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Study of Effects of Environmental Parameters on PV Performance Using Simulation/ Mat Lab

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Abstract—*There is a need of development of high-performance PV conversion system and study of effects of environmental parameters to make it economic viable and stable in integration with the utility grid. The PV system produces electric power with no hampering the atmosphere by straight converting the solar radiation into electric power. On the other hand, the solar radiation, not at all, remains stable. It keeps on unbalanced all over the day. The demand of the hour is to send unchanging voltage to the grid irrespective of the deviation in solar irradiance and temperatures. The consumer wants to run the solar panel at its maximum energy transfer output by constantly utilizing the highest accessible solar power of the panel. Solar scheme The output of PV module depends on the cell temperature and the solar insulation. In this paper a study has been carried out on the effects of environmental parameters on PV performance using simulation/ mat-lab.*

Keywords: *Solar irradiance, solar system, PV cell, module, current source, open circuit voltage, standard conditions, optimal value, economic viable.*

1. INTRODUCTION

A module normally has a numeral of solar cells in series. The predictable system to representation a solar cell is to revise the p-n junction physics [2]. A solar cell contains a non-linear current-voltage (V-I) characteristic that is to be modeled by means of diode(s), resistors, and current source. Double-diode and single-diode models are generally utilized to create PV characteristics.

PV cells changes the sunlight honestly to electricity. **Fig.1. (a)** presents the PN junction and **1.(b)** presents the solar current generation principle of PV cells. Actuality, as soon as sunlight falls on the solar cell, the photons are held by the semiconductor atoms, bitter electrons from the negative level. These liberated electrons finds its pathway throughout an outdoor circuit towards the positive level consequential in an electricity current from the positive level to the negative one.

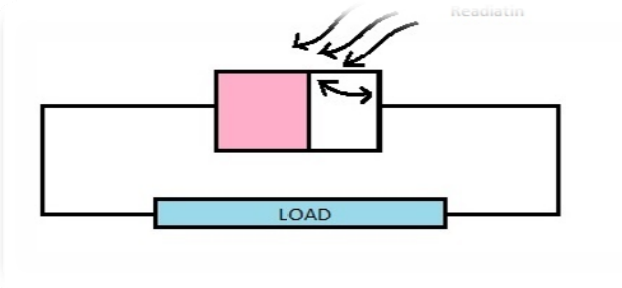

Fig. 1. (a) PN Junction

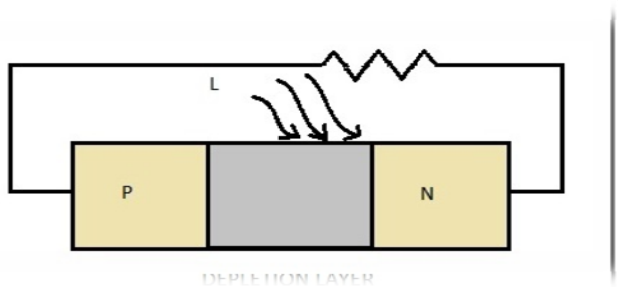

Fig 1.(b) Photo Current Generation

A solar cell produces a voltage something like 0.6 to 0.8 volts depending on the semiconductor and the built-up expertise. The voltage is very small, insufficient, as it is of no use. Consequently, to get advantage from this expertise, tens or more of solar Cells are linked in series to form a module. These modules will be interrelated in series and or parallel to make a panel. When the modules are linked in series, their voltages are additional with the same current and when they are joined in parallel; their currents are additional though voltage is same.

2. MATHEMATICAL MODEL OF A PV CELL:

The model is simulated on the base of some electrical equations and basic theorems. The model is considered as an equivalent circuit, having a diode, a photo current source, shunt resister and a series resister.. The most commonly-used models of solar cell is illustrated in Fig 2. (a), (b), (c), having a current source, in parallel through one or two diodes . The model presented in fig 2.(b) is a two diode model [7-9]. This model has additional diode for enhanced correct curve. A simple single-diode [4-6] equivalent circuit diagram has been shown in fig 2.(c), This has been considered for simulation purpose. The model contains four parameters, a solar current source, diode, series resister (Rsh), and shunt resister (Rs).

