Analysis of efficiency of Solar PV module with the variation of Temperature and Irradiation Level in SMIT, Sikkim

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Abstract : With a steeping decline in the availability of conventional resources of energy production like coal, there has been a notable rise in the demand of unconventional energy sources like solar and wind energy. Solar energy, though finding dominating application in many sectors, the major issue with its usage is its low output efficiency. The average efficiency of a solar panel is around 11 - 15% for home use. The power output for a solar panel varies greatly with respect to the atmospheric temperature and the irradiation level of sunlight. The results obtained from the graphs are used to calculate the efficiency of solar power output.

Keywords : Irradiance level, Ambient temperature, Solar Photo-voltaic cell, Solar Panel PV Junction.

I. INTRODUCTION

The development of viable and long-term solution to meet our energy needs that also maintains the quality of our environment remains one of the most critical challenges faced by the scientific community. The novel approach for renewable energy sources has led to increasing usage of solar energy, which has, over the years, proved itself to be a pioneer in the field of unconventional power sources. [1]

The first big oil crisis, back in the late seventies, was a major accelerator in the increment of usage of renewable energy. At that period of crisis, as oil prices fell, there was resurgence in harvesting of non-fossil based energy systems. In current times, vulnerability of the environment in general is one of the driving factors of that drift. However, especially in case of solar energy, daily and seasonal effects and limited predictability result in intermittent generation. [2]

Absences of carbon emissions make solar energy count among clean energy sources. With development of photo-voltaic technology, large scale grid connected PV power plants have been established around the world in recent years. However, factors such as environmental temperature and irradiation levels broadly affect the maximum power output, making it a non-deterministic and stochastic process. [3]

In case of the various solar thermal power plants which is accompanied with a storage system, their management and operation demand predictions of solar irradiance with the same temporal resolution as the temporal capacity of the back-up system. [4]

The power output of Photo-voltaic Systems, despite its impending growth, is broadly affected by weather conditions. Accurate forecasting of PV power output is important for system reliability and promotion of large scale PV deployment. [5]

System Modeling:

Internal Structure of a Solar Panel:

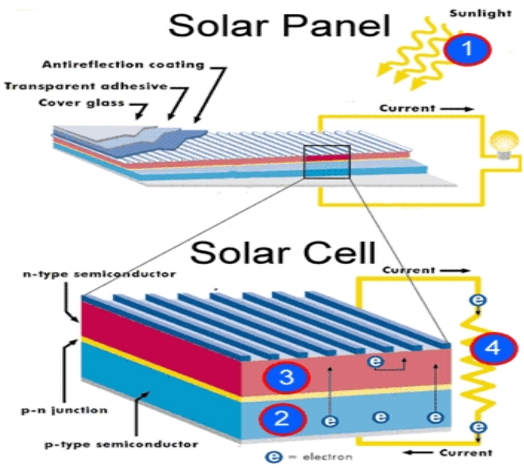

Fig:1 Internal Structure of a Solar Panel

Solar Cells have been known as a clean and green source of energy. Solar cells are made to produce Direct (DC) Currents. To get Alternating Current from a solar cell, we need to add different components in order to get the desired current. These extra components are integrated into a special Solar Photo-voltaic System, mainly comprising:

a. Solar Module- Directly converts solar energy into DC Current

b. Solar Charge Controller- the voltage and charge regulator, which charges and protects the battery.

c. Battery- the charge storing center when solar energy is unavailable.

d. Inverter- the DC Current to AC Current convertor.

e. Protection- specially, Lightning protection, which prevents external damage to the euipments due to lightning and other environmental factors.

The solar cells are connected in groups, called modules, which are further connected in arrays to increase the amount of current produced. Quite naturally, when connected in parallel, output current increases and a series connection accounts for a greater voltage output.

Solar Panel P-N Junction working:

Solar cells are essentially photo diodes ie., they are excited with light. A photo-diode is reverse biased silicon or germanium p-n junction, in which junction current increases when it is exposed to light. Greater the intensity of light falling on the diode, greater will be the reverse current. When light falls on the p-n junction, energy is imparted by photons to the atoms. This creates more free electrons, resulting in increased reverse current.

