Electrical Design and Implementation & Installation of 5kw Solar System

Yogeshwar Patil, Bhushan Pawar, Dipak Chaudari, Bhuvan Mahajan, Khemraj Patil

***Abstract:** Solar photovoltaic power generation system is one of the burning research fields these days, even governments are also making plans toward increasing the amount of power generation from renewable energy sources because in future viability and crisis of conventional energy sources will increase. Further government liberalization and technical developments encourage the use of renewable sources for power generation in terms of distributed generation system. In order to rigging the present energy crisis one renewable method is to develop an efficient manner in which power extracts from the incoming son light radiation calling Solar Energy. This thesis deals with the design and hardware implementation of a simple and efficient solar photovoltaic power generation system for isolated and small load up to 5 KW. It provides simple basic theoretical studies of solar cell and its modeling techniques using equivalent electric circuits. Solar Photovoltaic (PV) power generation system is comprising several elements like solar panel, DC-DC converter, MPPT circuit and load, and DC-DC (Boost) converter, MPPT circuit using microcontroller and sensors adopting perturbation and observation method and single phase inverter for AC loads are implemented in hardware in simple manner.*

***Keywords:** (PV), CDC-DC (Boost), MPPT, AC loads, Solar photovoltaic, government KW.*

I. INTRODUCTION

As the demand for solar electric systems grows, progressive builders are adding solar photovoltaic (PV) as an option for their customers. This overview of solar photovoltaic systems will give the builder a basic understanding of evaluating a building site for its solar potential Common grid-connected PV system configurations and components. Considerations in selecting components. Considerations in design and installation of a PV system. Typical costs and the labor required to install a PV system Building and electric code requirements Where to find more information.

Emphasis will be placed on information that will be useful in including a grid-connected PV system in a bid for a residential or small commercial building. We will also cover those details of the technology and installation that may be helpful in selecting subcontractors to perform the work, working with a designer, and directing work as it proceeds. A summary of system types and components is given so the builder will know what to expect to see in a design submitted by a subcontractor or PV designer.

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* Correspondence Author (s)
Yogeshwar Dilip Patil, Godavari College of Engineering, Jalgaon (Maharashtra)-425003, India.
Bhushan Pawar, Godavari College of Engineering, Jalgaon (Maharashtra)-425003, India.
Dipak Chaudari, Godavari College of Engineering, Jalgaon (Maharashtra)-425003, India.
Bhuvan Mahajan, Godavari College of Engineering, Jalgaon (Maharashtra)-425003, India.
Khemraj Patil, Godavari College of Engineering, Jalgaon (Maharashtra)-425003, India.

1.1. Necessity

PV panels provide clean – green energy. During electricity generation with PV panels there is no harmful greenhouse gas emissions thus solar PV is environmentally friendly. Solar energy is energy supplied by nature – it is thus free and abundant! Solar energy can be made available almost anywhere there is sunlight Solar energy is especially appropriate for smart energy networks with distributed power generation – DPG is indeed the next generation power network structure! Solar Panels cost is currently on a fast reducing track and is expected to continue reducing for the next years – consequently solar PV panels has indeed a highly promising future both for economic viability and environmental sustainability. Photovoltaic panels, through photoelectric phenomenon, produce electricity in a direct electricity generation way Operating and maintenance costs for PV panels are considered to be low, almost negligible, compared to costs of other renewable energy systems. PV panels have no mechanically moving parts, except in cases of –sun-tracking mechanical bases; consequently they have far less breakages or require less maintenance than other renewable energy systems (e.g. wind turbines).PV panels are totally silent, producing no noise at all; consequently, they are a perfect solution for urban areas and for residential applications. Because solar energy coincides with energy needs for cooling PV panels can provide an effective solution to energy demand peaks – especially in hot summer months where energy demand is high. Though solar energy panels' prices have seen a drastic reduction in the past years, and are still falling, nonetheless, solar photovoltaic panels are one of major renewable energy systems that are promoted through government subsidy funding (FITs, tax credits etc.); thus financial incentive for PV panels make solar energy panels an attractive investment alternative. Residential solar panels are easy to install on rooftops or on the ground without any interference to residential lifestyle.

