International Journal of Advance Research in Science and Engineering
Volume No.07, Issue No.05, May 2018
www.ijarse.com
IJARSE
ISSN: 2319-8354

Experimental analysis of I-V and P-V characteristics for series and parallel combination of PV modules

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ABSTRACT

The renewable energy has increased much attraction these days as it can be recycled. The solar energy can be able to transform solar energy in to electrical energy, which is more efficient than other renewable sources. PV module is characterized by its I-V and P-V characteristics. The output power of PV system is always changing with whether condition. Thus the proposed system should present the experimental analysis showing the I-V and P-V characteristics of PV system under different temperature and irradiation with two panels are connected in series and parallel. The experimental analysis provides that the effect of irradiation and temperature on series and parallel connected PV module. It has been performed by using solar PV panel.

Keywords- Characteristic, Irradiation, I-V, P-V, PV module, Temperature

1. INTRODUCTION

A solar cell is a device that converts the energy of sunlight directly into electricity by the photovoltaic effect. Sometimes the term solar cell is reserved for devices intended specifically to capture energy from sunlight. The most commonly known solar cell is configured as a large area p-n junction made from silicon. As a simplification, one can imagine bringing a layer of n-type silicon into direct contact with a layer of p-type silicon. In practice, p-n junctions of silicon solar cells are not made in this way, but rather by diffusing an n-type doping into one side of a p-type wafer (or vice versa) on of PV modules.

As per Fig. 1 if a piece of p-type silicon is placed in intimate contact with a piece of n-type silicon, then a diffusion of electrons occurs from the region of high electron concentration (the n-type side of the junction) into the region of low electron concentration (p-type side of the junction). When the electrons diffuse across the p-n junction, they recombine with holes on the p-type side. The diffusion of carriers does not happen indefinitely, however, because charges build up on either side of the junction and create an electric field which prevents the further diffusion of charge carriers. The region where electrons and holes have diffused across the junction is called the depletion region because it no longer contains any mobile charge carriers. It is also known as the space charge region. This phenomenon can be understood easily by following diagram.

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ISSN: 2319-8354

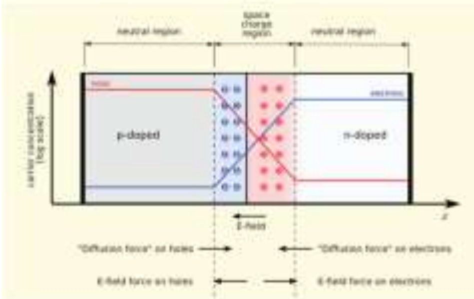

Fig. 1 Formation of P-N junction

When a photon hits a piece of silicon, one of three things can happen

1) The photon can pass straight through the silicon — this (generally) happens for lower energy photons,

2) The photon can reflect off the surface,

3) The photon can be absorbed by the silicon, if the photon energy is higher than the silicon band gap value. This generates an electron-hole pair and sometimes heat, depending on the band structure.

When a photon is absorbed, its energy is given to an electron in the crystal lattice. Usually this electron is in the valence band, and is tightly bound in covalent bonds between neighboring atoms, and hence unable to move far. The energy given to it by the photon "excites" it into the conduction band, where it is free to move around within the semiconductor. The covalent bond that the electron was previously a part of now has one fewer electron — this is known as a hole. The presence of a missing covalent bond allows the bonded electrons of neighboring atoms to move into the "hole," leaving another hole behind, and in this way a hole can move through the lattice. Thus, it can be said that photons absorbed in the semiconductor create mobile electron-hole pairs. These mobile charge carriers are responsible for the current conduction across the junction.

2. CHARACTERISTIC CURVES

Solar cell can be represented by an equivalent circuit also. This circuit also includes the losses due to the solar cell manufacturing process. In this circuit Rs is the series resistance associated with the cell which is due to the grids above the solar cells and interconnection of solar cells. R_{sh} is the parallel resistance with cell which represents the leakage current through the cell. Equivalent circuit of cell is shown in Fig. 2.

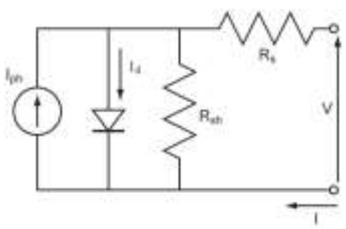

Fig. 2 Equivalent Circuit of Solar PV Cell

PV module is characterized by its I-V and P-V characteristics. At a particular level of solar insolation and temperature it will show a unique I-V and P-V characteristics. These characteristics can be altered as per requirement by connecting both modules in series or parallel to get higher voltage or higher current as shown in Fig. 3(a) and 3(b) respectively.

