control so that

- Intelligent power control
- Distributed advanced power delivered network.

1.2.1 The Need for a Microgrid

There are several factors driving the gradual development and integration of microgrids. They are always addressed in areas of environmental concerns, economic benefits, and reliability requirements and can be summarized as follows: [29]

1. Reduction in environment pollution: micro sources having zero or low emission in the microgrid networks.
2. Utility grid support: Microgrids and the utility grid operate in parallel to feed a given load. This prevents the overloading of the grid during peak load period that may result in blackouts consequently.
3. Reduction in transmission line losses: When microgrids are installed near to the load then losses on the lines are lower and the power transmitted through overhead lines also reduces. This decreases the consumption of fossil fuel by the conventional generators and it is economically beneficial.

4 System reliability: Microgrids operate in both the modes i.e. grid connected and autonomous mode. Therefore, high quality power without interruption can be ensured to the loads.

5 Thermal energy savings: The micro sources can be placed near the electrical loads to maximize the energy efficiency. The location of a micro source has no technical difficulty associated with in a micro grid.

1.2.2 MG Concept

Power system is experiencing a rapid growth around the world i.e. small and medium scale distributed generators(DGs). These DGs are usually powered by renewable or nonconventional generators i.e. photovoltaic systems, fuel cells, and wind turbines. They were employed to supply along with the utility grid during peak load hours when there is a shortage in power supply and to provide stand by generation during system outages. Parallel DG systems and cluster of loads are grouped together in a given area to form the micro grid. The traditional approach focuses on the impacts on grid performance of interconnected micro generators [6]. This approach ensures that interconnected generators will shut down automatically when power disappears in the grid network.While, a microgrid has been designed to independently serve its local load and to automatically disconnect itself when a problem is occurs in the utility grid, and then to reconnect with the grid once the problem is solved.

MG concept defines the operation and control of distributed generation (DG), where DER'S (Distributed Energy Resources) operating as a single controllable unit, which supply power. The concept and definition of MG is as given below

1. An integrated power management system consisting of DER's and electrical loads operate as an autonomous grid either in islanded mode or in parallel with the present main power grid.
2. The US consortium is a Electricity Technology solution (CERTS)has published a article integrated of (DER's) The CERTS define concept of MG as given below

"MG concepts suppose a collecting of loads and DG's operating as a single system providing both power and heat. The most of the DG'S must be power electronic based to provide the required elasticity to insure operation as a single complete system. This control elasticity allows the CERTS MG to present itself to the large power system as a single controlled unit that met up local needs for security and reliably".

1.2.3 Management of micro grid

The micro grid is incorporated with distributed resources for instance wind plant, solar plant, fuel cell and storage energy system. Microgrid is coupled with the main (Medium voltage) grid and the circuit breaker. The circuit breaker can connect or disconnect the total micro source as per selected configuration such as feeder power flow controlled mode and unit power flow controlled mode. A microgrid controller controls the entire functions of microgrid [5].

1.2.4 Protection of micro grid

The microgrid should be provided the protection and management of the renewable resource against fault conditions. The circuit breaker should operate after measurement of power and current to disconnect the faulted line. [16]

1.2.5 Basic structure of micro grid

Distributed generations to connect with utility, which are also connecting with power electronic converter. [18] These converters are providing to perform reliable operation. Micro grid system are the three important components.

- Individual distribution control
- Optimize the system operation
- Distributed generation protection

1.2.6 Power control system

The control systems in micro grids are designed to regulate the operation of the system in autonomous mode and grid-connected mode securely. If there are physical communications between micro sources, then the control system is based on one central controller for all micro sources, otherwise the control system is a part of each micro source. The aim of the control system is to control the frequency and voltage in the micro grid locally. [17], [29]. Whenever the utility is disconnected from the micro grid, the frequency and voltage must remain within the acceptable limits. The grid voltage has to be resynchronized with the micro source voltages at the time of reconnection and regulates the output active and reactive power from these sources.

MG is smart electricity grid with coordination between distributed generator and automatic load controller. MG has emerged as necessary building block for future SG and enabling technology for distributed electricity generation and control.

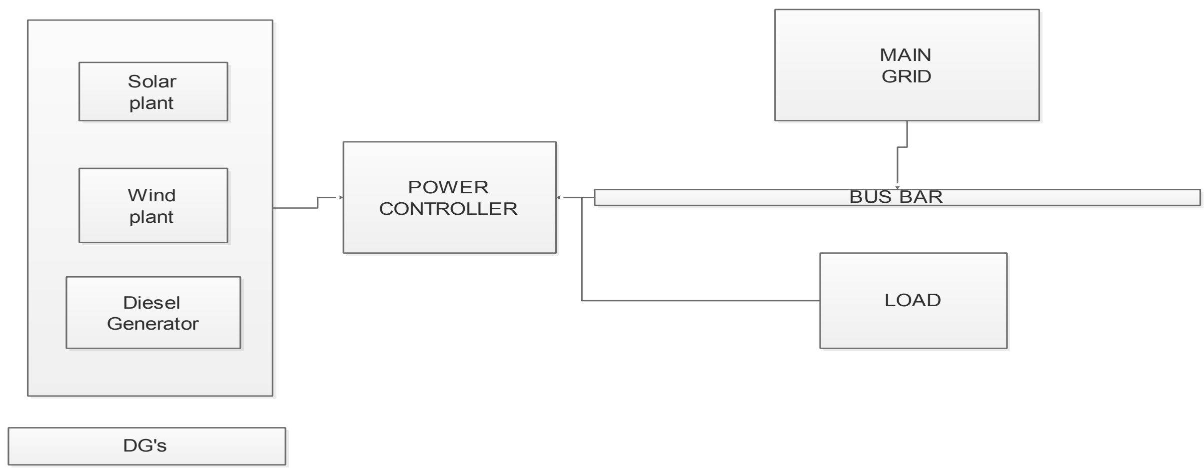

Figure 1-2 Structure of micro grid

Restricted supply of fossil fuels, security problems, the increased difficulty in supply of fuels, and variation of fuel prices has reason for internal concerns, alarming the world economy. Devolution of electricity power generation using different energy resources can concentrate on these challenges. Photovoltaic (PV) generation, wind generation and diesel generation are usual sources of distributed generation (DG).

Energy security and Independence act of 2007 includes the following charactestics of a MG.

1. Increasing the choice of consumer
2. Enabling new service and markets
3. Opportunities to improve the security of MG
4. Oil consumption is reducing the need for ineffective generation during peak hours
5. Computerized operation and maintain

In termination the following benefits can see by structure a MG

- Flexibility: This is working for two modes of operation 1) Grid connected mode 2) Standalone mode
- Sustainability: This is utilization renewable energy resources and trimming down the reduce fuel cost
- Reliability: when a severe fault occurs in the utility grid, MG is able to isolate itself from main grid

1.3 Literature review

Hua Han and XiaochaoHouhave presented renewable energy integration of multiple distributed generators connected to the grid through power inverter. The voltage and frequency stabilities are maintained to share the load demand amongst multiple parallel connected inverters proportionately for islanding operation of an ac microgrid [1].

Amira Nisar and Mini Thomashave presented control and management strategies to achieve optimal autonomous operation and coordinate microgrid resources including distributed generation, smart electric vehicles, and loads for frequency and voltage regulation. Comprehensive control (CC) and Vehicle aided CC strategies maximizes customer satisfaction by enabling calculative load manipulation for demand response (DR) considering customer load priority [2].

Md. AminulIslam*etal* has presented power management system design in a standalone hybrid energy system for multiple energy resources. Voltage regulation, Maximum power point tracking (MPPT), and basic power electronic interfaces have been considered for both solar and wind energy conversion system along with diesel generator to support and increase the reliability of standalone system for resistive load banks [3].

Gang Yao*etal*have designed a central controller for different operating modes of microgrid to maintain stable operation. The conventional droop control has been used to achieve autonomous frequency and voltage regulation considering only local parameters [4].

M.A. Tabirizi proposed a Micro Grid Voltage Controller to improve the dynamic voltage profile. A dynamic simulation has been carried out of the test system considering both cases, grid-connected and islanded modes of operation with and without MGVC for various disturbances to show that the dynamic voltage profile at the load buses has improved [5].

Jin-hog*et al* proposed an active control scheme to synchronize with the networkof energy storage systems and multiple distributed generators. A traditional synchronizer cannot control the synchronization of microgrids that operate with multiple DGs and loads. Islanded micro grid has to be synchronized to the main grid before changing its operational mode to grid-connected [6].

ManojDatta*et al* has proposed a method to control output power of PV generator considering power utilities conditions and the maximizing of energy capture. When the penetration is large, photovoltaic output power changes with weather conditions that cause deviations in frequency in the power utilities. A fuzzy-based frequency control method has been suggested for PV source in PV–diesel generator hybrid system without smoothening of solar output power fluctuations [7].

S. Chowdhury*et al*have studied current, voltage and power in the microgrid system at selective points. The settling time, rise time and peak response in the line currents has been analyzed for a step change in grid voltage [8].

XiangzhenYang *et al* have analyzed the micro grid operation and control of distributed generation on local-level. They introduced an emergency operation mode of microgrid. In supervisory operation control mode it has microgrid central controller, micro-source controller, communication system, and smart switches [9].

S.chowdhury*et al* have demonstrated the operation of a microgrid in islanded mode, sharing critical and non-critical loads. In islanding mode, it automatically eliminates the non-critical loads and continues to supply power to critical loads. The issues related to coordination of micro sources and storage device in islanding operation has been observed [10].

Zaiddaa*et al* have discussed an intelligent and self-configurable microgrid system with automated load management. The microgrid central controller communicates with the loads and addresses them to reduce the overall load demand during peak-load hours to isolate the system from the main grid in real time. Each load is coupled with control node to become an intelligent load. Control node consists of communication node, power measuring device and a switch, under central controller management that can isolate the load from the grid [11].

Xiongliu*et al*have proposed a hybrid ac/dc micro grid to reduce the processes of multiple conversions in an individual ac/dc grid. In hybrid grid both ac and dc networks are connected together through multi bidirectional converters.AC sources and loads are tied to the ac grid while dc sources and loads are connected to the dc grid. Energy storage systems can be connected to any grid. The proposed coordination control algorithm ensures smooth power transfer between ac and dc grids under different generation and load conditions for stable system operation. Uncertainty and intermittent characteristics of solar irradiation level, wind speed, ambient temperature, and load have been also considered in system control and operation [12].

SeonjuAhn*et al* has analyzed the FFC mode to be advantageous for both the main grid and microgrid considering the active power and frequency-control principles of multiple distributed generators (DGs) in a microgrid. An algorithm has been proposed to modify the droop constant of the FFC-mode DGs to ensure proper power sharing among DGs [13].

Huang jiayi *et al* have proposed the coordinated operation and control of distributed energy resources together with controllable loads and storage devices, i.e. flywheels, energy capacitors and batteries. The distributed energy resources comprise of diesel engines, small wind turbines, micro turbines, fuel cells, photovoltaic, etc. [14].

1.4 Research objective

Micro grid system is an isolated system and comprises generation that use only non-conventional energy, the electric power has been generated by these generators which vary sharply, making it difficult for the system to supply electric power with constant quality. This system cannot generate power in response to demand as the generation also depends on environmental conditions. The two difficulties faced are:

1. Stabilizing quality of electric power
2. Supplying power in response to load

To resolve the above problem, power management system has been assumed in this thesis and objective of the thesis as follows:

- Study the micro grid and distributed energy generation and its control in grid connected mode and islanded mode.
- Study the PV array and develop power management scheme between solar, utility and diesel generator for critical and non-critical load.
- Study the induction generator and develop power management scheme between main grid, wind generation and diesel generation for critical load and non-critical load.
- Develop power management scheme with solar, wind, utility and diesel generator for critical load and non-critical load.

1.5 Structuring of dissertation work

Dissertation work consists of five chapters.

Chapter -1 Givesthe brief idea about the micro grid, distributed generation control and classification of the distributed generation

Chapter- 2 Covers a brief study of PV array and the power management between solar, utility and diesel generator for critical and non-critical load.

Chapter-3. Covers study of the induction generator and the power management between main grid, wind generation and diesel generation for critical load and non-critical load.

Chapter- 4 Covers power management of critical load with solar, wind, utility and diesel generator for critical load and non-critical load.

Chapter- 5. Conclusion and future scope.

CHAPTER-2.
DISTRIBUTED ENERGY RESOURCES

2.1 Introduction of distributed generations in micro grid plants

Distributed energy Generation sources are diesel generator, wind plants, PV panels and fuel cell. These units have advantages over the conventional energy generation such as increased reliability and decreased cost of generation. Distributed generation is controllable by the utility and meets the requirement of the high load demand periods like the summer periods loads. The figure 2.1 shows the block diagram of PV plant and main grid

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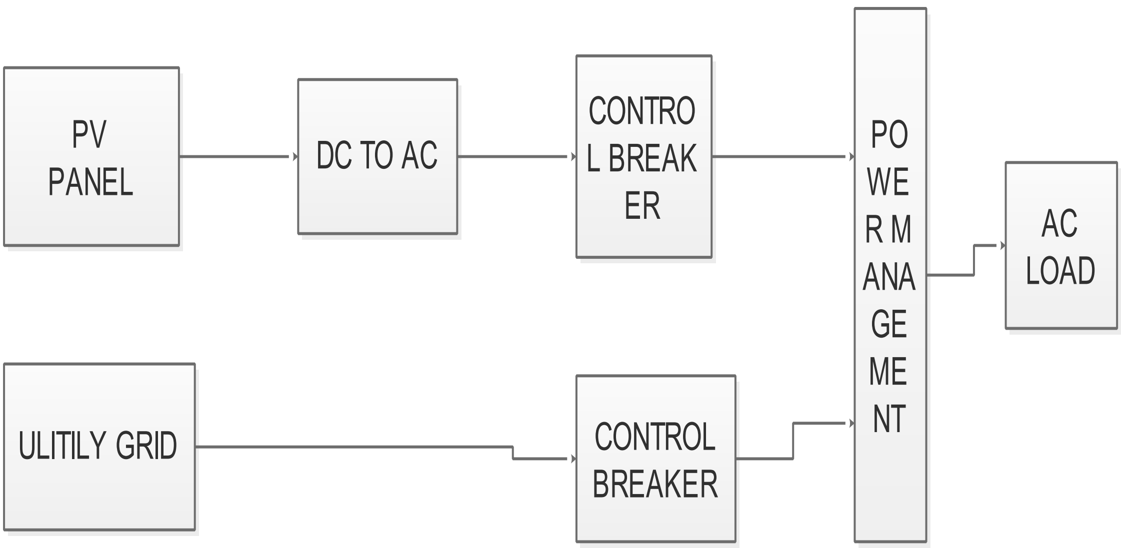

Figure 2.1 Power control of PV cell and utility

The photovoltaic (PV) generation systems are renewable energy resource and preferred due to its small size and noiseless operation for distributed urban power generation. Solar cell technologies have the advantage to meet the increased demand in load as more units can be added as per requirement.

Key advantages of the photovoltaic cell are as follows:

- Time to design, install, and setup a new unit is quite less.
- Highly modular technique.
- Output power of PV cell matches with peak load demands.
- Static structure, hence no noise.

- High power capability per unit weight.
- Long life with less maintenance.
- Highly transportable and portable.

Photovoltaic systems can convert the solar energy directly to electricity. PV expertise has been widely used for power supplies in remote areas to form the distribution network. Photovoltaic cells can be divided into four groups: crystalline cells, thin-film cells, dye sensitized solar cells and multilayer cells. The latter can also be considered as several layers of thin-film PV cells. The dc is converted to ac using inverter that typically consists of the following:

1. Maximum power point tracking circuit.
2. Energy storage element, usually a capacitor.
3. DC converter to increase the voltage.
4. AC inverter stage.

2.2 Solar energy

The solar energy conversion systems can be divided into two types:

i) Concentrating solar power systems (CSP) through heat transfer

ii) Solar PV systems (SPV), through light energy.

Photovoltaic (PV) cells use the energy in sunlight to produce electricity. The amount of electricity produced depends on the quality of PV cells and amount of the light available. The conversion efficiency of a photovoltaic (PV) cell is percentage of the solar energy falling on a PV device being converted into electricity. Improving the conversion efficiency is a key goal of research and helps make PV technologies cost competitive with more conventional sources of energy.

2.3 Study of PV array

PV system models vary in complexity from highly advanced to basic models. The aim of the modeling in this project is to gain insight into the performance of the PV system, in response to two parameters: ambient temperature and irradiance. In table 2.1 shows input data for solar panel. A photovoltaic cell is a nonlinear device. It converts the sunlight into electricity. The photovoltaic array consists of parallel and series combination of PV cells. The cells are grouped together to form the panels/modules. The voltage and current produced at the terminals of a PV cell can feed a DC load directly or connect to an inverter to produce AC at desired frequency. The series resistance R_s represents the internal resistance to the current flow, and depends on the depth of p-n junction, the impurities and the contact resistance. The shunt resistance R_{sh} is inversely related to the leakage current to the ground. In an ideal PV cell, R_{sh}= 0 (no series loss), and R_{sh}= 1(no leakage to ground). The PV cell conversion efficiency is sensitive to small variations in R_s but is insensitive to variations in $R_{sh.}$

A basic solar cell can be symbolized by an electrical equivalent circuit with one diode model [19]. The PV cell circuit is shown in Figure 2.2.

