THE EFFECT OF IRRADIANCE AND TEMPERATURE ON THE PERFORMANCE OF POLYCRYSTALLINE SILICON SOLAR MODULE, AT AJMER

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Abstract: Around the world electricity is mainly generated by using fossil, however these resources are limited. Now solar energy is becoming an important source of energy all over the world and especially in India. Located in the equatorial region, India has huge potential for high solar power generation. But, at present very few solar plants has been installed in India so far. India is having different climate zones which are dominated by its temperature and relative humidity. This means that a solar system at different climatic regions it will behave different as far as its output is concerned. After a system has been established, it will be very difficult to upgrade the system or change the operation method. A proper understanding of the mechanisms of solar cells and their quantitative knowledge is an essential requirement for possible application of solar cell in power generation. In this paper real time experiment has been conducted to analyze the effect of irradiance and temperature in Ajmer region. The characterization of a 20 W poly-crystalline silicon module was investigated under different values of solar irradiance and module surface temperature. Temperature is a pessimistic aspect which minimizes the efficiency of the module and can be lower by various cooling techniques. Short circuit current of the solar PV module rise notably with increasing irradiance while open circuit voltage was slightest affected**.**

Key Words: solar Irradiance, Fill factor, Short circuit current, open circuit voltage.

Introduction Ever since the industrial revolution, humans have sought to generate power from a variety of energy sources. In India, renewable energy sources include hydro, wind, solar, biomass and geothermal. Currently, India heavily relies on hydro as the predominant source of electrical energy production. However, the unusual pattern of weather and certain other causes have affected power generation. There is an urgency to find alternative solutions for energy other than use of fossil fuels, water and wind. Solar energy is one such alternative option. Earth receives solar radiations at the rate of approximately 1,20,000 TW, which is sufficient for both the current annual global energy consumption rate of about 15 TW and for future requirement [1]. One of the broad utilization of solar energy is photovoltaic. Photovoltaic is the field of technology and research related to the application of solar cells for energy by converting sunlight directly into electricity by the photovoltaic effect [2]. Efficiency of solar photovoltaic panel depends on solar insolations and ambient temperature. Photovoltaic panels are able to collect both direct and diffuse irradiations [3]. Desert states are naturally supreme befit to photovoltaic power generation due to abundant availability of sunlight throughout the year. Due to India's geographical locations near tropic of cancer, it is blessed with adequate solar radiation. Nearly 58% areas are receiving annual average global insolation more than 5 KWh/m^2/day [4] Polo et al. estimated daily global horizontal and direct normal irradiations for six locations in India from the year 2000-2007 [5]. Here western Rajasthan receives the highest annual radiation of 6-7 KWh/ m^2. It has about 2,08,110 km^2 desert land which is 60% of total state land, low rainfall and 325 days with good sunshine in a year. Ajmer is situated at 26.45° N latitude and 74.64° E longitude in Rajasthan. Averaged insolation on horizontal surface is 1.88 MWh/ m^2 /Year and averaged insolation on equator pointed surface is 5.46 MWh/ m^2 /day. Annual averaged air temperature is 24.6°C [6]. Most PV sizing and installations at the region have been done based on the Standard Test Conditions which are very different from the ambient conditions in the region. Performance of a solar photovoltaic system not depends on its basic electrical characteristic, but also it negatively depends on several obstacles such as ambient temperature, relative humidity, dust storms, suspension in air, shading , spectrum and angle of irradiance[7-8]. Acquaintance with facts about solar irradiance and power output of a solar module at particular site would give accurate information which is indispensible in stiffening and planning for a photovoltaic system to utilize solar energy [9]. The aim of this study is to find out the variation of efficiency of solar photovoltaic module with ambient temperature.

Theory:-A solar cell is basically a P-N semi conductor junction, when exposed to light, a dc current is generated. Photovoltaic system offer several advantages such as: high reliability, low intensity S (W/m^2) and cell temperature t (◦C), that is I=f(V,S,t).

