A Comparative Analysis and Performance of Polycrystalline and Monocrystalline PV Module

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***Abstract*:- The spectrum of solar energy is quite wide and its intensity varies according to the timings of the day and geographic locations. This solar energy can be converted into electricity with particular emphasis on photovoltaic system. This paper deals with performance, comparison between polycrystalline and monocrystalline photovoltaic module under different temperature and varying irradiance. As the result of this study, the overall efficiency of monocrystalline PV module was found more in conversion compared to polycrystalline PV module depending on the climatic data measurements.**

1. INTRODUCTION

The production of electrical energy by means of renewable and innovative source is one of the solutions to limit the problems related to the greenhouse effect and energy crisis. Focusing on the use of renewable resources, studies aim to show how renewable resources can efficiently replace traditional sources. In this context, the photovoltaic (PV) technology is playing an important role as a clean, long lasting and maintenance free electrical source.

The electricity is conventionally generated by using coal energy, hydro energy, nuclear energy, and also by using renewable energy resources like wind, solar, tidal energy etc. In India about 55% of electricity is generated using coal energy. In the whole process only, fraction of coal energy is eventually used in power generation. The most of the coal is wasted in conversion process. Other than waste of energy, there is also environmental pollution caused in coal-based power plant. Among renewable energy sources like wind, solar, tidal energy etc. solar energy is found to more convenient compared to other renewable energy sources. One of the modern ways of generating electricity is by using solar photovoltaic (PV) system; a technology that converts solar energy into electricity. The solar system is environmental friendly, abundant source of energy which converts sunlight into electricity directly without any intermediate conversion steps, since solar radiation energy is available everywhere, the solar PV electricity can be generated everywhere in decentralized manner in small quantities as per the need.

There are five common factors affecting the power generated by solar panel. One of the most important factors that affect the power generated by solar module is conversion efficiency which is the ratio of electrical energy generated by the solar module to the input light energy falling on the module. The electric current generated by solar PV is directly proportional to the amount of light falling on it. Therefore the power rating of the PV cell is directly dependent on the area of the cell and also affects the output power generated by it. The solar cell output voltage, power and efficiency ratings are given at standard test conditions (STC=1000W/m^2 and 25⁰C). Temperature coefficient of PV module affects the output voltage generated by it. For every degree celsius rise in temperature from standard test condition (25⁰C) the output voltage reduces by the temperature coefficient. In practical applications, the operating temperature of solar cell may be different than 25⁰C. The change in the temperature from standard operating temperature directly affects the output voltage, efficiency and output power of solar cell reduces. The amount of maximum output current (Isc or short circuit current) of a solar cell and the power generated by the PV cell depends on the area of the solar cell. The angle at which solar radiation strikes on the PV module greatly affected by the power generated by it. The PV module will generate maximum output power when sunlight falls perpendicular to the surface of the module.

A single cell does not produce enough power to operate the load and, therefore, many cells are connected together to make a PV module [2]. The reason for connecting solar cells in series is to increase the output voltage. The number of cells connected in series will constitute a PV module and the numbers of PV modules are connected in series to form PV module string which increases the voltage in the PV system. In order to increase the current in the PV system individual PV modules or PV module strings are connected in parallel. Such a series and parallel combination of PV modules is referred as solar PV array.

Solar PV modules are differentiated based on the [4] single junction, multi junction or first, second or third generation solar cell. First generation solar panels are also called as traditional type of solar panel made of monocrystalline silicon or polycrystalline silicon [1] and are most commonly used in conventional surroundings. Second generations solar panels are different types of thin film solar cell and are mainly used for photovoltaic power station, integrated in buildings. We are concentrating on first generation solar panels by measuring the performance of polycrystalline and monocrystalline PV module under varying weather conditions and comparing the efficiency of different modules in the first-generation PV panel. The section.2 describes working principle of Solar PV cell, section.3 explains about parameters of Solar Cells, section.4 explains Types of PV cell and section.5 describes experimental setup for comparing polycrystalline and monocrystalline PV module and section.6 explain comparative analysis between in monocrystalline and polycrystalline PV module.

