

Solar Panel Selection for 5KW System

Vivek Kumar, Namrata Patil, Bhavesh Zope

Abstract: The theme of this project work is solar panel selection which capacity is 5KW. The first phase of the project is introduction, prospects, configuration about Photo-Voltaic systems (PV systems) and study of photo-voltaic cells, modular and array. The second phase includes the selection of solar panel, efficiency, economic considerations and calculations of the photo-voltaic system. The photo-voltaic technology is an off-shoot of the evaluation in semiconductor technology during 1980s. Several different base materials and doping materials were tried during early 1980s. By mid 1980s the silicon has been adopted as base material for producing photo-voltaic cells by almost all the photo-voltaic cell manufacturers. They work on principle of the light energy of the sun is directly converted in to electrical energy.

Keywords: photo-volatic; cell; modular; array

I. INTRODUCTION

Solar PV systems have become commercially successful during 1980s. Solar PV technology is the most significant renewable energy technology particularly for remote and stand-alone consumers away from main electrical distribution network.

The solar Photo-Voltaic cells (PV cells) convert the incident solar light energy directly to electrical energy in DC form. A single cell has a rated voltage of about 0.5V and rated power of about 0.3W. In solar system the intermediate thermal energy stage is omitted and the energy is converted in directly from the solar energy form to electrical energy form. Therefore problems of high temperature materials and excessive thermal loss are absent.

The vital component in a solar PV system is the solar cell, also called photo-voltaic cell (PV cell). A solar cell is a small semiconductor device which has a light-sensitive *N-P* junction. When solar light rays strike the *N-P* junction, DC e.m.f. is generated with *P* terminal as positive and *N* as negative. A solar PV panel delivers certain DC current at certain DC voltage for certain intensity of incident solar energy. The DC output power depends upon total number of cells and power per cell. The current and voltage are influenced by the circuit connections and external resistance.

Solar PV panels are installed outdoors in a position to receive maximum sun light during the day, and an year. Solar PV panels may be fixed type or tracking type; without focusing or with line focusing or with point focusing etc. Fixed type flat plate fixed panels without focusing are commonly used as they are simple, cheap and maintenance free [4].

II. PURPOSE FOR PAPER SUBMISSION

Now a day, demand of the electrical energy is increasing day by day and hence we require adopting of non-conventional energy resources. In renewable energy resources, the most advantageous and economical electrical energy generating system is solar PV system.

A. Prospects of solar PV systems

With increasing production volumes and development of cost effective PV panels, the cost of PV cells is reducing dramatically, the PV cells of efficient and reliable performance, long life, low cost and now commercially available.

For large central power plants of MW range. Solar PV systems are not yet technically suitable due to intermittent generation of power, high cost of storage batteries, large area of PV panels.

Solar PV technology has become commercially successful after 1980s. The cost of PV system is reducing and sales are increasing in advanced countries and developing countries. Solar PV technology has an importance place in the non-conventional, renewable energy technologies.

B. Economic Considerations of Solar PV System

Solar PV systems as power source are in use for variety of applications. This include

- Street lighting systems
- Community TV centers
- On-site power supply
- Telemetry systems
- Space station power supply
- Microwave repeater stations

Photovoltaic power supply systems have emerged as the chosen renewable technology for rural areas.

While selecting the power supply system for the above applications at the planning stage, the economic analysis is usually carried out by comparing. Solar PV systems are expected to be more and more popular during the coming decades and will become a very common source of electrical energy by the year 2000, for places where a solar panel can be installed [3].

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III. SYSTEM DEVELOPMENT

System development gives the structural and technical detail about the photo-voltaic system. It gives the overview of the solar PV cell, module, array and various connection of the system. In his system development various components of the PV system are explained.

