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# Effect of Temperature and Irradiance on Solar Module Performance

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***Abstract :*** *Solar Photovoltaic power generation systems are progressively widespread with the rise in the energy demand, to reduce consumption of fossil fuels and the concern for the environmental pollution around the world. Solar cell performance is determined by its parameters short circuit current ($I_{sc}$), open circuit voltage ($V_{oc}$), and fill factor. This paper analyses theoretically the effect of temperature, irradiance on the performance of solar cell and Module.*

***Keywords -*** *Solar PV cell, Irradiance, Temperature, Cell characteristics, Fill factor*

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## I. Introduction

Over the past decade utilization of solar energy has grown tremendously due to its advantages. These advantages include easy installing, no noise, maintenance free, inexhaustible and environment friendly. It is interesting to note that the surface of earth receives solar energy which is 6000 times the earth's energy demand. A solar PV system is powered by many crystalline and thin film PV modules. Individual PV cells are interconnected to form a module [1, 2]. This takes the form of a panel for easy installation. Photo voltaic arrays should be installed in such a way that their exposure to sun is maximized. The power provided by the PV array varies with solar irradiance and temperature. Since not all the light from the sun is absorbed by the solar panels, most of them have a 40% efficiency of conversion and most of PV panels are around 15–18% efficient. Therefore to increase the output efficiency of PV the PV energy conversion systems need to operate near maximum power point (MPP).

Currently, the majority of the solar photovoltaic (PV) applications are grid connected nature, which involves the PV modules connected to the utility grid through a power processing stage like grid-tie inverters, which convert dc power generated from PV modules to ac power used for ordinary power supply to electric equipments [4,5]. Here the authors study the temperature dependence of the performance parameters of PV solar cell and PV module.

## II. Solar PV Modeling

A material or device that is capable of converting the energy contained in photons of light into an electrical voltage and current is said to be photovoltaic. The generated current differs linearly with the solar irradiance. The characteristics of PV module are the basic requirement for tracking the maximum power points (MPPs) using any MPPT technique. For characterizing the solar PV module [7], it is required to model the characteristic equation from an electrical equivalent of solar cell (module) as in following figure:

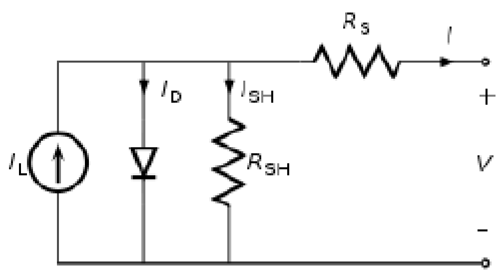


Fig: Equivalent model of a solar PV cell

The current produced by the solar cell is given by:
$I = I_L – I_D – I_{SH}$ (i)
where,
I = output current (amperes)
$I_L$ = photo generated current (amperes)
$I_D$ = diode current (amperes)
$I_{SH}$ = shunt current (amperes).
The current through these elements is governed by the voltage across them:

$Vj = V + IR_S$ (ii)
where,
Vj = voltage across both diode and resistor $R_{SH}$ (volts)
V = voltage across the output terminals (volts)
I = output current (amperes)
$R_S$ = series resistance (Ω).

By the Shockley diode equation, the current diverted through the diode is:

$$I_D = I_0 \left\{ \exp\left[ \frac{qV_j}{nKT} \right] - 1 \right\} \qquad \text{(iii)}$$

where,
$I_0$ = reverse saturation current (amperes)
n = diode ideality factor (1 for an ideal diode)
q = elementary charge
K= Boltzmann's constant
T = absolute temperature
At $25^0$C, $\frac{KT}{q} \approx 0.0259\, volts$
By Ohm's law, the current diverted through the shunt resistor is:

$$I_{SH} = \frac{V_j}{R_{SH}} \qquad \text{(iv)}$$

Where $R_{SH}$=Shunt resistance (Ω).
Substituting these into the first equation produces the characteristic equation of a solar cell, which relates solar cell parameters to the output current and voltage:

$$I = I_L - I_0 \left\{ \exp\left[ \frac{q(V + IR_S)}{nKT} \right] - 1 \right\} - \frac{V + IR_S}{R_{SH}} \qquad \text{(v)}$$

Since the parameters *I0, n, RS,* and *RSH* cannot be measured directly, the most common application of the characteristic equation is nonlinear regression to extract the values of these parameters on the basis of their combined effect on solar cell behavior.

Since an individual cell produces only about 0.5 V, for most PV applications a module consisting of a number of pre-wired cells in series, all encased in tough, weather-resistant packages is used. A typical module has 36 cells in series and is often designated as a “12-V module” even though it is capable of delivering much higher voltages than that. Multiple modules, in turn, can be wired in series to increase voltage and in parallel to increase current, the product of which is power. An important element in PV system design is deciding how many modules should be connected in series and how many in parallel to deliver whatever energy is needed. Such combinations of modules are referred to as an array. When photovoltaic are wired in series, they all carry the same current, and at any given current their voltages add. Modules can be wired in series to increase voltage, and in parallel to increase current. Arrays are made up of some combination of series and parallel modules to increase power. Figure1 illustrates schematic diagram of photo voltaic cell, module and array.