2. WORKING PRINCIPLE OF SOLAR PV CELL

A solar cell is a semiconductor device which directly converts sunlight into electricity by photovoltaic effect [1] hence they are also called as photovoltaic cell. A photovoltaic cell comprises of P-type and N-type semiconductor materials with different electrical properties joined together. The joint between these two semiconductors is called P-N junction. Photons in the sunlight falling on the solar cell front face are absorbed by semiconducting materials due to which electrons hole pairs are generated, when solar cell is connected to a load electrons and holes near the junctions gets separated from each other. The holes are collected at positive terminal and electrons at negative terminal. As a result electric potential is built across the terminals. Hence due to this difference between the electric potentials at the terminals we get voltage across the terminals. The voltage developed at the terminals of solar cell is used to drive the current in the circuit. This current in the circuit will be a DC quantity. A typical diagram of production of electricity from PV panel is shown figure1.

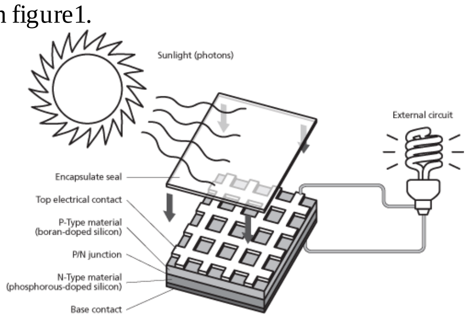


Figure 1: Working of solar photovoltaic cell

3. PARAMETERS OF SOLAR CELLS

The conversion of sunlight into electricity is determined by the parameters [1] of the solar cells. There are several parameters of solar cells that determine the effectiveness of sunlight into electricity. The solar cell parameters are: - Short circuit current (Isc): It is the maximum current a solar cell can produce. Higher the short circuit current (Isc) better is the cell it is measured in ampere or milli ampere. The value of this maximum current depends on cell technology, cell area, amount of solar radiation falling on cell, angle of cell etc.

Open circuit voltage (Voc): It is the maximum voltage that a solar cell produces. Higher the Voc better is the cell; the value of this maximum open circuit voltage depends on cell technology and operating temperature.

Maximum power point (Pmax): It is the maximum power that a solar cell can produce under STC. It is given in terms of watts. A solar cell can operate at many current and voltage combinations. But a solar cell will produce maximum power only when operating at certain current and voltage. The maximum power point for an I-V curve of solar cells occurs at the knee or bend of the curve.

$$P_{max} = I_m \times V_m \qquad (1)$$

Current at maximum power point (Im): This is the current which solar cell will produce when operating at maximum power point. The Im will always be lower the Isc.

Voltage at maximum power point (Vm): This is the voltage which solar cell will produce when operating at maximum power point. The Vm will always be less than open circuit voltage (Voc).

Fill factor (FF): The Fill Factor is defined as the squareness of the I-V curve and mainly related to the resistive losses in a solar module. It can be defined as the ratio of actual maximum power output to the ideal maximum power output.

$$\text{Fill Factor} = \frac{V_m \times I_m}{V_{oc} \times I_{sc}} \qquad (2)$$

Efficiency: The efficiency of a solar cell is defined as the maximum output power divided by input power, which means that the percentage of radiation input power is converted into electrical power. The Pin for STC is considered as 1000W/m^2. This input power is power density which is power divided by area.

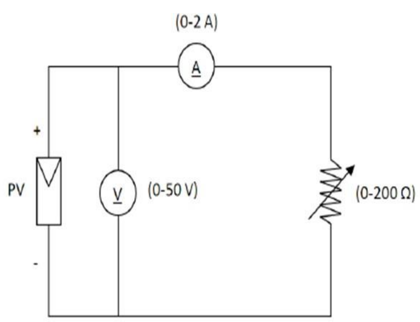
$$\text{Efficiency} = \frac{\text{Output power}}{\text{Irradiance} \times \text{Area}} \qquad (3)$$

