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A Study on Solar Photovoltaic Conversion

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Abstract— Renewable Energy is now a must as an alternative of fossil fuel based energy as the demand for power is increasing day by day and the reservation of fossil fuel is coming towards an end. That is why renewable energy is important. Solar Energy is one of the best important ways to get energy from solar radiation. Solar PV (Photovoltaic)/Solar Thermal is one of the best ways to extract solar energy and convert it to electrical energy. This paper aims to discuss different articles about solar thermal system clearly and discuss the process of solar thermal conversion.

Index Terms— PV Efficiency, Solar PV etc

1 INTRODUCTION

ANY discussion of solar energy and solar (photovoltaic) cells should begin with an examination of the energy source, the sun. Our sun is a dG2 star, classified as a yellow dwarf of the fifth magnitude. The sun has a mass of approximately 1024 tons, a diameter of 865,000 miles, and radiates energy at a rate of some 3.8 x 1020 megawatts. Present theories predict that this output will continue, essentially unchanged, for several billion years. It is necessary to say essentially, because the sun's energy output may fluctuate by a few percent from time to time. For our purposes we will consider the solar energy output to be a constant. Between the sun and the earth there exists a hard vacuum and a distance which varies from 92 to 95 million miles. This instance variation implies, using the inverse square law, that the light energy reaching the earth in June (when the earth is at its maximum distance from the sun) is approximately 94% of the light energy reaching the earth in December. In this work, we will follow the common practice of assigning an average value to the high energy density available to a collector positioned just outside the earth's atmosphere. This quantity is known as the solar constant and has been measured variously as lying between 0.1338 and 0.1418 W/cm2. For our purposes, we will take for the solar constant [3]: Solar Constant = 0.1353 W/cml. This power density is available, on the sunlit side of the earth, 24 hours a day, each day of the year, yielding an annual energy flux to the earth of 1,186 kwh/cml.

Once the sunlight has reached the earth's atmosphere a number of additional effects play a part. Those effects resulting from weather, and photon absorption by water vapor, ozone, and other atmospheric constituents. They have the general overall effect of reducing the energy density in sunlight at the earth's surface. Atmospheric effects are at a minimum on a dry, cloudless day with the sun directly overhead (and at the zenith). Under these conditions (known collectively as air-mass-one or AMI) the power flux in sunlight at the earth's surface is AMI power flux = 0.107 W/cml. Two other factors influencing the availability of solar energy are geometric in nature. The first we have already considered, in part. The earth rotates on its axis with a period of approximately 24 hours; hence sunlight is available for only an average of 12 hours a day. Next, the earth's axis of rotation is tilted approximately 23.5° to the normal of its plane of revolution about the sun. Together, these two effects act to produce a shift in the number of hours of daylight and a geometrical situation in which the sun is almost never directly overhead, thereby enhancing light losses due to various atmospheric phenomena.

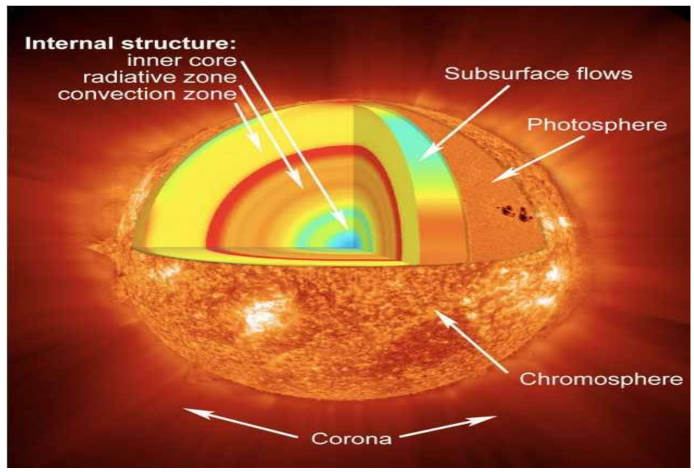

Figure : Different parts shown in the cross-section of the Sun

Sunlight, the observed solar light output (spectrum) is not constant with respect to wavelength or to time. Time variations depend on solar flares, sunspot activity, and other phenomena. Overall, the variation in solar output with wavelength corresponds quite closely to that expected of a 5,800 °K black-body radiator. However, there are departures due to Fraunhofer absorption lines and a number of emission lines from the solar corona and elsewhere close to the surface of the sun. For our purposes, the solar spectral irradiance, defined as the power density per unit wavelength in sunlight, may be presented as a time and wavelength smoothed envelope.

