

Solar Panels and their Diverse Characteristics: An All-Inclusive Study

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Abstract

In recent years the use of solar energy is found to have grown by a large amount. Solar energy is renewable energy and the demand for it as clean energy shows its growth by nearly 50 percent in the past decade. It is estimated that the sun is able to generate energy within 24 hours that the entire population of the world could consume in 27 years. Solar power is the energy from the sun that is converted into thermal or electrical energy. The energy harnessed from the sun's rays is used for a variety of applications like electricity generation, to provide light for the interior environment, and many other domestic, commercial, and industrial purposes. Usage of fossil fuels for electricity production results in increased pollution and this mandates many governments to encourage moving to electricity generation using solar power. The large amount of solar energy that is available is found to be the most appealing source of electricity. Solar panels form a major part of the solar energy setup. Hence in this article let us review the various types of solar panels. This paper also deals with comparing the merits and demerits of the different types of solar panels that are available in the market. A section that presents the efficiency of the different kinds of the solar panel is also present in this paper. The role of temperature coefficient, fire rating, and hail rating in the performance of the solar panel is also addressed in this paper.

Key-words: Solar Energy, Solar Panels, Pollution, Temperature Coefficient, Fire Rating, Hail Rating.

1. Introduction

The energy from the sun is converted to electrical energy that is useful for commercial and industrial needs. This is called solar energy. This solar energy is the most abundantly available renewable energy and it is also clean energy. The various solar technologies are employed to harness the solar energy to be used for different uses namely electricity generation, to heat water for domestic, commercial, and industrial use.

The amount of solar energy that falls on the earth in a time period of three days is comparable to the energy stored in fossil fuels. Solar energy is free energy and it needs to be harnessed efficiently. Solar cells for practical applications are made about 30 years ago and many improvements have been made every year. Many companies are involved in the production of solar panels which is an indication that all are made to adopt the practice of using solar cells. Also, the advancement of transistor and semiconductor technologies facilitates harnessing solar energy in an efficient manner. Its non-polluting nature makes it an ideal choice for using solar energy. Also, the absence of moving parts and the need for less maintenance is a unique feature. Solar energy can be harnessed by different methodologies namely photovoltaic, solar heating & Cooling, and concentration of solar power. In the photovoltaic technique, electricity is generated directly from sunlight by using an electronic process. The energy generated in this way can be used to power anything namely from calculators to road signs up, homes, and large businesses. Besides being a reliable and long-lasting energy solar energy is also cost-effective.

The other two techniques namely solar heating and cooling and solar power concentration use the heat of the sun to heat water and to run electricity-generating turbines [1]. Solar panels are the most important component of solar energy harnessing. In this paper let us review the different types of solar panels. We will also analyse the power ratings and performance of the different types of solar panels.

2. Related Work

In this section let us present some of the earlier works that were carried out by different authors in the area of solar panels. The authors in [2] present the importance of solar energy in underdeveloped and developing nations that are still struggling for constant electricity supply. The authors address the fact that the use of fossil fuel leads to an increase in pollution and argues that solar power is the best alternative. The authors also make a review of the various advancements in the different solar technologies.

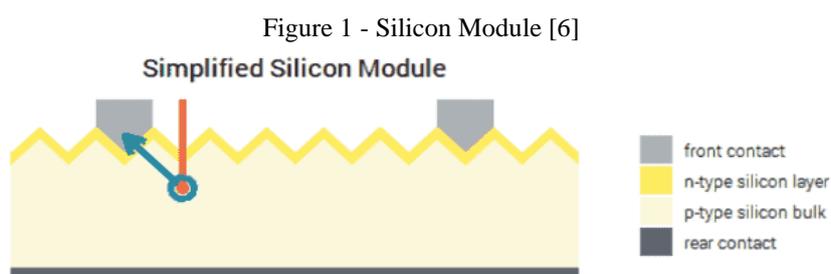
The authors in [3] evaluate the various parameters that are taken into consideration in the modelling of solar cells. The authors focus on selecting the optimized parameter of a photovoltaic cell. The authors investigate monocrystalline, polycrystalline, CdTs for modelling. A comparison of the above different solar cells is also conducted in the research. The authors in [4] present the various materials used for the construction of solar cells and the different fabrication methods of solar cells.