A. Principle of a Photo-Voltaic Cell

The photo-voltaic cell (solar cell) is a light sensitive, two terminals, semiconducting *N-P* junction made of semiconducting material such as silicon. A solar cell has two layers called *N*-type and *P*-type and two corresponding electrodes, negative and positive. *N*-type material is obtained by doping silicon crystal with *N*-type impurity like antimony (Fig. 3.1 [a]). *P*-type material is obtained by doping silicon crystal with *P*-type impurity like boron (Fig. 3.1 [b]).

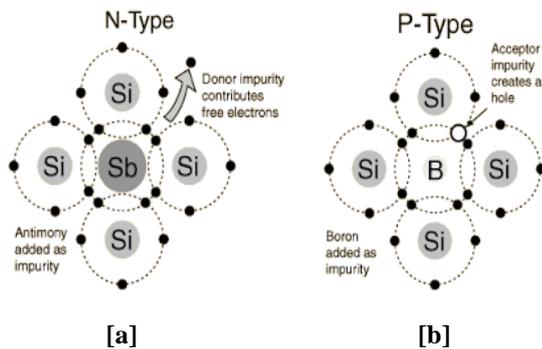


Fig. 3.1 [a] N-Type Material with Impurity Antimony and [b] P-Type Material with Impurity Boron.

The *N*-type layer is thin and transparent. The *P*-type layer is thick. When sun light strikes the *N*-type thin layer, some of the waves of light energy penetrate up to *P*-type layer. The energy from ‘Photons’ in the light waves is imparted to the molecules and atoms in the *N-P* junction resulting in liberation of electron-hole pairs. Electrons are released from *N*-type material and hole are created in *P*-type material. Electrons are negative charges and holes are positive charges (lack of electrons). When external electric circuit is completed by connecting electrodes to the load, the electrons flow in the closed external circuit from *N*-type terminal (negative) to *P*-type terminal (positive). Direction of current (by convention) is from the positive terminal (*P*-type) to negative terminal (*N*-type) in the external circuit.

Within the *N-P* junction ‘electron-hole’ pairs are continuously generated during the incidence of the sunlight. Energy from solar rays is captured by the solar cell and is converted directly to electrical energy [1].

B. Photo-Voltaic Cell Module

A module is a smallest non-divisible, self contained, environmentally protected unit with a transparent cover. Several solar cells and with interconnected in series, parallel, series-parallel (Fig. 3.2). A module has two terminals and delivers certain DC output when exposed to full sunlight [2].

$$P_m = n P_c \dots \text{Watts}$$

P_m = Power of one module, watts

P_c = Power of one cell, W

n = Number of cells in a module.

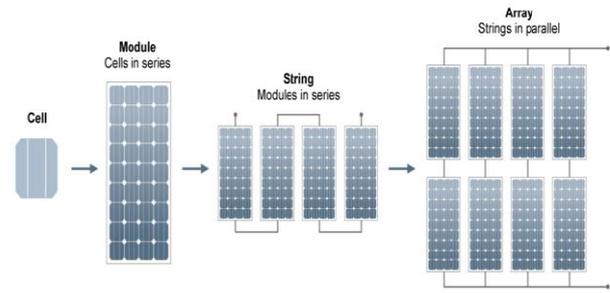


Fig. 3.2 Connection of Cell, Modular and Array in PV System.

C. Photo-Voltaic Array

An array has several modules connected in series, parallel and delivers DC power through two terminal leads.

Power of an array P_p

$$P_p = n m P_c$$

n = number of cells in a module

m = number of module in a panel.

Fig. 3.2 shows interconnections of solar PV modules to from an array. Configuration of the solar PV array is selected to obtain desired voltage and current by suitable series, parallel connections of PV modules [2].

D. Types of Photo-Voltaic Module

There are mainly three types of photo-voltaic module, which are following:-

Mono-crystalline cells

Poly-crystalline cells

Amorphous thin film cells

Mono-crystalline cells are made up of wafer cut and thin slice a single layer crystal of silicon. The cells are then doped and the fine current flow through the wires and these wires are printed on the surface or in the surface of the mono-crystalline cell. Mainly the efficiency of the mono-crystalline cells is very high but its cost is too high. This cell consumes more solar energy as compare to other and hence it has greater energy payback period. It has greater heat resistance and generate more electricity which is high efficient [2]. The mono-crystalline cells module is shown in fig. 3.3 [a].

