International Journal of Research
Available at https://edupediapublications.org/journals
p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 03 Issue 11
July2016

Design of Stand-Alone Solar Photovoltaic Power Generation System

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ABSTRACT: Increasing demand for electrical energy as well as environmental concerns related to fossil fuel usage are the driving forces behind the development of new energy sources, which are renewable and ecologically safe.
The energy sources, which include energy from wind, water and biomass, geothermal and solar energy are renewable and environmentally friendly. Among these clean energy sources, solar energy is one of the most promising and fastest growing renewable energy sources worldwide.
The main objective of this paper is to study design of solar photovoltaic stand alone power generating system. In this paper, system of solar power generation is explained. The system consists of solar panels, DC-DC converter, charge controller, inverter and battery storage.

INTRODUCTION: In this paper, design of solar photovoltaic stand-alone power generation system is important aspect. Solar energy is freely obtained from the sun and its supply is unlimited. Solar power is the conversion of sunlight into electricity, either directly using photovoltaic (PV), or indirectly using concentrated solar power (CSP).Solar photovoltaic system may be stand-alone or grid connected system. A stand-alone power generation system is an off grid system. In stand-alone system power which is generated can be directly utilize or store. A grid connected solar photovoltaic power generating system is directly connected to the utility grid.

CONFIGURATION OF STAND ALONE PV SYSTEM:

PV systems are designed to meet the load requirement in the best possible manner. In doing so, a system designer determines the configuration of PV system, which components to connect in system and how? The components may be PV panels, battery, controllers, etc. Depending upon type of load (AC or DC, light or heavy, etc.), depending on the load requirement (critical/ non-critical, reliability, cost, etc.) and depending upon the geographical location (wind resources, solar resources, proximity with grid, etc.), the configuration of the system will change.
Solar PV system configuration can be very simple, incorporating only two components (load and the PV panel), or it can be very complex, containing several power sources, sophisticated controllers and multiple energy storage units to meet load requirements.

1. SOLAR PHOTOVOLTAIC POWER GENERATION:

Solar panels turn energy from the sun's rays directly into useful energy that can be used in homes and businesses. There are two main types: solar thermal and photovoltaic, or PV. Solar thermal panels use the sun's energy to heat water that can be used in washing and heating. PV panels use the photovoltaic effect to turn the sun's energy directly into electricity, which can supplement or replace a building's usual supply.

A PV panel is made up of a semiconducting material, usually silicon-based, sandwiched between two electrical contacts. To generate as much electricity as possible, PV panels need to spend as much time as possible in direct sunlight. A sloping, south-facing roof is the ideal place to mount a solar panel. A sheet of glass protects the semiconductor sandwich from rain, grit blown by the wind, and wildlife. The semiconductor is also coated in an antireflective substance, which makes sure that it absorbs the sunlight it needs instead of scattering it uselessly away.

When sunlight strikes the panel and is absorbed, it knocks loose electrons from some of the atoms that make up the semiconductor. The semiconductor is positively charged on one side and negatively charged on the other side, which encourages all these loose electrons to travel in the same direction, creating an electric current. The contacts capture this current in an electrical circuit.

The electricity PV panels generate is direct current. Before it can be used in homes and businesses, it has to be changed into alternating current (AC) electricity using an inverter. The inverted current then travels from the inverter to the building's fuse box, and from there to the appliances that need it. PV systems installed in homes and businesses can include a dedicated metering box that measures how much electricity the panels are generating. As an incentive to generate renewable energy, energy suppliers pay the system's owner a fixed rate for every unit of electricity it generates - plus a bonus for units the owner doesn't use, because these can help supply the national grid. Installing a PV system is not cheap, but this deal can help the owner to earn back the cost more quickly - and potentially even make a profit one day.

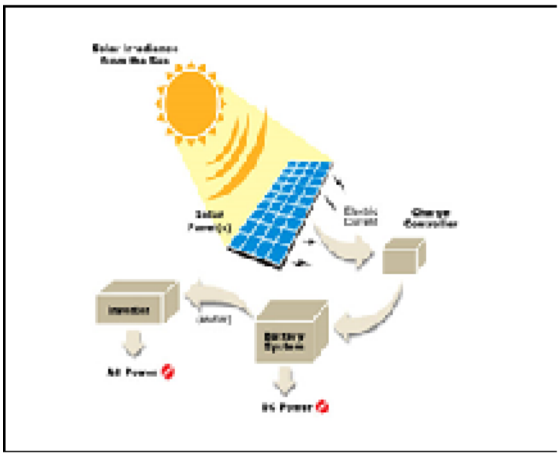

Fig. 1 : Stand-Alone Solar Photovoltaic Power Generation

Stand-alone solar photovoltaic power generation system:

