A Review Paper on Different Types of Solar Cells Available in Market and Factors Affecting its Efficiency

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***Abstract*:** In renewable energy sources, solar energy is most powerful and trending source. For utility point of view, solar power is available at each and every place but problem is that the efficiency of solar cell is very low. Also the efficiency of solar cell under different atmospheric conditions like different temperature and irradiation, the power we get from the solar cell is different and same as that the efficiency is also changed so for analyzing the behavior of different kind of solar cell I have analyzed different types of solar cell for different temperature and irradiation and results are taken. For analysis point of view the mono crystalline solar cell is analyzed into solar simulator under different values of irradiation and temperature and then experimental results for the same are taken. For cross checking the results that I got from the solar simulator, I have done mathematical modeling of solar cell into MATLAB and then the simulated results are taken, the similar kind of results came from the simulation and experimental readings as well.

Keywords: Distributed Generation (DG), Solar Energy, Solar Cell, mono crystalline solar cell

I. Introduction

Sun is the greatest source of energy almost all renewable energy is there due to Sun, Only 0.01% of the energy from sun can power the entire world. The solar radiation outside the atmosphere of earth is 1366 W/m2 and the radius of earth is 2/π * 10^7. So the total solar radiation reaching the earth is 1.73* 10^17.

Annual Solar Energy = 1.73* 10^17 * 86400 * 365.2422 = 5.46* 10^24 J

So, The Solar Energy is the biggest source of energy and the generation of electrical energy from solar radiation is the trending concept. For that different types of solar cells are used and different electronic circuits are also used to get higher efficiency, The efficiency of solar cell is ranging from 10-20% so there is room for improvement, So in this paper I have analysed different types of solar cells by simulating them in MATLAB as well as performing experiments on them and at last the results of simulated and experimental data is compared.

The utilization of this energy can make the world independent from the non-renewable energy sources and for that research is going on for improving the efficiency of solar cell. The photovoltaic cell converts the solar energy into DC electrical energy directly. For making solar cell material used is Silicon which is having electrons at valance band so as the solar radiation falls n the material these electrons absorbs energy and goes from valance band to conduction band. These excited electrons of the Silicon now have energy and travel through the material by making electron hole pairs and thus the DC current flows into the material and as a result the DC Electrical energy is generated and can be fed to the other end of the solar cell.

Silicon is the most commonly used material in crystalline as well as polycrystalline solar panel. In polycrystalline solar cell the material used the most is silicon with that Boron is doped on the layer of silicon to make it p-type material and at a part of the cell the silicon is doped with phosphorus to make it n-type of material. Intersection between these two layers make the cell junction so when the cell will be exposed to the Sunlight the valance electrons from the p-type region will travel to the n-type region. Here the electron-hole pairs are generated because the p-type material is having extra electrons on its valance band similarly the n-type electrons requires that electrons to complete the external band so when the cell will be exposed to the sunlight energy from photon will be transferred to the valance band electrons of p-type material and that electrons will go to conduction band and this empty space of electron is called hole such that the electron-hole will be generated and the electrons will travel through the cell if they have sufficient energy to overcome the electrical field at junction.

A single cell is the building block of solar Module and such Modules are used in series and parallel to make a solar PV Array. Solar Module is not sufficient feed electricity to any load so many Solar Modules in series and parallel are used practically for utility point of view.

II. Literature Review

[1] Solar Cells: In Research and Application-A Review. This paper proposes all the types of solar cells. All the Solar cells are divided into major three type’s first generation, second generation and third generation solar cells. They are also further divided into many types which are also explained into this paper. All the types of solar cells are briefly described, the details like materials used to make these types of solar cell also their efficiency as well as the issue related to the solar cells are given. After providing this much information all the solar cells are compared based on different parameters like size of cell, cost of cell and performance at high temperature is given. This paper concludes that solar power is a trending source of renewable energy and the utilization of this will increase day by day after research work goes up to such a limit that lower the cost of solar cell with higher efficiency compared to the cells available to us right now.

[2] Critical Factors that Affecting Efficiency of Solar Cells.

In this paper the solar cell P-V and I-V characteristics are given which are drawn from the equivalent circuit of the solar cell. Then after different factors that affect the efficiency of the solar cell are given, one by one effect of each factor on the characteristic of solar cell is described. Cell temperature is a factor affecting solar cell efficiency which can be seen in the figure given in paper that with increase in temperature the efficiency of solar cell decrease, Energy conversion efficiency which is percentage of power converted and collected when a solar cell is connected to an electrical circuit, cell efficiency increase with increase in the energy conversion efficiency and vice-versa. Maximum Power Point Tracking is a method for improving the solar cell efficiency, the function of maximum power point tracker is to change the equivalent load taken by the solar cell array and adjust the working point of array, in order to improve efficiency.