4. TYPES OF PV CELL

There are wide variety of solar cells are available. These cells are made using different materials. Properties of material used in different types of solar cells are different. The different types of solar photovoltaic modules are Monocrystalline solar cell, Polycrystalline solar cell, Thin film solar cell, Amorphous silicon solar cell etc. [4]. The monocrystalline solar cell consists of silicon in which the crystal lattice of the entire solid is continuous, unbroken to its edges and free of any gain boundaries. The polycrystalline solar cell consists of multiple small silicon crystals, and it has blue speckled look. These type solar panels are made by melting raw silicon which is faster and cheaper process than that used for monocrystalline process. Third type of classification is thin film solar cell which is manufactured by placing one or more films of photovoltaic material (such as Si, Cd, or Cu) on to a substrate since these types are easiest to produce and hence these are cheaper. Fourth type of classification is amorphous silicon solar cells (A-Si) which are most widely used in pocket calculators.

5. EXPERIMENTAL SETUP FOR COMPARING POLYCRYSTALLINE AND MONOCRYSTALLINE

PV MODULE



Connection diagram to find out current versus voltage characteristics of a single Solar PV Module

Figure 2: Circuit diagram

The experimental setup [1] includes the supporting structure for panels with different tilt angle, two types of PV modules, two rheostats of same ratings, two DC ammeters and voltmeters of same range, connecting wires, thermometer and pyranometer [1]. In this experimental setup rheostat is used as load for PV module. Pyranometer is a device used to measure the intensity of solar radiation whereas the thermometer is used to measure the temperature. The first step is to fix the two panels on the same supporting structure, so that same amount of sunlight falls on both the PV panels. Then the open circuit voltage (Voc) and short circuit current of respective PV panel are measured without connecting load. Then connections are made for both the PV module as per the circuit diagram. After making the connections gradually load (rheostat) is applied in such a way that voltage is varied in steps and corresponding current produced in each module is noted down in each step. Then the efficiency and power are calculated for each reading by using the equations (3) and (4). The above steps are carried out under different temperature and irradiance. The graphs of current versus voltage, power versus voltage are plotted for each PV module.

Output Power (Pout) = Voltage x Current -----------------(4)

Table 1: Voltage and Current readings of Polycrystalline module at 46°C temperature and irradiance of 720W/m^2

Sl.no	Voltage	Current	Pout	Efficiency
1	0	0.51	0	0
2	2	0.51	1.02	1.96
3	4	0.51	2.04	3.93
4	6	0.51	3.06	5.9
5	8	0.51	4.08	7.87
6	10	0.5	5.0	9.64
7	12	0.5	6.0	11.57
8	14	0.46	6.44	12.42
9	**16**	**0.43**	**6.88**	**13.27**
10	16.5	0.4	5.77	11.30
11	17	0.38	5.44	10.47
12	17.5	0.25	4.375	4.96
13	17.92	0.18	2.68	8.43
14	18	0.1	1.8	5.16
15	18.16	0.05	0.908	3.47
16	18.2	0	0	0

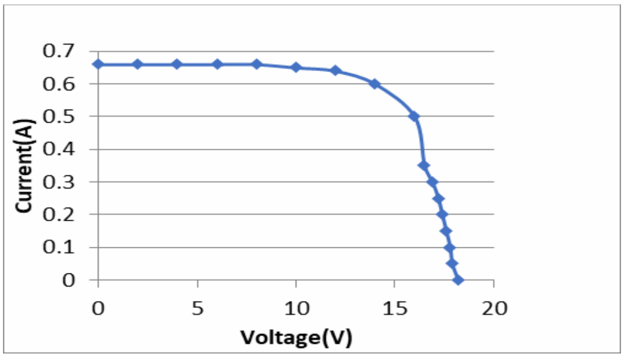


Figure 3: I-V characteristics of polycrystalline module

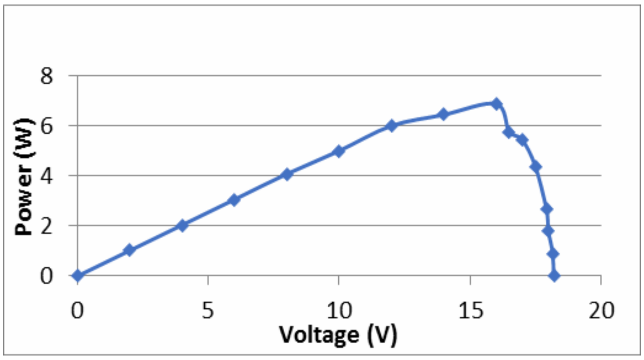


Figure 4: P-V characteristics of polycrystalline module.