1.2. Objectives

- Our main objective is to design solar system for 5KW load.
- The objective this project is to select appropriate ratting of solar panel and design calculation of wiring system, selection of charge controller,

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Selection of inverter, selection of battery, considering their rating as per requirements.

1.3. Theme

- Theme of this project is based on solar photovoltics system including designing of electrical system.

1.4. Organization:

Chapter 1: Summaries about introduction to the solar power system.
Chapter1.2: Summaries about necessity of the solar power system.
Chapter 1.3: Summaries about objectives of solar power system.
Chapter 2: Summaries about literature review/literature survey.
Chapter 3: Summaries about system development.
Chapter 4: It Summaries about advantages, disadvantages &conclusion.

II. LITERATURE REVIEW

In the field of power sector in these days one of the major concerns is day-by- day increasing more power demand but the quantity and availability of conventional energy sources are not enough resources to meet up the current day's power demand. While thinking about future availability of conventional sources of power generation, it is become very important that the renewable energy sources must be utilized along with source of conventional energy generation systems to full fill the requirement of the energy demand.

In order to rigging the current day's energy crisis one renewable method is the method in which power extracts from the incoming son radiation calling Solar Energy, which is globally free for everyone. Solar energy is lavishly available on the earth surface as well as on space so that we can harvest its energy and convert that energy into our suitability form of energy and properly utilize it with efficiently. Power generation from solar energy can be grid connected or it can be an isolated or standalone power generating system that depends on the utility, location of load area, availability of power grid nearby it. Thus where the availability of grids connection is very difficult or costly the solar can be used to supply the power to those areas. The most important two advantages of solar power are that its fuel cost is absolutely zero and solar power generation during its operation do not emanate any greenhouse gases. Another advantage of using solar power for small power generation is its portability; we can carry that whenever wherever small power generation is required.

In the last few years the power conversion mechanisms for solar energy has been significantly comes in compact size. The advance research in the field of power electronics and material science have greatly helpful for engineers to develop such a system that very small but effective and powerful systems that have capability to withstand for supplying the high electric power demand. For every country day by day power density demand is increasing. Solar power generation have also the capability to handle the voltage fluctuation very effectively by setting the system for the use of multiple input converter units. But in solar power generation system due to its high installation cost and the low efficiency of the solar cells, this power generating systems can hardly participate in the competitive power markets as a main renewable source of power generation.

Scientists are constantly trying to improve in the field of development of the solar cells manufacturing technology for increasing efficiency. That will definitely help to make the solar generation as in habit for use in daily life as prime renewable source of electrical power on a wider range basis than present day conditions. In solar power generation system the latest power control mechanisms is using now these days calling the Maximum Power Point Tracking frequently referred as MPPT, it has guide to the increase in the efficiency of operation of power generation from the solar cells.

A new method for MPPT named CVT (Constant Voltage Tracking) is proposed by Zheng Shicheng et al with the analysis of characteristic curve and operation theory of PV array. A lower power photovoltaic (PV) system with simple structure has been designed. This method has been verified by PV charging system and it showed that MPP of PV array can be tracked well by applying the charger controller. An adjustable Self-Organizing Fuzzy Logic Controller (SOFLC) for a Solar powered Traffic Light Equipment (SPTLE) with an integrated MPPT system on a low-cost microcontroller has been presented by Noppadol Khaehintung et al. It comprises of boost converter for high performance SPTLE. Variation of duty ratio for DC-DC boost converter is implemented on PIC16F876A RISC-microcontroller. A fuzzy based perturb and observe (P&O) MPPT in solar panel was presented by C. S. Chin et al . The solar system is modeled and analyzed in MATLAB/SIMULINK. Simulation results showed that fuzzy based (P&O) MPPT has better performance and more power is produced from solar panel. Panom et al introduced a maximum power point tracking algorithm using an artificial neural network for a solar power system. energy conservation plays an important role for this network. Usually the battery powered is used as power sources for sensor nodes, but energy harvesting offers an alternative, although it not able to avoid from the problem. In this paper, an analysis is performed to compares the use of batteries powered against solar cells powered.

III. CHAPTER 3. SYSTEM DEVELOPMENT

System development gives the structural and technical details about the system. it gives the overview of the solar pv panels, inverter, ,various connection of the system In this system development various components of the system are explained

3.1. Solar Cell Overview

A solar cell is an electronic device that converts the light energy directly into electric energy without any form of moving parts by using photovoltaic effect.