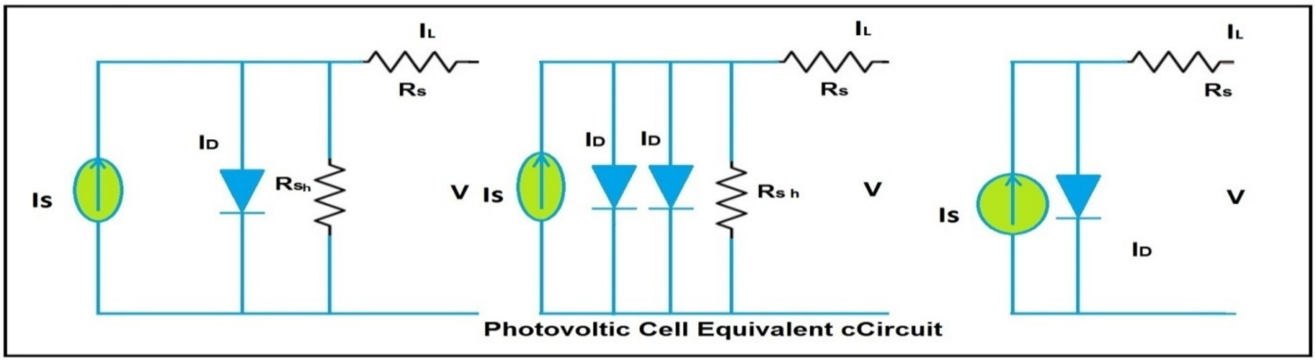

Fig. 2: Solar-cell equivalent-circuit diagrams models (a) Single-diode (b) Two-diode (c) Simplified-solar-equivalent circuit

2.1. Simplified Equivalent Circuit:

The value of shunt resistance (Rsh) is excessively huge; subsequently it is not considered and neglected in the modified circuit [8]. **Fig.2. a)-** The 4- parameter models [**Fig 2 (a)**] can be simplify addicted to **Fig.2 (c).** The correlation between the output voltage and the load current as given below.

$$I_L = I_S - I_D = I_L - I_D \{\exp(\frac{V+I_L R_S}{\alpha}) - 1\} \quad (1)$$

where, I_S = Solar current (A); I_D = leakage current (A);

I_L = Current through load (A); V = Output voltage of cell(V);

Rs = Series resistance (Ω); α = Thermal voltage factor (V);.

The four parameters of solar cell are *IL*, I_D , *Rs*, and α which are to be determine to get the current and voltage relationship. The methods to calculate these parameters are presented herewith, the solar current, (I_S) , is to be estimated as ,[10-12],

$$I_S = \frac{\emptyset}{\emptyset_{SC}} = [I_{S,,SC} + I_{,SC} (T_C - T_{C,,SC})] \quad (2)$$

where, Ø = Solar irradiance at any instant, (W/m2);

$\emptyset_{SC}$= irradiances at standard condition (1000 W/m2) is used in the case,

$I_{S,sc}$ = solar current at the standard condition; T_C = solar cell temperature at any instant,

$T_{C,SC}$ = temperature at standard condition;

I_{SC} = temperature coefficient of the short-circuit current at standard condition (A/°C);

Saturation Current I_D ; is to be represented by its value at standard conditions [10-12]:

$$I_D = I_{D,SC} \{\frac{T_{C,,SC+273}}{T_C+273}\}^3 \exp [\frac{\propto_{SC} N_S}{q\propto_{sc}}\{ 1 - \frac{T_{C,SC}+273}{T_C+273}\}] \quad (3)$$

where, $I_{D,SC}$ = leakage current (A) at standard conditions

e gap = Band gap of Si (1.17 eV for Si), *Ns* = Total number of solar cells in series

q = Charge held by single electron (1.60217733×10-19 C),

$\propto_{SC}$ = ∝ at standard conditions;

$I_{D,SC}$ is to be estimated from the equation as given

$$I_{D,SC} = I_{S,sc} \exp\{ -\frac{V_{OC,sc}}{\propto_{sc}} \} \quad (4)$$

where, $V_{OC,SC}$ = Open-circuit voltage at standard condition (V) of the PV module.

In [10-12], state that $\propto_{SC}$ is to be estimated from equation given below.

$$\propto_{SC} = \frac{2\,V_{mp,SC} - V_{oc,,SC}}{\frac{I_{sc,,SC}}{I_{sc,SC}} + In\left[1 - \frac{I_{mp,SC}}{I_{sc,SC}}\right]} \quad (5)$$

where, *Vmp,sc* = Maximum voltage (V) at standard conditions,

Imp,sc = Maximum current (A) at standard conditions,

Isc,sc = short-circuit current (A) at standard conditions

.α is related with temperature, presented, as:

$$\propto = \frac{T_C + 273}{T_{C,,sc+273}} \propto_{ref} \quad (6)$$

The equation is to be utilized to find out the value of series resistance Rs [11, 12]

$$R_S = \frac{\propto_{sc}\{1 - \frac{i_{mp,sc}}{I_{SC,sc}}\} + V_{OC,sc} - V_{mp,sc}}{I_{mp,sc}} \quad (7)$$

