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A STUDY OF EFFECT OF FILL FACTOR ON EFFICIENCY OF SOLAR PANEL WITH LOAD VARIATION AND HEIGHTS

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ABSTRACT

Ultimate focus of our study is to increase the efficiency of solar panel and its life time. The V-I characteristics, power calculations, variation of power with load, efficiency of solar panel are studied. The calculations are made at different timings, different heights and different days. From this study we can know the availability of sunlight during office hours, so that solar energy can be used for entire day without any hurdle. Solar panel efficiency can be known from calculation of Fill factor. Increased Fill factor increases efficiency of solar panel. By knowing maximum power, one can know the peak loads handled by solar panel .Solar panel peak power helps in preventing the photovoltaic panels from damaging, thus increasing the life time. From calculation of fill factor, we can also select the best solar cells from the available in market. From our study, we can also know watt peak, which is a measure of panels peak performance, it also tells amount of electricity solar panel produces. Watt peak information also tells about the best PV system out of many. V-I Characteristics at different temperatures and different loads helps us to optimize power characteristics, which can be known from Maximum power point of solar panel in full sunlight. If enough current is not taken from panel at a particular load, then power is not maximized, or if too much power is taken then voltage collapses and panel damages. The optimum current drawn is roughly proportional to amount of sunlight striking the panel. For best performance panel temperature must be low.

Keywords: Solar Cell, V-I Characteristics, Efficiency, Watt Peak, Fill Factor.

I. INTRODUCTION

Energy is a necessity like food and water. Everything around us requires energy. Over the years there has been an increase in the earth's population which is directly proportional to the energy used as well [1]. All the possible gadgets and equipment need some or the other kind of energy to function. With depleting fossil fuel reserves it becomes necessary to identify viable renewable energy resources that can decrease the dependency on fossil fuels [2, 3].A solar cell [4] is a device which converts sunlight energy into electrical energy by utilizing photovoltaic process. A solar panel is a device that converts sunlight into electricity by using photovoltaic (PV) cells. PV cells are made up materials that produce excited electrons when exposed to light. The electrons flow through a circuit and produce direct current (DC) electricity, which can be used to power various devices or we stored in batteries. Solar panels are also known as solar cell panels, solar electric panels, or PV modules consist of a large number of solar cells and use light energy(photon) from the sun to generate electricity through the photovoltaic effect. Most modules use wafer based crystalline silicon cells or thin film cells. The cells are usually connected electrically in series, one to another to get the desired voltage, and then in parallel to increase current the power of module is the voltage multiplied by current and depends both on amount of light and on electrical load connected to the module. A PV junction box is attached to the back of solar panel and functions as its output interface. A USB power interface can also be used. A single solar module can provide only a limited amount of power, most installation can try multiple module adding these voltages or current. A photovoltaic system typically includes an array of photovoltaic modules, an inverter, a battery pack for energy storage, a charge controller, interconnection wiring, circuit breakers, fuses, disconnect switches, voltage meters and optionally a solar tracking mechanism. Equipment is carefully selected to optimize output, energy storage and reduce power laws during power transmission, and convert DC into AC [5, 6].

II. LITERATURE REVIEW

Some of the barriers for wide spread usage of solar energy is the installation cost, efficiency and life time of solar panel [7]. Energy conversion efficiency is measured by dividing the electrical output by the incident light

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power .Factors influencing output methods are spectral distribution, spatial distribution of power, temperature and resistive load. IEC 6145 is used to compare the performance of cells and is designed around standard (terrestrial temperature) temperature and conditions (STC) irradiance of 1KW/m2 , a spectral distribution close to solar radiation through AM (air mass) of 1.5 and a cell temperature 250C .The resistive load is varied until the peak or maximum power point is achieved. The power at this point is recorded as watt peak [8]. The same standard is used for measuring the power and efficiency of PV modules. Solar cell efficiencies vary from 6% for amorphous silicon - based solar cells to 44.0% with multiple junction production cells and 44.4% with multiple dies assembled into a hybrid package. Solar cell energy conversion efficiencies for commercially available multi crystalline Si solar cells are around 14-19%. The highest efficiency cells have not always been most economical way to boost solar power. By increasing the light intensity, typically photo generated carriers are increased, increasing efficiency by upto 15%. These concentrator systems have only begun to become cost-competitive as a result of the development of high efficiency GaAs cell. The increase in intensity is typically accomplished by using concentrating optics. A typical concentrator system may use a light intensity 6-400 times the sun and increase the efficiency of a one GaAs cell from 31% at AM1.5 is to 35%. Commercially available solar cells CGS of 2006 reached system efficiencies between 5 & 19%. [9].