p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 03 Issue 11
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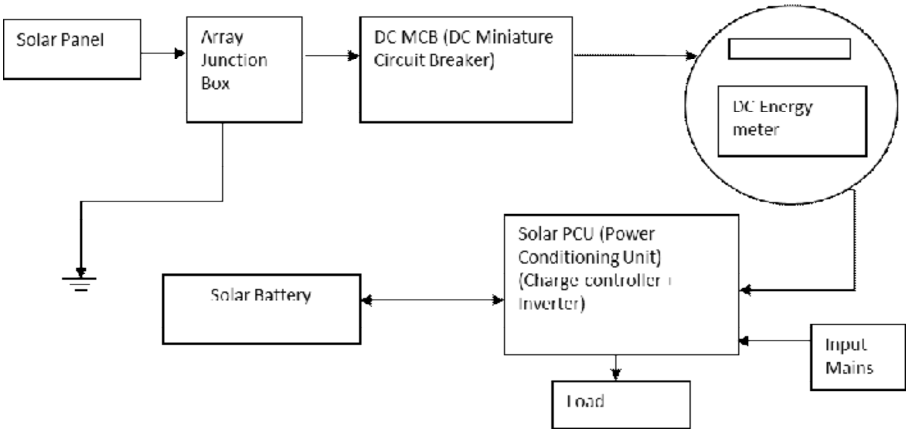

Fig. Block diagram of stand-alone solar PV power generation system

The block diagram shows the design of stand-alone solar PV power generation system. From this diagram we can see that electricity is generated from solar radiation by using solar panel. Solar panels are connected in series to obtain desired voltage level and connected in parallel to obtain desired current value. Solar panels can also be connected in series-parellel fashion to obtain desired current and voltage level. For series-parallel connection, after connecting panel in series, rows of series connected panel are then connected in parallel fashion by using array junction box. Power from solar panel is then send through DC Miniature Circuit Breaker, then through DC energy meter towards solar power conditioning unit then power is provided to load. Solar power conditioning unit consist of charge controller and inverter. Input from mains is also connected to load via Solar PCU.

(a) Solar Panel: Parallel connecting solar panels gives higher current. And voltage will remain the same. By connecting Solar Panels in series connection. It will increase Voltage and current will remain the same. Solar panels can also be connected in series-parellel fashion to obtain desired current and voltage level.
Angle of latitude for mounting solar panel is 19.95 N for Chandrapur it may be below upto (19.95 – 7)N but not more than 19.95 N.

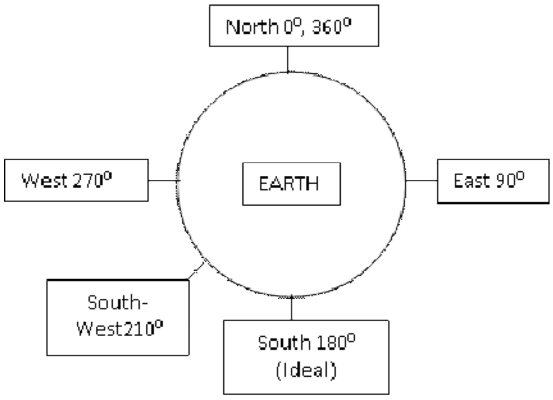

Fig.: Compass for measuring correct angle

At 180^0 maximum power is obtain from solar panel for northern hemisphere. Because of lacking of proper place we can consider angle greater than or equal to 180^0 or less than or equal to 210^0.

(b) Array Junction Box: Array Junction Box is meant for combining all the incoming lines from the solar panel strings/arrays and deriving one common array output for the multiple array inputs. Array Box is a junction box which allows several photovoltaic strings (from 8 to 32) to be connected in parallel. The total DC power is then distributed to the photovoltaic inverter. It includes photovoltaic string protection, overvoltage protection and a DC output switch disconnector. They are well adapted for Power plants as well as for photovoltaic large buildings. AJB is use upto 20 kW power, above 20 kW DC fuse terminal block is use. For 4 kW power internal structure of AJB is as shown in figure below. In this figure we can see that input to the terminal block is given by the each string which is made by connecting solar panel in series. Here terminal of each string is shorted to connect the strings in parallel manner. Then the total output obtained from the AJB is then forwarded towards DC MCB.

(c) DC MCB: In addition to fuses, protection of photovoltaic modules is provided by string circuit-breakers. They protect photovoltaic modules from fault currents. For example, in large systems they prevent regeneration from intact modules to modules with a short-circuit. Their advantage over fuses is that they are immediately ready for use after a trip and when the cause of the trip has been remedied.

