DESIGN AND DEVELOPMENT OF CHARGE CONTROLLER FOR SOLAR PHOTOVOLTAIC SYSTEM WITH MPPT ALGORITHMS

DISSERTATION

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CERTIFICATE

I, **Sachin Pachauri**, Roll No. 2K14/PSY/15 student of **M. Tech. (Power System)**, hereby declare that the dissertation titled **"DESIGN AND DEVELOPMENT OF CHARGE CONTROLLER FOR SOLAR PHOTOVOLTAIC SYSTEM WITH MPPT ALGORITHMS"** under the supervision of Dr. M. Rizwan, Assistant Professor, Department of Electrical Engineering, Delhi Technological University in partial fulfillment of the requirement for the award of the degree of Master of Technology. This dissertation has not been submitted elsewhere for the award of any Degree.

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ABSTRACT

Solar photovoltaic (PV) technology is becoming more popular because of number of advantages. These advantages include zero greenhouse emission, low maintenance cost, least limitations with regard to site installation. However, the conversion efficiency of PV technology is very low about 15-18%. Also, the power generated from PV system is varying with meteorological parameters like solar irradiance, temperature etc.

It is very important to analyse the performance of Solar Photovoltaic system under different meteorological conditions and also track the maximum power point (MPP) using MPPT technique. By considering the aforesaid statements a performance analysis of perturb and observe (P&O), Incremental Conductance (I&C) come out and presented in this research work. The obtained result from their analysis are also compared.

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Abbreviations & List of Symbols

AC	Alternating Current
CO_2	Carbon di Oxide
DC	Direct Current
I&C	Incremental and conductance
I_{MPP}	Current at Maximum Power Point
Isc	Short Circuit Current
MPPT	Maximum Power point tracking
MW	Mega-Watt
p-p	Peak to Peak
P&O	Perturb and Observe
SPV	Solar Photovoltaic
SPWM	Sinusoidal Pulse Width Modulation
SOC	State of Charge
Voc	Open circuit Voltage
V_{MPP}	Voltage at Maximum Power Point
μH	Micro Henry
μF	Micro Farad
Ω	ohm

CHAPTER 1

INTRODUCTION

1.1 GENERAL

This part presents the general renewable energy and the motivation about the research work. In this chapter necessity is defined and the scope of this particular work is explained and provide the main objective of the research work

A developing country requires more energy. Nowadays, most of the energy supplied by fossil fuels such as diesel, coal, petrol, and gas is 80% of our current energy. On top of this energy demand is expected to grow by almost half over the next two decades. Plausibly this is causing some fear that our energy resources are starting to run out, with disturbing consequences for the global economy and global quality of life. Increasing demand of energy results in two main problem climate change and energy crisis. The global energy demand increases, the energy related greenhouse gas production increases. It is a global challenge to reduce the CO_2 emission and offer clean, sustainable and affordable energy. The worldwide increasing energy demand Energy saving is one cost effective solution, but does not tackle. Renewable energy is a good option because it gives a clean and green energy, with no CO_2 emission. Renewable energy is defined as energy that comes from resources which are naturally refilled on a human timescale such as sunlight, wind, rain, tides, waves and geothermal heat.

1.2 MAJOR RENEWABLE ENERGY SOURCES

1.2.1 Solar Energy

Solar energy is profusely available that has made it possible to harvest it and utilize it properly. Solar energy can be a standalone producing system or can be a grid connected generating unit depending on the availability of a grid nearby. Thus it can be used to produce power in rural areas where the availability of grids is very low. Solar energy is form of energy that directly available from sun and convert in to electrical energy, which is best form of energy without any climatic change and energy crisis. This conversion can be achieved with the help of PV cell or with solar power plants.

1.2.2 Wind Energy

The wind turbine can be used to harness the energy from the airflow. Now a day's wind energy can be used from 800 kW to 6 MW of rated power. Science power output is the function of the wind speed; it rapidly increases with increase in wind speed. In recent time have led to airfoil wind turbines, which is more efficient due to better aerodynamic structure.

1.3 MOTIVATION

India is a developing country and densely populated. The factors influencing its status are very common but lack of electricity is also a big issue in the development of this country. Lack of electricity factor can be eliminated by providing sufficient electricity to the increasing load demands. In rural areas where power supply is very unstable due to lack of quantity, there renewable power generation takes place for that small need.

According to Ministry of Power statistics, the inbuilt power generation capacity of India as on May 31, 2016 was 303083 MW [1]. Further, the total demand of load for electricity in India is expected to cross 950,000 MW by 2030 and it is beyond doubt that a substantial contribution would be from renewable energy. As on May 31, 2016, the current installed capacity of thermal power is 211670 MW which is 69.84% of total installed capacity. Current installed capacity of coal based thermal power is 186243 MW which comes to 61.45% of total installed base and current installed base of gas based thermal power is 24509MW which is 8.09% of total installed base, while Sebaceous (oil) based thermal power is 919 MW which is 0.3% of total installed base. In addition, 42783 MW of power is generated through large hydro and 5780 MW and 3882.51 MW of power is generated from nuclear energy and renewable energy sources respectively. The graphical representation of Indian power sector as on May 31, 2016 is presented in Fig. 1.1

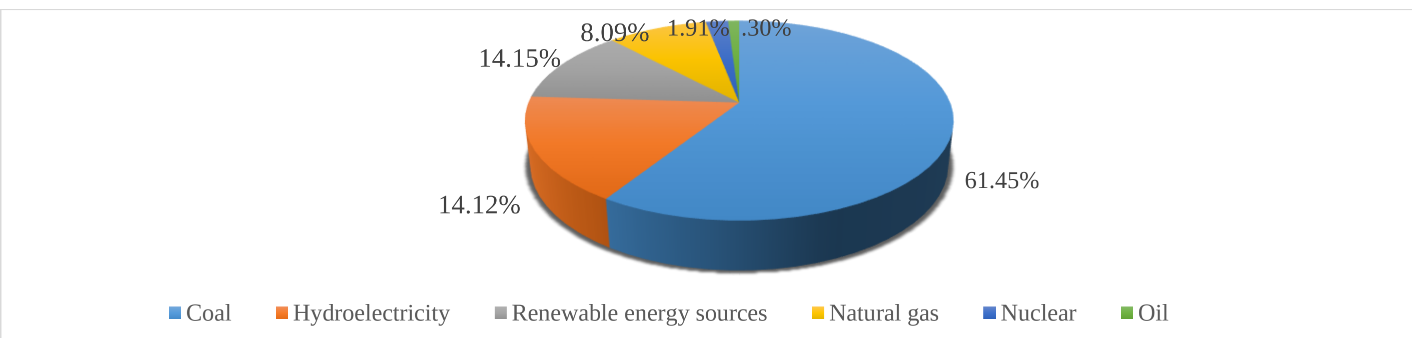

Fig. 1.1 Indian Power Sector at Glance

In the given survey it is clear that the contribution of renewable sources is very less. But it is increasing continuously as the advantages are more over fossil fuels. In these renewable sources wind power, solar power, small hydro power, biomass power, Bagasse Cogeneration and waste to power are some examples. The contribution of wind turbines is high in electricity generation.

Wind power generation is good and efficient for large scale production. But now watching the changes in cost of solar PV cells, attention goes to generate electricity from solar photo voltaic. One more reason is of getting huge power in the form of photons from the sun. That much amount of power is enough to generate continuous electricity for long duration. And this form of energy generation has some advantages also over others. On those bases, it is continuously growing in electricity production field.

New technologies are introducing in this field of generation. These kinds of approaches are making this system more useful for the future electricity generation. Solar power generation also generates by two ways: solar photo voltaic and solar thermal. This report concentrated on solar photo voltaic.

The main aim in nowadays is to maximize the power generation as required too. So the available areas of generation are limited. Still having that many opportunities solar power generation made a change in the running system strategy. This is adopted due to having numerous advantages in itself and one is that it is maintenance free system. Because of having these kinds of qualities, this system is adopted more quickly in domestic use too. The system can be installed at any scale means the system has a quality of running at any installed capacity. The only difference is of efficiency but it is not so big to worry about. So the advantage goes up of this system.

Table1 Projected Contribution of grid Interactive Power

Source	Capacity/Total Projected Capacity(MW)				
	30/06/2012	30/9/2013	31/03/2015	31/03/2017	31/03/2022
Conventional	180507.58	200537.39	202838.32	283000	383000
Wind				27300	38500
Small Hydro				5000	6600

Biomass	24832.68	28184.34	55863.13	5100	7300
Solar Power				4000	20000
Total	205340.26	228721.73	258701.45	324300	455100

1.4 SCOPE OF WORK

The power generated from PV system is varying with meteorological parameters like solar irradiance, temperature etc. Therefore, it is important to analyse the performance of PV system under different meteorological conditions and also track the maximum power point (MPP) using MPPT technique. Also the PV systems have very low overall efficiency about 13-20% as they suffer from many conversion losses. Hence this thesis is aimed to develop, analyze and study the simulation of the solar PV system with MPPT for improving the efficiency and performance. The main objective of this work is

- To design and develop MATLAB/Simulink model of Solar Photo Voltaic (SPV) system
- Performance analysis of Maximum Power Point Tracking (MPPT) techniques for PV system with battery storage.
- To develop the simulation charging model for single phase solar PV system with different MPPT technique.

1.5 ORGANIZATION OF DISSERTATION

CHAPTER 2–The chapter contains literature survey on solar PV technologies, DC/DC converters, MPPT techniques, battery storage system and SPWM inverters.

CHAPTER 3 – In this chapter solar PV technology, converter and the battery system is described.

CHAPTER 4 – A modeling & simulation of the given systems is described.

CHAPTER 5 – This chapter contains theoretical approach of different MPPT techniques.

CHAPTER 6 – Description of charge controller and MPPT technique for standalone SPV system

CHAPTER 7 – For a given systems measure the output with different charge controllers and the different MPPT technique. Also discussion on the result of the system

CHAPTER 9 – This chapter brings out the main conclusion of this research work and suggest for scope of further works.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter consists of a literature survey on various modules in this project. Various books and research paper related to Solar PV technology, MPPT algorithms, DC/DC converters, Battery charging and discharging and the inverter technology.

2.2 SOLAR PHOTOVOLTAIC TECHNOLOGY

Photo voltaic is the best known ecofriendly technology of electricity generation by sun into flow of electrons. This requires no extra circuitry to convert sunlight into electricity. The available solar energy is around 23000 TW, while world energy consumption is 16 TW. And many other resources are also available for generation but this is best from any point of view.

India have a vast solar energy potential, which is about 5000 trillion kWh/year (MNRE). Out of which we are able to generate the small amount of power i.e. 42849 MW as on 30 April 2016. Monocrystalline silicon is the more expansive and more efficient material than any other types of silicon material. Copper indium gallium selenide is a direct band gap material having high efficiency (~20%). Like these materials many others are also tried in solar photovoltaic and some are under experiment. Because of having low conversion efficiency, many new materials are introducing in this field of electricity generation.

2.3 MODELING, DESIGN AND SIMULATION OF PV ARRAY

A Solar cell is grouped in a module to form an array for the energy conversion. The array depends upon the power requirement to the particular load. So that is designed in a sequential manner. Many other parts are also assembled to the full circuitry of the PV panel. This complete arrangement is simulated in MATLAB/SIMULINK software.

Habbati Bellia presents a detailed modeling of the effect of temperature and irradiance on the parameters (voltage and current) of the PV module. The given model of the single diode model with both series and parallel resistors have a greater accuracy. The detailed modeling is then simulated using MATLAB/Simulink software by step by step, due to its frequent use and its effectiveness.

Natrajan Pandiarajan [3] et.al presented a complete model of solar PV power generation. The mathematical equations of currents are modeled and simulated in simulink. In this approach the complete PV model is connected to the converter and further to inverter. For maximum power point tracking, P&O methodology is used. Hence the P-V and I-V curves are plotted for various temperature and irradiance situations

A basic concept of PV array is proposed by Ram Krishan [4] et.al show the performance of PV array with variable temperature and irradiance. It is clear that sun light is not fixed at any time. This makes the solar power generation more complex. This depends on weather conditions for their out coming parameters. The output PV and IV characteristics are analyzed on different temperatures and irradiance conditions. This all is done using MATLAB/SIMULINK platform.

R. Chedid [5] et.al describe a new way to understand the significance of renewable energy resources. This is more effective due to having advantages like: less capital cost, increased efficiency and power electronic interface. Many universities are offering this branch of engineering in electrical and mechanical department to increase the use of this technology. This research shows the modes of design of PV cell to various operations. Experiments are modeled using mathematical analysis and MATLAB/SIMULINK software.

Yousef A. Mahmoud [6] et.al proposed a scheme to increase the efficiency of solar plate. And the efficiency of conversion of sunlight to electricity is very low. So they take many samples of materials to check the efficiency. Manufacturers gave less information of the plate and the required is more, so they analyze other parameters for their calculations. In which short circuit current, open circuit voltage and MPPT is included.

J.A Gow [7] developed a general model of solar PV array which can be implemented on various simulation platforms. Model is used to obtain P-V and I-V characteristics for the cell by taking temperature and irradiance as input parameter. The developed model is suitable for the use with power electronics interface.

2.4 POWER ELECTRONICS(DC-DC CONVERTER) INTERFACE

The output dc voltage level is very low, which is unable to achieve the load demand. So to make it in a desirable range power electronic components are required. In this scenario converters are used as boost, buck, half bridge, push pull, flyback, full bridge and buck-boost etc.

Swapnil Zadey [8] designed and simulated buck converter it can be seen that by using buck converter, we were able to convert variable current and voltage into a constant parameter. As the solar panel provides variable current and voltage depending upon the solar radiations.

Dr. B.J. Ranganath and Mr. Amurth [9] paper presents the application and design of proposed DC/DC buck-boost converter based MPPT +PWM charge controller and Artificial Neural Network technique used for optimizing the working condition.

G Deepak et.al [10] describe the concept of grid connected energy management solar system using batteries. Batteries provide the stable and reliable use of PV generation. A bidirectional DC/DC converter is used to control the battery charging and discharging. Inverter is also plays a vital role to convert the DC to AC form. Inverter is controlled by grid synchronization using microcontroller. Under this, various modes of operations are performed and verified. For MPPT, I&C method is utilized here. It provides stable output power irrespective of the solar irradiance.

Ahmed H. El Khateb [11] presented a combination of cuk and buck DC-DC converter for a standalone PV system. A MPPT control technique is implemented with the converter to provide a constant voltage/current to battery even under the changing atmospheric conditions. The proposed system has been tested under different operating conditions.

A.N. Natsheh, J.G. Kettleborough [12] paper describes the control of the bifurcation behaviour of a DC/DC buck-boost converter used to provide an interface between photovoltaic (PV) arrays and energy storage batteries for renewable energy sources.

Standalone photovoltaic charging system is proposed by B. Sree Manju [13] with control scheme. This work comprises a charge control phenomena in battery storage system. A boost converter is more efficient than buck-boost converter but it is only applicable where battery voltage is greater than PV module voltage. In battery, charge controller is attached to increase the battery life. This work is done in MATLAB/SIMULINK and can be installed in hardware form too.

2.5 MAXIMUM POWER POINT TRACKING ALGORITHMS

MPPT is the technique to maximize the power output from the PV panel. It takes the samples of the PV output voltage and current. There are many ways to achieve this by incremental conductance, open circuit voltage, perturb and observe, constant voltage, extremum seeking control, short circuit current and hybrid etc.

Bidyadhar Subudhi [14] presents the classification of different MPPT technique based on their control variables. Comparing of MPPT technique is done on the basis of circuitry, cost of their application and their technique which is useful for selecting a particular technique for a specified application.

Shaowu Li et.al [15] concentrate to the maximum power providing at any stage by the power generation. This maximum power output will be verified by the different converter like buck, boost, buck-boost converter . By the MPPT maximum power point is tracked to increase the system efficiency. System designed as per the application used.

In research of Moein Jazayeri **[**16] evaluate the maximum power point technique (MPPT). The research comprises the "perturb & observe" and "incremental conductance" methods of MPPT. A boost converter is designed with these MPP techniques. Experiments show the same characteristics of both two techniques under identical conditions. Incremental conductance is more complex but reached at MPP in shorter time. But due to simple structure P & O is preferred. The complete design is computed at MATLAB/SIMULINK platform.

F. Z. Hamidon et.al[17] presented a model of PV array with most widely used P & O maximum power point tracking algorithms. This model has been used to obtain PV array characteristics at different irradiance and temperature values. Further the authors analyzed the characteristics of the model on the basis of other parameters also like series resistance, shunt resistance and series parallel combination of PV modules.

Ali F Murtaza et.al[18] identified problems related to P & O MPPT technique and presented a hybrid technique in MATLAB/Simulink. Presented hybrid technique combines the two most widely used general MPPT techniques i.e. P & O and fractional open circuit voltage technique. The proposed hybrid technique overcome the demerits of P & O algorithms and provides a fast tracking speed even under rapidly changing atmospheric conditions.

Mostafa Mosal et.al[19] proposed a modified MPPT controller using a model predictive control. Developed controller has been implemented using DC-DC multilevel converter which is used to step up the small dc voltage. Performance of designed system has been analyzed under different solar irradiance and temperature conditions on a MATLAB/Simulink platform and obtain results are validated by using dSPACE 1103 control desk with a real time simulation.

2.6 BATTERY CHARGE CONTROLLER

A charge controller, charge regulator or battery regulator limits the rate at which electric current is added to or drawn from electric batteries. It prevents overcharging and may prevent against overvoltage, which can reduce battery performance or lifespan, and may pose a safety risk. To protect battery life, charge controller may prevent battery from deep discharging or it will perform controlled discharges, depending on the battery technology. The terms “charge controller” or“charge regulator” may refer to either a stand-alone device, or to control circuitry integrated within a battery pack, battery-powered device, or battery recharger.

Sherif Imam et.al [20] design different operating and design parameters on the sizing and economics of standalone PV systems for residential utilization and define component size and COE(cost of Energy). Also explain the effect of some parameter like battery bank voltage, solar irradiation and Demand of Discharge in the investing the COE.

Sarina Adhikari et.al[21] describe P-Q and V-f control of solar PV generator with battery storage and MPPT in micro grids. It provides small distributed generation system when required. The concept of MPPT is also used in this research for maximum power extraction. Battery is connected to store the power when there is more power available than required. Battery state of charge (SOC) is inbuilt for the battery charge control as over charge and under charge. V-f control makes this system more stable than any other diesel generators.

S.J. Chiang et.al describes [22] the current mode control and zero slope regulation is presented. Aexperimental 600W system is implemented to get the maximum power from the PV array with the help of the converter. It also proposed a residential storage system where the PV panel is controlled by the BESS.

2.7 INVERTER CONTROL TECHNIQUE

Fatima Binte Zia et. al [23] aimed to describe the inverter design for grid tied. In which it is clear that the inverter used in standalone is different from this grid tied inverter. While connecting to grid, some extra care to be taken so that during fault it didn’t affect the generation system. In this procedure the inverter compares its output parameters to the grid parameters. This whole is also verified on hardware too.

S. Yousofi-Darmian and S. Masoud Barakati[24] proposed a new four-level transformer-less single phase inverter design. This approach is used in residential areas due to its low cost and high efficiency. In these inverters leakage current flows through stray capacitors. This leakage current is harmful and causes losses and electromagnetic interferences. This inverter works on non-unity power factor and has low leakage losses. This is done by switching control strategy.

CHAPTER 3

AN OVERVIEW, DESIGN OF STANDALONE SOLAR PV SYSTEM

3.1 INTRODUCTION

This chapter presents a brief overview of solar photovoltaic technology. A detailed information regarding the solar photovoltaic system design is also provided by this text. Design and overview of a solar photovoltaic system. The parameters used to develop P-V and I-V curves are changing continuously.

3.2 SOLAR PHOTOVOLTAIC TECHNOLOGY

Solar energy can be utilized with the help of two technologies i.e. solar thermal technology and solar photovoltaic technology. In India, solar thermal technology for power generation is limited. However there is a drastic advancement in photovoltaic technology. The power generated from PV system can be expressed using the following equation:

$$P = Ax^2 + Bx + C \qquad \text{(Watts)} \qquad (3.1)$$

Where, P = power generation (watts),

x = solar radiation and

A, B, C are the constants, which may be derived from the measured data**.**

The photovoltaic (PV) cell is the smallest constituent in a photovoltaic system. Photovoltaic Cells are basically made up of a PN junction. In fact, when sunlight hits the cell, the photons are absorbed by the semiconductor atoms, freeing electrons from the negative layer. This free electron finds its path through an external circuit toward the positive layer resulting in an electric current from the positive layer to the negative one.

With the growing demand of solar power new technologies are being introduced and existing technologies are developing. There are four types of solar PV cells:

- ❖ Single Crystalline or Mono Crystalline
- ❖ Multi- or Poly-Crystalline
- ❖ Thin Film
- ❖ Amorphous Silicon

Single-Crystalline or Mono Crystalline:

It is widely available and the most efficient cell materials among all. They produce the most power per square foot of module. Each cell is cut from a single crystal. The wafers then further cut into the shape of rectangular cells to maximize the number of cells in the solar panel.

Polycrystalline Cells:

They are made from similar silicon material except that instead of being grown into a single crystal, they are melted and poured into a mold. This forms a square block that can be cut into square wafers with less waste of space or material than round single-crystal wafers.

Thin Film Panels:

It is the newest technology introduced to solar cell technology. Copper indium dieseline, cadmium telluride, and gallium arsenide are all thin film materials. They are directly deposited on glass, stainless steel, or other compatible substrate materials. Some of them perform slightly better than crystalline modules under low light conditions. A thin film is very thin-a few micrometer or less.

Amorphous Silicon:

Amorphous silicon is newest in the thin film technology. In this technology amorphous silicon vapor is deposited on a couple of micro meter thick amorphous films on stainless steel rolls. Compared to the crystalline silicon, this technology uses only 1% of the material.

Table 3.1 Efficiency of different type of solar cells

	Cell	**Efficiency (%)**
1	Monocrystalline	12 – 18
2	Polycrystalline	12 – 18
3	Thin film	8 – 10
4	Amorphous Silicon	6 – 8

3.3 TYPES OF SPV SYSTEM

There can be various types of solar system design. But there are two basic design consideration, they are-

1. Grid connected
2. Stand alone

Grid Connected:

The system is mainly composed of a matrix of PV arrays, which converts the sunlight to DC power, and a power conditioning unit that converts the DC power to AC power. The generated AC power is injected into the grid and/or utilized by the local loads. In some cases, storage devices are used to improve the availability of the power generated by the PV system. Grid tied systems have the potential for the customer to sell back generated power at cost to the utility.