[3] A Comparative Study on Different Types of PV Modules and Their Optimization for Increasing the Efficiency Part-1.

This paper presents implementation of mathematical modelling of a solar PV system into MATLAB. A solar simulator is used to check different kinds of material and then experimental data were taken for different illumination and some parameters of the cells are found out like Io, Voc, Isc, Vm and Im. All these parameters are measured for monocrystalline, polycrystalline, CdTe, A-Si and CIGS solar cells the value of experimental results are taken at 974W/m^2 and 780W/m^2 illumination. The experimental results are then compared with the data from the data sheet. The characteristic curve shows that it is very close to the data sheet value even by considering three points at three different location on the characteristic curve.

[4] The Effect of Temperature on a Mono-crystalline Solar PV Panel. Most important three electrical parameters for a solar photovoltaic panel performance are Maximum output power, Short-circuit current, and open-circuit voltage, all these parameters are affected by the variation in temperature. The maximum output power and open-circuit voltage are reduced with increase in the temperature while the short circuit current increases. The efficiency of solar panel reduces with increase in surface temperature of solar PV panel. For validation of this an experiment was performed on box containing 49 halogen lamps where one lamp equal to 50W and the graph for temperature verses open circuit voltage and Temperature verses Output power is drawn and this experimental data was conformed with the simulation results, the average percentage difference of experimental and simulated data was 9.65%. Based on the experimental and simulated results the best efficiency of monocrystalline solar cell can be taken in between 25 and 35 degree Celsius.

[5] MATLAB/Simulink Based Modelling of Solar Photovoltaic Cell

This paper focuses on MATLAB/Simulink based modelling of a solar cell which is based on the mathematical modelling of the solar photovoltaic cell. Mathematical equations are modelled and the circuit is described with the help of a diode, a series resistor, a shunt resistor and a photo current source. Mathematical equation is given for effect of radiation on solar cell which is modelled into Matlab and I-V and P-V curves are drawn for different irradiation. Simultaneously equation for effect of temperature, varying series resistance and varying shunt resistance are given and for all of them I-V and P-V characteristics are drawn, also P-V and I-V curves for different is are drawn. All these results are validated using 124W solar panel. Such a model can provide a tool to predict the behaviour of any solar PV cell under different climate change and physical parameter changes.

[6] Behavior Modelling of Polycrystalline Module ET-P660230WW, In this paper solar cell model is presented using input of solar cell which are solar irradiation (G) and ambient temperature (T). The outputs are Short circuit current (Isc), Open circuit voltage (Voc), Power at maximum power point (Pm), Cell temperature (Tcell), Voltage at maximum power point (Vm). The data is taken from a 230W solar cell module and for that module the illumination is varied from 300 W/m^2 to 974 W/m^2. For constant temperature the value of irradiance is varied and such that all the parameters are taken and graph is drawn for the same. After that the same data is measured by making irradiation constant and temperature is varied and then behaviour of the solar module is observed by taking all the parameters. The same parameters are measured by actually varying the temperature and irradiance and then the simulated and measured data are compared. In case of short circuit current the average accuracy is 1.25% whereas for open circuit voltage the average accuracy is 1.01% and in case of comparing the data of power the average accuracy is 7.50%, simultaneously the data for variation in temperature is measured and average accuracy is found out. This models predicts the behaviour of solar module in different atmospheric condition and the simulation results accurately match the experimental results: the accuracy of short circuit current and open circuit voltage is under 4%.

[7] Performance Optimization for Perovskite Based Solar Cells. Perovskite based solar cell have attracted much recent research because of very high efficiency for simple planar structures. In this paper comprehensive modelling framework, well calibrated from the experimental results from literature is given. In perovskite based solar cell the efficiency greater than 20% can be achieved. The cell consist of three materials sandwiched between two electrodes- Front contact and Back contact, middle layer consist of perovskite compound that absorbs solar radiation resulting in electron-hole pairs. The analytical model identify the origin of dark characteristic, unravel the reason for unexpected large Voc reported in literature and explore the parameter space that affect the form factor as well as Jsc. For optimally designed perovskite solar cell efficiency of 20% and above can be achieved that is given into this paper.

III. DIFFERENT TYPES OF SOLAR CELLS, MATERIAL USED AND THEIR EFFICIENCY

The photovoltaic effect was first observed by Alexandre-Edmond in 1839 and the first solar cell made up of silicon was invented in 1946 by Russel Ohl. In thin film solar cells the thin silicon solar wafers were used to convert the solar energy in to electrical power but now in modern photovoltaic technology the material used is made up of two different types of material: p-type and n-type material of a semiconductor material. Creation of electron-hole pair is the major concept in modern solar cells. On the bases of different materials the solar cells are divided into different types which are shown in the fig.2 and all of them are briefly described below.