III. EXPERIMENT

A Solar panel of dimensions 7.5cm and 3.5cm (Area= 26.25×10^{-4} m^{2})) is taken to study efficiency and I-V characteristics under load and no- load conditions [10]. The experiment is conducted in our college campus on the roof and on different floors and in ground from 10:00am to 5:00pm by arranging slantly from north (high) to south (low) [11]. The voltage (V), current (I) obtained from the panel are recorded for a time duration of 1 hour [12]. The result obtained from the panel can be used to find the panels required to meet our requirements. To study the characteristics of solar panel, it is connected to a load of 300**Ω** and a voltmeter of range (0-10V) across load in parallel and an ammeter of range (0-100mA) is connected in series. The circuit diagram is shown in figure 1. This experiment is conducted at a height of approximately 15meter from ground, in winter season for two days. In order to calculate conversion efficiency of a standard solar power of 1000 W/m^2 at a temperature of $25^{o}C$ is taken as incident ideal power. The experimental setup is shown in Figure 2. For best results it is better to operate panel at low temperatures [13].

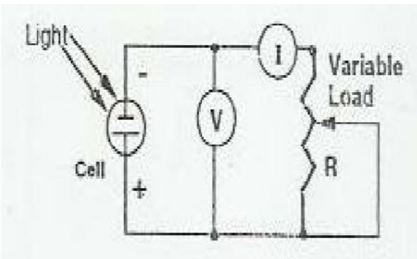

Figure 1: Circuit diagram

Figure 2: Experimental arrangement to study characteristics of solar panel a) without load resistance b) with load resistance.

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With a resistive load of 300Ω, parameters like voltage (V), current(I),Open circuit voltage(Voc) and short circuit current (Isc) are recorded with a duration of 1 hour and the values are tabulated. Maximum power and resistive power at different timings on day 1 where the sky is clear are also calculated. The Readings obtained for the experiment conducted on day-1(with a load of 300 ohm) are shown in Table 1. The Readings obtained for the experiment conducted on day-2 (with a load of 300ohm) are shown in Table 2. Readings obtained when experiment is conducted at different heights are tabulated in Table 3. The same experiment is conducted on day-2 during noon where there is maximum power. The Readings obtained at 1:30 pm and at 3:00 pm are shown in Table 4 and Table 5.

Table 1: Following are the values obtained for the experiment conducted on day-1 (with a load of 300 ohm)

Temperature (^{0}C)	Time	Voltage (V)	Current (mA)	Power (Pr)x10^{-3}	Open circuit (V_{OC})	Short circuit (I_{SC})	$P_{MAX*}10^{-3}$ (W)
25	10:00	0.4V	20	8	6.2	20	124
27	11:00	0.6 V	22	13.2	6.2	22	136.4
28	12:00	0.7 V	23	16.1	6.2	23	142.6
28.5	12:15	0.7 V	23	16.1	6.2	23	142.6
28.5	12:30	0.7 V	23	16.1	6.2	23	142.6
28.5	12:45	0.7 V	23	16.1	6.2	23	142.6
29	1:00	0.6 V	20	12	6	20	120
29.5	1:30	0.4 V	16	6.4	6	14	84
30.5	2:30	0.4 V	12	4.8	6	12	72
30	3:00	0.3 V	10	3	5.8	10	58
30.5	3:30	0.2 V	8	1.6	5.8	8	46.4
29	4:00	0.1 V	2	0.2	4.6	2	9.2