Standalone System:

Stand-alone systems can be built to power small loads, like water pumps and street lights, to the vast loads of a house. The equipment required to build a stand-alone system includes a solar panel, a voltage controller, and batteries. For loads that require AC power, an inverter would be added to the design. To control the output voltage of a panel, an MPPT is employed to increase the efficiency of the power to the batteries and load. The components of each system vary due to the size of the load and the hours of operation during the night. For projects that operate during the day, the battery may only need to last minutes to hours, depending on the load. Systems that have loads that operate at night require determining the number of hours the load operates and from this the panel and batteries are selected. Dependability of the load must be considered to determine the amount of reserve energy the system must have to provide continuous operation. The advantages of a stand-alone system are independent from the power grid, replacement of petroleum-fueled generators, and cost effective compared to running the power lines to remote areas. The disadvantages are the availability of the grid power to most locations, the cost and replacement of equipment, and the loss of power during periods of poor solar insolation.

3.4 PV ARRAY AND ITS CHARACTERSTICS

PV technology enables direct conversion of sunlight to electricity through semiconductor devices called solar cells. The power produced by solar cell is not enough for power generation applications. To obtain the higher power, solar cells are interconnected and hermetically sealed to constitute a photovoltaic module. Further, series – parallel combination of PV modules constitute a PV array. The equivalent circuit of PV module is presented in Fig. 3.1.

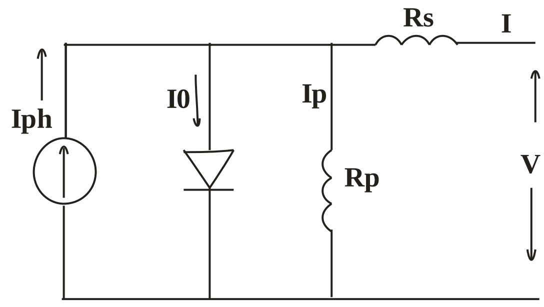

Fig. 3.1 Equivalent Circuit Model of Solar cell

P-V and I-V characteristics of Photovoltaic system 5000W for different irradiance levels like 1000w/m^2 at the fixed temperature of 25^{o}C is plotted and presented in figure 3.2 and 3.3

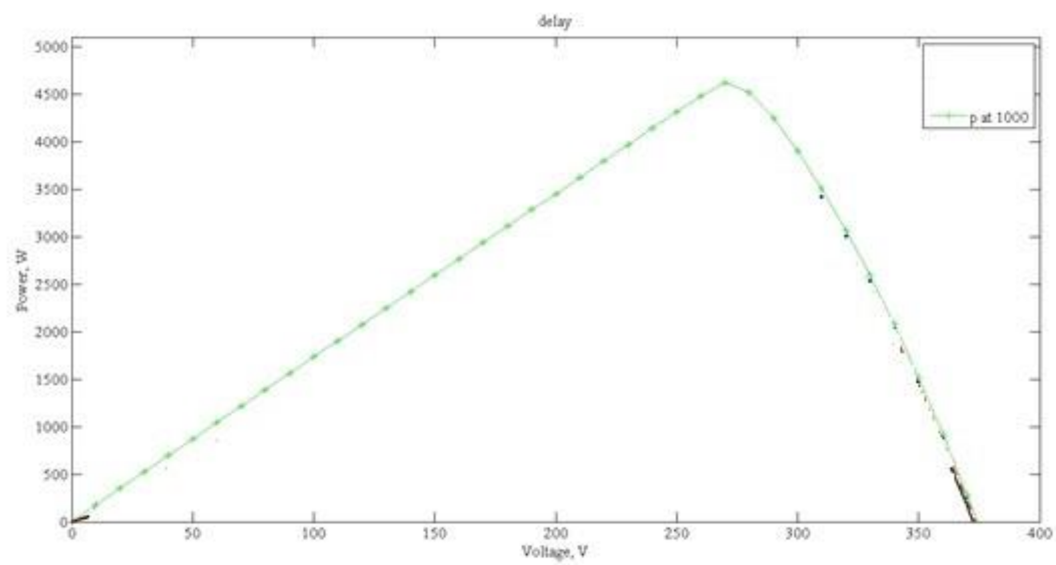

Fig. 3.2 P-V Characteristics of Photovoltaic System

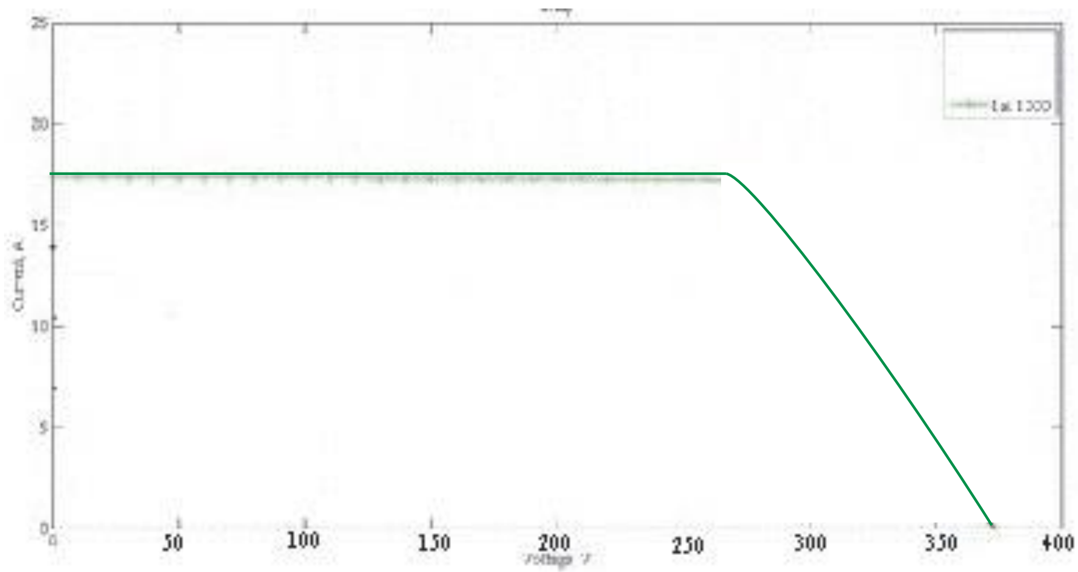

Fig. 3.3 I-V Characteristics of Photovoltaic System

3.5 DC - DC BOOST CONVERTER

DC–DC converter is used to interface the PV array to dc bus to perform three major functions including step up/step down the PV voltage, regulate the varying dc output voltage of PV array and implement the MPPT of solar array to ensure operation at maximum efficiency. However, there are various topologies of DC-DC converter including buck, boost, push pull, half bridge, full bridge, flyback, buck-boost etc. The choice of topology depends on system requirements and its applications. In this paper, DC-DC boost converter is designed to step up the PV voltage.

A boost converter is designed to step up a fluctuating or variable input voltage to a constant output voltage. To produce a constant output voltage feedback loop is used. The output voltage is compared with a reference voltage and a PWM wave is generated. It has been studied that the efficiency of the DC to DC converter is maximum for a buck converter, then for a buck-boost converter and minimum for a boost converter but as we intend to use our system either for tying to a grid or for a water pumping system, so we use a boost converter.

The circuit diagram for boost converter is presented in Fig. 3.4, and the data of various parameters of buck converter are presented in Table 3.2.

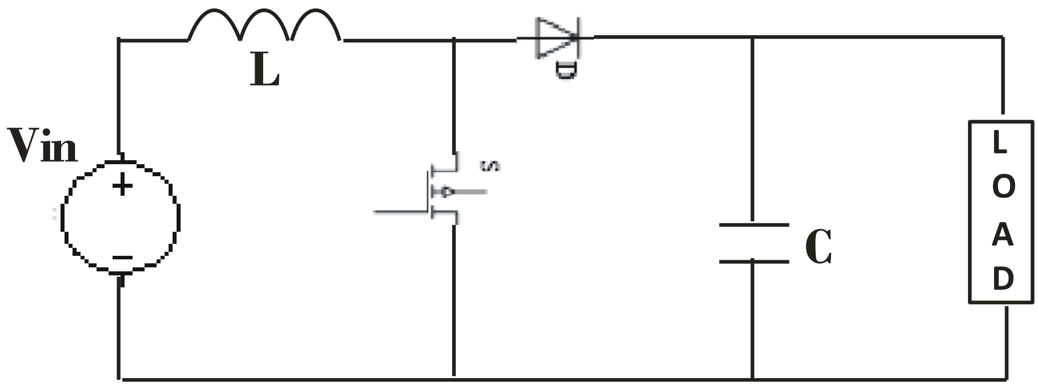

Fig. 3.4 Boost Converter Circuit Diagram

Table 3.2 Various parameters of Boost converter

S. No.	Parameter	Formula
1.	Output Voltage	$\frac{V_{PV}}{(1-\mathrm{D})}$
2.	Inductance (L)	$\frac{V_{PV}}{f_{sw}\,\Delta I_L}$ D
3.	Output Capacitance (C)	$\frac{I_{out}}{f_{sw}\,\Delta V_O}$ D

3.6 BATTERY STORAGE SYSTEM

The primary storage energy source is the battery bank. The battery bank usually consists of a many number of batteries connected in series or parallel. Each battery in the bank is typically 6 or 12V, and multiple batteries are connected in series or parallel to obtain the desired system voltage.

A individual battery is actually made from multiple "cells. There are many types of commercial batteries available today. Some examples particularly applicable for solar are sealed (maintenance free) lithium-iron , Lead-acid, silver-zinc and zinc-air. Among of them Lead-acid batteries is used because of its relatively cheap cost and ease of availability. One major drawback of it is a relatively large weight/energy density ratio. Each type of batteries have different characteristics (e.g. energy density/kg, charge/discharge rate) and uses however a comprehensive study of batteries is beyond the scope of this thesis.

The power generated from PV system is fluctuating in nature, therefore there is a need of storage systems. In addition, energy storage systems are useful in both utility and small scale applications. The battery storage systems in grid connected systems helps to achieve the objectives like mitigation of the variability and intermittency of PV power by ensuring the maintenance of constant voltage and frequency meeting the peak electricity demand during low power generation from PV system. There are many battery models are available in literature. However, this paper uses the lead acid battery. This model is chosen for its simplicity, low cost and easy availability.

$$\mathrm{E} = E_0 + A[\exp\{-B\int idt\} - 1] - K\frac{\mathrm{Q}}{Q - i\int dt} \qquad (3.2)$$

where E0 is the no load battery voltage (V), K is the polarization voltage (V), Q is the battery capacity (Ah), A is the exponential zone amplitude (V), B is the exponential zone time constant inverse (Ah)−1, VBattery is the battery voltage (V), Rin is the battery internal resistance (Ω), IBattery is the battery current (A), and ∫i dt is the charge supplied and drawn by the battery (Ah)**.**

$$V_{battery} = E - R_{in}I_{battery} \qquad (3.3)$$

3.7 DESIGNING OF H-BRIDGE INVERTER

The main function of the inverter is to ensure that the PV modules are operated at the maximum power point (MPP) by ably supporting the DC converters. The other is to inject a near sinusoidal current into the load with fewer harmonics. The inverters can be operated in two modes such as

1. Square wave inverters
2. PWM inverters of following types

- Single pulse width modulation
- Multiple pulse width modulation
- Sinusoidal pulse width modulation

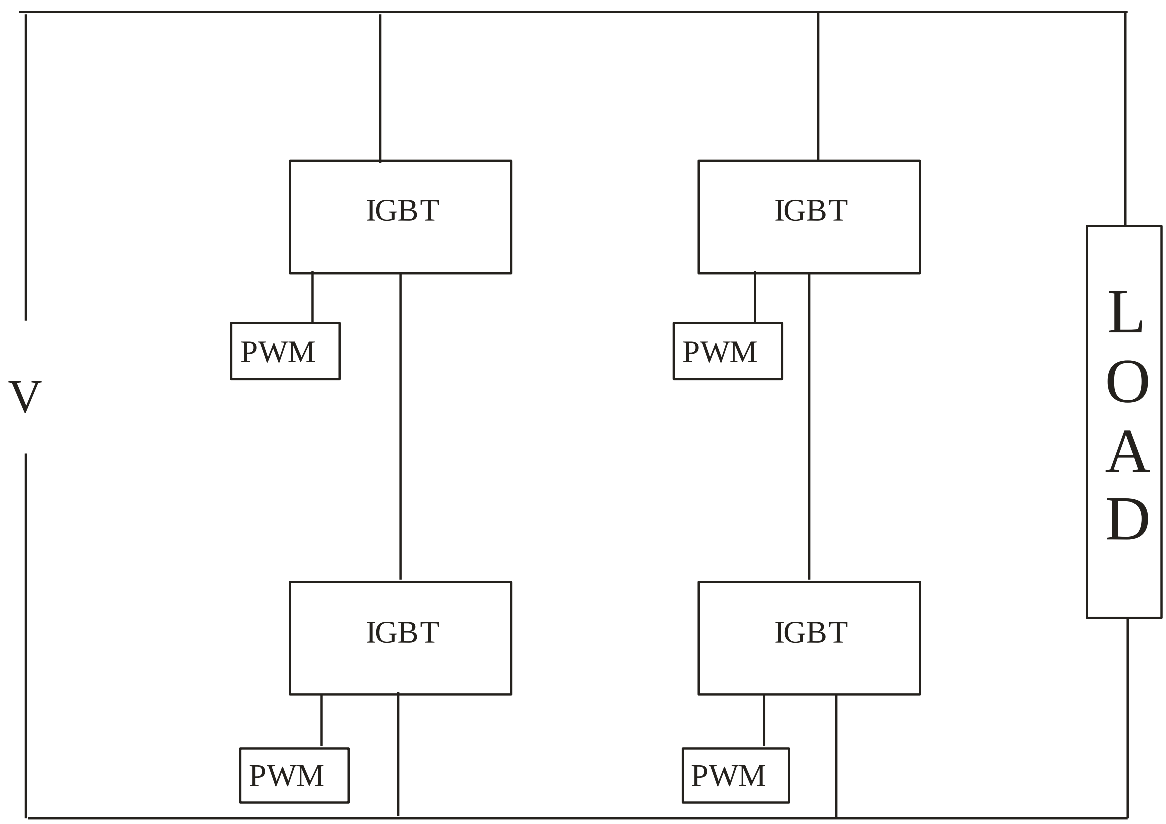

Fig. 3.5 Single Phase H-bridge Inverter

3.8 CONCLUSION

In this chapter the detailed discussion of PV cells, modules, DC-DC boost converter, battery bank and inverter has been presented.

CHAPTER 4

MODELLING AND SIMULATION OF STANDALONE SOLAR PHOTOVOLTAIC SYSTEM

4.1 INTRODUCTION

This chapter presents a modelling of Photovoltaic system. A detailed information regarding the modelling and simulation of solar photovoltaic system, boost converter, battery bank and the inverter is presented in the next section.

4.2 MATLAB/SIMULINK MODELING OF 5000 W PV SYSTEM

In our dissertation 5000W Photovoltaic System design in MATLAB.

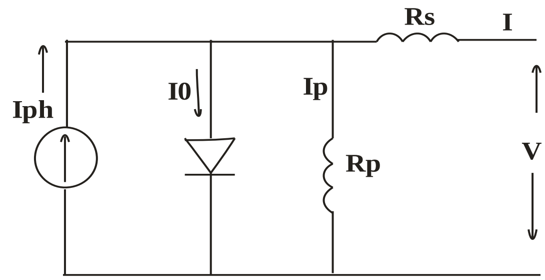

Fig. 4.1 Equivalent Solar Module with Rp and Rs

$$\mathrm{I} = I_{Ph} - I_o\left[\exp\left\{\frac{q(\mathrm{V} + \mathrm{I} * \mathrm{ns} * Rs)}{N_s AkT}\right\} - 1\right] + \frac{\mathrm{I} * \mathrm{ns} * .55 + \mathrm{V}}{Rp}$$

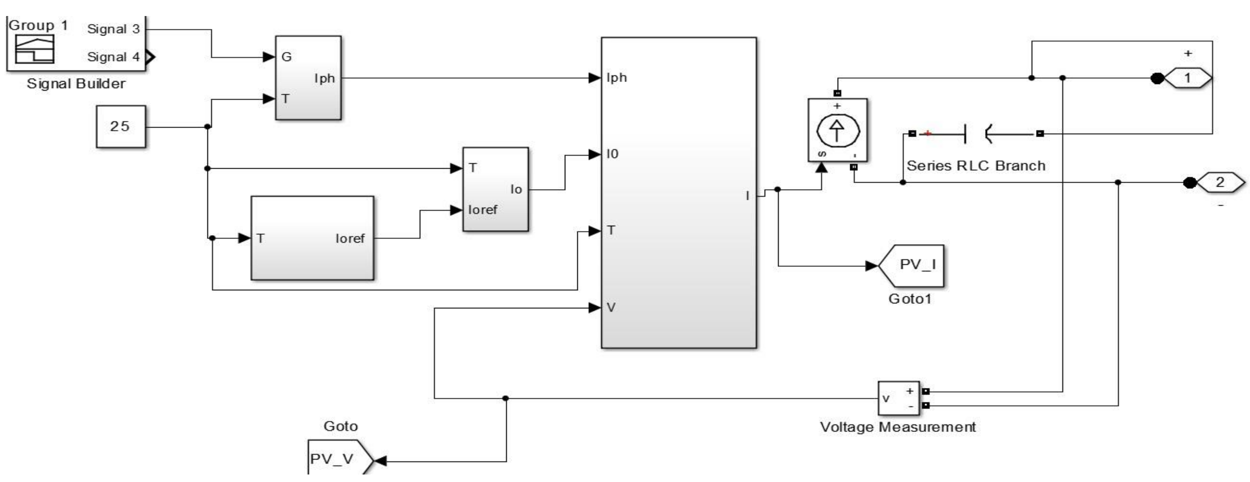

Fig. 4.2 MATLAB-Simulink Model of Photovoltaic System

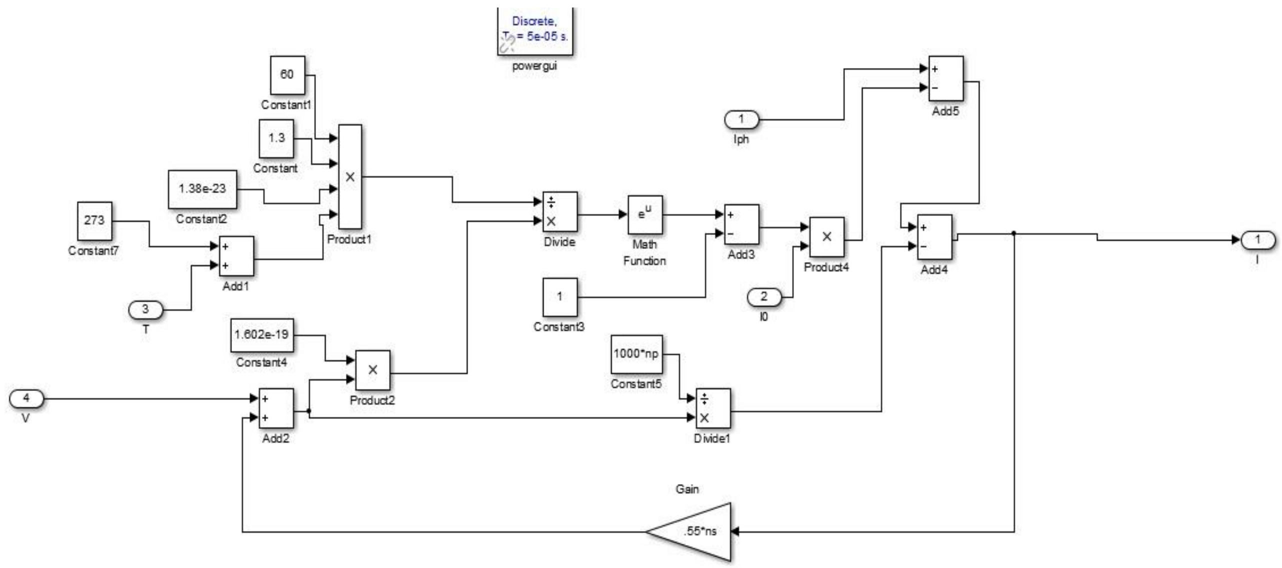

Fig. 4.3 MATLAB-Simulink Model of I

$$I_{Ph} = \left(\frac{G*[((T+273)-298)*.0013+8.71*np]}{1000}\right) \qquad (4.1)$$

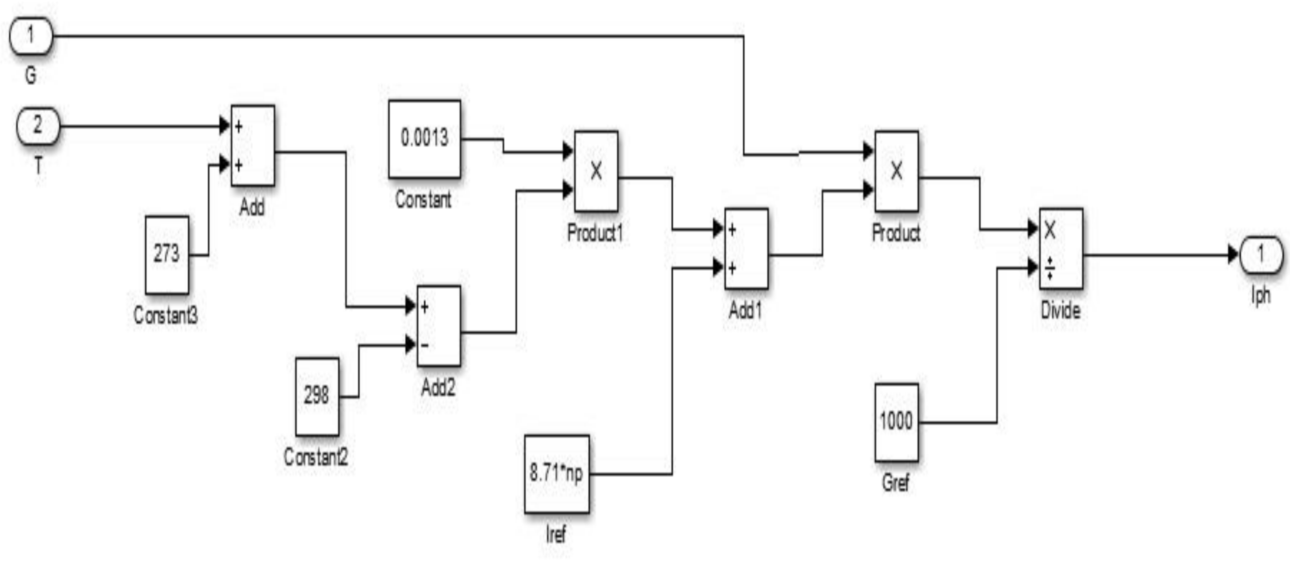

Fig. 4.4 MATLAB-Simulink Model of Iph

$$I_{oref} = 8.71 * np/[\exp\left(\frac{q37.3*ns(=Voc)}{(T+273)*(1.38*10^{\wedge}-23)*1.3*60}\right) - 1] \quad (4.2)$$

