A REVIEW OF SOLAR PANEL

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Abstract - *A lot of efforts and research is being carried out to produce power from photovoltaic solar energy converters. The energy which is produced by using sunlight is a totally non-vanishing renewable source of energy which is free from noise and air pollution. There is enough sunlight energy that meets the world's energy demand for a whole year. Solar is one of the best mainstreams for the cheapest energy source in the world, leaving many people wondering how solar PV can be so efficient and inexpensive while still providing green energy. A solar cell is a key factor which produces both voltage and current for generating the electricity. So, it is very efficient and pollution-free. Nowadays solar power has great potential for large scale renewable energy sources and is currently a point of attraction is its utilization with a wide area of improvement. This article tries to discuss three major types of solar panels which are used in the solar power system and its applications which emphasize promoting solar energy.*

Key Words: Solar Energy, Photovoltaic or Solar Cells, Solar Panels

1. INTRODUCTION

Solar energy is radiant light and heat from the sun which is harnessed using a range of ever-evolving such as solar heating, photovoltaic, solar thermal energy and etc. It is important to the source of renewable energy and its technologies are broadly characterized [2]. The potential of solar energy is wide since about 200,000 times worlds total daily electricity generating capacity is received by our earth every day in the form of solar energy. The solar energy is itself free, the high cost of its collection, conversion, and storage still limit its utilization in many places. Solar radiation may be transformed either into thermal or electrical energy through the former is easier to manage or fulfill. Even if it is the highly costed renewable energy technology, there is photovoltaic technology which is the easiest energy technology in respect of design and installation. But its main advantage arises from the fact that it is an environmentally friendly technology with low maintenance cost [3]. Advancement of technology in the future will definitely lead to a higher potential for each energy source. The demand for energy is expected to keep increasing at 5 percent each year world. Solar energy can satisfy a huge and steadily increasing demand. As per the IRENA, annual global solar PV additions are expected to reach 270GW in 2030 and 372GW in 2050 compared to 94GW in 2018 [4]. Earlier in 2011, the International Renewable Energy Agency, cleared that the development of affordable and clean solar technologies will have huge long-term benefits. Energy securities of countries automatically increased and the most important factor is it has independent which enhances its sustainability, reduces global warming, and prices of fossil fuels lower than otherwise.

1.1 Installation Capacity

Growth of the photovoltaics is very different and varies according to the countries. Solar PV technology has one of the efficient techniques to produce electricity, as per IRENA, there are 10 leading countries having an installation of Solar PV technology. Where China is the leading country for the installation of solar PV from 2016 to till the date. Before 2016 Germany was the leading country in the world. In 2019, 580,159MW Solar PV installed all over the world, whereas 40,277MW in 2010 [11]. The below table shows how solar PV technology is using all over the world. The usage of this technology is rapidly increasing.

Table- 1: Installation Capacity of Solar PV technology for top 10 leading countries [10].

Country	Capacity in (MG) & Year	
	2018	2019
China	175,015.864	205,072.165
Japan	55,500.000	61,840.000
USA	51,425.500	60,539.900
Germany	45,179.000	48,960.000
India	27,126.824	34,831.384
Italy	20,107.589	20,900.000
Australia	11,303.000	15,928.000
United Kingdom	13,118.344	13,398.025
France	9,617.025	10,562.025
Republic of Korea	7,129.859	10,505.102

Table-2: Installation Capacity of Solar PV technology year wise [11].