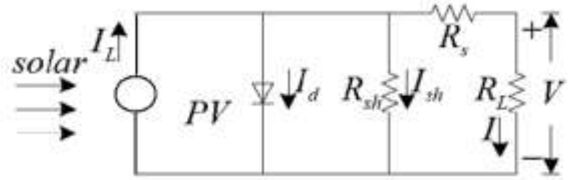

Figure 1.The equivalent circuit of a PV cell. [11]

The capability characteristics of a solar module are decided by the cell key parameters such as the V_{OC} {Open circuit voltage}, I_{SC} {short circuit current}, FF {Fill Factor} and Ƞ {efficiency} etc. Short circuit current is because of the production and collection of light generated bearer. The maximum current produced by the solar cell, corresponding to zero voltage, is called short circuit current. When the load not connected to the cell, there is no current flowing and the voltage across the PV cell is extreme. The maximum voltage produced from a solar cell, corresponding to zero current flow, is called open circuit voltage. The ratio of maximum power from actual solar cell and the maximum power from ideal solar cell is called fill factor. It determines the quality of the cell. $FF = P_{max}/V_{oc}=V_m I_m/ V_{oc}I_0$

The ability of a panel to convert sunlight into usable energy for human consumption is measured by efficiency of a photovoltaic solar panel. It determines the power output of a panel per unit of area.

$Ƞ = P_{max}/ (S * A_c)$, S= Incident radiation flux, Ac= area of collector.

The efficiency is frequently used parameter to compare the capability of one solar module to second. It depends on solar spectrum, intensity of sunlight and the temperature of solar cell [12].

Effect of Irradiance and Temperature Solar irradiance is the measure of radiant flux received by the earth's surface per unit area. As irradiance increases photon generation rate rises, hence more radiant flux is gained at the panel surface. I-V and P-V characteristics vary with changing irradiance. With the enlarged solar flux density V_{oc} as well as I_{sc} grows and so the P_{max} changes. Solar module temperature is a chief parameter that has major impact on the output power of a solar system. The speed of photon generation increases when the temperature increases resulting rapid rise in reverse saturation current.

Materials and methods since the energy in terms of photon, received by solar cell and converting it into electricity is a multitasking phenomenon so it depends on numerous environmental factors like dust accumulation, heat, humidity, shadow and material –technique used. Studies show that with these reasons, radiation extent and ambient temperature has to give importance which affects the capability of PV module. For finer performance of a PV system these factors should be given more importance. The study was carried out in real time basis on the month of March in the lab of campus, S.P.C.Govt. College, Ajmer (India). A 20 Watt Photovoltaic module of make Topsun Solar, digital multimeter, digital thermometer and 50 Ω variable resistors were used. A solar meter was used to measure the irradiance level. Resistance temperature detector was used to measure the temperature of the PV module. Voltage-current (I-V) feature and output variables of solar cell were measured. A rheostat was connected for changing the resistance which works like a load. The output characteristics of solar cells are expressed in the form of I-V curve and P-V curve. A reflective lamp was used to illuminate the sample to achieve the solar cell I-V characteristics, sample was enlightened. The measurements were performed at 25, 40, and 55 ^{0}C temperatures.

table 1.specification of the Photovoltaic Module

Specification of the Photovoltaic Module	
Parameter	Specification
Maximum power (W)	20 watt
Opencircuitvoltage (V_{OC})	21.8 V
Short circuit current (I_{SC})	1.15 A
Maximum Voltage (V_{mp})	17.5 V
Maximum Current (I_{mp})	1.1 A
Area	0.120 m^2

Observation: The voltage, current and power at various irradiance levels:-

table 2. The voltage, current and power at various irradiance levels

Set 1	Irradiance: 45 watt/m^2			Set 2	Irradiance:68 watt/m^2		
S.no	Voltage (V)	Current (mA)	Power (W)	S.no	Voltage (V)	Current (mA)	Power (W)
1	16 **V_{OC}**	0	0	1	16.3 **V_{OC}**	0	0
2	14.6	22	0.321	2	15.2	28	0.425
3	13.5	27	0.364 **P_{MAX}**	3	13.9	40	0.556
4	10.1	30	0.303	4	11.7	60	0.702 **P_{MAX}**
5	3.1	35	0.108	5	4.2	64	0.268
6	1.1	35	0.038	6	2.9	65	0.188
7	0.4	35	0.014	7	0.9	65	0.058
8	0	35 I_{SC}	0	8	0	65 I_{SC}	0
Set 3	Irradiance:120 watt/m^2			Set 4	Irradiance:180 watt/m^2		
S.no	Voltage (V)	Current (mA)	Power (W)	S.no	Voltage (V)	Current (mA)	Power (W)
1	17.7 **V_{OC}**	0	0	1	18.2 **V_{OC}**	0	0
2	16.6	30	0.498	2	17.6	43	0.756
3	14.5	70	1.015	3	14.7	110	1.167 **P_{MAX}**
4	12.5	85	1.062 **P_{MAX}**	4	12.7	120	1.13
5	4.2	89	0.373	5	5.8	127	0.707
6	3.2	89	0.284	6	4.3	130	0.58
7	1.1	95	0.104	7	2.1	130	0.283
8	0	95 I_{SC}	0	8	0	130 I_{SC}	0