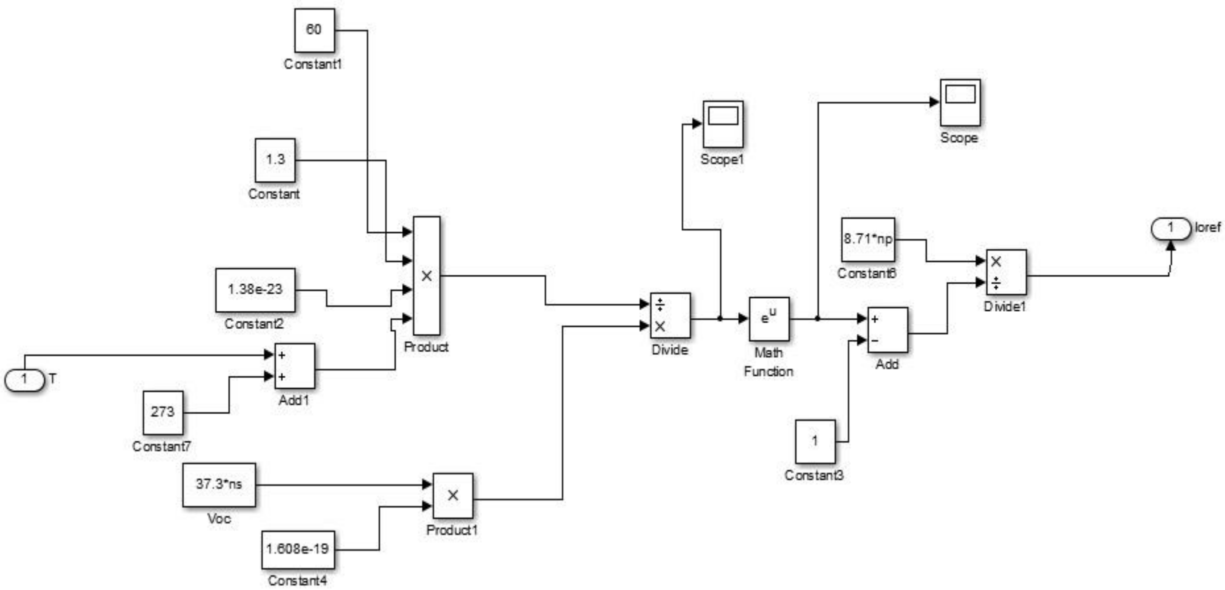

Fig. 4.5 MATLAB-Simulink Model of Ioref

$$I_o = I_{oref}\left[\frac{\left(\frac{T+273}{298}\right)^3}{A(=1.3)k} * e^{\frac{(1.12*1.6*10^{-19})/}{1.3*1.38*10^{\wedge}-23}\left(\frac{1}{298} - \frac{1}{T+273}\right)}\right] \quad (4.3)$$

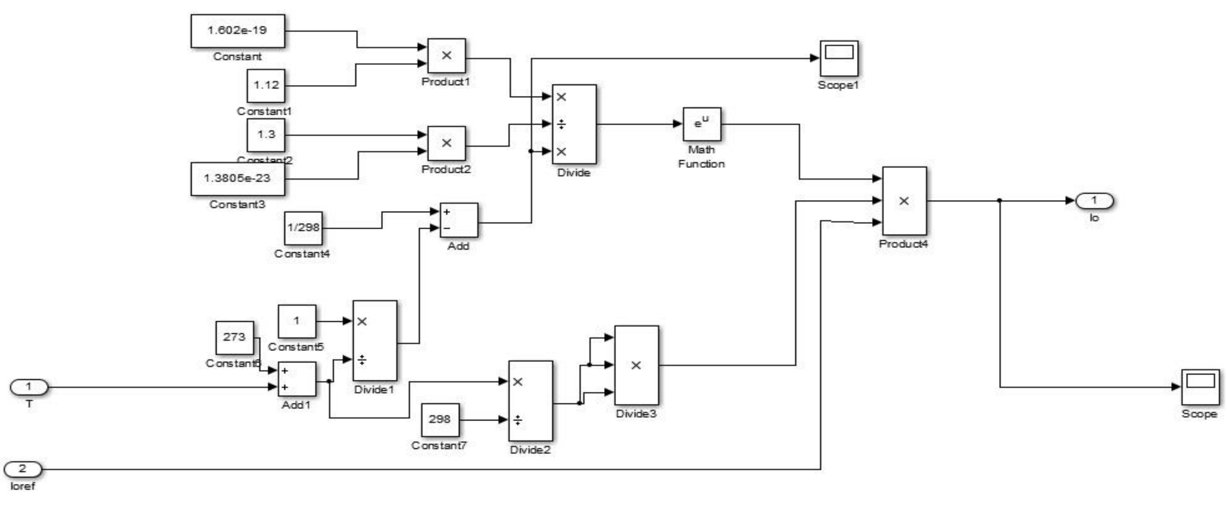

Fig. 4.6 MATLAB-Simulink Model of Io

Table 4.1 Electrical Characteristics of 5000W system

Parametre	**Values**
Rated Power	5000W
Maximum Power Voltage	320V
Maximum Power Current	18 A
Open circuit Voltage	37.38*ns V
Short circuit current	8.71*np A
Temprature coffiecient	.0013
Series Resistance(Rs)	.55 Ω
Shunt Resistance(Rp)	1000 Ω
ns and np are the series and parallel path respectively	10, 2
A is the diode ideality factor	1.3
K(Boltzman constant)	1.38 x 10^{-23} J K^{-1}
q is the electronic charge	1.602 x 10^{-19} C

T is the cell temperature (K); A is the diode ideality factor, G= irradiations, n_S is the number of cells connected in series. n_p is the number of cells connected in parallel, V is the terminal voltage across the array.

4.3 MATLAB-SIMULINK MODELING OF BOOST CONVERTER

Boost Converter is used in our Photovoltaic system for stepping up the voltage. Other parameter like the duty cycle of converter is varying DC voltage obtain from the PV module.

$$D= 1-V_{in}/V_{out}$$

D is the duty cycle for the boost converter

$$L = [\left(\frac{Vin*(Vout-Vin)}{dI*fs*Vout}\right)] \tag{4.4}$$

$$Cout = [\left(\frac{Iout*D}{fs*dVout}\right)] \tag{4.5}$$

L= Inductor

Vin=Input Voltage,

Cout=Output capacitance

dVout=Change in output voltage

dI= change in current

Vout=Output Voltage

fs= switching frequency

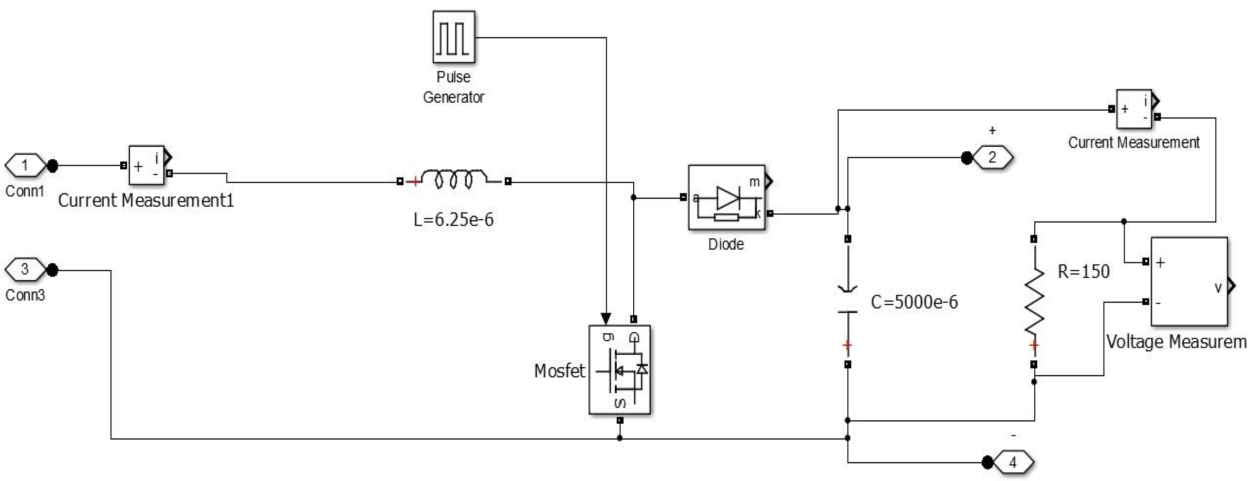

Fig. 4.7 MATLAB-Simulink Model of Boost Converter

Table 4.2 Specification for Boost Converter

S.No.	Component	Values
1	Inductor	6.25 µH
2	Input Capacitor	1000 µF
3	Output Capacitor	5000 µF
4	Resistive Load	150 Ω

4.4 MATLAB-SIMULINK MODELING OF BATTERY BANK

Battery Bank for 5000W Photovoltaic system is obtained by connecting many battery in series by connecting in series their capacity is increase

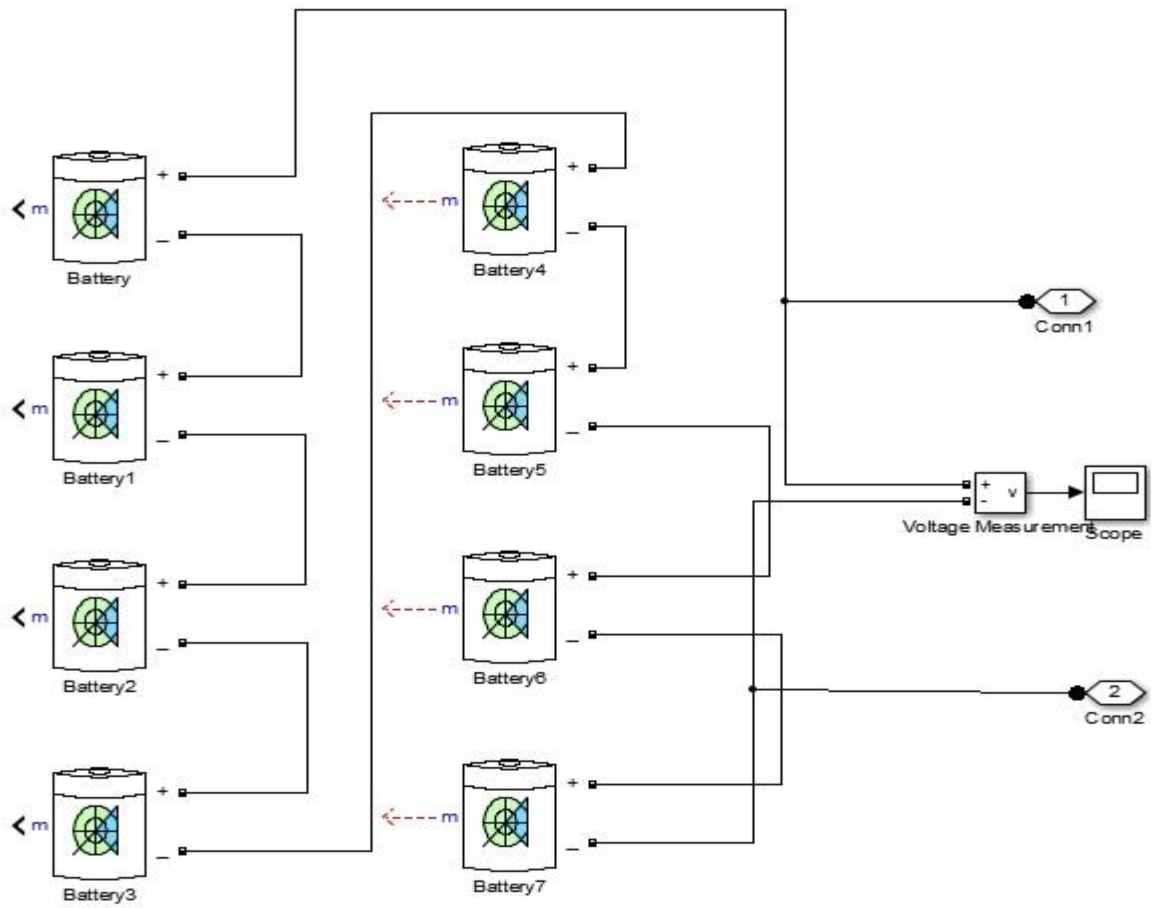

Fig. 4.8 MATLAB/Simulation of Battery Bank

Table 4.3 Specification of Battery

Nominal Voltage	30V
Rated Capacity	13Ah
Initial State of Charge	95%
Internal Resistance	0.036923

4.5 MATLAB/SIMULINK MODEL OF H-BRIDGE INVERTER

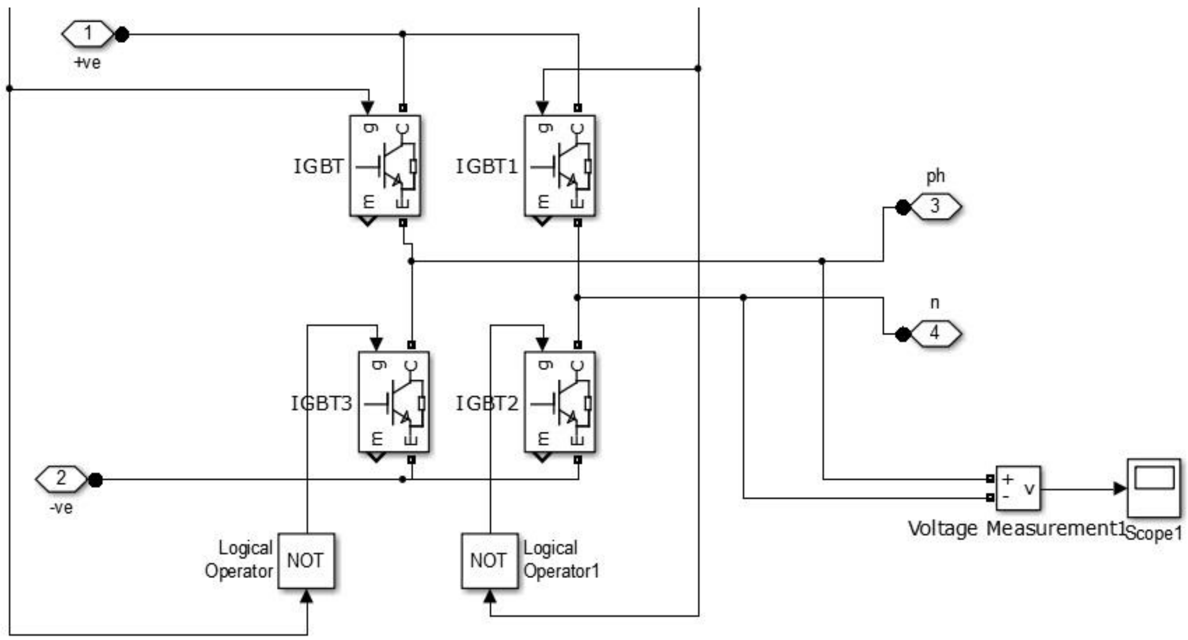

Fig. 4.9 Simulink model of Single phase H-bridge inverter

4.6 CONTROL TECHNIQUE FOR INVERTER

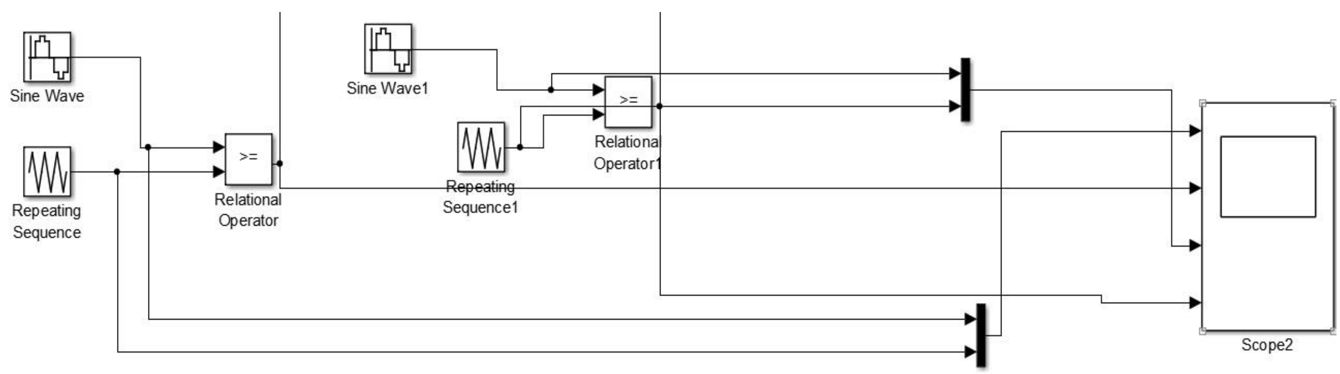

Fig. 4.10 Control Technique for Single phase H-bridge inverter

4.7 CONCLUSION

In this chapter detail discussion on simulated model of PV system in MATLAB. Simulate the solar PV array model, dc-dc boost converter, battery bank and inverter model with their parameter.

CHAPTER 5

MPPT TECHNIQUES FOR PV SYSTEM

5.1 INTRODUCTION

Solar system utilize the sun energy in power generation during recent years. Solar system have a nonlinear characteristics so it require max. Power point tracking(MPPT) to maximize the available energy. Significant parameter are temperature, irradiations, shading and humidity. Pont of maximize power always vary so we have to adopt Peak power point to attain maximum power from the system. There are as many as different of MPPT method. The classification of methods depends on many parameters like the control strategies, parameter sensed, complexity of implementation, cost, response time etc.

5.2 DIFFERENT MPPT TECHNIQUES

The conventional method are Perturb & Observe, Hill climbing, Incremental conductance, fractional voltage control and many more. Some of the new methods proposed in literature includes intelligent based techniques like particle swarm optimization, fuzzy logic based, hybrid techniques etc. Every algorithm has relative advantages as well limitations, like some are simple, easy to implement but suffer from response time, inaccurate, inexpensive. Some methods provide good accuracy, good response but very difficult to implement. So it is very important to have a thorough review of the techniques and select the optimum method.

Maximum power point tracking is necessary in order to track the maximum power point (MPP) under varying meteorological conditions. These MPPT techniques are based on the reference voltage or reference current signal of the PV system which is adjusted in order to achieve maximum power point. In this work a most widely used MPPT algorithms; perturb and observe has been used.

There are different techniques used to track the maximum power point. Few of the most popular techniques are:

1) Perturb and Observe (hill climbing method)
2) Incremental Conductance method
3) Fractional open circuit voltage

4) Fractional short circuit current
5) Fuzzy logic
6) dP/dV and dP/dI feedback Control
7) Neural network

5.2.1 CONVENTIONAL P AND O/HILL CLIMBING

In PandO perturbation in the operating voltage but Hill climbing perturbation in the duty ratio of the converter. In the case of a PV array connected to a power converter, perturbing the duty ratio of power converter perturbs the PV array current and consequently perturbs the PV array voltage.

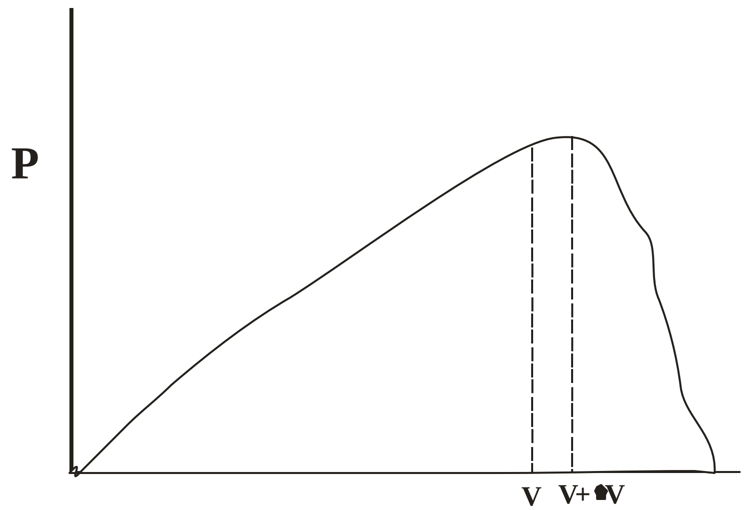

Fig. 5.1 PV curve for PandO technique

It is seen that increment in the voltage then increase the power when the point lies in the left side of the dotted line and decrement in the power when the point in the right side of the dotted line. Therefore if there is an increase in power perturbation should be kept the same to reach the Mpp when power is decrease then perturbation should be reversed. This process repeat periodically until the Mpp is occure then system oscillates about the Mpp this oscillation can minimized by the reducing the perturbation step size. When the step size is less the MppT process is slow.

PandO and the Hill Climbing method can fail under rapidly changing atmospheric conditions. Two sensor are usually requires to measure the PV array voltage and the current from which power is computed.

5.2.2 I&C (Incremental and Conductance)

This method based on the fact that the slope of the PV array power and voltage curve is zero at the the Maximum Power point and it is negative on the right side and positive on the left side of the curve. Incremental conductance (IC) locates the maximum power point when

$$dP/dV = I + V(dI/dV) = 0 \qquad (5.1)$$

this leads to

$$dI/dV = \Delta I/\Delta V = -Impp/Vmpp \qquad (5.2)$$

$$dP/dV = 0 \text{ at MPP}$$

$$dP/dV > 0 \text{ Left of MPP}$$

$$dP/dV < 0 \text{ right of MPP}$$

Maximum point is tracked by comparing instantaneous conductance to the incremental conductance. When the MPP is reached, unless the change in the dI is occurs Pv array is maintained at the maximum point. Speed of the Mpp is determines by the incremental size. When incremental size is wide then fast tracking of Mpp will occur but system might not operate exactly. The ineffective way of performing the I nad C technique is to use the incremental conductance and the instantaneous conductance to get the error signal. Error signal is zero at the Maximum power point.