Year	Installed Capacity (MW)
2010	40,277
2011	72,030
2012	101,511
2013	135,740
2014	171,519
2015	217,243
2016	290,961
2017	383,598
2018	483,078
2019	580,159

2. SOLAR CELL OR PHOTOVOLTAIC CELL

A solar cell, or PV cell, is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon having electrical characteristics – such as current, voltage, or resistance – varies when exposed to light [5]. There are two types of semiconducting materials i.e. p-type and n-type which is based on the principle of each PV cell of modern technology of photovoltaic cells. At the junction of positive/negative, holes and free electrons are created because of sunlight and it is absorbed solar cells [7]. If the two junctions of solar cells i.e. positive and negative are connected to the DC electrical equipment, then-current is delivered to operate electrical devices[8]. For detection of light, measuring the intensity of light and other radiation of electromagnetic which is near to the visible range that time solar cells also work as a photodetector. The maximum open-circuit voltage is approximately 0.5 to 0.6 volts for single-junction silicon solar cells.

The operation of a photovoltaic (PV) cell requires 3 basic aspects:
- Absorption of light, generating either electron-hole pairs or excitons.
- Separation of charge carriers of opposite types.
- The separate extraction of those carriers to an external circuit [2].

Photovoltaic cells include various types of material in the form of silicon (single crystal, multi-crystalline, amorphous silicon) cadmium-telluride, copper-indium-gallium-selenide, and copper-indium-gallium-sulphide [1]. In the market 90% of solar cells are made from crystalline silicon out of that one-third is monocrystalline silicon and two-third is polycrystalline silicon. And the remaining market falls on thin-film solar cells and only 3% of the other materials in 2012 [6]. Nowadays thin-film solar cell technology has completely replaced the silicon wafer technology. Today, the cell is one of the fastest-growing renewable energy technologies and is ready to play a major role in the future global electricity generation mix.

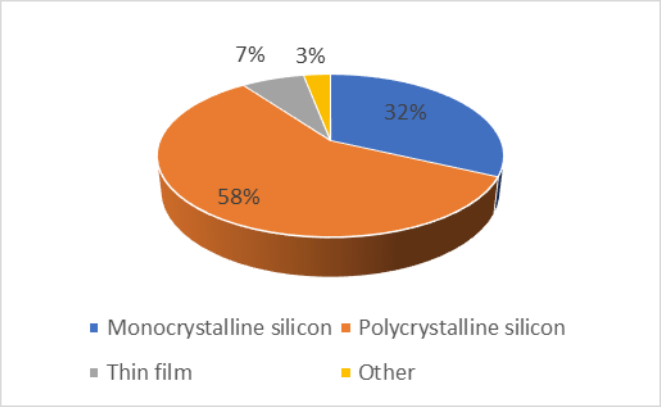

Chart-1: Participation of different types of silicon in the global production of solar cells.

3. SOLAR PANELS

The solar panel is the device that absorbs the sun rays and converts these rays into electricity or heat. With the help of the PV effect, electricity is generated whereas solar panel is a collection of solar cells. The amount of electricity produced, as measured in volts or watts, varies according to the system and the type of solar cell. Each module has its different DC output power depending upon the standard condition, and it has ranged from 100 to 365 watts. The arrangement of solar cells is mainly a grid-like pattern on the surface of the solar panels. That is why sometimes it may be called a set of modules, mounted on the structure supporting it. A photovoltaic module is packaged and connected assembly of 6×10 PV cells. [2]. When it comes to erosion, these panels are healthy. Solar panels wear out very slow once a year. Most of the solar panels are made up of crystalline silicon solar cells. Solar panels mainly made from these three key components which are silicon, metal, and glass.

Individual solar panel or module having an array which consists of PV cells packaged together in a metal frame. Single solar panel consist of around 60,72 or 96 photovoltaic cells. Solar panels are used in wide-ranging electronic equipment like calculators, which work as long as sunlight is available. Solar PV is a fast-growing, most mature, and cost-competitive renewable energy technologies. In the upcoming decades, solar power will clearly continue to be an essential renewables source. The popularity of green energy in today's era is increasing day by day Installation of solar panels reduces global warming by installing in homes and helps in the battle of the harmful emission of greenhouse gases. Solar panels are eco-friendly and are clean, solar panels are the traditional power sources.