The authors also discuss the different classifications of solar cells. A comparison of the different types of solar cells on the basis of efficiency, cost, and lifespan is presented in this work.

The authors in [5] make a comprehensive study of the different types of solar cells and their applications of the solar cells. The authors have discussed the Amorphous silicon solar cell, Biohybrid solar cell, Buried contact solar cells, and concentrated PV cells.

3. Solar Panels

Solar Panels are the most important components of the solar energy system. These solar panels collect solar energy from the sun which is converted into electricity. A solar panel is made up of solar cells. Each of the solar cells is made up of silicon, boron, and phosphorous layers. A positive charge is provided by the boron layer, a negative charge is provided by the phosphorous layer and the role of semiconductor is played by silicon. When photons from the sun strike the surface of the solar panel electrons are cracked from the silicon layers. This produces current that is harnessed for commercial applications. This complete phenomenon is termed the photovoltaic effect and hence the solar panels are named photovoltaic panels. Usually, a solar panel consists of 60, 72, or 90 solar cells [6].



Types of Solar Panels

The Solar Panels that are present in the market today are mainly of four types. These four types are monocrystalline solar panels, polycrystalline panels, passivated Emitter and Rear cell Panels (PERC), and thin-film type. In this section let us elaborate on each of the above-mentioned solar panel types.

Monocrystalline solar panels are also referred to as single-crystal panels. These are the oldest type of solar panels. These are the more commonly used type of panels in the commercial market. These panels are prepared from a single pure silicon crystal which is cut into wafers. They are dark

black in colour. These solar panels are efficient in saving space and the lifetime of this type of solar panel is also high. A high amount of silicon is wasted for the production of a single monocrystalline panel and hence the cost of such panels is high.

Figure 2 - Monocrystalline Solar Panel [7]



Polycrystalline panels are produced from more than one silicon crystal. The fragments of silicon are melted and poured into a mold. Hence the cost of polycrystalline panels is less and affordable. However such panels are less efficient in converting solar energy and occupy more space. These panels exhibit lesser heat tolerance that is they perform poorly in environments of high temperature.

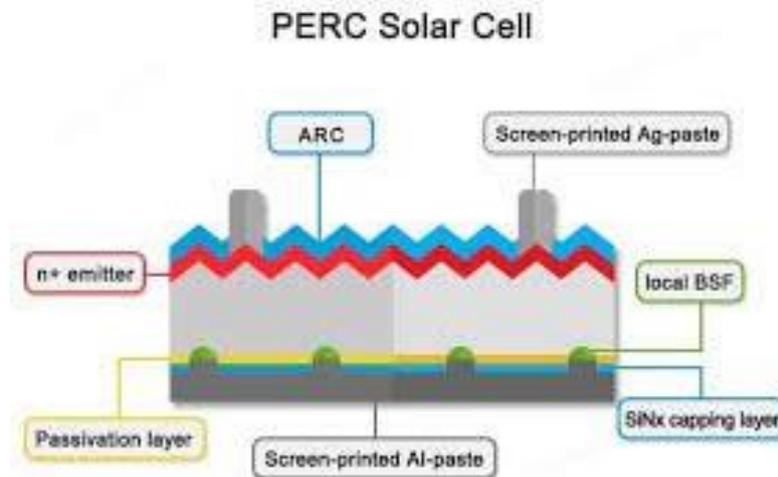
Figure 3 - Polycrystalline Solar Panels [8]



Passivated Emitter and Rear Cell type of solar panels are an improved version of the traditional monocrystalline cell. This technology employs the addition of a passivation layer in the cell's rear surface and hence the efficiency is improved. Light is reflected back into the cell and hence

more solar radiation is absorbed. Recombination of electrons is reduced and hence the electron flow is inhibited. Light waves of larger wavelengths are reflected in these types of panels. These types of panels allow to collect more solar energy in a small area. This makes these panels attractive for small spaces.

Figure 4 - PERC Solar Cell [9]



Thin-film solar panels have very fine layers that are highly thin and flexible. The panels do not mandate frame backing and hence they are light and easy to install. Thin-film panels are available in various sizes for different needs. But these are comparatively less efficient than silicon-based solar panels.

