International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 4, April - 2014

Study the Characteristics of PV Module Using a Sun Simulator

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***Abstract*— A sun simulator has been developed using indigenous materials to study the I-V curves of solar module. In this research 18 tungsten bulb each of 200 watts mounted in a fixed frame is used as the source of light. We use incandescent lamp, as the spectrum of these lamps is very close to the spectrum of the sun. The lights are so adjusted and arranged in such a way that the illumination projected on the target becomes uniform. The whole system is housed in a square shaped steel frame. A vertical adjustment facility for the desired illumination and temperature has been constructed. An adjustable frame is used for study the characteristics of a larger module. To increase the intensity we use reflector which is made of aluminum. To study the performance of the system the I-V curves and the module characteristics have been determined manually. The series resistance, fill factor and efficiency have been determined from the I-V curves.**

Keywords—solar cell; illumination; Sun; sun simulator; FF;.

I. INTRODUCTION

Mankind needs energy for a living. Besides the energy in our food necessary to sustain our body and its functions (100W), 30 times more energy is used on average to make our life comfortable. Electrical energy is one of the most useful form of energy, since it can be used for almost everything .we can produce electrical energy through photovoltaic energy conversion by solar cells. for the first time in history , mankind is able to produce a high quality energy from solar energy directly , without the needs of the plants .since any suitable energy , i.e. long term energy supply must be based on solar energy , photovoltaic energy conversion energy is becoming essential day by day A sun simulator (also artificial sun) is a device that provides illumination approximating natural sunlight. The purpose of the solar simulator is to provide a controllable indoor test facility under laboratory conditions, used for the testing of solar cells, sun screen, plastics, and other materials and devices.

II. THE BASIC CHARACTERISTICS OF SUNLIGHT

Sunlight is a component of energy particles called photons with variable energy. The energy of the photon

$$E = h\nu = hc/\lambda \qquad (1)$$

Where h= Planck's constant=6.62×10^{27} erg-sec =4.14×10^{-15} ev-sec. C = the velocity of light in the vacuum = $3\times10^{8}ms^{-1}$, ν =wave length of the light.

III. I-V CHARACTERISTICS OF A SOLAR CELL

A solar cell is mainly a photodiode, whose I-V curve is shown in the Fig.1.1. In the absence of light, the relationship between the flow of junction current I_j and imposed voltage V in a p-n junction is given by,

$$I_j = I_0\,[\exp(qV/KT) - 1] \qquad (2)$$

Where, I_0 = saturation current of the diode.

When light (photons) is incident on the junction, the electron-hole pairs are generated an electric current is given by

$$I = I_L - Io[\exp((qV+I_j R_s) / KT) - 1] \quad (3)$$

The behavior of the Solar Cell is characterized by

A. Short-circuit current (I_{sc}): It is the output current of the Solar Cell when the external circuit is shorted, i.e. zero load resistance.

B. Open-circuit voltage (V_{oc}): It is the output voltage of a Solar Cell when the external circuit is open, i.e. infinite load resistance. V_{oc} is also referred to as photovoltaic voltage.

C. Fill-factor (FF): It is defined as the ratio of the maximum power a Solar Cell can produce ($V_m I_m$) to the theoretical limit ($V_{OC}I_{SC}$).The expression for the FF of the Solar Cell is

Where, $FF = P_m / V_{oc} I_{sc}$

$$= V_m I_m / V_{oc} I_{sc} \qquad (4)$$

The FF strongly determines the performance of a Solar Cell and the FF is determined by the series resistance (R_s) and shunt resistance (R_{sh}) of the Solar Cell.

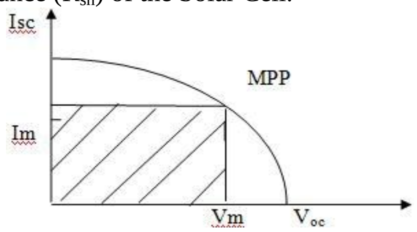

Fig 1.1: The fourth - quadrant portion of I-V characteristics an illuminated Solar Cell.

D .Series resistance and shunt resistance

The series resistance of solar cell can be determined by the I-V characteristics of the cell at two different intensities of illuminations. The equation for series resistances,

$$R_s = \frac{V_{L1} - V_{L2}}{I_{L2} - I_{L1}} \qquad (5)$$

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ISSN: 2278-0181
Vol. 3 Issue 4, April - 2014

An estimation of shunt resistance R_{Sh} of a cell can be made by determining the slope of the I-V curve at the short circuit point.