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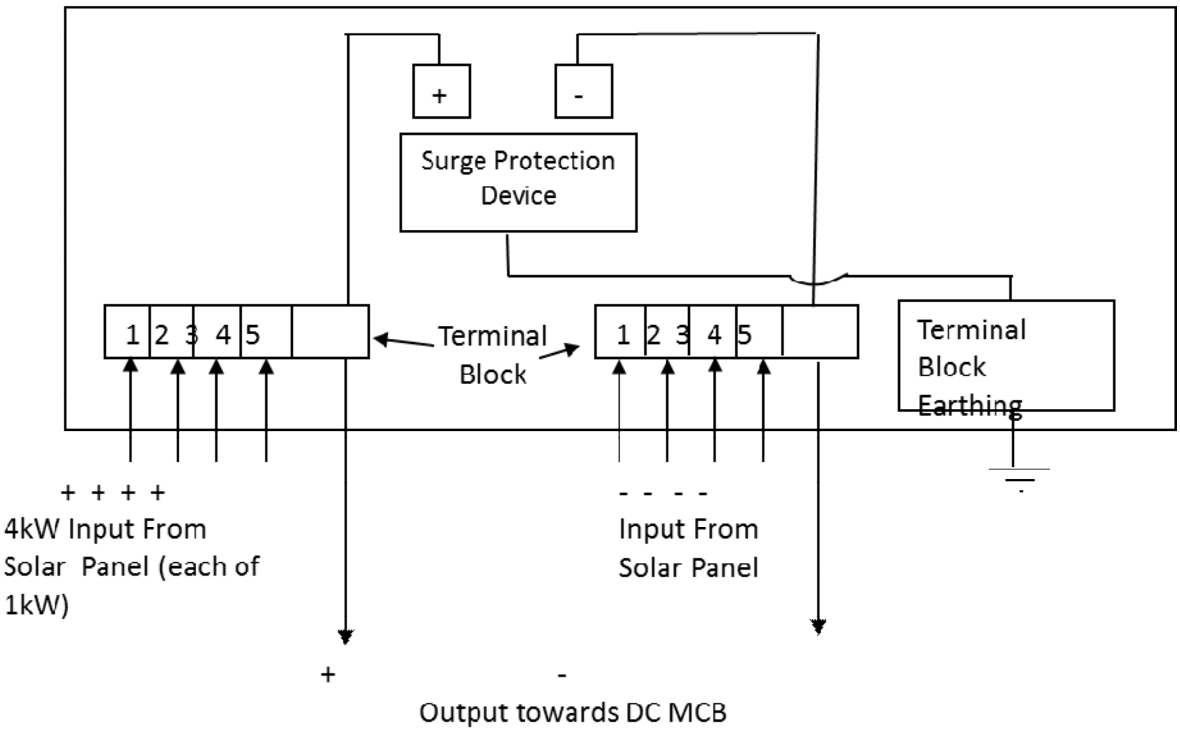

Fig. : Internal Structure of Array Junction Box

(d) DC Energy Meter: The DC energy meter is an electrical measuring device, which is used to record Electrical Energy Produced over a specified period of time in terms of units.

(e) Solar PCU: Solar Power Conditioning Unit (PCU) is an integrated system consisting of a solar charge controller, inverter and a Grid charger. It provides the facility to charge the battery bank either through Solar or Grid/DG Set. The PCU continuously monitors the state of Battery Voltage, Solar Power output and the loads. Due to sustained usage of power, when the Battery Voltage falls below a preset level, the PCU will automatically transfer the load to the Grid/DG power and also charge the Batteries through the in-built Grid Charger. Once the Batteries are charged to the preset level, the PCU cuts off the Grid / DG power from the system and will restore to feeding the loads from the battery bank & continue to charge the battery bank from the available Solar power.

The PCU always gives preference to the Solar Power and will use Grid/DG power only when the Solar power/ Battery charge is insufficient to meet the load requirement. It's a Power Conditioning Unit (PCU) with special feature like pure sine wave output and more for using in remote areas, where utility line is weak and renewable Energy (RE) sources are available. The PCU is designed to convert energy from RE source as the first priority and to stream energy from grid line when energy from the RE source is lower than the set level.

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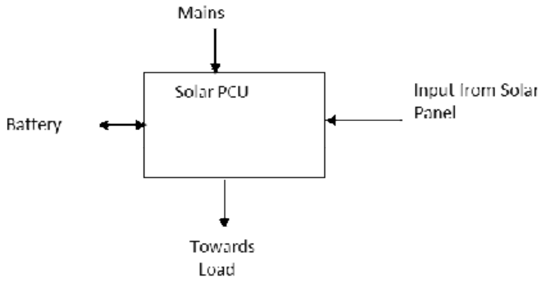

Fig.: Solar PCU

i) Solar charge controller: It saves battery from damaging.

PWM	MPPT
1. Pulse Width Modulation	1. Maximum power point tracking
2. Up to 1.5 kVA PWM is use	2. Above 1.5 kVA MPPT is use
3. Less Cost	3. Costly
4. Efficiency is 80%	4. Efficiency is 98%
5. Mainly use in polycrystalline solar cell	5. Mainly use in Monocrystalline solar cell

Operating Conditions of Solar PCU for 5kW power is given in following table:

Sr. No.	Output from Solar Panel (kW)	Battery	5kW Mains	Running Load (kW)	Condition
1.	4.5	Greater than 50%	Connected	4.5	Load run on power obtained from solar panel
2.	3.5	Greater than 50%	Connected	4.5	Load run on power obtained from solar panel + Battery
3.	4.5	Less than 50%	Connected	4.5	Battery get charged by using solar power + Load run on mains
4.	4.5	75%	Connected	3	Load run on power obtained from solar panel + rest solar power is use for battery charging
5.	3	100%	Connected	2	Load run on power obtained from solar panel + 1kW power get waste

(f) Solar Battery:

In stand-alone photovoltaic power systems, the electrical energy produced by the photovoltaic panels cannot always be used directly. As the demand from the load does not always equal the solar panel capacity, also electrical power usually needs to be available when the sun is not shining, it usually necessary to store electricity, hence battery banks are used.

An electric battery is a device consisting of two or more electrochemical cells that convert stored chemical energy into electrical energy. Each cell has a positive terminal, or cathode, and a negative terminal, or anode. The terminal marked positive is at a higher electrical potential energy than is the terminal marked negative. The normal storage is the Lead-Acid battery. Lead–Acid batteries are widely used.

