CHAPTER ONE

INTRODUCTION

1.1 Over View

Energy is plays pivotal role in our daily activities The electricity is most form of energy favorite and important because the development new technology made it possible to convert electrical energy into any form of energy. With growing worldwide demand for electricity, rising fuel cost, increasing concerns for global climate change and the impact of fossil fuel on the environment concerns over Green House gases (G H Gs). The scientists was looking for clean energy and they found renewable energy which it is energy is derived from natural processes that are replenished constantly in its various forms and do not has bad effect to environment . it derives directly or indirectly from the sun like wind, biomass ,geothermal, hydropower ,ocean resources tidal, Bio fuels and hydrogen derived from those renewable resources. Solar energy is most available renewable energy in the Sudan, which is regard one of the countries that have high insulation (7Kwh/m2/day)

1.2 Problem

The power of the solar energy used in local area such as homes ,farmer and so on . The main problem of the project is how to used some of the power out put for the solar energy in the grid

1.3 Objectives

The aim of this project are:

- Design control circuit of solar system with utility grid.
- Simulator the proposed system using MATLAB.

1.4 Methodology

- Conducting literature review to understand the concept of solar system

- ❖ Developing mathematical model for solar power system
- ❖ Designing MATLAB program to simulate the system

1.5 Project layout

This project consist of five chapter including Chapter one: the scope of each chapter explained as state below.

Chapter Two**:** this chapter obtains background of solar power system.

Chapter Three**:** explain main component of photovoltaic solar power system and how it connects with grid.

Chapter Four: determine the model solution and result.

Chapter Five: this chapter shows the results in conclusion and recommendations.

CHAPTER TWO

BACKGROUND REVIEW

2.1 Solar Power Systems

The sun delivers its energy to us in two main forms :heat and light their are two main types of solar power system namely ,solar thermal systems that trap heat to warm up to benefit of it, and solar pv system that convert sun light directly into electric which offer consumers the ability to generate electricity in a clean quite and reliable way. they are often called solar cells because the source of light is usually the sun or called photo voltaic

There are two ways which we can convert solar energy into electrical energy:

- **Solar thermal power plant**

Which generate electricity by concentrate solar radiation and focused it in one point with high temperature to generate high pressure fluid to drives turbine which convert high pressure to mechanical power and connected to generator for convert mechanical power to electrical power

- **Photovoltaic energy**

Another way to generate electricity from solar energy is to use photovoltaic cells which convert solar radiation falling on them directly into electricity

Solar power systems can be generally divided into two basic groups:

- Photovoltaic systems not connected to the network, stand-alone systems (off-grid)
- Stand-alone photovoltaic systems with peak PV power can have from milli - watts to several kilowatts. They do not have a connection to an electricity grid as shown in Figure (2.1). In order to ensure the supply of the stand alone system with electric power also in this times without radiation (e.g. at night)or with very low radiation(e .g., at times with strong cloud cover), stand alone system

mostly have an integrated storage system .if the system are used only during the time when the radiation is sufficient to supply the system with electric power directly , a storage system is not necessary . this is also applies to the situation in which the product delivered by the system can be stored(e .g ,water).

At present ,a very great variety of stand alone system exists .examples rang from solar calculators and watches to system for traffic control to systems that are able to supply one or several buildings in remote areas with electric power. they can be DC systems with or without a storage battery ,or they can be AC systems with an inverter.

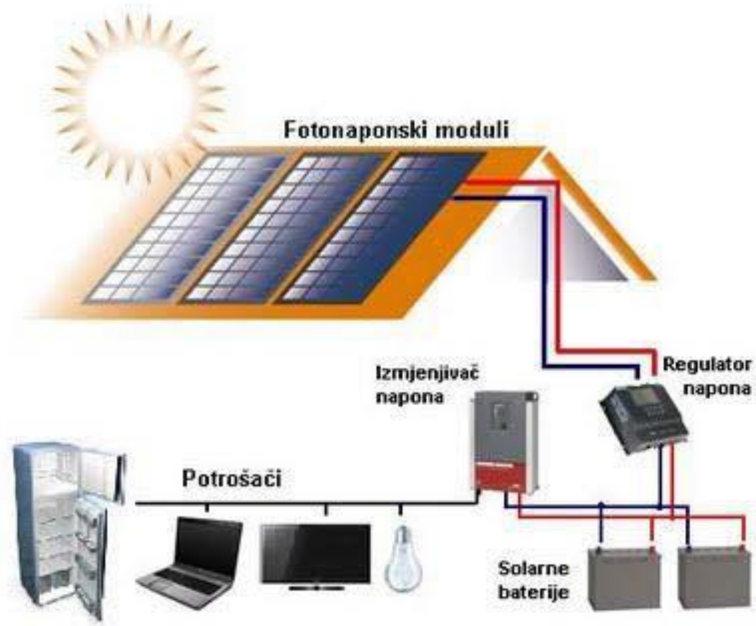


Figure 2.1: stand-alone solar system

Stand alone system can be implemented with a PV generator as the only power sourcse or with auxiliary power sources ,as so called hybrid systems ,where additional generators employing fossil (for example ,wind, ,hydro power ,or biomass) complement the PV energy production. the choice of storage capacity and of the relative power of a PV generator and an auxiliary power source depend on radiation conditions, the required security ,and last but not the least on economic s. today ,system designers can use layout programs that make it easy to find the optimum

- ❖ The advantage of stand alone system are :
- Provides power independently of the utility grid(still have power when the grid is down).
- Do not have to deal with utility company .
- Can save significantly on initial cost if a long of grid extension is needed to get to your house.
- Really encourages conservation and efficiency in the use of electricity off-grid people typically get along on far less power than on grid and do it without any significant life style changes.
- ❖ While the main disadvantages are :
- Higher initial cost(needs a set of batteries and charge controller).
- Higher ongoing time and cost(the cost of batteries over time is significant some say it is about as much as buying grid power).
- A good generator will likely be necessary from time to time .
- The system must be large enough to supply your full power needs during the lowest sun part of the year (also a generater can be used to supplement during the worst times)
- You are the power company ,and responsible for safe and reliable operation ,and maintenance.
- Photovoltaic systems connected to public electricity network (on-grid) Grid-connected PV systems always have a connection to the public electricity grid via a suitable ,inverter ,because a PV module delivers only DC power .Two application types can be distinguished ,central(directly connected to public grid) ,and distributed (connect to public grid via house grid).

The system size for residances is typically in the2 to 4kWp range .for commercial buildings the system size can range up to 100 kWp or more .

❖ The advantages of this system are:

- Lowest initial cost (because there is no need for batteries to maintain and charge controller)
- Lowest ongoing maintenance cost(no batteries to maintain and replace) Simplest to install.
- Most efficient (because there are no losses associated with charging batteries).
- You can start small and add(with some limitations)

While the main disadvantages are:

No power when the grid is down.

Access to the utility power grid is required.

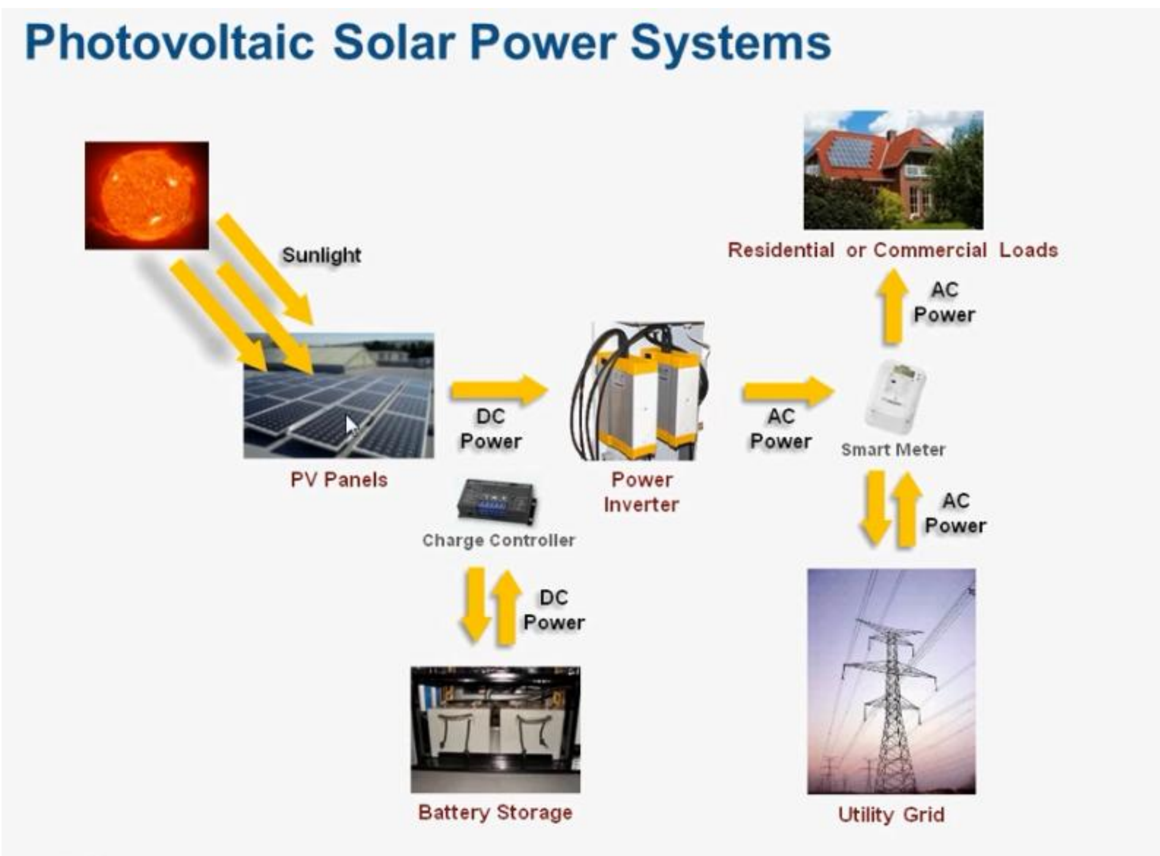


Figure 2.2: grid connect solar power system

- **System Component**

Pre-engineered photovoltaic systems can be purchased that come with all the components you will need, right down to the nuts and bolts. Any dealer can size and specify systems for you, given a description of your site and needs. Nevertheless, familiarity with system components, the different types that are available, and criteria for making a selection is important.