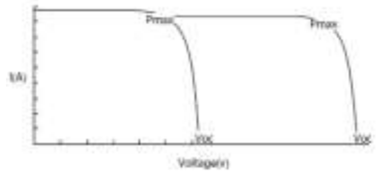

Fig. 3(a) I-V characteristic of series connected modules

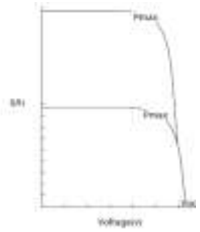

Fig. 3(b) I-V characteristic of parallel connected modules

Therefore, if modules are connected in series then power reduction is twice when connected in parallel. On changing the solar insolation, I_{sc} of the module increases while the V_{oc} increases very slightly, therefore there is overall power increase. In parallel connection power increment is twice than when connected in series.

3. EXPERIMENTAL SET-UP

The circuit diagram to evaluate I-V and P-V characteristics of modules connected in series and parallel are shown in Fig. 4(a) and 4(b) respectively.

Form a PV system with modules in either series or parallel and a variable resistor (Pot meter) with ammeter and voltmeter for measurement. Modules in series or parallel are connected to variable load (pot meter). The effect of load change on output voltage and current of the modules connected in series or parallel can be seen by varying load resistance (pot meter).

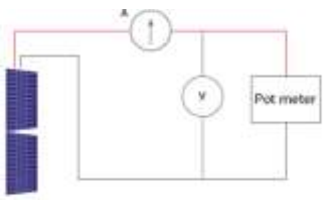

Fig. 4(a) Circuit diagram for evaluation of I-V and P-V characteristics of series connected modules

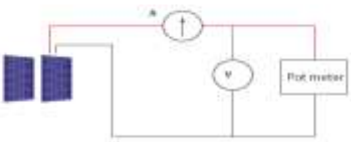

Fig. 4(b) Circuit diagram for evaluation of I-V and P-V characteristics of parallel connected modules

4. EXPERIMENT RESULT

PV module is characterized by its I-V and P-V characteristics at particular solar irradiation and temperature. I-V characteristics maximum current at zero voltage is the short circuit current (I_{sc}) which can be measured by shorting of PV module and maximum voltage at zero current is the open circuit voltage (V_{oc}). On changing the solar isolation I_{sc} of the module increases while the V_{oc} increase very slightly. When both modules connected in series and parallel the effect of irradiance and temperature is given below.

4.1 Two series connected PV module with varying Radiation and Temperature:

PV module when it is connected in series the effects of solar irradiation and temperature on of I-V and P-V characteristics at particular condition as shown below.

Table I. 200 W/m^2 radiation for two parallel connected PV modules

Voc [V]:	36.7676
Isc [A]:	0.179688
Vm [V]:	36.7188
Im [A]:	0.0996094
Pm [W]:	3.65753
Radiance [W/m.sq]:	200
Panel Area [m.sq]:	0.2
Fill Factor:	0.553612
Efficiency [%]:	9.14383

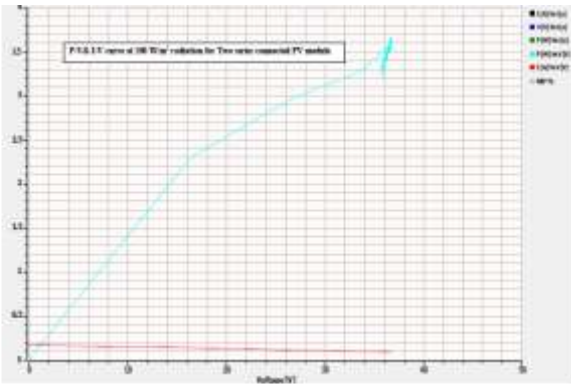

Fig. 5 P-V and I-V characteristics at 200 W/m^2 for two series connected PV modules

Table II. 400 W/m^2 radiation for two series connected PV modules

Voc [V]:	36.7676
Isc [A]:	0.179688
Vm [V]:	36.7188

Im [A]:	0.0996094
Pm [W]:	3.65753
Radiance [W/m.sq]:	200
Panel Area [m.sq]:	0.2
Fill Factor:	0.553612
Efficiency [%]:	9.14383