Table 2: Following are the values obtained for the experiment conducted on day-2 (with a load of 300ohm)

Temperature (^{0}C)	Time	Voltage (V)	Current (mA)	Power (Pr)*10^{-3}	Open circuit (V_{OC})	Short circuit (I_{SC})	$P_{MAX*}10^{-3}$ (W)
27	10:00	0.8	28	22.4	6.4	28	179.2
28	11:00	0.9	32	28.8	6.3	32	201.6
29	12:00	1	36	36	6.4	36	230.4
29	1:00	1	36	36	6.3	36	226.8
30	2:00	1	32	32	6.2	36	223.2
29	3:00	0.6	22	13.2	6.2	22	136.4
28	4:00	0.2	11	2.2	5.9	12	70.8

Table 3: Values at different heights

Floors	Time	Voltage (V)	Current (mA)	Power (Pr)*10^{-3}	Open circuit (V_{OC})	Short circuit (I_{SC})	$P_{MAX*}10^{-3}$ (W)
3rdfloor	12:00	1	36	36	6.4	36	230.4
2ndfloor	12:10	0.9	30	27	6.3	36	226.8

1st floor	12:20	0.8	29	23.2	6.3	36	226.8
G floor	12:30	0.7	23	16.1	6.2	23	142.6

Table 4: The same experiment is conducted on day-2 during noon (where there is maximum power) Readings at 1:30 pm

Load (Ω)	Voltage (V)	Current (mA)	Power ($V*I*10^{-3}$)(W)
100	3.8	34	129.2
120	4.4	32	140.8
140	4.6	30	138
160	4.8	28	134.4
180	5.2	24	124.8
200	5.5	23	126.5
220	5.6	22	123.2
240	5.7	20	114
260	5.8	19	110.2
300	5.8	16	92.8
320	6	15	80
340	6	14	84
400	6	11	66
500	6	7	42
600	6.2	7	43.4
700	6.3	6	37.8
800	6.3	5	31.5
900	6.3	4	25.2
1000	6.3	3	18.9
10K	6.4	0	0

Table 5: Readings at 3:00 pm

Load (Ω)	Voltage (V)	Current (mA)	Power ($V*I*10^{-3}$)(W)
100	2.4	22	52.8
120	3	22	66
140	3.4	22	74.8
160	3.8	21	79.8
180	4	20	80
200	4.4	19	83.6
220	4.6	18	82.8
280	5	16	80
300	5.1	14	71.4
320	5.2	14	72.8
340	5.3	13	68.9

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380	5.5	12	66
400	5.6	11	61.6
500	5.7	8	45.6
600	5.8	7	40.6
700	5.8	6	34.8
800	5.9	5	29.5
900	5.9	4	23.6
10K	6.1	0	0

With a resistive load of 300Ω voltage (V), current(I),Open circuit voltage(Voc),short circuit current (Isc) are recorded with a time duration of 1 hour and the values are tabulated maximum power and resistive power at different timings on day 1 where the sky is clear. The values obtained are shown in table 1[14, 15, and 16]. The experimental results obtained on day 2 with various loads are shown in tables 2, 3, 4 and 5, and Figure 3 reflect V-I characteristics of solar panel [17]. The graph shows variation of voltage (V) and current (I) with different loads varying from 100Ω to 10kΩ. Figure 3a show variation of V& I at 1:30pm. The Isc obtained is 34mA at load "0". V_{OC} obtained is 6.4V at load of 10kΩ. The current remains almost constant up to 400Ω and at 6V and then falls rapidly with increasing load. Figure 3b gives the variation of V and I with load at 3:00pm. The Isc obtained is 22mA at load "0". Voc obtained is 6.1V at a load of 10kΩ.The current remains almost constant up to 400Ωand at 5.6V and then falls rapidly with increasing load resistance.