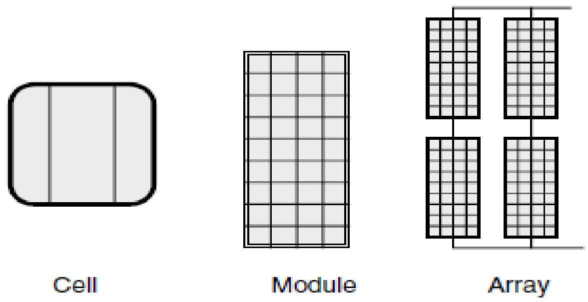


**Fig 1:** Photovoltaic cell, module, array

Another quantity that is often used to characterize module performance is the *fill factor* (FF). The fill factor is the ratio of the power at the maximum power point to the product of $V_{OC}$ and $I_{SC}$. Fill factors around 70–75% for crystalline silicon solar modules are typical, while for multi junction amorphous-Si modules, it is closer to 50–60%.

$$Fillfactor = \frac{Power\,at\,maximum\,Power\,Point}{V_{OC} I_{SC}} = \frac{V_R I_R}{V_{OC} I_{SC}}$$

There are various ambient conditions that affect the output of a PV power system. These factors should be taken into consideration so that the customer has realistic expectations of overall system output. Module temperature is a parameter that has great influence on the behavior of a PV system, as it modifies system efficiency and output energy. In addition to this, the atmospheric parameters such as irradiance level, ambient temperature, dirt/dust and the particular installing conditions also have influence on the performance of a PV system.

## III. Simulation Results and Analysis

**Solar Panel specifications:** Specifications of the solar panel considered [3]

| Parameter | Variable | Value |
|---|---|---|
| Maximum Power | $P_m$ | 60 Watts |
| Voltage @ $P_m$ | $V_m$ | 17.1 volts |
| Current @ $P_m$ | $I_m$ | 3.5 Amps |
| Short circuit current | $I_{sc}$ | 3.8 Amps |
| Open Circuit voltage | $V_{oc}$ | 21.1 volts |
| Temperature coefficient of $V_{oc}$ | B | -(80±10) V/°C |
| Temperature coefficient of $I_{sc}$ | α | (0.0065±0.015)%/°C |
| Temperature coefficient of NOCT | | -(0.5±0.05) %/°C |

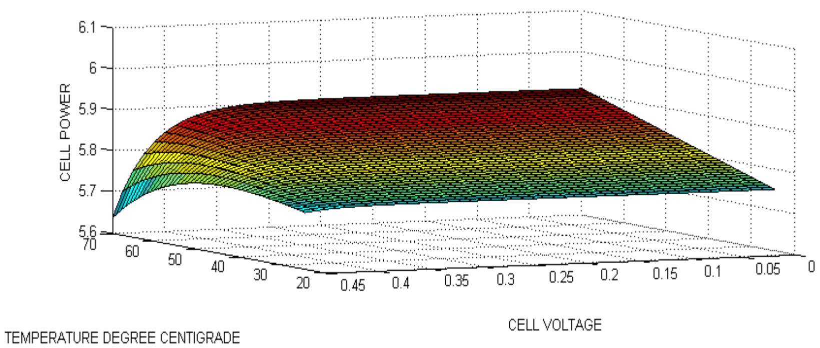


**Fig-2:** Variation in the cell-power with the cell-voltage and Temperature (in °C)

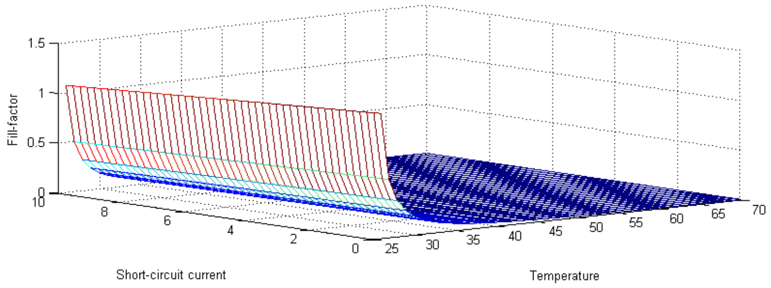

**Fig-3:** Variation in the Fill-factor with the Short-circuit current and Temperature (in $^{o}C$)

The effect of temperature on the Fill factor of the cell with variation in the short-circuit current of the cell in the range of 0-10 Amps is shown in but there Fig-3, it is observed that with increase in the temperature the Fill factor decreases as shown in Fig-3. Also the effect of Irradiance on the Fill factor is shown in Fig-4.

