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International Journal Of Engineering And Computer Science ISSN:2319-7242
Volume 2 Issue 1 Jan 2013 Page No. 214-220

Analysis of Solar PV cell Performance with Changing Irradiance and Temperature

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Abstract

Solar energy is most readily available source of energy. It is Non polluting and maintenance free. To make best use of the solar PV systems the output is maximized either by mechanically tracking the sun and orienting the panel in such a direction so as to receive the maximum solar irradiance or by electrically tracking the maximum power point under changing condition of insolation and temperature. 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. Not only this both irradiance and temperature affect solar cell efficiency as well as corresponding Fill factor also changes. This paper gives an idea about how the solar cell performance changes with the change in above mentioned factors in reality and the result is shown by conducting a number of experiments.

Keywords: Irradiance, Fill factor, Insolation

Introduction:

Solar PV cells are electronic devices that use P-N junctions to directly convert sunlight into electrical power. A complex relationship between voltage and current is exhibited by the P-N junction in the solar cell. The voltage and current both being a function of the light falling on the cell, there exists a complex relationship between insolation (sunlight) and output power. Solar cells capture slow-moving low energy electrons. These effects are saturated and cause a fixed energy loss under bright light condition. However, on an overcast day i.e. at lower insolation levels these mechanisms show an increasing percentage of the total power being generated. Too much insolation causes saturation of cells, and the number of free electrons or their mobility decreases greatly. For an example in case of silicon the holes left by the photoelectrons neutralizes taking some time, and in this time these absorb a photoelectron from another atom inside the cell. This causes maximum as well as minimum production rates.

I-V Characteristics:

I-V Characteristics is a curve between current and voltage. The curve shows a inverse relation. The area under the I-V curve is the maximum power that a panel would produce operating at maximum current and maximum voltage. The area decreases with increase in solar cell voltage due to its increase in temperature. Due to fluctuations in environmental conditions, temperature change and irradiance level the IV curve will change and thus maximum power point will also change. Thus the MPPT algorithm keeps on tracking the knee point.

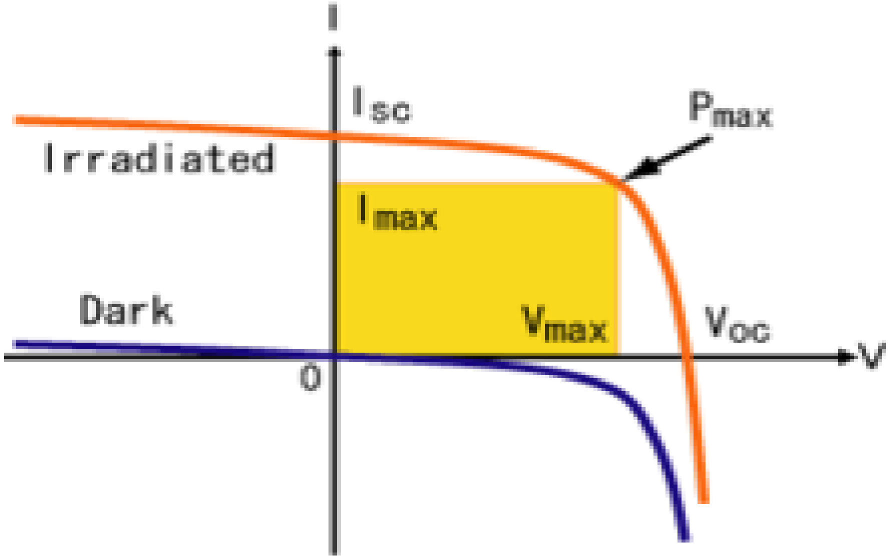

Fig 1: Shows the IV-curve of a solar cell both under irradiated and dark conditions. The yellow area shows the maximum power operating region.

The above figure shows two characteristics i.e. Dark and Irradiated characteristics. When the PN junction is illuminated the characteristics get modified in shape and shift downwards as the photon generated component gets added with the reverse leakage current. The maximum power point can be obtained by plotting the hyperbola defined by V*I= constant such that it is tangential to the I-V characteristics. The voltage and current corresponding to this point are peak point voltage and peak point current. There is one point on the curve that will produce maximum electrical power under incident illumination level. Operating at any other point other then maximum power point will mean that cell will produce maximum thermal power and less electrical power.