Poly-crystalline cell has many crystals in single silicon. The poly-crystalline material has inter-grain boundaries within a cell. The electrons are inhibited at these boundaries resulting in its reduction in efficiency below single-crystal silicon cells. Efficiency of poly-crystalline solar cells is around 7 percent. Manufacturing process of polycrystalline silicon cells is less complex and less costly than that of single crystal silicon process [2]. Due to lesser complexity, lesser cost, higher production speed, polycrystalline silicon cells are commercially competing with single crystal silicon cells which is shown in fig. 3.3 [b]. Amorphous thin films cell means non-crystalline silicon. Such material is used in film process. Pure silicon without crystals is used. There is no alignment of crystals.



Crystals are scattered in random fashion. Amorphous silicon solar cells are least efficient but easy to manufacture which is shown in fig. 3.3 [c]. Efficiency of amorphous cells does not exceed 5 percent [2].

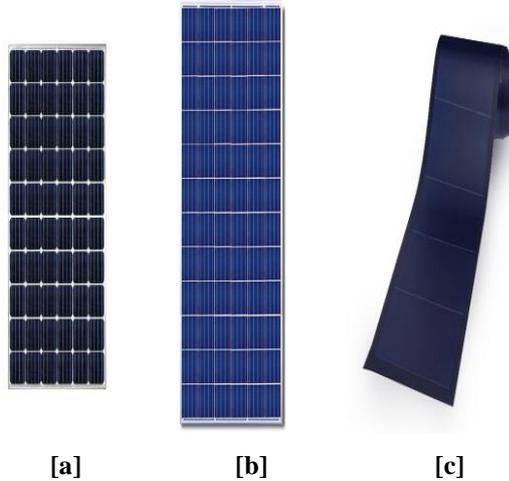


Fig. 3.3 [a] Mono-crystalline cell, [b] Poly-crystalline cell and [c] Amorphous thin film cell.

IV. SELECTION OF PV TECHNOLOGY

During the selection of the best solar panels to use for the solar power system installation cost is very important point of view. But the major considerations during the selection of solar panels except for the cost:

- The material use for solar module
- Conversion efficiency
- Light induced degradation (LID) resistance
- Potential-induced degradation (PID) resistance
- Embodied energy
- Durability/Warranty
- Size and capacity of watts
- Read more about the company which manufactures the modules.

According to above factors, in India the poly-crystalline silicon cells module is better because it is economical and the manufacturing process of polycrystalline silicon cells is less complex and less costly than that of single crystal silicon process. Due to lesser complexity, lesser cost, higher production speed, polycrystalline silicon cells are commercially competing with single crystal silicon cells.

A. V-I Characteristics of a solar cell

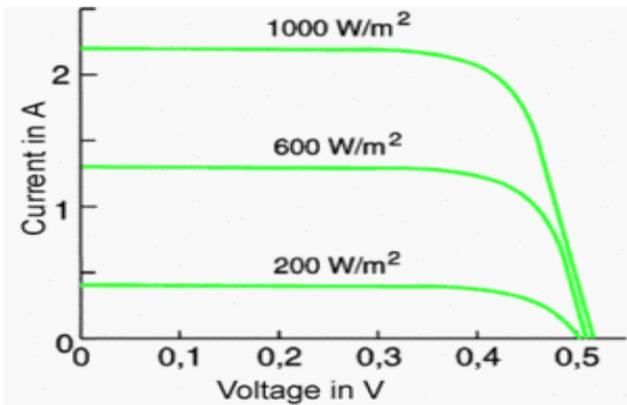


Fig. 4.1 V-I characteristics of a solar cell

All silicon solar cells have voltage about 0.5V cell. This is because this cells are the type of diode and analogous to the diode's forward break over voltage. When the numbers of cells are connected in series and if they are all the same then these all the cells deliver same current and voltage of all cells are added correctly but the voltages of the all cells are not same. The silicon is doped very deeply separately from cell to cell and pureness of the silicon varies and at different temperature different cells are operated. So some cells will deliver maximum current then other cells. In a series string, cells cannot be stand because all the cells are forced to deliver the absolutely same current. This will affect the lots of cells to run inadequately. Hence after the cells are tabbed, the cells are measured, and after that they are arranged like with like.