Figure 5 - Thin Film Solar Panels [10]

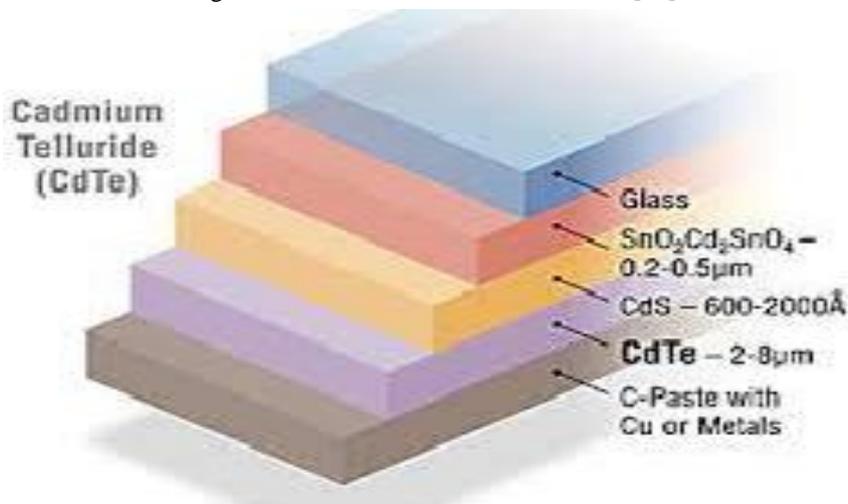


3.1. Thin Film Solar Panel Variants

Crystalline solar panels are made up of silicon whereas thin-film solar panels are made from a variety of materials namely Cadmium telluride (CdTe), Amorphous silicon(a-Si), Copper indium

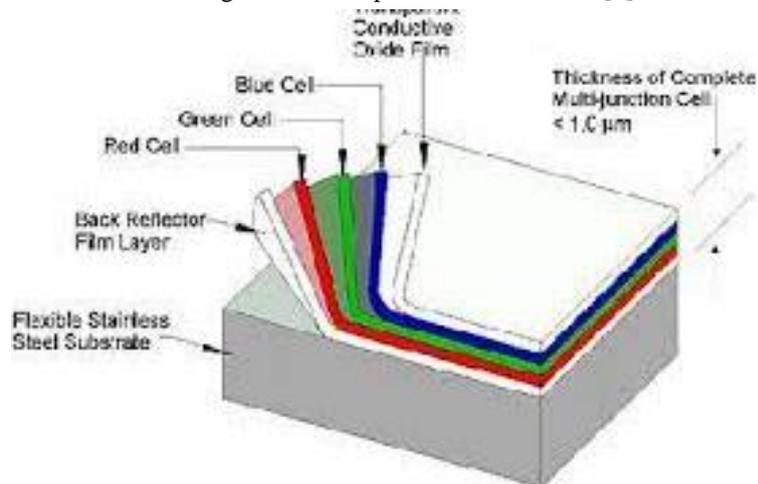
gallium selenide(CIGS). Cadmium telluride (CdTe) is low in cost. It requires less water and less energy payback time but cadmium is toxic in nature and hence recycling is costly.

Figure 6 - Cadmium Telluride Solar Cell [11]



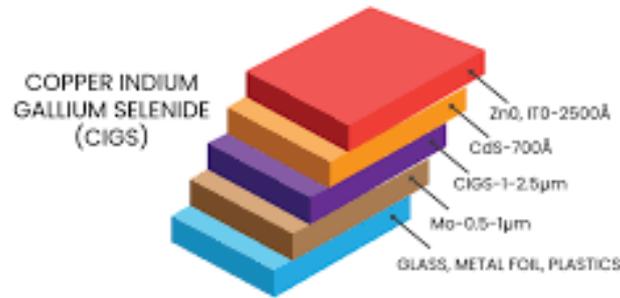
Amorphous silicon panels are shapeless in nature. This requires only a very small fraction of the silicon needed to produce a basic silicon cell. Hence they are cheaper in cost but are relatively less efficient. These are suitable for applications that demand less power namely calculators.