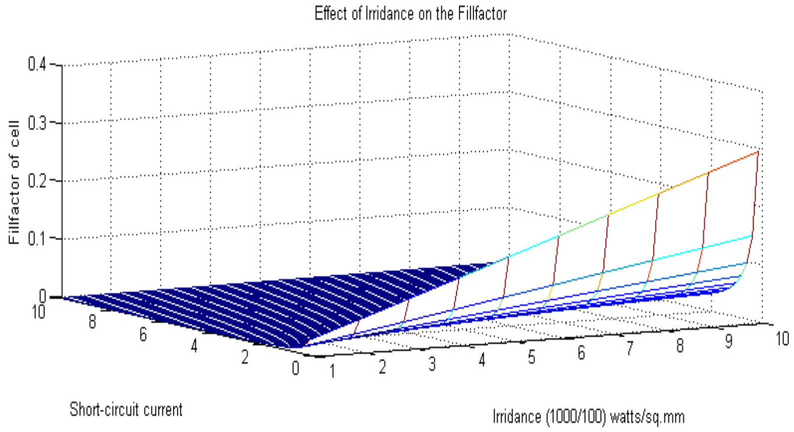

**Fig-4:** Variation in the Fill-factor with the Short-circuit current and Solar Irradiance (Watts/sq.mm)

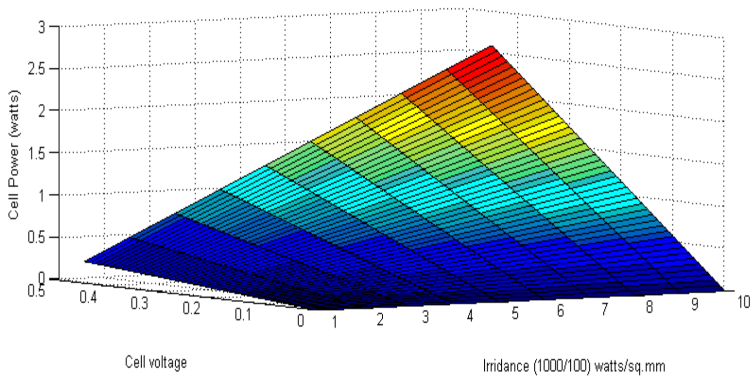

**Fig-5:** Variation in the Cell-power with the Cell-voltage and Solar Irradiance (Watts/sq.mm)

The effect of variation in the solar Irradiance on the P-V characteristics of the cell is shown in Fig-6, it is observed that with the increase in the solar irradiance the cell-voltage and cell-power increases.

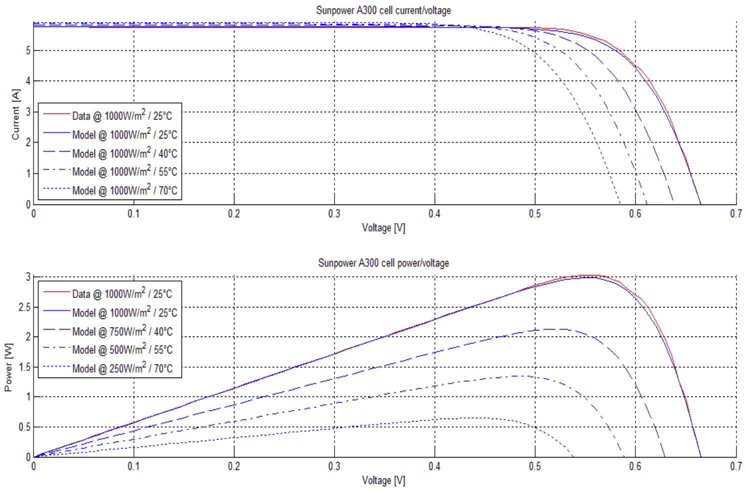


**Fig-6:** V-I and P-V characteristics of the considered PV solar Cell with the variation in Irradiance

The effect of temperature on the P-V characteristics of Module have been studied with the temperature variation in the range of $25^{o}$ C and $50^{o}$ C, for different Irradiances is shown in Fig7.

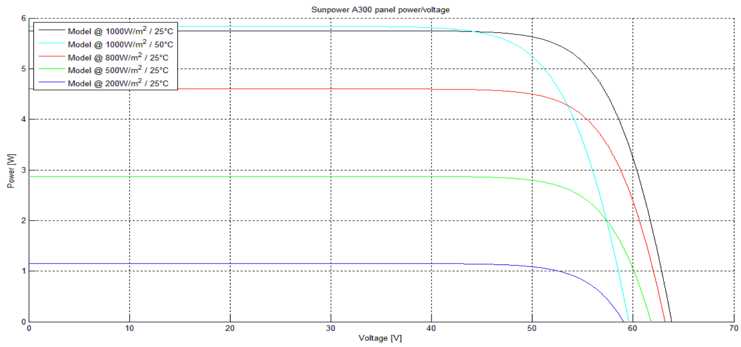


**Fig-7:** Variation in the Module-voltage with the Module-current for different Irradiances (Watts/sq.mm) and Temperature (in $^{o}$C)

## IV. Conclusion

The considered solar PV cell characteristics have been presented with specifications. The PV cell has been tested under different temperature and Irradiance conditions and their effect on the power output and the Fillfactor of the cell have been presented. Also the basic V-I and P-V characteristics of the PV cell and P-V characteristics for a Module with 92 cells connected in series have been obtained for different temperature and Irradiance conditions. The three-dimensional plots analyze the variation in the fillfactor and the power output of the cell with Temperatures and Irradiances has been presented.

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