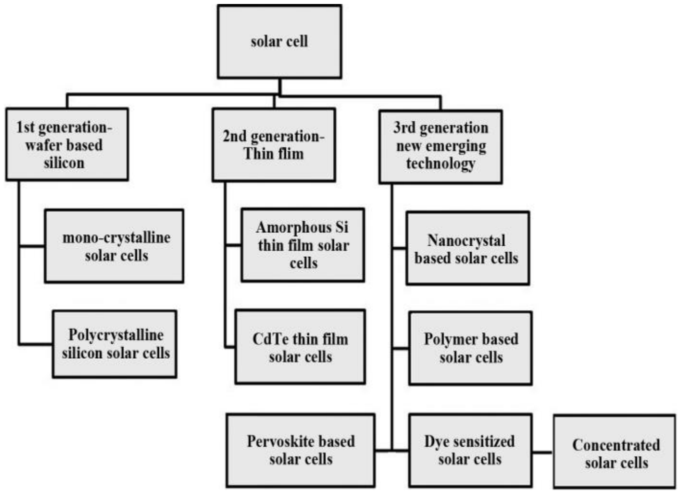

Figure 1 Different Types of Solar Cells

First Generation Solar Cell:

The first generation solar cells are produced on silicon wafers. They are oldest and very popular technology because of their applicability and high power efficiencies. The silicon wafer based technologies are further divide into two parts which are described below. First generation cells consist of large-area, high quality and single junction devices. First Generation technologies involve high energy and labor inputs which prevent any significant progress in reducing production costs.

Mono-Crystalline Solar Cell:

This type of solar cells are manufactured from single crystals of silicon this process is called Czochralski, in this process the Si crystals are sliced. This sliced cells requires precise processing as 'recrystallizing'. Mono-Crystalline cell is more expensive and of this type of silicon solar cell lies between 17% - 18%.

Polycrystalline Solar Cell:

Polycrystalline Modules are generally composed of number of different crystals, coupled to one another in a single cell. The efficiency of polycrystalline solar cell is lesser than the mono crystalline solar cells. Generally polycrystalline solar cells are made up of silicon around the half the modules produced worldwide are polycrystalline silicon solar cell due to their lower cost. The efficiency of this type of solar cell is around 12% to 14%.

Second Generation Solar Cells:

Most of thin film solar cells and amorphous Silicon solar cells are second generation solar cells, they are cheaper than the first generation solar cells. Different types of second generation solar cells are described below. Second generation materials have been developed to address energy requirements and production costs of solar cells. Alternative manufacturing techniques such as vapor deposition and electroplating are advantageous as they reduce high temperature processing significantly.

Amorphous Silicon Thin Film Solar Cells:

The first modules that manufactured industrially are a-Si Solar cells. Many polymers and flexible substrates can be used to measure these type of solar cell because they are manufactured at a low temperature. They require low temperature and low energy is required so they are cheaper in cost. The reflecting surface is of brown color and conducting side is silverfish color. The main drawback of this type of solar cell is that their efficiency is very low around 4% to 8%.

Cadmium Tellurium (CdTe) Thin Film Solar Cells:

The CdTe is having a band gap of around 1.5 eV and they are chemically stable, this properties make them more attractive than other cells. The absorption coefficient of CdTe solar cell is 1.5*10^15/cm so their efficiency is around 9 to 11%. The main disadvantage of using this type of cell is that cadmium is a toxic material which can be hazardous to human as well as animals and plants also their disposition is also costly so a limited use of this type of cell is possible.

Copper Indium gallium Di-Selenide (CIGS) Solar Cells:

This is a quaternary compound semiconductor which comprises: Copper, Indium, Gallium and Selenium. The efficiency of this type of solar cell is around 10% to 12% so into thin-film technology, this is the best preferred solar cell having highest efficiency among all thin-film solar cells. Main advantage of CIGS cell is their prolonged life without significant loss into efficiency.

Third Generation Solar Cells:

These type of cells are having promising efficiency but they are not commercially used, some of the third generation solar cells are briefly described below.

Nano Crystal Based Solar Cells:

Nano crystal based solar cells are generally also known as Quantum dots (QD) solar cells. Nano crystal solar cells are solar cells based on a substrate with a coating of Nano crystals. The Nano crystals are typically based on silicon, CdTe or CIGS and the substrates are generally silicon or various organic conductors. With the research in this field the Nano crystal materials will replace Si and CdTe materials.