Basic components of grid-connected PV systems as shown in Figure(2.2)with and without batteries are:

- Solar photovoltaic modules
- Grounding equipment
- Inverter
- Meters – system meter and kilowatt-hour meter
- converters (low-harmonic rectifiers).
- Inverter AC disconnect

If the system includes batteries, it will also require:

- Battery bank with cabling and housing structure
- Charge controller
- Battery disconnect

2.2 Grid

An electrical grid is an interconnected network for delivering electricity from supplier to consumers. it consist of generating station that produce electrical power, high voltage transmission lines that carry power from distant sources to demand centers ,and distribution lines that connect individual customers .

Electric utilities across regions are many time interconnected for improved economy and reliability. Interconnection allows regions to have access to cheap bulk energy by receiving power from different sources The structure, or "topology" of a grid can vary depending on the constraints of budget, requirements for system reliability, and the load and generation characteristics. The physical layout is often forced by what land is available and its geology. Distribution networks are divided into two types, radial or network

❖ Smart gird

The electrical grid is expected to evolve to anew grid paradigm: the smart grid an enhancement of the 20th century ele ctrical grid the traditional electrical grids are generally used to carry power from a few central generators to a large number of user or customers in contrast the new emerging smart grid uses two way flows of electricity and information to create an automated and distributed advanced energy delivery net work "Smart grid" people are using tob ring utility electricity delivery systems in to the 21stcentury,using computer-based remote control and automation .

These systems are made possible by two way digital communications technologies and computer processing that has been used for decades in other industries .They are beginning to be used on electricity networks ,from the power plants and wind farm sall the way To the consumers of electricity in homes and businesses. They offer many benefits to utilities and consumers mostly seen in big improvements in energy efficiency and reliability on the electricity grid and in energy users 'homes and offices. According to a newest survey on smart grid the research is mainly focused on three systems in smart grid- the infrastructure system, the management system, and the protection system. The infrastructure system is the energy, information, and communication infrastructure underlying of the smart grid that supports. advanced electricity generation, delivery, and consumption advanced information metering, monitoring, and management; and advanced communication technologies

❖ Interconnected Grid

Electric utilities across regions are many times interconnected for improved economy and reliability. Interconnections allow for economies of scale, allowing energy to be purchased from large, efficient sources. Utilities can draw power from generator reserves from a different region in order to ensure continuing, reliable power and diversify their loads. Interconnection also allows regions to have access to cheap bulk energy by receiving power from different sources. For example, one region may be producing cheap hydro power during high water seasons, but in low water seasons, another area may be producing cheaper power through wind, allowing both regions to access cheaper energy sources from one another during different times of the year. Neighboring utilities also help others to maintain the overall system frequency and also help manage tie transfers between utility regions.

2.3 Control

Contol system are integral system part of modren societyNumeruos aplication are all aruond us: the rocket fire, and the space shuttle lifts off to earth orbit; in splashing cooling water,ametalic part isautomaticly machined.

A contol system consist of subsystems and processes (or plant) assembled forfor the purpose of controlling the output of processes .

- Advanteges of control system;

With control system we can move large equipment with precion that would other wisebe impossible .

We build control system for four primary reasons :

- Power amplification
- Remote control
- Convenience of input form
- Compensation for disturbance
- Voltage control

For interfacing with the utility grid lines, the renewable power system output voltage at the inverter terminals must be adjustable. The voltage is controlled by using one of the following two methods: The first is controlling the alternating voltage output of the inverter using a tap changing autotransformer at the inverter output Figure (2,3).

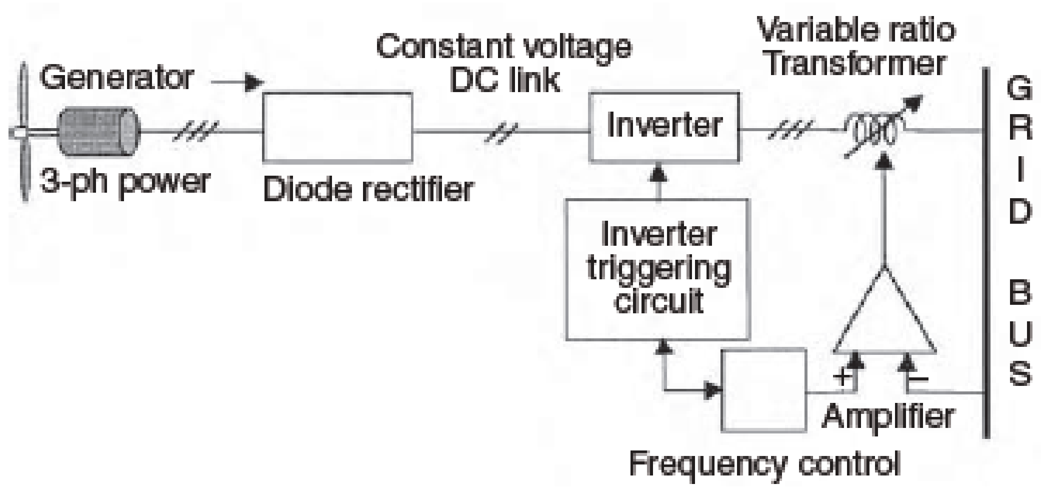


Figure 2.3: control of voltage

The tap changing is automatically obtained in a closed-loop control system. If the transformer has power Electronics

phase-changing winding also, complete control of the magnitude and phase of the site voltage can be achieved. The advantages of this scheme are that the wave shape of the site output voltage does not vary over a wide range, and a high input power factor is achieved by using uncontrolled diode rectifiers for the DC-link voltage. The added cost of the transformer, however, can be avoided by using the following method. Because the magnitude of the AC voltage output from the static inverter is proportional to the DC voltage input from the rectifier, voltage control can be achieved by operating the inverter with a variable DC-link voltage. Such a system also maintains the same output voltage, frequency, and wave shape over a wide range. However, in circuits deriving the load current from the commutating capacitor voltage of the DC link, the commutating capability decreases when the output voltage is reduced. This could lead to an operational difficulty when the DC-link voltage varies over a wide range, such as in a motor drive controlling the speed in a ratio exceeding 4:1. In renewable power applications, such a commutation difficulty is unlikely because the speed varies over a narrow range. The variable DC-link voltage is obtained in two ways. One is to connect a variable-ratio transformer on the input side of the rectifier. The secondary tap changing is automatically obtained in a closed-loop control system. At reduced output voltages, this method gives a poor power factor and high harmonic content and requires filtering of the DC voltage before feeding to the inverter

❖ Frequency control

The output frequency of the inverter solely depends on the rate at which the switching thyristors or transistors are triggered into conduction. The triggering rate is determined by the reference oscillator producing a continuous train of timing pulses, which are directed by logic circuits to the thyristor gating circuits. The timing-pulse train is also used to control the turn-off circuits. The frequency stability and accuracy requirements of the inverter dictate the selection of the reference oscillator. A simple temperature-compensated R–C relaxation oscillator gives frequency stability within 0.02%. When better stability is needed, a crystal-controlled oscillator and digital counters may be used, which can provide stability of .001% or better. Frequency control in a stand-alone power system is an open-loop system. Steady-state or transient load changes do not affect the frequency. This is a major advantage of the power electronic inverter over the old electromechanical means of frequency control.

2.4 DC/D C Converter

Dc-dc power converters are employed in a variety of applications, including power supplies for personal computers, office equipment, spacecraft power systems, laptop computers, and telecommunications equipment, as well as dc motor drives. The input to a dc-dc converter is an unregulated dc voltage Vg. The magnitude (and possibly polarity) that The ideal dc-dc converter Exhibits 100% efficiency; in practice, Efficiencies of 70% to 95% are typically obtained. This is achieved using *switched-mode*, or *chopper*, circuits whose elements dissipate negligible power. *Pulse-width modulation* (PWM) allows control and regulation of the total output voltage. This approach is also employed in applications involving alternating current , including high-efficiency dc-ac power converters (inverters and power amplifiers), ac-ac power converters , and some ac-dc power

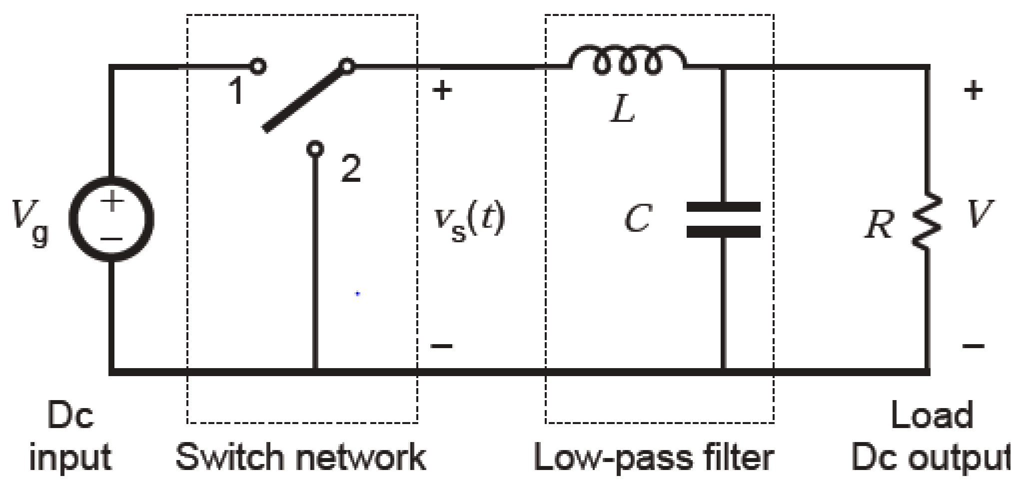


Figure2.4: circuit of DC to DC converter

The buck converter consists of a switch network that reduces the dc component of voltage ,and a low pass filter that removes the high frequency switching harmonics :

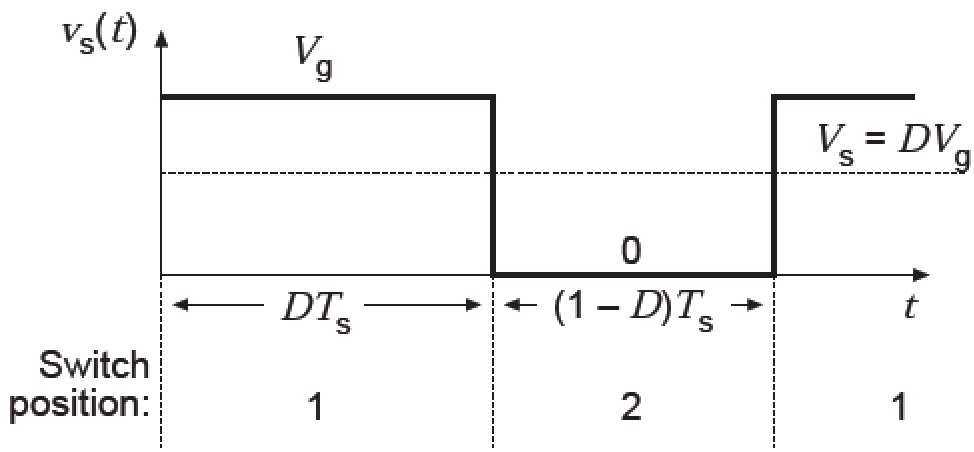


Figure 2.5 : switched voltage wave form

$v_{s.}(t)$ is equal to V_g when the switch is in position 1, and is equal to zero when the switch is in position 2.