The cost of solar panels has fallen substantially which makes them economical as well as the cheapest form of electricity

because in many countries it is cheaper than ordinary fossil fuel electricity from the grid. The installation costs of the solar panels are USD1210/kw in 2018 compare to the next three decades it would decline dramatically from now to 2050 globally, the averaging cost in the range of USD 340 to 834/kw by 2030 and USD 165 to 481/kw by 2050 as per the International Renewable Energy Agency [4]. The technologies supporting three of these types of solar panels have made significant improvements over time to meet energy needs better. Monocrystalline Silicon Solar Panel, Polycrystalline/Multicrystalline Silicon Solar Panel, and Thin-Film Solar Panel these three are the major types of solar panels:

3.1 Monocrystalline Silicon Solar Panel

Monocrystalline is the first-generation solar panels. Monocrystalline solar panels are comprising of silicon solar cells, this silicon is formed into bars and cut into wafers [6]. The power output of the monocrystalline solar panel is high, less space, and last the longest. Monocrystalline silicon solar panel cells tend to achieve a higher level of efficiency because they are made from pure silicon, and these cells have a quite cylindrical shape to achieve high efficiency. It has around 25% efficient as per the national renewable energy laboratory [12].These types of solar panels have a variety of colors for their frame and back sheet. Most often it has black, silver, or white back sheet, while the metal frames are black or silver. Monocrystalline solar panels are generally thought of as a premium solar product and it has a distinctive pattern of small white diamonds. And because of their high silicon content, they are more expensive. Today, these are the more efficient types of solar panels. The monocrystalline silicon solar panel works when sunlight falls and cells absorb the energy through a particular process which creates an electric field. This electric field consists of current and voltage which generates power, and it is governed by equation P (power) = V (voltage) x I (current). And usage of this power for the devices who run on direct current (DC), otherwise it can be converted into alternating current (AC) using an inverter.

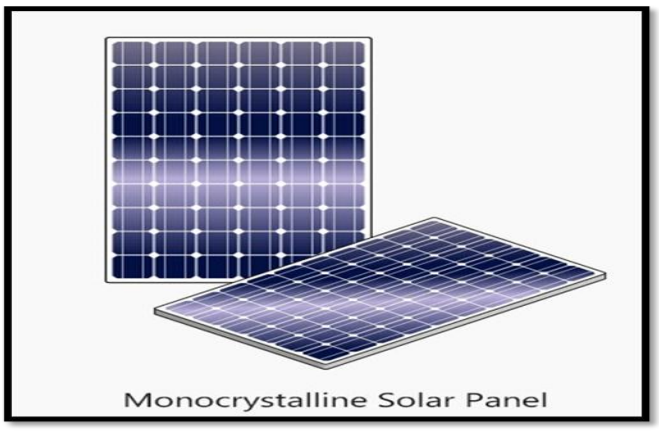

Fig.- 1: Monocrystalline Solar Panel [13].

3.2 Polycrystalline Silicon Solar Panel

Polycrystalline is also the first-generation solar panel. Polycrystalline or Multicrystalline solar panels are panels that consist of several crystals of silicon in a single PV cell [7]. These panels have lower silicon than monocrystalline panels. Polycrystalline silicon solar cells are of bluish color because of the light reflecting off the silicon fragments in the cells in a different way than it reflects off a pure silicon wafer i.e. monocrystalline. Because there are multiple silicon crystals in each cell, so polycrystalline solar panels allow little movement of electrons inside the cells. These solar panels are square in shape. They are arranged in an irregular manner. Polycrystalline silicon solar panels have different colors for back sheets and frames. Constantly, the frames of these panels are silver, and the black sheets are either white or white. These solar panels are more resistant to degradation due to irradiation. The rate of degradation is about 1 to 2 percent per year for multiple crystalline technologies. Polycrystalline cells are less efficient than monocrystalline cells, it's about 23.3% efficient as per the national renewable energy laboratory [12]. Demand for this solar panel more as compared to others. All these solar panels are made up of multiple photovoltaic cells, and they work as a semiconductor device because each cell contains silicon crystals. When photons coming from the sunlight is directly fall on the PN junction (junction between N-type and P-type) it totally imparts energy to the electrons due to which they can flow as electric current. In this P-type material are well deficient electrons wile on the other hand N-type materials do not contain electrons. Two electrodes are connected with PV cells. The electrode which contains small wires is on the top of the surface while the electrode on the which contains a foil-like conductor is on the bottom of the surface [5].