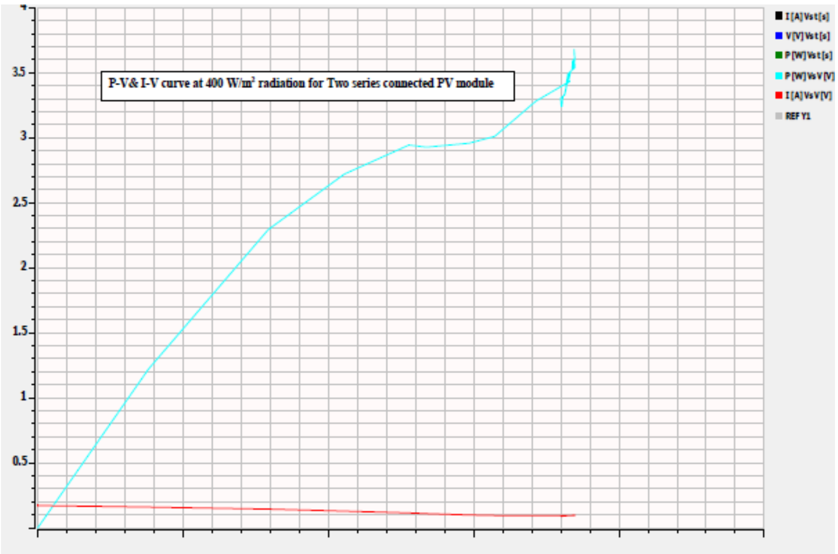

Fig. 6 P-V and I-V characteristics at 400 W/m^2 for two series connected PV modules

Table III. 600 W/m^2 radiation for two series connected PV modules

Voc [V]:	38.7207
Isc [A]:	0.232422
Vm [V]:	35.0098
Im [A]:	0.189453
Pm [W]:	6.63271
Radiance [W/m.sq]:	600
Panel Area [m.sq]:	0.2
Fill Factor:	0.737006
Efficiency [%]:	5.52726

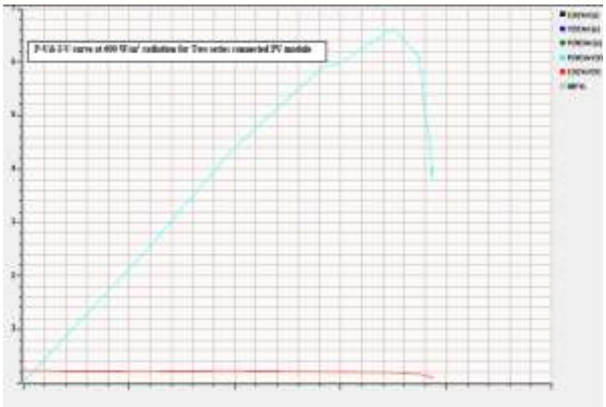

Fig. 7 P-V and I-V characteristics at 600 W/m² for two series connected PV modules

Table IV. 800 W/m² radiation for two series connected PV modules

Voc [V]:	19.4824
Isc [A]:	0.0117188
Vm [V]:	19.4336
Im [A]:	0.0117188
Pm [W]:	0.227737
Radiance [W/m.sq]:	800
Panel Area [m.sq]:	0.2
Fill Factor:	0.997494
Efficiency [%]:	0.142336

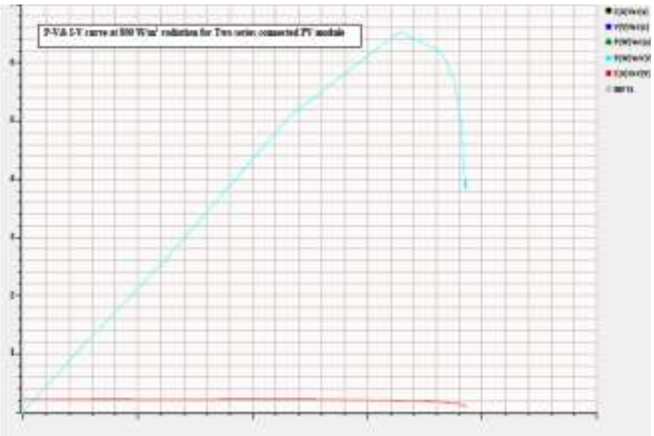

Fig. 8 P-V and I-V characteristics at 800 W/m² for two series connected PV modules

Table V.1000 W/m² radiation for two series connected PV modules

Voc [V]:	19.5312
Isc [A]:	0.0117188
Vm [V]:	19.4336

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ISSN: 2319-8354

Im [A]:	0.0117188
Pm [W]:	0.227737
Radiance [W/m.sq]:	1000
Panel Area [m.sq]:	0.2
Fill Factor:	0.995
Efficiency [%]:	0.113869

4.2 Two Parallel Connected PV Module With Varying Radiation and Temperature:

PV module when it is connected in parallel the effects of solar irradiation and temperature on of I-V and P-V characteristics at particular condition as shown below.