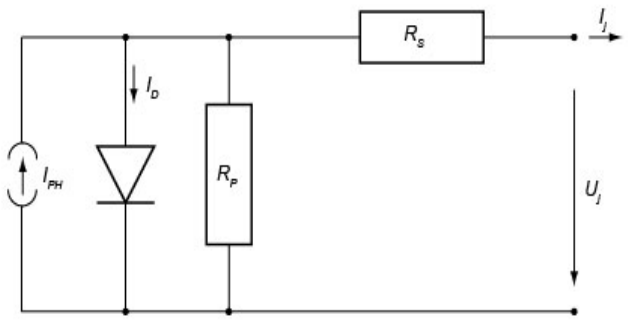

Figure 2.2 Circuit diagram of PV array

$$I = I_p - I_0[\exp \frac{q(V + IR_S)}{nkT - 1}] - (V + IR_S) \qquad 2.1$$

This is a single diode model of PV panel. Where I is the represent the load current or light current, I_p represent the photon current and I_d is represent the diode current.

$$Id = Io[\exp \frac{q(V+IR_S)}{nkT-1} - 1] \qquad 2.2$$

Where *n* is the diode factor, and *Io* is saturation current,

Where *k* is a Boltzmann's constant

$$I_{sh} = \frac{(V + IRs)}{Rsh} \qquad 2.3$$

$$I = Ip - Io[exp \frac{q(V + IR_S)}{nkt - 1}] - \frac{(V + IR)}{Rsh} \qquad 2.4$$

Ip= photo current

Io = reverse saturation current

N = diode ideal factor

The detail of solar irradiance data are tabulated in Table 2.1.

Table 2.1 Solar radiation data [27]

Time in hours	Irradiance in W/m^2
1	0
2	0
3	0
4	0
5	0
6	0
7	76.08
8	139.48
9	177.52
10	177.52
11	190.20
12	190.20
13	190.20
14	177
15	139.48
16	114.12
17	50.72
18	0
19	0
20	0
21	0
22	0
23	0
24	0

2.3.1 PV panel module

The current at maximum power point (I_{mp}), voltage at the maximum power point(V_{mp}) and the(V_{oc}) is open circuit voltage are given below in the Table 2.2. (I_{sc}) is short circuit current The standard temperature conditions (STC) of PV module At $1000W/m^2$and $25 \pm C^o$ and This fundamental parameter is used in solar panel. This PV parameter are the given below from panel data sheet.

Table 2.2 Specifications of PV module

Electrical speciation	Parameter
Open circuit voltage(Voc)	64.2V
Short circuit current(Isc)	5.96A
Number of series connect cell	50
Number of parallel combination cell	660
Maximum voltage	37.59

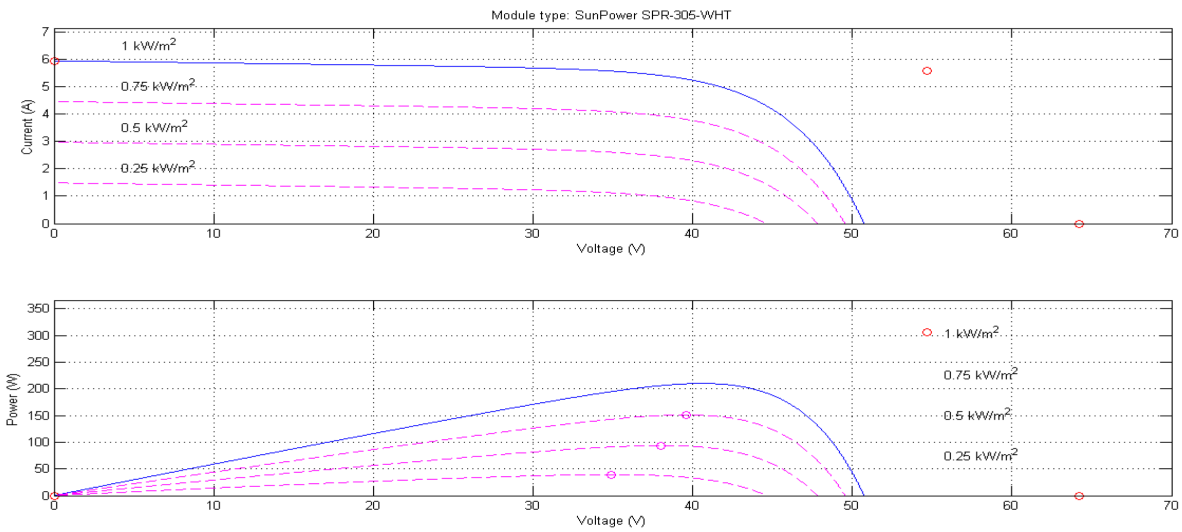

Figure 2.3 I-V and P-V characteristics of array single module

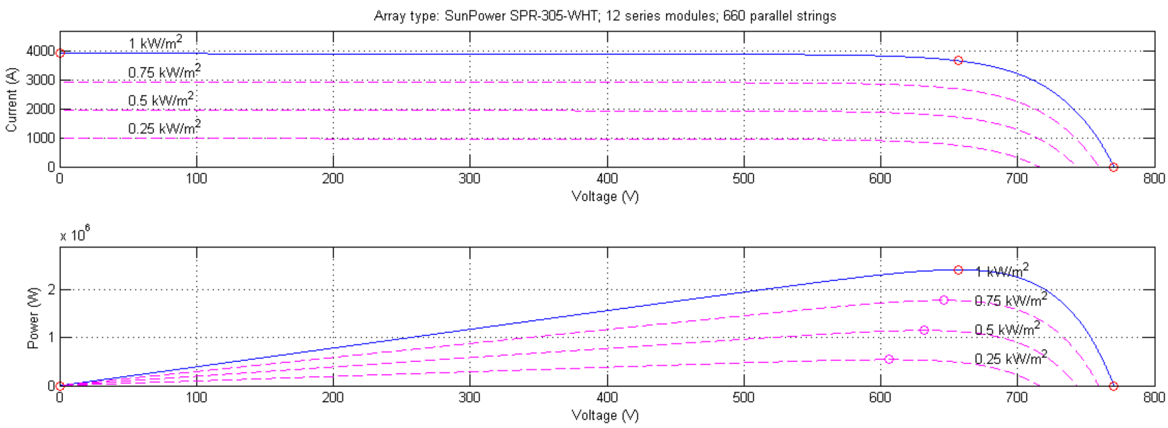

Figure 2.4 I-V and P-V characteristics of array

As can be seen from the figure2.3, the ambient temperature of the PV panel has a great effect on the open circuit voltage, which consequently leads to a significant variation in the maximum power point of the PV panel. The value of short circuit is slightly affected since it insignificantly depends on the thermal voltage, which in turn has a linear relationship with the operation temperature short circuit current is the only parameter that has a linear dependency with the solar radiation. Any increase or decrease in the irradiance level will proportionally change the value of the short circuit current, and as a result the output power will respond almost in the same manner, except for the fact that the open circuit voltage will be slightly different at different irradiance levels, if the temperature is kept constant. This is illustrated in figures 2..3 and 2.4.

2.4 Three Phase Inverter

The inverter is an electrical device used to converter DC power into AC power with required frequency and voltage magnitude. In micro grids, an inverter interfaces the DC source of a renewable energy system to AC systems where the loads and utility grid are coupled. Technically, the inverter is the key component in the microgrid by which the voltage, frequency, active and reactive power can be controlled and stabilized. Therefore, a proper understanding of inverter control ensures stable micro-generator operation and consequently microgrid operation. The circuit of a typical three-phase voltage source inverter is as shown in figure 2.5.

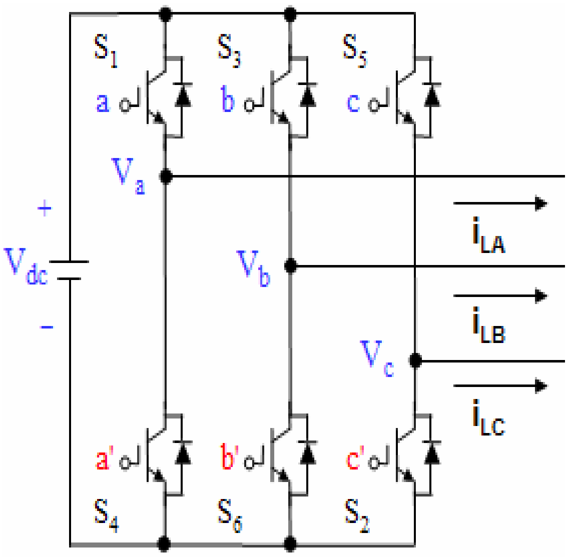

Figure 2.5Three phase voltage source inverter

The circuit model shown in the Figure is simply an arrangement of three single phase inverters connected in parallel. It operates exactly like a single phase inverter but with 120° delay in the gating signals of each arm with respect to each other, in order to obtain three phase balanced voltage This can be done by controlling the operation of the six transistors and six diodes in the inverter circuit, provided that the two switches in one arm are not switched ON or OFF simultaneously. The space vector for this type of inverter can be defined as [20]

$$v = \frac{2}{3}(v_a + \alpha v_b + a v_c{}^2) \qquad 2.5$$

The space vector representation can be applied to both Delta and Star connected loads. Assuming a star load, the sum of the phase voltages at the star load for both balanced and unbalanced conditions is zero:

$$v_a + v_b + v_c = 0 \qquad 2.6$$

The phase voltage at the load can be defined as

$$v_i = v_j - v_{jn} \qquad 2.7$$

where$i$ =a, b, c j =A, B, C

n is the neutral point at the load N is the negative rail of the dc bus in the inverter Now, from equations 3.5 and 3.6, Vn can be expressed in terms of voltages at A, B and C

$$v_a + v_b + v_c = 0 = v_A - v_{RN} + v_B + v_C - v_{RN}$$

$$v_{RN} = \frac{1}{3}(v_A + v_B + v_C) \qquad 2.8$$

Therefore, the relationship between the switching variable vectors $a*$, $b*$, $c*$ and phase neutral output voltage vector will be in the following form

$$\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} = \frac{v_{dc}}{3} \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix} \begin{bmatrix} a \\ b \\ c \end{bmatrix} \qquad 2.9$$

The phase-phase voltage is approximately equal to $3V$ in magnitude and 30^0 out of phase. Thus, the relationship between the switching variable vectors and the phase to phase voltage are:

$$\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} = v_{dc} \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 0 \end{bmatrix} \begin{bmatrix} a \\ b \\ c \end{bmatrix} \qquad 2.10$$

2.5 Wind generation micro grid

The electric power generated from non-conventional energy source not able to meet the load demand, so in order to meet load demand now days' renewable sources like (PV system, wind, fuel cell) etc. using to meet load demand [11]. Non-renewable sources restricted according sources restricted according sources availability and economic load dispatch conditions. Conventional energy sources main causes the health problem but renewable energy sources there is no pollution, no health problem so that's way these are most useful now a days' to generate to generate power [6].

The conventional power generation sources of electrical energy use fossil fuels i.e. coal, natural gas and petroleum that are limited in resource. Natural resources are getting drained due to mega generation units. Nuclear power generation can pose serious health hazard and the radioactivity in nuclear waste may last for even 1000 years. Wind and solar energy are natural resources that do not get expended and are also pollution free. The capital cost of wind and solar energy is high but the operating cost is low. The microgrid concept can help to reduce the transmission and distribution losses as well as the capital cost required for installation of the transmission lines. The area that is closer to coastal line should prefer the wind energy and the plain area should install solar energy. The cost of wind energy has declined and is cheaper 4 to 5 times than the PV array. Since the space required by wind generator is much less than photovoltaic cells. The height required by a 100 kW is approximate 25 m, for 600 kW it is nearly 40 m, for 1500 kW it is nearly 70 m and for 5 MW the height which is approximate 125m. The average size of the wind turbine is 1 MW worldwide. The rotor diameter of 5 MW turbines is 13 m. Its base is 12m with tapering to top width of 4m. Turbine rating of 300 kW needs wind speed of 7m/sec and 450 kW needs 8m/sec. The distance between the wind turbines facing the wind in 1 horizontal line should be 2 to 4 times the rotor diameter and the wind turbine behind the other wind turbines should be 22placed at a distance of 8 to 12 times the rotor diameter. We also have to consider the number of plates as the more number of plates do not give more power but they help to give more torque so the construction become heavier. The number of blades ranging from 1 to 40 or even more is used. A single blade wind turbine is technically feasible but it will give excessive vibration and highly pulsating torque. Modern rotors have two and three blades. We have to control the speed to protect the rotor, generator and power electronic equipment at the time of very high wind speed. It can be controlled by controlling the pitch angle. It has also effect on environment as the speed at the tip of blade can be more than 350km/hr and it is danger to birds. It has also electromagnetic interference with radio, TV tower signals. A 600 kW machine has 55 dB noise levels. If we compare it, the noise level of average office is 50 db, average factory noise is 60 dB and average Street is 70dB. In India, we have many sites with 25 to 30 km/hr wind speeds at annual average level at 10-25 m height. Earth is covered by 71% ocean and the wind speed is 30-40% higher in the oceans. An offshore wind generation can generate 50-70% more power. But cost 50-100% more than on land wind turbines. HVDC cable is use in the oceans and it is a well-established technology. Normally the single-fed induction generator is used with the wind turbines but the machine with higher rating from 3 to 5 MW DFIG is used [7].

Wind turbines include rotor, generator, turbine blades, drive and coupling device. When the wind blows across the blades, it turns the rotor using aero dynamic forces. When the rotor rotates, its speed is transformed to pair with the operating speed of the generator. Most of the systems have a gearbox and the generator as single unit behind the turbine blades. The output of the induction generator is processed through power converters to achieve the main grid voltage and frequency. Different topologies of wind turbines have evolved in the process. The major components of wind turbine can be divided in two parts. The first is the mechanical power section consisting of power conversion and its control and power transmission. These components are connected to the second section, the electrical power system. The section of electrical power consisting of generator, power converter, power transformer and supply grid and figure 2.6 shows the control of power between wind plant and main grid.

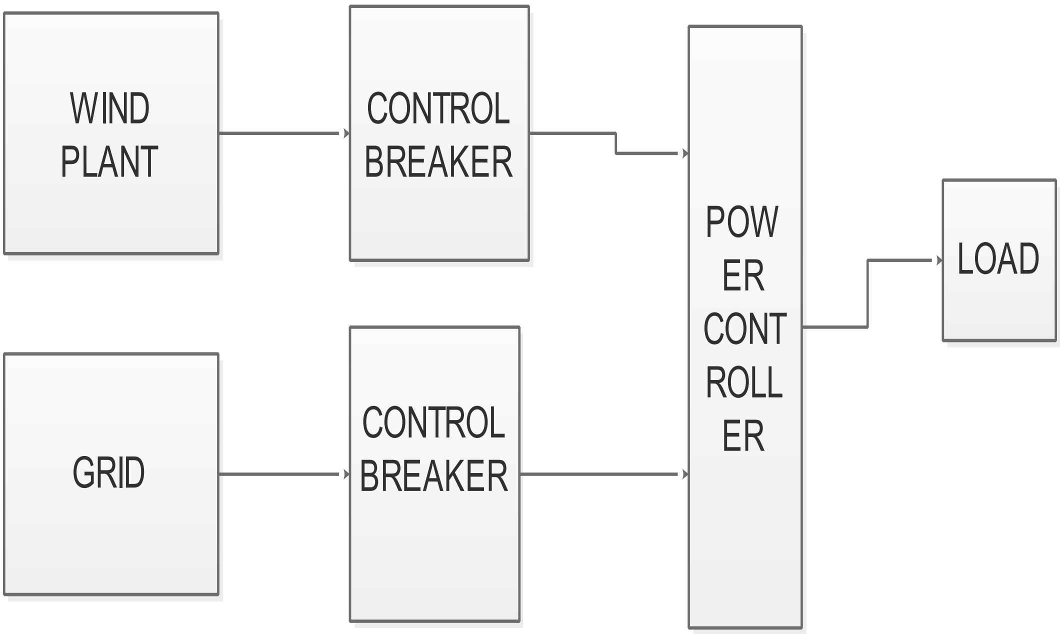

Figure 2.6 Block diagram for control in wind plant and main grid

In conventional Energy sources like thermal plants, nuclear plants every time fuel requirement is more, but in renewable energy resources there is no requirement fuel only initial cost main advantages of renewable sources.