The switch position is varies periodically, such that $v_s(t)$ is a rectangular waveform having period T_s and duty cycle D. The duty cycle is equal to the fraction of time that the switch is connected in position 1, and hence 0 <= D <= 1. The *switching frequency* f_s is equal to $1/T_s$. In practice, the SPDT switch is realized using semi-conductor devices such as diodes, power MOSFETs, IGBTs, BJTs, or thyristors. Typical switching frequencies lie in the range 1 kHz to 1 MHz, depending on the speed of the semiconductor devices.

The switch network changes the dc component of the voltage. By Fourier analysis, the dc component of a waveform is given by its average value. The average value of $v_s(t)$ is given by

$$V_S = \frac{1}{T_S}\int_0^{T_S} V_S(T)dt = DV_g \tag{2.1}$$

The integral is equal to the area under the waveform, or the height *V*g multiplied by the time *DT*s. It can be seen that the switch network reduces the dc component of the voltage by a factor equal to the duty cycle *D*. Since 0 <=*D* <= 1, the dc component of *V*s is less than or equal to *V*g. The power dissipated by the switch network is ideally equal to zero. When the switch contacts are closed, then the voltage across the contacts is equal to zero and hence the power dissipation is zero. When the switch contacts are open, then there is zero current and the power dissipation is again equal to zero.

Therefore, the ideal switch network is able to change the dc component of voltage without dissipation of power.

In addition to the desired dc voltage component V_s, the switch waveform $v_s(t)$ also contains undesired harmonics of the switching frequency. In most applications, these harmonics must be removed, such that the converter output voltage $v(t)$ is essentially equal to the dc component $V = V_s$. A low-pass filter is employed for this purpose. The converter of Figure (2,4) contains a single-section *L*-*C* low-pass filter. The filter has corner frequency f_0 given by

$$f_0 = \frac{1}{2\pi\sqrt{LC}} \tag{2.2}$$

The corner frequency f_0 is chosen to be sufficiently less than the switching frequency f_s, so that the filter essentially passes only the dc component of $v_s(t)$. To the extent that the inductor and capacitor are ideal, the filter removes the switching harmonics without dissipation of power. Thus, the converter produces a dc output voltage whose magnitude is controllable via the duty cycle *D*, using circuit elements that (ideally) do not dissipate power.

The *conversion ratio* $M(D)$ is defined as the ratio of the dc output voltage *V* to the dc input voltage

V_g under steady-state conditions:

$M(D) = V/v_g$

For the buck converter, $M(D)$ is given by

$M(D)=D$

2.5 DC/AC Converter

The main source of electrical power is the battery which is a DC source. The DC output of the battery is bucked or boosted according to the requirement and then converted into AC using a 3.phase DC to AC converter.

The function of an inverter is to change a dc input voltage to a symmetric ac output voltage of desired magnitude and frequency. The output voltage waveforms of ideal inverters should be sinusoidal. However, the waveforms of practical inverters are non-sinusoidal and contain certain harmonic.

The process of inversion called synchronous inversion is advantageous only to regenerate the power of dc source in the load to the a fixed frequency ac supply . the basic principles of inversion are illustrated in Figure(2.6)a switches s1,s4 when closed apply dc voltage with a positive with respect to B across the load .

When switches s2,s3 are closed the polarity of the voltage across the load changes, b being at a positive potential. Therefore by alternately having the pairs of switched closed it is possible to get an ac voltage across the load . the period of the closure of the switches can be controlled so that the frequency of ac voltage is variable or an ac of desired can be obtained.

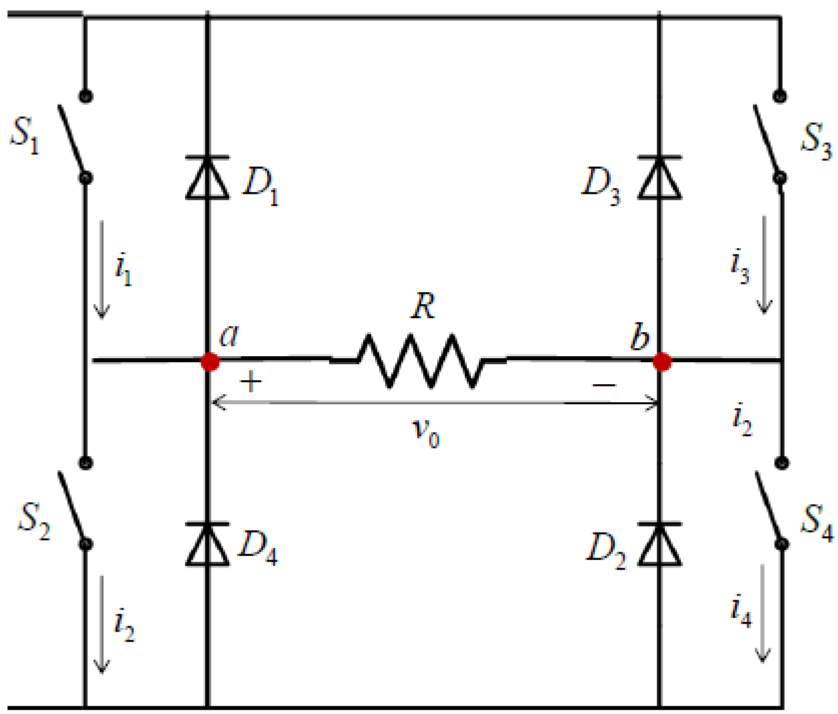


figure2.6 Single Phase Bridge DC-AC Inverter with *R* Load

A single phase bridge DC-AC inverter is shown in Figure (2.6)The analysis of the single phase DC-AC inverters is done taking into account following assumptions and conventions:

The current entering node a in Figure (2,6) is considered to be positive.

The switches S1 , S2 , S3 and S4 are unidirectional, i.e. they conduct current in one direction.

When the switches 1 S and 2 S are turned on simultaneously for a duration 1 0, the input voltage in V appears across the load and the current flows from point a to b. If the switches 3 S and 4 S are turned on for a duration the voltage across the load is reversed and the current through the load flows from point b to a. The voltage and current waveforms across the resistive load are shown in Figure (2,5)The instantaneous output voltage can be expressed in Fourier series as

$$v_0 = \frac{a_0}{2} + \sum_{n=1}^{\infty} \cos(n\omega t) + b_n \sin(n\omega t) \tag{2.3}$$

Due to the square wave symmetry along the ***x-axis*** , both and are ***zero***, and is obtained as o a n a n b

$$b_n = \frac{1}{\pi}\left[\int_{\frac{-\pi}{2}}^{0} \frac{-V_{in}}{2} d(\omega t) + \int_{0}^{\frac{\pi}{2}} \frac{V_{in}}{2} d(\omega t)\right] = \frac{4V_{in}}{n\pi} \tag{2.4}$$

Substituting the value of n b from equation v0 into equation bn gives

$$v_0 = \sum_{n=1,3,5,\ldots}^{\infty} \frac{4V_{in}}{n\pi} \sin(n\omega t) \tag{2.5}$$

The instantaneous current through the resistive load is given by

$$v_0 = \sum_{n=1,3,5,\ldots.}^{\infty} \frac{1}{R}\frac{4V_{in}}{n\pi} \sin(n\omega t) \tag{2.6}$$

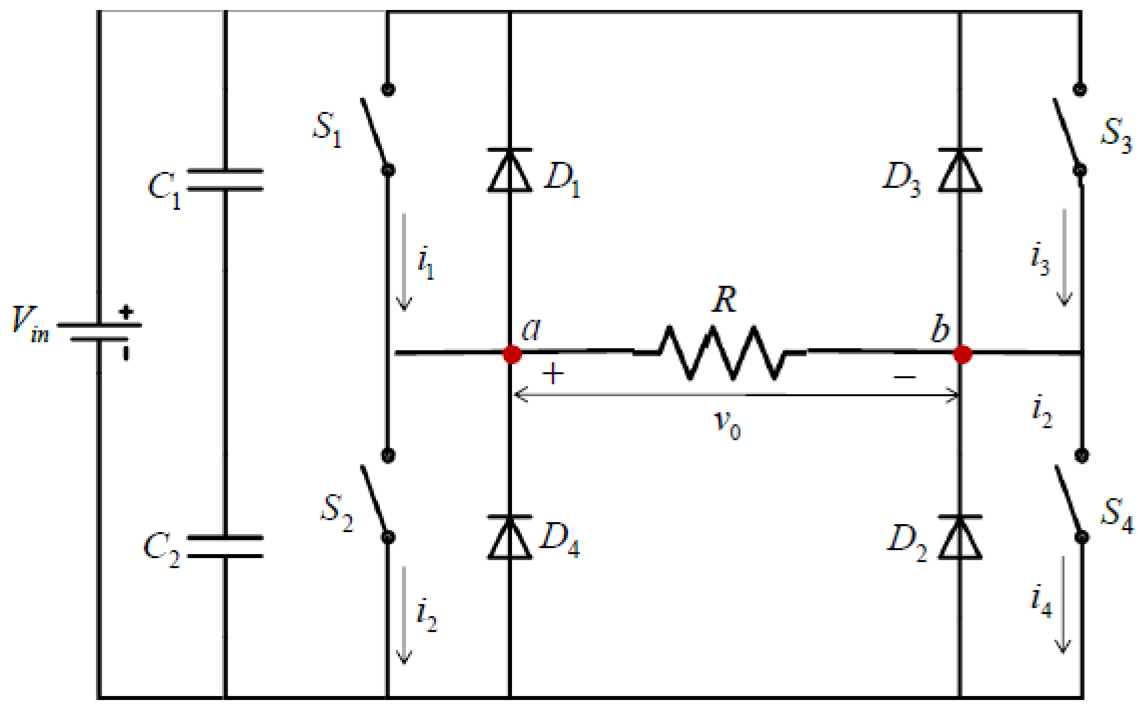


Figure 2.7: three phase inverter with resistive load

CHAPTER THREE

PHOTOVOLTIC SOLAR POWER SYSTEM

3.1 P V Panels

The basic building block of a photovoltaic module is the photovoltaic cell; these convert solar energy into electricity. The solar cell is composed of a P-type semiconductor and an N-type semiconductor. Solar light hitting the cell produces two types of electrons, negatively and positively charged electrons in the semiconductors. Negatively charged (-) electrons gather around the N-type semiconductor while positively charged (+) electrons gather around the P-type semiconductor. When you connect loads such as a light bulb, electric current flows between the two electrodes. The power output will depend on the amount of energy incident on the surface of the cell and the operating temperature of the photovoltaic cell. The power output of a single cell can supply small loads like calculators or watches, but in order to be useful for high energy demand projects these cells must be arranged in series and parallel connections. A photovoltaic module is an array of photovoltaic cells pre-arranged in a single mounting mold. The type of module is therefore determined by the cells that compose the module itself. There are three dominating cell technologies:

