REVIEW ARTICLE

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Analysis of Photo Voltaic Array under Changing Climatic Conditions

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Abstract

In the current scenario, the world is moving towards advancement of technology and all things have automated. This advancement of lifestyle is completely dependent on energy requirement. We need to switch to alternate source of energy as fossil fuel energy sources will finished after some decades and it also creates lots of pollution. So solar photovoltaic (PV) energy is one on which we can rely. But it is intermittent in nature because sun is not present in the daytime and the weather is unpredictable. The two parameters, radiation and temperature, vary with the weather and time. It is very much necessary to understand the characteristics of photovoltaic energy that how it behaves in different climatic conditions. This paper simulates the PV panel to study the characteristics of solar energy.

Keywords: Intermittent, PV panel, Radiation, Solar cell, Temperature.

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Introduction

The energy sector is the world's largest industry that affects any country's economic growth.[1] Energy demand is growing very fast because economy and growth of any country depend on its energy supply. The energy consumption directly depends on population size, standard of living and industrialization. Energy supply has not kept speed with increasing demand and therefore world continues to face serious energy shortage.[2,3] There are two sorts of energy sources renewable and non-renewable. Non-renewable energy sources are oil, gas, coal and atomic energy. These sources emit carbon in the atmosphere which is a great cause of concern of the world. This emission crossed the 440 ppm limit in 2017.[4] These sources will diminish after a period. For the world's sustainability, we need to think about reducing carbon emission caused by non-renewable energy sources. So in the present power sector we need to switch towards the promotion of green energy, especially solar power for technical, economic and environmental policies globally. The solar energy is converted into DC electricity by photovoltaic cells.[5] As the solar radiations are available worldwide to a large extent Solar PV energy is the great choice over other energy sources.[6] It is expensive to produce electricity from sun because solar panel are made of expensive semiconductor material and the efficiency of solar cell is very low.[7,8] In this paper we compare the solar cell types, efficiency, appearance and also study about VI characteristics under variation of radiation and temperature.

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Solar Cell

During the Photovoltaic effect sun's photons strike the surface of the cell and knockout out the electrons from the silicon and generate the electric field.[9] This Voltage is only 0.6V. To increase the output voltage, multiple cell are connected in series. A solar panel contains 60, 72 or 96 cells typically.

Solar panels are of 4 types:

- Monocrystalline
- Polycrystalline
- PERC
- Thin-film panels

Monocrystalline solar panels are made of single crystal of silicon.[10] The color of panel is dark black. It is costly because lots of silicon is wasted to make the panel. Polycrystalline panels are made of different silicon crystals and appearance is blue with square edges. These cells are affordable. These cells are less power efficiency in high temperature. PERC means passivated emitter and rear cell panel. These are the modification of Monocrystalline cell. The efficiency of these panels are increased. The PERC panel collects more radiation in less space. The thin film panels are made of very thin fine layers comes in different sizes. No requirement of frame backing makes them lighter and easy to install but less efficient. Different materials like Cadmium telluride (CdTe), Amorphous silicon (a-Si), Copper indium gallium selenide (CIGS) are used for its construction. The recycling is expensive in CdTe since cadmium is toxic in nature. The a-Si is Shapeless in nature and lowest production cost. These are suitable for very little power such as pocket calculator. CIGS has the highest efficiency in thin film types, but its efficiency is lesser than crystalline silicon panels. Table 1 shows Monocrystalline panels are up to 20% efficient. PERC panels add 5% extra efficiency than Monocrystalline panels. Polycrystalline panels have an efficiency between 15–17%. Thin film panel are 2–3% less efficient than crystalline panels. The efficiency range of CIGS is 13–15%, CdTe range is 9–11% and a-Si range is 6–8%.