2.6 Wind power

The kinetic energy from the air rotates the wind turbine blades. The generator rotor coupled to turbine directly or through a gearbox also rotates to generate electricity. [21] Here, the kinetic energy of air is translated to mechanical energy by wind turbine and then to electrical energy by induction generator. When a stream of air with mass (m) moves with a velocity (v) its kinetic energy (E) is given by

$$E = \frac{1}{2mv^2} \qquad 2.11$$

During a time period (t), the mass of air passing through a given area at a velocity is given as

$$M = \alpha A v^3 t \qquad 2.12$$

Generated power is depending upon the design of the wind turbine. In the which actual speed are the depend upon rotor efficiency or coefficient of power (C_p). In which concept actual power also depends upon the mechanical power.

$$Pm = \frac{1}{2\ \alpha A v^3 Cp} \qquad 2.13$$

C_p is coefficient of power depend upon the design of the wind turbine model and also depend

Tip speed ratio,β angle

$$\text{Tip speed ratio} = \frac{w * R}{v} \qquad 2.14$$

Coefficient of power is expressed in form of tip speed ratio, β angle for horizontal axis blade

$$Pm = \frac{1}{2\ \alpha A v(y,\ b)3Cp} \qquad 2.15$$

2.7 Wind energy conversation system

The wind energy installation cost has been reducing due to the technology advancement in the last few years. The wind turbine topology can be classified on the basis of different factors as:

1. Axis orientation of rotor:
   (i) horizontal and (ii) vertical
2. Position of rotor with respect to tower :(i) upwind and (ii) downwind
3. Rotational speed: (i) constant and (ii) variable

The source of wind energy requires conversion system so that the voltage and frequency matches with the main grid for synchronization. Different methods of power control are done on the basis of the speed of rotor of generator for the wind turbine [21].

2.8 Different wind generation plant for micro grid

- Synchronous generator for fixed speed generation
- Doubly Fed Induction Generator (DFIG) for variable speed generation
- Squirrel Cage Induction Generator

2.8.1 Synchronous generator

In wind turbine generator machines mainly used for fixed speed these machines generally range KVA ratings. Machine required separate dc excitation and these low cost machine and enhance dynamic performance. PMSG machines operate low wind speed station this machines mostly useful. [15]

2.8.2 DFIG generator

These are used for variable speed turbines. It has been used to increase the energy produced with the help of aerodynamic rotor and maintaining the optimal power coefficient for a wide range of wind speed. Power electronic converters are used for decoupling the speed of the rotor from the grid frequency. A three-phase back-to-back voltage source converter is used to feed the rotor winding in DFIG. The electrical and mechanical rotor frequencies are decoupled. The mechanical rotor speed is independent. The stator and rotor frequency are harmonized in DFIG. The output the generator is rectified and connected to the grid through voltage source inverter consisting of IGBT bridge. The excitation of the generator can be done by an excitation winding or permanent magnets.

Doubly fed induction generator work with variable speed these machines mostly operate at high power rating on the range of (MVA). DFIG machines no requirement the present time status are more used for variable the wind speed These generator are used for the variable speed used in it. The eye-catching quality of DFIG are the 30% power send to the frequency converter 100% power send to generator these generators are used for high wind speed. These machine are protecting for the over speed of induction generator with the control of pitch control in machine.

2.8.3 Squirrel Cage Induction Generator

The conventional squirrel cage induction generator is directly connected to grid. The aerodynamic rotor is coupled to the rotor through a gearbox to match the generator speed for grid frequency synchronization. To maintain the frequency of the generated power the slip of the induction generator varies but the variations are small. To improve the power factor of the system, capacitors are added to feed the reactive power being consumed by the squirrel cage induction generator. The overloading of the generator should be prevented to prevent instability.

2.9 Wind Turbine Modeling

Presently, the variable speed wind turbine coupled to doubly fed induction generator connected to power electronic converter of rated power is being used. The power developed is proportional to the cube of the wind speed. Hence wind farms are located in the areas of high mean annual wind speed.

2.9.1 Generator Equation

Using the synchronous generator convention, the following set of equations are obtained as function of time

$$\begin{aligned} v_{ds} &= -R_s i_{ds} - w_s \psi_{qs} + \frac{d\psi_{ds}}{dt} \\ v_{ds} &= -R_s i_{qs} - w_s \psi_{ds} + \frac{d\psi_{ds}}{dt} \\ v_{ds} &= -R_r i_{dr} - s w_s \psi_{qr} + \frac{d\psi_{ds}}{dt} \\ v_{ds} &= -R_r i_{qr} - s w_s \psi_{dr} + \frac{d\psi_{ds}}{dt} \end{aligned} \qquad 2.16$$

where

v= voltage [V]

I = current [A]

R= resistance [Ω]

ω_s= stator electrical frequency [rad/s].

Ψ = flux linkage

s= rotor slip

Subscripts d and q are direct and quadrature axis components respectively

Subscripts s and indicate the stator and the rotor quantities respectively

The d-q reference frame is rotating at synchronous speed with the q- axis 90^0aheadof the d-axis. The position of the d-axis coincides with the maximum of the stator flux. The flux linkages can be calculated using the following set of equations in per unit

$$\begin{aligned} \psi_{ds} &= -(L_s + L_m) i_{ds} - L_m i_{dr} \\ \psi_{qs} &= -(L_s + L_m) i_{qr} - L_m i_{qr} \\ \psi_{ds} &= -(L_r + L_m) i_{dr} - L_m i_{ds} \\ \psi_{qs} &= -(L_r + L_m) i_{qr} - L_m i_{qs} \end{aligned} \qquad 2.17$$

where L_m= mutual inductance and

L_s= stator leakage inductance

L_r= rotor leakage inductance

The rotor slip is defined as:

$$s = \frac{w_s - p/2w_m}{w_s} \qquad 2.18$$

Where p= number of poles

w_s=mechanical frequency of the generator [rad/sec]

Substituting (2.17) into (2.18)results in:

$$\begin{aligned} v_{ds} &= -R_s i_{ds} + w_s((L_s + L_m)i_{qs} + L_m i_{dr}) \\ v_{qs} &= -R_s i_{qs} + w_s((L_s + L_m)i_{ds} + L_m i_{dr}) \\ v_{dr} &= -R_r i_{dr} + sw_s((L_s + L_m)i_{qr} + L_m i_{qr}) \\ v_{ds} &= -R_s i_{ds} + sw_s((L_s + L_m)i_{qr} + L_m i_{ds}) \end{aligned} \qquad 2.19$$

2.9.2 Wind turbine

The active power p and reactive power q generated by the generator can be written as:

$$\begin{aligned} p &= v_{ds}i_{ds} + v_{qs}i_{qs} + v_{dr}i_{dr} + v_{qr}i_{qr} \\ q &= v_{ds}i_{ds} - v_{qs}i_{qs} + v_{dr}i_{dr} - v_{qr}i_{qr} \end{aligned} \qquad 2.20$$

The electromechanical torque developed by the generator:

$$T_c = \psi_{dr}i_{qr} - \psi_{qr}i_{qr} \qquad 2.21$$

The changes in generator speed that result from a difference in electrical and mechanical torque can be calculated using the generator equation of motion

$$\frac{dw_m}{dt} = \frac{1}{2H_m}(T_m - T_e) \qquad 2.22$$

In which H_m is the equivalent inertia constant of the generator (s) and

T_m is the mechanical torque in per unit

The parameters of wind generator and wind turbine are presented in the Table 2.3 and 2.4 respectively and the wind speed data are presented in Table 2.5.

Table 2.3 Parameters of wind generator

Machine	1
Power	15 kVA
Voltage	575 V
Frequency	60Hz
Stator resistance	0.004843Ω
Stator induction	0.1248mH
Rotor resistance	0.0043770 Ω
Rotor inductance	0.1791mH
Magnetizing inductance (Lm)	6.77mH
Base wind speed	14.49 m/s
Inertia constant	5.04

Pair of poles	3

Table 2.4 Parameter for wind turbine

Nominal wind turbine power	15 kVA
Base speed of wind	14.49 m/s
Pitch angle controller gain	5,25
Maximum pitch angle	45^0
Rate change in pitch angle	2

Table 2.5 Wind speed data [23]

Time in Hrs.	Wind speed in m/s
1	11.59
2	7.24
3	8.69
4	13.04
5	14.49
6	14.49
7	12.31
8	10.86
9	10.86
10	10.14
11	10.14
12	8.69
13	6.52
14	7.24
15	8.69
16	9.42
17	10.14
18	8.69
19	7.97
20	8.69
21	8.69
22	8.69
23	13.04
24	13.04

2.10 Diesel Generator

Diesel power generators are considered to be most reliable for emergency power backup. Diesel generators have advantages of fast response time, fuel supply, load carrying capacity, availability and reliability that makes it popular and are effectively implemented in modern building code and standards. Quick response time is one of the unique features of diesel generators and it is able to absorb a full electrical load within ten seconds of power failure

A diesel generator comprises of diesel engine with governor control and alternator is shown in figure 2.7. The major components of diesel engine consist of controller to check the steady state error in speed and an actuator with PI controller for the fuel rack position. These engines are highly nonlinear devices and their characteristics are a function of power output, speed and ambient temperature. The existence of non-linear, time-varying, dead time between the fuel injection and production of mechanical torque makes the control of diesel engine much more complex. PI controller has controlled the steady state error of speed of diesel engine. The expression of mechanical torque, T_{mech} is obtained from the following equation where TD is a time delay. The governor control system controls the diesel flow to the engine regulating the speed and the power produced.

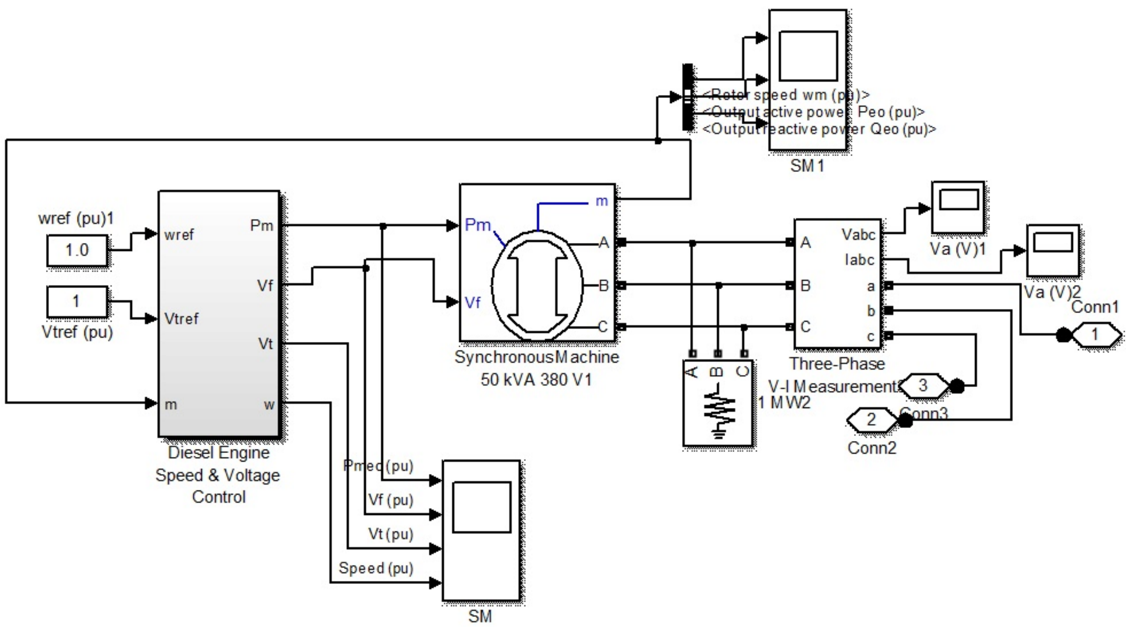

Figure 2.7 Diesel generator

2.10.1 Synchronous Machine

A synchronous generator mainly consists of the field and armature. The field is located on the rotor and the armature on the stator. The field winding has DC supply to produce constant magnetic field and rotates with the rotor shaft. This magnetic field while rotating cuts the stator conductors, wound to produce three voltages. Each phase consists of a voltage source in series with RL impedance, which represents the internal impedance of the machine.

2.10.2 Excitation System

In order to supply an adjustable direct current to the main generator field winding, an excitation system is required. The exciter may be a DC generator on small set sizes. It is possible to regulate the terminal voltage when operating in generator mode. The excitation system applied in this work is a DC exciter and it is assumed that there is no saturation in the system. Major components of an excitation system include a voltage regulator and an exciter circuit as shown in figure 2.8. The excitation system is represented by the transfer function expressed in equation 4.1

$$v_{fd} = \frac{E_r}{K_{ex} + sT_{ex}} \qquad 4.1$$

Where, V_{fd} is the exciter voltage, E_r is the output of voltage regulator, $K_{ex}$is the exciter gain and T_{ex} is the time constant of exciter

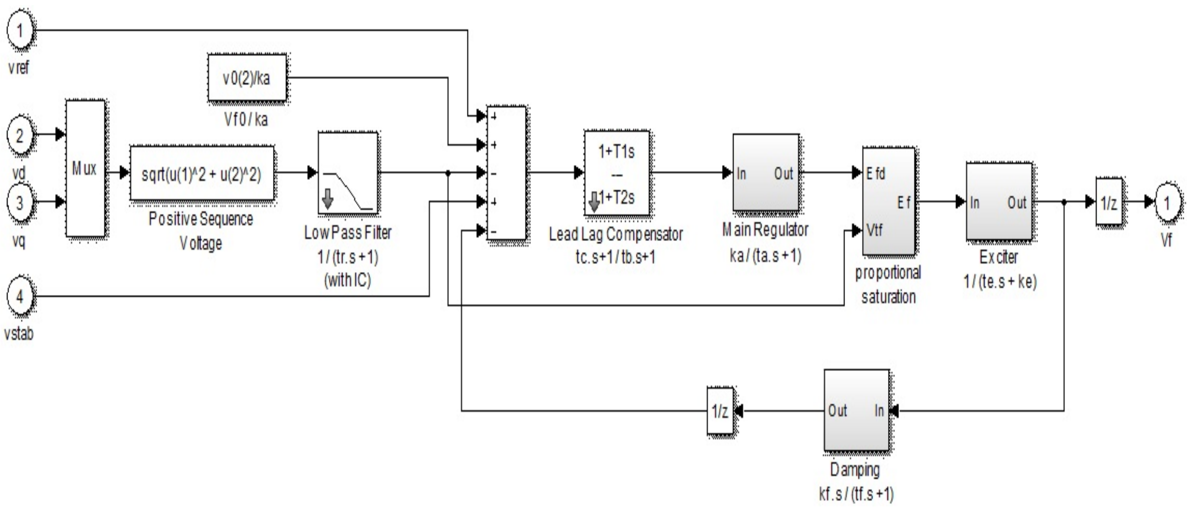

Figure 2.8 Excitation system for synchronous machine

2.10.3 Governor Control System

It is possible to regulate the speed of a diesel engine by controlling the flow of diesel into the cylinders with the help of injectors The device performs this task is known as governor in diesel generators. Regardless of any change occurring in the demand, governor is responsible to operate the engine at constant speed. In a DECS, the diesel engine acts as the prime mover which is coupled with the generator shaft in order to 63 generate electricity. A governor that operates the engine within a range of speed is known as the speed limiting governor. A constant speed governor is chosen in this work to integrate with the hybrid system. The simulation model of the diesel engine along with a governor control system is shown in the following figure 2.9.

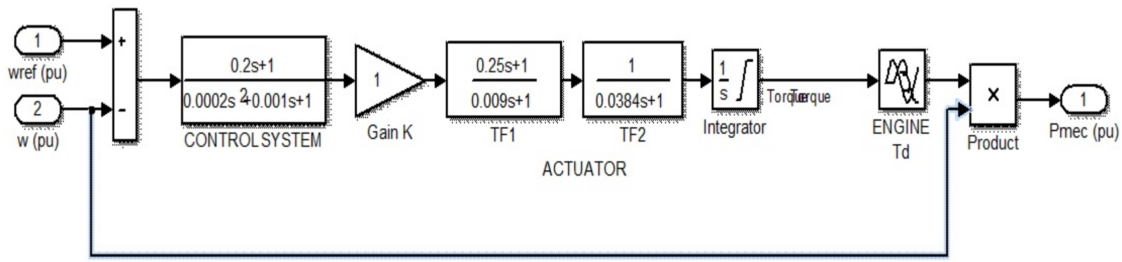

Figure 2.9Governer control system

The governor can be controlled using either speed or the frequency. But control based on speed is recommended since the generator frequency signal depends on the excitation of the generator. In case of failure in excitation, the residual magnetism may fail to generate the required signal. Such failure can damage the prime mover shaft by operating at over speed.

CHAPTER-3.
POWER MANAGEMENT OF WIND, SOLAR, DIESEL AND ULITILY

3.1 Introduction

Various types of non-conventional energy resources along with the main grid generate dc or ac at different level of voltage but are synchronized at the same frequency and same voltage level. Matching of the voltage level has been achieved by selecting the proper rating and configuration of converter and transformer. The main grid is connected with power controller and the power controller technique is show in figure 3.1. The control and measurement of local power and central power have been done using comparator, logic gate and circuit breaker [19]. Different load conditions for critical load and non-critical load have been assumed. The control algorithm to meet load demand has been implemented for considering different condition of load power management.