- **Monocrystalline**: As the name implies, these are cells that are grown from a single crystal. The production methods are difficult and expensive. These tend to be more efficient (more power in less area) and more expensive.
- **Multi crystalline:** The production process allows multiple crystalline structures to develop within the cell. It is easier to implement in a production line. It is relatively cheaper than mono- crystalline at the expense of lower efficiency.
- **Thin-film:** Uses less silicon to develop the cell (hence the name thin film)

allowing for cheaper production costs (silicon is in high demand). It tends to be less expensive but has also lower efficiency.

The overall efficiency of the module will depend on the cell efficiency and placement within the module, and on the laminating materials used. The standard testing condition (STC), defined as a total irradiance of $1000W/m^2$ and an ambient temperature of 25^oC, is used to define module ratings. Typical module efficiencies range between 11% and 17% for crystalline technologies at STC; most of the commercially available modules are in the lower bound of this range. Thin-film module efficiencies range between 6% and 12% . Since 2003 total PV production grew in average 50%, whereas the thin film segment grew almost 80% and reached 196 MW or 8% of total PV production in 2006. About 90% of the current production uses wafer-based crystalline silicon technology.

The main advantage of this technology was that complete production lines could be bought, installed and manufactured within a relatively short time. This predictable production start-up scenario constitutes a low-risk placement with high expectations for return on investment

Figure 3.1 thin film, Mono crystalline, Multi crystaline

Thin film silicon And should be use a thickness and short conductor to a void power losses (to decrease resistor) To avoid using long conductor PV modules should fixed on one surface and tilted the surface tilt with respect to horizontal

3.1.1 Module and array

The solar cell described in the preceding subsection is the basic building block of the PV power system. Typically, it is a few square inches in size and produces about 1 W of power. To obtain high power, numerous such cells are connected in series and parallel circuits on a panel (module) area of several square feet . The solar array or panel is defined as a group of several modules electrically connected in a series–parallel combination to generate the required current and voltage.

3.1.2 Peak power operation

The sun tracker drives the module mechanically to face the sun to collect the maximum solar radiation. However, that in itself does not guarantee the maximum power output from the module. , the module must operate electrically at a certain voltage that corresponds to the peak power point under a given operating condition. First we examine the electrical principle of peak-power operation. If the array is operating at any point at voltage V and current I on the

I-V curve, the power generation is P = VI watts. If the operation moves away from the preceding point such that the current is now I + ΔI, and the voltage is V + ΔV, then the new power is as follows:

$$P + \Delta P = (V + \Delta V)(I + \Delta I) \quad (3.1)$$

which, after ignoring a small term, simplifies to the following:

$$\Delta P = \Delta V \cdot I + \Delta I \cdot V \quad (3.2)$$

ΔP would be zero if the array were operating at the peak power point, which necessarily lies on a locally flat neighborhood. Therefore, at the peak power point, the preceding expression in the limit becomes:

$$dV/dI=V/I \quad (3.3)$$

3.1.3 The array holder

PV Array is mounted on stationary holder having a fixed tilt with respect to horizontal PV Array is oriented east west ,facing south.

3.2 Power Inverter

The inverter is an electronic device that converts direct current DC power(from a battery ,solar panel ,etc)into alternating current AC power to operate lights appliance ,or anything that normally operates on power supplied by the utility grid .the power used in utility grid is AC power that because AC power does not suffer from critical power losses over long distance like DC power.

The photovoltaic power is DC power, when we connected these power to the utility grid we must use invert to convert the DC power to AC power.

Most inverters to their job by performing two main functions first they convert the incoming DC into AC and then they step up the resulting AC to mains voltage level using a transformer.

Inverters take care of four basic tasks of power conditioning:

- Converting the DC power coming from the PV modules or battery bank to AC power
- Ensuring that the frequency of the AC cycles is 60 cycles per second
- Reducing voltage fluctuations
- Ensuring that the shape of the AC wave is appropriate for the application, pure sine wave for grid-connected systems

❖ The DC input to the inverter can be from any of the following sources:

- PV power modules
- Battery used in the wind or PV power system

Figure shows the DC-to-three-phase AC inverter circuit diagram. The DC source current is switched successively in a 60-Hz three-phase time sequence so as to power the three-phase load. The fundamental frequency (60 or 50 Hz) phase-to-neutral voltage is as follows:

$$V_{ph} = \frac{2\sqrt{2}}{\pi}\cos\left(\frac{\pi}{6}\right)V_{dc} \tag{3.4}$$

The line-to-line AC voltage is given by √3·Vph. Unlike in BJT, MOSFET, and IGBT, the thyristor current once switched on must be forcefully switched off (commutated) to terminate conduction. If the thyristor is used as a switching device, the circuit must incorporate an additional commutating circuit to perform this function. The commutating circuit is a significant part of the inverter circuit. There are two main types of inverters, the line-commutated and the forced-commutated. The line-commutated inverter must be connected to the AC system they feed power to. The design method is well developed and has been extensively used in high-voltage DC (HVDC) transmission line inverters. This inverter is simple and inexpensive, and can be designed for any size. The disadvantage is that it acts as a sink for reactive power and generates high content of high-frequency harmonics. Therefore, its output needs a heavy-duty harmonic filter to improve the quality of power at the AC output. This is done by an inductor connected in series and a capacitor in parallel to the inverted output voltage, similar to that done in the rectification process. The poor power factor and high harmonic content in the line-commutated inverter significantly degrade the quality of power at the grid interface. This problem has been recently addressed by a series of design changes. Among them are the 12pulse inverter circuit and increased harmonic filtering. These new design features have resulted in today's inverter operating with near-unity power factor and less thanPower Electronics 3 to 5% total harmonic distortion. The quality of power at the utility interface at many modern wind power plants now exceeds that of the grid they interface. The forced-commutated inverter does not have to supply load and can be freerunning as an independent voltage source. The design is relatively complex and expensive. The advantage is that it can be a source of reactive power and the harmonic content is low. Among the inverters commonly used for high-power applications, the 12-pulse line-commutated bridge topology prevails. However, with the advent of GTOs and high-power IGBTs, the voltage source inverter with shunt capacitors in the DC link is emerging as a preferred topology. There are three basic approaches to inverter design:

• One inverter inverts all DC power (central inverter). • Each string or multistring unit has its own inverter (string inverter). • Each module has a built-in inverter (module inverter).

Economies of scale would dictate the most economical design for a given system. Present inverter prices are about $1500/kW for ratings below 1 kW, $1000/kW for 1 to 10 kW, $600/kW for 10 to 100 kW, and $400/kW for ratings near 1000 kW. The DC–AC efficiency with the transformer at full load is typically 85 to 90% in small ratings and 92 to 95% in large ratings. Most PV inverters incorporate active and/or passive islanding protection. Islanding, in which a section of the PV system is disconnected from the grid and still supplies the local loads, is undesirable for personnel safety and quality of power, and because of the possibility of equipment damage in the event of automatic or manual reclosure of the power island with the grid. With islanding, an electrical generating plant essentially operates without an external voltage and frequency reference. Operating in parallel is the opposite of islanding. Islanding prevention is therefore included in the inverter design specification. A grid computer could offer an inexpensive and efficient means for participants to cooperate in reliable operation. The inverter is a key component of the grid-connected PV system. In addition to high efficiency in DC–AC conversion and peak-power tracking, it must have low harmonic distortion, low electromagnetic interference (EMI), and high power factor. Inverter performance and testing standards are IEEE 929-2000 and UL 1741 in the U.S., EN 61727 in the EU, and IEC 60364-7-712 (the international standards). The total harmonic distortion (THD) generated by the inverter is regulated by international standard IEC-61000-3-2. It requires that the full-load current THD be less than 5% and the voltage THD be less than 2% for the harmonic spectra up to the 49th harmonic. At partial loads, the THD is usually much higher.

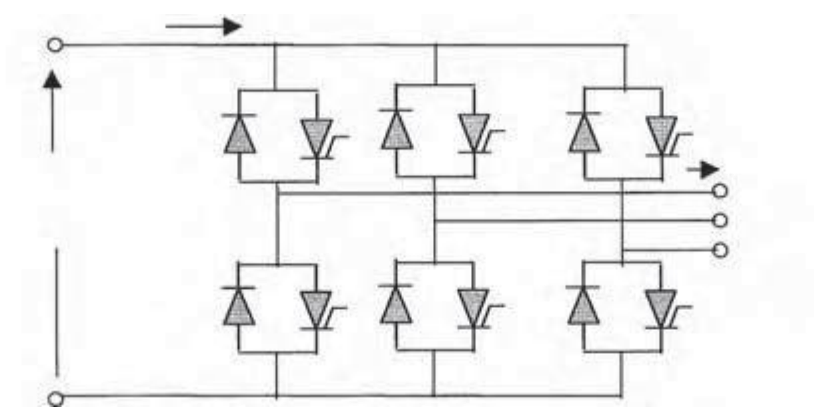


Figure 3.2: three phase inverter

3.3 Charge Controller

A charge controller, sometimes referred to as a photovoltaic controller or battery charger, is only necessary in systems with battery back-up. The primary function of a charge controller is to prevent overcharging of the batteries. Most also include a low voltage disconnect that prevents over-discharging batteries. In addition, charge controllers prevent charge from draining back to solar modules at night. Some modern charge controllers incorporate maximum power point tracking, which optimizes the PV array's output, increasing the energy it produces.