The current v/s voltage, power v/s voltage characteristics of polycrystalline PV module at 46°C temperature and intensity of solar radiation of 720 W/m^2 with open circuit voltage of 18.2V and short circuit current of 0.51A is shown in the above figure 3 and 4.

Table 2: Voltage and Current readings of Monocrystalline module at 46°C temperature and Irradiance of 720W/m^2

Sl.no	Voltage	Current	Pout	Efficiency
1	0	0.65	0	0
2	2	0.65	1.3	2.25
3	4	0.65	2.6	4.51
4	5	0.65	3.25	5.64
5	6	0.65	3.9	6.77
6	8	0.65	5.2	9.02
7	10	0.65	6.5	11.28
8	12	0.6	7	12.15
9	14	0.57	7.98	13.85
10	**15**	**0.55**	**8.25**	**14.32**
11	16	0.45	7.2	12.50
12	16.5	0.40	6.6	11.45
13	17	0.30	5.1	8.88
14	17.5	0.19	3.5	6.07
15	18	0.05	0.9	1.56
16	18.11	0	0	0

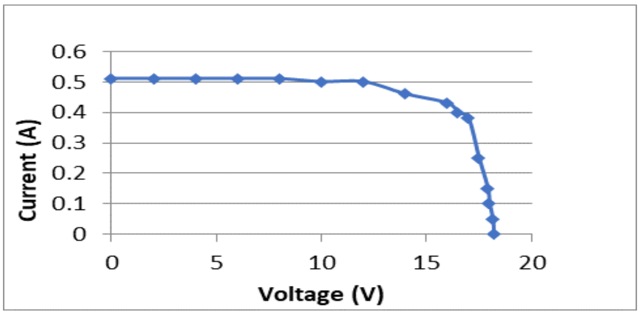


Figure 5: I-V characteristics of monocrystalline module

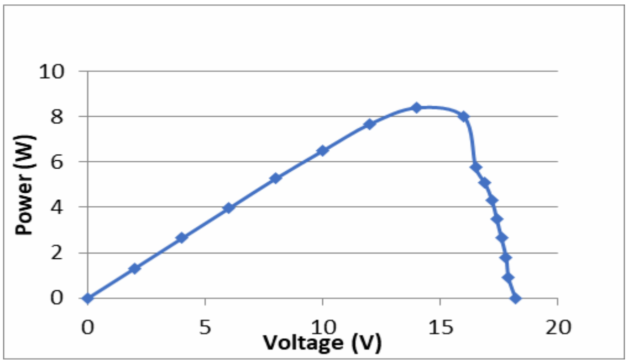


Figure 6: P-V characterstics of monocrystalline module

The current versus voltage, power versus voltage characteristics of monocrystalline PV module at 46°C temperature and intensity of solar radiation of 720 W/m^2 with open circuit voltage of (Voc) = 18.2V and short circuit current of (Isc) = .66A is shown in the figure 2.

Table 3: Voltage and Current readings of Monocrystalline module at 52°C temperature and Irradiance of 865W/m^2

Sl.no	Voltage	Current	Pout	Efficiency
1	0	0.66	0	0
2	2	0.66	1.32	1.90
3	4	0.66	2.64	3.81
4	6	0.66	3.96	5.71
5	8	0.66	5.28	7.63
6	10	0.65	6.5	9.39
7	12	0.64	7.68	11.09
8	**14**	**0.6**	**8.4**	**12.13**
9	16	0.5	8	11.56
10	16.5	0.35	5.78	8.35
11	16.9	0.3	5.07	7.32
12	17.2	0.24	4.3	6.21
13	17.4	0.2	3.48	5.02
14	17.6	0.14	2.64	3.81
15	17.8	0.1	1.78	2.57
16	17.9	0.06	0.895	1.29
17	18.2	0	0	0