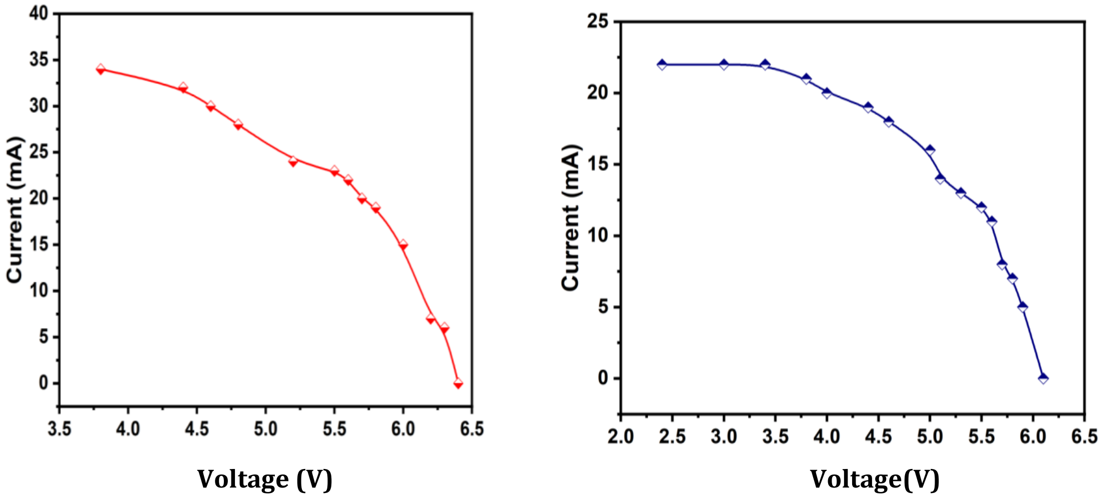

Figure 3: V- I Characteristics of Solar panel on Day-2 at (a) 1.30 PM and (b) at 3.00 PM

IV. RESULTS AND DISCUSSIONS

The biggest rectangle that can be inscribed between x- and y- axis and curve at Vmp = 5.25V & Imp = 25mA.

Maximum power = 131.25mW = Vmp x Imp

Fill factor (FF) is a measure of the squareness of the solar cell and is also the area of the largest rectangle which will fit in the V-I curve.

FF = (Vmp x Imp)/ (Voc x Isc) [18]

At 1:30pm

Voc = 6.2V, Isc = 23mA.

Vmp = 5.25V, Imp = 25mA.

FF= 5.25x 25 / 6.2x23 = 0.92

At 3:00pm

Voc = 6.2V, Isc = 22mA.

Vmp = 4.4V, Imp = 19mA.

FF= 4.4x19 / 6.2x22 =0.61.

The FF is an important parameter that determines the power conversion efficiency of an organic solar cell. There are several factors that can significantly influence FF. Due to this reason, a deep understanding of FF is important. This parameter is used to access the performance of solar cell. Solar cells with a higher fill factor have a higher efficiency and are therefore more desirable.

Specifications

Solar standard 1000W/m^2 (25^{0}C) (77^{0}F)

Length = 7.5cm

Width = 3.5cm

Resistive load at maximum power point = 200 Ω (at 3.00pm

Resistive load at maximum power point=120 Ω (at 1:30pm)