This is done in Figure. The outer curve depicts the solar spectral irradiance above the earth's atmosphere; the condition known as air-mass-zero (AM0). The inner curve in Figure is the solar spectral irradiance at sea level with the sun at the zenith on a clear, dry day-the air-mass-one condition. Note that the inner curve shows the effects of ozone on the ultraviolet portion of the spectrum and the effects of water vapor, smog, carbon dioxide and other atmospheric gases and pollutants on the long wavelength portions of the spectrum.

As indicated earlier, the air-mass-zero condition corresponds to a solar power flux density of 0.1353 watts per square centi-

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meter and a potential of 24 hours of sunlight each day. The air-mass-one condition corresponds to a maximum power flux density of 0.107 watts per square centimeter and a potential average of approximately 12 hours a day of sunlight.

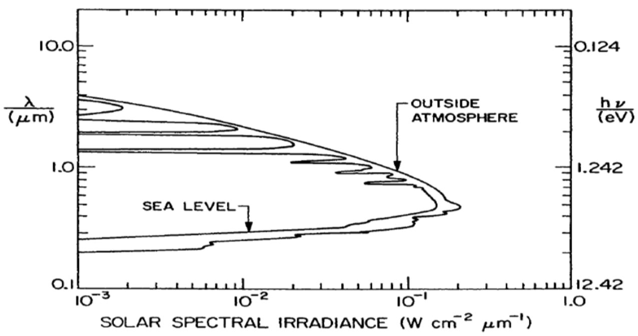
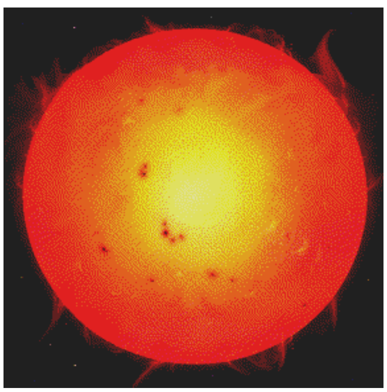


Figure: Solar Spectral Irradiance

2 PHOTOVOLTAICS



2.1 Solar Photovoltaic Cell

Solar PV cell is the basic unit in a PV system. It consists of a junction between two thin layers of dissimilar semi conducting materials. One is the positive type semi conductor or P-type and the other is the negative type semi conductor or N-type. These semi conductors can be made from Silicon, Germanium, Gallium - Arsenide, Indium-Phosphate, Cadmium-Sulphide, Cadmium-Telluride etc. But semi-conductors are usually made from Silicon. Because, Silicon is one of the most available elements on earth. It exists in nature predominantly in a combined form (Silicon-Oxide). For solar PV cell the pure Silicon is needed.

N-type semi conductors are made from crystalline silicon that is doped with tiny quantities of an impurity (usually phosphorus) in such a way that the doped materials possess a surplus of free electrons. P-type semi-conductors are also made from crystalline silicon that is doped with very small amount of a different impurity (usually boron) which causes the material to have deficit of electrons. An individual solar cell can vary in size from about 1 cm (0.4 inch) to about 15 cm (6 inches) across and typically produces between 1 and 2 watts, hardly enough power for the great majority of applications. The power is increased by connecting cells together.

2.2 PV Basic Principle

The actual creation of usable electrical current in a solar cell takes place at the atomic level. Two important steps are involved in the PV principle. These are:

(1) Creation of pairs of positive and negative charges (called electron hole pairs) in the solar cell by absorbed solar radiation.

(2) Separation of the positive and negative charges by potential gradient within the cell.