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Fig 3.1 Solar Cell

- A Solar cell is also calling Photovoltaic (PV) Cell.
- It is a static device, no moving part.
- "Photo" means Light and "voltaic" means producing electricity.
- It is a solid state electronic device made of semiconductor materials like silicon.
- Solar cell converts energy of light directly into Direct Current (DC).
- Solar cell does not use heat of light to produce electrical energy.
- Efficiency of solar cell depends on many factors like shading on cells, temperature, etc.
- In 2014 the highest 44.7% efficiency has achieved by using the multiple junction cells.

3.1.1 Basic Theory of Solar Cell

Solar cells are made by two types of semiconductor materials one is N type semiconductor and other is P-type semiconductor material for generation of electricity. When light strikes on semiconductor, it generates electrons (-) and holes (+) pairs. when electron and hole pair reaches between two different type of semiconductor's joint surface then electron and hole are separated, electron is attached by N-type semiconductor and hole is attached by P-type semiconductor after that they are not rejoin due to joint surface do not allow both way traffic.

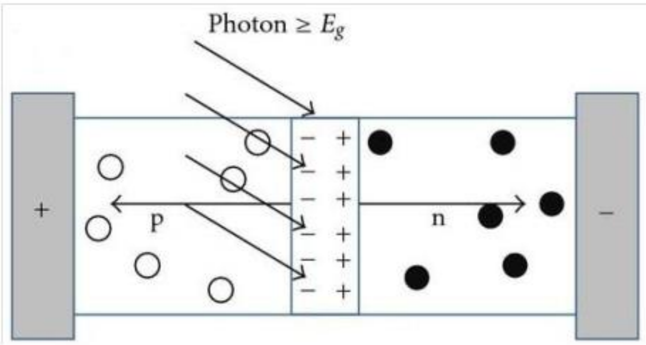

Fig 3.1.1(i) P-N junction illustration of PV cell

Now electrons are contained by N-type semiconductor and holes are contained by P-type semiconductor, an electro motive force (emf) is generated in electrodes. When these electrodes are connected together by a conductor electrons run toward O-type semiconductor and holes run toward N-type semiconductor.

3.1.2 Solar Cell Connections

Solar cell connection is just like battery connection. When positive terminal of one solar cell is connected to negative terminal of another solar cell then they form series connection. In series connection current is same for all cells and voltage is added by each cell shown in figure 2.4. And when all positive terminals of solar cells connected to one terminal and all negative positive terminals of solar cells connected to another one terminal then forms parallel connection. As shown in figure 3.1(i) here current is added and voltage is same for all cells.

3.1.3 Solar Cell Technologies

Solar cell is manufacturing by different materials. The two major technologies are wafer-based silicon and thin-film. Crystalline silicon solar cell is more efficient than thin-film solar cell but that is more expensive to produce. They are most commonly uses in large to medium electric applications like grid connected PV power generation. Mono-crystalline solar cell is manufactured by pure semi-conducting materials so it has higher efficiency (above 17% in industrial production and 24% in research laboratories. Poly-crystalline solar cell is slightly less efficient than Mono-crystalline but less in cost. In thin-film solar cell very thin layers of semiconducting materials are uses so they can be produces in large quantity at lower cost but it efficiency is less. This technology is uses in calculators, watches and toys etc.

There are too many other PV technologies available like Organic cells, Hybrid PV cells combination of both mono crystalline and thin film silicon etc.

3.2. Solar PV System

Solar photovoltaic system or solar power system is one of renewable energy system which uses PV modules to convert sunlight into electricity. The electricity generated can be stored or used directly, fed back into grid line or combined with one or more other electricity generators or more renewable energy source. Solar PV system is very reliable and clean source of electricity that can suit a wide range of applications such as residence, industry, agriculture, livestock, etc.

3.3. Major System Components

Solar PV system includes different components that should be selected according to your system type, site location and applications. The major components for solar PV system are solar charge controller, inverter, battery bank, auxiliary energy sources and loads (appliances).