2.2 PV Cell Operating Points : .

The *current-voltage* working distinctiveness of a solar cell has been illustrated in Fig 3.The parameters of a PV array are estimated in the ways given below.

$$I_{tot} = N_p \text{ Is}$$

$$V_{tot} = N_S \text{ Vs}$$

$$R_{s,tot} = \frac{N_S}{N_S} Rs \quad (8)$$

Where, I_{tot} = Total current of PV module; V_{tot} = Total voltage of PV module;

$R_{s,tot}$ = Total series resistance of PV module; Rs = series resistance of PV module;

N_S = Number of PV cells in series; N_p = Number of PV cells in parallel,

The voltage output of PV module is estimated via multiplying the number of cells joined in series with the voltage of an individual cell and total current through multiplying the number of cells associated in series with the current of an individual cell. Similarly the series and parallel resistance of PV array can be estimated. The operating points are short-circuit current ,open circuit voltage, and maximum power point. These points are identified operating points.

The open-circuit voltage is represented by point A on the working characteristics of a PV array as shown in **fig 3**.The corresponding circuit at O.C condition has been presented in **fig 4**.and neglecting the shunt resistance (Rsh), the equations (9) and (10) are to be utilized to symbolize the open- circuit voltage. and PV array current.

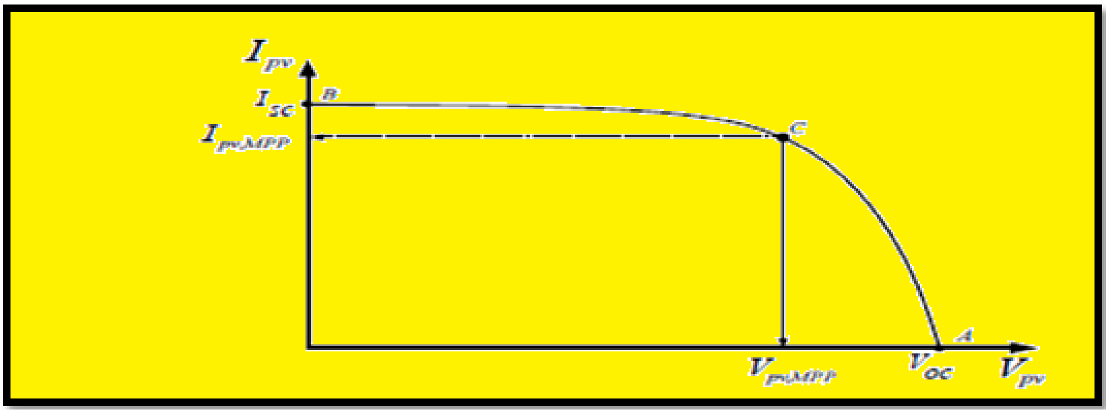

Fig. 3: Solar array operating points.

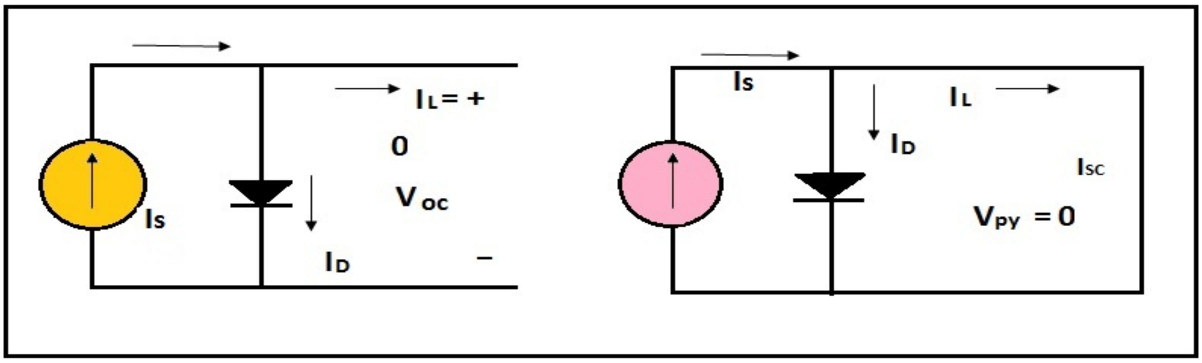

Fig. 4: Electrical circuit at O.C condition Fig.5: Electrical circuit at S.C condition

- $I_s - I_0 [\exp(\frac{V_{OC}}{\propto}) - 1] = 0$ (9)
- $V_{OC} = \propto \text{In} (\frac{i_l + I_0}{I_0})$ *(10)*

The current at point B in graph **fig 3** represents the short-circuit current. The equivalent circuit at short circuit condition is shown in **fig.5**, Neglecting; the series resistance, short circuit is represented by equation

$$Isc = Is \quad (11)$$

The load current at short circuit condition becomes equal to the solar current generated by PV module and the output voltage becomes zero. In case of open circuit voltage, the load current becomes zero, while the open circuit voltage will be the maximum voltage of the PV module..