Figure 7 - Amorphous Silicon Panels [5]



Copper indium gallium selenide solar panels use the combination of thin layers of copper, indium, gallium, and selenium that are made to deposit on a glass or plastic backing. These exhibit greater efficiency in the category of thin-film panel variants.

Figure 8 - Copper Indium Gallide Solar Cell [12]



4. Choice of Solar Panels

Thin-film solar panels are not ideal for residential solar installations. They are comparatively cheaper but will occupy more space and will not produce electricity as that produced by monocrystalline or polycrystalline types.

For residential types, monocrystalline types are the best suited. Although the price is higher efficiency is higher and sleek. For a very strict budget, one may opt for a polycrystalline type of solar panel.

5. Solar Panels and their Efficiency

Among the different types of solar panels, crystalline solar panels are highly efficient. Monocrystalline panels have an efficiency of more than 20 percent. The presence of a passivation layer in the PERC panels has an efficiency of nearly 25 percent. The efficiency of polycrystalline panels varies between 15 and 17 percent. On the contrary, thin-film panels are 2-3 percent less efficient than their crystalline counterparts. The efficiency of CIGS panels lies in the range of 13 to 15 percent. CdTe panels have an efficiency range between 9 and 11 percent whereas A-Si type panels have an efficiency of 6 to 8 percent which is the lowest among the solar panel types [6]. The following table gives a comparison of the different types of solar panels and their efficiency.

Table 1- Comparison of the Efficiency of different Solar Panels

Cell type	Efficiency rate	Lifespan	Advantages	Disadvantages
Monocrystalline	20%	25 years	Highly efficient, durable	Expensive
Polycrystalline	16%	25 years	Lower cost	Less efficient
Thin film	10%	15-20 years	Less expensive, easily produced	Lower efficiency, shorter Lifespan

6. Solar Panel types and Power Capacity

Among the different solar panels, the power of the monocrystalline types is the highest. This is due to the fact that monocrystalline panels are constructed from a single crystal. Such cells have a higher output rating. A majority of the monocrystalline panels generate power of nearly 300 watts. The polycrystalline panels have the ability to generate power between 240 and 300 watts [6]. There is no standard power capacity in thin-film panels as they come in various sizes and the capacity differs with regard to the physical size of the panel.

7. Temperature Coefficient, Fire Rating, Hail Rating

Temperature also plays a crucial role in the energy generation of solar panels. This is felt through the temperature coefficient. The temperature coefficient is a measure of the solar panel's decrease in power output for every 1-degree centigrade rise over 25 degrees centigrade. The Temperature Coefficient of monocrystalline and polycrystalline panels varies between -0.3 percent per degree centigrade to -0.5 percent per degree centigrade. The temperature coefficients of thin-film panels are 0.2 percent per degree centigrade. From this, it is evident that thin-film panels are suitable for hot environments or for places that have sunlight throughout the year.

Apart from the temperature coefficient fire rating is one other factor that is to be considered when choosing a solar panel. This is needed to make sure that the modules never accelerate the spread of flames in case of fire. On this basis, the panels are classified as Class A, Class B, and class C. Class A category is very effective and the flame spread should not exceed 6 feet. This is suitable for regions with high fire severity and wildfire risk. Class B is suited for moderate fire conditions and the flame spread should not exceed 8 feet. Class C is suitable for light fire tests and the flame spread should not exceed 13 feet.

Hail rating is another parameter of interest in Solar Panels. Crystalline panels are good at resisting hails that hits at speed of nearly 50 mph whereas thin-film panels have a lower resistance because of their thin and flexible nature.

8. Light-induced Degradation

Light-induced degradation is a loss in performance that is evidenced in crystalline solar panels. This is realized in the first few hours of exposure to the sun. This is the result of the reaction of sunlight with oxygen. These oxygen traces are the remains of the manufacturing phenomenon that

alters the silicon lattice structure. This loss is directly related to manufacturing and can vary between one and three percent.

9. Conclusion

In this paper, the different types of solar panels are discussed in an elaborate manner. The efficiency of the different types of solar panels is also presented in this paper. The Power capacity of each solar panel is also discussed in this paper. Also, the role of the temperature coefficient in power generation is discussed in this paper. In short, this paper addresses the different aspects of solar energy that are to be harnessed to produce electricity that is non-polluting.

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