Solar Pv Module and Array

The output voltage of solar cell is only 0.6V. Solar photovoltaic cell is also called PV cell. To increase the Voltage, these are connected in series. As shown in Figure 1 when it is connected in series or parallel circuit for larger Voltage or current, than we get a PV module. To get the higher range of Voltage and current, these modules are connected in series or parallel combination and become panels than these panel converted

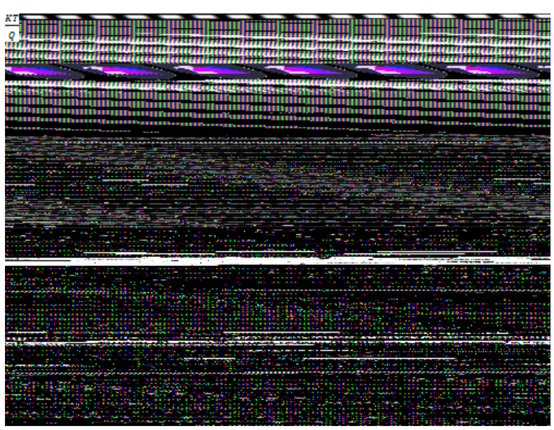

Figure 1: PV Cell, Module, Panel and Array.

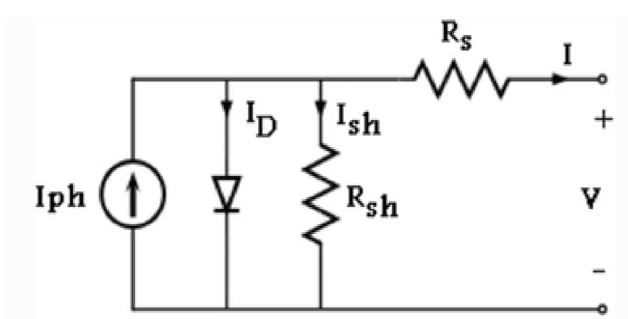

Figure 2: One Diode Model.

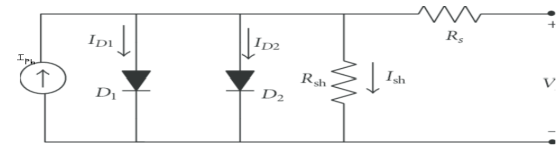

Figure 3: Two Diode Model.

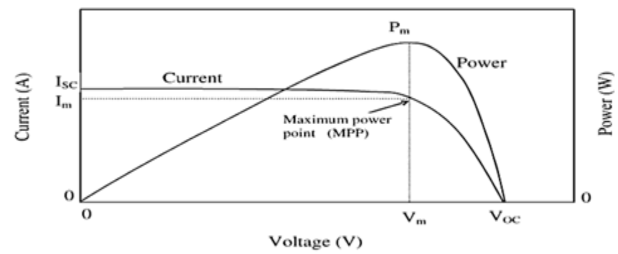

Figure 4: VI and PV Characteristics

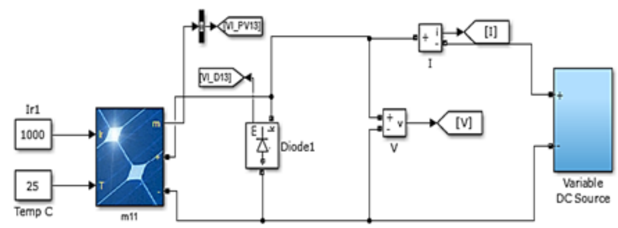

Figure 5: Matlab Simulation of PV Cell.

in to PV array. The power voltage characteristics of PV array shows that if Voltage is increased than power is also increased and at one point it reached at its maximum point after that power started decreasing. These characteristics depends on temperature and radiation. All panel characteristics written on the panel ratings are specified at standard temperature and radiation i.e. $1000W/M^2$ and 25°C.

PV Array Models

In literature review there are many models for the mathematical modelling of PV cells. One is one diode model and other is two diode model.

One Diode Model

The Figure 2 shows one diode model of PV cell. In this a current source Iph is connected across a diode. A series and parallel resistance Rs and Rsh respectively connected in the circuit.

he photo current is given by this equation:

$$I = I_{ph} - I_d - I_{sh} \quad (1)$$

$$I = I_{ph} - I_s\left[e^{\frac{V+IR_s}{n_s a V_T}} - 1\right] - \frac{V+IR_s}{R_{sh}} \quad (2)$$