Area = 7.5x10^{-2} x 3.5x10^{-2} m^2

= 26.25x10^{-4} m^2

On day-1, a consistent maximum voltage of 0.7V and a current of 23mA is observed from 12:00 noon to 12:45pm with a maximum power of 16.1mW able to produce under a load of 300Ω. Open circuit voltage of 6.2V (V_{OC}) and a short circuit current of 23mA was observed. The maximum power is 142.6mW. The maximum efficiency of 0.61% can be obtained at an average temperature of 21^{o}C under Air mass 1.5 conditions. The maximum operating voltage (V_{mp} =5.25v) and maximum operating current (I_{mp} =25mA) that gives maximum output power is (V_{mp} = 5.25, I_{mp} = 25mA). 131.25 mW. The experimental results obtained on the day-2 (where there is clear sky) are consistent maximum voltage of 1V and a maximum current of 36mA were observed from 12:00 noon to 1:00pm. The maximum power during this time is 36mW. Maximum open circuit voltage (V_{OC}) of 6.4V and maximum short circuit current (I_{SC}) of 36mA are observed from 12:00 noon to 1:00pm.The maximum power of 230.4x10^{-3} W (230.4mW) can be observed from 12:00 noon to 1:00pm. Energy Conversion efficiency is 5.33%. As the characteristics of cell are consistent from 12:00 noon to 1:00pm, the performance of cell is studied at different heights. It is observed that voltage (V) and current I(mA) increases as the height increases. The power is also increasing. Open circuit voltage (V_{OC}) and short circuit current (I_{SC}) also increase with height. The maximum power of 230.4mW can be observed. Energy conversion efficiency at this value is 5.33%. V-I characteristics are also studied by variable load ranging from 100Ω-10KΩ. As the load increases voltage increases and current decreases. Power becomes maximum at a particular resistance which is called Watt peak and it is 120Ω for light intensity at 1:30pm.V-I characteristics of solar panel also recorded at 3:00pm i.e (less intensity).And intensity of the light can be increased by using concentrators, so that on low intensity days , we optimize current requirements[19]. As load increases voltage (V) increases and current (I) decreases. Peak watt can be observed at 200Ω. Energy conversion efficiency at this value is 3.18%, which is maximum.

V. CONCLUSION

Electricity bill can greatly cut down by installing solar power plant. As height increases some of the radiation will be filtered. It is better to arrange solar panels at high attitude, where we can achieve more power. For maximum efficiency solar panels must be placed facing towards south, so that there is a maximum exposure to sunlight and solar panel. For best results solar panels must be tilted for a latitude angle for that place. For early and late hours of day, the output current and voltage are less, as interaction of light with panel is low. When solar panels are installed on ground large space is required, which is major drawback. It is better to install panels on roof of the building. Concentrators can be used to improve intensity of incident light, to increase current under poor light conditions. Solar panels must be maintained slantly from north (high) to south (low). Arrangement of solar panels with sunlight making large glancing angle is suggestible. With increased intensity of light, photo current also increases and with decreased intensity current decreases. In both cases as load increases voltage increases but current decreases. The power generated also increases with increased intensity. Maximum power generated on day-1 is 142.6 m W from 12.00 noon to 12.45pm, on day-2 it is 230.44 mW. Wattpeak on day-2 during 1:30pm is 120 ohm, whereas during 3:00pm is 200ohm. Increase in wattpeak tells that maximum power generated at that load. This is very important characteristic property of panel. It tells about best system out of many and also, if current is not taken from panel at a particular load, then power is not maximized or of too much power is taken then voltage collapses and panel damages. Thus its life time decreases and cost increases and solar power system becomes failure. It also gives an idea about peak load hours in a season. The optimum current drawn is proportional to amount of sunlight striking the panel. Value of fill factor (FF) is generally less than 1. FF value on day-2 is during 1:30pm is 0.92 and at 3:00pm is it is 0.61.FF determines conversion efficiency of solar panel. We need a solar cell of higher efficiency. V-I characteristics helps us to optimize power characteristics. To bear the load enough current must be generated. On day-1 maximum of Voc=6.2V&Isc=23 mA are generated. Maximum voltage generated under closed circuit is 0.7V& current generated is 23 mA. On day-2 maximum of Voc=6.4V and Isc=36 mA. Maximum voltage generated is under closed circuit conditions is 1V and current is 36 mA. Efficiency of solar panel on day-1 is 5.43% , on day-2 is 5.8% (this is due to increased intensity of sunlight).

VI. REFERENCES

[1] Joshi AS, Tiwari A, Tiwari GN, Dincer I, Reddy BV (2009) Performance evaluation of a hybrid photovoltaic thermal (PV/T) (glass-toglass system. Int J Thermal Sci 48:154.

[2] T. Tafticht, K. Agbossou, M.L. Doumbia and A. Cheriti, "An improved maximum power point tracking method for photovoltaic system", Renewable Energy, vol. 33, pp. 1508-1516, 2008.