Types of losses in solar PV system,

1) Array Mismatch Loss
2) Soil Loss
3) Heat Loss
4) Inverter Loss

If average solar insolation per year is 6 kWh / Sq. m or more then the losses to be considered as 51 %.

If average solar insolation per year is below 6 kWh / Sq. m then the losses to be considered as 48 %.

Estimation of power generation:

We know that,

1 Unit = 1 kWh…………………. (A)

Also,

1kW = 10 Sq. m

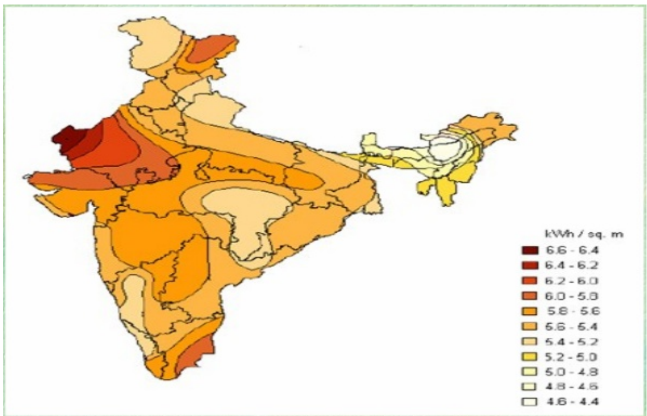

Fig.: Average solar insolation data

From above figure,

For Chandrapur average solar insolation is 5.6 – 5.4 kWh/ Sq. m

Therefore, 1 Sq. m = 5.6 kWh (5.6 units) / day

Then,

10 Sq. m = 56 kWh (56 units) / day

From equation (A),

1 kW = 56 kWh / day

Here we consider 1 day is of 5 hours,

Efficiency of solar panel = 15.2 %

Therefore,

1 kW = (56 kWh / day × efficiency of solar panel) - Losses

= (56 kWh / day × 15.2 %) – Losses

= 8.512 kWh / day – 48%(8.512)

= 4.43 kWh/ day

As we know that,

5.6 kWh / Sq. m is average for 1 year,

Therefore,

Energy will generated in 1 year = 4.43 kWh/ day × 365 days

= 1616.95 kWh / year

PV SYSTEM DESIGN METHODOLOGY:

PV system are designed and sized to meet a given load requirement. PV system sizing exercise involves the determination of size and capacity of various components, like PV panels, batteries, etc.

Calculation for designing of stand-alone solar pv system:

The design of the pv involves 3 steps:

Step 1:- Load estimation (or specific load):

To determine the total load demand, individual ac and dc loads and usage hours of particular equipments or appliances are considered. The total load is calculated using equation (1).

Total load = (ac load × hours of operation per day)+(dc load × hours of operation per day)…..(1)

Component	No.s	Wattage	Total Wattage	Run Time	Watt Hours
TV	01	150	150	4	600
Fan	04	80	120	6	1920
Computer	01	250	250	2	500
Light	06	20	120	6	720
Motor (0.5 HP)	01	375	375	5	187
Refrigerator (Inverter)	01	100	100	4	400
TOTAL			1315		4327

Peak Load= 1315 Watt (From Table)

= 1.315 kW

kVA= 1.2×kW

= 1.2×1.315 kVA
= 1.57 kVA

Step 2:- Battery Sizing

Consider Power Conditioning Unit= 2 kVA/48V

Therefore system voltage would be 48 V………………….(1)

No. of Battery = 48/12 = 4 no. of batteries

Capacity of Battery = 4327 Wh (From Table)
= 4327 (V×A)h
For battery capacity unit is Ah
= 4327 VAh / 48 V
= 90.14 Ah
Therefore, we use 90 % out of total charging capacity of battery
Now,
Loss or Realization Factor = 15 % (10 % we not use out of total charging of battery + 5 % chemical reaction loss)
= 90.14 + 15% (19.14)
= 103.661 Ah
Transformation loss from DC to AC or Inverter Loss or Conversion Loss = 15%
= 103 + 15 % (103)
= 118 Ah
Therefore, we can use 120 Ah Battery
Capacity of battery = 120 Ah

For PCU of 2 kVA/48 V, here we have to use 4 Batteries.
At full charge 1 Battery = 15 V
4 Batteries = 60 V
Therefore 4 Batteries are connected in Series.

Step 3:- Panel Capacity
P(W)=V(V)×I(A)
Require Current Rating = (Battery Capacity × hrs) / No. of sun hrs
= (120 Ah/ h) / 5 h
= 24 A……………..(2)
Battery Full Charge Voltage = 15 V
No. of Battery = 4
System Full Charge Voltage =15×4 V
= 60 V
Panel Capacity = 24×60
= 1440 W
= 1.440 kW

International Journal of Research
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Therefore, panels of approximately 1.5 kW capacity we need to install.