Effect of Irradiance and Temperature

The term Irradiance is defined as the measure of power density of sunlight received at a location on the earth and is measured in watt per metre square. Where as irradiation is the measure of energy density of sunlight .The term Irradiance and Irradiation are related to solar components. As the solar insolation keeps on changing throughtout the day similarily I-V and P-V characteristics varies.With the increasing solar irradiance both the open circuit voltage and the short circuit current increases and hence the maximum power point varies. Tempearture plays another major factor in determing the solar cell efficiency.As the temperature increases the rate of photon generation increases thus reverse saturation current increases rapidly and this reduces the band gap.Hence this leads to marginal changes in current but major changes in voltage.The cell voltage reduces by 2.2Mv per degree rise of temperature.Temperature acts like a negative factor affecting solar cell performance.Therefore solar cells give their full performance on cold and sunny days rather on hot and sunny weather. Now adays Solar panels are made of non-silicon cells as they are temperature insensitive.Thus the temperature remains close to room temperature.

Observation table:

SL NO	SET: 1	VOLTAGE	CURRENT(mA)	POWER(WATTS)
1	**Irradiance: 48 watt/m^2 Intensity: 590 lux**	16.5(Voc)	0	0
2		14.9	24	0.357
3		14.6	26	0.3796
4		**13.9**	**30**	**0.417 (Pmax)**
5		11.2	36	0.40
6		2.9	39	0.078
7		1.2	39	0.0468
8		0.5	39	0.0195
9		0	39 (Isc)	0

SL NO	SET: 2	VOLTAGE	CURRENT(mA)	POWER(WATTS)
1	**Irradiance: 67 watt/m^2 Intensity: 910 lux**	17(Voc)	0	0
2		16.9	26	0.439
3		16.6	32	0.5312
4		16.4	38	0.6232
5		15.9	44	0.6996
6		**15.0**	**56**	**0.840 (Pmax)**
7		11.1	68	0.7548
8		6.4	70	0.448
9		0	70	0

SL NO	SET:3	VOLTAGE	CURRENT(mA)	POWER(WATTS)
1	**Irradiance: 115 watt/m^2 Intensity: 2000 lux**	17.7 (Voc)	0	0
2		17.5	28	0.49
3		17	46	0.782
4		16.1	68	1.0948
5		**15.8**	**74**	**1.574 (Pmax)**
6		8.8	96	0.8448
7		2.2	98	0.2156
8		0.1	98	0.098
9		0	98	0

SL NO	SET: 4	VOLTAGE	CURRENT(mA)	POWER(WATTS)
1	**Irradiance: 165 watt/m^2 Intensity: 3230 lux**	18.1 (Voc)	0	0
2		17.9	30	0.537
3		17.6	42	0.7392
4		17.1	72	1.2312
5		16.8	86	1.448
6		**13.9**	**128**	**1.779 (Pmax)**
7		9.2	132	1.214
8		3.5	132	0.462
9		0	132	0