3.3.1. PV Module

It Converts sunlight into DC electricity. A solar panel is a set of solar photovoltaic modules electrically connected and mounted on a supporting structure. A photovoltaic module is a packaged, connected assembly of solar cells. The solar panel can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications. Each module is rated by its DC output power under standard test conditions (STC),

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and typically ranges from 100 to 320 watts. The efficiency of a module determines the area of a module given the same rated output - an 8% efficient 230 watt module will have twice the area of a 16% efficient 230 watt module.

3.4. Basics of Photovoltaic module

Basic photovoltaic module consist of PV cell, PV module, PV array and which are given as below,

3.4.1. PV Cell

As shown in Fig.3.3 (ii), PV cell is basically a semiconductor *p-n* junction-based photodiode. This semiconductor photodiode generates electrical power when exposed to light. PV cells can be made up of various semiconductor materials. But mono-crystalline silicon and poly-crystalline silicon are the most common types known commercially.

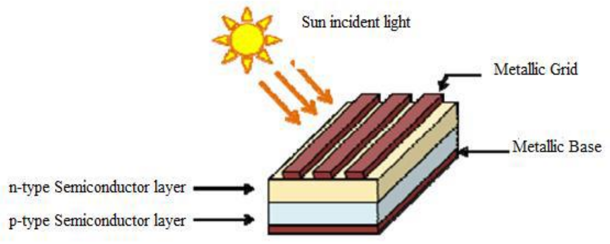

Fig. 3.4.1: Construction of PV cell

3.4.2. PV Module

The power produced by a single PV cell is not enough for general use. Therefore, by connecting PV cells in series, higher voltage can be obtained and in parallel higher current can be obtained consequently higher power. Generally, a combined series and parallel connection of PV cells is known as a module. Mostly, commercial modules consist of 36 or 72 cells. The modules consist of transparent front side, encapsulated PV cells, and back side. The front side material is usually made up of low-iron and tempered glass. The efficiency of a PV module is less than a PV cell due to the fact that some solar irradiation is reflected by the glass cover and frame shadowing.

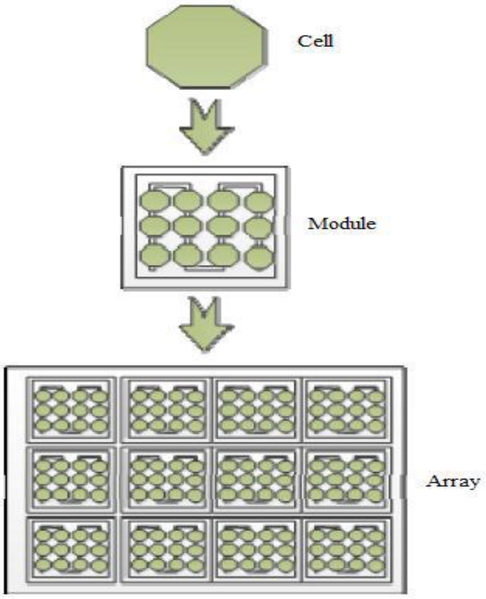

Fig. 3.4.2: Photovoltaic Hierarchy

3.4.3. PV Array

A PV array (system) is an interconnection of modules which in turn is made up of many PV cells connected in series and parallel. The power produced by a single module is seldom enough for commercial use, so modules are connected to form an array to supply the load. The connection of modules in an array is the same as that of cells in a module. Modules can also be connected in series to get an increased voltage or in parallel to get an increased current. Connecting several modules in series gives a string where several strings in parallel are an array.

Fig 3.4.3 PV Solar Array

3.5. Types of PV Modules

3.5.1. Monocrystalline cells
3.5.2. Photocrystalline cells
3.5.3 Amorphous thin films

3.5.1. Monocrystalline cell

Monocrystalline cells are made from a thin slice or wafer cut from a single large crystal of silicon. The cells are then doped and the fine current collecting wires printed on or in the surface of the cell. Generally monocrystalline cells have the highest efficiency, but this comes at a price. This type of cell takes more energy to make than any other, and so has a greater energy payback period, though this is usually still within five years.