IV. SUN SIMULATOR

To test the values of the characteristic parameters of Solar modules of different types and sizes may be tested to find a suitable system for the particular load requirements. Field testing is costly, time consuming and depend heavily on prevailing weather conditions. By using sun simulator we can overcome these problems. Our steady state sun simulator is ideal for many different investigations. It is easy to build, working safely and are simple in maintenance. Because modular structure, combining a large number of lamps we could have required amount of output. One can take 1, 2, 3... Or .01, .1 Sun for their experiment, which is not possible in normal sun. Characterization is much easier by using this because the sun gave nonlinear output, while here we will get linear output. Beside these sun simulator has special features. Such as-

a. Illumination variation 0 to 6 sun with manual variation.
b. Measuring platform area 2.5 sq. feet
c. Height variation 0.5 FT. to 5 Feet.
d. Light sources are possible as our requirement.
e. Computer interfacing and data acquisition circuit may use for instant analysis and display the results.

V. DESIGN AND CONSTRUCTION OF SUN SIMULATOR

The sun simulator which was available for us was suitable for one solar cell or very small panel. There were only three light sources which are halogen bulb. The bulbs were highly directive. The instrument consists of four main sections such as optical, electrical, mechanical and computerized data acquisition. The optical part includes three halogen projection lamps of 250 watts. The lamps were fixed at the top of a square shaped steel frame having fine adjustment option for uniform light distribution. The mechanical section includes a square shaped mild steel frame mounted on four wheels for easy transportation .Inside the steel frame there is a vertically changeable flat horizontal platform which can be fixed at different heights .Force water circulating cooling system for the solar cell is incorporated in the simulator. The solar cell will be placed on the flat surface of the cooling system during measurement so that the cell temperature remains under control. The illumination level on the cell can be varied by changing the position of the flat horizontal platform according to the requirement. The electronic unit consists of two control circuits. One is a mono-stable multi-vibrator that controls the illumination light of the projection lamps. The other one is metering circuit to vary the solar cell load current and voltage step by step. In the computerized data acquisition unit a standard 16 bit multi channel data acquisition card has been used to collect the solar cell voltage and current readings. A computer program has been developed using QBASIC for real time data acquisition. The menu driven program is capable of real time plotting of the I-V curve and providing the instant value of maximum power point, efficiency, open circuit voltage, short circuit current and fill factor, shunt and series resistance of a solar cell .To study the performance of the developed system the I-V curves of different solar cells have been obtained using the simulator. In the study normal and concentrator types of silicon solar cell of 5cm* 5 cm and 10 cm*10 cm dimension have been used. To compare the performance of the instrument the I-V curves for these cells were plotted using the sun simulator as well as manually obtained data [10].But for our experiment we wanted to characterize a panel of length 120 cm and 54 cm width. So we need a different lighting system. We took step to increase the area of movable plane and lighting platform. The movable expands to 130 cm long and 54 cm width accordingly to our module. Newly developed lighting platform contained 18 light sources. These 18 tungsten bulbs each of 200 watts as light source to get uniform light intensity in the module.

Fig 1.2: Developed sun simulator and module testing arrangement

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VI. RESULTS

The developed sun simulator has been prepared to test the characteristics of PV module. The system was set in proper place where the accurate data can be measured. For measuring the data the panel was placed in different position to get different illumination. Also we take some reading in open sunlight at various times for different radiation level. We want to get full sun in the sun simulator. From these data we can calculate the performance of a solar panel in different light intensity. We can also compare the performance of a panel in open sunlight and in the sun simulator.

A .Graphs

Case 1: Data for 1080 watt/m^2 Time 12:00pm

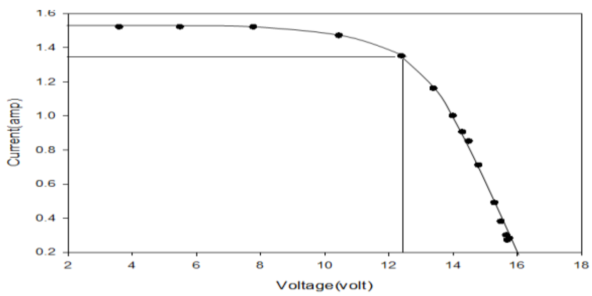

Figure: 1.3 I-V characteristics curve when light illumination 1080 w/m^2

Case 2: Data for 950 watt/m^2 Time: 2.00 P.M.