3.2 Power management of algorithm for power management

The renewable energy systems are those systems where the source is solar or wind energy. Where the availability of the wind speed will be high, the wind plant should be of the high priority for the generation. Wind plants generate continuous power for a complete day period i.e. 24 hrs. Whereas the solar power plant can generate only during the day time [13,1]. At the starting stage when wind and solar could generate base power, the utility and diesel generator are used for peak load or critical loads in case of disturbances or fault.

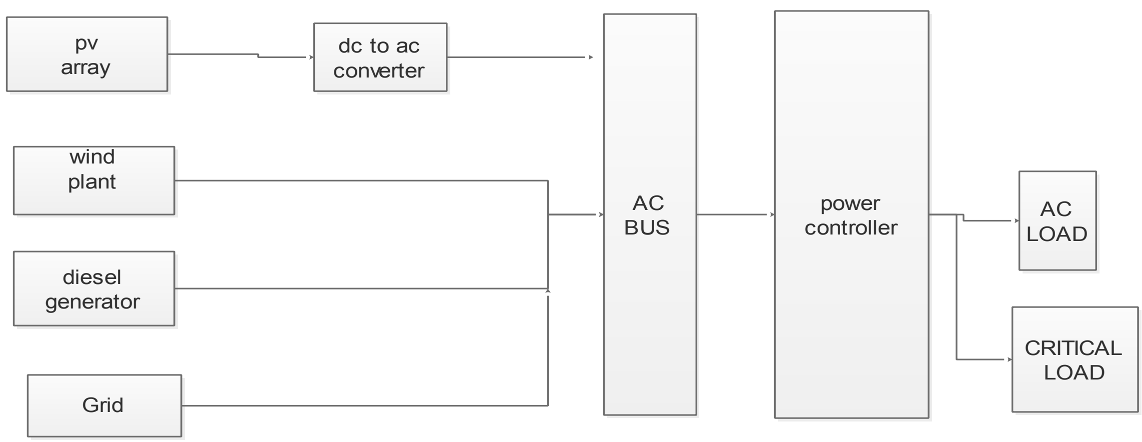

Figure 3.1 Block diagram of the micro grid controller

When the solar and wind plants are generating maximum power and they meet the load requirement, the utility and diesel will have disconnected from the load. When the load demand is more than the wind and solar plant maximum generation then the main grid and diesel generator could deliver extra power to the load. While the utility can be turned ON instantaneously, the diesel generator requires a minimum operational time. For critical loads diesel generation is used as back up and not the utility, as the latter generation is beyond the control of MG. There is two additional load as non-critical load and is dependent on the total generation of power.

3.3 Power supervisory control

The main idea behind the power control is the power for compensation according to generation of power and load demand. It is to compensate and minimize the mismatch of power between the load demand and generation of power [17]. Power management controller are managing both the connected mode i.e. grid connect and islanding mode. The complete generated power of grid and distributed generation resources are to meet the load demand on consumer side. Throughout the period of power management, the real and reactive powers are measured, that flows for distributed generation.

The core part of supervisory control is to measure the power and send signal to the power controller to match the power between load and generation. The active control of power is to synchronize the system and to get desired voltage according to the load variation. [7]

3.3.1 Basic control scheme for active power control

The micro grid is central power controller (CPC) is the central controller for active power scheme as this is distributed in the different ranges [6]. The planned control of active power is uses the commutations network [22], [23], [24]. At first CPC checks the system at which operational mode the microgrid is working and then CPC sends signal to the control breaker. CPC also decides as to which of the system is to operate or stop.The control signal is send by the CPC to the control breaker so that, they can control the power from the DG's to meet the load demand .

3.3.2 Measuring and switch control

In the concept of distributed generation control of micro grid, the power controller is responsible for measuring and controlling of power. The measuring signal is send to the controller with the help of circuit breaker [25], [22], [26]. These control switches are operated according to change in measured power and change in load demand. Power measured by three phase voltage and current is compared with the generated power with the help of the comparing circuit. In this process we can on /off control breaker according to the load demand and change in DG's power.

3.4 Power management algorithm for PV System and grid

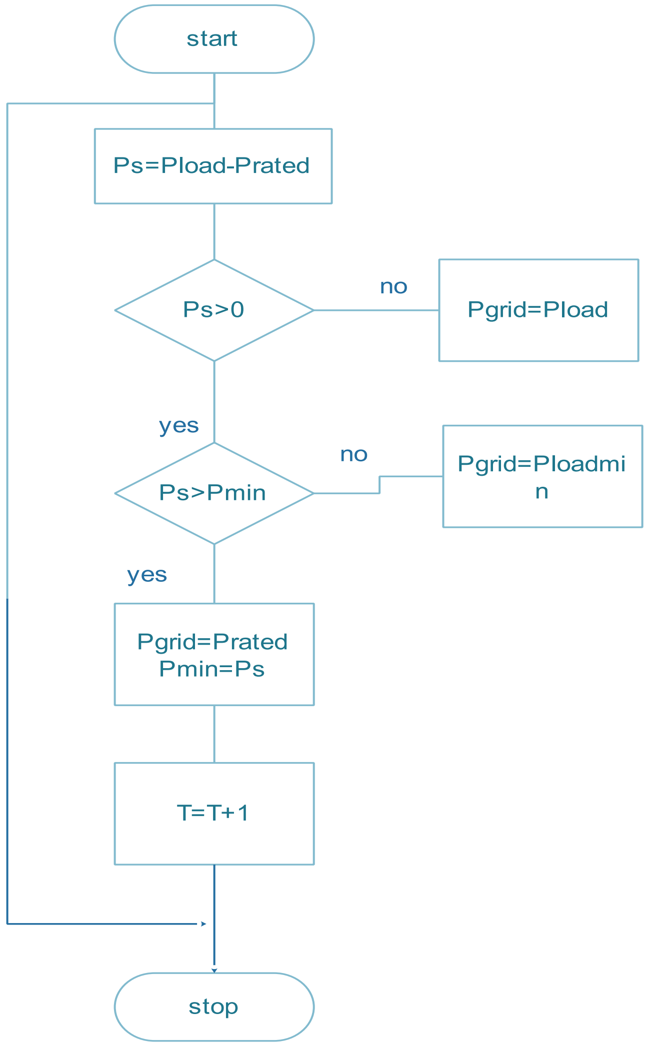

Figure 3.2 Power management algorithm for PV system and grid

The overall power management strategy for renewable energy source is given the highest priority to supply the primary load demand. The inverter fed through the PV generator is referred as the renewable energy supply. The net load is defined by the difference between the output from the renewable energy generator power supply and the primary load demand.

When there is shortage of power, the net load is greater than the minimum loading, but lowers than the rated value of the grid-form generator; the grid-form power generation will meet the NL. If the NL exceeds the grid-form generator's power rating, the grid-feed generator will be activated to supplement the power supply

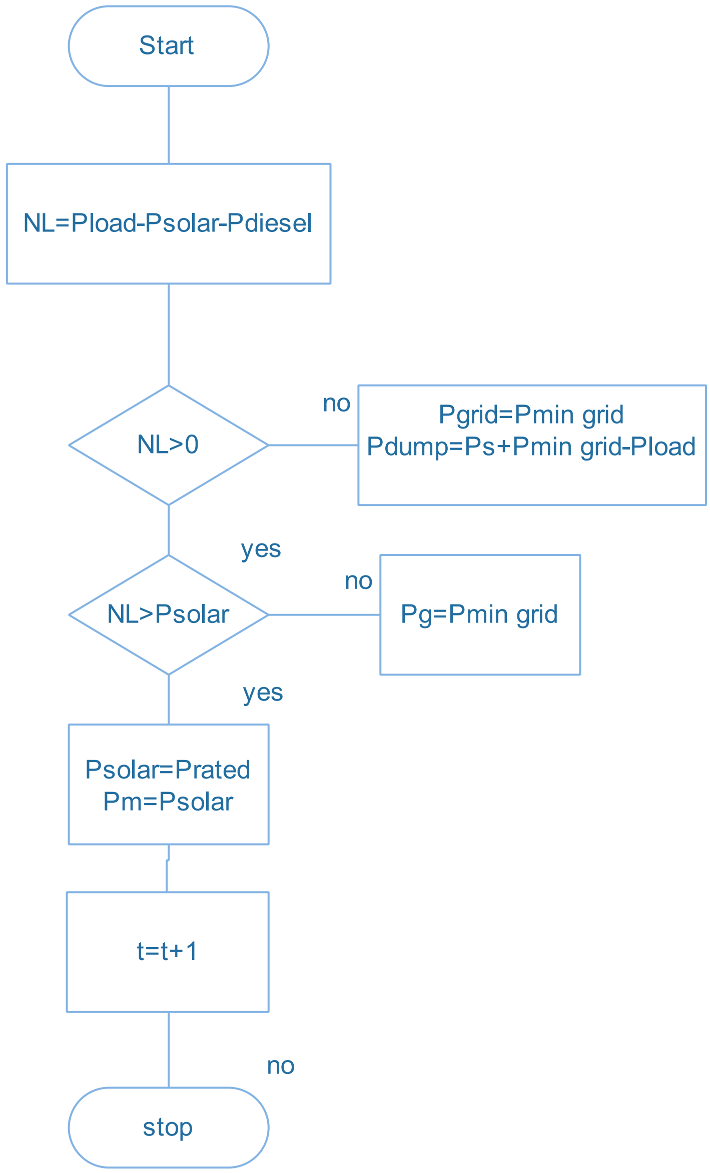

Figure 3.3 Power management algorithm for the PV-Diesel Main grid hybrid power system

A PV-Diesel hybrid power system operates in two states.

(i)The system operates without contribution of PV generator from during the night

(ii) The system operates without contribution of PV generator from during the night

For most locations, the solar cell contribution between 6am to 6pm is significant. During this period, major part of the load demand is supplied by the renewable energy. The operation of a typical PV-Diesel hybrid system has been shown in Figure

3.3. A synthesized load demand contour has been used to exhibit the changes in daily operation modes. The operation modes are described as below:

- The primary load demand is fed by the solar power plant only,
- If PV power availability is less then the net load demand is fed by the main grid and peak load demand has been met by diesel generator

3.5 Power management algorithm for main grid and wind plant

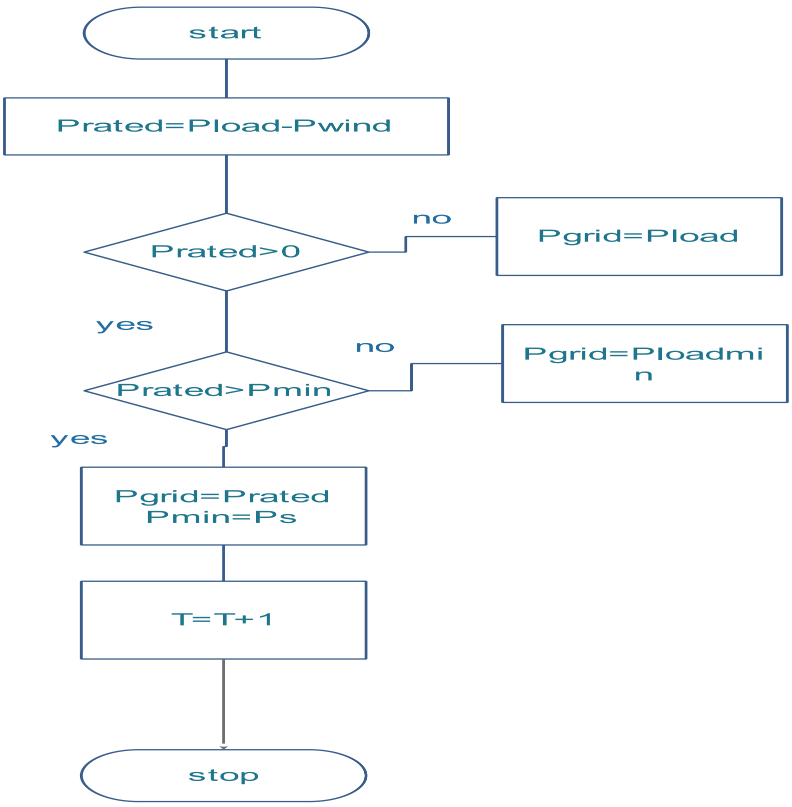

Figure 3.4 Power management algorithm for the PV- Main grid hybrid power system

The power management approach with a integrated wind energy system is shown in Figure 3.4. The wind energy is given the highest priority to feed the load demand. The net load is the difference between the output power of wind planter and the primary load demand.

When wind power is in excess after meeting the load requirements, then the utility will be fed from the wind source. And when there is shortage of power, then the utility will feed the net load.

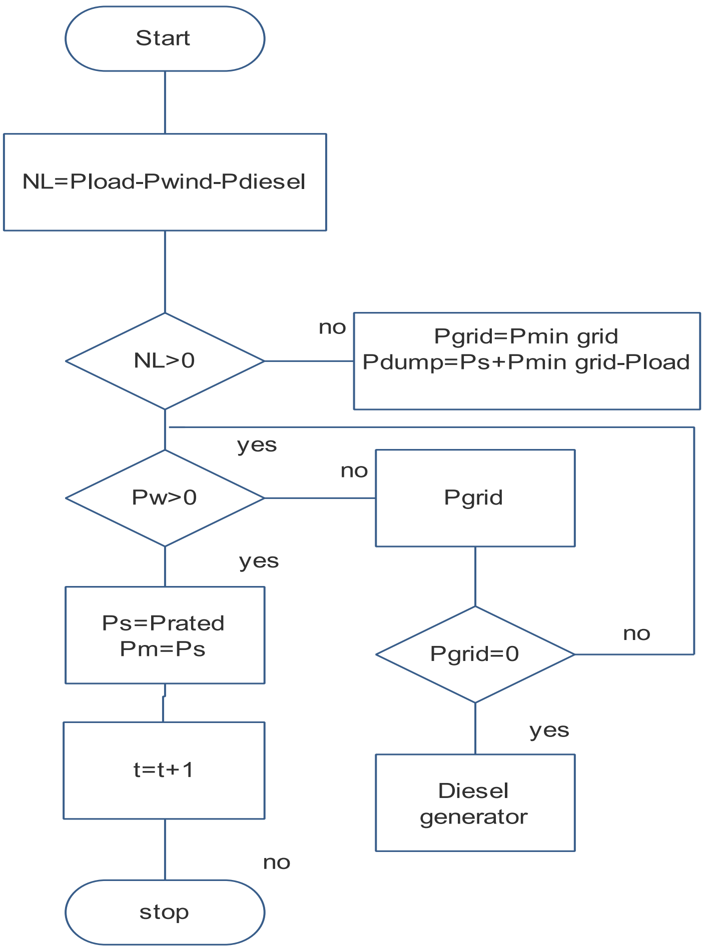

Figure 3.5 Power management algorithm for the PV-Diesel Main grid hybrid power system

Wind-Diesel hybrid power system operates in two states.

(i)The system operates without contribution of Wind Energy when the wind speed is less than the minimum or more than the maximum requirement of generator.

(ii) The system operates with contribution of Wind Energy when the wind speed is with the requirement of generator.

Normally wind generator is installed in the location where winds blow almost throughout the day with little variation in speed. Figure 3.5 shows typical operation modes (OM) of a PV-Diesel hybrid power system. A created load demand contour has been used to demonstrate the changes in operational modes of the system.

3.6 Power management micro grid system with the wind generation

The power management of micro grid is the different mode such as feeder flow mode UPFC mode this is new approach of an intelligent control algorithm. This configuration are using for the automatic load management system. In this central power controller are designed for the control of power according to availability of power and load demand in the system. Power controller can communicate with the load demand side or customer side and when load increases during peak hour's diesel generator is put ON [22].

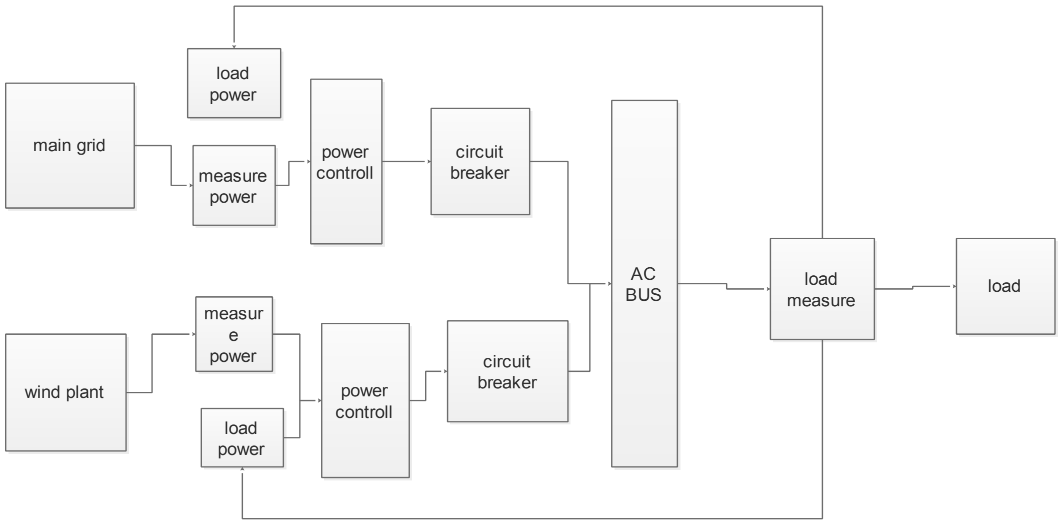

Figure 3.6 Design of power controller of wind generation and main grid

Fig 3.6 shows central power controller design for the control of power according to availability of power and load demand in this system. type of control and power controller can communicate with the load demand side or customer side and when load increases is at peak hours also ON the DG [20]. This also helps to improve power quality of the system and increases reliability of system. This power control can communicate with controlled circuit breaker to help ON / OFF the DG system.