- ❖ **Types of Charge Controllers**

There are essentially two types of controllers: shunt and series. A shunt controller bypasses current around fully charged batteries and through a power transistor or resistance heater where excess power is converted into heat. Shunt controllers are simple and inexpensive, but are only designed for very small systems.

Series controllers stop the flow of current by opening the circuit between the battery and the PV array. Series controllers may be single-stage or pulse type. Single-stage controllers are small and inexpensive and have a greater load-handling capacity than shunt-type controllers. Pulse controllers and a type of shunt controller referred to as a multi-stage controller (e.g., three-stage controller) have routines that optimize battery charging rates to extend battery life.

Most charge controllers are now three-stage controllers. These chargers have dramatically improved battery life.

- ❖ Selection

– Charge controllers are selected based on:

• PV array voltage – The controller's DC voltage input must match the nominal voltage of the solar array.

• PV array current – The controller must be sized to handle the maximum current produced by the PV array.

- ➢ Interaction with Inverter – Since the majority of charge controllers have been installed in off-grid systems, their default settings may not be appropriate for a grid-connected system. The charge controller must be set up such that it does not interfere with the

proper operation of the inverter. In particular, the controller must be set up such that charging the batteries from the PV array takes precedence over charging from the grid.

For more information, contact the manufacturer.

Interaction with Batteries – The charge controller must be selected to deliver the charging current appropriate for the type of batteries used in the system. when fully charged, . Refer to the battery manufacturer for the charging requirements of particular batterie.19not honored by General Electric.

The following diagram shows the hardware interface of the PV Charge Controller

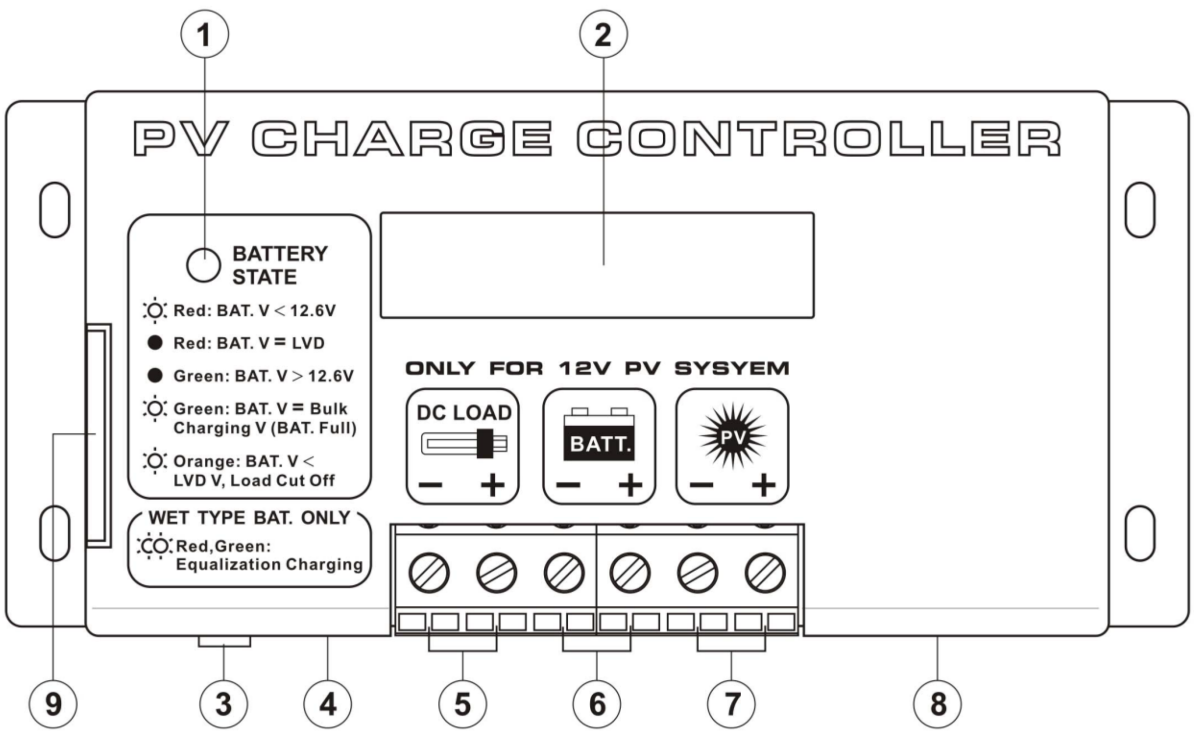


Figure 3.3: Front view of PV Charge Controller

- Battery LED Indicator
- LCD Display

- . Reset button (see Section 3.4)
- Temperature Sensor (Optional)
- 12V DC Load terminal with Low Voltage Disconnect/NIGHT-LIGHT mode (Section 4.3)
- 12V Battery connection terminal
- PV Panel connection terminal
- Remote Signal Terminal (Optional)
- Side Door (open to access switches for setting

When an external temperature sensor (optional accessory) is installed, the controller will adjust the Bulk and Float Charge Voltage according to the temperature of the battery type. The
regulation set point is 25ºC

➢ 3 Stage charge control

The main function of charge controller is to regulate the flow of electricity from the photovoltaic panels to the batteries. In PV systems with batteries, the batteries must be protected from overcharging and be maintained at fully charged state.

The PV Charge Controller uses the Micro-Processor and PWM (Pulse Width Modulation) to give optimal and safe charging .

It makes varying On-Off pulses of electrical energy from the photovoltaic(PV) panel in charging the battery according to the battery state. It has 3 stages of charging, as follows:

- ❖ **Bulk charge** – At this mode, a preset maximum constant amount of current (amps) is fed into the battery as the no PWM is present. As the battery is being charged up , the voltage of

the battery increases gradually.

- **Absorption charge** – After the preset voltage is reached (approximately 14.3 volts

for a 12 volt system) the voltage is then held constant. As the battery continues to be charged at constant voltage, the charging current decreases. The charging voltage is held at the Bulk Voltage Setting for one full hour with various rapid On-Off pulses (PWM). It then switches to Float Charge Mode.

- ## Float charge

The controller will maintain the battery voltage at the float voltage setting by giving shorter On-pulse charge to make up for any detected self discharge of the battery. When the battery voltage drops below the Float Voltage Setting for a total period of 10 minutes, a new charging cycle is activated in Bulk or Absorption Charge.

The three stages charging method works well with the chemical reaction that occurs as a battery is being charged. When a battery is more discharged, a regulated maximum current can be applied, since there is a lot of material available for the reactions to occur.

As the battery refills, less and less chemical material is available for the reaction. By using PWM

to slowly reducing the charge current, while maintaining a preset high voltage, the battery is more closely refilled at the reaction rate of the chemicals. Finally, the Float voltage keeps the battery fully charged at all times taking care of the self discharge .

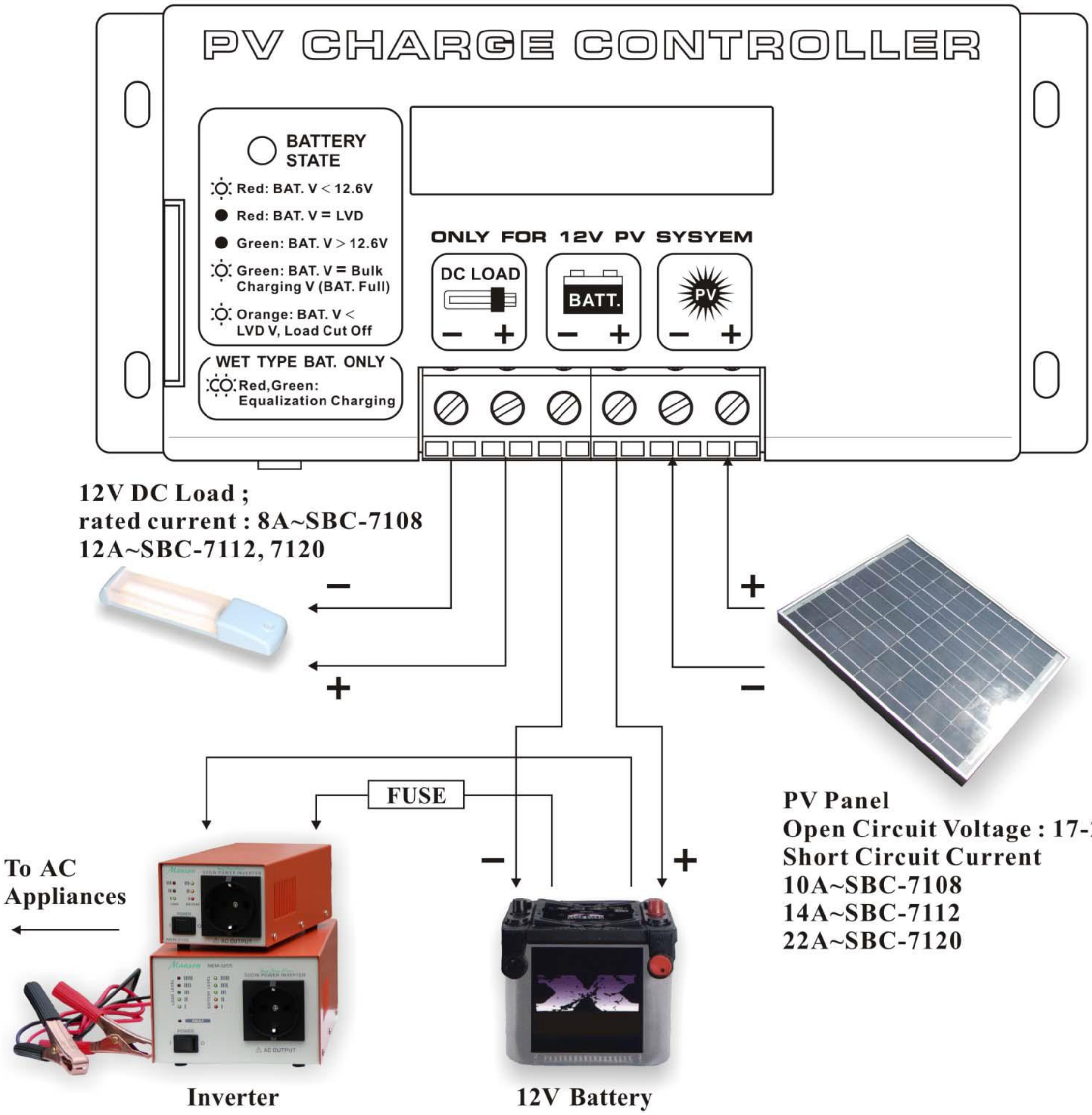


Figure 3.4 connect charge controller in solar system

3.4 Battery Storage

Batteries store direct current electrical energy for later use. This energy storage comes at a cost, however, since batteries reduce the efficiency and output of the PV system, typically by about 10 percent for lead-acid batteries. Batteries also increase the complexity and cost of the system.