5.2.3 Fractional Open-Circuit Voltage

In PV array, near linear relationship between V_{MPP} and V_{OC} under varying irradiance and temperature levels has given rise to fractional V_{OC} method.

$$V_{MPP} = kV_{OC} \qquad (5.3)$$

k is the proportionality constant, it depend on the PV characteristics, k usually determined beforehand by empirically determining V_{MPP} and V_{OC} for a specific PV array at different temperature and the irradiance. Usually k value is determined in between 00.71 and 00.78.

Once k is found then V_{MPP} can be found by $V_{OC.,}$ and measured periodically by momentarily shutting down the power converter. This is a disadvantage including the loss of power it can be prevented by pilot cells from which is V_{OC} found, these pilot cells carefully chosen to close representation of PV array. Voltage generate by pn--junction diode 0.75 of $V_{OC.}$ This approximation eliminates the need of V_{MPP} and V_{OC} . Once Maximum voltage is approximated then the control of power converter asymptotically found at desire value.

It is an approximation, technically Array never operate at Maximum power point. Depending on the use(application) of the system this technique is adequate.
Value of k is no more valid in the presence of partial shading condition of the PV system proposes sweeping of PV array voltage is to upgrade the value of k. this add to complexity and incurs more power loss.

5.2.4 Fractional Short-Circuit Current

This method is just like constant voltage type, Fractional I_{SC} approximately linearly related to $I_{MPP.}$

$$I_{SC} = k1\ I_{MPP} \tag{5.4}$$

.k1 is proportionality constant it value is vary in between 00.78 to 00.92.

Here I_{SC} is measured by the current sensor not direct ally. This sensor increase the components and the cost of the system.

5.2.5 Fuzzy Logic Control

Fuzzy logic not needing accurate mathematically and handling nonlinearity because it has imprecise input available, fuzzy logic is popular from last decade for MPPT.

Fuzzy control logic have three state are: Fuzzification, Rule base table lookup and defuzzification. In fuzzification numerical input variables are converted into linguistic variables based on the membership function similar to fig

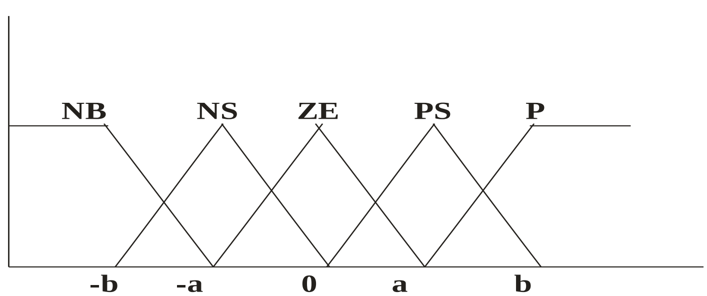

Fig. 5.2 Fuzzy logic curve

In this case five levels are NB(negative big), NS(negative small), ZE(zero), PS(positive small), PB(positive big). Range a and b are used on the numerical variables.

Input to the MPPT are E and dE. Since dP/dV vanishes at the maximum power point.

$$E(n) = \frac{P(n)-P(n-1)}{V(n)-V(n-1)} \tag{5.5}$$

and,

$$dE(n) = E(n) - E(n-1) \tag{5.6}$$

Once E and dE are calculated and converted to linguistic variable, the fuzzy logic controller output change in duty ratio dD of the converter. In the defuzzification stage, the fuzzy logic controller output is converted from a linguistic variable to a numerical variable, it provide an analog signal that will control the converter at Mpp.

5.2.6 dP/dV or dP/dI Feedback Control

In this technique compute the slope of dP/dV or dP/dI of power curve of PV array and it will feed into power converter with control to drive it to zero. Duty ratio of power converter is either increment and decrement to reach MPP, step size is used to improve the transient response of the system. Linearization method is used to compute dP/dV after that it will integrated with dP/dI to improve the transient response, in PV array voltage is periodically incremented or decremented and compared with marginal error until MPP is reached.

5.2.7 Neural Network

Like the fuzzy logic another MPPT controller technique is developed is Neural Network Technique this technique is also implemented with microcontroller.

Neural Network have three layers are: input, hidden and output layer

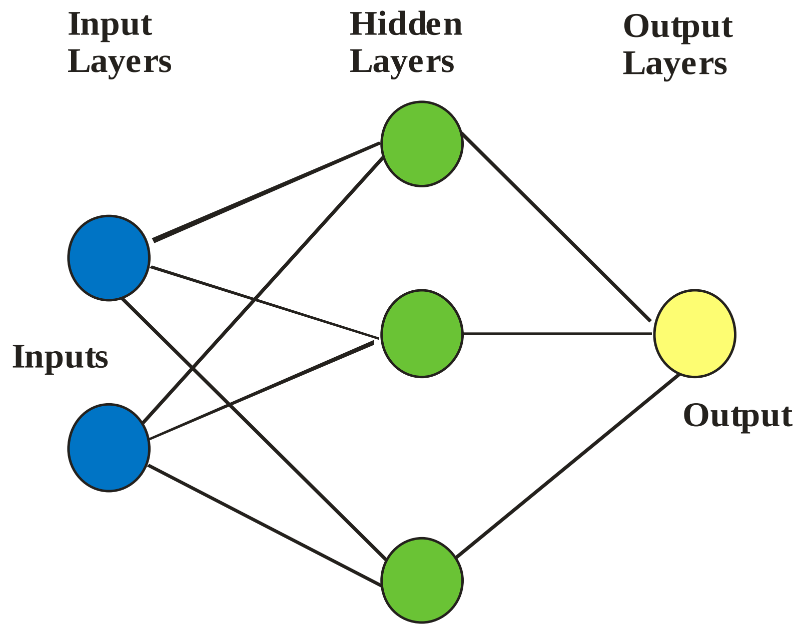

Fig. 5.3 Architecture of Artificial of Neural Network

Node is user defined in it, Input variables are the Output voltage and the Output current of PV system. Output is the duty cycle for the converter to operate at the Maximum Power Point. Operating point at MPP depend upon the hidden layer and the neural network trained.

Table 5.1 Comparison of Various MPPT techniques

MPPT Technique	PV Array Dependent	True MPPT	Analog and Digital	Speed	Complexity	Sensed Parameter	Periodically tuned
P&O/HillClimbing	No	Yes	Both	Varies	Low	V, I	No
I and C	No	Yes	Digital	Varies	Medium	V, I	No
Fractional Voltage	Yes	No	Both	Medium	Low	V	Yes

Fractional Current	Yes	No	Both	Medium	Medium	I	Yes
Fuzzy Logic	Yes	Yes	Digital	Fast	High	Varies	Yes
dP/dV and dP/dI Feedback Control	No	Yes	Digital	Fast	Medium	V, I	No
Neural Network	Yes	Yes	Digital	Fast	High	Varies	Yes

5.3 CONCLUSION

In this chapter detail discussion on the different MPPT techniques and compare their performance different condition. From the above discussion conclusion is come that P&O and I&C is basic maximum power point algorithms and the speed of these algorithms is vary mean its speed is depend upon the step size we used. Fractional voltage and the fractional current schemes both are not true MPPT algorithms in these techniques sensor requirement is less in compare to other techniques. Fuzzy logic and Neural Network technique are used with digital system and their speed also fast but their complexity is more in compare to other hardware.

CHAPTER 6

CHARGE CONTROLLER AND MPPT TECHNIQUE FOR STANDALONE SOLAR PHOTOVOLTAIC SYSTEM

6.1 INTRODUCTION

This chapter presents the design and simulation of charge controller and MPPT technique for standalone solar photovoltaic system. The main contents of this chapter are system description of Perturb and observe and the Incremental Conductance.

6.2 STAND ALONE SYSTEM WITH CONVERTER DESCRIPTION:

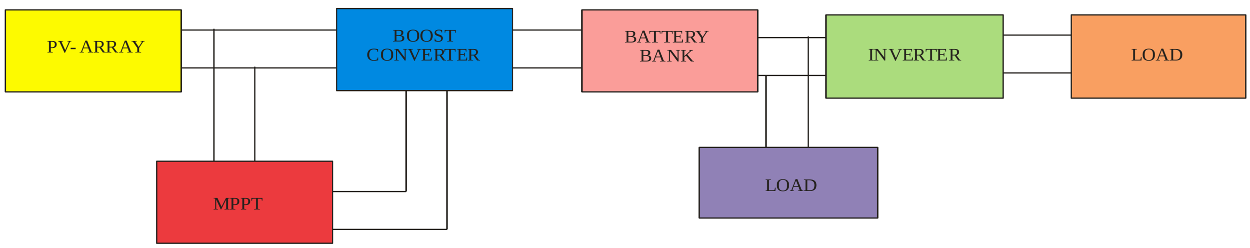

Fig. 6.1 Block Diagram of Standalone system with converter

In this standalone system we get the current and voltage from the PV array system, these parameter are given to the control algorithm of the duty cycle of the converter for getting the maximum power from the Photovoltaic system, Different MPPT techniques (Perturb and Observe or Incremental and conductance) generates duty cycles for the converter, to getting the maximum power to battery bank for charging. Battery is connected in between the converter and the inverter that supply the power to the dc and ac load.

6.3 STAND ALONE SYSTEM WITH CHARGE CONTROLLER DESCRIPTION:

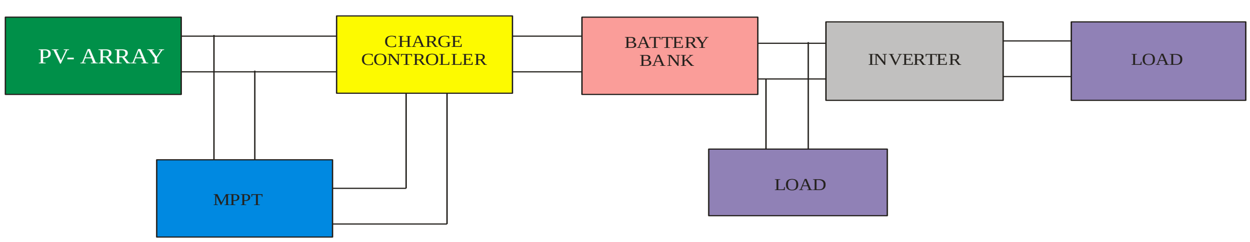

Fig. 6.2 Block Diagram of Stand alone system with charge controller

Standalone system with charge controller technique we implement the Perturb and observe for getting the maximum power from Photovoltaic system. It will charge the battery upto a certain limit after that it will stop the charging of battery.

6.4 MATLAB/SIMULATION MODEL OF PV SYSTEM WITH CHARGE CONTROLLER

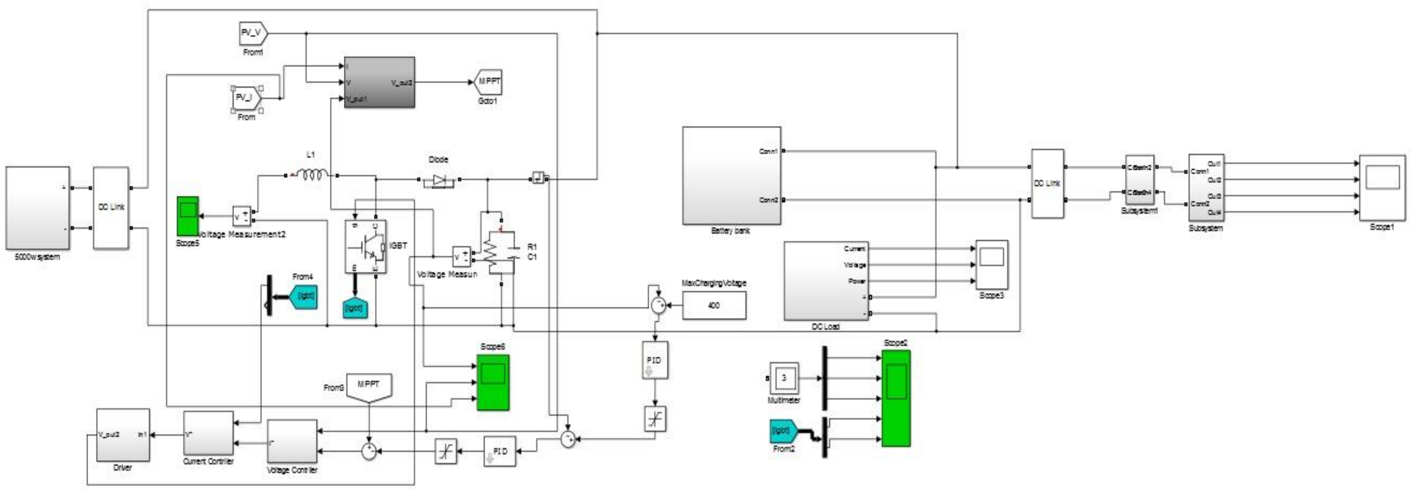

Fig. 6.3 Simulation Model of Stand alone system with charge controller

6.5 CHARGING CIRCUIT OF BATTERY

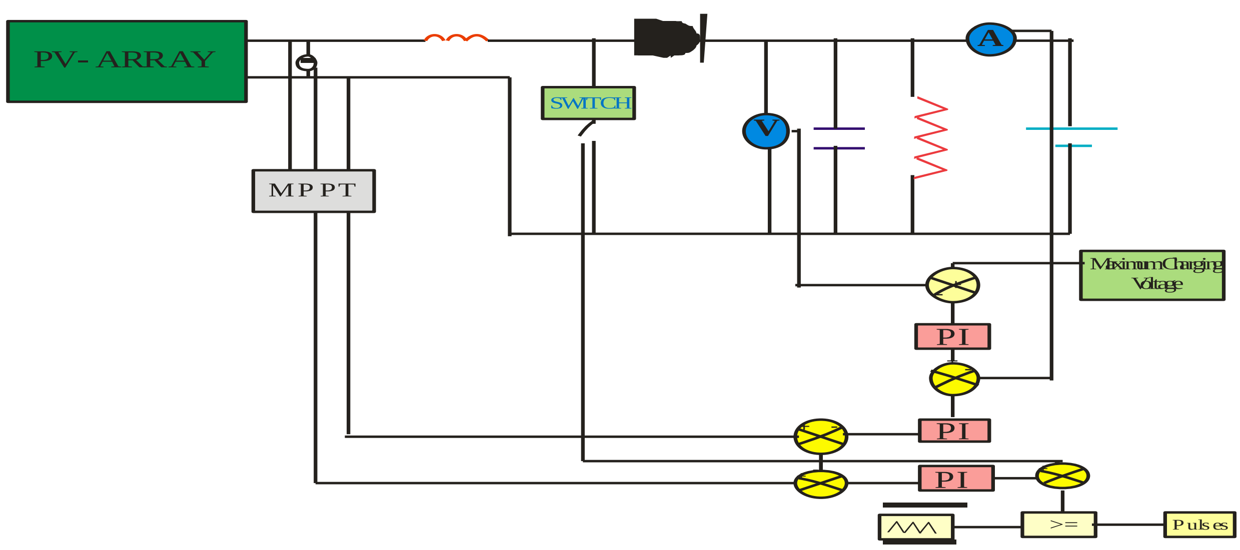

Fig. 6.4 Charging circuit block diagram for battery

In charge controller we will use the Maximum power point technique for charging and discharging of the battery. MPP power point at the PV curve is used get the maximum power output to charge the battery. In this circuit diagram Parallel RC network is connected in parallel to the battery for charging and discharging time constant, from the battery terminal we get the voltage, this battery terminal voltage is compare with the maximum charging voltage then the error signal is generate which will given into the PI controller.

6.6 MAXIMUM POWER POINT SCHEMES

The two most frequently discussed MPPT algorithms are the perturb-and-observe (P&O) and the incremental conductance (INC). These methods are based on the fact that, on the voltage–power characteristic, the variation of the power w.r.t. voltage is positive ($dP/dV > 0$) on the left-hand side of the maximum power point (MPP), while it is negative ($dP/dV < 0$) on the right-hand side of the MPP. The main advantages of these methods are that they are generic, e.g., suitable for any PV array, they require no information about the PV array, they work reasonably well under most conditions, and they are simple to implement on a digital controller. A detailed literature review today would lead to the conclusion that although the INC is slightly more complicated to implement, it provides better performance than P&O under both static and dynamic conditions. The two main problems of the P&O that are frequently mentioned in the literature are the oscillations around the MPP under steady-state conditions and the poor tracking (possibly in the wrong direction, away from MPP) under changing irradiance. Methods to improve the dynamic behaviour of the P&O, including variable step size and perturbation frequency, have been reported in the literature. On the other hand, it is often stated in the literature that the INC can determine the position of the actual operating point relative to the MPP, and it can find the distance to it; it can also stop perturbing when the MPP has been reached, thus offering a superior performance to the P&O. It is also often stated that the INC can track fast changing irradiance better than the P&O, Typical statements include "The [INC] method has been proposed to improve the tracking accuracy and dynamic performance under rapidly varying conditions" "The disadvantage of the P&O method can be improved by comparing the instantaneous panel conductance with the incremental panel conductance" "[INC] gives a good performance under rapidly changing conditions" "Incremental conductance can determine that the MPPT has reached the MPP and stop perturbing the operating point," and "[INC] can track rapidly increasing and decreasing irradiance conditions with higher accuracy than P&O". In a recent work, both the P&O and INC have been implemented on a commercial PV system, challenging the common belief of higher INC performance. The performance of these two methods using various perturbation amplitudes and frequencies has been compared. The results "suggest that the two algorithms are similar", however, the author does not provide mathematical explanation of why the two methods perform so similarly.

6.7 PERTURB AND OBSERVE

The Perturb and Observe algorithm is considered to be the most commonly used MPPT algorithm of all the techniques because of its simple structure and ease of implementation. It is based on the concept that on the power-voltage curve dP/dV goes to zero at the top of the curve. The P&O operates by periodically perturbing (incrementing or decrementing) the PV array terminal voltage or current and comparing the corresponding output power of PV array P(n+1) with that at the previous perturbation P(n). If the perturbation in terminal voltage leads to an increase in power (dP/dV >0), the perturbation should be kept in the same direction otherwise the perturbation is moved to the opposite direction. The perturbation cycle is repeated until the maximum power is reached at the dP/dV=0 point. This method is also known as 'hill climbing method'.

Table 6.1 Perturbation for P&O technique

Perturbation	Change in power	Next perturbation
Positive	Positive	Positive
Positive	Negative	Negative
Negative	Positive	Negative
Negative	Negative	Positive

With reference to the above table, perturbation varies according to the variation in power, when change in power is positive then next perturbation depend upon the previous duty cycle, if previous duty cycle is positive then change in perturbation is also positive otherwise perturbation change is negative. When change in power is negative then next perturbation is negative for the previous positive perturbation and next is positive for the negative previous perturbation. A flow chart illustrating this method is shown in Figure

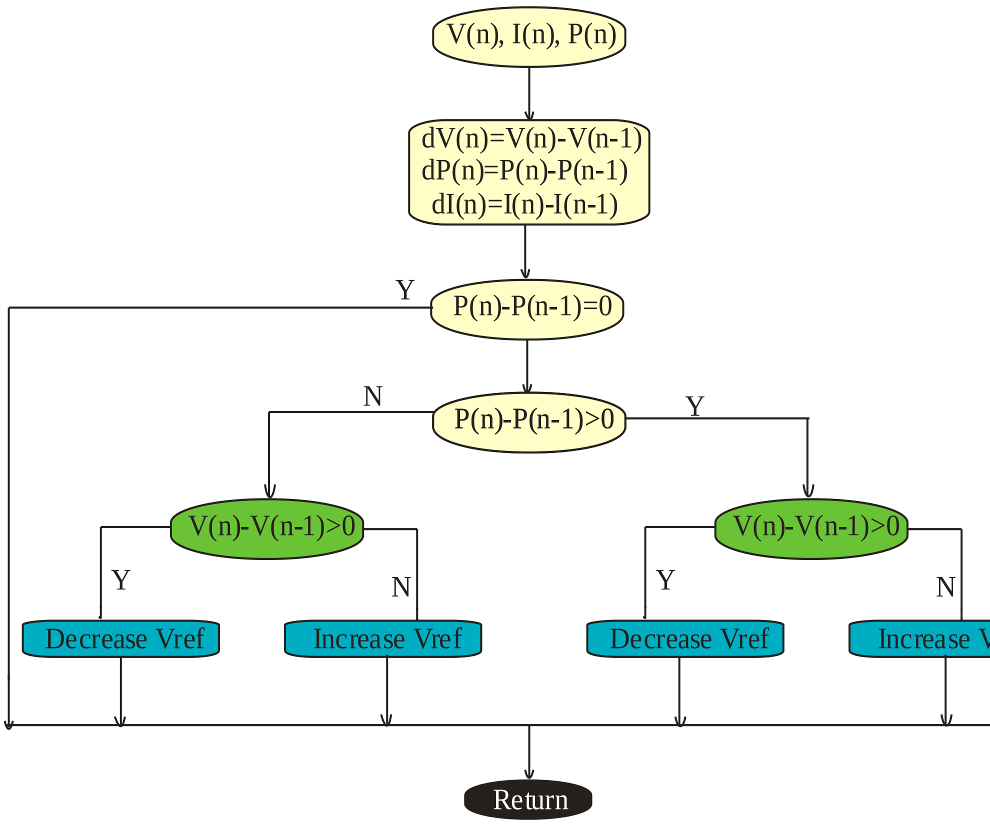

Fig. 6.5 Algorithm Technique of P&O Technique

6.8 MATLAB/SIMULINK MODELLING OF PERTURB AND OBSERVE

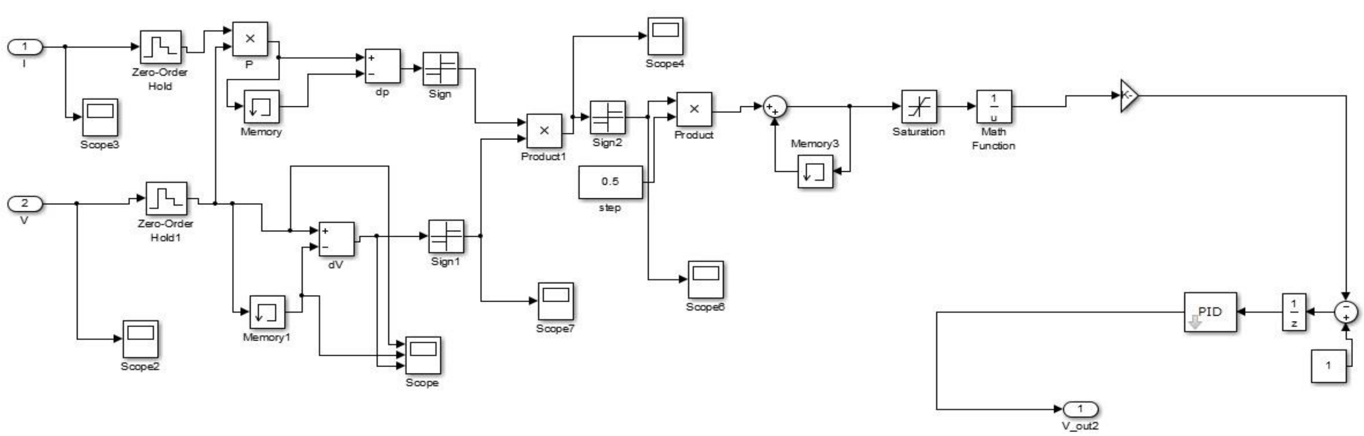

Fig. 6.6 MATLAB-Simulation of P&O technique

6.9 INCREMENTAL AND CONDUCTANCE

In Incremental method for the maximum power point terminal voltage always adjusted. The basic idea is that at the Maximum Point Of Point the derivative of the power with respect to the voltage vanishes because the Maximum Point Of Point is the maximum of the power curve. it is noted that slope of dP/dV negative on the right side and positive on the left side of the curve. Incremental conductance (IC) locates the maximum power point when

$$dP/dV = I + V(dI/dV) = 0$$

this leads to

$$dI/dV = \Delta I/\Delta V = -\,Impp/Vmpp$$

$$dP/dV = 0 \text{ at MPP}$$

$$dP/dV > 0 \text{ Left of MPP}$$

$$dP/dV < 0 \text{ right of MPP}$$

the PV array terminal voltage can be adjusted relative to the Maximum Power Of Point voltage by measuring the incremental and instantaneous array conductance (dl/dV and I/V) respectively.