2.3. Load Characteristics Curve :

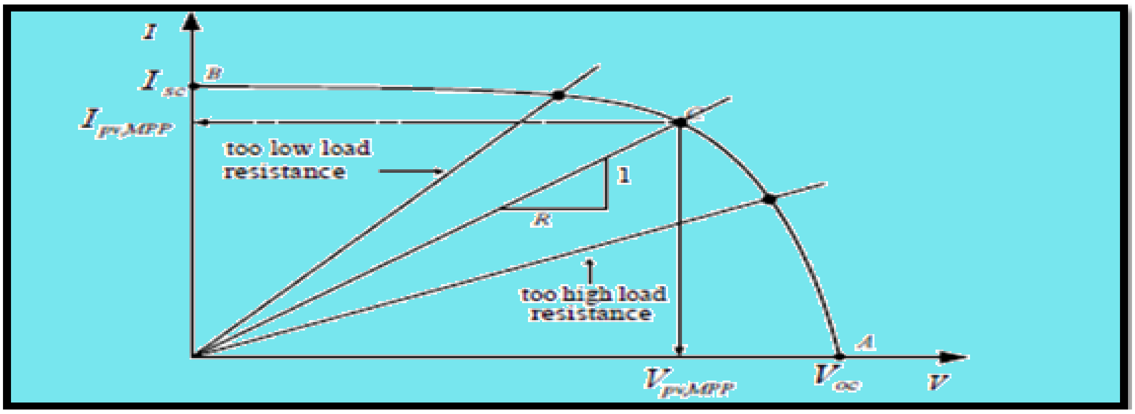

Fig. 6: Working site of a PV module under stable irradiance and temperature

The meeting point of the load characteristics *and I-V* characteristics is the working point of a solar array under stable irradiance and solar cell temperature as shown in **Fig.6**.The load characteristic is signified via a straight line by means of slope *M=1/R= I Load/V.* The working spot moves about through the side of the *I-V* typical graph, i.e. from point B to point A, as load resistance enlarges beginning 0 to ∞. The utmost power spot lies at B, wherever the area below the *I-V* characteristic graph is highest. In favor of very high load resistances, the working spots leaves in to the CA section. For very-low load resistances, the working spot leaves in to the CB section. The highest power point is to be consequently, attained via matching load resistance to PV panel distinctiveness [13].

3. SOLAR ARRAY CHARACTERISTICS :

The solar current is non- linear variable and its value depends on solar irradiance. The output voltage and current of a solar module changes with variation in temperature and irradiance [5]. The characteristics of PV-cell depend on insulation and temperature; refer equations from (1 to 6). These equations are evaluated for some selected values of irradiance and temperature. The I-V graph is plotted from the evaluated values.

The output current (I_S) of a PV array *is* subjective to change in values of insulation *S*, while, output voltage (V_o) is about stable, as shown in **Fig.7.(a)**. Defiantly, for the temperature so as to changes, output voltage appears to vary generally, but current is unaffected; as shown in **Fig.7(b).** The *P-V* characteristics of solar module are to be get as of *I-V* characteristics. The power output relationship is presented as ***P=Vo.I.***

The expected behavior of a solar-energy-conversion system is also confirmed from **fig.7**, The output power decreases by declining in the value of irradiations. The decreased-power results from enlarged panel-temperature is not instantly clear, however is concordant through considerable consequence on open-circuit voltage Voc.