3.7 Power management for PV system, wind plant, Diesel generator and main grid

The objective of this model is to optimize the available power or energy. The objective are set to trim down the fuel cost and active power control for different time as per generation from micro sources and renewable resources and according to priority level of load. They are operating at different condition or different modes.

- Output of the wind power plant is calculated with help of relation between wind speed and the output power of plant.
- Output power of solar photovoltaic panel is calculated with effects of solar radiation that is constant standard temp condition.

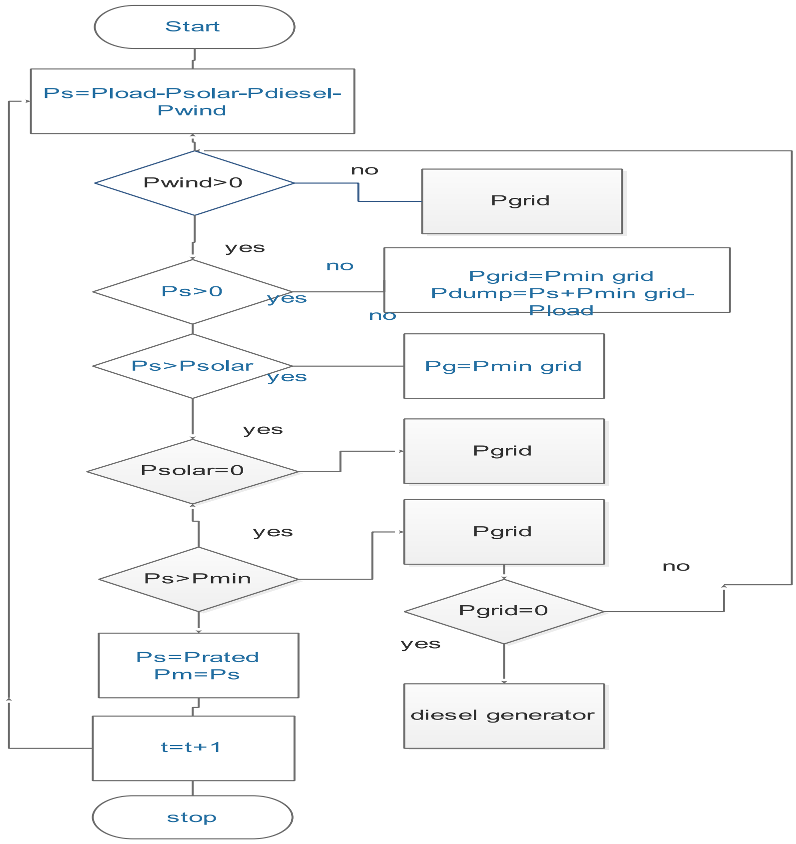

Figure 3.7 Power management algorithm for the PV-Diesel, wind and Main grid hybrid power system

Power management is shown in fig 3.7. It has been assumed that there is no data available prior to the prediction process. This implies that the synthesized data for the first N hour will be stored as historical data for the forecasts of the following days. Forecasts of the PV power and load demand are carried out simultaneously each hour to give the resultant. When the power generated from therenewable generator is lower than the load demand, the net load is met by the grid-form generator.This algorithm supports the selection of the grid-form or grid-feed generator by recording the accumulated run time of each diesel generator. The algorithm counts the diesel generator run time based on inputs such as the grid-form and grid-feed generator activation signals of each diesel generator.

3.8 Power controller for critical load

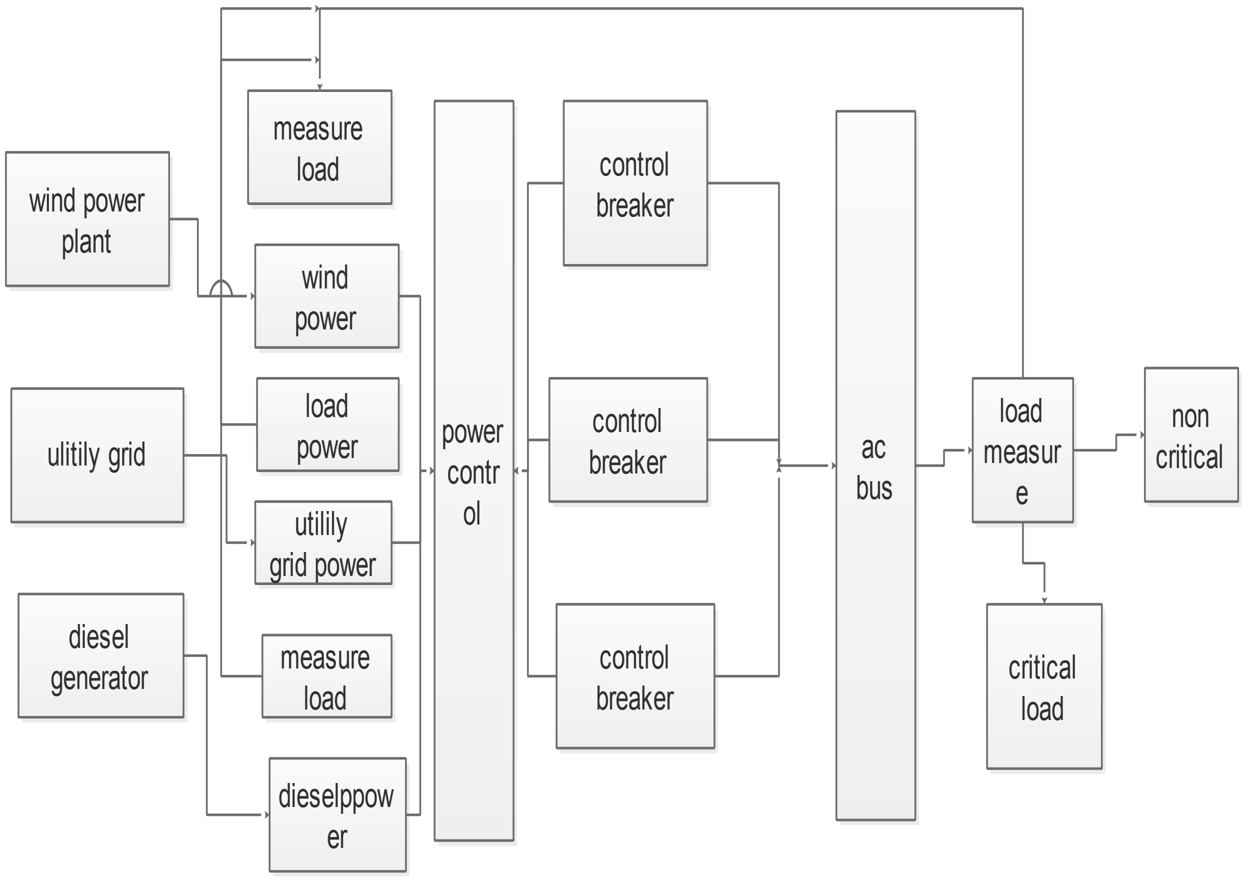

Figure 3-8 Structure of power controller critical load

This control scheme is shown in fig 3.8.Different distributed generations are connected with utility grid to share the power to fulfill net load demand and the power management system is developed for controlling power.

CHAPTER-4.
SIMULATION AND RESULTS

4.1 Simulation of the Power management on solar plant and utility grid

In operation and control of the solar plant and main grid, they are controlling power flow according to the power requirement of load demand and solar generation power, where power utility grid is according to load demand and the solar generation power is according to change in radiation input. So with change in irradiance solar power may not in constant generation. So we can control the solar power with utility grid as shown in fig 4.1. The power flow control in microgrid according to different operating mode has been considered i.e. grid connected mode and islanded mode with single generation system [22].

When considering grid connected mode. This mode is selected according to generation of solar power and load demand when solar generation is maximum utility grid is off. Then considering different cases according to change in solar power

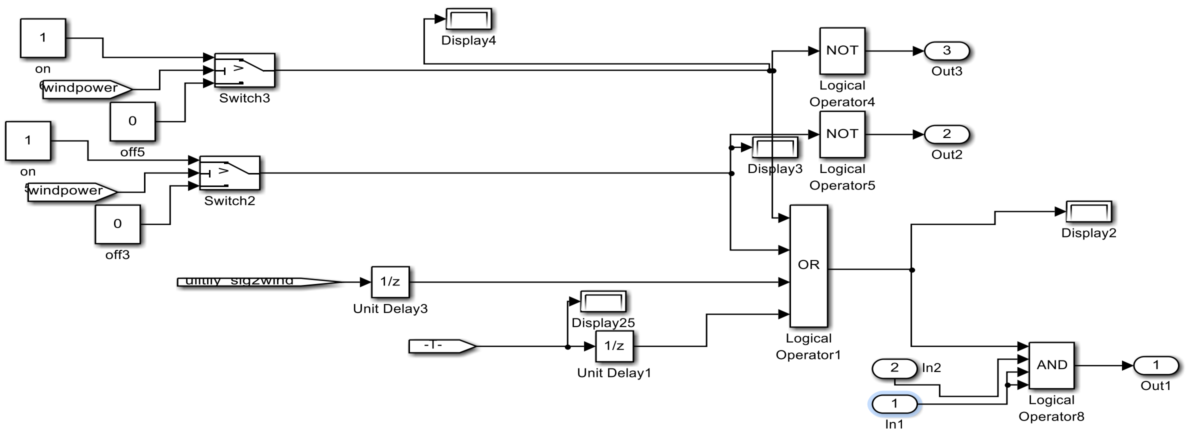

Figure 4.1 Implementation of the power controller for main grid and solar plant

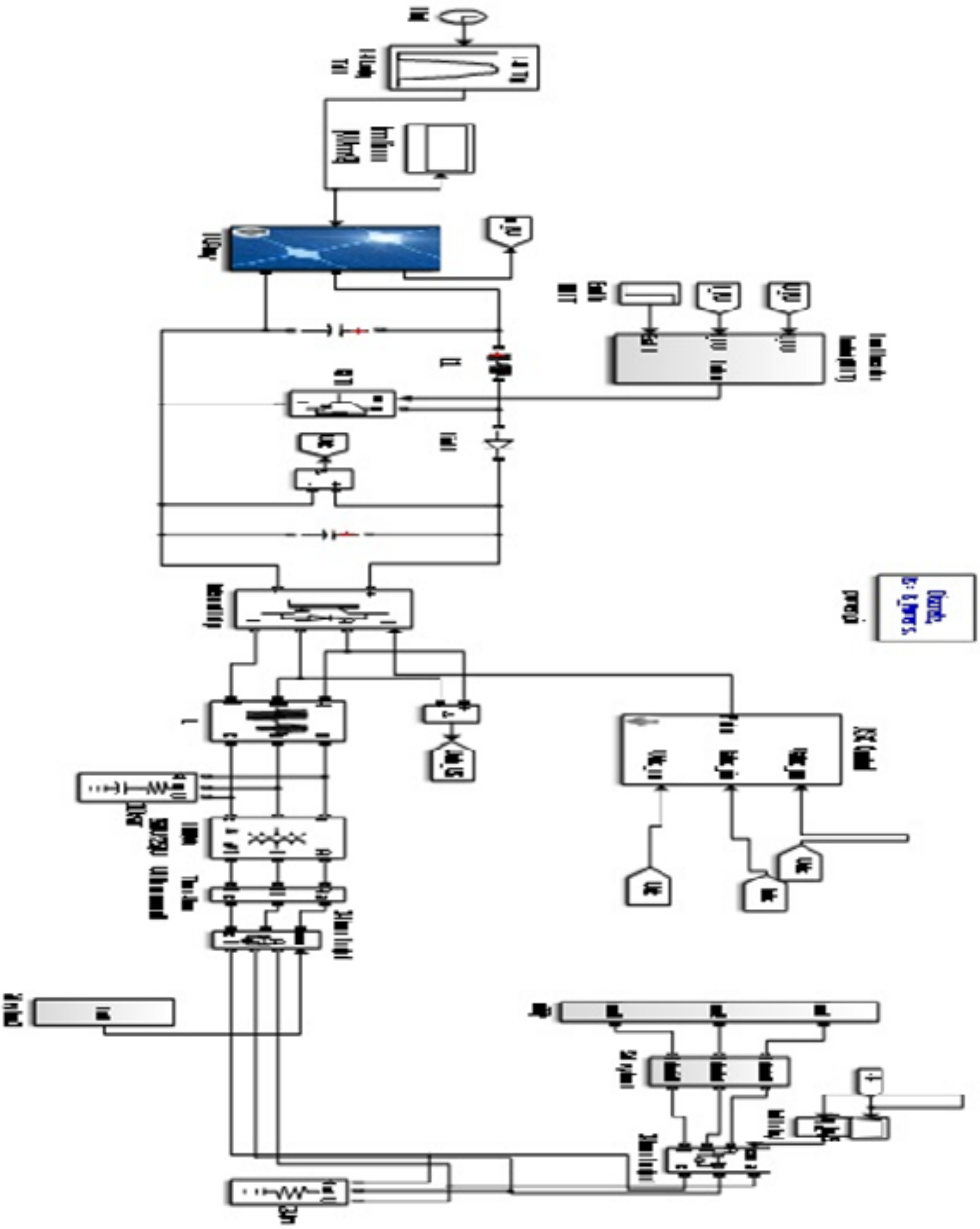

Figure 4.2 model of micro grid for controlling solar output power

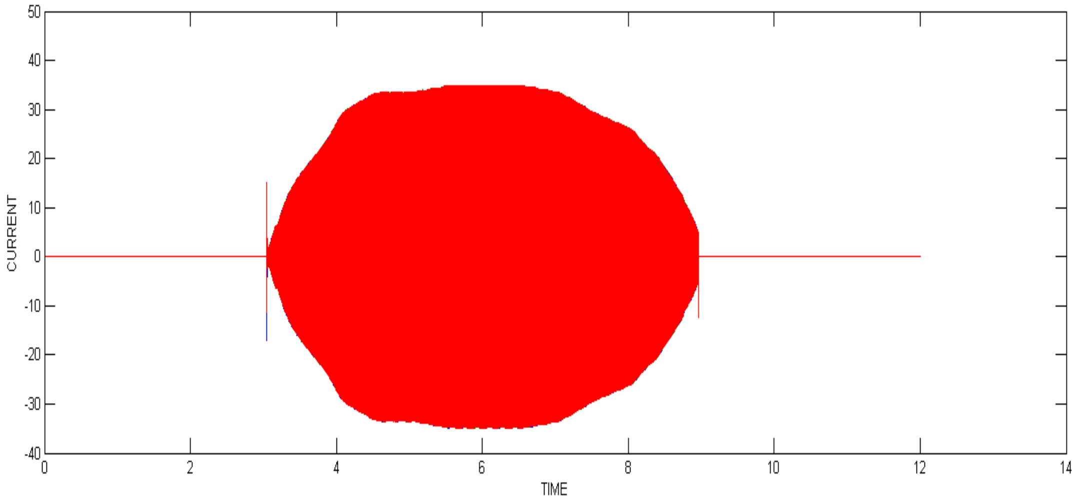

Figure 4.3 current of solar plant control

This result shows that when solar generation is maximum then it supplies total power to the load and when generation is zero and current of solar is also zero as shown in fig 4.3 and the power draw by load from main grid is shown in fig 4.4.