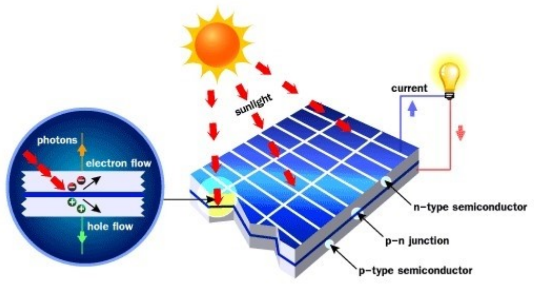

Fig:2 Working model of solar panel

When no light is incident on p-n junction of the photo-diode, reverse current is extremely small, known as dark current. When light falls on the p-n junction, energy is transferred to the atoms in the junction, releasing free electrons, hence increasing the current.

I-V Characteristics:

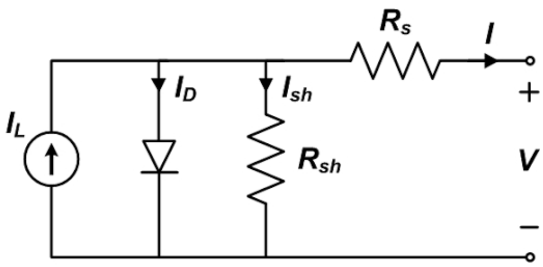

Fig:3 PV cell equivalent circuit

Essentially a graph between current and voltage, the I-V characteristics of a Solar Cell shows inverse relation. On scrutinizing closely, we find that when the current and the voltage, both are at their maximum magnitude, the area under the curve gives the maximum output power of the solar cell. Evidently, environmental fluctuations like a change in temperature or a change in irradiation level of sunlight leads to a change in the maximum power output of the solar cell.

We can also obtain the magnitude of the maximum power by plotting the curve obtained taking Voltage*Current=constant. The curve obtained will meet the IV characteristics tangentially. When the solar cell functions at any power other than the maximum power point, it simply implies that the solar cell is producing more thermal power and less electrical power ie., unwanted energy dissipation occurs. Thus to get maximum efficiency at a given temperature and irradiation level, our aim should be to make the solar panel function at its maximum power point. [7]

Effect of Irradiance and Temperature

Simply going by dictionary terms, irradiance level is the amount of solar power which the Earth receives per metre square. Thus it is power per unit area and its SI Unit is obviously, Watts per metre square.

Observation Table:

In our charts as shown below, we have taken a note of the temperature of the atmosphere and the corresponding irradiation level throughout the day, also keeping a track of the output voltage and output current of the solar panel. The output power is easily calculated by multiplying the output voltage and current.

Table :01

1st FEB, 2018		
Ambient Temperature (Degree C)	**Irradiation (W/m2)**	**Power (Watt)**
21.3	449.45	13124
22.5	451.2	13366
21.28	437.26	13815
25.4	454.16	14509
28.2	474.26	14608
27.6	490.91	15107
26.4	497.16	15324
26.9	502.22	15855
27.6	510.14	15100
28.1	524.22	14803
34.74	310.91	3402
23.14	104.19	5937
23.87	295.51	5344
24.73	258.13	4300

Table: 02

5th FEB, 2018		
Ambient Temperature (Degree C)	**Irradiation (W/m2)**	**Power (Watt)**
22.16	275.72	6559
22.77	214.14	6962
21.67	271.32	7658
22.53	288.91	6151
22.66	359.29	7376
23.63	385.68	8447
24.36	346.09	8927
23.5	407.67	8964
22.16	376.88	9203
25.21	337.3	8954
21.67	128.38	3261
22.89	119.58	3261
23.01	161.36	3606
22.4	77.8	2662

Table: 03

7th FEB, 2018		
Ambient Temperature (Degree C)	**Irradiation (W/m2)**	**Power (Watt)**
22.28	271.32	7491
22.77	335.1	8836
21.92	352.69	9173
23.26	372.48	9444
23.99	456.05	8606
23.75	412.07	10902
26.68	464.85	10991
25.58	409.87	10934
29.98	392.27	9921
29.61	447.25	10667
20.82	159.16	2452
19.96	88.79	1451

RESULT AND DISCUSSION:

Based on the collected data throughout the day, variation of power of PV panel is plotted at different temperature and irradiation level.