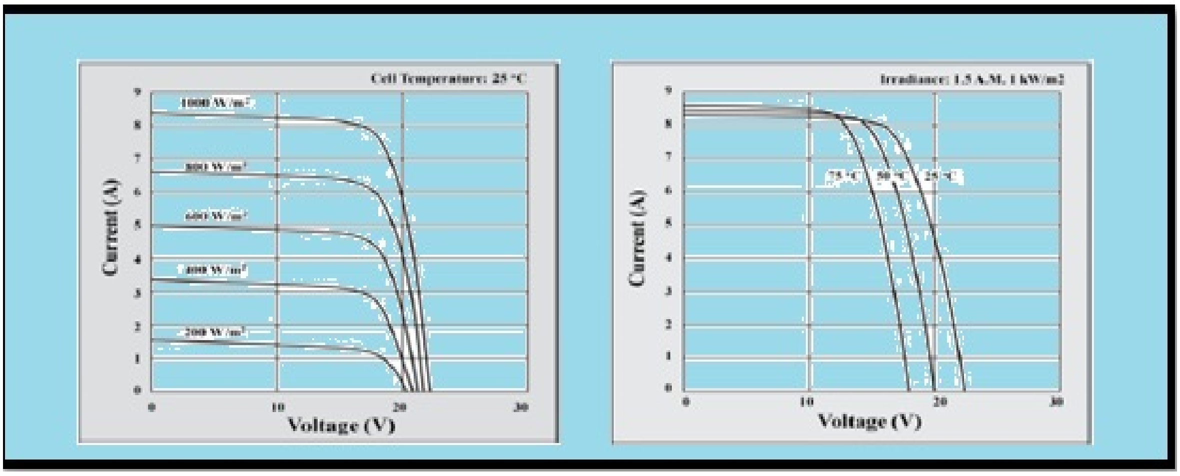

Fig 7: I-V graphs of a PV module [14] (a) for divergent values of irradiance S at 25℃ (b) for dissimilar values of temperature T at 1000W/m2

3.1 Correlation between Open Circuit Voltage and Temperature:

The voltage Output of a module, is in fact a changeable value, that is dependent on temperature. There is in fact an reverse correlation between module voltage and temperature as illustrated in **Fig.9.** As soon as the module's temperature is increased, the value of voltage decreases and vice versa. When the module's temperature is less than the standard test condition value of 25°C, the module's open circuited voltage, Voc value will, really, be better than the value mentioned in label.

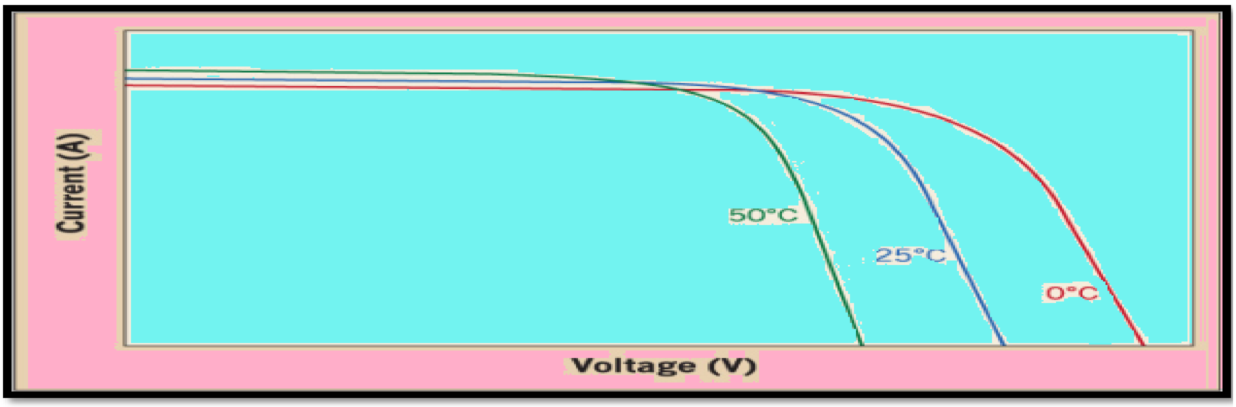

Fig. 9: V-I characteristics of a PV module with temperature variation

let's consider the voltage temperature coefficient is − 0.087℃ . This means that for each degree alter in temperature, the module's open-circuit voltage, Voc is to be adjust in the opposite direction with 8.7%. A case to the point, while the PV module get colder with 1°C, the solar voltage will raise by 8.7%. let's assume the most terrible case of temperatures has been taken in [14] it shows for the facts recorded the standard maximum temperature was 14.4**°C** with irradiance of 123W/m2h in the month of December. Whereas the minimum standard temperature was obtained in January and the facts recorded was -3.4°C with irradiance of 18W/m2 h.