Panel Capacities for 12V and 24V

For 12 V panel capacities we can use are as follow:
40 W, 60 W, 75 W, 100 W, 120 W, 150 W
For 24 V panel capacities we can use are as follow:
200 W, 250 W, 275 W, 300 W
Therefore, for 24 V, 1500 W panel,
Three strings of 500 W are connected in parallel, provided each string contains two 250 W series connected PV panels.
All panels must be same because, maximum voltage is different for different panel.

$$\begin{array}{c} 250\ W \times 2 = 500\ W \\ 250\ W \times 2 = 500\ W \\ 250\ W \times 2 = 500\ W \\ \hline 1500\ W \end{array}$$

Connection of solar panel

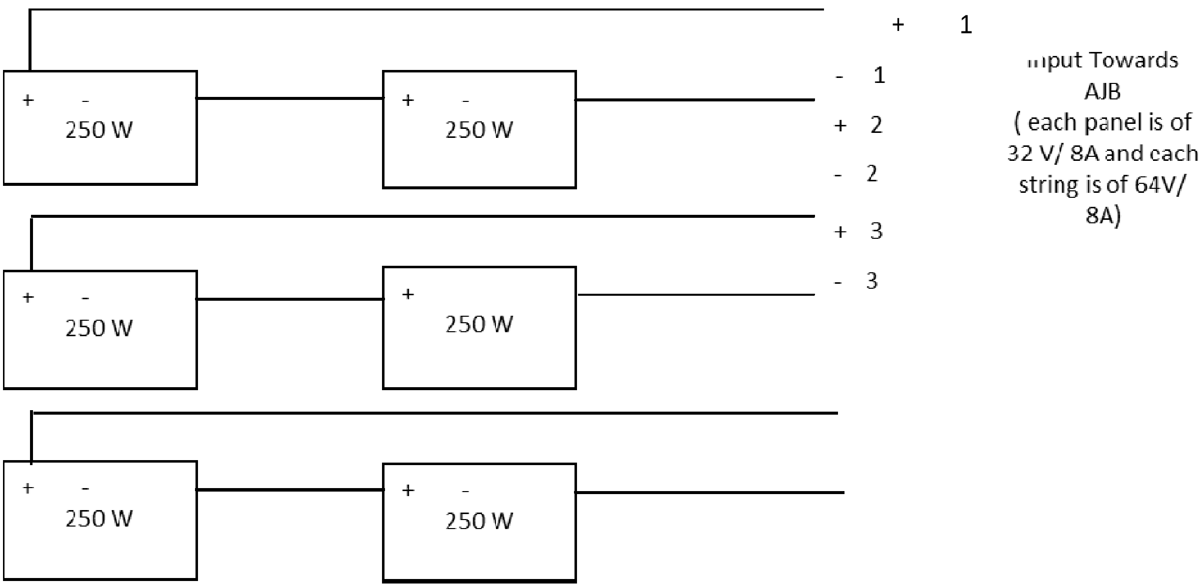

Fig.: Connection of solar panel
We know that system voltage is 48V (from 1) and require current rating is 42A (from 2)
Here we consider Vmp for each solar panel is,
Vmp= 32 V
Therefore, each panel has rating = 32V/ 8A

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Rating of each string = 64V/ 8A

When three strings would be connected in parallel,

Rating of whole structure would be = 64V/ 24A

Design of AJB :

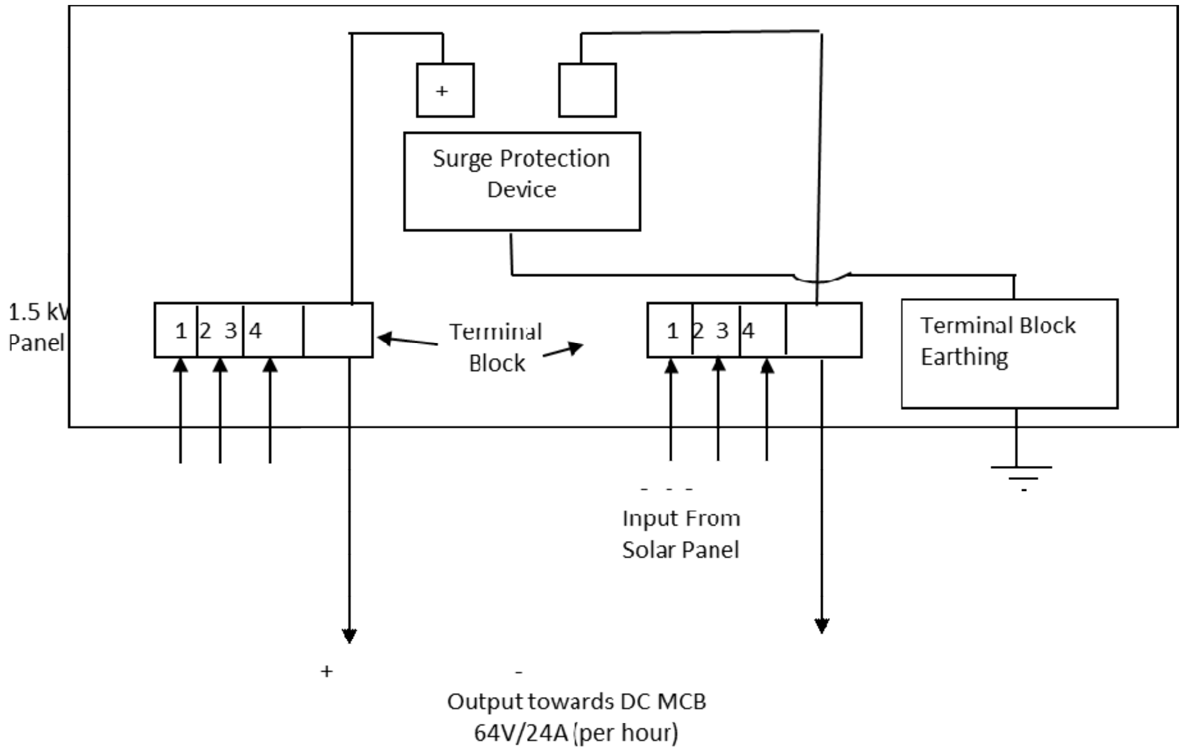

Fig.: AJB for 1.5 kW system

Wiring Specification (minimum thickness of wire) :