The algorithm starts its cycle by obtaining the present values of I0 and V0, then using the corresponding values stored at the end of the preceding cycle, I0 and V0, the incremental changes are approximated as: dI=I(n)-I0 and dV=V(n)-V0.

The main check is carried out by comparing dl/dV against - I / V , and according to the result of this check, the duty cycle D will be adjusted in order to move the array terminal voltage towards the MPP voltage. At the MPP dl/dV =- I / V , no control action is needed, therefore the adjustment stage will be bypassed and the algorithm will update the stored parameters at the end of the cycle as usual.

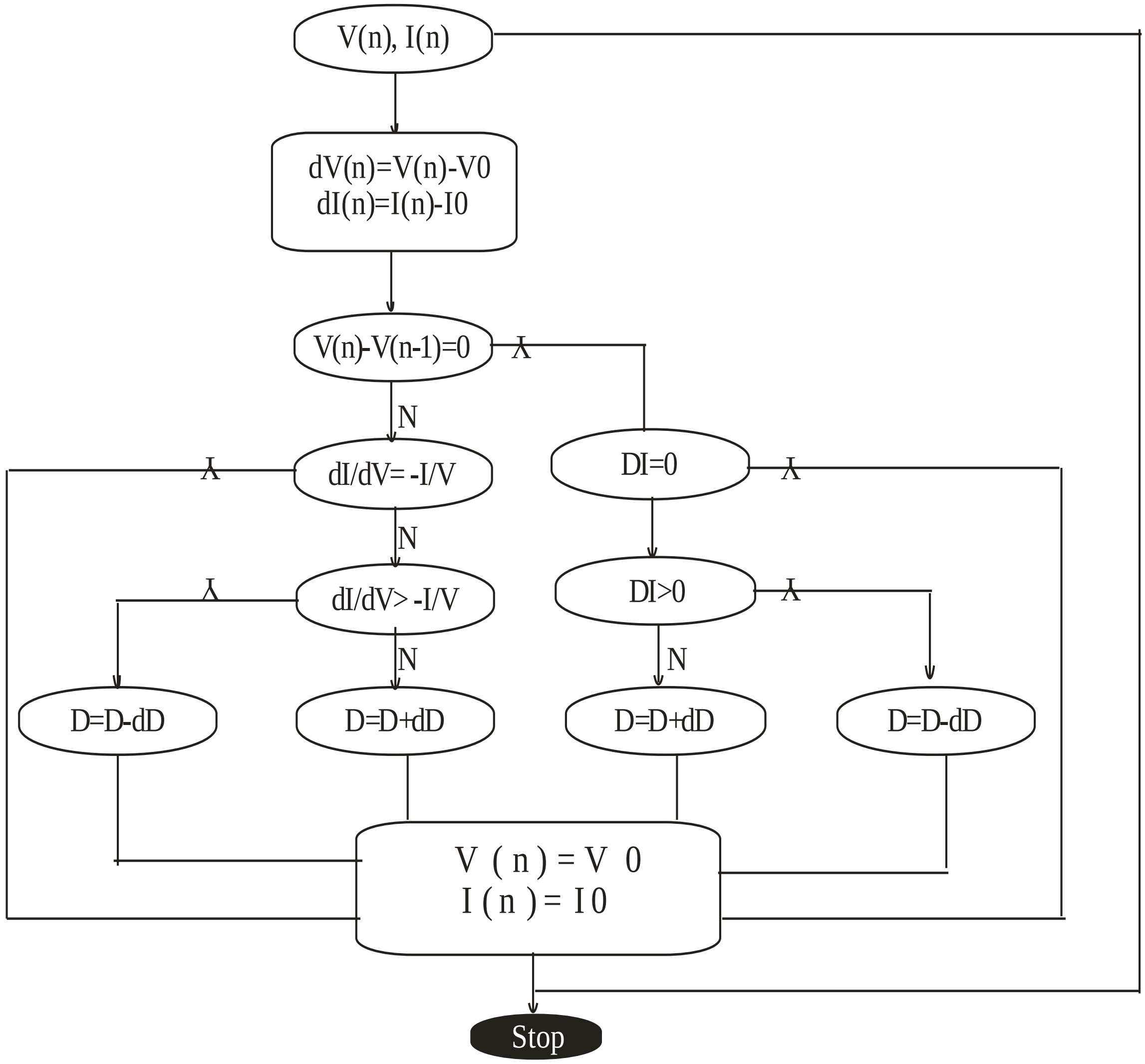

Fig. 6.7 MATLAB/Simulink Algorithm of I&C

Two other checks are included in the algorithm to detect whether a control action is required when the array was operating at the MPP in the preceding cycle (dV=0); in this case the change in the atmospheric conditions is detected using (dl # 0). Now the control signal D, adjustment will depend on whether dl is positive or negative, as shown in the flow chart. When the above IncCond MPT algorithm was tested we noted that the condition dP/dV = 0 (or dI/dV =-I/V) seldom occurred because of the approximation made in the calculation of dl and dV. However, this condition can be detected by allowing a small marginal error (E) in the above comparisons, i.e. dP/dV = *E and the value of E depends on the required sensitivity of MPT.

6.10 MATLAB/SIMULINK MODELING OF INCREMENTAL AND CONDUCTANCE

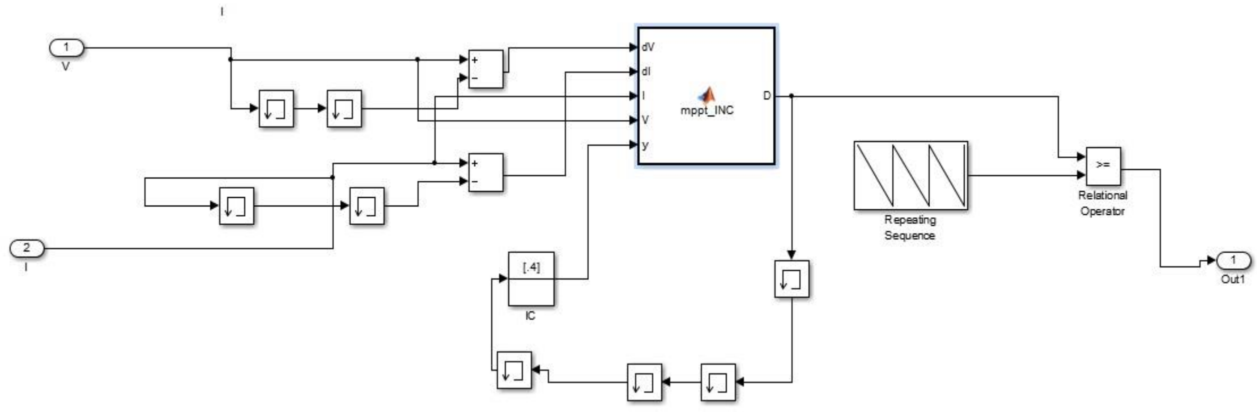

Fig. 6.8 MATLAB/Simulated modelling of I&C

6.11 MATLAB CODING OF INCREMENTAL AND CONDUCTANCE

```
function D = mppt_INC(dV,dI,I,V,y)
%#codegen
        N=1e-5; %max

        Step=N*abs(dI/dV);
        if  (dV==0)||(dI==0)
            D=y;
        elseif dI>0
            D=y-Step;
        else
            D=y+Step;
        end
        if dV~=0
            if dI/dV==-I/V
                D=y;
            end
            if dI/dV>=-I/V
                D=y-Step;
            elseif dI/dV<=-I/V
                D=y+Step;
            end
        end
%         if dV==0
%             D=y-Step;
%         end

%     y=D;
end
```

Fig. 6.9 MATLAB Coding for Variable I&C

CHAPTER 7
RESULT AND DISCUSSIONS

7.1 INTRODUCTION

There are two MPP algorithm (P&O or I&C) is implemented at the standalone system. In this chapter we analysis the result of the Photovoltaic Array, Boost converter output (with the different MPPT condition), and the system result for AC and DC load with different controller and the MPPT condition with constant temperature and the irradiation. A detailed discussion on the outcome of this research work. Firstly, the comparative analysis of various MPPT techniques is presented. Further various simulated charge controller technique for the battery. Also results of standalone PV system with battery backup are discussed.

7.2 RESULT OF PHOTOVOLTAIC SYSTEM AT DIFFERENT IRRADIATIONS AND CONSTANT TEMPRATURE

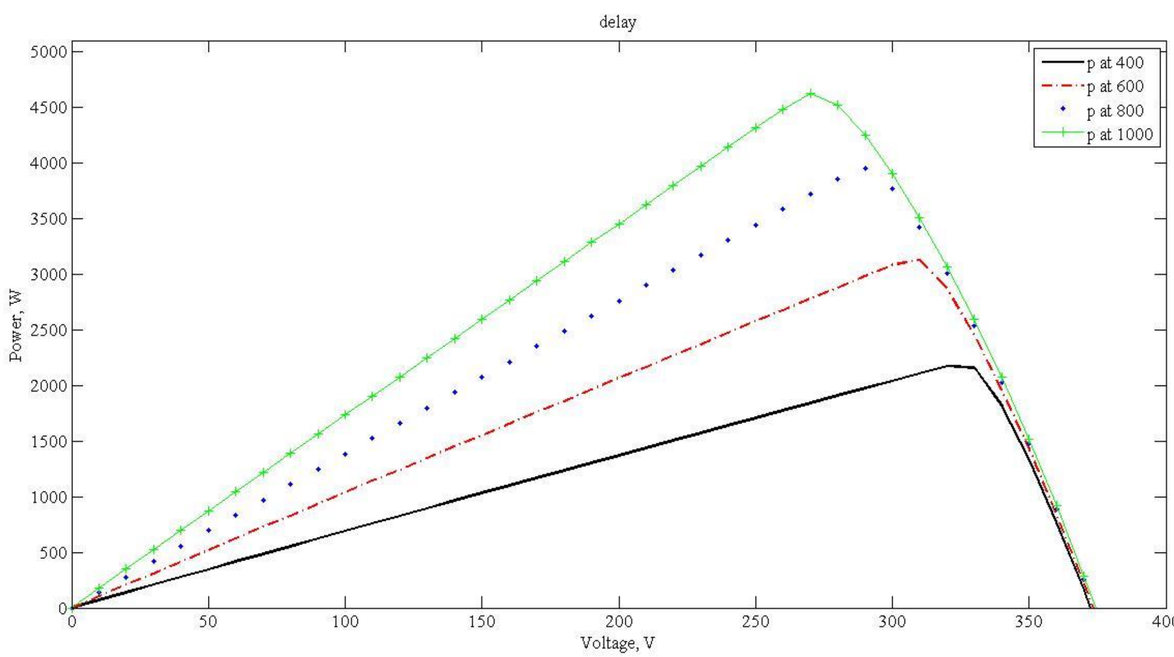

Fig. 7.1 P-V curve for 5000W system at 1000, 800, 600 and 400 radiation

In the given figure we shown the PV characteristics of the 5000W system with different irradiation (400,600,800,1000W/m^2) at constant temperature 25. Maximum Power point is shifted down as our irradiation level is decrease. In curve at 1000 irradiation we get 4600W power and 270V.

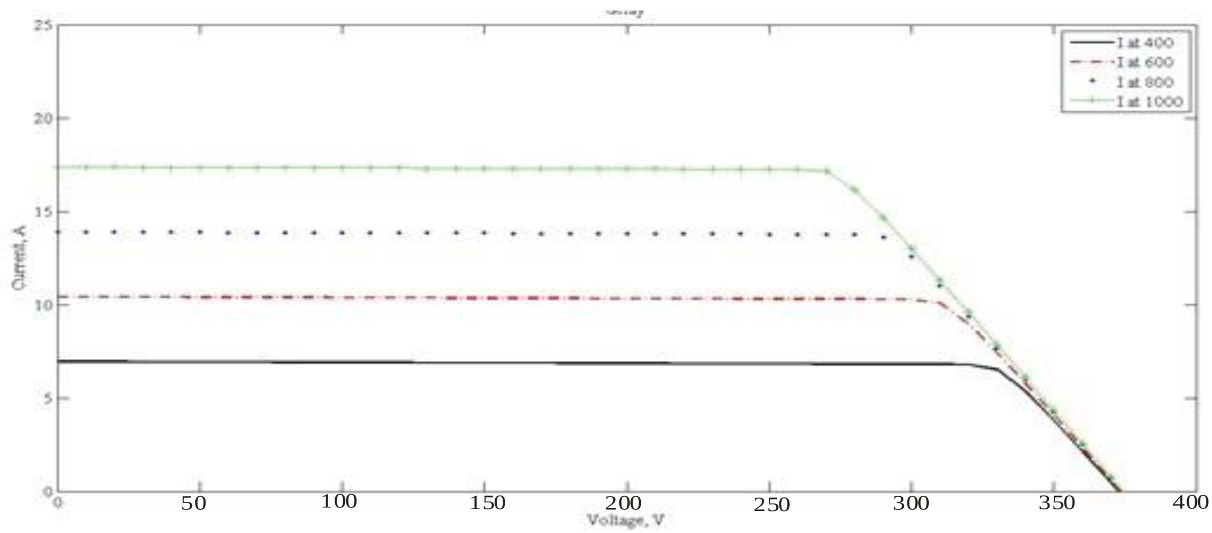

Fig. 7.2 I-V curve for 5000W system at 1000, 800, 600 and 400 radiation

In the given figure we get the I-V characteristics of 5000W system with different irradiation at constant temperature. Maximum Current we get 18A at 1000W/m^2.

7.3 RESULT OF BOOST CONVERTER AT THE CONVERTER TERMINAL

7.3.1. RESULT WITH P&O TECHNIQUE

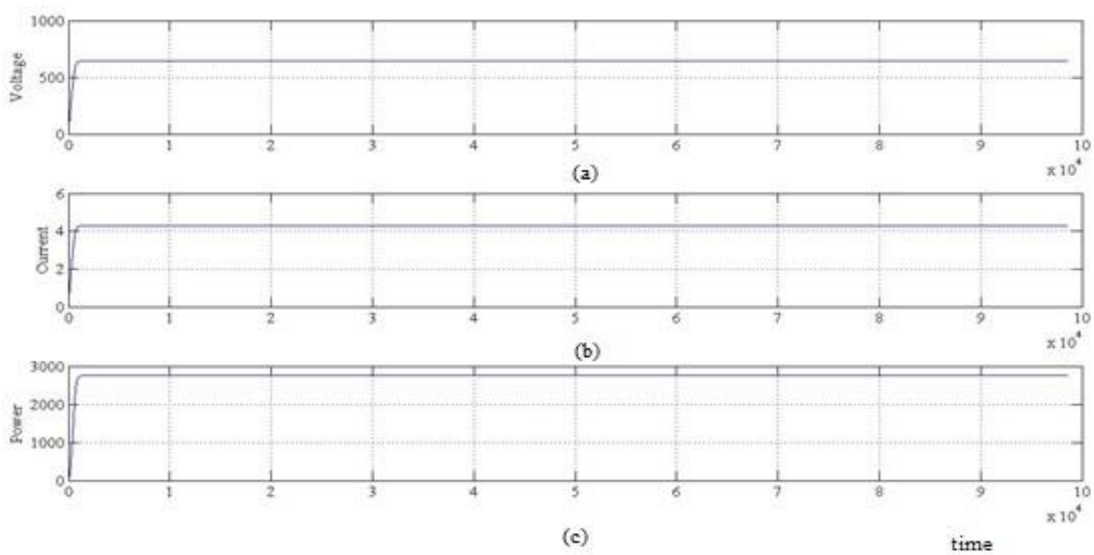

Fig. 7.3 a. Voltage b. Current c. Power at the converter terminal with P & O

7.3.2 RESULT WITH I&C TECHNIQUE:

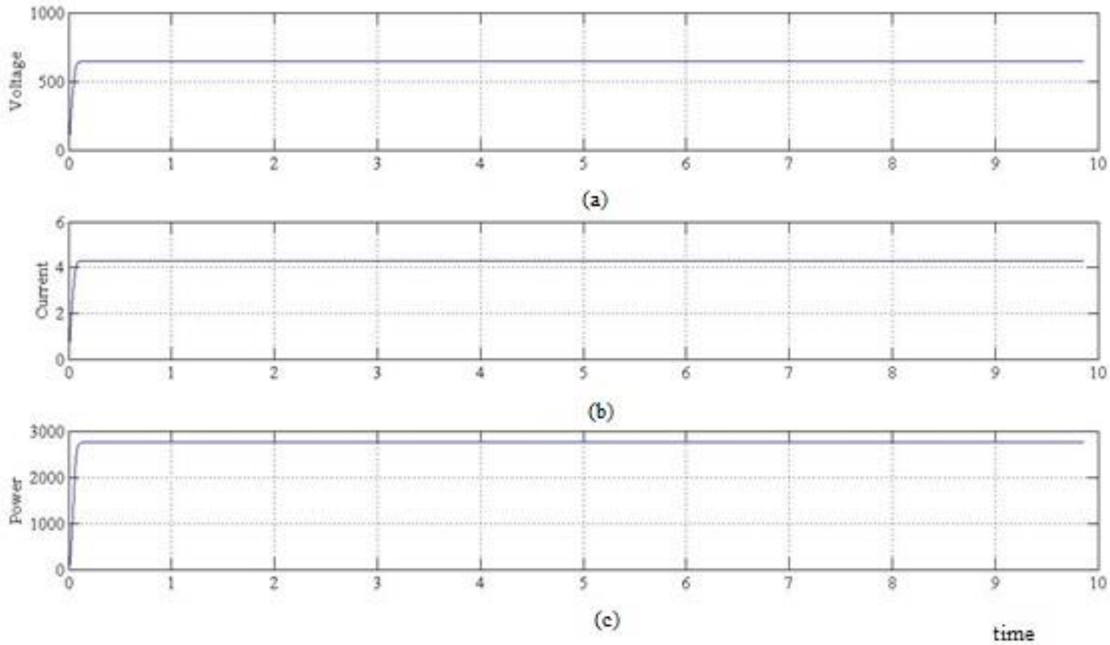

Fig. 7.4 a. Voltage b. Current c. Power at boost converter terminal with I&C

In the standalone system for step up the dc voltage Boost converter is used. For getting the maximum power from the array we use the MPPT technique, which will change the duty cycle of the converter according to the maximum power point.

Analysis of converter with two MPPT technique P&O and I&C with constant dc load of 150 ohm.

With I&C we get the more power in compare to the Perturb and observe technique.

Table 7.1 Parameter competition at converter terminal with MPPT

S.N.	Technique	Power(W)	Current(A)	Voltage(V)	Load
1	P&O	2752	4.28	642.2	R=150
2	I&C	2790	4.31	646.2	R=150

7.3.3 UNDER PARTIALSHADING:

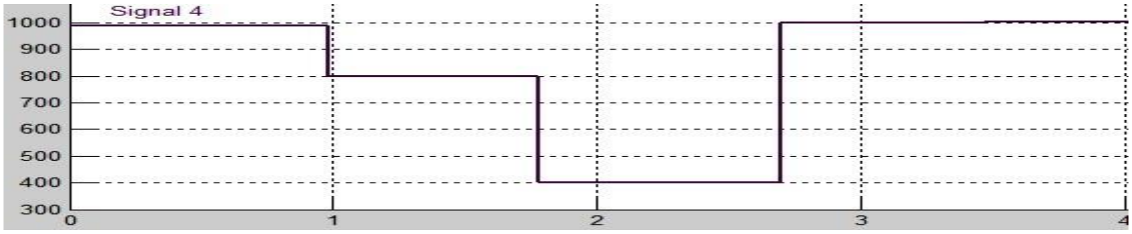

Fig.7.5 Signal generator with different radiations levels

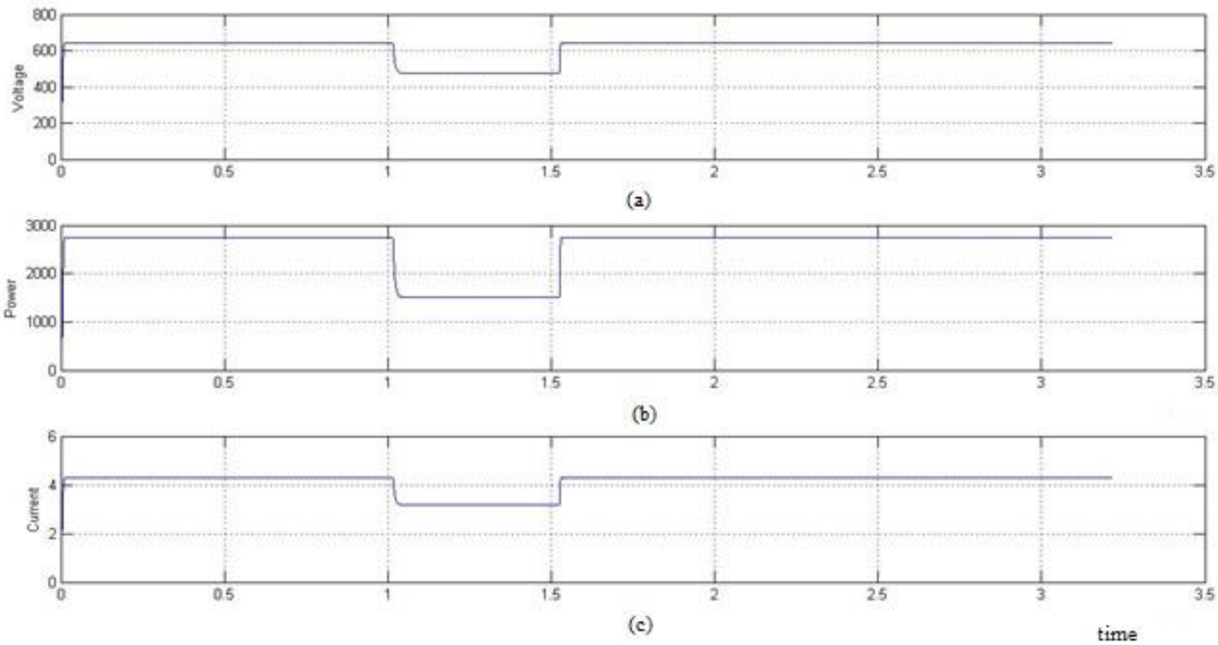

Fig. 7.6(A) a. Voltage b. Power c. Current Under Partial Shading with P&O

Analysis of Parameter (like Power, Voltage and current) at the boost converter terminal with MPPT algorithm. In partial shading condition I&C response is good in compare to the P&O. In shading condition maximum power point is change according to the irradiation level.