For the first step to occur, the cell must be made of a material which can absorb the energy associated with the photons of sunlight. The only materials for absorbing the energy of the photons of sunlight are semi-conductors. In a semi-conductor, the electrons of one of two energy bands-the valence band and the conduction band. The valence band has electrons at a lower energy level and is fully occupied, while the conduction band has electrons at a higher energy level and is not fully occupied. The difference between the energy levels of the electrons in the two bands is called the band gap energy Eg. Photons of sunlight having energy E (= hυ, h = Planck's constant and υ = Frequency of photon) is greater than the band gap energy Eg.

When (photons) strikes the face of cell, it is absorbed in the cell material. As a result, electrons within the cell are excited and jump across the band gap from the valence band to the conduction band leaving behind holes in the valence band. Thus electron hole pairs are created. The electron in the conduction band and the holes in the valence band are mobile. They can be separated and made to flow through an external circuit if a potential gradient exists within the cell. This flow of electrons current from the negative (N-type) semi-conductor to positive (P-type) semi-conductor is what we call the PV effect.

2.3 Solar PV Module, Pannel & Array

SOLAR PV MODULE

When solar PV cells are connected in series to from larger units, then it is called a PV module. The cells are welded in series to a string of several solar cells. Standard modules use around 36 solar cells and have a peak rating (Wp) of around 60 watts. For large modules (150Wp), two cell strings are exploded and can be connected at the back to electrical junction boxes. Thin film materials such as amorphous silicon, CIS and cadmium telluride can be made directly into modules. The cell material is sputtered onto a substrate, either glass, polyamide or stainless steel, or interconnected to a module by laser. A PV module is composed of interconnected cells that are encapsulated between a transparent cover and weatherproof backing. The modules are typically framed in aluminum for mounting, although frames may not be required for building applications. The PV module is the basic building block of any PV power system.

Solar cells are laminated to protect them from the external environment. On the front a tempered, low iron content glass is usually used. This type of glass is relatively cheap, strong and stable. Furthermore it has high transparency, good self claiming properties and prevents the penetration of water, water vapor and gases. On the rear side, a thin polymer sheet is usually used. The sheet should also prevent the penetration of

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undesirable vapors and gases. For bi-facial modules, which can generate electricity from front and rear, or when extra strength or semi transparency is required, glass is used at the rear, to provide adhesion between the different opponents of the module; the cells are sandwiched between thin sheets of ethyl vinyl acetate. The encapsulate should be stable at elevated temperatures and under UV exposure .The stability of the encapsulate is one of the major contributors to the expected lifetime of the module. To improve the strength and rigidity of the module, it can be framed using aluminum. Some of the crystalline silicon PV module manufacturers now guarantee a lifetime of 20 years for their modules. Typical module sizes are 0.5×1.0 meter and 0.33×1.33 meters. However, modules of any desired size can be produced.

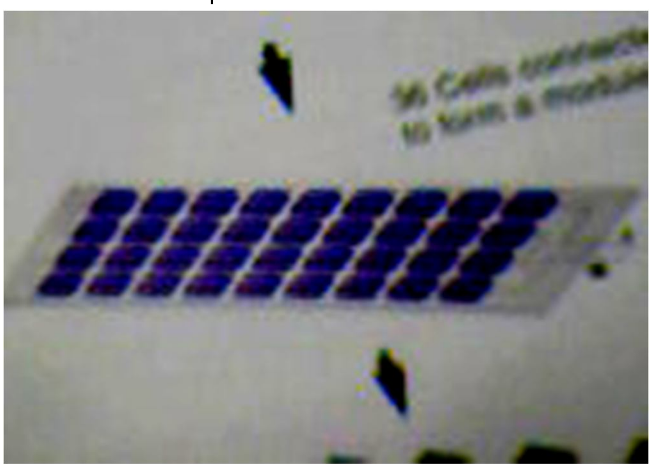

Figure: Solar PV Module

SOLAR PV PANNEL

Solar PV panel is formed by grouping a number of modules in series or parallel combination.

SOLAR PV ARRAY

The PV array is defined as "a mechanically integrated assembly of modules (or panels) together with support structure (but exclusive of foundation, tracking, thermal control and other components), as required to from a DC power producing unit".