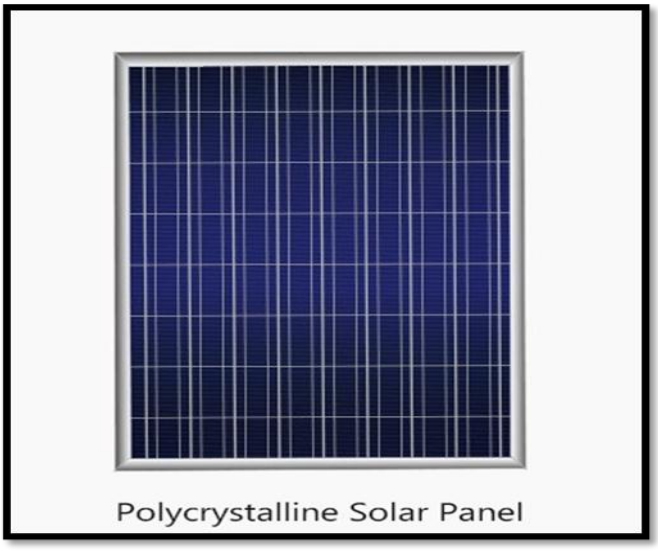

Fig.- 2: Polycrystalline Solar Panel [13].

3.3 Thin-Film Solar Panel

Thin film is the second-generation solar panel. A thin-film solar panel is made up of one or more thin layers of solar cells. These solar panels convert solar energy to electrical energy by using the principle of the photovoltaic effect. Several layers of photon-absorbing materials are made from each solar cell. The layer of the standard silicon solar panels is nearly up to 300-350 times smaller than the solar cells of solar panels. It's very much useful to be remembered that thin-film cells themselves may be much thinner than traditional solar cells, an entire thin-film panel may be similar in thickness to a monocrystalline or polycrystalline solar panel of it includes thick frame. The size of solar cells used with built-in-semiconductors; thin-film solar panels are the lightest panels [5]. The thickness of the film is varying from few nanometers (nm) to tens of micrometers (µm), because of this, cells used in this solar panel way thinner than the other technology. Crystalline silicon solar cells have wafers pf up to 200 µm thick. These solar panels are categorized on the basis of the material that is used as a substrate in them. Materials such as Amorphous Silicon (a-Si), Copper Indium Gallium Selenide (CIGS), and Cadmium Telluride (CdTe) [7]. The efficiency of these panels is less as compared to others expect Copper Indium Gallium Selenide (CIGS), because it has almost the same efficiency to polycrystalline which is 23.4%. Remaining Amorphous Silicon (a-Si) and Cadmium Telluride (CdTe) having efficiencies 14.1% and 22.1% as per the national renewable energy laboratory [12].

In these three, Cadmium Telluride (CdTe) is the most conventional type of thin-film solar panel, for making this type of panel place a layer of CdTe between the transparent conducting layer that help to capture sunlight. Another type of solar panel is of amorphous silicon (a-Si), which is similar to the composition of monocrystalline silicon and polycrystalline silicon panels. Silicon is used as a component in a solar thin film, but they are not made from the silicon wafers whereas they must be composed of non-crystalline silicon placed on top of glass, plastic, or metal. For the formation of copper indium selenide panels, these are all four elements placed between two conductive layers i.e. glass, plastic, aluminium and steel, and electrodes are placed on the front and back of the material to capture electrical current. These solar panels can come in both blue and black color depending on what they are made from[7]. The thin-film solar panel is formed from the various cells/photovoltaic cells and is basically semiconductor in nature. Whereas P-type and N-type combinations formed each PV cell. The material which is deficient of electrons is generally P-type and those that contain free electrons are N-type. The electrons get excited when panels come in the contact of sunlight and flow through the p-n junction and generate a large amount of current, this current can directly send to a building to power various appliances or it can be stored in batteries to use whenever required.