The procedure has been given in [15] may be use to work out the standard highest and least voltages of the modules. While the string voltage in the case would have a voltage, Voc is obtained to be 300 V. Considering as noted in [14], the functioning temperatures of the module is to be from -10°C to 50°C.

$$V_{OC} = V_{OC,SC} - [\, \beta \times (T - T_{STC})\,] \tag{11}$$

where,

V_{OC} = open circuit voltage, (V) $V_{OC,SC}$ = open circuit voltage at standard condition

β = voltage temperature coefficient, T = temperature of PV module at any instant

Consequently using equation (11) for the most terrible atmosphere conditions we have the lowest and highest open circuit voltage as 296.9V and 302.2V respectively. This gives the voltage alteration of around to $\Delta V = 5V$.

3.2 Correlation between Current and Irradiance:

The current generated by PV module is directly proportional to light density Advanced levels of irradiance will drive extra electrons to run from the PV cells to the attached load. Conversely, the voltage produced by the PV module is exaggerated by the irradiance value, but the outcome is very small. As illustrated in Fig.10, the voltage of module changes extremely small with unstable levels of irradiance.

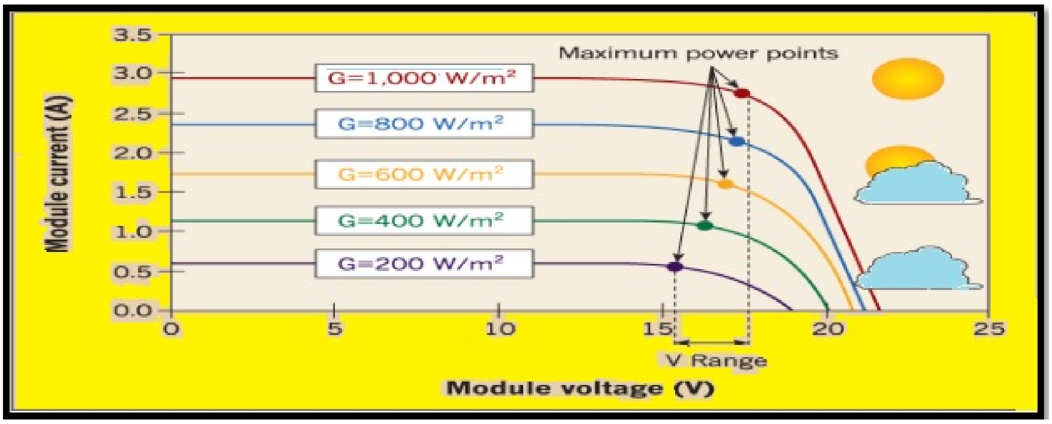

Fig. 10: I-V characteristics of a PV module with irradiance variation [62]

4. SIMULATIONS RESULTS :

The parameters of solar modules are specified at particular environment. The *P-V* curves and *I-V* curves have been simulated for a choice of irradiances and temperatures by means of MATLAB. The module's parameters are presented in table 1

Table 1: Parameter of reference PV Module

Parameter	Values
Number of cells in a module	96
Reference Solar irradiance	G= 1000 W/m^2
Open circuit Voltage Voc (V)	64
Short-circuit current Isc (A)	5.96
Current at maximum point Imp (A)	5.54
Voltage at maximum point Vmp (V)	54.7
Ideality factor m	1.2
Temperature coefficient of voltage Ki=	-0.286
Temperature coefficient of current Ki=	0.062
Series résistance	R_S =0.272
Shunt resistance	R_{SH}=271.6

A study is carried out on simulation model to predict how the P-V and I-V characteristics changes with the variations of irradiance and temperature in a PV module. In this segment, a standard I-V curve and P-V curve are offered. The PV Module type Sun power SPR-305E-WHT-D. has been taken to use in the experimental purpose.

4.1 Simulation of PV Module at standard condition:

- **Fig. 11 (a**) shows, *I-V* graph for stable irradiances (1000W/m^2) and stable temperatures (25°C) **Fig.11(b)** Module's *P-V* graph for stable irradiances (1000W/m^2) and stable temperatures (25°C).