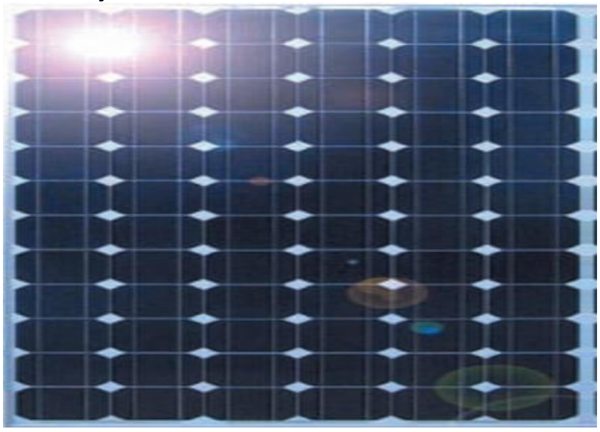

Fig 3.5.1: Monocrystalline cells

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3.5.2. Photocrystalline cells

Photocrystalline cells are made from thin wafers of silicon cut from a large cast billet. The billet is not a large single crystal, but many crystals clumped together, hence the name. Polycrystalline cells are usually slightly less efficient than monocrystalline cells, but because they are square, can be fitted into the rectangular frame of a solar panel with high space efficiency, although polycrystalline panels are still slightly larger than monocrystalline panels of the same rating. Polycrystalline cells must also have current collecting grids printed onto them. Kyocera panels use this cell technology, as do many other panels.

Fig 3.5.2 Photocrystalline cells

3.5.3. Amorphous thin films

Amorphous/thin film panels involve deposition of very thin films of silicon or other materials directly onto a substrate such as glass or stainless steel. This technique produces a cell with a lower efficiency than the cut wafer varieties, but has the advantage of eliminating the need for inter-cell connections. Uni-Solar makes triple-junction, nine-layer thin-film amorphous panels with a much higher efficiency than the older types. The layers of silicon are deposited directly onto a stainless steel substrate and are then coated in a flexible plastic protective layer. There are now a number of manufacturers of thin-film panels, including Uni- Solar, Kaneka and Schott Solar.

Fig 3.5.3: Amorphous thin films

3.6. Solar Cell Modeling

From the physical heavier and mechanism of a solar cell an equivalent electrical circuit is derived, worldwide two different circuit are accepted as equivalent electrical circuit of solar cell, the first one is a simplified model of a single solar cell that exhibits an approximate characteristic of a solar cell and second one having two diodes combination one for reflecting diffusion and other for carrier. The equivalent circuits are shown in figure 3.6(i) and 3.6(ii) below.

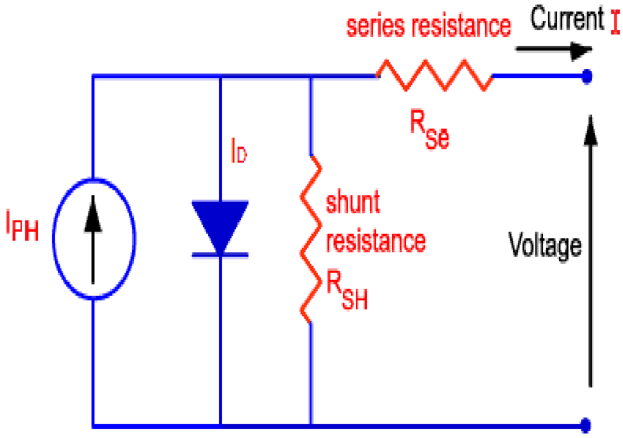

Fig. 3.6(i) Equivalent circuits of solar cell

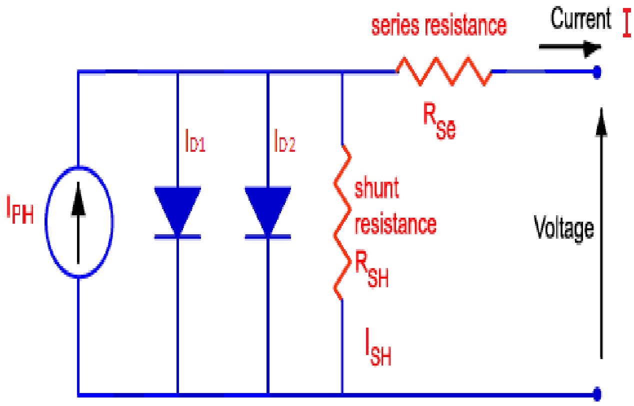

Fig. 3.6(ii) Equivalent circuits with dual diode of solar cell

3.7. Photovoltaic System Types

Photovoltaic system types can be broadly classified by answers to the following questions:

Will it produce alternating current (AC) or direct current (DC) electricity, or both?