Polymer Based Solar Cells:

Polymer solar cells (PSC) are generally flexible solar cells due to the polymer substrate. A PSC is composed of a serially connected thin functional layers coated on a polymer foil or ribbon. It works usually as a combination of donor and an acceptor. The PSC and other organic solar cells operate on same principle known as the photovoltaic effect, i.e., where the transformation of the energy occurs in the form of electromagnetic radiations into electrical current. PSCs opened a new gateway for new applications in the formation of stretchable solar devices including textiles and fabrics

Dye Sensitized Solar Cells:

The first DSSC solar cell was introduced by Michel Gratzel in Swiss federal institute of technology. The DSSC device consists of four components: semiconductor electrode, a dye sensitizer, redox mediator, and a counter electrode. Efficiencies greater than 10% are achieved from Dye Sensitized Solar Cells. The main disadvantage of this type of solar cell is that the dye molecules generally degrade after exposure to ultraviolet and infrared radiations leading to a decrease in the lifetime and stability of the cells.

Concentrated Solar Cells:

The main principle of concentrated cells is to collect a large amount of solar energy onto a tiny region over the PV solar cell. The principle of this technology is based on optics, by using large mirrors and lens arrangement to focus sunlight rays onto a small region on the solar cell. Thus this heat collected will be used to generate the electrical energy with the use of heat engine. Efficiency more than 40% can be achieved using this technique because there is no moving part used so the losses due to the friction and moving parts will be eliminated. This is most trending and promising technology in the field of generation of electrical energy with the use of solar energy.

IV. Factors affecting Efficiency of solar cells

Several factors are there which affect the efficiency of solar cell, the efficiency under standard test condition can't be achieved on field because the value of temperature, illumination and many other factors are changed in external atmosphere. So how these external factors affect the efficiency of solar cell is elaborated below.

Cell Temperature:
Temperature plays an important factor in determining solar cell efficiency. Photon generation increases with increase in temperature. Simultaneously the reverse saturation current increases rapidly and reduces the band gap that affects both current and voltage but effect on voltage is more pronounce. The open-circuit voltage (Voc) and short-circuit current (Isc) are the two major parameters used to characterize solar cells. With the change in value of cell temperature the simultaneous change in open circuit voltage and current can be seen. As the value of temperature rises the efficiency will be reduced simultaneously. So the cell will be operated at standard temperature which is 25 degree Celsius according to the variation in temperature, we will get change in cell efficiency.

Energy Conversion Efficiency:
Energy Conversion efficiency simply means the percentage of power converted and collected, when a solar cell is connected to an electrical circuit. The amount of energy converted from the sunlight to the Electrical energy can be given by the energy conversion efficiency. Energy conversion efficiency is calculated using the ratio of the maximum power point, Pm, divided by the input light irradiance (E, in W/m2) under standard test conditions and the surface area of the solar cell (A in m2). There are two methods to improve energy conversion efficiency, one is reduction of the reflection of incident light with an antireflection coating, and the other is optical confinements of incident light with textured surfaces.

Maximum Power Point Tracking:
The efficiency of Solar cell is around 14% right now, so for improving them there are many methods one of them is maximum power point tracking. The MPPT operates with DC to DC high efficiency converter that presents an optimal and suitable output power. The maximum power point focuses on operating the solar system at the peak point where we will get maximum.
Current as well as maximum voltage. A factor called fill factor which is ratio of maximum power to the output voltage generally the value of fill factor is around one but it will never exceed one. In short we will operate our system at a point where the magnitude of current and voltage is maximum.
FF=Vm*Im/Voc*Il
Vm and Im are voltage and current at maximum power point.

Solar Irradiance:
The overall performance of solar cell varies with varying Irradiance and Temperature with the change in the time of the day the power received from the Sun by the PV panel changes. The voltage and current both being a function of the light falling on the cell, there exists a complex relationship between irradiation and output power. At lower irradiation levels these mechanisms show an increasing percentage of the total power generated. Too much irradiation causes saturation of cells, and the number of free electrons or their mobility decreases greatly. The irradiance and spectral distribution vary greatly from day to day. Resulting into flow of current. The PV cell current is strongly dependent on the solar radiation. However, the voltage has a small change with increasing solar irradiation. Short circuit current (ISC) is proportionally increasing with increasing irradiation. But the change of VOC is very small with increasing irradiation. Variation power output as a function of irradiance for the module. Pmax gradually increases with increasing solar radiation.

V. Conclusion

After working on the mono crystalline, polycrystalline and thin-film solar cell, the simulation result and Experimental analysis proves that the Temperature and illumination change affects the output of solar cell. With increase in temperature the cell output voltage decrease and in case of irradiation, the output voltage and efficiency of solar cell increases simultaneously with increase in illumination.
The Third generation Solar cells are easy to make but due to some issues they can't be used commercially right now. But their efficiency is higher than the conventional cells and their synthesis needs very simple procedure to be followed, Also higher temperature is not required for their synthesis. Also the cost of making this type of cell is very low compared to conventional solar cells.
So, third generation solar cell gives higher efficiency at lower synthesis cost but due to shorter lifetime they can't be used commercially right now.

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