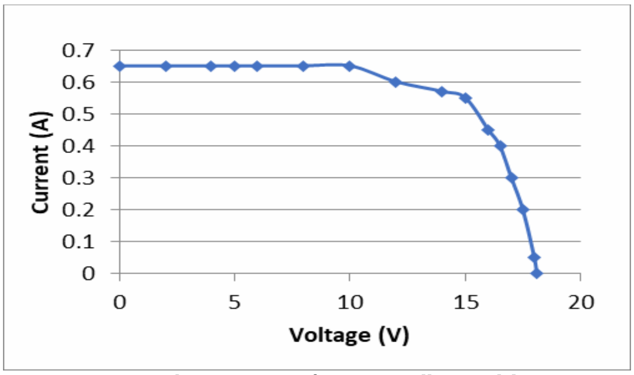


Figure 7: I-V characteristics of monocrystalline module

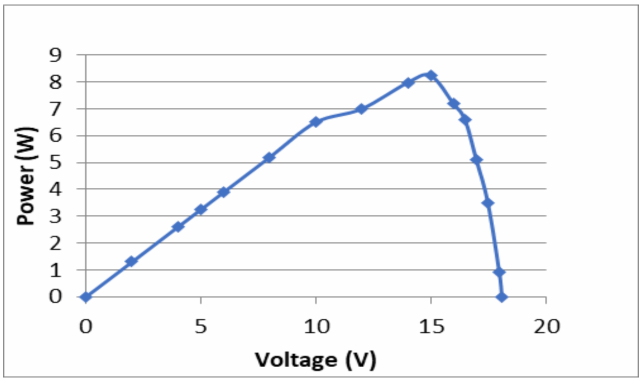


Figure 8: P-V characterstics of monocrystalline module

The current versus voltage, power versus voltage characteristics of monocrystalline PV module at 52°C temperature and intensity of solar radiation of 865 W/m^2 With open circuit voltage of (Voc) = 18.11V and short circuit current of (Isc) = 0.65A is shown in the figure 3.

Table 4: Voltage and Current readings of Polycrystalline module at 52°C temperature and Irradiance of 865W/m^2

Sl. no	Voltage	Current	Pout	Efficiency
1	0	0.52	0	0
2	2	0.52	1.04	1.66
3	4	0.52	2.08	3.39
4	6	0.52	3.1	4.97
5	8	0.52	4.12	6.61
6	10	0.52	5.2	8.34
7	12	0.5	6.0	9.63
8	**14**	**0.48**	**6.72**	**10.78**
9	15	0.39	5.85	9.39
10	16	0.37	5.92	9.50
11	17	0.27	4.59	7.36
12	17.5	0.21	3.67	5.89
13	18	0.15	2.7	4.33
14	18.5	0.05	.925	1.48
15	18.9	0	0	0

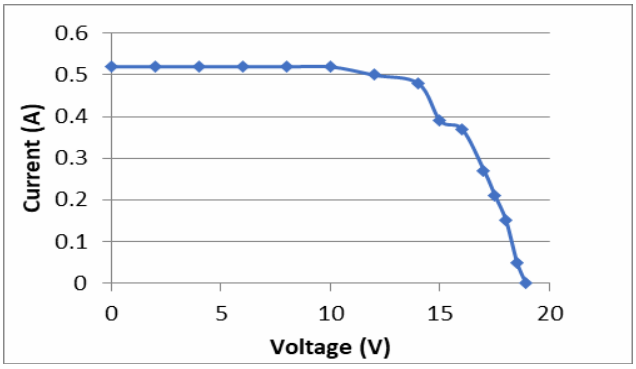


Figure 9: I-V characteristics of polycrystalline module

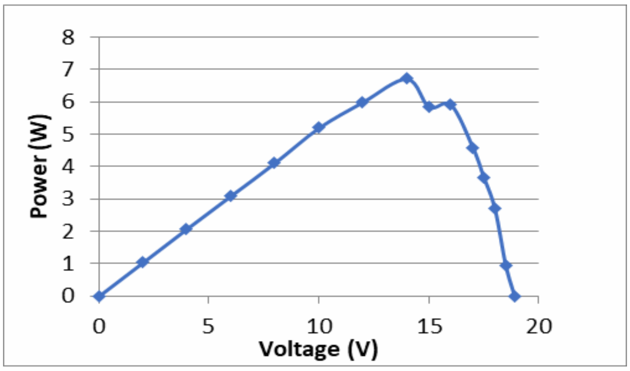


Figure 10: P-V characterstics of polycrystalline module.