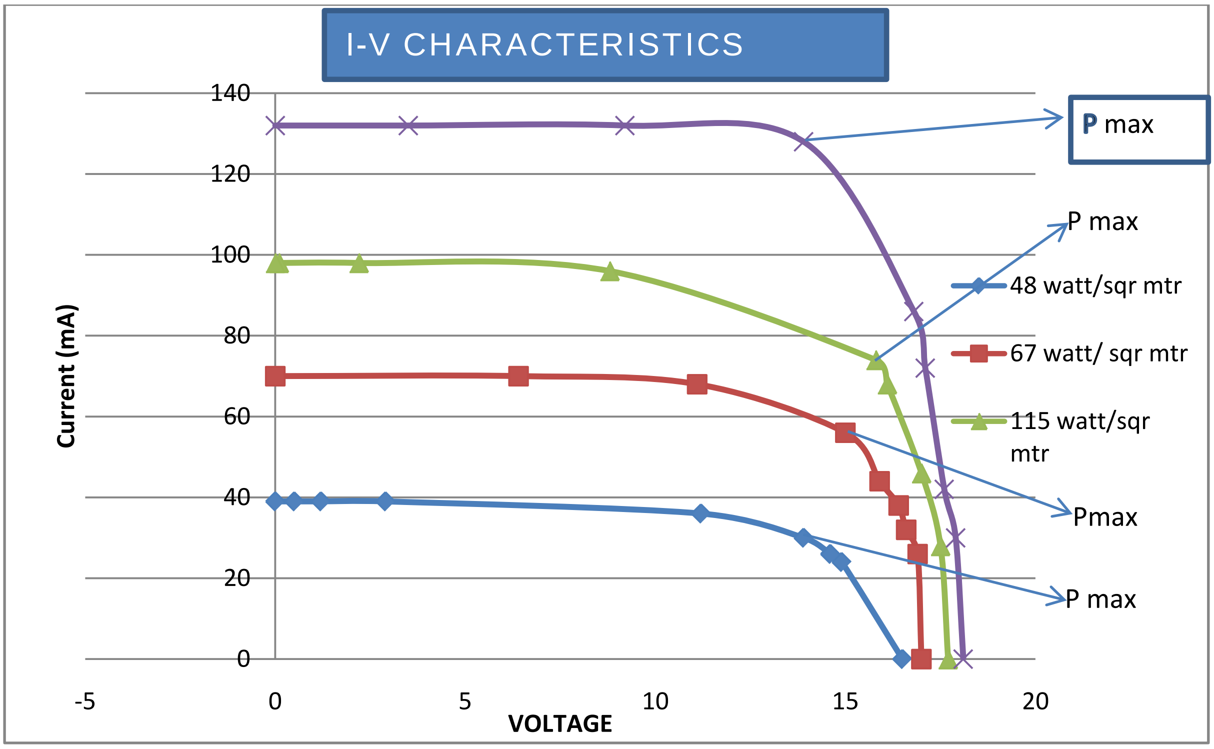

Fig 2: Shows the current versus voltage curve at various irradiance level and the corresponding maximum power point.