1) For below 5kW:
   - i) 4 mm wire is use from solar panel to AJB
   - ii) 6 mm wire is use from AJB to DCMCB
   - iii) 10 mm wire is use from DCMCB to PCU
2) For 5 kW to 10 kW:
   - i) 6 mm wire is use from solar panel to AJB
   - ii) 10 mm wire is use from AJB to PCU
3) For above 10 kW to 25 kW:
   - i) 6 mm wire is use from solar panel to AJB
   - ii) 16 mm wire is use from AJB to PCU

2. MAJOR COMPONENTS OF SOLAR PV SYSTEM:

[A] SOLAR CELL, SOLAR MODULE OR PANEL AND SOLAR PV ARRAY:

A.1 SOLAR CELL:

A solar cell is the key component in the chain of the photovoltaic solar system. The word photovoltaic is broken into photo and voltaic. Photo is associated with light and voltaic means voltage.

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. Solar cell is manufacturing by different materials. (Figure 2)

A.2 SOLAR PANEL:

A solar panel or module is a group of connected solar photovoltaic cells electrically and mounted on a sustaining structure. A photovoltaic module is a systematically arranged series connection of solar cells. (Figure 2)

A.3 SOLAR ARRAY:

Solar photovoltaic panels constitute the solar array of a photovoltaic system that generates and supplies solar electricity in commercial and residential applications. A photovoltaic array, or solar array, is a linked collection of solar panels. The power that one module can produce is seldom enough to meet requirements of a home or a business, so the modules are linked together to form an array.

The modules in a PV array are usually first connected in series to obtain the desired voltage; the individual strings are then connected in parallel to allow the system to produce more current. (Figure 2)

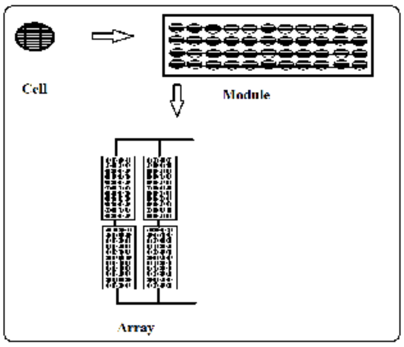

Fig.2 : Solar Panel Design

A.4 TYPES OF SOLAR CELLS:

Solar cells contain materials with semiconducting properties in which their electrons become excited and turned into an electrical current when struck by sunlight. While there are various types of solar cells, the two most common types are those made of crystalline silicon (both monocrystalline and polycrystalline) and those made with what is called thin film technology. 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.

A.4.1 SILICON SOLAR CELLS:

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Silicon solar cells are also called as first generation solar cells. The majority of the solar cells on the market today are made of silicon. However silicon can take many different forms. Variations are most distinguished by the purity of the silion; purity in this sense is the way in which the silicon modules are aligned. The greater the purity of the silicon modules, the more efficient the solar cell is at converting sunlight into electricity. The majority of silicon based solar cells are comprised of crystalline silicon. There are two types of srystalline-

A.4.1.i. Monocystalline silicon solar cells:

Monocrystalline solar cells are made from a very pure type of silicon. The more pure the alignment of molecule, the more efficient the material is at converting sunlight into electricity. Beyond being most efficient in their output of electrical power, monocrystalline solar cells also last longest of all types. 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).

A.4.1.ii. Polycrystalline silicon solar cells:

Poly-crystalline solar cell is slightly less efficient than Mono-crystalline but less in cost. Polycrystalline solar cells, also known as polysilicon and multisilicon cells, were the first solar cells ever introduced to the industry, in 1981. Polycrystalline cells do not go through the cutting process used for monocrystalline cells. Instead, the silicon is melted and poured into a square mold, hence the square shape of polycrystalline. In this way, they're much more affordable since hardly any silicon is wasted during the manufacturing process.

A.4.2 THIN-FILM SOLAR CELLS:

A thin-film solar cell, also called a thin-film photovoltaic cell, is a second generation solar cell that is made by depositing one or more thin layers, or thin film of photovoltaic material on a substrate, such as glass, plastic or metal. Film thickness varies from a few nanometers (nm) to tens of micrometers (µm). Thin-film technologies reduce the amount of active material in a cell. Most sandwich active material between two panes of glass. Since silicon solar panels only use one pane of glass, thin film panels are approximately twice as heavy as crystalline silicon panels.