Will it have battery back-up?

Will it have back-up by a diesel, gasoline or propane generator set?

Here we will focus on systems that are connected to the utility transmission grid, variously referred to as utility-connected, grid-connected, grid-interconnected, grid-tied or grid-intertied systems. These systems generate the same quality of alternating current (AC) electricity as is provided by your utility. The energy generated by a grid-connected system is used first to power the AC electrical needs of the home or business. Any surplus power that is generated is fed or “pushed” onto the electric utility’s transmission grid. Any of the building’s power requirements that are not met by the PV system are powered by the transmission grid. In this way, the grid can be thought of as a virtual battery bank for the building.

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3.7.1. Common System Types

Most new PV systems being installed in the United States are grid-connected residential systems without battery back-up. Many grid-connected AC systems are also being installed in commercial or public facilities. The grid-connected systems we will be examining here are of two types, although others exist. These are:

• Grid-connected AC system with no battery or generator back-up.

• Grid-connected AC system with battery back-up.

Example configurations of systems with and without batteries are shown in Figures 1 and

2. Note there are common variations on the configurations shown, although the essential functions and general arrangement will be similar.4

3.7.2. Is a Battery Bank Really Needed?

The simplest, most reliable, and least expensive configuration does not have battery back-up. Without batteries, a grid-connected PV system will shut down when a utility power outage occurs. Battery back-up maintains power to some or all of the electric equipment, such as lighting, refrigeration, or fans, even when a utility power outage occurs. A grid-connected system may also have generator back-up if the facility cannot tolerate power outages with battery back-up, power outages may not even be noticed. However, adding batteries to a system comes with several disadvantages that must be weighed against the Advantage of power back-up. These disadvantages are:

• Batteries consume energy during charging and discharging, reducing the efficiency and output of the PV system by about 10 percent for lead-acid batteries.

• Batteries increase the complexity of the system. Both first cost and installation Costs are increased.

• Most lower cost batteries require maintenance.

• Batteries will usually need to be replaced before other parts of the system and at considerable expense.

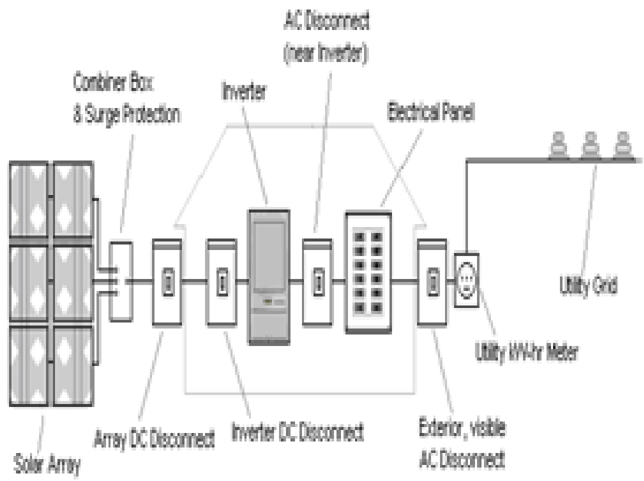

Fig 3.7.2: one common configuration of a grid-connected AC photovoltaic system without battery back-up

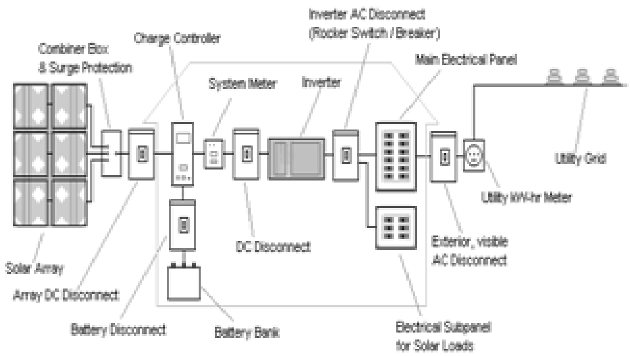

Figure 3.7.3: One common configuration of a grid-connected AC photovoltaic system with battery back-up

3.8. Grounding Equipment

Grounding equipment provides a well-defined, low-resistance path from your system to the ground to protect your system from current surges from lightning strikes or equipment malfunctions. Grounding also stabilizes voltages and provides a common reference point. The grounding harness is usually located on the roof.