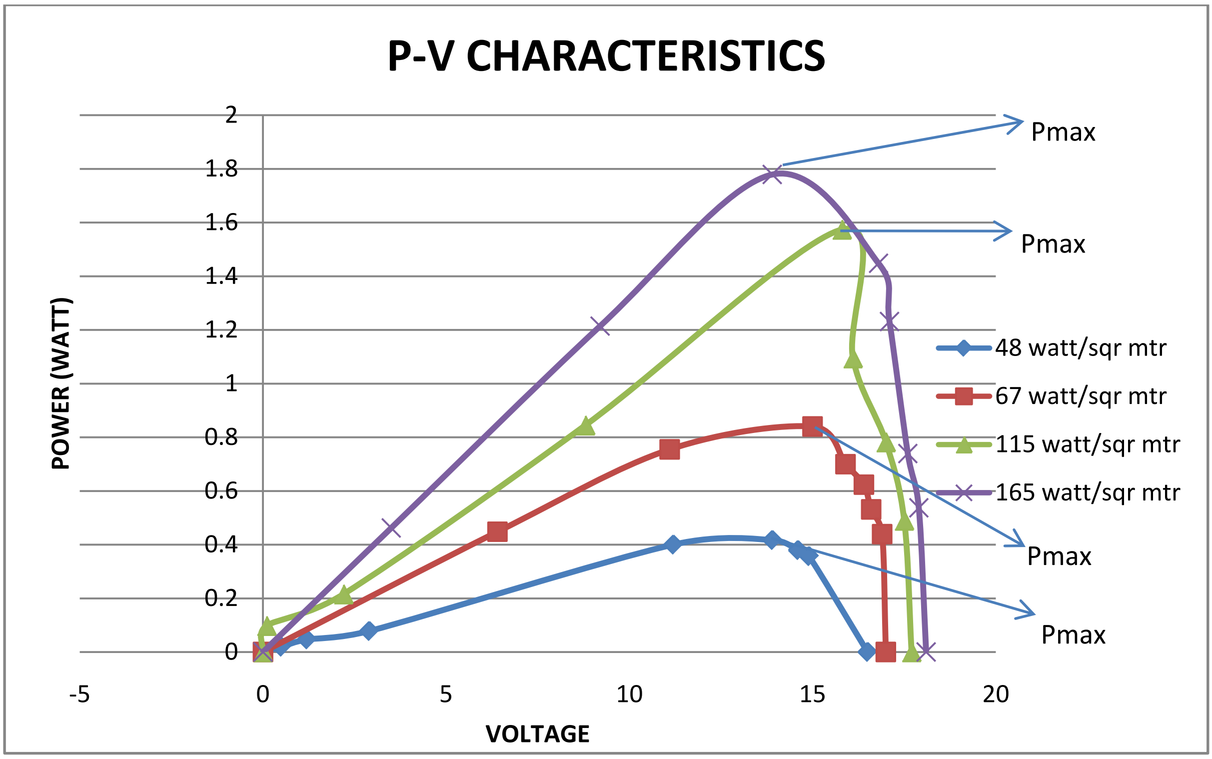

Fig 3: Shows the power versus voltage characteristics at four different irradiance levels.

OBSERVATION TABLE 2 (AT VARIOUS TEMPERATURE)

SL NO	SET: 1	VOLTAGE	CURRENT(A)
1		0.7(Voc)	0
2		0.64	0.1
3		0.5	1.1
4	Temp: 25 Deg	**0.3**	**2.3**
5		0	3.5
SL NO	**SET: 2**	**VOLTAGE**	**CURRENT(A)**
1		0.6(Voc)	0
2		0.58	0.2
3		0.4	1.4
4	Temp: 45 Deg	0.33	2.8
5		0	3.6
SL NO	**SET:3**	**VOLTAGE**	**CURRENT(A)**
1		0.55 (Voc)	0
2		0.41	0.8
3	Temp: 60 Deg	0.32	1.6
4		0.21	2.5
5		**0**	**3.7**

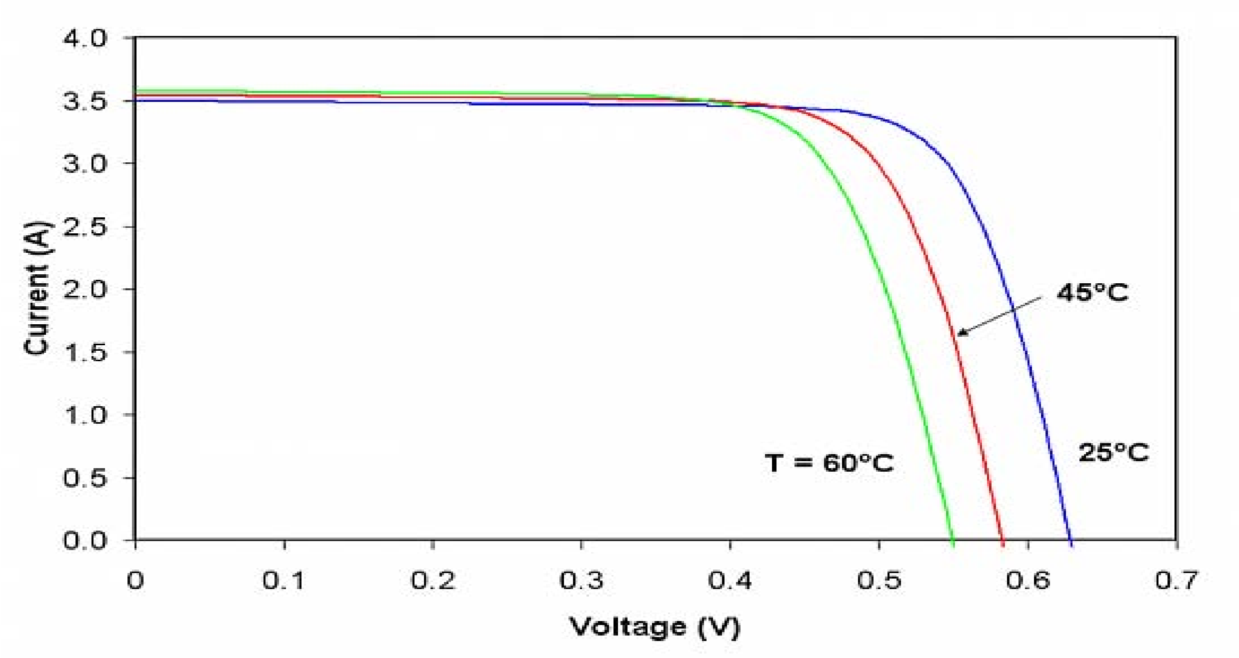

Fig 4: Shows how the I-V curve varies with varying temperature.