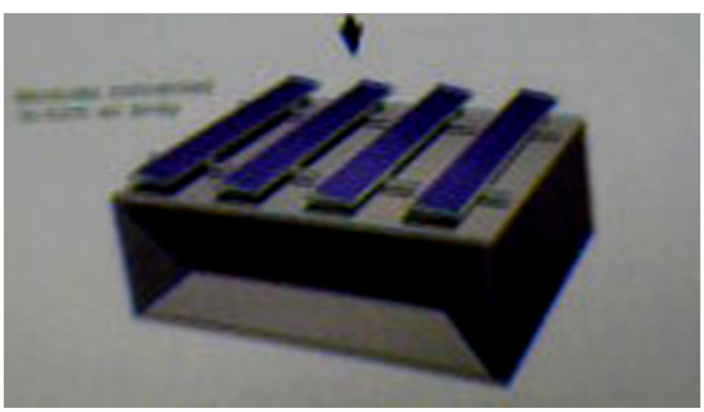

Figure:Solar PV Array

2.4 Solar PV Conversion Technology

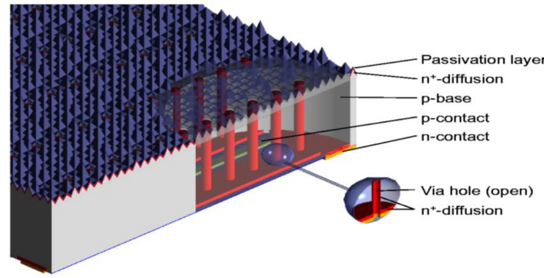

Figure: Construction of Solar PV Cell (A)

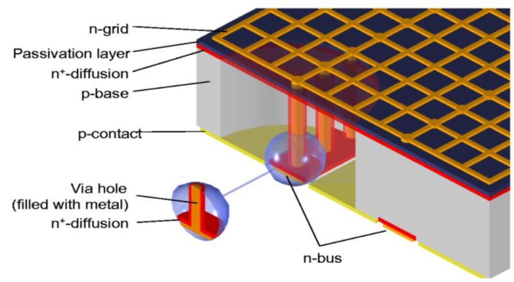

Figure: Construction of Solar PV Cell (B)

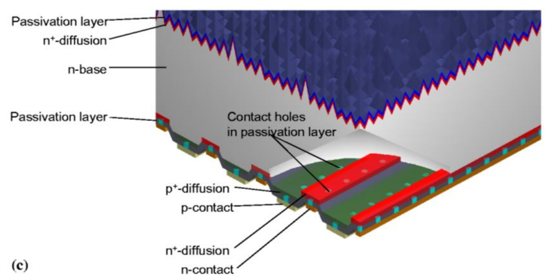

Figure: Construction of Solar PV Cell (C)

Thin silicon wafers permit new technologies for the contacts. Both n and p-type contacts can now be moved to the rear side. There are three different technological solutions for this task. The point contact cell which is an improved version of the interdigitated back contact cell shown emitter wrap through emitter contact wrap through cell.

The last two types are made by laser drilling holes through the silicon. In the emitter wrap through cell, the n-type emitter is brought to the rear side of the cell and both emitter and base contacts are made there in interdigitated manner. The emitter diffusion also covers most of the rear of the cell. The emitter metal contact cell is similar, with the difference that the emitter metal contact fingers are still at the front side but connected through metalfilled holes to the rear.

The difference of this technique is that fewer holes are required. Such cells have the following advantages:

Little or no shadowing of the front by metal grids, therefore, more light current.

(ii) The front of the cells and modules has a very uniform appearance, an important aspect for architectural applications.

(iii) Series connection of the cells in the modules is much simpler, because all connections are in the same plane. (iv) Lower quality silicon material can be employed, because the emitter junction is on both sides of the cell and therefore, carriers have to diffuse not more than half the cell thickness.