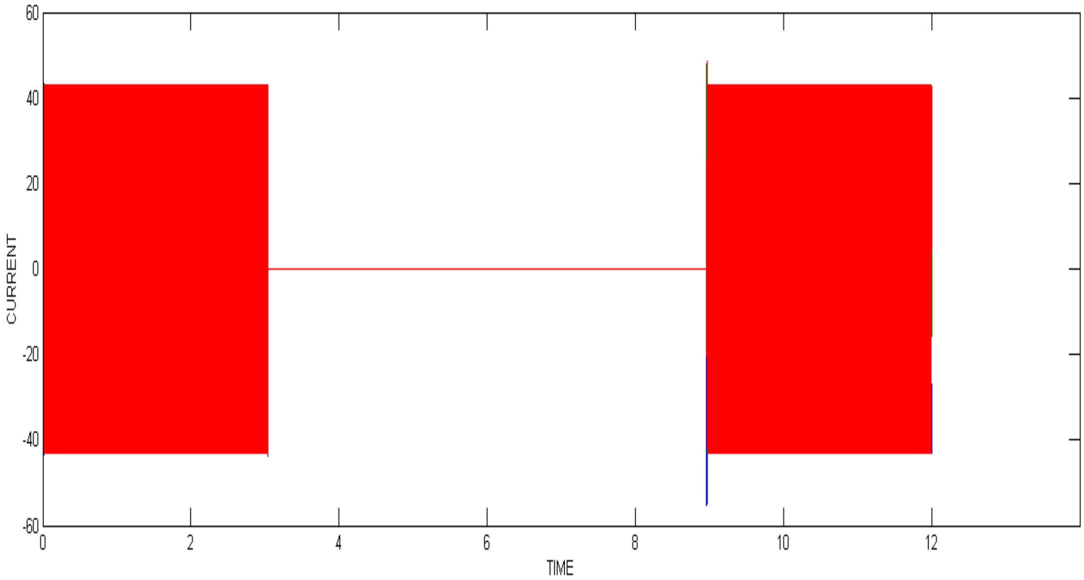

Figure 4.4 Maximum power generation by utility grid

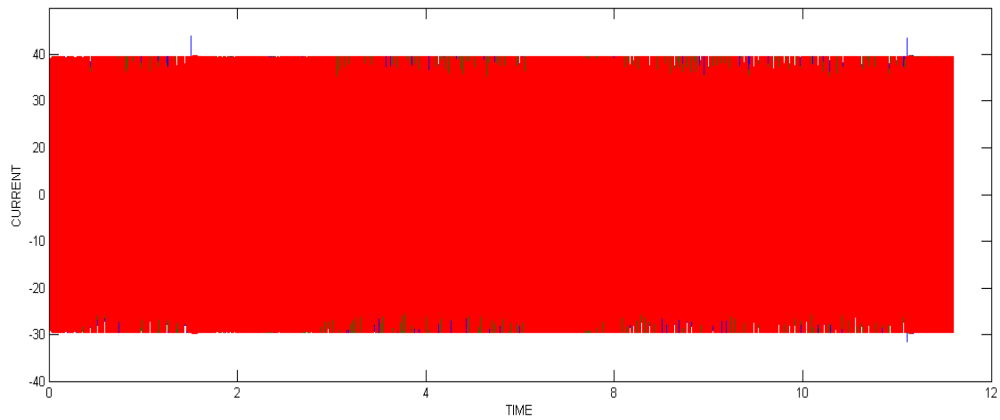

Figure 4.5 Load current

In First case when there is no solar generation then power could be drawn maximum from the main grid as shown in fig 4.4. The micro grid system is connected with the solar plant. The solar plant is not always giving maximum output so, power is drawn by load through main grid when the output of solar power plant (P_{solar}) is zero, power controller sends signal to controlled breaker. Control breaker functions ON/OFF according to the measured power send by the power controller are shown in fig 4.3 and 4.4. When P_{solar} power is zero or less then minimum load power is drawn from the utility grid. In first case when solar plant is delivering maximum power then solar plant is supplying power to load. When irradiance is zero then output of the solar plant is zero and hence load gets directly connected to the utility grid. Now power controller measures power demand of the load and power supplied by the solar plant, and sends signal to control circuit breaker. Then, the circuit breaker cuts off the solar plant if power output of solar plant is zero and it sends signal to the control breaker applied at the utility grid to supply the load. Fig 4.6 shows the irradiance data for solar panel.

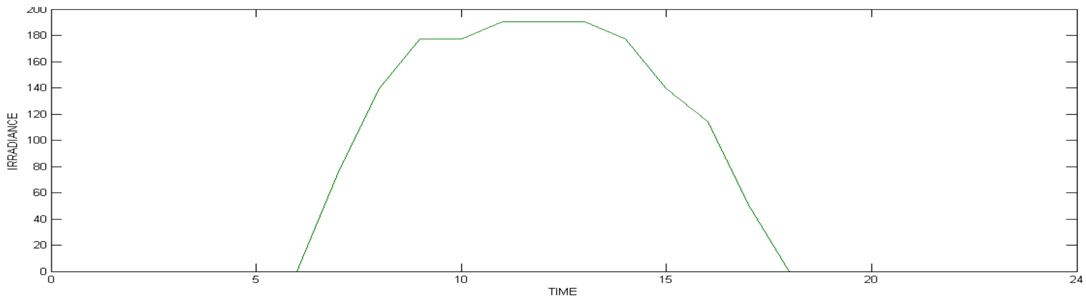

Figure 4.6 Input data of Solar irradiance

4.2 Simulation and results of solar, wind, diesel

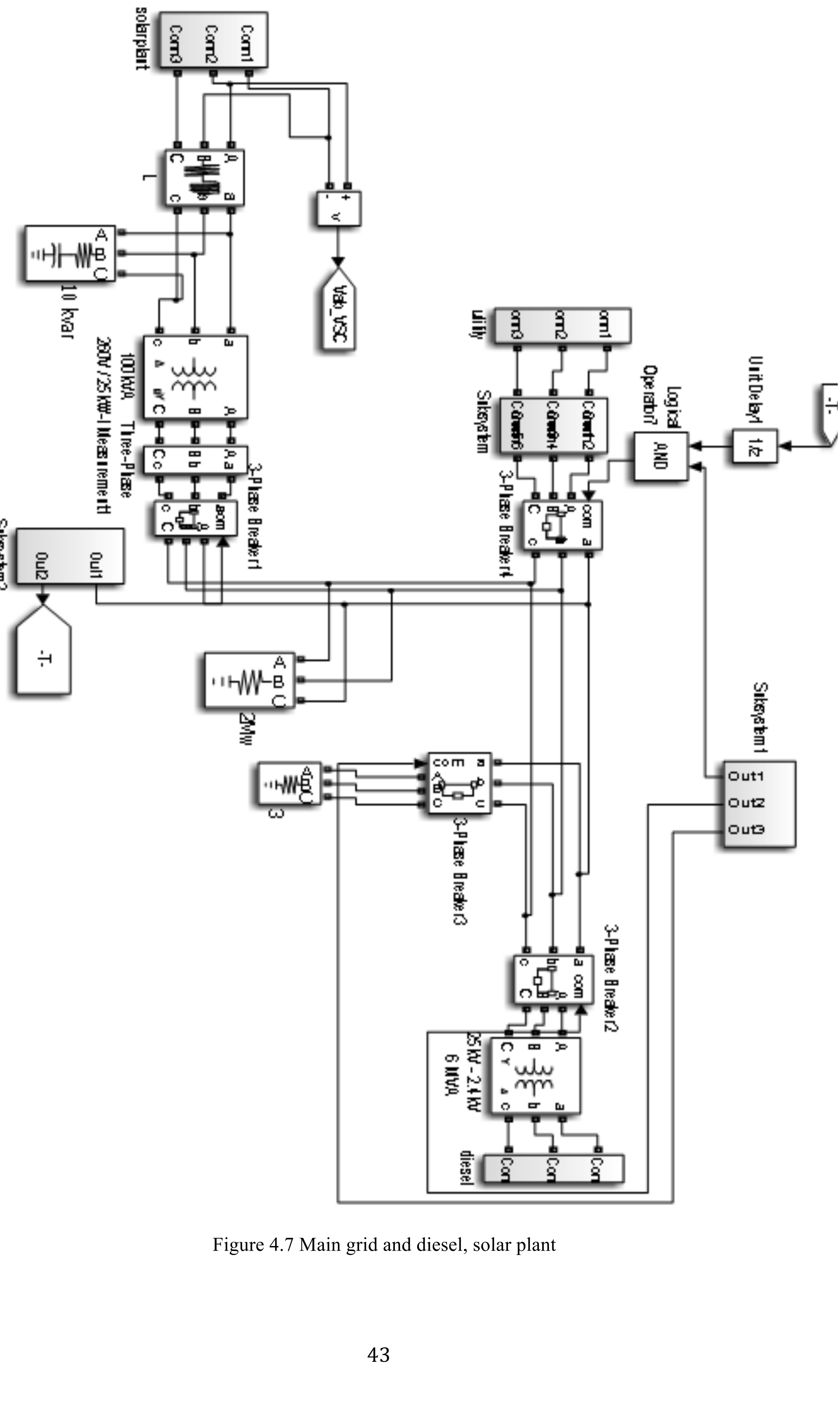

Figure 4.7 Main grid and diesel, solar plant

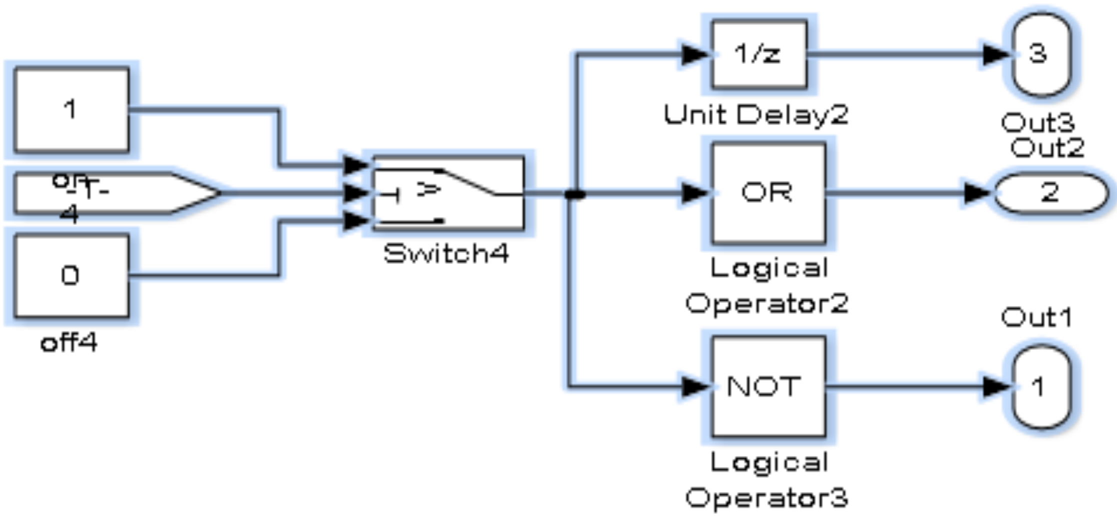

Figure 4.8 controlling of solar with main grid and diesel plant

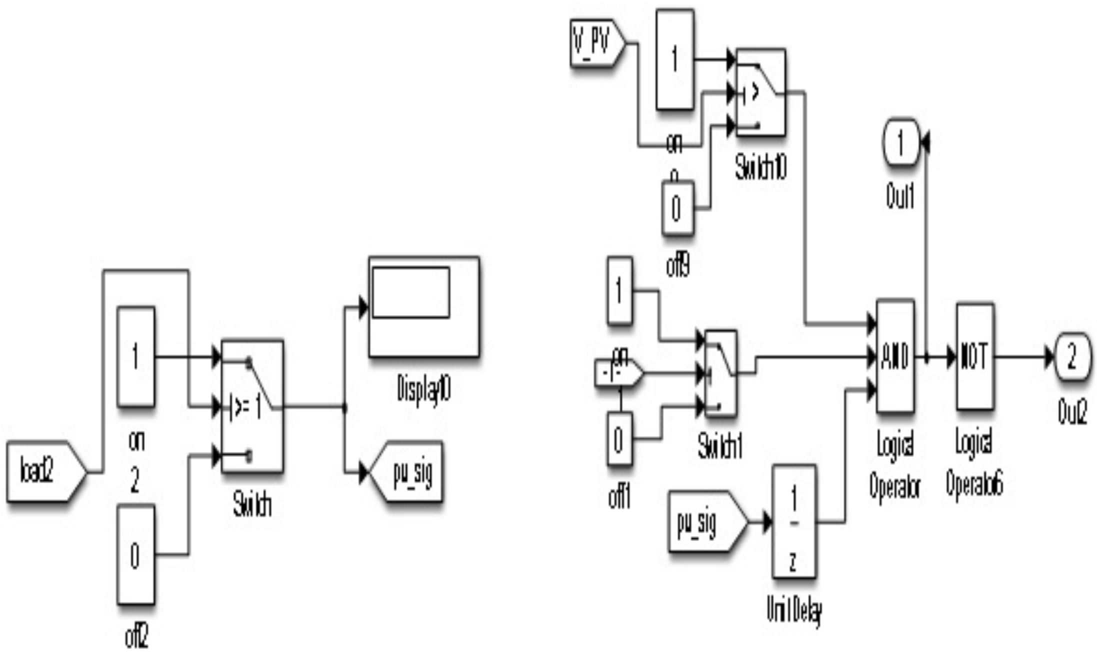

Figure 4.9 Power flow Controller for main grid and solar plant

Sometimes the demand of the load become higher than the generation then at the time some load is to be shut down and it also helps for the control of voltage and frequency for stable operation of micro grid. To fulfill the demand of various load in micro grid, the distributed source are incorporated with the utility grid. Power management controller fulfills demand of energy generated by distributed generation and critical load supplied by the controller in that system. Power management control identifies the power at the load side and makes a decision whether to connect or disconnect the load as per generation. Power management controller with restored voltage and frequency of utility grid completes resynchronization. Power management has trim down the fuel cost of distributed generation resource for customer. As power management meet the demand of load at customer. The model and the controllers are shown in fig. 4.7,4.8 4.9 and the results are shown in fig. 4.10

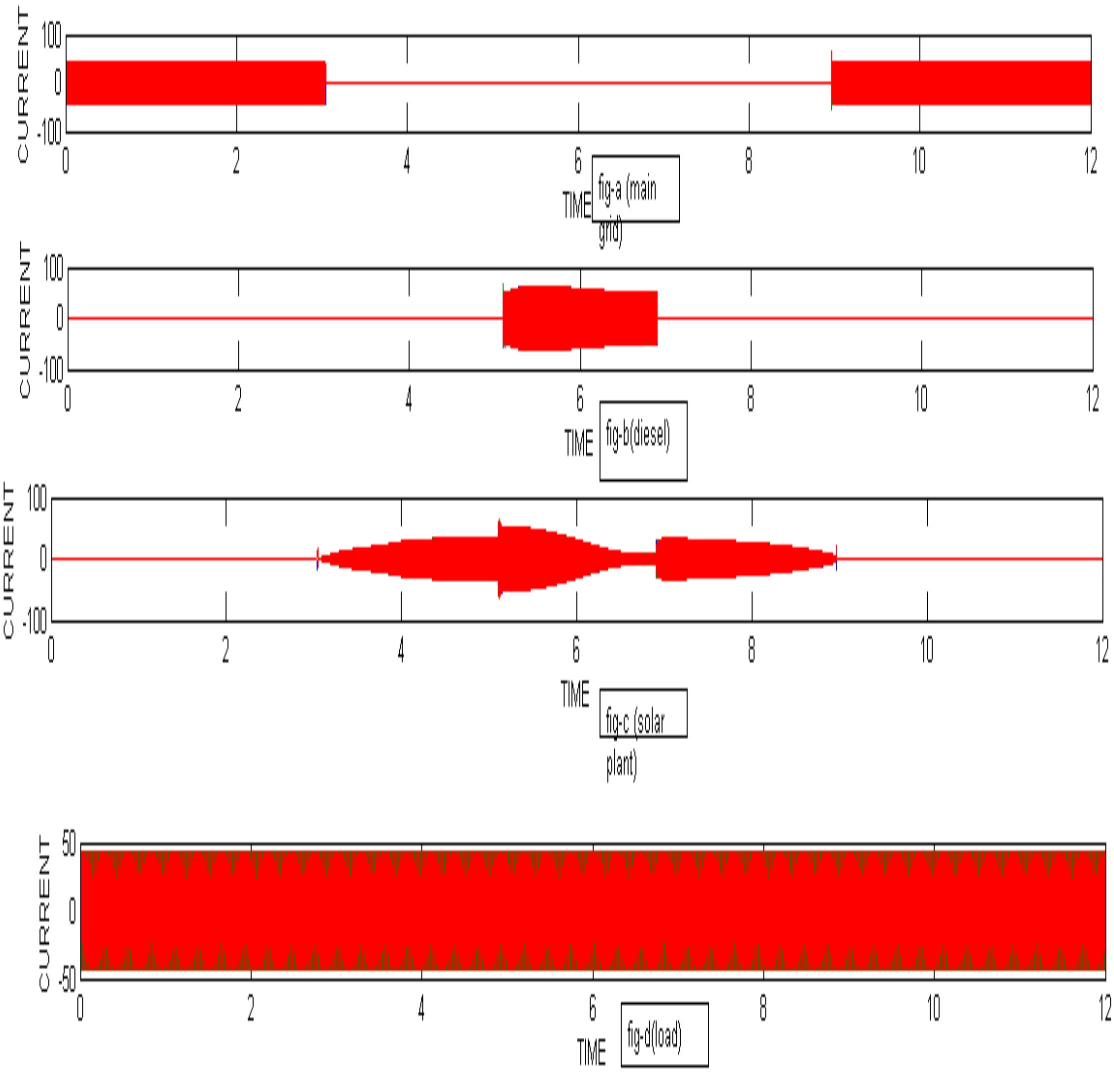

Figure 4.10 Result of wind, solar, diesel, main grid and load

4.3 Simulation and Results of utility and wind

The simulation model and power controller for the wind plant and utility has been shown in fig 4.11, 4.12,4.13. The result of controlled output between main grid and wind generation plant is shown in fig 4.14.