$$V_T = \frac{KT}{Q} \quad (3)$$

It is a five parameter model here V_T is thermal Voltage

I= Output Current of PV Cell

I_d = Diode Current

I_{ph} = Photo Current

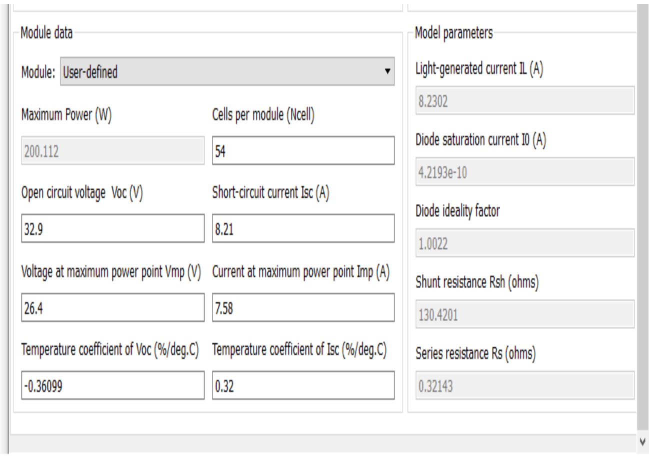

Figure 6: PV Panel Data.

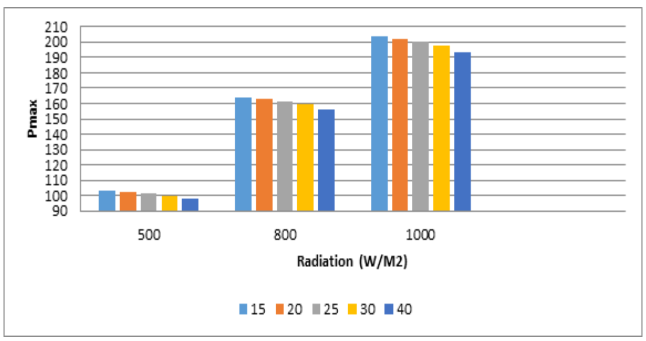

Figure 7: Variation of Pmax with Radiation and Temperature.

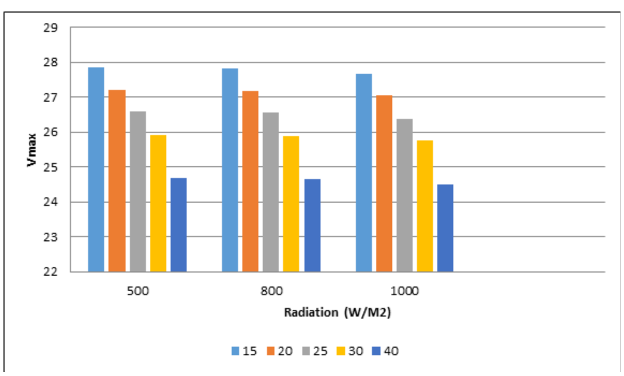

Figure 8: Variation of Vmax with Radiation and Temperature.

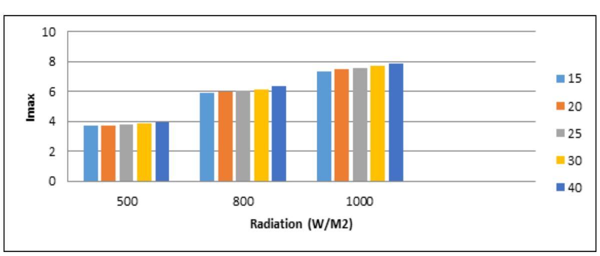

Figure 9: Variation of Imax with Radiation and Temperature.

Is = Diode Saturation Current
R_s = Series Resistance
R_{sh} = Shunt Resistance
n_s =Number of Cell in Series
a = Ideality Factor
K=Boltzmann Constant (1.3805X10-23)
T=Temperature of PV Module
Q=Electron Charge (1.6X10-19 C)

Two Diode Model

This time two diodes are used to represent equivalent circuit of PV cell. Figure 3 shows the two-diode model.

$$I = I_{ph} - I_{S1}\left[e^{\frac{V+IR_s}{n_{s1}aV_T}} - 1\right] - I_{S2}\left[e^{\frac{V+IR_s}{n_{s2}aV_T}} - 1\right] - \frac{V+IR_s}{R_{sh}} \quad (4)$$

Here I_{s1} and I_{S2} are saturation currents of diodes D_1 and D_2.