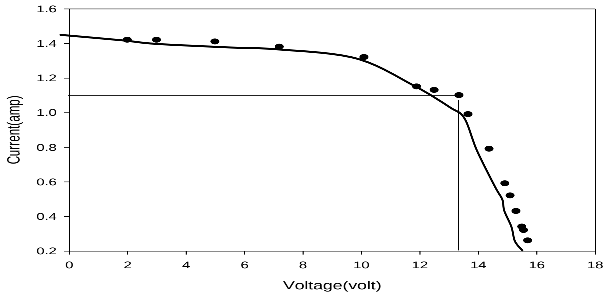

Figure 1.4: I-V characteristics curve when light illumination 950 w/m^2

Case 3: Data for 850 watt/m^2 Time: 10.00 A.M.

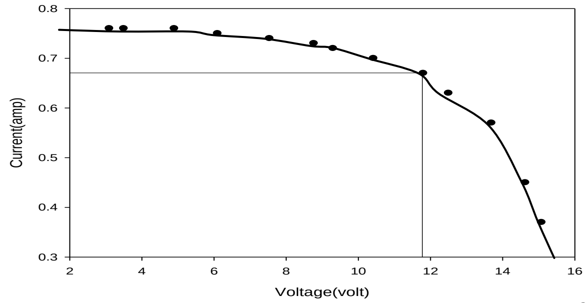

Figure 1.5: I-V characteristics curve when light illumination 850w/m^2

Case 4: Data for 100 watt/m^2 Using Sun Simulator.

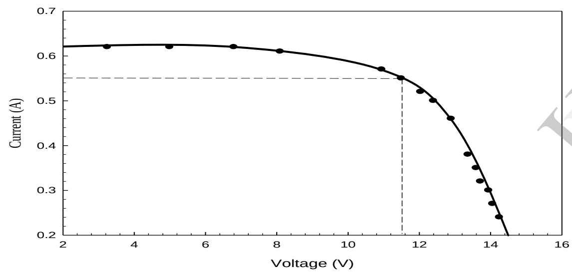

Figure 1.6: I-V characteristics curve when light illumination 100w/m^2

B. Result Table

Fill factor	
Case-1	67.36%
Case-2	65.05%
Case-3	66.26%
Case-4	66.06%
Ideality factor(n)	0.009
Efficiency(ῃ)	12.45%
Series resistance(R_s)	2.5Ω
Shunt resistance(R_{sh})	137Ω

VII. DISCUSSION

In this study short circuit current, open circuit voltage, power at maximum power point, fill factor and efficiency of a solar module has been determined. After considering the series resistance, the efficiency has become less than that of the previous one. In the calculations optical power loss, wave nature of light, loss due to glass cover and all other losses have been ignored .So, the estimated short circuit current, open circuit voltage, Pm of the cell has some variations with the rated value on the module .Another reason of difference in Voc is that the temperature dependent reverse saturation current is considered independent of temperature .The I-V characteristics curves considering series resistance differ from the curve without considering series resistance. .From the efficiency curve we observe that the efficiency increases with increasing light intensity. The analysis reveals that the results are well-matched with the theoretical value. There is no sun simulator to test the characteristics of a solar module in the country. In this study a sun simulator with facilities to test a small solar cell has been modified. The modified sun simulator is capable of testing solar module with area 130cm×70cm. The illumination at the base of the sun simulator is around 100W/m^2. The variations of illumination over small grids of 5cm×5cm is on an average is 4.5%. A solar module (model no. GL230/M25, Japan, 22Wp, 56cm×33cm) has been tested using the developed sun simulator. The module has also been tested under open sky at a shiny day. The values of the tested results revealed that the Fill Factor of the solar module is about same in all conditions. Hence the developed sun simulator can be used to test a solar module at low illumination than that of a standard illumination of 1000W/m^2.

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VIII. SCOPE FOR THE FUTURE WORK

In future one can do some work to get a standard sun simulator. A few of them are-

- Some modifications can be done to get at least one sun (1000W/m^2)
- Variations of illumination over small grids (1cm×1cm) can be done using small lux meters or small solar cell.
- To get characteristic values of a solar module other standard testing conditions can be determined using other instruments

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