B. Efficiency of a Solar Cell

Most of the manufacturers give the efficiency values of the solar cells on the basis of the following definition:

Efficiency of a solar cell

$$= \text{Incident radiation (W)} \div \text{Power delivered (W)}$$

For specified conditions of temperature, irradiance solar spectra. Typical standard test conditions for efficiency measurement are:

Irradiance 1000 W/m²

Cell temperature 25°C to 45°C

Maximum efficiency of a particular solar cell depends on the materials, design parameters, manufacturing process, test conditions etc. and the efficiency range of economically available solar cells is 12 to 15 percent [1].

Maximum efficiency achieved in laboratories is between 15 to 20 percent. Maximum theoretical efficiency is 25 percent. The maximum efficiency for various type of silicon used for the PV cells are reported to be between 5 to 14%. The module efficiency is lesser than cell efficiency due to lesser area coverage factor (solar cell area/module area). Rectangular solar cells have higher surface coverage area than round cells. Hence rectangular cell modules have higher efficiency than round cell modules.

C. Specification of solar PV panel

Table 4.1 Electrical Characteristics of Solar Panel

Cell	Poly-Crystalline Silicon
No. of Cells and Connections	72 IN SERIES
Open Circuit Voltage (Voc)	45.25V
Maximum Power Voltage (Vpm)	36.75V
Short Circuit Current (Isc)	9.29A
Maximum Power Current (Ipm)	8.58A
Maximum Power (Pmax)	315W (+10% / -5%)
Module Efficiency (m)	12.30%
Maximum System Voltage	1000VDC
Type of Output Terminal	Cable with mc connector

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Table 4.2 Mechanical Characteristics of Solar Panel

Dimensions (L x W x D)	77.1" x 38.9" x 1.5" / 1960mm x 990mm x 40mm
Weight	48.5 lbs / 22kg

Table 4.3 Electrical Characteristics of Solar Panel

Operating Temperature (min to max, °F/°C)	-40 to +194°F / -40 to +90°C
Storage Temperature (min to max, °F/°C)	-40 to +194°F / -40 to +90°C

D. Calculation

Total number of panels (PV module) = 16 panels

Maximum voltage per panel (V_{mpp}) = 36.75V

Maximum current per panel (I_{mpp}) = 8.58A

Maximum power per panel (P_{mpp}) = 315W

So,

$$P = VI$$

$$P_{mpp} = (V_{mpp}) \times (I_{mpp})$$

$$315W = 36.75V \times 8.57A$$

$$315W = 314.94VA$$

$$315W \approx 315W$$

Now, we want to install 16 solar panels connected in series so the look on the specifications sheet and see that the ratings are:

$$P_{mpp} = 315W$$

$$V_{mpp} = 36.75V$$

$$I_{mpp} = 8.58A$$

In series connection of the panels the voltage increase but current stays the same. So, the total output power is

$$P_{series} = (V_{mpp}) \times (I_{mpp})$$

$$P_{series} = (36.75V \times 16 \text{ solar panel}) \times (8.58A)$$

$$P_{series} = 5045.04W \approx 5KW$$

V. CONCLUSION

During the selection of the best solar panels to use for the solar power system installation cost is very important point of view. In India the poly-crystalline silicon cells module is better because it is economical and the manufacturing process of polycrystalline silicon cells is less complex and less costly than that of single crystal silicon process. Due to lesser complexity, lesser cost, higher production speed, polycrystalline silicon cells are commercially competing with single crystal silicon cells.

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