Characteristics of Pv Panel

V- I and P-V Characteristics

Figure 4 shows the VI and PV characteristics of solar PV panel. The maximum power of one solar cell can deliver at its standard test condition. If we draw the characteristics of a solar cell than at the bend point of the characteristic curve we find the peak point. P_m is the maximum power of solar cell. V_m and I_m are the Voltage and current at global peak power. V_{oc} and I_{sc} are the open circuit voltage and short circuit current of solar panel. All the rating present on solar panel are under the standard test condition

Effect of Temperature and Radiation

The solar cell are very sensitive to radiation and temperature because output power generated by the solar cell completely depends on solar radiation and the temperature. When the temperature increases, it affects all cell parameters like maximum global power, Voltage at maximum power and current at maximum power. Many times it happened that at same radiation temperature is different. This temperature variation cause the variation in characteristics of PV cell. In this paper, we have simulated the PV cell in MATLAB and observed the effect of temperature and radiation. Figure 5 shows the modeling of PV cell. Figure 6 shows the PV cell data used for modulation.

Observations

In this paper we have simulated a solar panel of 200 watt with MATLAB simulation. Table 2 shows that at temperature 25°C and radiation 500 watt/m^2, 800watt/m^2 and 1000 watt/m^2 the value of I_{max} are 3.8043A, 6.0724A and 7.5845A respectively. Similarly, at other temperatures like 15^{0}C, 20^{0}C, 30^0 and 40^{0}C it is observed that at a fixed temperature and different radiations, the value of current at a global peak is increased with the increase of radiations.

Table 3 shows that at temperatures 25°C and radiation 500 watt/m^2, 800watt/m^2 and 1000 watt/m^2 the value of V_{max} are 26.5832V, 26.5503V and 26.3858V Similarly, at other

Table 1: PV panel types and characteristics

Type	*Efficiency*	*Cost*	*Apperance*
Perc	5% more than Monocrystalline	Very high	Passivated emitter
Monocrystalline panels	20%	Costly	Dark black
Polycrystalline panels	15-17%	Less cost	Blue
Thin film panel	13-15% CIGS 9-11% CdTe 6-8% a-Si	Very less cost	Can be blue or black

Table 2: Effect of Temp and Radiation on Maximum Current

	Solar Radiation (Watt/m2)			*Temp (^{o}C)*
	500	800	1000	
	3.6905	5.8911	7.3594	15
I_{max}(A)	3.7498	5.9857	7.4679	20
	3.8043	6.0724	7.5845	25
	3.8630	6.1659	7.6910	30
	3.9692	6.3351	7.9001	40

Table 3: Effect of Temp and Radiation on Maximum Voltage.

	Solar Radiation (watt/m2)			*Temp (^{o}C)*
	500	800	1000	
	27.8663	27.83w34	27.6689	15
V_{max}(V)	27.2083	27.1754	27.0438	20
	26.5832	26.5503	26.3858	25
	25.9252	25.8923	25.7607	30
	24.6750	24.6421	24.5105	40

Table 4: Effect of Temp and Radiation on Maximum Power

	Solar Radiation (watt/m2)			*Temp(^{o}C)*
	500	800	1000	
	102.8393	163.9703	203.6272	15
P_{max}	102.0266	162.6641	201.9596	20
	101.1296	161.2232	200.1244	25
	100.1488	159.6495	198.1249	30
	97.9396	156.1093	193.6352	40

temperatures like 15, 20, 30 and 40^{o}C it is observed that at a fixed temperature and different radiations the value of Voltage at global peak is decreased with the increase of radiations.

Table 4 shows that at temperature 25^{o}C and radiation 500 watt/m^2, 800watt/m^2 and 1000 watt/m^2 the value of P_{max} are 101.1296 W, 161.2232W and 200.1244W Similarly, at other temperatures like 15, 20, 30 and 40^{o}C it is observed that at a fixed temperature and different radiations the value of power at global peak is increased with the increase of radiations.

With these tables we also can observed that at the same radiation with the increasing temperature I_{max} increased, V_{max} decreased and P_{max} decreased. Figure 7 to 9 shows the exact view of data that effect of temperature on V_{max} is higher than P_{max} and I_{max}. Effect of radiation on P_{max} is higher than V_{max} and I_{max}.

Conclusion

The effect of temperature and radiation on the generated power is studied in this paper. We find that increasing temperature will reduce the generated power and Voltage at the global peak and maximum current increases with temperature rise. The effect of temperature on Voltage is very high as compared to power and current. When radiation is increased, than power is increased considerably. Maximum Voltage and current is very less affected by radiation.

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