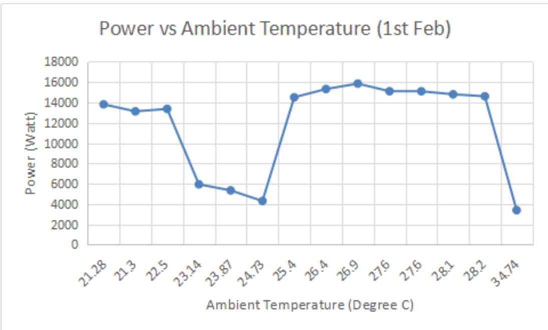

Fig.4 Power vs Ambient Temperature curve for 1st Feb

Maximum power on 1st February was observed to be 15855W at 26.9^0 C and at irradiation level of 502.22 W/m^2 as shown in figure 4 and figure 5.

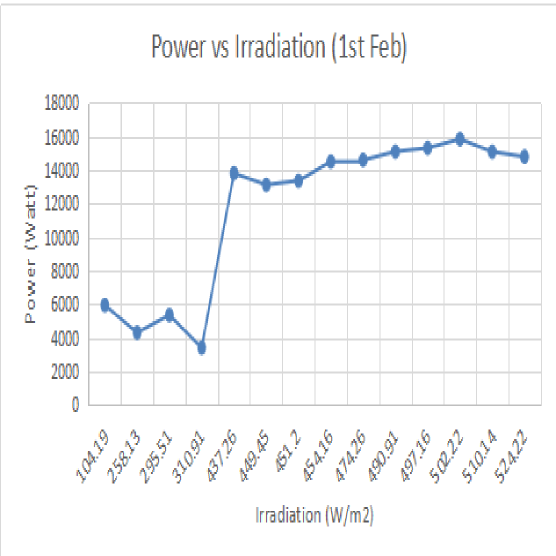

Fig.5 Power vs Irradiation curve for 1st Feb

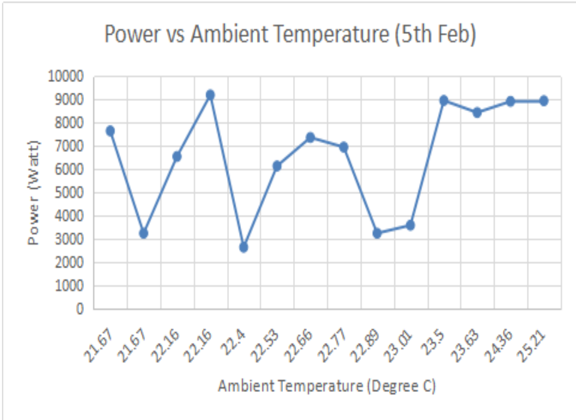

Fig.6 Power vs Ambient Temperature curve for 5th Feb

Maximum power on 5th February was observed to be 9203W at 22.16^0 C and at irradiation level of 376.88W/m^2 as shown in figure 6 and figure 7.