Table VI. 200 W/m^2 radiation for two parallel connected PV modules

Voc [V]:	19.3359
Isc [A]:	0.0117188
Vm [V]:	19.3359
Im [A]:	0.0117188
Pm [W]:	0.226593
Radiance [W/m.sq]:	200
Panel Area [m.sq]:	0.2
Fill Factor:	1
Efficiency [%]:	0.566483

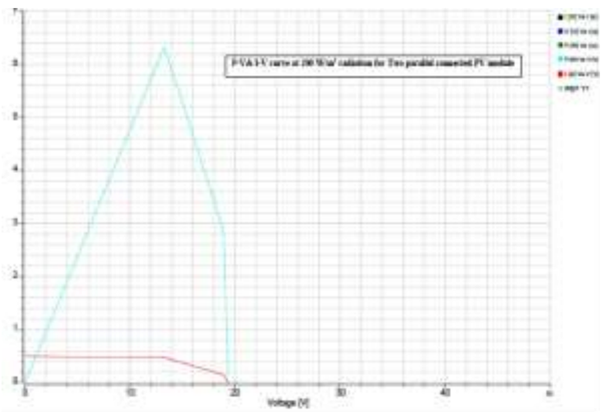

Fig. 9 P-V and I-V characteristics at 200 W/m^2 for two parallel connected PV modules

Table VII. 400 W/m^2 radiation for two parallel connected PV modules

Voc [V]:	19.3848
Isc [A]:	0.525391
Vm [V]:	19.1406
Im [A]:	0.103516
Pm [W]:	1.98135
Radiance [W/m.sq]:	400
Panel Area [m.sq]:	0.2
Fill Factor:	0.194545
Efficiency [%]:	2.47669

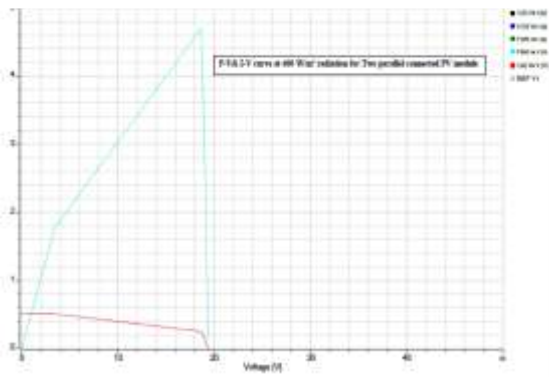

Fig. 10 P-V and I-V characteristics at 400 W/m^2 for two parallel connected PV modules

Table VIII. 600 W/m^2 radiation for two parallel connected PV modules

Voc [V]:	19.4824
Isc [A]:	0.523438
Vm [V]:	18.1641
Im [A]:	0.304688
Pm [W]:	5.53436
Radiance [W/m.sq]:	600
Panel Area [m.sq]:	0.2
Fill Factor:	0.5427
Efficiency [%]:	4.61197

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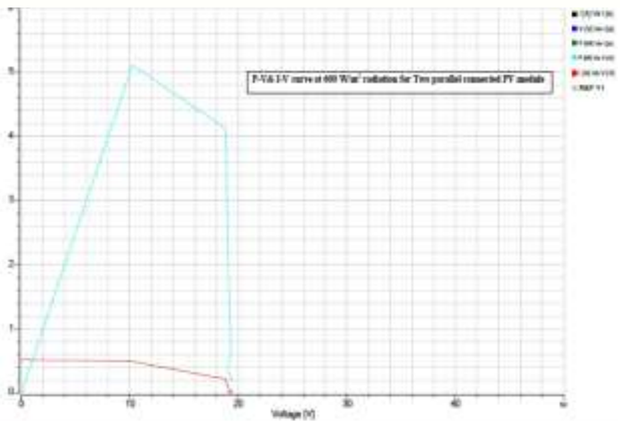

Fig. 11 P-V and I-V characteristics at 600 W/m^2 for two parallel connected PV modules

Table IX. 800 W/m^2 radiation for two parallel connected PV modules

Voc [V]:	19.4824
Isc [A]:	0.0117188
Vm [V]:	19.4336
Im [A]:	0.0117188
Pm [W]:	0.227737
Radiance [W/m.sq]:	800
Panel Area [m.sq]:	0.2
Fill Factor:	0.997494
Efficiency [%]:	0.142336