MODULE TECHNOLOGY:

One single crystalline silicon solar cell with a surface area of approximately 100 cm2 generates a current of 3A at a voltage of 0.5V when exposed to full sunshine. Up to five years ago, the typical PV module made of crystalline silicon consisted of 30 to 36 cells connected in series with a peak power of approximately 50 W. Today, modules with a peak power up to 300W are being marketed. Such a module consists of more than 100 solar cells connected in series and parallel. In the case of thin-film materials (e.g., amorphous silicon or copper indium diselenide), complete modules are manufactured.
So the above mentioned step from single solar cell to a solar module is not necessary. The module's top layers are transparent. The outermost layer, the cover glass, protects the remaining structure from the environment. It keeps out water, water vapor, and gaseous pollutants that could cause corrosion of a cell if allowed to penetrate the module during its long outdoor use. The cover glass is often hardened (tempered) to protect the cell from hail or wind damage.

A transparent adhesive holds the glass to the cell. The cell itself is usually covered with an antireflective coating. Some manufacturers etch or texture the cell surface to further reduce the reflection. The cell's bottom layer is called the back contact and is a metal film, which in connection with the front contact forms a bridge to an external circuit.

The module's back side is either covered with a layer of Tedlar TM or glass.Often a frame of aluminum or composite material gives the module the needed mechanical stability for mounting it in different. A single crystalline silicon solar cell generates electric power in a range of 1.5Wp at the maximum only. In most practical cases, this is not enough.

Therefore, it is necessary to interconnect a certain number of solar cells to a solar module. Depending on the power range of a PV module, the connection 926 Solar Cells and Solar Modules of the separate solar cells can be realized in series only or both in series and parallel. In industrial manufacturing, the connection of solar cells to produce a PV solar module requires a number of different steps, which will not be described in detail here.

It makes a great difference whether the PV modules are produced in a plant with great output, maybe 20MWp per year or in a smaller plant with an output of less than 1MWp per year. The production
process in a plant with a high yearly output of PV modules is fully or nearly fully automated. In the small PV solar module plants, many production steps are not automated. They are carried out by hand or with simple mechanical devices. The degree of automation of the production process has great influence on the production cost of the PV solar modules.Today; PV solar modules have a power of up to 300 Wp.
Because commercially used PV systems mostly need a higher power than can be delivered by a single PV module, the connection of several PV modules to a so-called solar generator is necessary. The same connection principles as for the connection of solar cells apply to modules, i.e., they can be connected in series and parallel or in series only.

SERIES CONNECTION:

Figure 1.7 shows a series connection of solar cells. Here, the same current flows through every solar cell, and the total voltage is the sum of the partial voltages across the individual cells. Series connection of the solar cells and also of the solar modules causes an undesired effect when a solar cell or module is fully or partly shaded. The weakest link in the chain determines the quality of the whole system. Even when only one cell is (partly) shaded, the effect is the same as if all the series connected cells or modules were shaded. In this way the power output drops drastically. Thus, it is imperative to avoid even slight shadows.

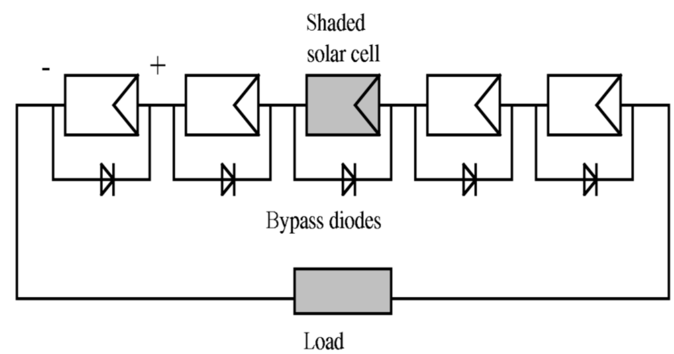

Figure: Series Connection

The bypass diodes prevent the occurrence of hot spots when one of the cells is shaded. A further intolerable effect caused by series connection is the occurrence of local hot spots when individual cells are partly shaded. The occurrence of the hot spot can be understood by realizing that the shaded diode presents a very high resistance compared to the load.

Then most of the voltage drop generated by the rest of the cells appears at the shaded diode, which is driven into breakdown. To avoid this operating condition, so-called bypass diodes are connected antiparallel to the solar cells such that larger voltage differences cannot arise in the reverse-current direction of the solar cells. The ideal solution is shown in Fig. 2.14, with one such bypass diode for each solar cell. However, in practice, it is sufficient to provide one bypass diode for every 15 to 20 solar cells. In general, connections for these are included by the manufacturer in the connection box.