For show the partial shading condition in the system we use the signal generator in which we change the irradiation level like 1000, 800 and 400 at different time of the interval.

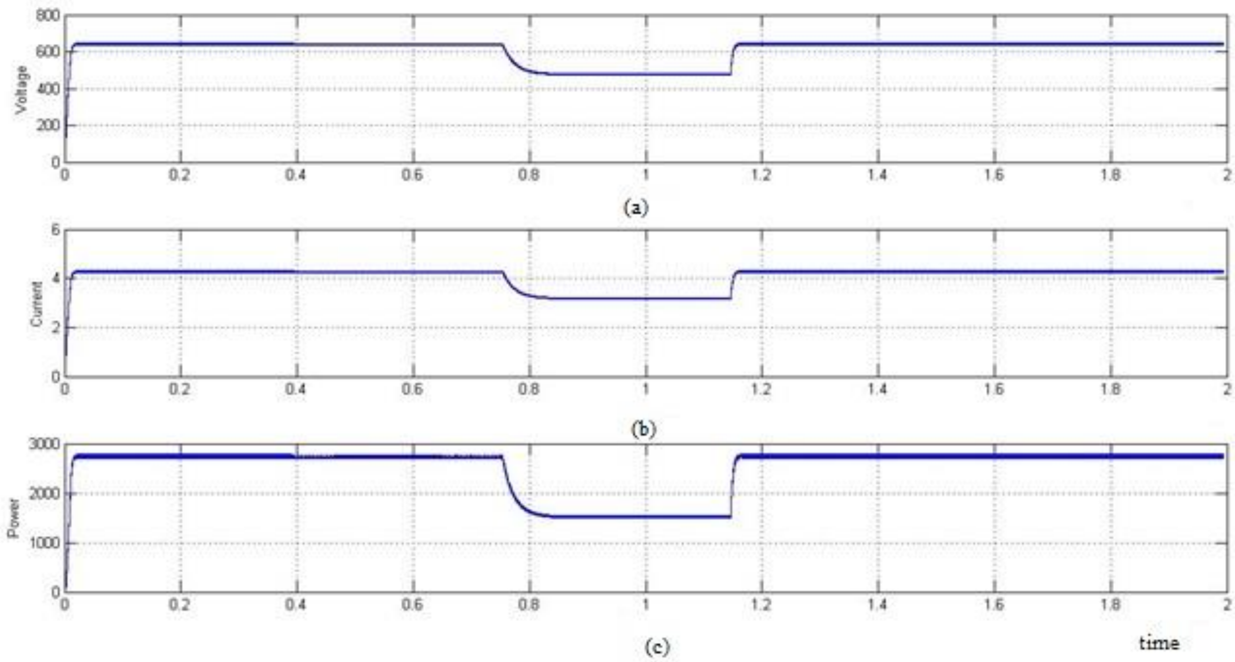

Fig. 7.6(B) a. Voltage b. Current c. Power under Partial Shading with I&C

7.4 RESULT OF STANDALONE SYSTEM WITH DIFFERENT MPPT TECHNIQUE

Table 7.2 Parameter value of the standalone system

PV array maximum power output	5000W
DC Load Capacity	R=1000, $L=1*10^{-3}$
Ac load capacity	P=1500W Q=400VAR f=50Hz
Battery bank capacity	4992Wh

For the standalone system we require various system like PV array, converter and the battery bank and the load (like dc and ac). In 5000W system we have two types of load one load at the inverter terminal (P=1500W, Q=400VAR at 50HZ) and second one at the battery terminal which is dc load(R=1000, L=1*10^{-3}).
Battery bank capacity is decided by how much loading is taken from the battery bank. In our system battery bank is made by the 8 battery connected in series each have same rating like 13Ah, 54V.

7.4.1. RESULT WITH P&O TECHNIQUE:

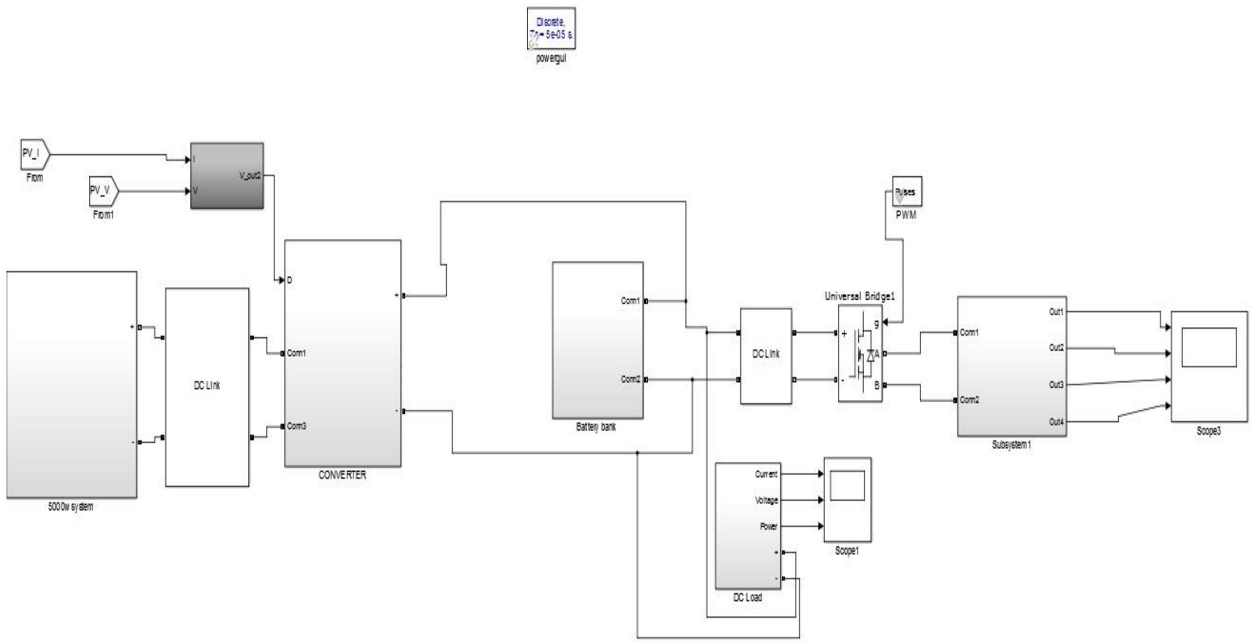

Fig.7.7 Simulate Stand Alone system with P&O technique

In our system analysis is done with different MPPT technique. First analysis is done with P&O algorithm, in which we measure the various parameter like voltage, current, power, SOC of the battery for the different load like ac load and dc load, with different methodological condition like irradiation, without irradiation and the partial shading condition at constant temperature.

7.4.1 (A) WITH IRRADIATIONS

(1) PARAMETER AT AC LOAD TERMINAL

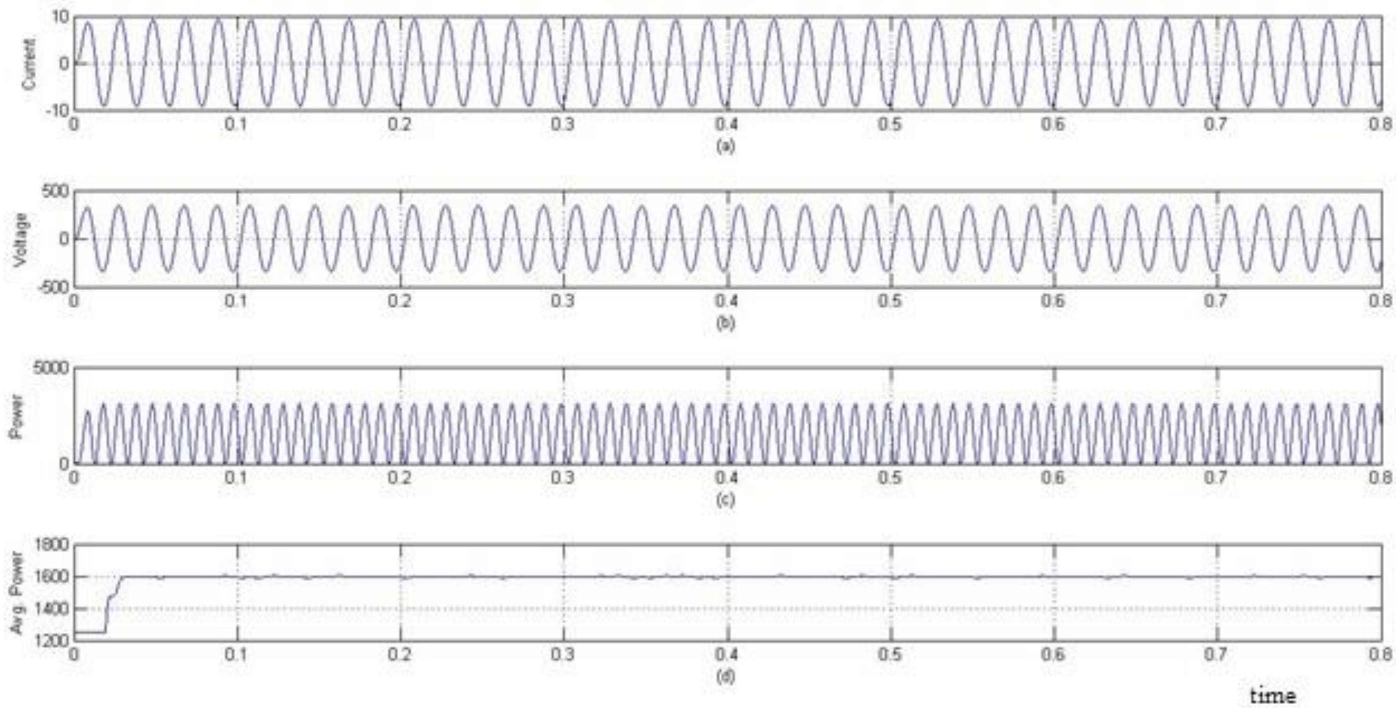

Fig. 7.8 a. Current b. Voltage c. Power d. Avg. Power for ac load

(2) PARAMETER AT DC LOAD TERMINAL

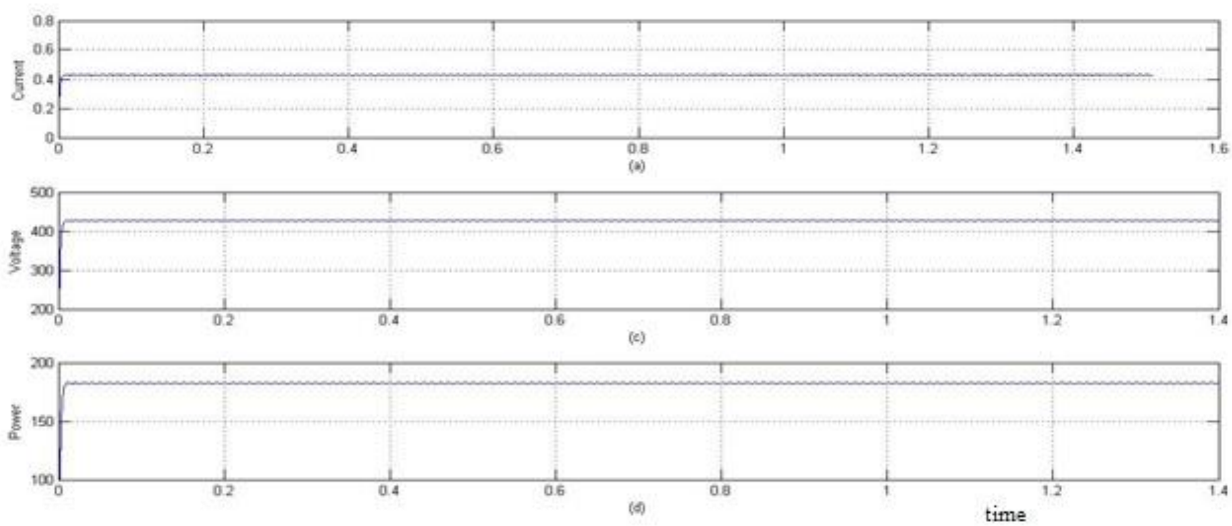

Fig. 7.9 a. Voltage b. Current d. Power for DC load

(3) PARAMETER AT BATTERY TERMINAL

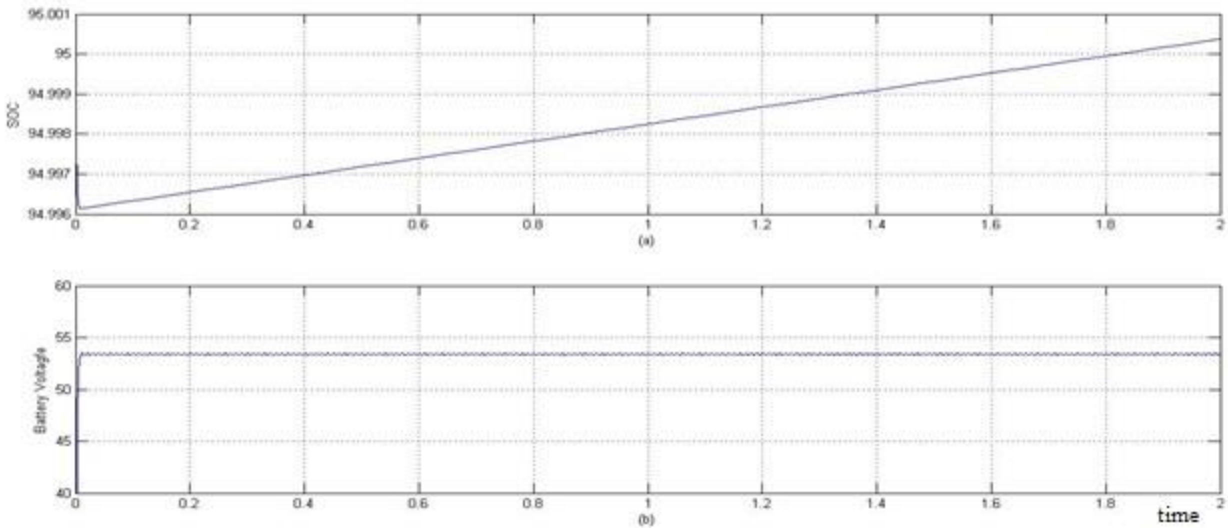

Fig. 7.10 a. SOC b. Battery Voltage

When the 1000w/m^2 irradiation is given to the PV system, then power is supply to the ac and dc load, at same time our battery will also charge. In figure 7.8 we get the power voltage and the current at the ac load terminal in sinusoidal in nature the avg. power of the instant power at the load terminal. In fig 7.9 we show the current, voltage and the power at the dc load terminal which is constant in nature and fig.7.10 we show the characteristics of the battery.

7.4.1 (B) WITHOUT IRRADIATIONS

(1) OUTPUT POWER AT AC LOAD TERMINAL

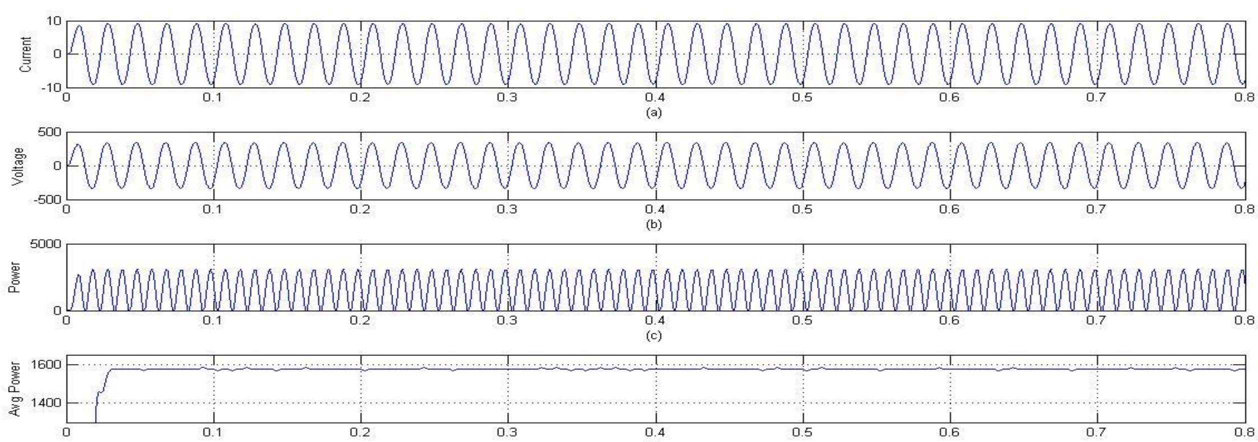

Fig. 7.11 a. Current b. Voltage c. Power d. Avg. Power for ac load w.r.t time

(2) PARAMETER AT DC LOAD TERMINAL

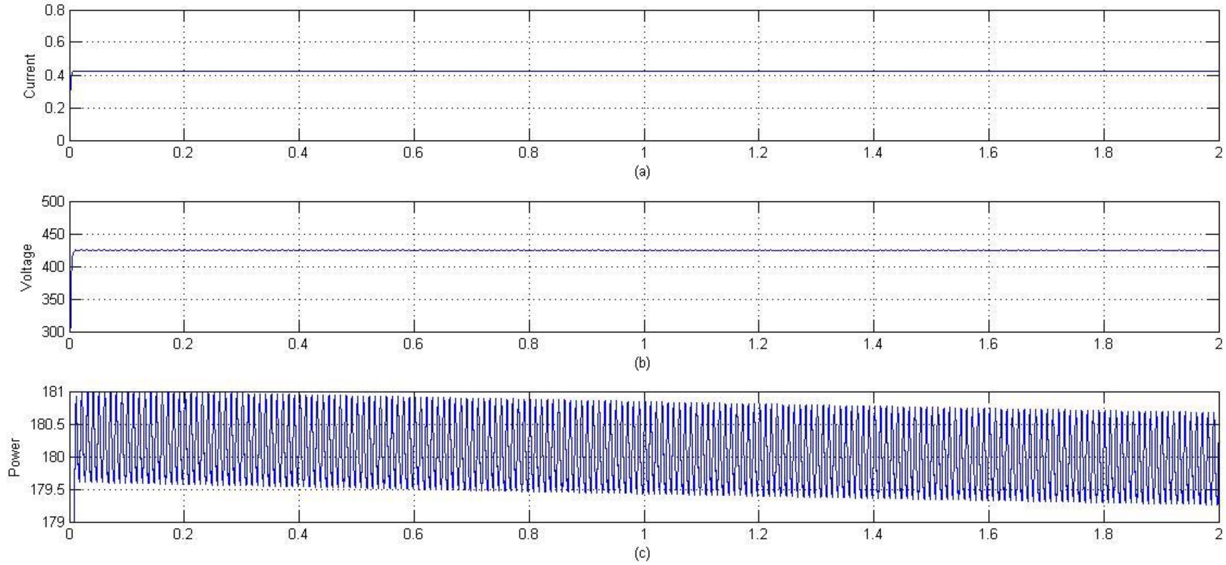

Fig. 7.12 a. Voltage b. Current c. Power for DC load w.r.t time

(3) PARAMETER AT BATTERY TERMINAL

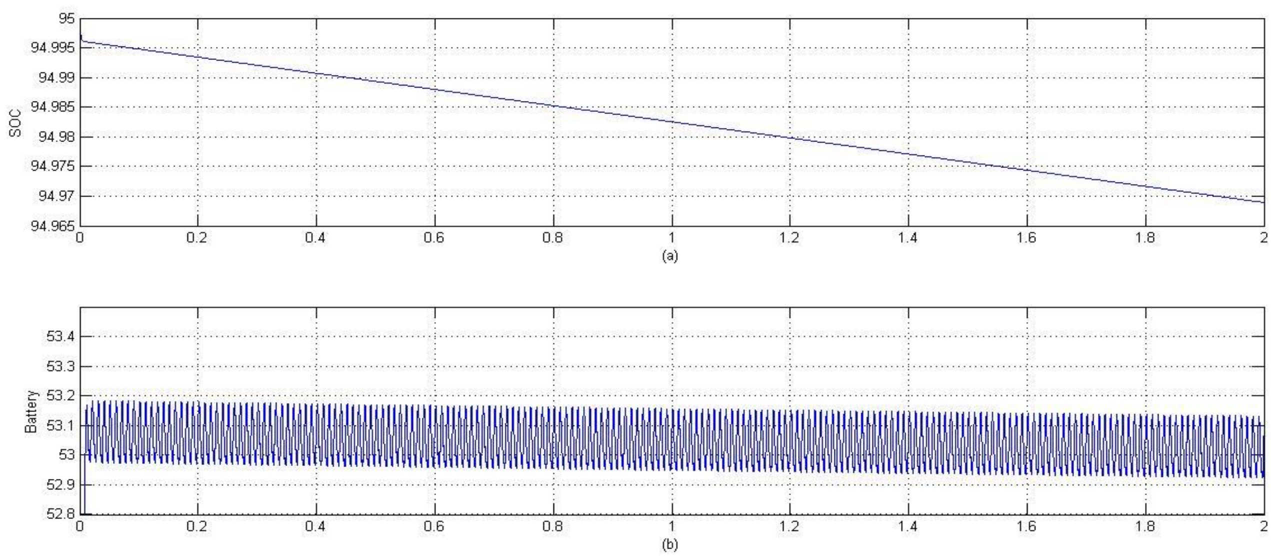

Fig. 7.13 a. SOC b. Battery Voltage w.r.t time

When irradiation is not given to the PV system, then power is supply to the ac and dc load, this power is given to load by the battery bank. In figure 7.11 we get the power, voltage and current at the ac load terminal in sinusoidal in nature the avg. power of the instant power at the load terminal.