The current versus voltage, power versus voltage characteristics of monocrystalline PV module at 52°C temperature and intensity of solar radiation of 865 W/m^2 with open circuit voltage of (Voc) = 18.9V and short circuit current of (Isc) = 0.52A is shown in the figure 4.

6. NAME PLATE RATING OF PV MODULE AT STC (1000W/m^2), AM 1.5, SPECTRUM, CELL
7.

TEMPERATRE 25°C.:

Table 5: Monocrystalline:

Rated maximum power	10Wp ± 3%
Open circuit voltage	21.49V
Short circuit current	0.68A
Voltage at maximum power	16.92V
Current at maximum power	0.59A
Area of the module	0.081m^2

Polycrystalline:

Table 6:

Rated maximum power	10W ± 3%
Open circuit voltage	21V
Short circuit current	0.65A
Voltage at maximum power	17V
Current at maximum power	0.6A
Area of the module	0.072m^2

8. COMPARATIVE ANALYSIS BETWEEN MONOCRYSTALLINE AND POLYCRYSTALLINE

PHOTOVOTAIC MODULE:

Table 7: Output power and Efficiency readings of Monocrystalline and Polycrystalline PV module at Temperature=52°C and Irradiance=865W/m^2

Sl.no	Monocrystalline		Polycrystalline	
	Pout (W)	Efficiency %η	Pout (W)	Efficiency %η
1	0	0	0	0
2	1.32	1.90	1.04	1.66
3	2.6	3.81	2.08	3.39
4	3.25	5.71	3.1	4.97
5	3.9	7.63	4.12	6.61
6	5.2	9.39	5.2	8.34
7	6.5	11.09	6	9.63
8	**7**	**12.13**	**6.72**	**10.78**
9	7.98	11.56	5.85	9.39
10	8.25	8.35	5.92	9.50
11	7.2	7.32	4.59	7.36
12	6.6	6.21	3.67	5.89
13	5.1	5.02	2.7	4.33
14	3.5	3.81	0.925	1.48
15	0.9	2.57	0.565	0.907

Table 8: Output power and Efficiency readings of Monocrystalline and Polycrystalline PV module at Temperature=46°C and Irradiance=720W/m^2.

Sl.no	Monocrystalline		Polycrystalline	
	Pout (W)	Efficiency %η	Pout (W)	Efficiency %η
1	1.3	2.25	1.02	1.96
2	2.60	44.51	2.04	3.94
3	3.25	5.64	3.06	5.97
4	3.90	6.77	4.08	7.87
5	5.2	9.02	5	9.64
6	6.50	11.29	6.00	11.57
7	7.98	13.85	6.44	12.42
8	**8.25**	**14.32**	**6.88**	**13.27**
9	7.20	12.50	5.77	11.30
10	5.10	8.88	4.37	8.43
11	3.5	6.07	0.90	3.04

In this regard the performance comparison of monocrystalline and polycrystalline photovoltaic modules of same rating at a time under two different temperature and irradiance are carried out as shown in Table 7 and 8. In Table 7 the comparisons of output power and efficiency of both the modules at a temperature of 52°C and irradiance of 865W/m^2 are made. And the maximum output power and efficiency of the monocrystalline PV module was found to be 8.25W and 7.79% whereas for polycrystalline PV module it was found to be 6.72W and 6.34% respectively. In Table.8 the comparisons of output power and efficiency of both the modules at a temperature of 46°C and irradiance of 720W/m^2 are made. And the maximum output power and efficiency of the monocrystalline PV module was found to be 8.48W and 9.62% whereas for polycrystalline PV module it was found to be 6.88W and 7.80% respectively.

CONCLUSION:

The comparative analysis of polycrystalline and monocrystalline PV module of same rating is carried out in this research paper under different varying conditions such as irradiance and temperature, and we concluded that monocrystalline PV module is more efficient than polycrystalline PV module, also we have found that the Irradiance is directly proportional to the output current produced by the PV module.

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