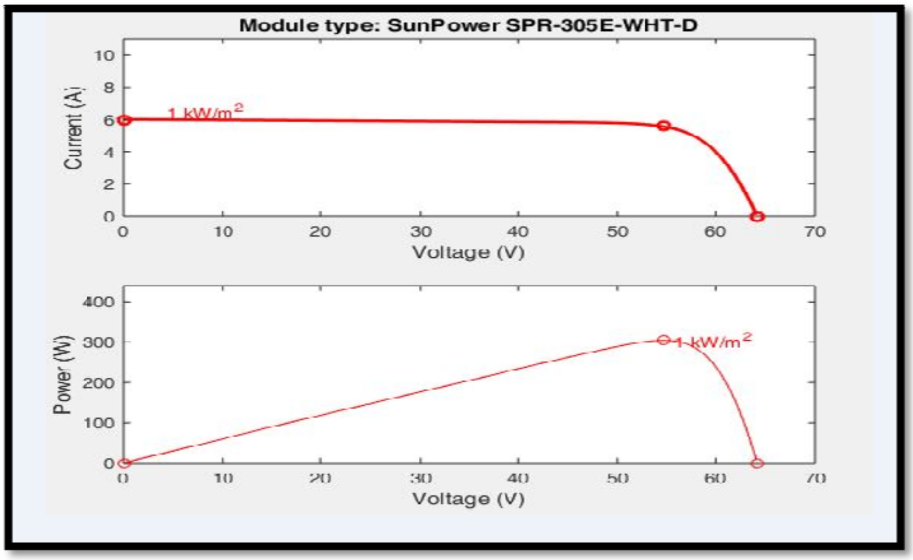

Fig. 11 Module's (a) I-V curve (b) P-V curve at standard test conditions

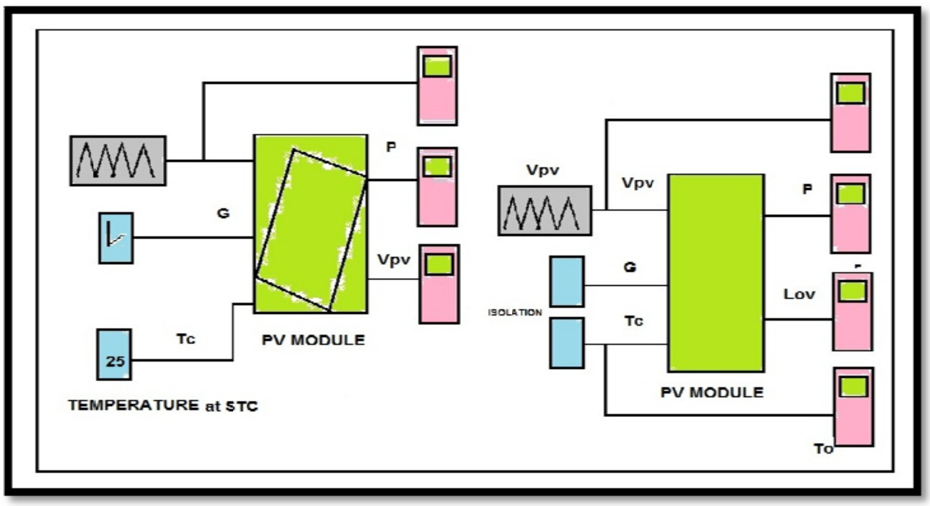

Fig. 12 (a) Solar module for unpredictable irradiance and stable temperature

Fig. 12(b): Solar module model for unpredictable temperature and stable irradiance

- **Fig.12 (a),** it presents solar module that has been modeled and simulated in Mat lab/for unpredictable irradiance and stable temperature at 25 °C. The model has been developed from equation (1 to 10). Fig.12 (b) offers PV modeled module on Mat lab **based** on the outcome of the temperature.

4.2 Simulation when G varies from 400 to 1000 w/m^2 at 25°C.

Fig. 13 (a) presents a *I-V* graph for variable irradiances and stable temperature, The irradiances varies between 400 to 1100 W/m2, while the temperature has been set up at 25 °C.. While the irradiance is enlarged, the current is also raised. Voltage, whereas, continued comparatively stable all over the irradiance range. Fig.13 (b) shows the P-V graph for variable irradiance and at 25℃ constant temperature.