[3] V. Kumaresh, M. Malhotra, N. Ramakrishna and R. Saravanaprabu, "Literature review on solar MPPT system." Advance in Electronic and Electric Engg., vol. 4, pp. 285-296, 2014.

[4] Avaritsiotis. J.N,"The efficient exploitation of photovoltaic electricity", Solar cells,1(1985)261-279.

[5] Martina Calais, and Vassillios G.Agelidis "A Transformer less Five Level Cascaded Inverter Based Single -Phase Photovoltaic System" Centre of Renewable Power deliver, University of Glasgow, U.K.2000.

[6] Ito M, Kato K, Sugihara H, Kichimi T, Kichimi J, Kurokawa K. A preliminary study on potential for very largescale photovoltaic power generation (VLSPV) system in the Gobi desert from economic and environmental viewpoints. Solar Energy Materials & Solar Cells vol. 7, pp.507–17, 2003.

[7] Eltamaly AM, Farh HMH (2020) PV Characteristics, Performance and Modelling. In: Modern maximum power point tracking techniques for photovoltaic energy systems. Springer, Cham, pp 31–63

[8] Rezk H, Eltamaly AM (2015) A comprehensive comparison of different MPPT techniques for photovoltaic systems. Sol Energy 112:1–11

[9] Bahadur Singh Pali I and Shelly Vadhera, "Renewable Energy Systems for Generating Electric Power: A Review" 1st IEEE International Conference on Power Electronics. Intelligent Control and Energy Systems (ICPEICES-2016

[10] J. P. Rama, H.Manghania, D. S. Pillai, T. S.Babu, M.Miyatake, N. Rajasekar, "Analysis on solar PV emulators: A review," Renewable and Sustainable Energy Reviews, vol. 81,pp. 149–160, 2018.

[11] Aurora, Domkundwar, A Course in Power Plant Engineering, Dhanpat Rai & Co. (P) LTD, Third Edition 2007, pp 31.1.

[12] Koteshwar rao B,Radhakrishna.K, Vijay.P,Rajasurya.N,Experimental Analysis of Solar panel efficiency with different modes of cooling,e-SSS N-404(IJET)Vol8.No.3 jan-jul 2016.

[13] Faranda, R., Leva, S., Maugeri, V., "MPPT techniques for PV Systems: Energetic and cost comparison" Power and Energy Society General Meeting -Conversion and Delivery of Electrical Energy in the 21st Century, 2008 IEEE, vol., no., pp.1,6, 20-24 July 2008 doi: https://doi.org/10.20546/ijcmas.2019.803.014.

[14] Rezk H, Eltamaly AM (2015) A comprehensive comparison of different MPPT techniques for photovoltaic systems. Sol Energy 112:1–11.

[15] Eltamaly AM, Addoweesh KE, Bawa U, Mohamed MA (2014) Economic modeling of hybrid renewable energy system: a case study in Saudi Arabia. Arab J Sci Eng 39(5):3827–383

[16] Faranda, R., Leva, S., Maugeri, V., "MPPT techniques for PV Systems: Energetic and cost comparison" Power and Energy Society General Meeting -Conversion and Delivery of Electrical Energy in the 21st Century, 2008 IEEE, vol., no., pp.1,6, 20-24 July 2008 doi: https://doi.org/10.20546/ijcmas.2019.803.014.

[17] Aurora, Domkundwar, A Course in Power Plant Engineering, Dhanpat Rai & Co. (P) LTD, Third Edition 2007, pp 31.1.

[18] E. M. G. Rodrigues et al., “Simulation of a solar cell considering single-diode equivalent circuit model” in Proc. International Conference on Renewable Energies and Power Quality, 2011.

[19] Chen, C. J. (2011). Physics of solar energy. New Jersey: Wiley.

[20] Eltamaly AM, Addoweesh KE, Bawa U, Mohamed MA (2014) Economic modeling of hybrid renewable energy system: a case study in Saudi Arabia. Arab J Sci Eng 39(5):3827–383.