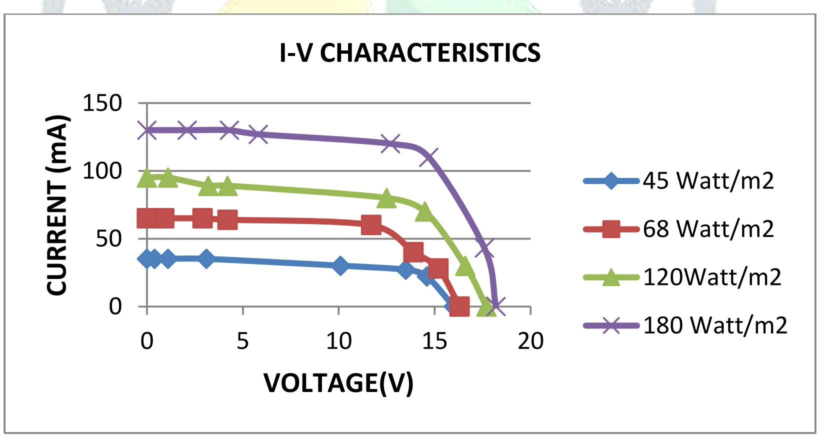

figure 2.The current against voltage trajectory at various irradiance values

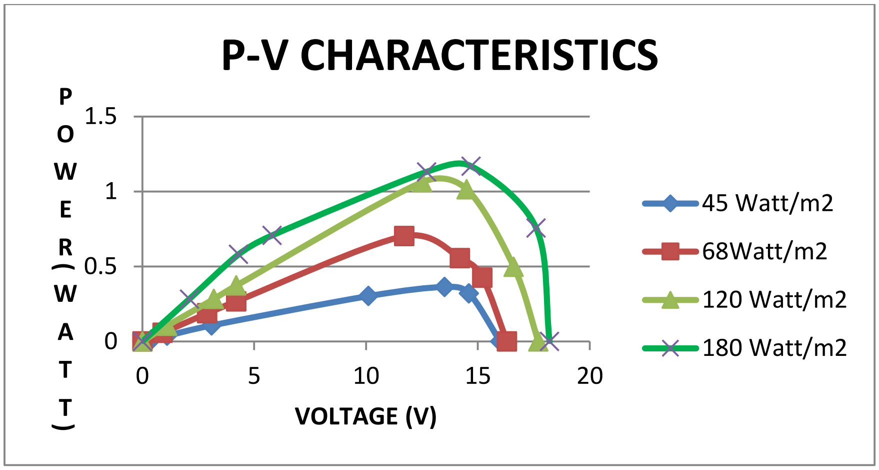

figure 3.The power versus voltage characteristics with the corresponding four different irradiance levels

Table 3. **The voltage and current at various temperatures**

Set 1 temperature 25^{0}C			Set 2 temperature 40^{0}C			Set 3 temperature 55^{0}C		
S. no.	voltage	current	S. no.	voltage	current	S. no.	voltage	current
1	0.8	0	1	0.75	0	1	0.7	0
2	0.63	1.9	2	0.6	2	2	0.51	2.1
3	0.5	2.5	3	0.5	2.4	3	0.25	2.6
4	0.3	2.6	4	0.3	2.6	4	0.19	2.6
5	0	2.6	5	0	2.6	5	0	2.6