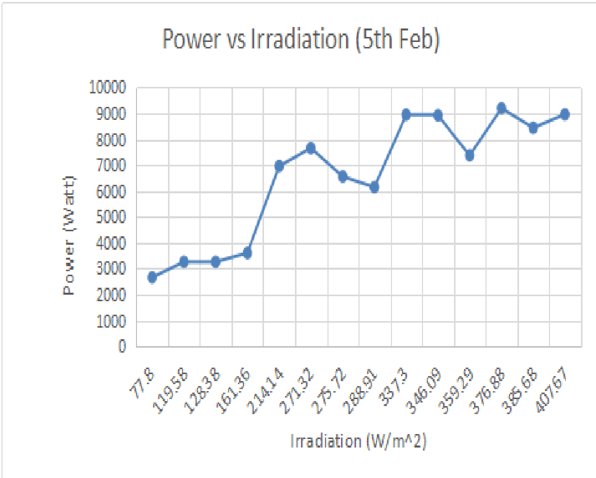

Fig.7 Power vs Irradiation curve for 5th Feb

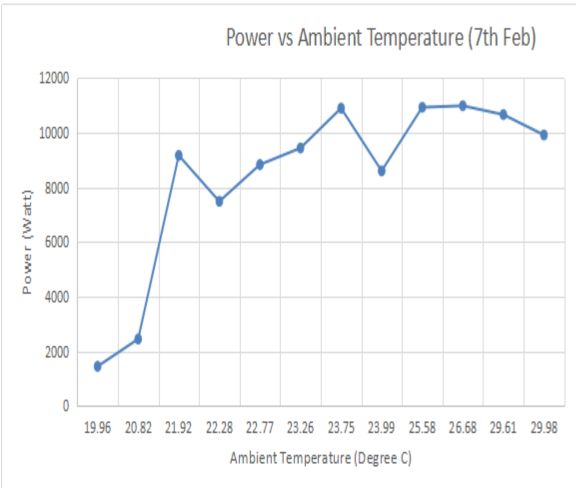

Fig.8 Power vs Ambient Temperature curve for 7th Feb

Maximum power on 7th February was observed to be 10991W at 26.68^0 C and at irradiation level of

464.85W/m^2 as shown in figure 8 and figure 9.

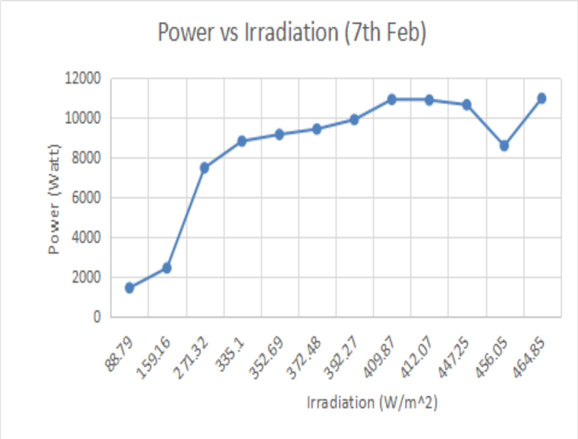

Fig.9 Power vs Irradiation curve for 7th Feb

Calculation

The rooftop PV system of SMIT features a total capacity of 100 KW with four panels, each of 25 KW. Dimension of solar panel is 2m x 1m. Total number of solar panels in a single unit is 80.

The efficiency of the solar module can be calculated using the following formula.

Efficiency

η = 100% * (V_{mp} * I_{mp}) / (Dimension of solar panel * Irradiation level)

where, V_{mp}= Voltage at maximum power,

I_{mp}= Current at maximum power

Efficiency of solar panel For 1st Feb 2018,

Maximum power of each panel

= (15855W/80)

=198.18 W

η =100%* (198.18) / (2*1*502.22)

=19.73%

Efficiency of solar panel for 5th Feb 2018,

Maximum power of each panel

= (9203 W/80)

=115.04 W

η =100%* (115.04) / (2*1*376.88)

=15.26 %

Efficiency of solar panel for 7th Feb 2018,

Maximum power of each panel

= (10991W/80)

=137.38 W

η =100%* (137.38) / (2*1*464.85)

=14.77%

CONCLUSION:

Efficiency of solar panel is 19.73% at irradiation level of 502.22 W/m^2, 15.26% at irradiation level of 376.88W/m^2 and 14.77% at irradiation level of 464.85W/m^2 on 1st, 5th , 7th February 2018 respectively. Thus, it is observed that efficiency of each solar panel is dependent on ambient temperature and irradiation level.

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