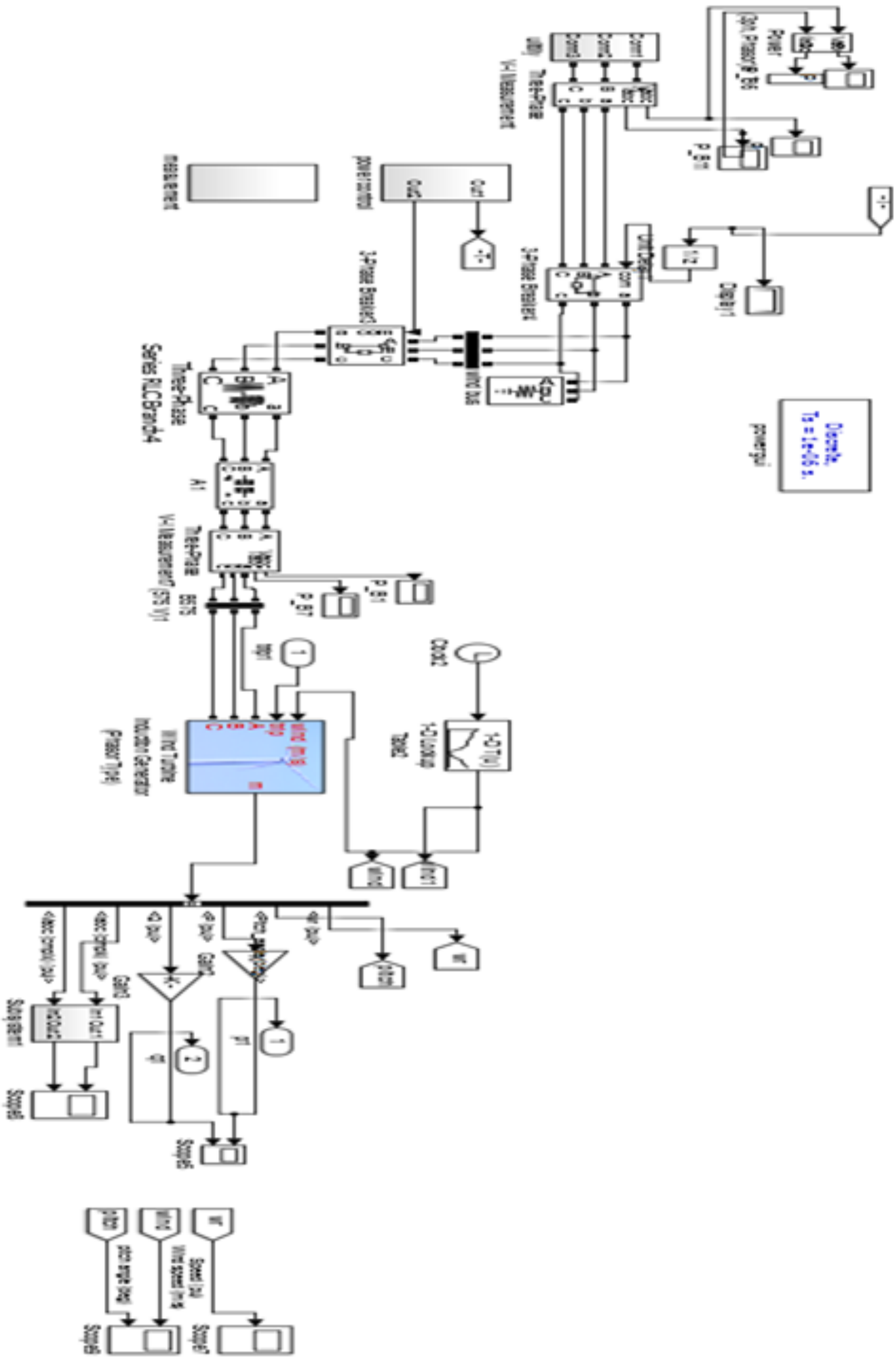

Figure 4.11 model of wind power plant and utility grid

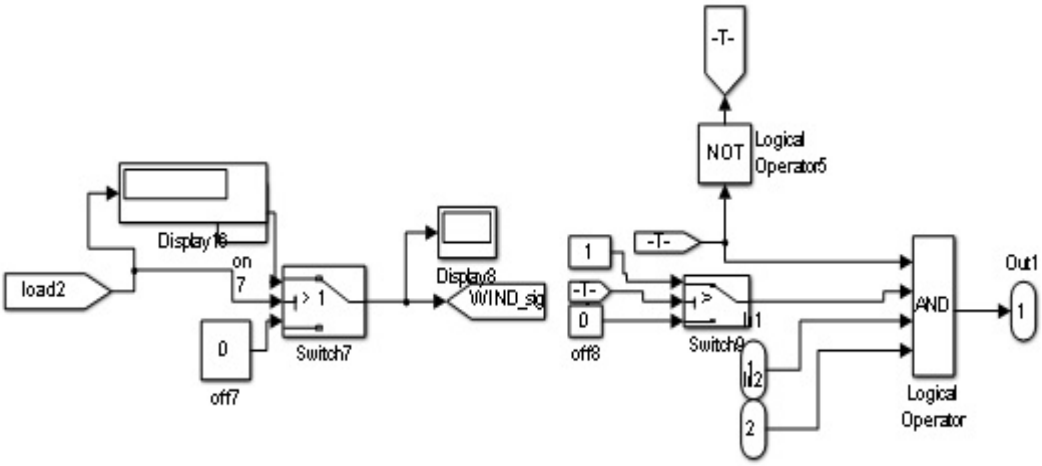

Figure 4.12 Power controller of wind plant and diesel

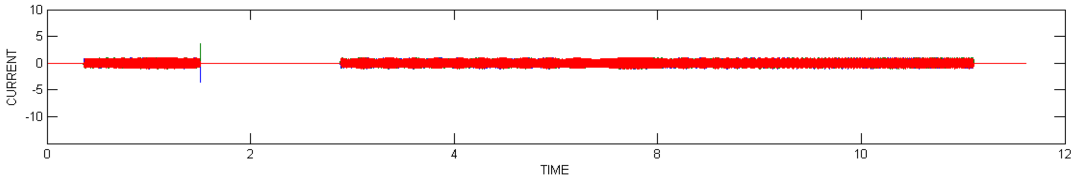

Figure 4.13 Current control by utility grid on

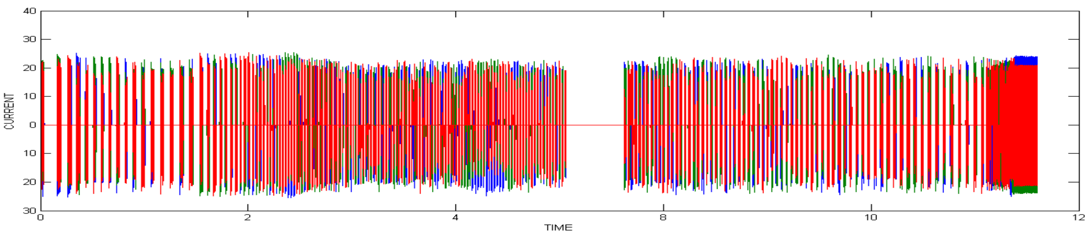

Figure 4.14 Load current power sharing by wind generation current flow

The power management of wind power plant and the main grid are controlled according to available power of plant and load demand. In this method we can measure power from wind power plant and utility grid when wind power is low, then power is drawn by the utility grid. First graph shows when utility grid is working and second graph shows power provided by wind turbine to the load. When power generated by the wind source is zero then power is drawn from the main grid to supply the load.

4.4 Simulation and result of utility and wind and diesel

4.4.1 Power flow for micro grid system

A. Grid connected mode   B. Standalone mode

A. **Grid connected mode**

The micro grid is operated in grid connected mode. In this model micro grid is connected with main grid to complete the load demand and It is compensating to mismatch the power between the load demand and wind generation. Main grid is operated at the different conditions such as when wind generation is low and load demand is met by the main grid it means that wind generation is always sharing power. When the wind speed is not satisfying the minimum or maximum limit of generating power, then at the time, the power controller isolates wind plant, and load demand met by the grid.

Different cases of grid connected modes

- Condition 1 Both P_{grid} and Pw delivered power load In this case Pw is always turn on with the P_{grid} for delivering power to load. Pw is always in ON state with the maximum limit.
- Condition2 Pw and P_{grid} delivered power to the load. In this case Pw delivered power is maximum but the load demand is more. Then at the same time the grid also delivers power.

B Standalone mode

The micro grid is operated in the standalone mode when the utility is disconnected. In this condition utility grid is not delivering power to load. The power controller measures renewable power and load demand and then disconnects some load due to insufficient power.

The micro grid system is designed for control of power to the distributed generation and load.In this case when the Pgrid power is unable to control or meet load demand and the main grid is also cut OFF under fault condition. Then the diesel generator is ON. The power sharing is done by diesel generator.

The simulation model and power controller for the wind plant, diesel and utility has been shown in fig 4.15, 4.16, 4.17 & 4.18. The result of controlled output between main grid, wind generation and diesel is shown in fig 4.19.