Because, as mentioned above, when connecting solar modules in series the weakest link in the chain determines the quality of the complete string solar modules of different technologies or from different manufacturers should not be series connected to a solar generator. This also applies for the series connection of several solar cells to a module. In practice, differences in the efficiency of solar cells or modules between the individual production charges from the same manufacturer are possible. This situation is called mismatch, and the losses are

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called mismatch losses.

PARALLEL CONNECTION:

If higher currents are demanded in a system, these can be obtained by parallel connection of the individual strings, as is shown in Fig. 2.15. In a parallel connected configuration, the voltage across each solar cell or solar module is equal, while the total current is the sum of all cell or module partial currents.

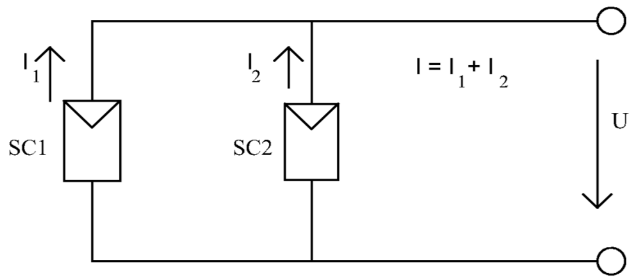

Figure: Parallel Connection

PV SYSTEM:

Terrestrial photovoltaic applications can be divided into: – stand-alone PV systems and – grid-connected PV systems. Figure 2.11- shows the annual percentage of grid-connected PV systems and off grid or stand-alone PV systems on the world PV market from 1990 to 2002. Clearly, it can be seen that the percentage of the grid-connected increased rapid

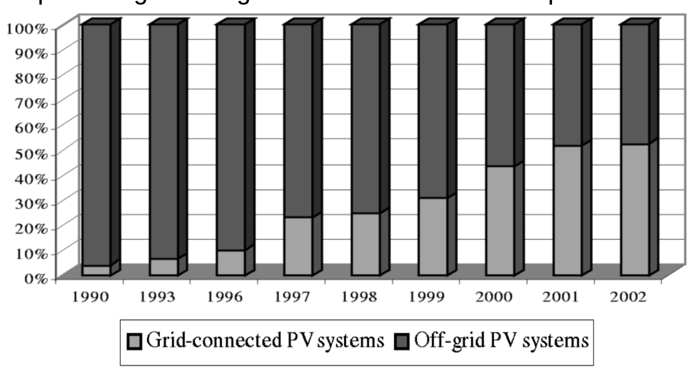

Figure: Percentage of grid-connected and off-grid PV systems on the world PV market

3 PV Efficiency

Efficiency in photovoltaic solar panels is measured by the ability of a panel to convert sunlight into usable energy for human consumption. Knowing the efficiency of a panel is important in order to choose the correct panels for your photovoltaic system. For smaller roofs, more efficient panels are necessary, due to space constraints. How do manufacturers determine the maximum efficiency of a solar photovoltaic panel is given below :

$$\eta_{max}(\text{maximum efficiency}) = \frac{P_{max}(\text{maximum power output})}{(E_{S,Y}^{SW}(\text{incident radiation flux}) * A_c(\text{area of collector}))}$$

The maximum power is also known as P_{max}. It is the area the solar panels use up to get thate maximum power that determines how efficient the panel is. The panel efficiency determines the power output of a panel per unit of area. The maximum efficiency of a solar photovoltaic cell is given by the following equation:

The incident radiation flux could better be described as the amount of sunlight that hits the earth's surface in W/m^2. The assumed incident radiation flux under standard test conditions (STC) that manufacturers use is 1000 W/m^2. STC includes several assumptions and depends on geographic location.

4 Conclusion

Finally it can be said that the process of Solar Photovoltaic Conversion is involved with some regular procedures and strict maintenance. Further study and research is going on for the betterment of the conversion process and to increase the efficiency.

Acknowledgment

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References

[1] All data is collected from Jagannath University Solar Energy Research Center laboratory, thesis books etc.

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