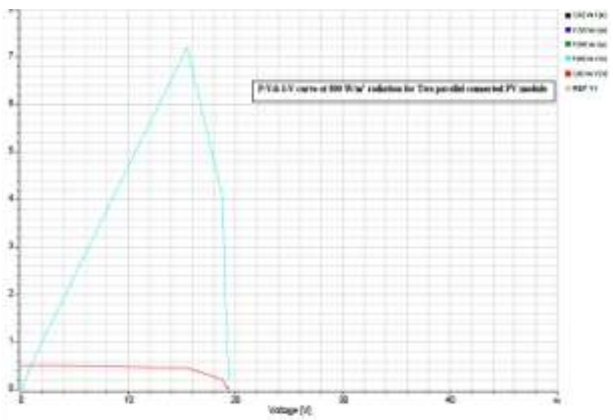

Fig. 12 P-V and I-V characteristics at 800 W/m^2 for two parallel connected PV modules

Table X. 1000 W/m^2 radiation for two parallel connected PV modules

Voc [V]:	19.5312
Isc [A]:	0.0117188
Vm [V]:	19.4336
Im [A]:	0.0117188
Pm [W]:	0.227737
Radiance [W/m.sq]:	1000
Panel Area [m.sq]:	0.2
Fill Factor:	0.995
Efficiency [%]:	0.113869

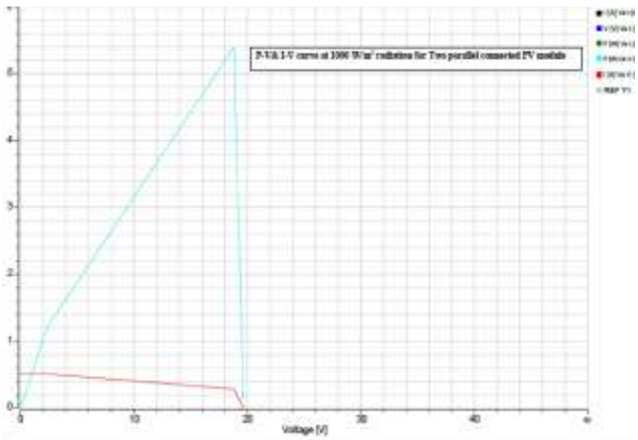

Fig. 13 P-V and I-V characteristics at 1000 W/m^2 for two parallel connected PV modules

4.3 Comparison of Two Series and Parallel connected PV module with varying radiation and temperature effect

Table XI: Two series connected PV modules

Sr. No.	Radiation (W/m^2)	Temp. (Deg.)	Voltage (V)	Current (A)	Power (W)
1	200	37.6	38.67	0.102	3.928
2	400	36.9	38.92	0.105	4.104
3	600	35.4	39.06	0.105	4.121
4	800	33.9	39.36	0.111	4.381
5	1000	32.3	39.6	0.109	4.331

Table XII: Two parallel connected PV modules

Sr. No.	Radiation (W/m^2)	Temp. (Deg.)	Voltage (V)	Current (A)	Power (W)
1	200	40	19.3359	0.009766	0.226593

2	400	39.6	19.1406	0.009766	1.981353
3	600	38.9	19.4824	0.304688	0.228313
4	800	38.4	19.5336	0.505859	0.227737
5	1000	37.3	19.4336	0.505859	0.227737

This section describes the criteria used to investigate solar irradiation and temperature is the factors with greater influence in the maximum peak of available power from a PV array. It is worth mentoring that the arrangement of PV modules in series and parallel connection is directly related to the efficiency of the system. From this experiments on solar panels, four different situation were performed to determine the criteria of comparison that both the two panels are connected in series with temperature fixed at 35˚C and irradiance in variable then same series connection irradiance is fixed at 1000 W/sq.m and temperature is fixed. Then same experiments done both the panels are connected in parallel. The standard test condition of this panel temperature is 25˚C and solar irradiation is 1000 W/sq.m.

5. CONCLUSION

On increasing the temperature, V_{oc} of module decreases as shown in different curve, while I_{sc} remains the same which in turn reduces the power. In I-V characteristic maximum current at zero voltage is the short circuit current (I_{sc}) which can be measured by shorting the PV module and maximum voltage at zero current is the open circuit voltage (V_{oc}). In P-V curve the maximum power is achieved only at a single point which is called MPP (maximum power point) and the voltage and current corresponding to this point are referred as V_{mp} and I_{mp}. On changing the solar insolation I_{sc} of the module is increases while the V_{oc} increases very slightly. If two solar panels are connected in series then total voltage can be higher as compared to parallel. Also if two solar panels are connected in series then the total power can be boost up.

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