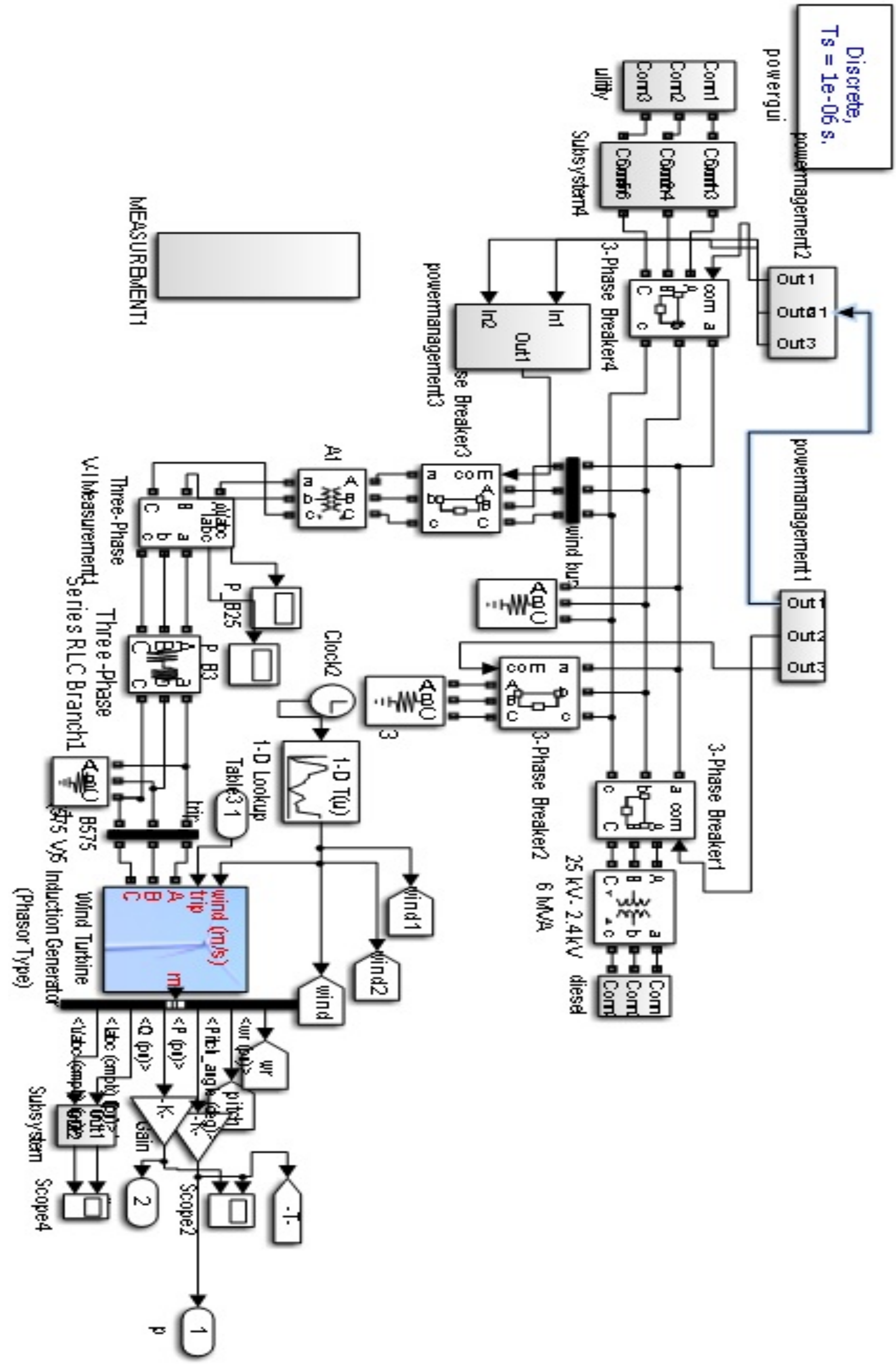

Figure 4.15 model of micro grid with operated diesel generator

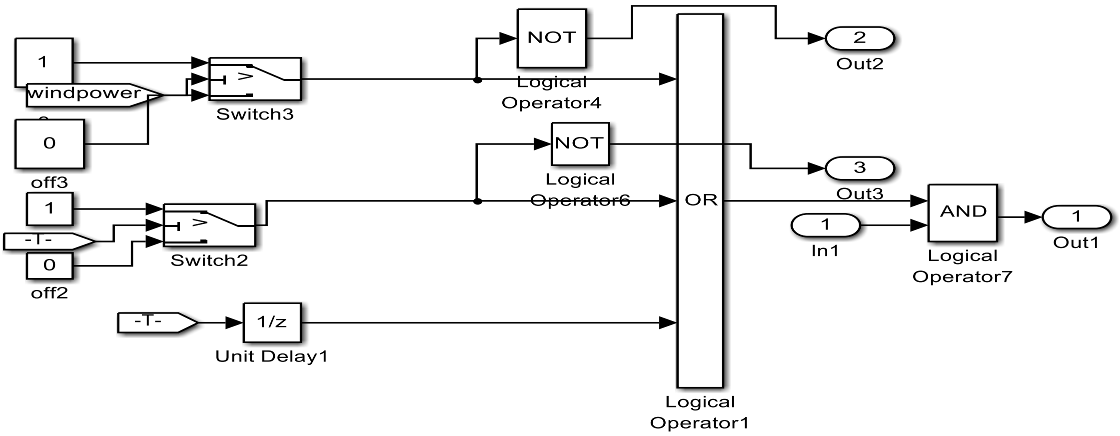

Figure 4.16 Power controller main grid and diesel generator for critical load

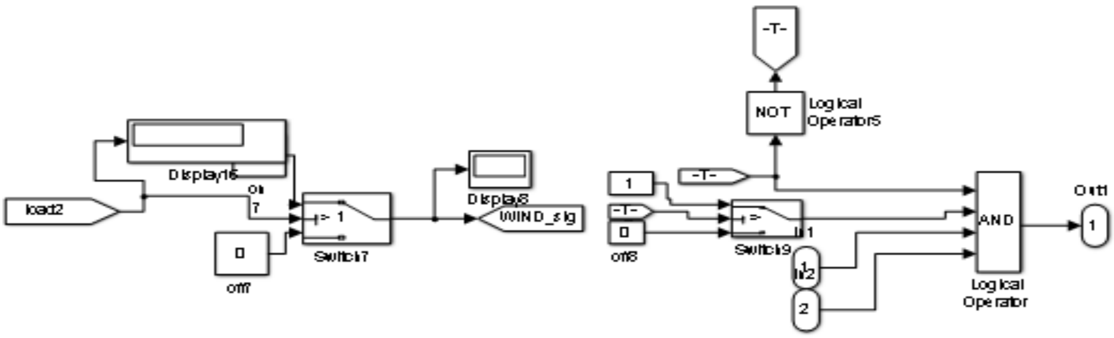

Figure 4.17 Power controller for main grid and solar plant

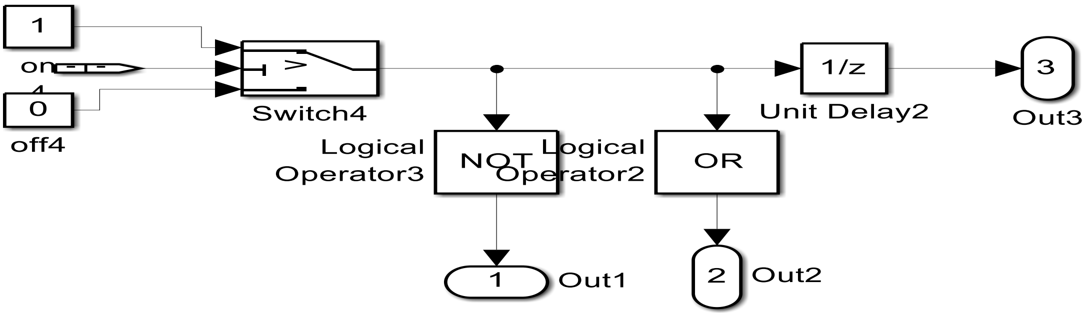

Figure 4.18 Power controller 3 for main grid and wind plant

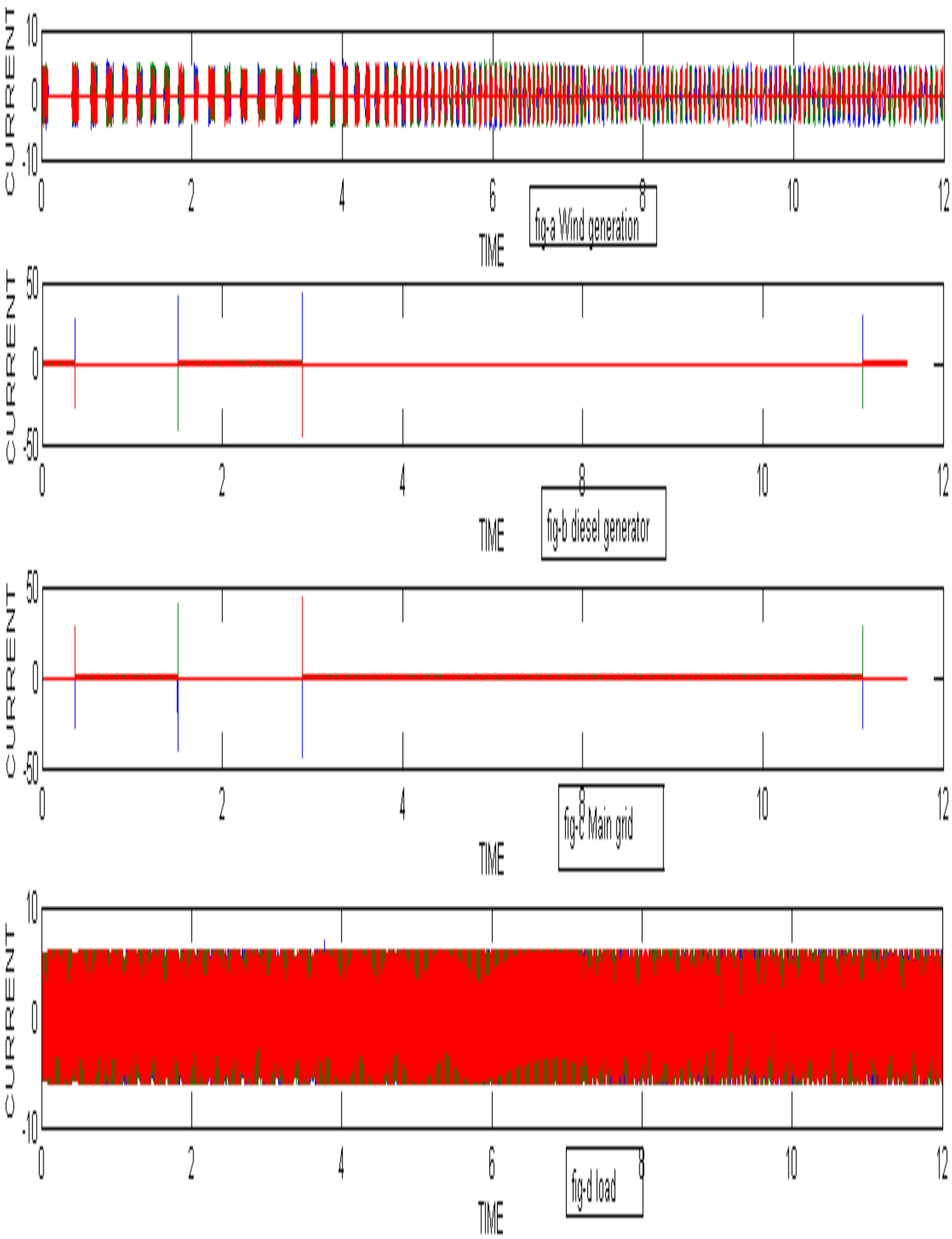

Figure 4.19 Results of power controller in the micro grid with wind, diesel and main grid.

4.5 Simulation and results of solar and wind, diesel, utility

The simulation model and power controller for the solar, wind plant, diesel and utility has been shown in fig 4.20, 4.21, 4.22 & 4.23. The result of controlled output between solar, main grid, wind generation and diesel is shown in fig 4.24.

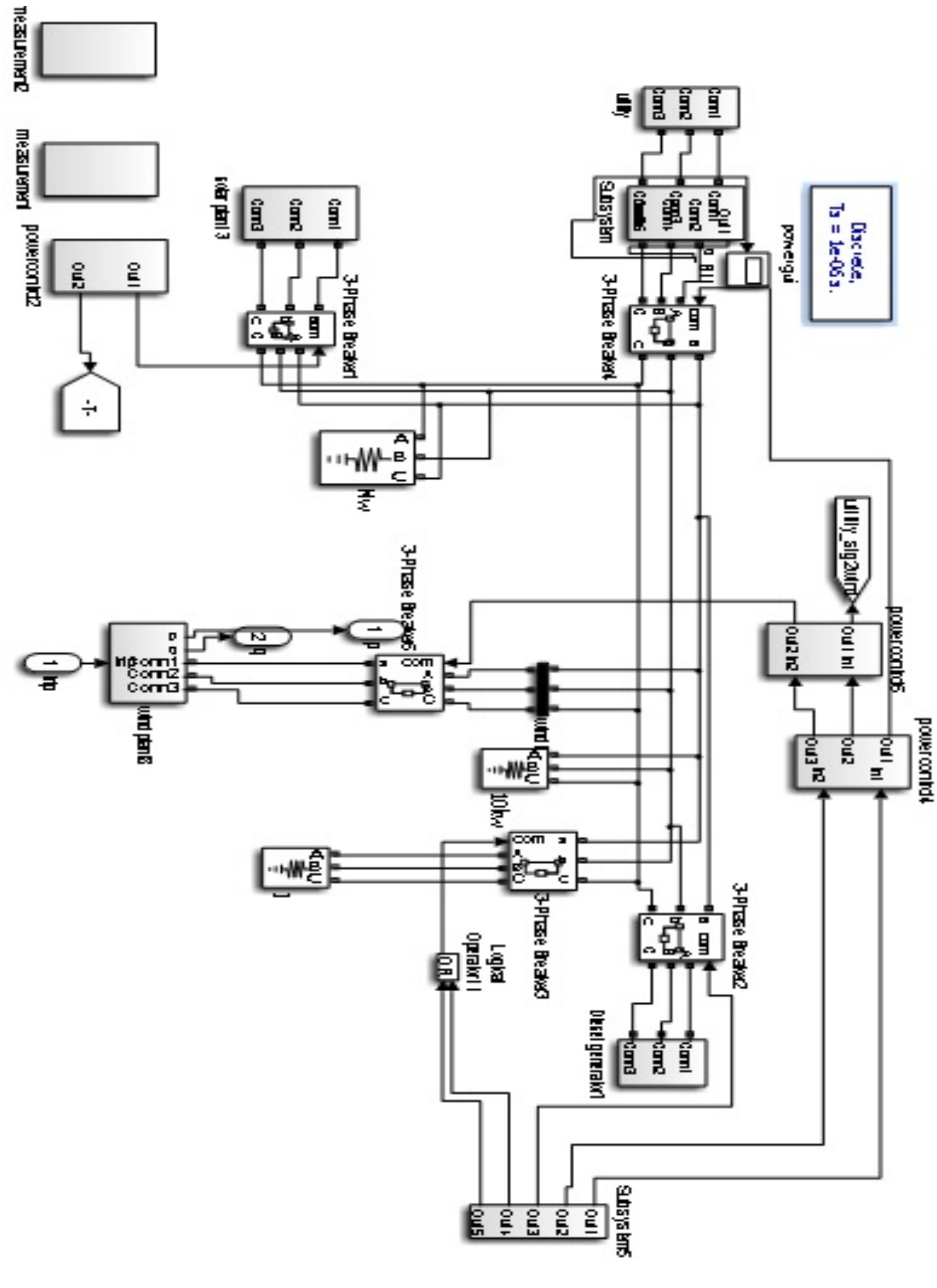

Figure 4.20 Complete model of micro grid

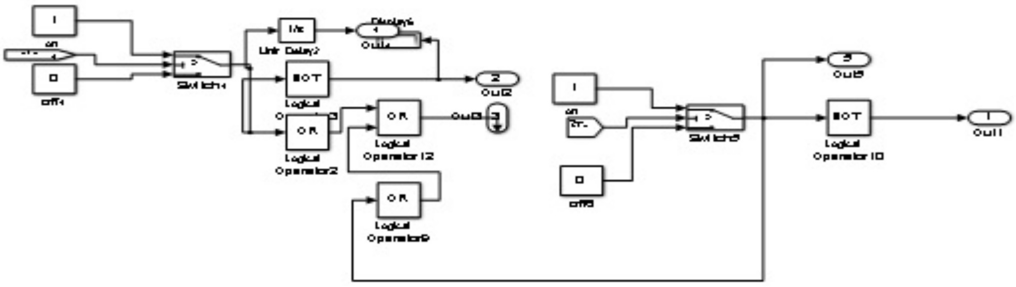

Figure 4.21 Power controller for wind plant and main grid

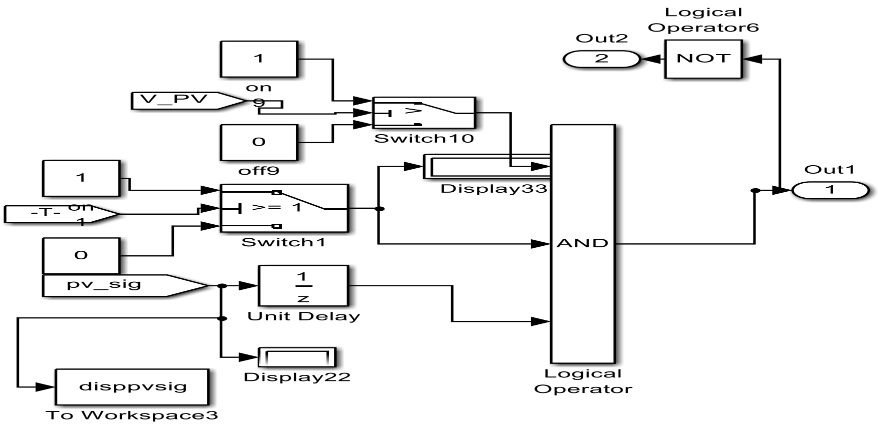

Figure 4.22 Power controller for main grid , diesel generator , critical load

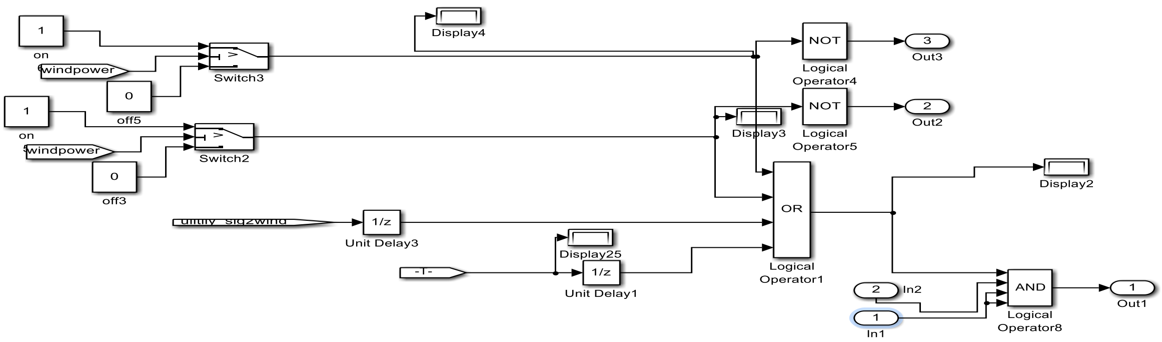

Figure 4.23 Power controller for main grid and solar plant

Results

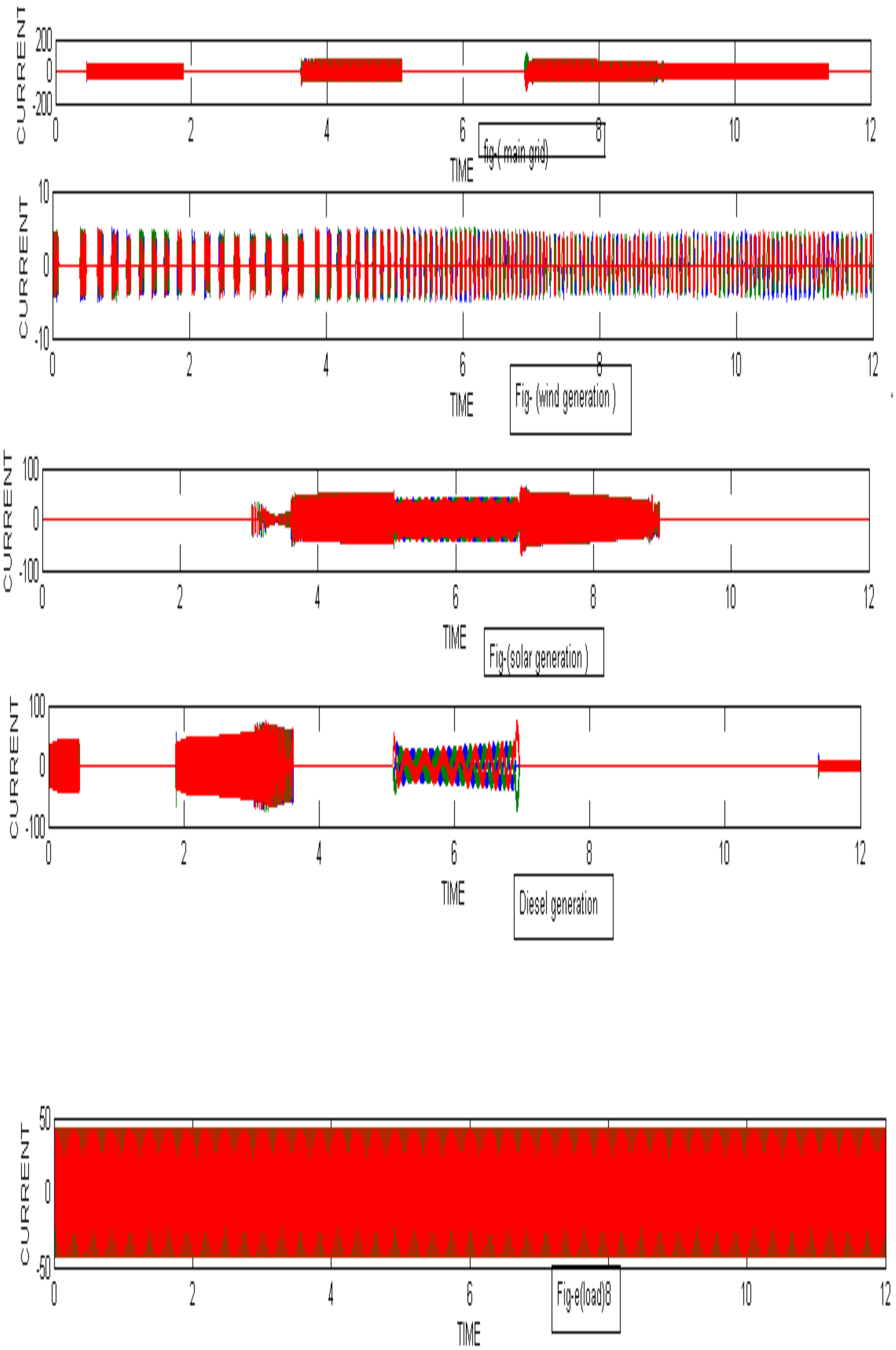

Figure 4.24 Output for main grid, diesel generator, solar generation and wind

CHAPTER-5.
CONCLUSION AND FUTURE SCOPE

5.1 Conclusion

In this work power management of the distributed generation in the micro grid is simulated with different conditions for power sharing. Control algorithm has been developed for sharing the power with the different distributed generators such as solar, wind, diesel and main grid. The power management controller has been the developed for controlling power and synchronization of grid.

The performance of the different condition for sharing has been tested successfully and results obtained for following condition.

- Considering only solar power and main grid for non critical loads.
- Considering solar power, diesel and main grid for critical loads.
- Considering only wind power and main grid for non critical loads.
- Considering wind power, diesel and main grid for critical loads.
- Considering only solar, wind, and diesel and main grid for critical loads.

5.2 Future scope

In this work we use for the sharing of power in the distributed generator purpose. This work is extended for the different configuration to use of the power sharing between the main grid and distributed generator with the help of different sharing method.

- This work can be compared with other different power sharing method.

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Micro Grid

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