Fig.-3: Thin-Film Solar Panel [13].

4. HISTORY

Solar cell technology is very old and work started in the 1800s. Alexandre-Edmond Becquerel was the first person who observed the photovoltaic (PV) effect in 1839. Later, in 1946 the first modern solar cell made of silicon was invented by Russel Ohl which was extremely inefficient and having an efficiency of about 1%. In 1954, at Bell Laboratories three American scientists Gerald Pearson, Calvin Fuller, and Daryl Chapin created the first practical PV cells whose having efficiency 6% with direct sunlight. After that in 1970, Thin-film solar cells were originally developed by researchers of the Institute of Energy Conversion at the University of Delaware in the USA [9].

5. FEATURES

5.1 Monocrystalline Silicon Solar Panel -

1) The efficiency of these panels is high which convert more solar energy into electric energy than other panels.
2) Monocrystalline Solar panels have longevity for up to 25 years.
3) The heat resistance of these panels is high.
4) The installation cost of monocrystalline solar panel is low.

5.2 Polycrystalline Silicon Solar Panel -

1) The production process of these panels simple, which is cost-effective, and also reduces the silicon waste compared to monocrystalline solar panels
2) Heat tolerance is low as compared to monocrystalline panels. So, at higher temperatures, these solar panels have lower efficiency than others.
3) Mounting of these solar panels is cheaper because it comes with a structural frame.
4) The density of these solar panels is high.
5) Polycrystalline Solar panels also have longevity for up to 25 years.

5.3 Thin-Film Solar Panel -

1) These solar panels are lightweight and flexible.
2) Thin-Film solar panel is having a much easier installation process than that of silicon panels.
3) It can be used in a situation where space is not a constraint.
4) Cost of these solar panels is low as compared to other two solar panels.
5) The lifespan of these solar panels is about 20 years.

6. APPLICATIONS

6.1 Monocrystalline Silicon Solar Panel -

1) In large scale applications, solar panels are utilized in commercial as well as residential solar installations.
2) The higher wattage appliances like refrigerators and microwave ovens which has powering between 130W and above get generated through monocrystalline panels.
3) Monocrystalline solar panels are stand-alone and suitable for street lighting.

6.2 Polycrystalline Silicon Solar Panel -

1) In roof-mounted arrays polycrystalline solar panels are suitable.
2) In large farms, these solar panels are used in high quantities to harness the energy of the sun and supply of electricity to the grid.
3) In remote areas, polycrystalline solar panels are used for self-powering devices such as off-grid households, traffic lights, and standalone.

6.3 Thin-Film Solar Panel -

1) These solar panels require a larger area for installation so they may be installed in commercial and institutional buildings with large rooftops/open spaces.
2) To powering small appliances such as Wi-Fi modems, fans these solar panels may be installed on the roof-top of buses and it can also maintain the temperature of buses.
3) These solar panels are also used in solar farms.
4) To providing electricity for pumping water, theses solar panels can be installed in large-sizes steel water tanks.

7. CONCLUSION

As it is concluded that solar energy has some disadvantages that may be overcome as technology is getting better day by day since the technology is growing faster with improvement and getting advanced, which results in decreasing the cost of solar plates as well as installation cost. However, the efficiency of solar PV cells is increasing day by day that's why electricity generation from the solar panel is growing rapidly which may result in high demand. The government is lying much emphasis on solar energy so after some years we may accept that every household and also every electrical system is powered by solar or renewable energy sources.

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