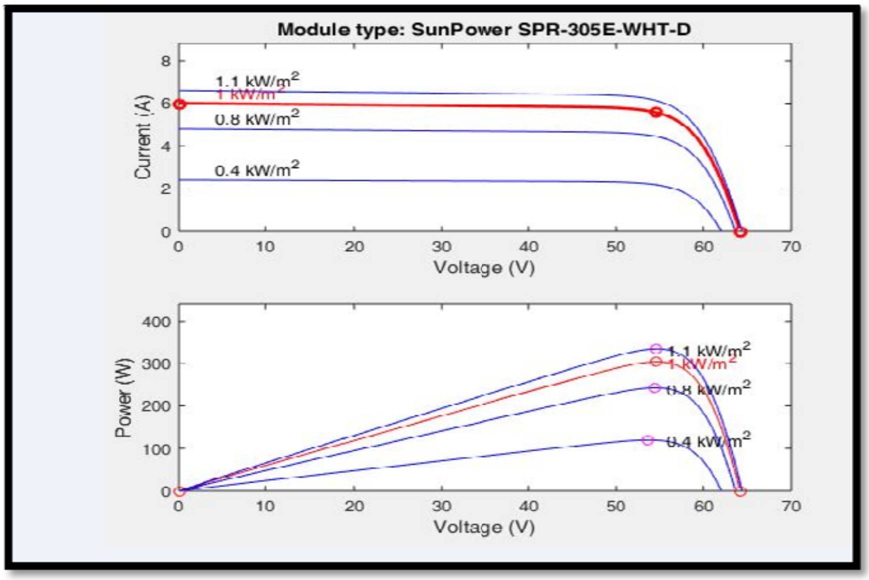

Fig. 13 Module's (a) *I-V* curves (b) *P-V* curves for unpredictable irradiance and stable temperature

4.3 Simulation when T varies from 0 ℃ to 75 ℃, at 1000 w/m^2

The Output voltage of a module is dependent on temperature. There is in fact an opposite correlation between module voltage and temperature as illustrated in **Fig.14 (a) &(b)** As the module's temperature is increased, the value of voltage decreases and vice versa. It has been observed that lesser the temperature, the maximum power is higher and the open circuit voltage is better. In addition, a smaller temperature provides to some extent small short circuit current.

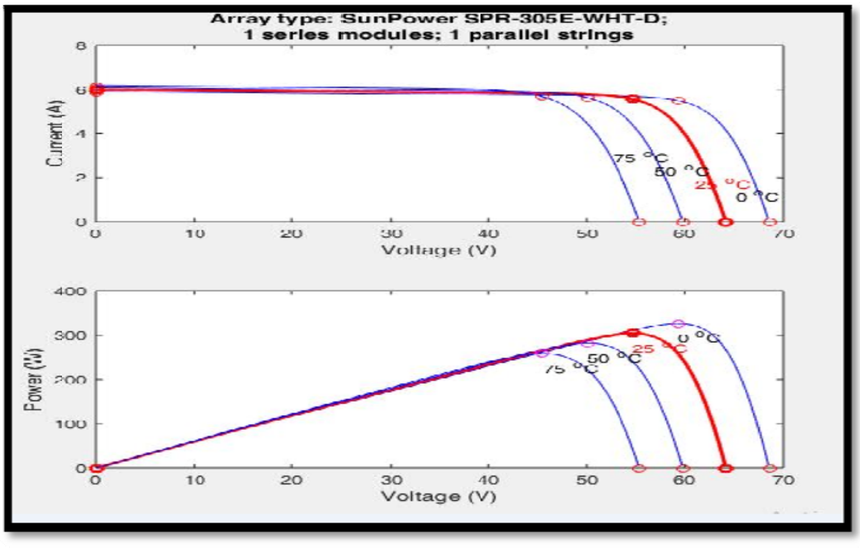

Fig. 14 (a) Module's *I-V* (b) *P-V* for various temperatures and stable irradiance

4.4 Effect of series resistance changes

The standard P-V and I-V graph has been compared with the P-V and I-V curve of solar module. The I-V and PV graphs have been taken on Mat-lab with variable resistance in series and parallel to study the effect of variable resistance. The study shows that PV Cell has low series resistance. In some case, it is neglected. While, in the study the value of resistance is varied, to predict the effect of resistance on the output of the solar cell., the deviation of Rs affects the slope of the I-V graph. It can also be seen that the series resistance causes an inward bending at the corners of the I-V and P-V curve, Curves with no changes in Isc or Voc. The optical value of series resistance is o.272 ∩ at which maximum power is obtained

5. SIMULATION SUMMARY:

A solar cell model by means of Mat lab has been introduced. This model is on the basis of fundamental electrical circuit equations. The simulation results offer the viability of the projected model. A MATLAB draft permits to verify the panel output in unusual weather circumstances. It can be seen that a raise in temperature leads to reduce in open circuit voltage and a small decline in short circuit current for a specified solar irradiance whereas boost in irradiance leads to better boost in short- circuit current and small raise in open circuit voltage at a specified temperature.

The study shows the effects of parameters (Rs, Rsh) of the PV Cell on I-V and P-V curve. The simulation results also show that lesser the series resistance (Rs), privileged the open circuit voltage and in case of rising of shunt resistance (Rsh), output voltage increases. The optimal values of series resistance, and shunt resistance of reference module are 0.272Ω, and 271.6 Ω respectively at which highest power is obtained. The model has excellent accuracy in generating the P-V and I-V curves. Moreover, the model can be built for any general purpose in simulation software.

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