Types of batteries commonly used in PV systems are:

- Lead-acid batteries
- Flooded (a.k.a. Liquid vented)

- Sealed (a.k.a. Valve-Regulated Lead Acid)
- Absorbent glass mat
- Gel cell
- Alkaline batteries
- Nickel-cadmium
- Nickel-iron

- **Lead-Acid Batteries** Lead-acid batteries are most common are spill-proof and do not require periodic maintenance. Flooded lead acid batteries are usually the least expensive but require adding distilled water at least monthly to replenish water lost during the normal charging process. There are two types of sealed lead acid batteries: sealed absorbent glass mat (AGM) and gel cell. AGM lead-acid batteries have become the industry standard, as they are maintenance free and particularly suited for grid-tied systems where batteries are typically kept at a full state of charge. Gel-cell batteries, designed for freeze-resistance, are generally a poor choice because any overcharging will permanently damage the battery.
- **Alkaline Batteries**
- Because of their relatively high cost, alkaline batteries are only recommended where extremely cold temperatures (-50oF or less) are anticipated or for certain commercial or industrial applications requiring their advantages over lead-acid batteries. These advantages include tolerance of freezing or high temperatures, low maintenance requirements, and the ability to be fully discharged or over-charged without harm.
- **Sizing Battery Banks**
- For grid-connected systems, batteries are usually sized for relatively short time periods with 8 hours being typical. Size may vary, however, depending on the particular needs of a facility and the length of power outages expected. For

comparison, battery banks for off-grid systems are usually sized for one to three cloudy days. 17

- **Interaction with Solar Modules**
- The solar array must have a higher voltage than the battery bank in order to fully charge the batteries. For systems with battery back-up, pay particular attention to the rated voltage of the module, also called the maximum power point (Vmpp), in the electrical specifications. It is important that the voltage is high enough relative to the voltage of a fully charged battery. For example, rated voltages between 16.5V and 17.5V are typical for a 12V system using liquid lead-acid batteries.

  Higher voltages may be required for long wiring distances between the modules and the charge controller and battery bank. disconnect that prevents over-discharging batteries. In addition, charge controllers prevent charge from draining back to solar modules.

3.5 DC Power

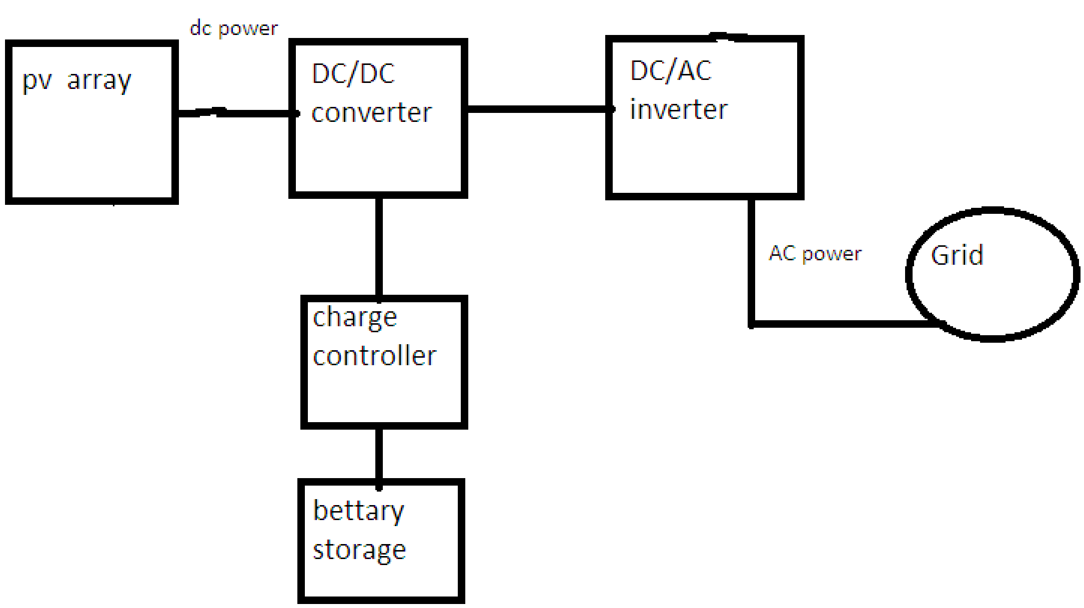
Direct current (DC) is the unidirectional flow of electric charge. Direct current is produced by sources such as batteries, power supplies, thermocouples, solar cells, or dynamos. Direct current may flow in a conductor such as a wire, but can also flow through semiconductors, insulators, or even through a vacuum as in electron or ion beams. The electric current flows in a constant direction, distinguishing it from alternating current (AC). A term formerly used for this type of current was galvanic current.[1]

Direct current may be obtained from an alternating current supply by use of a rectifier, which contains electronic elements (usually) or electromechanical elements (historically) that allow current to flow only in one direction. Direct current may be converted into alternating current with an inverter or a motor-generator

Direct current is used to charge batteries and as power supply for electronic systems. Very large quantities of direct-current power are used in production of aluminum and other electrochemical processes. It is also used for some railways, especially in urban areas. High-voltage direct current is used to transmit large amounts of power from remote generation sites or to interconnect alternating current power grids

3.6 AC Power

Power in an electric circuit is the rate of flow of energy past a given point of the circuit. In alternating current circuits, energy storage elements such as inductors and capacitors may result in periodic reversals of the direction of energy flow. The portion of power that, averaged over a complete cycle of the AC waveform, results in net transfer of energy in one direction is known as active power (sometimes also called real power). The portion of power due to stored energy, which returns to the source in each cycle, is known as reactive power.



Figure(3.4): diagram of system component

CHAPTER FOUR

MODEL SUMLATION AND RESULTS

4.1 MATLAB

MATLAB is used extensively in electrical engineering for signal processing applications for example includes several images created during a research program at the university of Utah to simulate collision-detection algorithms used by the housefly(and adapted to silicon sensors in the laboratory) the research resulted in the design and manufacture of a computer chip that detects imminent collisions. This has potential use in the design of autonomous robots using vision for navigation and especially in automobile safety application.

In renewable energy systems applications, MATLAB helps for selecting the matrix manipulations in the converters to grid inverter, plotting of functions and data, implementation of MPPT algorithms, creation of user interfaces for monitoring the Solar PV modules and for interfacing with inverters and converters, wherein which control algorithms would be written in other languages. As a result of the MATLAB simulation of the components of the solar PV system one can benefit from this model as a photovoltaic generator in the framework of the MATLAB/ SIMULINK toolbox in the field of solar PV power conversion systems.

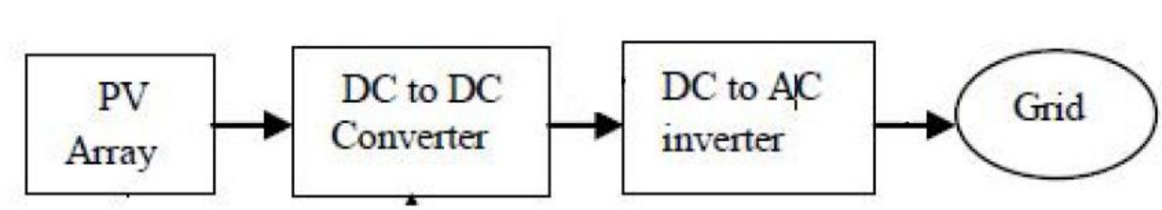


Figure (4.1): Basic structure of grid connected PV system

A Grid Connect solar PV system is a type of electrical inverter that convert direct current electricity from PV module into alternating current (AC). When the PV system is connected to the grid, it can transfer the extra energy to the grid after fulfilling the local demand. But when the system generates less than what is required to support the local demand, than extra energy is extracted from the grid. Thus PV solar energy acts as an alternative resource of electricity. The PV system, designed in this work, aims to transfer electrical power from PV panels to the grid. First, a dc-dc Converter is used to boost up PV voltage to a level higher than the peak of grid voltage.

The converter also tracks the maximum power point of PV module. There are many algorithm for tracking maximum power point . In this system I used perturb and observe method. PV module‘s voltage and power need to sense for tracking maximum power point in this method. Then, a pulse width modulation (PWM) based dc-ac inverter (voltage source inverter) is used for enforcing sinusoidal voltage waveform with matching phase frequency with grid voltage. The output voltage wave shape of PWM inverter is square PWM wave. Therefore, I used an LCL filter for coupling the inverter to the grid. It is one kind of low pass filter that converts PWM square wave to pure sine wave .

Finally I incorporated a control mechanism in order to supply the desired amount of real and reactive power to the grid from the PV system.

Active power is controlled by varying the angle between grid and inverter voltage. The supply of reactive power is controlled by varying the amplitude of inverter voltage.

4.2 Model of PV Module

The basic structure of PV cell is given below:

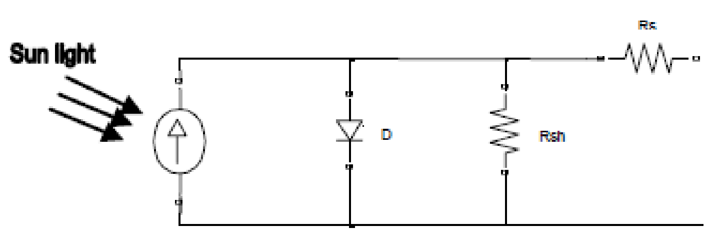


Figure (4. 2): Basic model of PV cell

In general PV module characteristics are dependent on temperature and insulation. The module ‘s current is affected by the insulation & little bit affected by temperature. On the other hand voltage is affected by temperature & little bit affected by insulation . That means;

Temp. ↑ , V ↓ , little bit current ↑

Temp. ↓ , V ↑ , little bit current ↓

ins.(W/m2) ↑ , I ↑ , little bit voltage ↑

ins.(W/m2) ↓ , I ↓ , little bit voltage ↓

The proposed model is now used to simulate the PV module at different values of irradiance and temperature. The I(V) characteristics are presented in Fig. 4.3 by varying irradiance from 200 W/m2 to 1000 W/m2 . From the above model we can write these equations:

$$Io = Ion\left(\frac{T}{T_n}\right)^3 exp\left(\frac{qEg}{ak}\right) * \left(\frac{1}{T_n} - \frac{1}{T}\right) \quad (4.1)$$

$$I_{on} = \frac{I_{scn}}{\exp\left(\frac{V_{ocn}}{aV_{Tn}}\right) - 1} \quad (4.2)$$

$$I_{pv} = \frac{G}{G_n}\left(I_{pvn} + k_1(T - T_n)\right) \quad (4.3)$$

$$V_T = \frac{N_s kT}{q} \quad (4.4)$$

$$I = I_{pv} - I_o * exp\left(\frac{V + IR_s}{aV_T} - 1\right) - \frac{V + IR_s}{R_{sh}} \quad (4.5)$$

Where:

k is Boltzman constant.

q charge of electron.