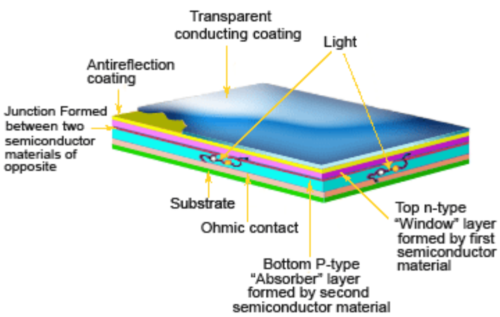

Fig. 3: Thin Film Solar Cell

A.5 CONNECTION OF SOLAR PANELS:

A.5.1 PARALLEL:

Parallel connecting solar panels gives higher current. And voltage will remain the same. Parallel Connecting is best for us. Because we do not need high voltage. Normal battery is 12v. And by selecting high voltage require

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higher voltage charge controller. To connect solar panels in parallel we have to connect plus + to plus and minus - to minus (Fig. 4).

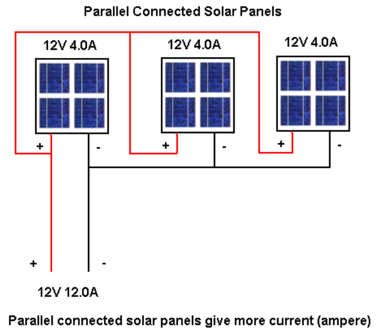

Fig. 4: Parallel connection of solar panel

A.5.2 SERIES:

By connecting Solar Panels in series connection. It will increase Voltage and current will remain the same. To connect solar panels in series we have to connect plus + to - minus on next panel. See the picture for details. In this example we have connected 2 solar panels in series which will give 24v output (Fig. 5)

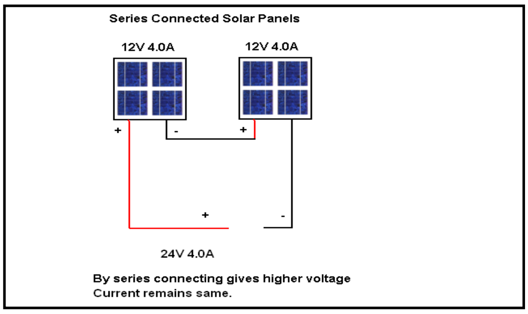

Fig. 5: Series connection of solar cell

A.5.3 SERIES-PARALEL:

If we are creating a 24v system. So then we have to connect two solar panels in series and connect two series connected panels in parallel as showed in figure under. Which isncreases voltage to 24v and when we have connected two other 24v connected solar panels in parallel so voltage remains same and increases current Amps. If we want to increase output current on 24v so we connect more solar panels in parallel same way under as shown in Fig. 6.

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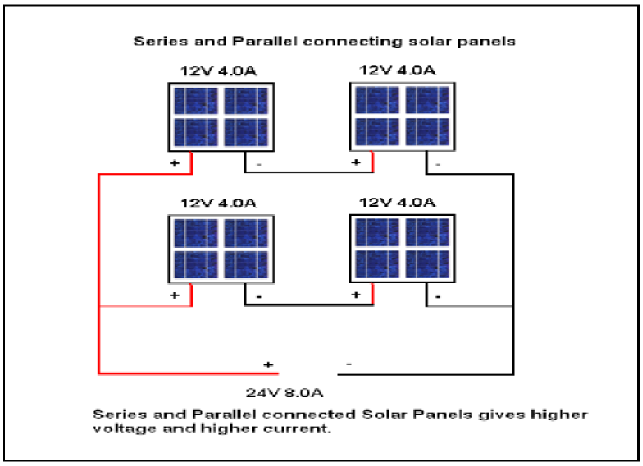

Fig. 6: Series and Parallel Connection of Solar Cell

A.6 PARAMETERS OF SOLAR CELL:

a) Isc: The short circuit current (Isc) is the current through the solar cell when the voltage across the solar cell is zero.

b) Voc: The open circuit voltage (Voc) is the voltage across the solar cell when the current through the solar cell is zero and it is the maximum voltage available from the solar cell.

c) Pmax: The maximum power point (Pmax) is the condition under which the solar cell generates its maximum power; the current and voltage in this condition are defined as Imax and Vmax (respectively).

d) FILL FACTOR: The fill factor (FF) and the conversion efficiency (η) are metrics used to characterize the performance of the solar cell. The fill factor is defined as the ratio of Pmax divided by the product of Voc and Isc.

$$FF = \frac{\text{Pmax}}{\text{Voc} \times \text{Isc}}$$

e) EFFICIENCY: The conversion efficiency is defined as the ratio of Pmax to the product of the input light irradiance (E) and the solar cell surface area (Ac).

$$\eta = \frac{\text{Pmax}}{E \times \text{Ac}}$$

A.7 CHARACTERISTICS OF SOLAR CELL:

The I-V and P-V characteristics of solar cell are as follows:

a) CURRENT-VOLTAGE CHARACTERISTICS:

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.

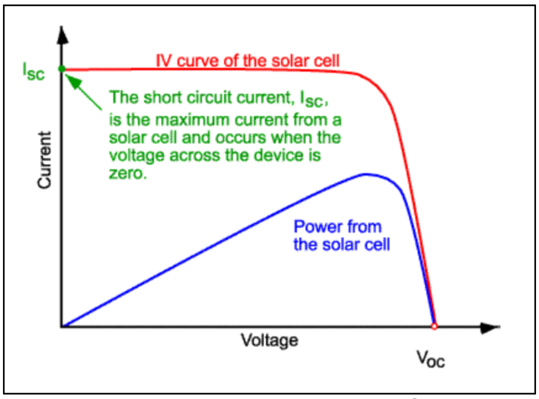

Fig. 7: I-V and P-V Characteristics of Solar Cell

b) POWER-VOLTAGE CHARACTERISTICS:

The power available from a photovoltaic device at any point along the curve is just the product of Current (I) in Amps (A) and Voltage (V) in Volts (V) at that point and is expressed in Watts. At the short circuit current point, the power output is zero, since the voltage is zero. At the open circuit voltage point, the power output is also zero, but this time it is because the current is zero.