3.8.1. Check with the AHJ

Grounding can be a particularly problematic issue. Be sure to check with the Authority Having Jurisdiction (AHJ) – typically the building department's electrical inspector – concerning local code requirements.

3.8.2. Equipment Grounding

Equipment grounding provides protection from shock caused by a ground fault. A ground fault occurs when a current-carrying conductor comes into contact with the frame or chassis of an appliance or electrical box. All system components and any exposed metal, including equipment boxes, receptacles, appliance frames and PV mounting equipment should be grounded.

3.8.3. System Grounding

System grounding requires taking one conductor from a two-wire system and connecting it to ground. In a DC system, this means bonding the negative conductor to ground at one single point in the system. This must be accomplished inside the inverter, not at the PV array.

3.8.4. NEC 2005 and System Grounding

In 2005, the National Electrical Code (NEC) was modified to remove the requirement for system grounding, although your local jurisdiction may not have adopted this revision. The requirement for system grounding was removed to permit transformer less utility-interactive inverters, which have higher efficiency. There are several additional NEC requirements intended to ensure that ungrounded arrays are as safe as grounded arrays, although this is still a point of controversy.

3.9. Surge Protection

Surge protectors help to protect your system from power surges that may occur if the PV.

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system or nearby power lines are struck by lightning. A power surge is an increase in voltage significantly above the design voltage.

3.9.1. V-I Characteristic Curve of a Solar Panel

A PV module produces maximum current when it's positive and negative terminal is shorted, this maximum current is named as short circuit current of PV panel. When panel is short circuited, it's voltage across terminal is zero.

When panel terminal is kept open circuited then the voltage across its terminal is maximum called open circuit voltage of that panel. This time panel fells infinite resistance since the current is zero this time. Between these two extremes point under different load resistance condition different pair of points of current and voltage are achieved, by connecting points a curve is find called I-V curve. This curve is called I-V characteristics of that particular panel showing the I-V curve with the output power curve.

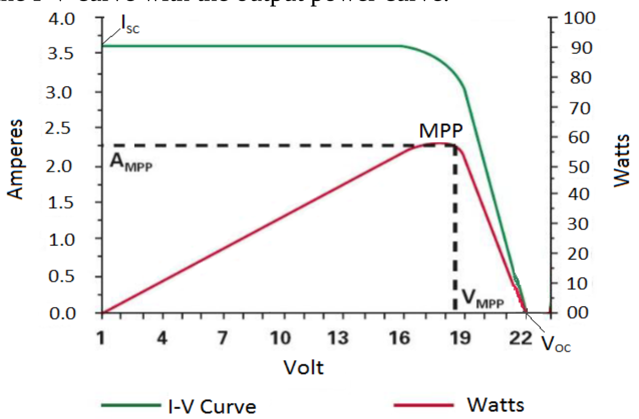

Fig. 3.9.1 Standard I-V Characteristic of a Solar Panel

As showing in figure 2.9 is occurred when current is zero and is occurred when voltage is zero on that curve and power of that panel at any point in Watt is calculated by multiplying both the current and voltage of that point.

3.9.2 Impact of Solar Irradiation on I-V Characteristic of a Solar Panel

Highest solar irradiance on the earth ground level is 1000 W/hrs. If the solar irradiance is decreases due to cloud, the earth movement or any other reason will reduce the output current of the solar panel because of the is directly proportional to the sun irradiance while the variation on voltage is much smaller as shown in Figure 3.9.2.