I_{scn} short circuit current.

V_{ocn} open circuit voltage

k_1 temperature current coefficient

N_s series cells

T operating temperature.

G irradiation.

Eg band gap.

Use block of SIMULINK of PV cell is shown in Figure (4.3)

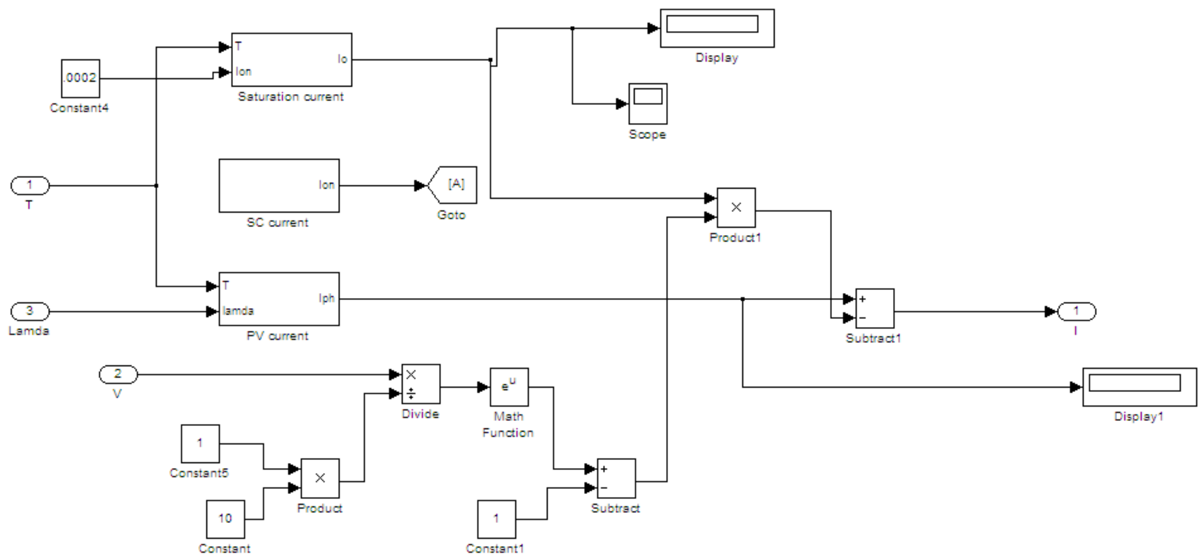


Figure (4.3) SIMULINK circuit of PV cell

The voltage of PV cell depend on radiation and temperature ,for variable value of radiation and temperature input in SIMULINK ,the result is shown in Figure (4.4) obtain the relation between current and voltage.

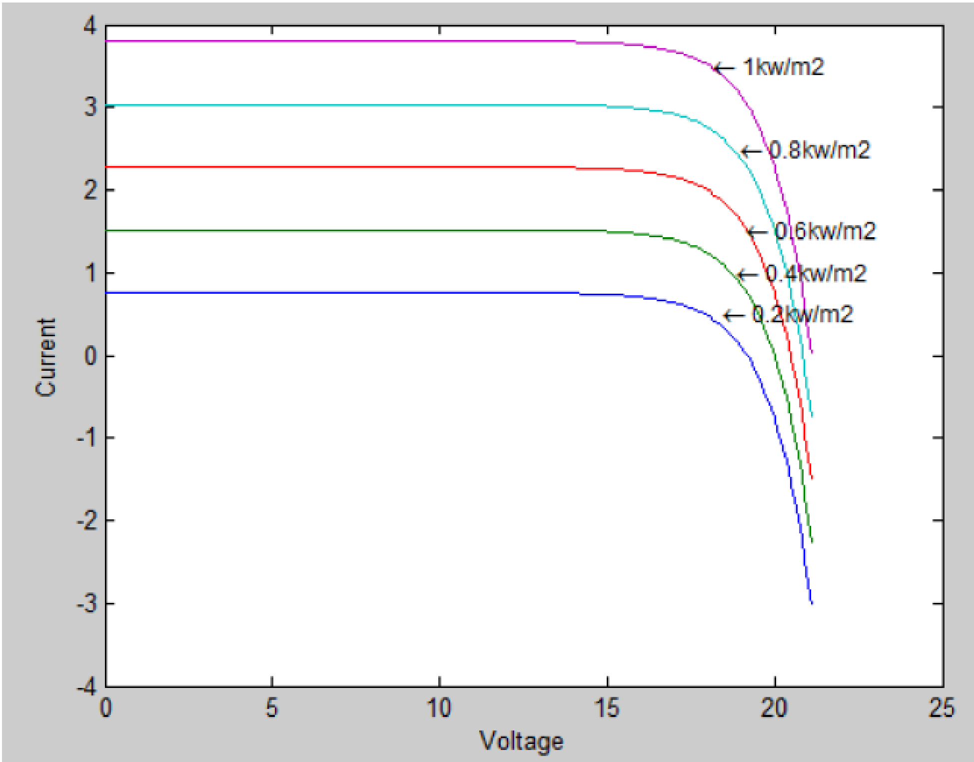


Fig 4.4: IV Relation between Current and Voltage

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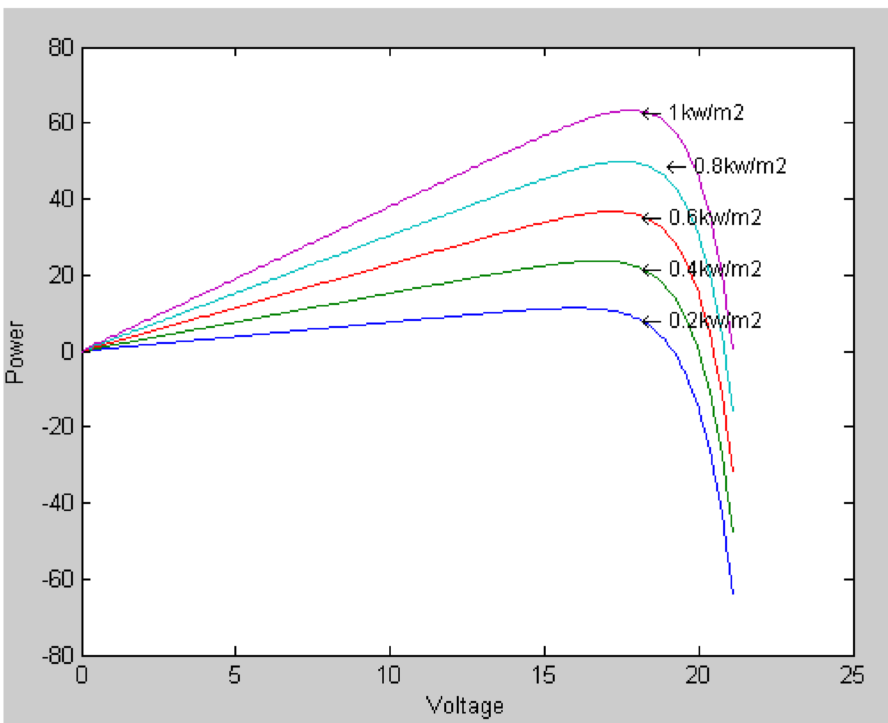
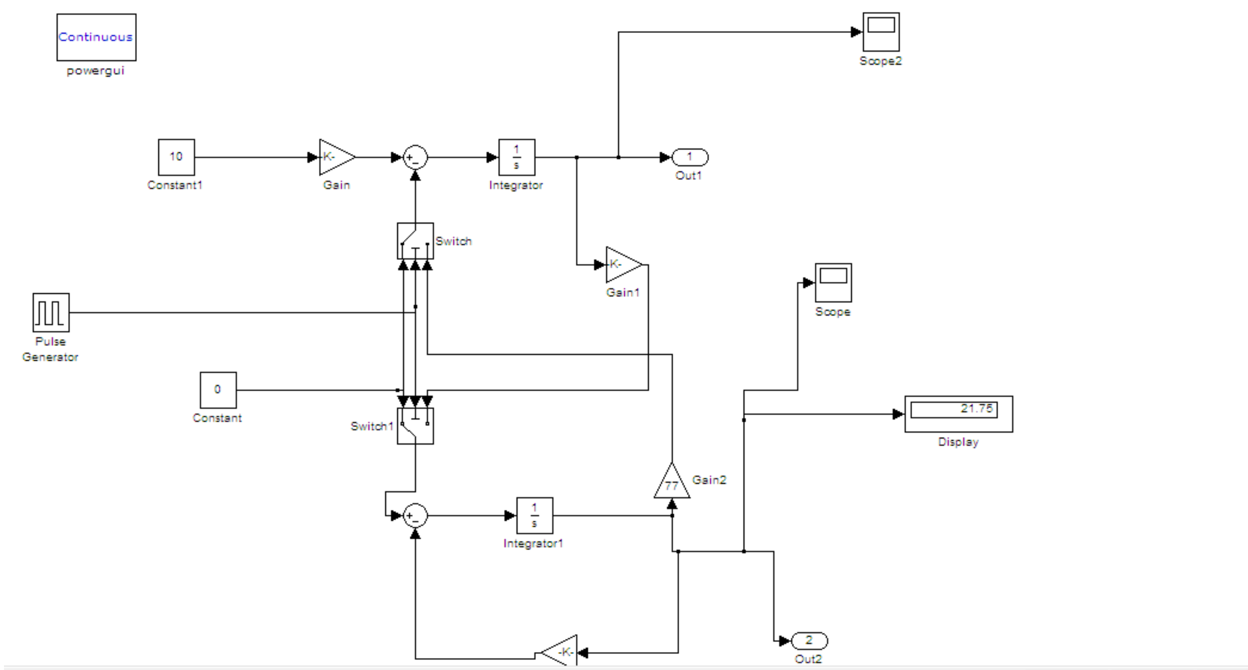