Fill factor

The fill factor is denoted as *FF*, is a parameter that helps in characterizing the non-linear electrical nature of the solar cell. Fill factor is defined as the ratio of the maximum power from the solar cell to the product of V_{oc} and I_{sc}, and it gives an idea about the power that a cell can produce with an optimal load under given conditions, $P=FF*V_{oc}*I_{sc}$. Fill factor is also an indicator of quality of cell. With FF approaching towards unity the quality of cell gets better. Fill Factor can be improved in many ways.

Comparative study of Solar Cell w.r.t Fill factor

SL NO	IRRADIANCE (Watt/m^2)	INTENSITY (lux)	FILL FACTOR
1	48	590	0.64
2	67	910	0.67
3	115	2000	0.705
4	165	3230	0.744

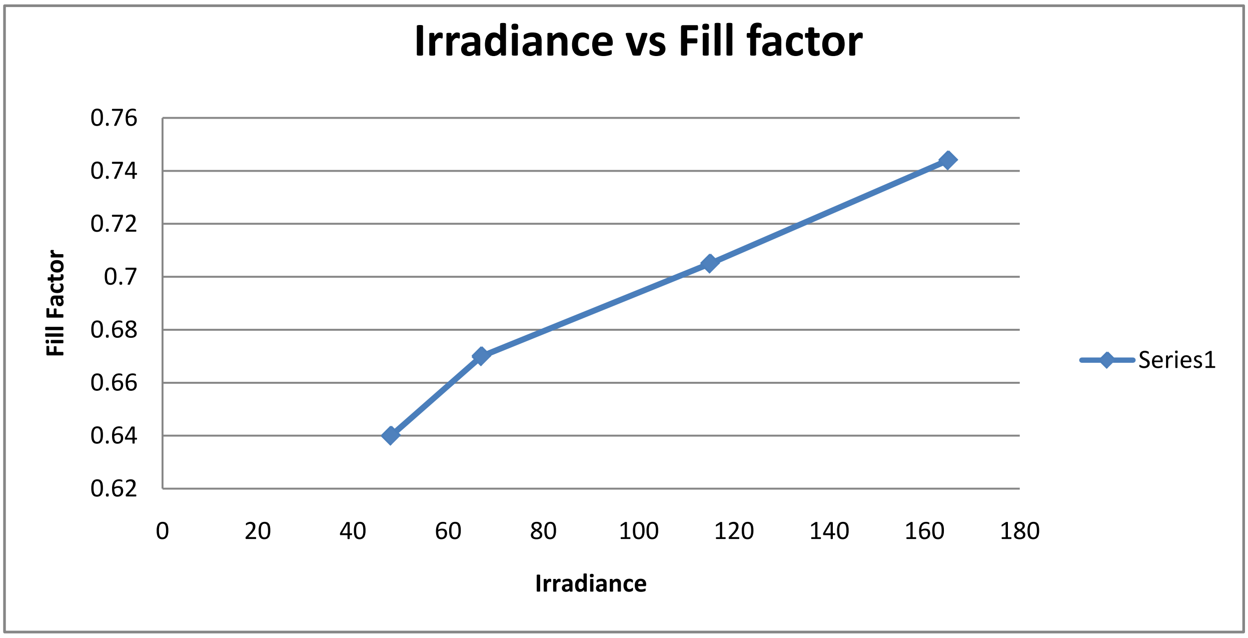

Fig:5 Shows the variation of Fill factor with changing Irradiance.

Analysis and Conclusion

With the increase in temperature the rate of photon generation increases thus reverse saturation current increases rapidly and this results on reduction in band gap.Hence this leads to marginal changes in current but major changes in voltage

Acknowledgement:

We would like to thank School of Electrical Engineering , KIIT University for providing necessary experimental platform for research and analysis for the completion of the paper.

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Author's Biography

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