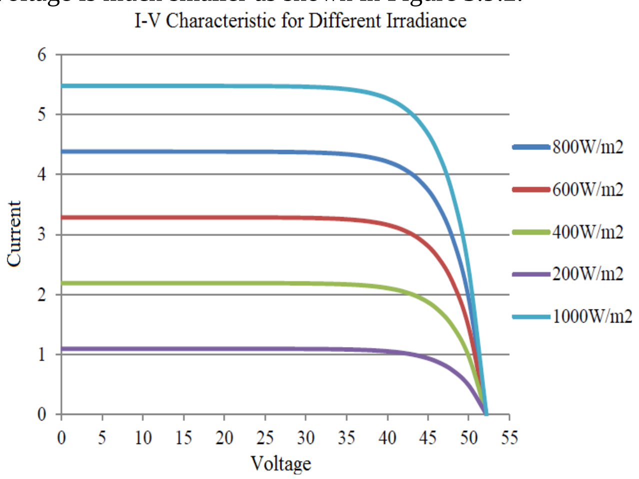

Fig.3.9.2 Effect of Solar Irraadiation

3.9.3 Impact of Temperature on I-V Characteristic of a Solar Panel

Temperature affects the saturation current of solar cell and small effect on so has negative (-) temperature coefficient (for silicon –2.3mV/°C), figure 2.11showing the I-V curve for different temperature variation.

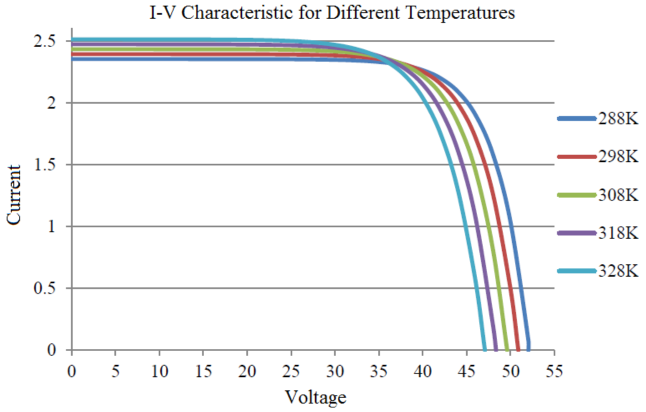

Fig. 3.9.3: I -V Curve For Different Temperatures

3.10.Solar Panel Calculations

A solar PV system design can be done in four steps:

- Load estimation
- Estimation of number of PV panels
- The total energy requirement of the system (total load) i.e. Total connected load to PV panel system:

$$\text{No. of units} \times \text{rating of equipment}$$

- Total watt-hours rating of the system:

$$\text{Total connected load (watts)} \times \text{Operating hours}$$

Actual power output of a PV panel:

$$\text{Peak power rating} \times \text{operating factor}$$

3.11.Overview on DC/DC converter

The basic DC/DC converter comprises a switch, a filter circuit and load. The DC/DC converter may classify by various methods, one of the basic methods is isolation, according to that it is classified into two types.

1) Isolated DC/DC converter.
2) Non-Isolated DC/DC converter.

In isolated DC/DC converter type the output and input are electrically isolated by the use of a transformer. It is bulky, requires more space and costly while comparing with the non-isolated type DC/DC converter.

The non-isolated DC/DC converters can be further differentiated by element connections like Buck converter, Boost converter, Buck-Boost converter, Cuk converter and Sepik converter. DC/DC converter is widely used for the purpose of converting unregulated DC input into a regulated DC output. A DC-DC converter is a hart of MPPT hardware implementation. MPPT uses the one of the above converter for regulating the solar input voltage to the MPP and providing impedance matching for the maximum power transfer to the load.

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Buck and Boost converter are the basic and simple, easy circuit and less components requires. In this project Boost converter is selected due to-

- It is a step up DC/DC converter, it boosting the input voltage and gives that voltage to the output.
- Boost converter operates by temporarily storing the input energy and then releasing that energy to the output at a higher level of voltage.
- In case if switching device is fail then load is still connected to the source.

IV. CONCLUSION

In this way we study the electrical design of solar system and total load demands of the system. From this project we learned about various design of solar system, pv grid inverter, cable selection, etc. In this project a simple low cost but effective solar PV power generation system for small and not grid connected load up to 5 KW prototype model is designed and implemented except solar panel that is not implemented only achieved its characteristics.

FUTURE ENHANCEMENT

Further work in this area may use different MPPT method and modified algorithms for increasing efficiency in fast changing environmental conditions. Try to design such model for solar PV system which should compact size and cheaper and also its maintaining and operating cost should be less so that people attract to use in behavior and don't go for conventional sources even for isolated systems. Inverter should be design by using SMPS circuits if further implementation will happen from this project. Over all physical implementation of the system will remains for the future research. In solar energy sector, many large projects have been proposed in India.

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