In fig 7.12 we show the current, voltage and the power at the dc load terminal which decrease in nature and fig.7.13 we show the characteristics of the battery in which battery voltage and SOC is decay as time is increases.

7.4.1 (C) WITH PARTIAL SHADING

(1) OUTPUT POWER AT AC LOAD TERMINAL

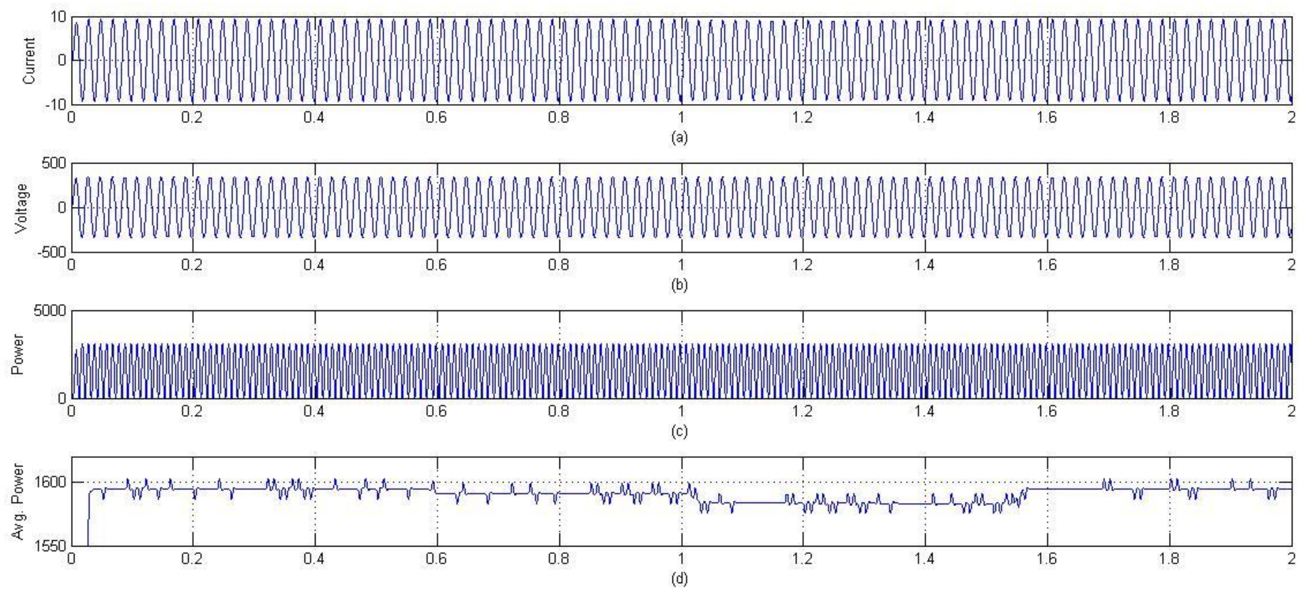

Fig. 7.14 a. Current b. Voltage c. Power d. Avg. Power for ac load w.r.t time

(2) PARAMETER AT DC LOAD TERMINAL

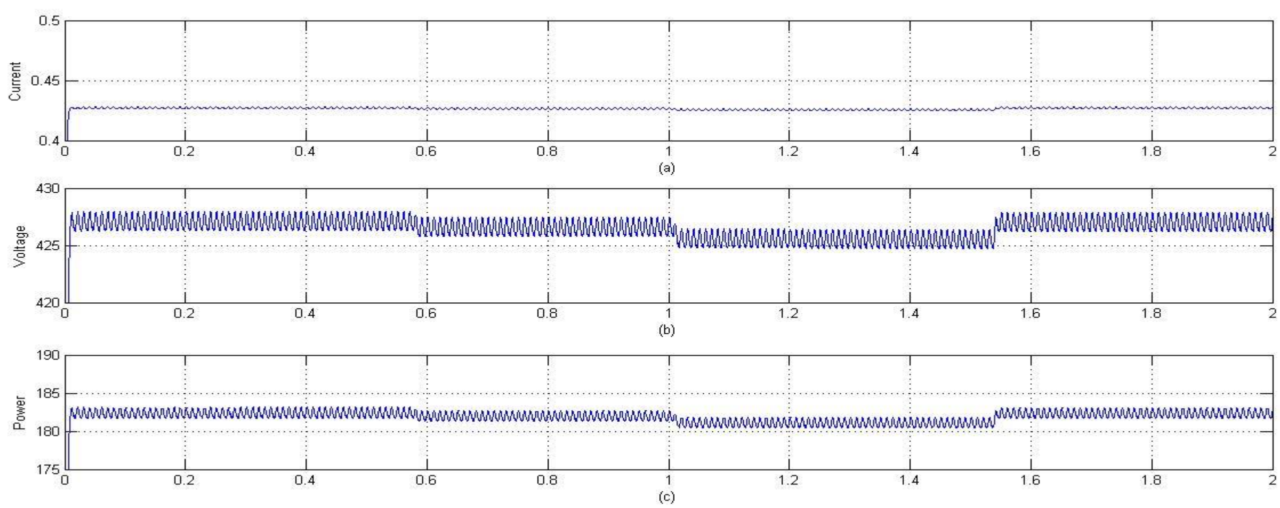

Fig. 7.15 a. Current b. Voltage c. Power for dc load w.r.t time

(3) PARAMETER AT BATTERY TERMINAL

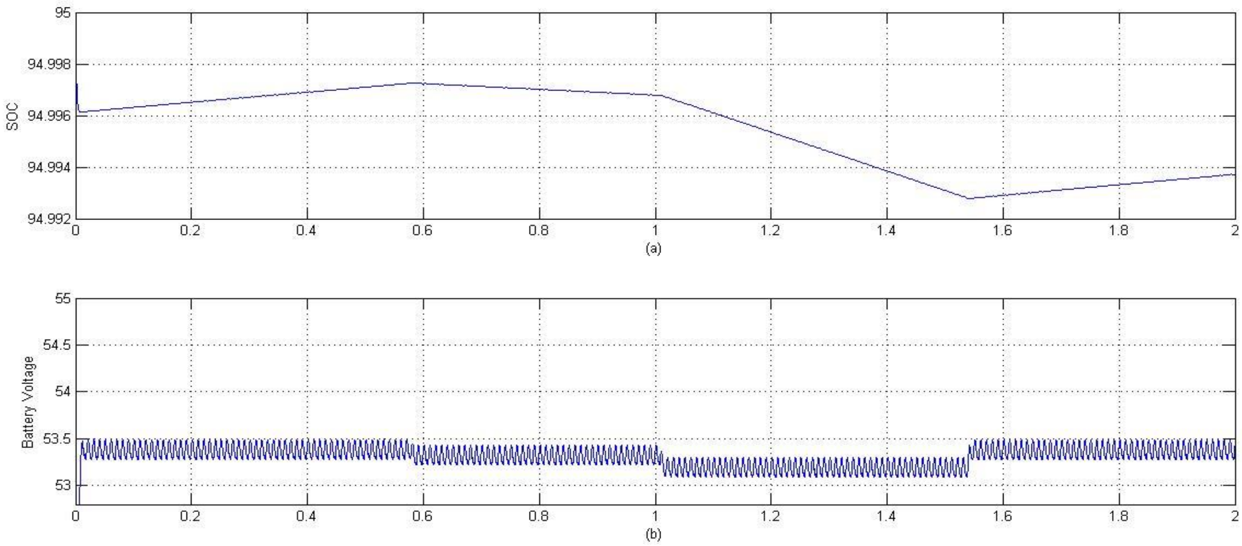

Fig. 7.16 a. SOC b. Battery Voltage w.r.t time

In partial shading condition, power from the PV system is supply to the ac and dc load, this power is given to load at same time battery discharging or charging is depend upon the irradiations level. In figure 7.14 we get the power, voltage and current at the ac load terminal in sinusoidal in nature the avg. power of the instant power at the load terminal this is supply by the PV system as well as the battery bank. In fig 7.14 we show the current, voltage and the power at the dc load terminal which decrease or increase it also depend upon the irradiation level and fig.7.15 we show the characteristics of the battery in which battery voltage is decay or increase as time is increases.

7.4.2. RESULT WITH I&C TECHNIQUE:

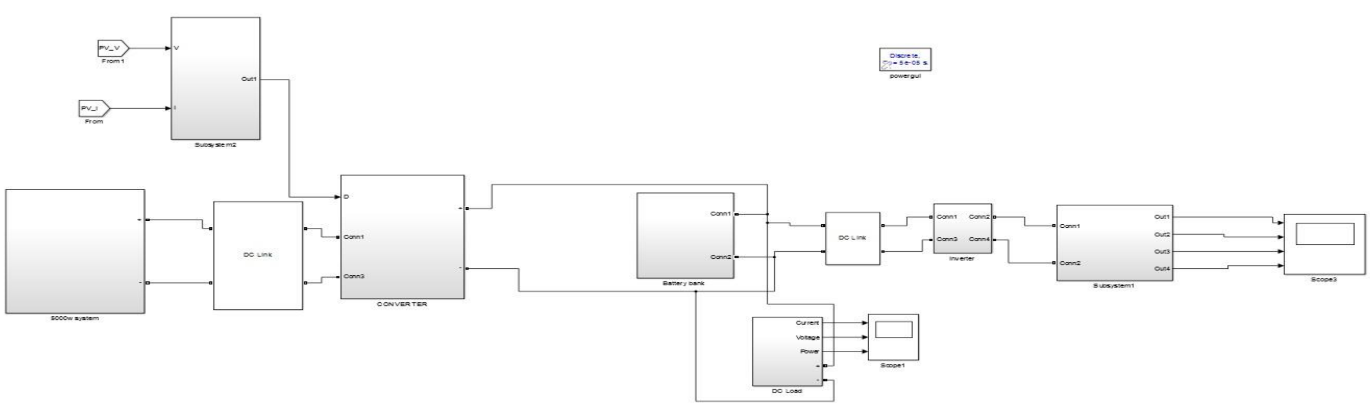

Fig. 7.17 Simulated Model of I&C with stand alone system

7.4.2 (A) WITH IRRADIATIONS

(1) PARAMETER AT AC LOAD TERMINAL

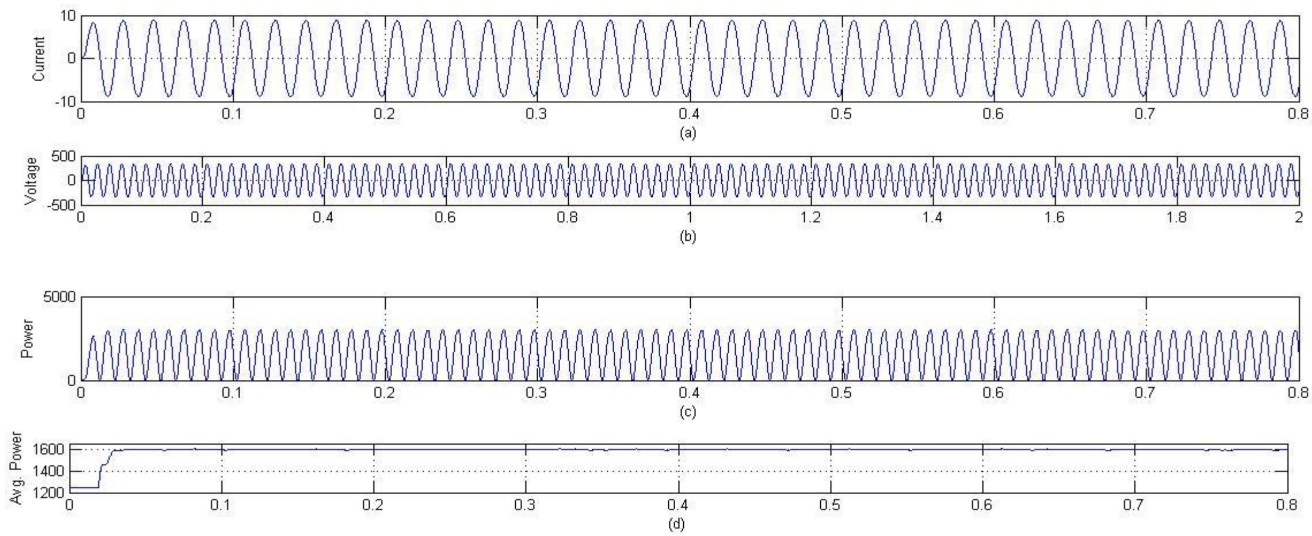

Fig. 7.18 a. Current b. Voltage c. Power d. Avg. Power for ac load w.r.t time

(2) PARAMETER AT DC LOAD TERMINAL

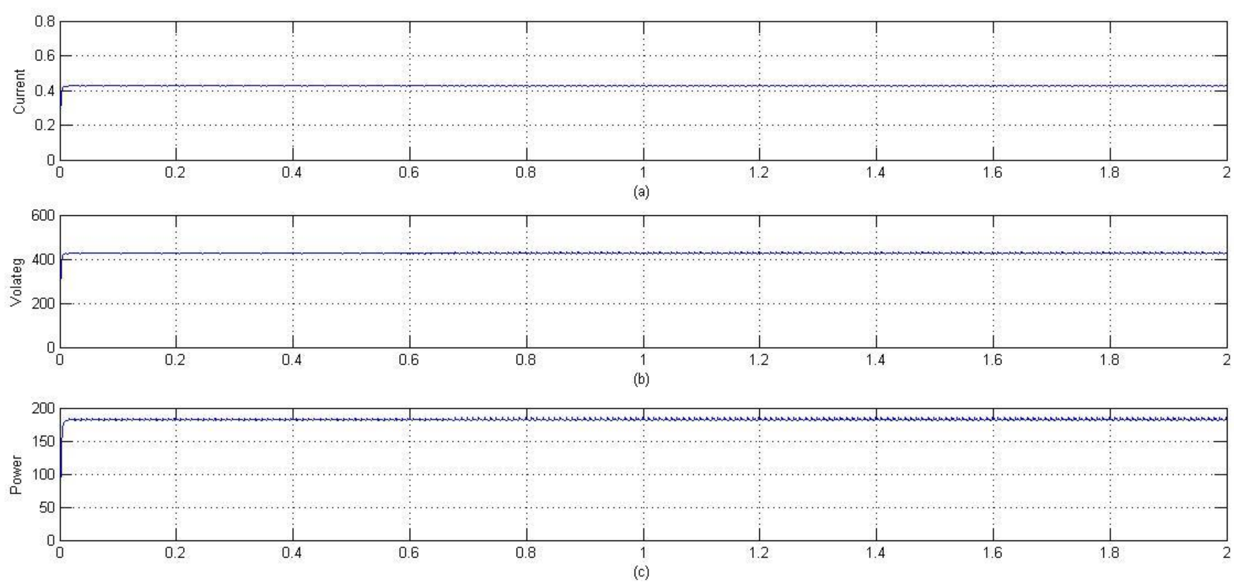

Fig. 7.19 a. Current b. Voltage c. Power for DC load w.r.t time

(3) PARAMETER AT BATTERY TERMINAL

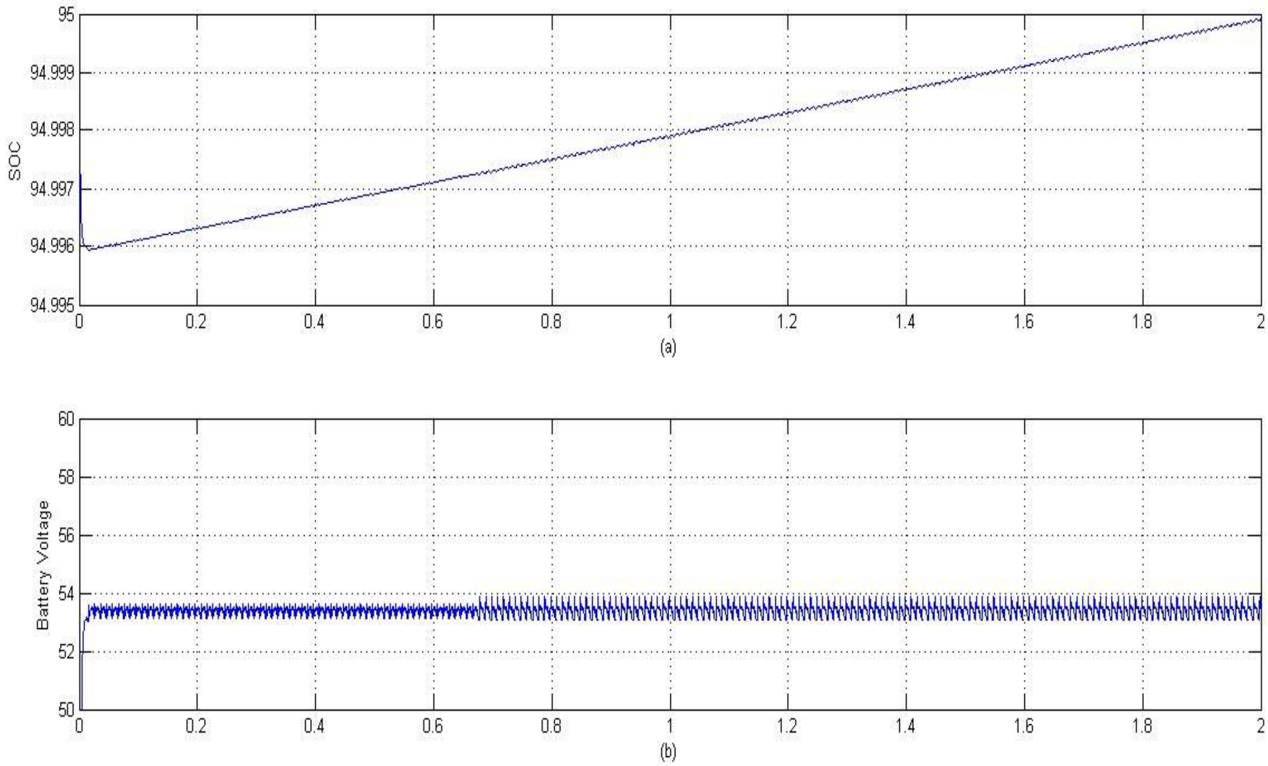

Fig. 7.20 a. SOC b. Battery Voltage w.r.t time

When the 1000w/m^2 irradiation is given to the PV system, then power is supply to the ac and dc load, at same time our battery will also charge. In figure 7.18 we get the power voltage and the current at the ac load terminal in sinusoidal in nature the avg. power of the instant power at the load terminal. In fig 7.19 we show the current, voltage and the power at the dc load terminal which is constant in nature and fig.7.20 we show the characteristics of the battery in which battery will charge and terminal voltage is constant.