Table 4. **Variation of Fill factor with respect to irradiance**

S. no.	Irradiance (Watt/m^2)	Intensity (lux)	Fill Factor
1	45	550	0.65
2	68	900	0.662
3	120	1800	0.67
4	180	3250	0.683

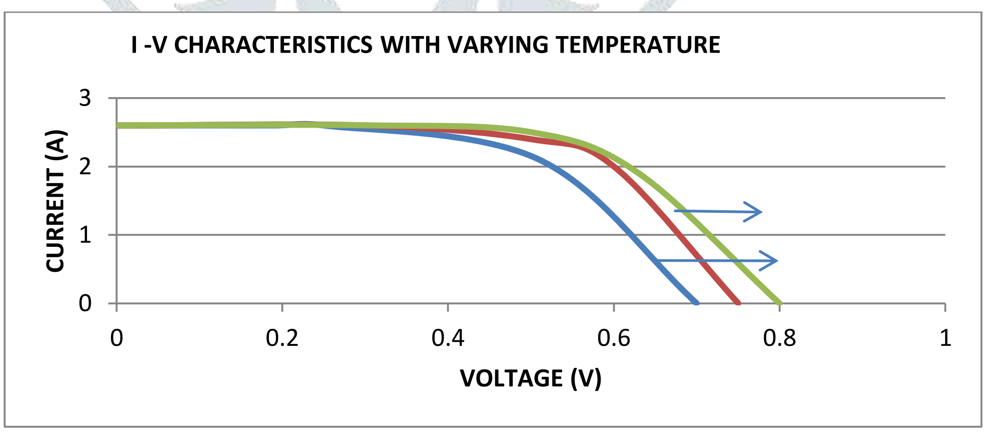

figure 4. **The current versus voltage curve at various temperature**

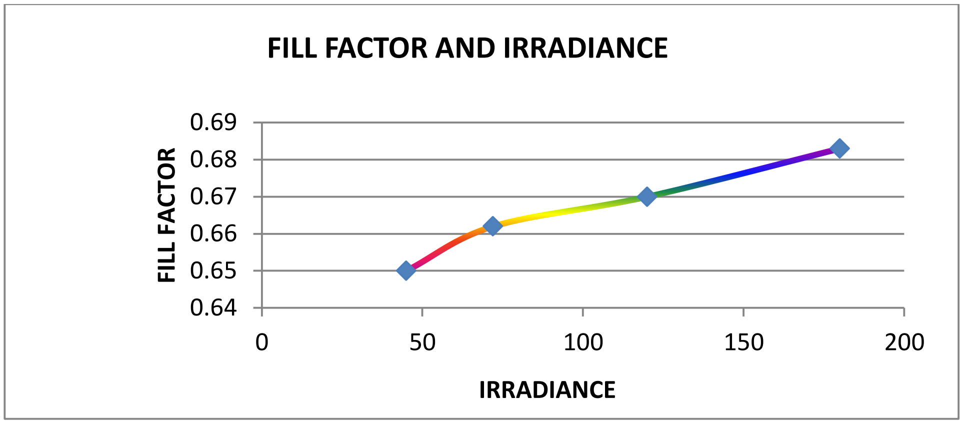

figure 5.**Variation of Fill factor with changing irradiance**

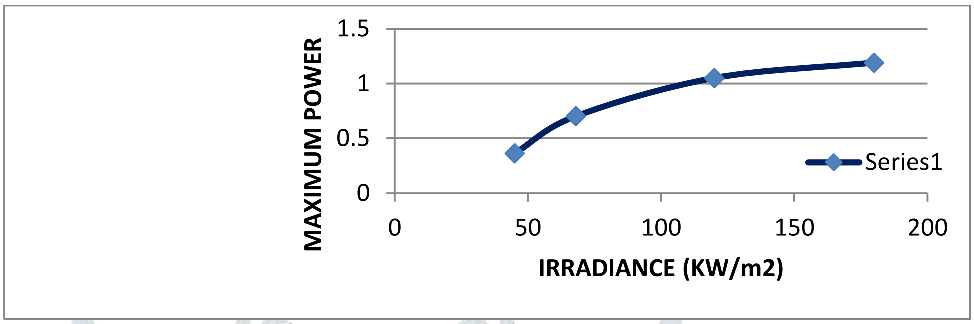

figure 6 .**Variation of maximum power with irradiance**

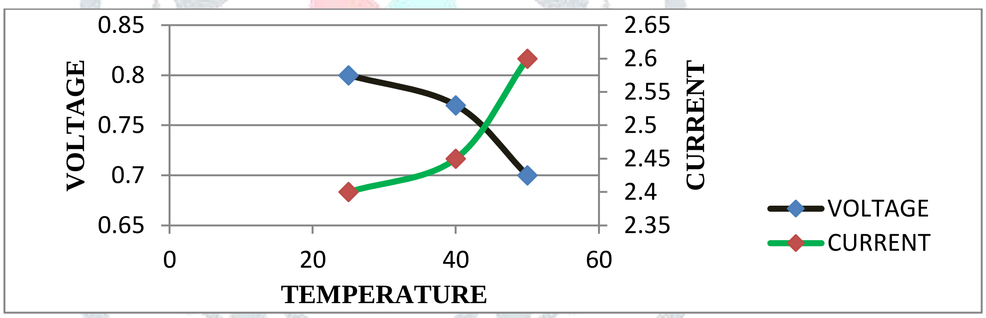

figure 7. **Temperature effect on short circuit current and open circuit voltage**

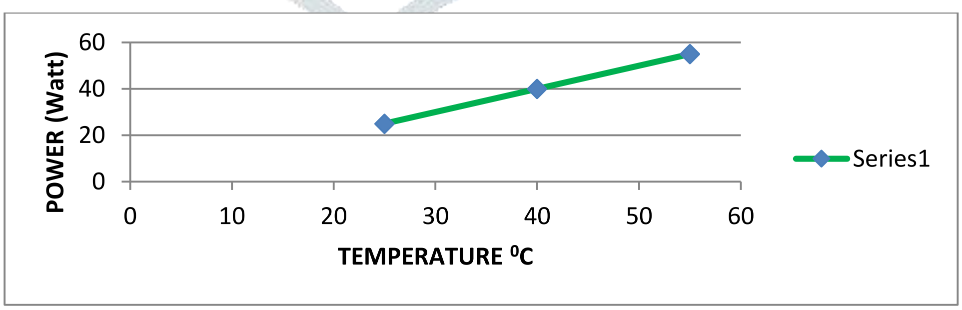

figure 8. **Power variation with temperature**

Discussion of results I-V curves of the module obtained at different values of irradiance is shown in fig.2. It is observed that as irradiance increases I_{SC} increases, while there is little change in V_{OC}. As the intensity of the radiation increases the photocurrent increases hence resulting increased short circuit current. This result is confirmatory to the work done by Yuki et al. (13). Fig 3 represents the P-V curve where the peak of the curve stands for the maximum power point of the module at each irradiance level. As the variation in irradiance the I-V curve is noticed to change and so the maximum power point. When the solar irradiance increases the maximum power produced by the module increases. For 45 Watt/m^2 it is 0.364, for 68 Watt/m^2 it is 0.702, for 120 Watt/m^2 it is 1.062, for 180 Watt/m^2 it is