[B] <u>DC-DC CONVERTERS:</u>

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. MPPT uses this converter for regulating the solar input voltage to the maximum power point and providing impedance matching for the maximum power transfer to the load.

B.1 BUCK CONVERTER:

A buck converter is a voltage step down and current step up converter. The simplest way to reduce the voltage of a DC supply is to use a linear regulator, but linear regulators waste energy as they operate by dissipating excess power as heat and do not yield any current step up. Buck converters, on the other hand, can be remarkably efficient (95% or higher for integrated circuits), making them useful for tasks such as converting the main voltage in a computer (12V in a desktop, 12-24V in a laptop) down to the 0.8-1.8V needed by the processor.

International Journal of Research
Available at https://edupediapublications.org/journals
p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 03 Issue 11
July2016

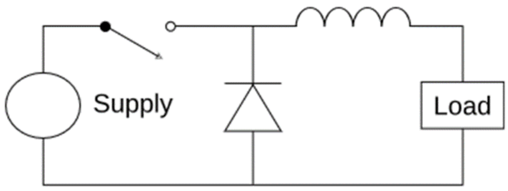

Fig. 8: Buck Converter

B.2 BOOST CONVERTER:

A boost converter (step-up converter) is a DC-to-DC power converter with an output voltage greater than its input voltage. It is a class of switched-mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor) and at least one energy storage element, a capacitor, inductor, or the two in combination. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple.

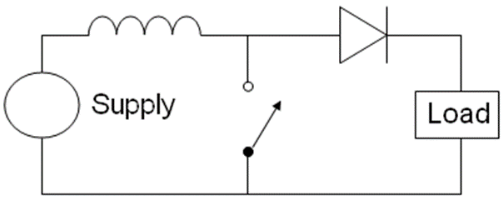

Fig. 9: Boost Converter

**[
C] <u>CHARGE CONTROLLER</u>:**

The DC electricity produced by the solar panel or module(s) is used to charge batteries via a solar charge controller. Any DC appliances that are connected to the battery will need to be fused. A charge controller, or charge regulator is basically a voltage and/or current regulator to keep batteries from overcharging. It regulates the voltage and current coming from the solar panels going to the battery. The two types of charge controllers most commonly used in today's solar power systems are pulse width modulation (PWM) and maximum power point tracking (MPPT). Both adjust charging rates depending on the battery's charge level to allow charging closer to the battery's maximum capacity as well as monitor battery temperature to prevent overheating.

a. PULSE WIDTH MODULATION (PWM) :

Pulse Width Modulation (PWM) is the most effective means to achieve constant voltage battery charging by switching the solar system controller's power devices. When in PWM regulation, the current from the solar array tapers according to the battery's condition and recharging needs. It adjust charging rate depending on the battery's charge level to allow charging closer to the battery's maximum capacity as well as monitor battery temperature to prevent overheating.

b. MAXIMUM POWER POINT TRACKING (MPPT):

The efficiency of a solar cell is very low and also when solar cells are connected together to form a panel then its efficiency is still not increased. In order to increase the efficiency (η) of solar cell or solar panel we have to use maximum power transfer theorem. The maximum power transfer theorem says that the maximum power is transfer when the output resistance of source matches with the load resistance i.e. solar cell or solar panel impedance. So all MPPT

p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 03 Issue 11
July2016

technique's principles are based on maximum power transfer theorem that always trying to matching the impedance of load to source.

The maximum power point tracking (MPPT) is now habitual in grid connected PV power generation system and it is becoming more popular in isolated or stand-alone power generation systems as well because of the V-I characteristics in PV power generation systems is nonlinear, So it is difficult to supply a constant power to a certain load.

[D] DC-AC CONVERTER (INVERTER):

Inverters play a crucial role in any solar energy system and are often considered to be the brains of a project, whether it's a 2-kW residential system or a 5-MW utility power plant. An inverter's basic function is to invert the direct current (DC) output into alternating current (AC). AC is the standard used by all commercial appliances, which is why many view inverters as the gateway between the photovoltaic (PV) system and the energy off-taker.

[E] BATTERY SYSTEM:

In stand-alone photovoltaic power systems, the electrical energy produced by the photovoltaic panels cannot always be used directly. As the demand from the load does not always equal the solar panel capacity, also electrical power usually needs to be available when the sun is not shining, it usually necessary to store electricity, hence battery banks are used.

An electric battery is a device consisting of two or more electrochemical cells that convert stored chemical energy into electrical energy. Each cell has a positive terminal, or cathode, and a negative terminal, or anode. The terminal marked positive is at a higher electrical potential energy than is the terminal marked negative. The normal storage is the Lead-Acid battery. Lead–Acid batteries are widely used.

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