7.4.2 (B) WITHOUT IRRADIATIONS

(1) OUTPUT POWER AT AC LOAD TERMINAL

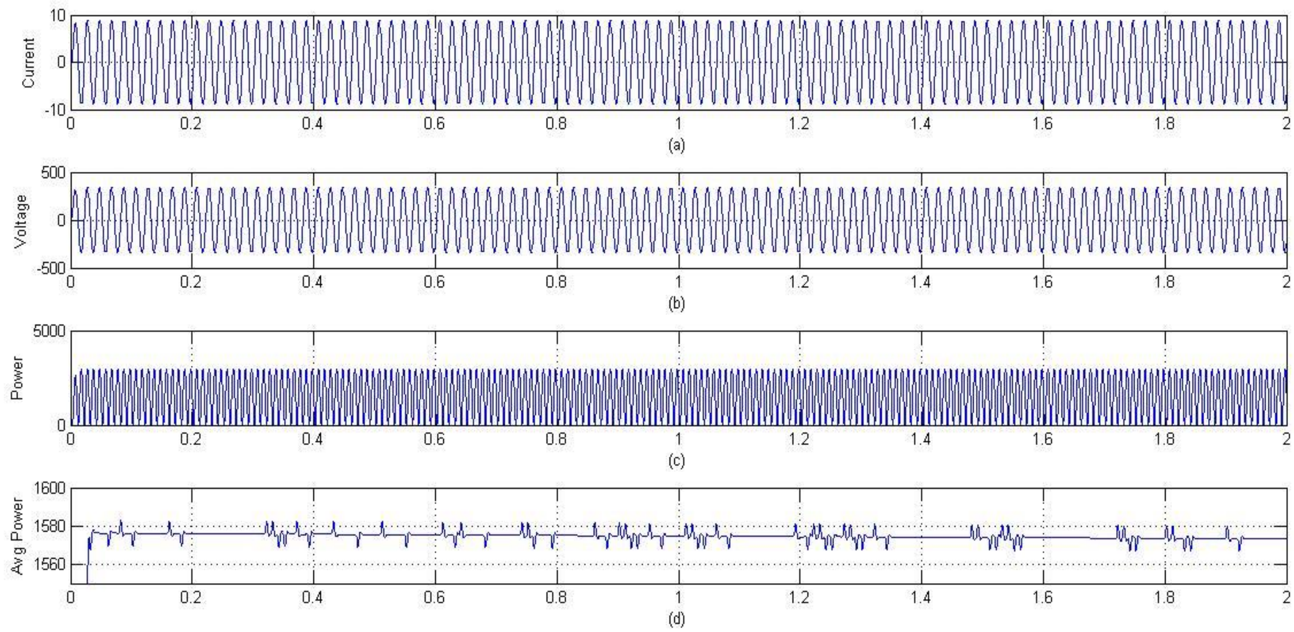

Fig. 7.21 a. Current b. Voltage c. Power d. Avg. Power for ac load w.r.t time

(2) PARAMETER AT DC LOAD TERMINAL

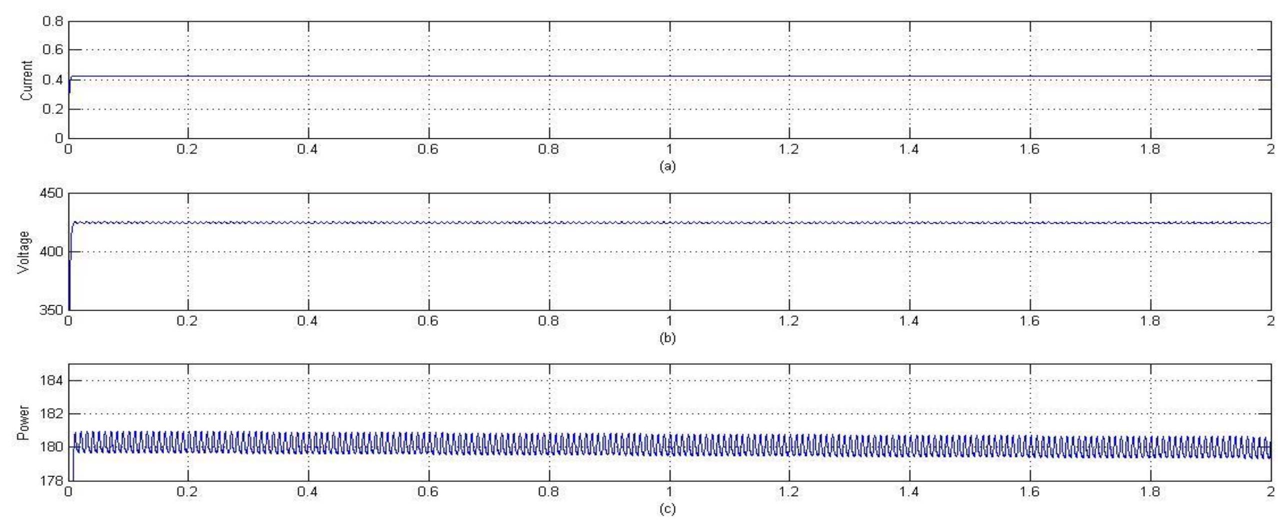

Fig. 7.22 a. Current b. Voltage c. Power for dc load w.r.t time

(3) PARAMETER AT BATTERY TERMINAL

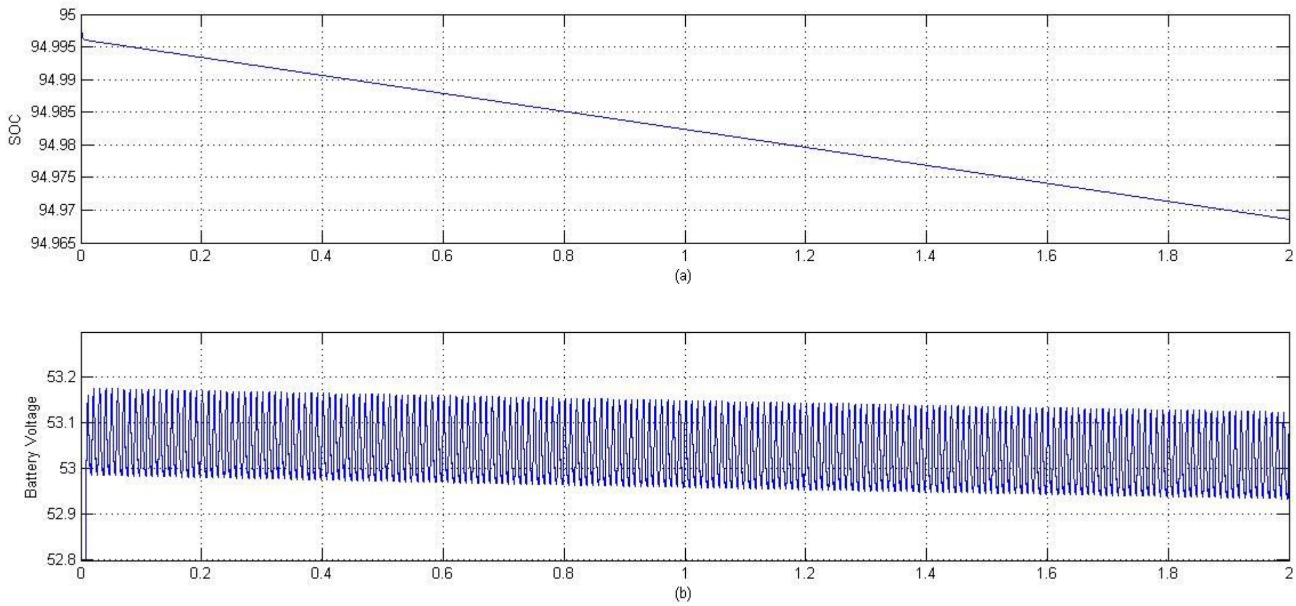

Fig. 7.23 1. SOC 2. Battery Voltage w.r.t time

When irradiation is not given to the PV system, then power is supply to the ac and dc load, this power is given to load by the battery bank. In figure 7.21 we get the power, voltage and current at the ac load terminal in sinusoidal in nature the avg. power of the instant power at the load terminal. In fig 7.22 we show the current, voltage and the power at the dc load terminal which decrease in nature and fig.7.13 we show the characteristics of the battery in which battery voltage and SOC is decay as time is increases

7.4.2 (C) WITH PARTIAL SHADING

(1) OUTPUT POWER AT AC LOAD TERMINAL

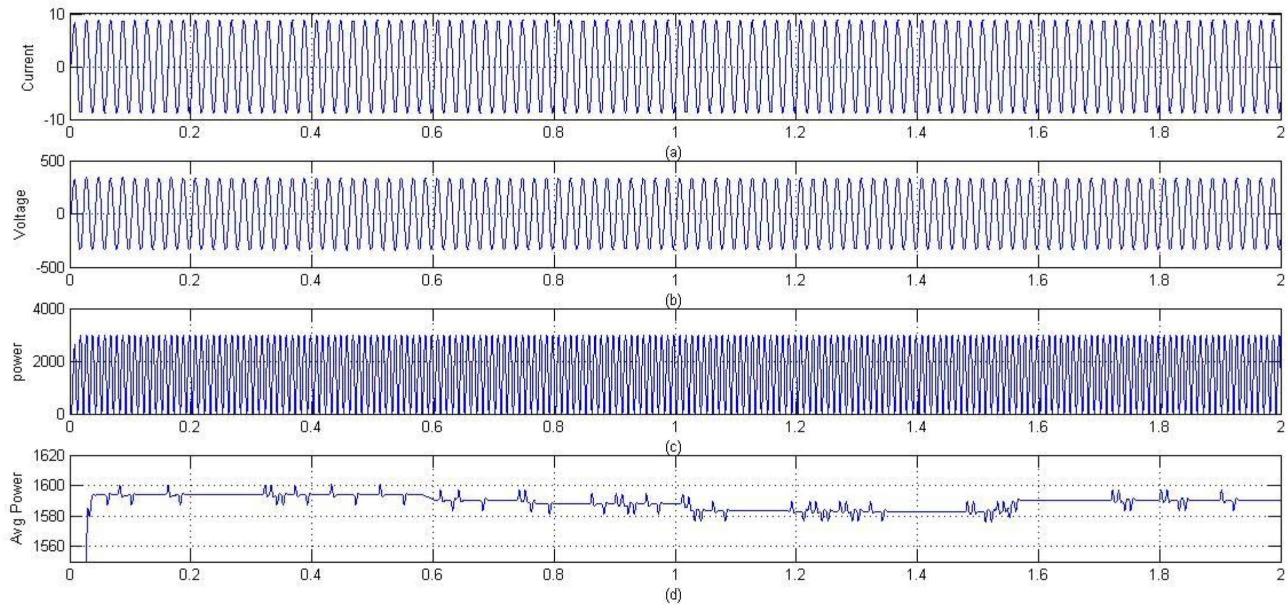

Fig. 7.24 21 a. Current b. Voltage c. Power d. Avg. Power for ac load w.r.t time

(2) PARAMETER AT DC LOAD TERMINAL

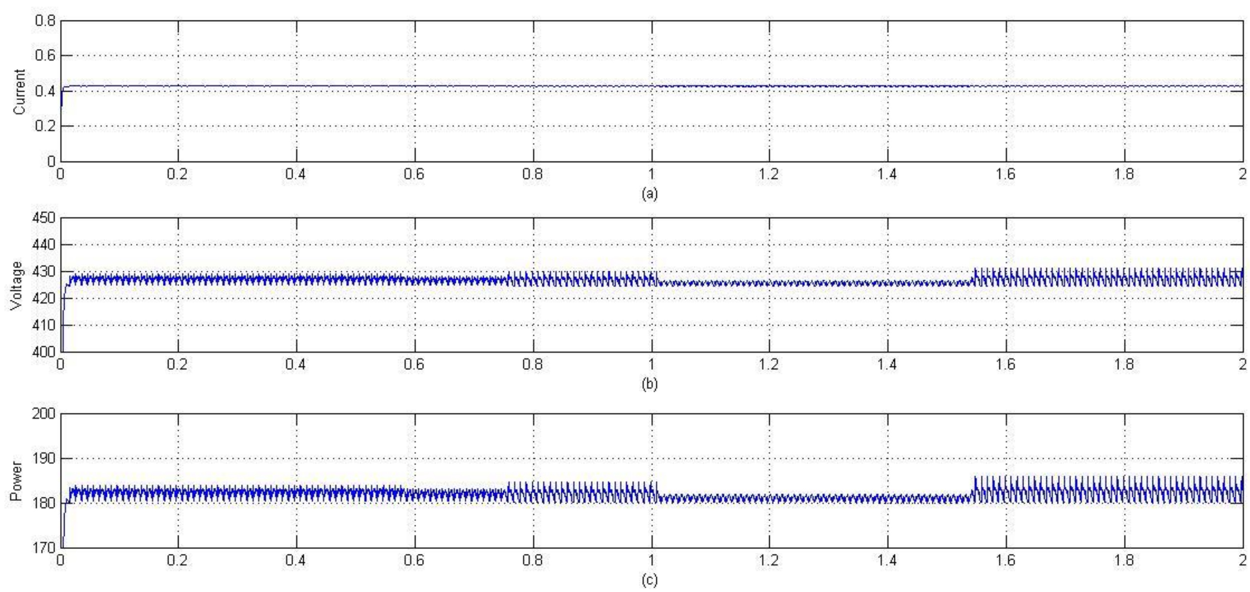

Fig. 7.25 a. Current b. Voltage c. Power for dc load w.r.t time

(3) PARAMETER AT BATTERY TERMINAL

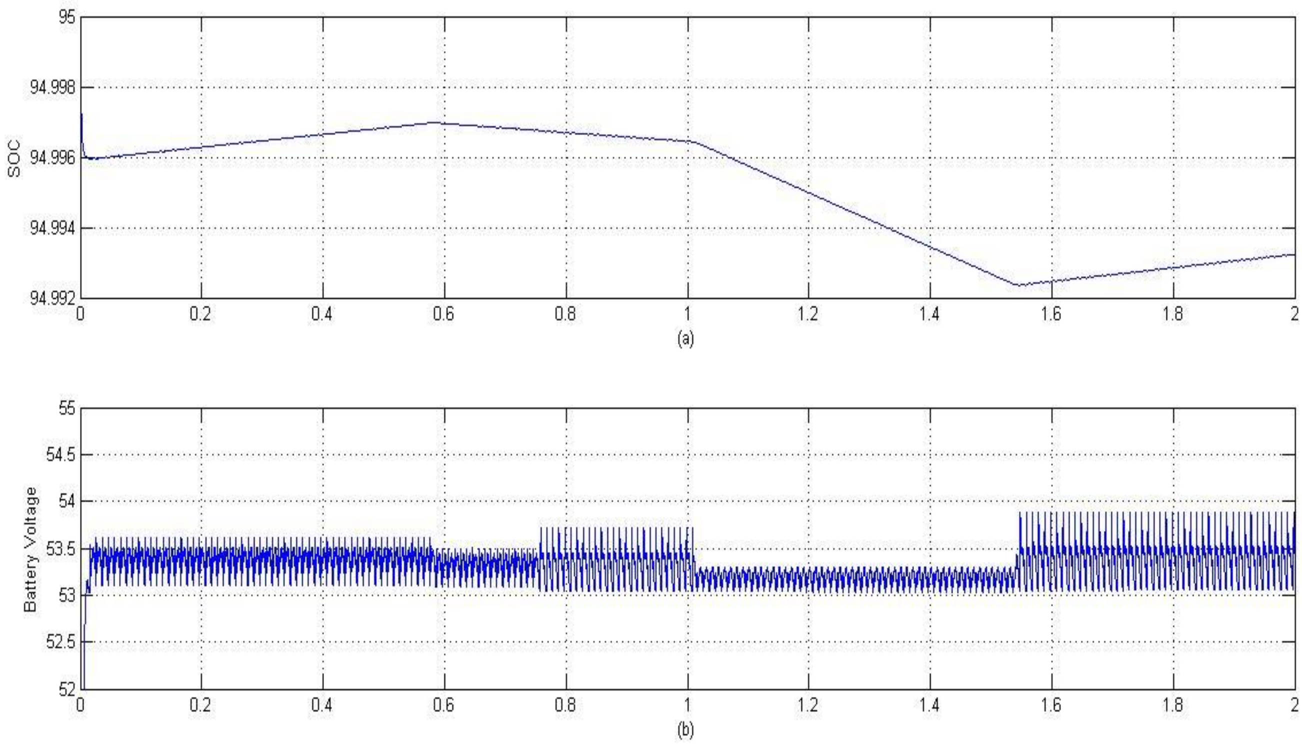

Fig. 7.26 1. SOC 2. Battery Voltage w.r.t time

In partial shading condition, power from the PV system is supply to the ac and dc load, this power is given to load at same time battery discharging or charging is depend upon the irradiations level. In figure 7.24 we get the power, voltage and current at the ac load terminal in sinusoidal in nature the avg. power of the instant power at the load terminal this is supply by the PV system as well as the battery bank. In fig 7.25 we show the current, voltage and the power at the dc load terminal which decrease or increase it also depend upon the irradiation level and fig.7.26 we show the characteristics of the battery in which battery voltage is decay or increase as time is increases.

7.4.3. RESULT WITH CHARGE CONTROLLER TECHNIQUE:

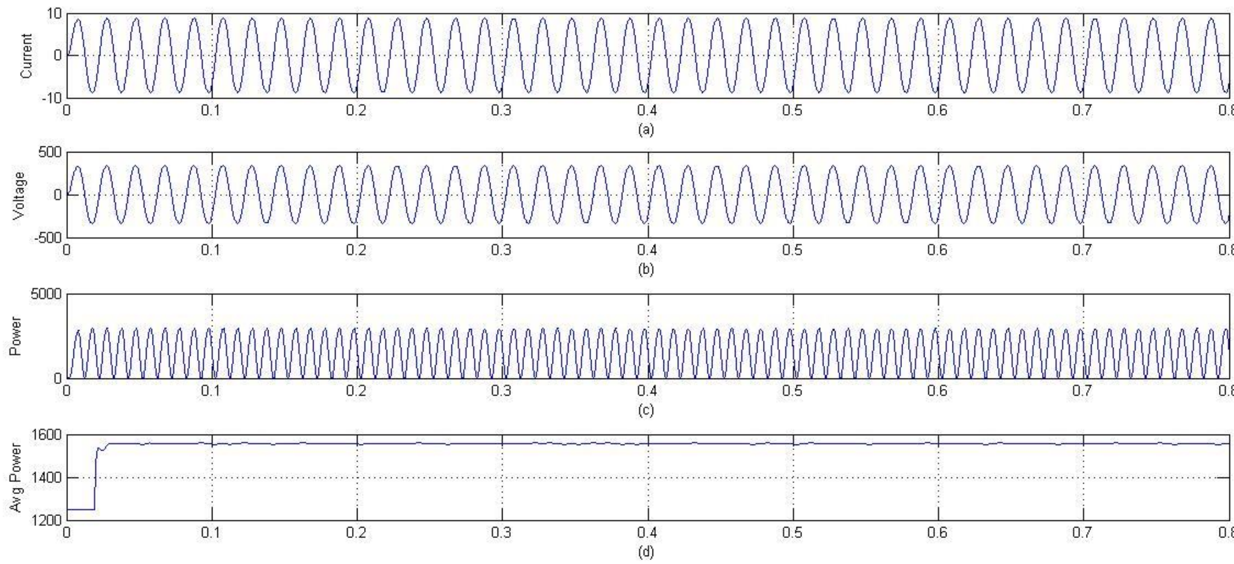

Fig. 7.27 a. Current b. Voltage c. Power d. Avg. Power for ac load w.r.t time

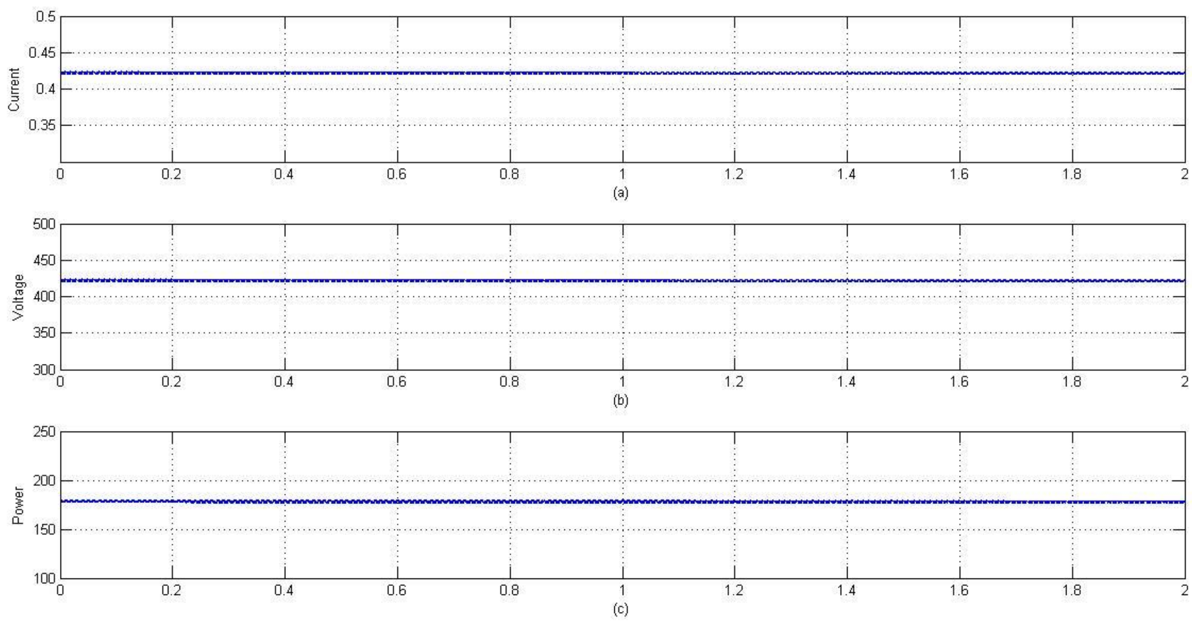

Fig. 7.28 a. Current b. Voltage c. Power for DC load w.r.t time

In charge controller technique for PV system we analysis the power, voltage and current for standalone system at dc and ac load. In charge controller technique battery will charge upto a certain voltage limit after that it will disconnect the charging system for the battery.

7.5 ANALYSIS OF DIFFERENT MPPT TECHNIQUE

Table 7.3 Comparison of various parameter with different MPPT

S.No.	**Parameter**	**Average Power**		**Voltage**		**Current**	
		AC	**DC**	**AC**	**DC**	**AC**	**DC**
1	**P&O**	1592W	195.5W	339(p-p)	442V	9.21(p-p)	0.4425A
2	**I&C**	1594W	180.5W	338(p-p)	424.5V	8.85(p-p)	0.425A
3	**Charge Controller**	1550W	179W	335(p-p)	423V	8.7A(p-p)	0.423A

7.6 DISCUSSION

In this work, performance analysis of two MPPT techniques namely P & O and incremental conductance is carried out and presented. The performance is evaluated on different meteorological conditions like constant irradiance and temperature, varying irradiance and constant temperature.

In addition, battery charging characteristics is also evaluated on the basis of battery voltage and battery charging current. It is concluded that the performance of constant voltage technique is better as compared to others at constant irradiance and temperature whereas P & O approach is better at constant irradiance and varying temperature

This Thesis presents PV/Battery energy system for the standalone system using Matlab/Simulink.. Standalone system is better than that a single source of energy. Charge Control method presented lead acid battery charging faster and efficiently. The control algorithm of charge controller execute P&O allow module to operate at maximum power point according to solar irradiation, and match load with the source impedance to provide maximum power. This MPPT model is more suitable because of less cost, easier circuit design. And efficiency of the circuit is increased by 20-25% in case of MPPT solar charge controller compare to a circuit with MPPT.

And also saved the extra energy required in mechanical tracking. As Arduino based controlling is used, it maintained constant 400V at the output terminal i.e. at the battery terminal. However, the performance of incremental conductance approach is better as compared to perturb and observe at varying irradiance and constant temperature. Therefore incremental conductance technique is better for evaluating the performance of PV system under meteorological parameters.

CHAPTER 8
CONCLUSION AND FUTURE SCOPE

8.1 INTRODUCTION

After discussing about the various aspects in this dissertation from concept to design and simulation conclusion and future scope is most important for research work. In this chapter conclusion of the research work is discuss.

8.2 CONCLUSION

In this dissertation first we have Annalise the different MPPT algorithm from that algorithms like Variable step Incremental and Conductance (I&C) and Perturb and Observe (P&O) for this research work. Done the implementation and simulation of Variable step I&C and P&O and Charge controller for standalone system. In this research work a single phase standalone system is implemented with battery bank. For our PV system comparison of various parameter like power, voltage and current is done by the MPPT algorithms, by this analysis we conclude that Variable step I&C is better in compare to P&O we find that power output is more and under partial shading condition I&C technique is superior. A charge controller is also implemented for the battery bank.

8.3 FUTURE SCOPE

- Battery DC Output is directly utilized to feed power in dc grid which is used to charging electronic devices like mobile, laptop etc directly.

- Stand Alone system with battery backup can be used in urban and sub-urban areas with modified technology for saving the electricity bill.

- We can generate our electricity for houses appliances with initial investment.

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