1.167. This modification of Power with increasing irradiance is similar as the study done by Salim et al. (14). Fig. 4 illustrates the behavior of I-V curve with increasing temperature. On average there is little change in short circuit current but open circuit voltage increases with increasing temperature. In Fig 5 fill factor was observed to increase with irradiance at low intensities below 900 lux, from 0.65 to 0.665 and then it dropped for irradiance above 0.665 at intensities above 900 to 3250 lux. As irradiance increased fill factor is increased due to increased light generated current but at high intensities fill factor is decreased due to rise in temperature which lowers the efficiency of the module. Power output of the module was shown in fig.6 which increases with increasing irradiance. Maximum power was therefore seen to be produced at 0.18 $/m^2$ in this experimental study. Fig. 7 represents the change in open circuit voltage and short circuit current with temperature. With increasing module surface temperature, the band gap of the semiconductor decreases then more charge carriers are excited from the valence band to the conduction band resulting in a slight increase in Isc. Fig. 8 explains the output power variance with temperature produced by the module during the experiment.

Conclusion This study investigated the effect of solar irradiance and temperature on the performance of polycrystalline module at S.P.C.Govt. College, Ajmer (India). The efficiency of this module was assessed in terms of its apparent variables (Voc, Isc, FF, Vmp, Imp, and Pmax) as a function of solar irradiance and module surface temperature. Voc, Isc, and Pmax were found to decrease with increasing module surface temperature while isc increased slightly with the rising temperature.

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