Fig 4.5: IV Relation between power and voltage

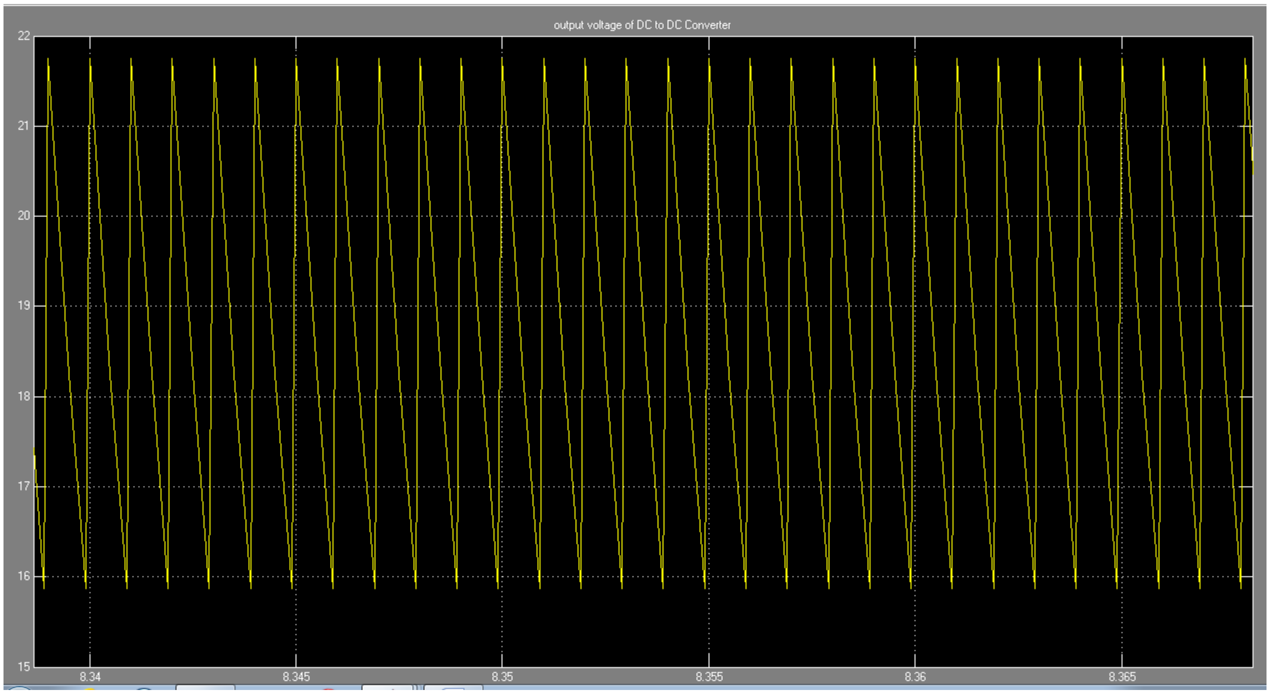
4.3 Model DC to DC Power Converters

In this section we used Boost converter. It is one of the DC to DC converter. Boost converter is used to step up‘a source voltage to a higher level. The gain from boost converter is directly proportional to the duty cycle (D). boost converter is in PV applications, the input voltage coming from PV panel is changed with atmospheric conditions. Therefore if the duty cycle vary than we get maximum power point of PV module. The design law of Boost converter is given below:



Figure(4.6): DC to DC convertor

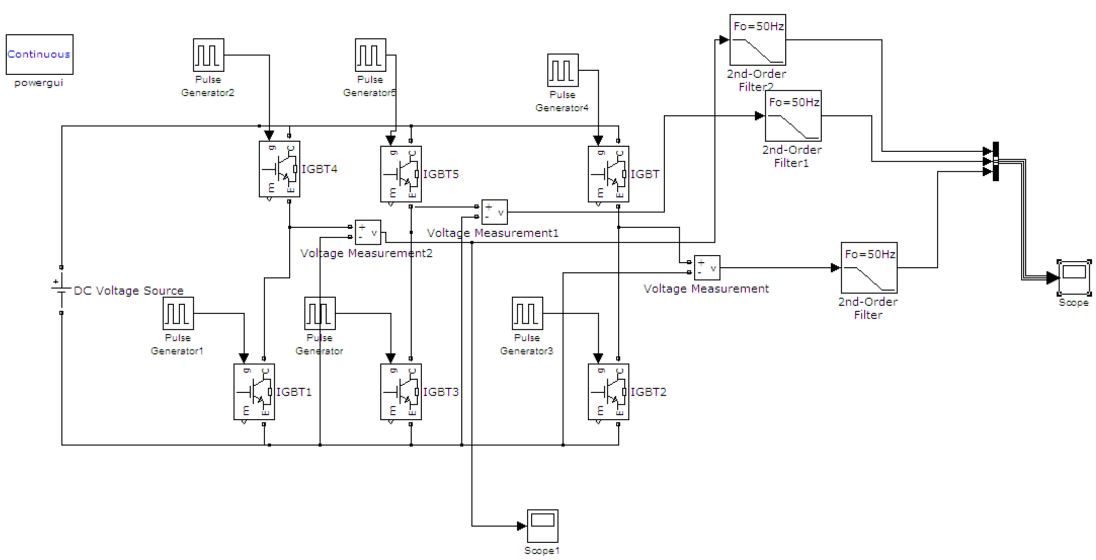
The result of Simulation is shown in figure (4.7) , result explain the out put voltage from DC to DC Converter for value of input voltage(10v).



Figure(4.7): Output of DC to DC converter

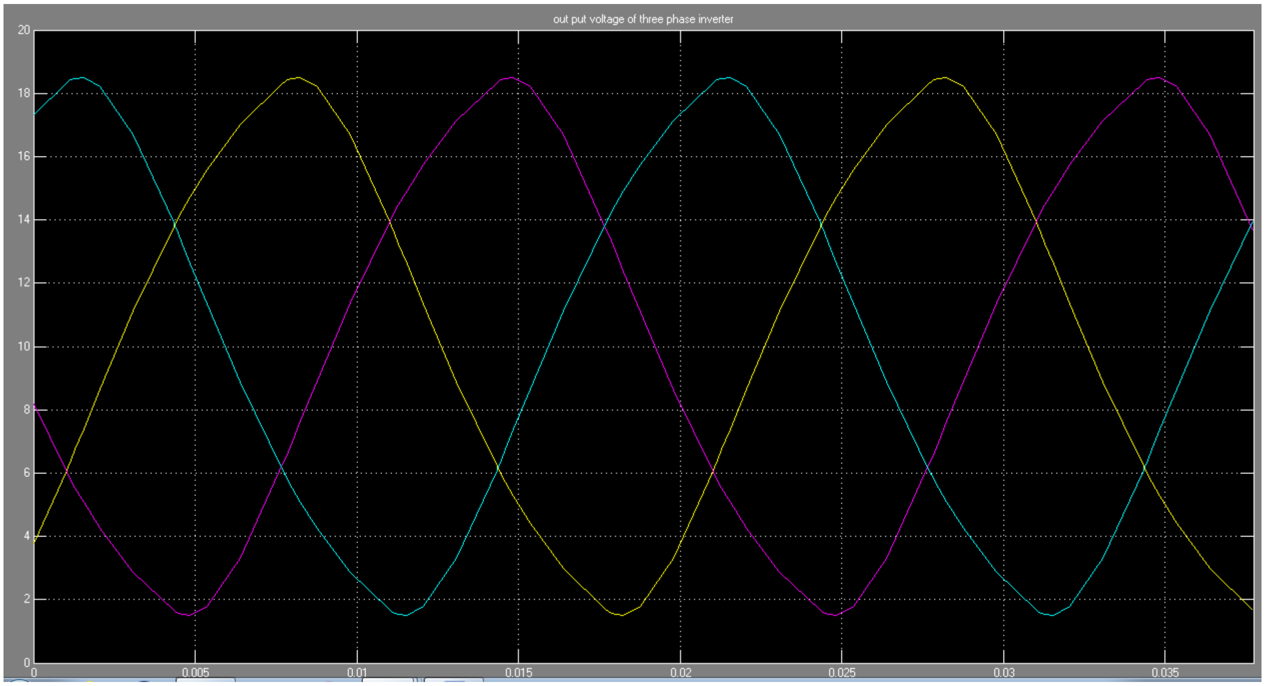
4.4 Model DC to AC Power Inverters

Unipolar based Voltage source PWM (pulse width modulation) dc to ac inverter is used. So that the shape of the output is Square PWM wave .This item is used because if we pass this type of signal in a low pass filter than we get pure sine wave which matched to the grid.



Figure(4.8): DC to AC inverter

The result of three phase inverter is shown in Figure (4.9) .



Figure(4.9): Output of DC to AC inverter

- **Voltage and Frequency Synchronization**

  Inverters should operate without problem for normal fluctuations of voltage and frequency at the utility grid side. The controllers must include protection devices that continuously monitor the grid voltage and frequency. If these go outside of the tolerable ranges established the unit should trip within an acceptable time frame, while permitting inverter operation through instantaneous voltage sags or swells. Inverter must inject current in phase with utility voltage (Power Factor=1). Four conditions that must be satisfied before the synchronizing switch permits the closure are as follows:

- ✓ The frequency must be as close as possible to the grid frequency, preferably about one third of a hertz higher.
- ✓ The terminal-voltage magnitude must match with that of the grid, preferably a few percent higher.
- ✓ The phase sequences of both three-phase voltages must be the same.

- ✓ The phase angle between the two voltages must be within 5°.

- Islanding Protection-

Islanding occurs when a DG continues to energize a distribution network that would otherwise be de-energized for any reason (e.g. Breaker opens because of a fault). It has been determined that this is a low probability event and the probability of continued operation of DG's is also very low, especially for residential grid tied PV systems which would not be able to perform load following. Yet in the event that load balance occurs, islanding represents a safety hazard.

CHAPTER FIVE

CONCULOTION AND RECOMMENDATION

5.1 Conclusion

This research learn solar cells and how it produce electric learn photovoltaic power system connect to grid component specification and synchronization requirement this research present how to feed grid utility with photovoltaic to provide the operation of system using MATLAB program show in the result output of dc to dc power converter and dc to ac power converter which supply the grid

5.2 Recommendation :

The Recommendation of this project are :

- ❖ Recommended to impalement model practically with three phase inverter.
- ❖ Recommended decrease high primary cost.
- ❖ Recommended to test synchrony with grid practically.

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