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Evaluation of Industrial solar Cell w.r.t. Temperature

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ABSTRACT: *The rapid development of PV modules has created promising business environment in the foreseeable future .However the electricity cost from PV is still several times higher than from the conventional power generation, for solar energy, PV is identified to be of good potential for wide –scale application.*

Performance of solar PV system depends upon individual solar cell V,I characteristic w.r.t. input conditions i.e. temperature and humidity. The efficiency of solar cell drops with increase in temperature .However a methodology is created to test the cell performance in changing input conditions and its effect on output & field in terms of generation.

This paper summarizes test procedures, results, and implications of in-depth investigations of the performance and efficiencies characteristics of commercial solar cells, the present study relate to do a detailed study of the effect of temperature and humidity on the performance of solar cell and evaluate solar cell efficiency for the different weather conditions

The analysis shows that the characteristic of silicon solar cell with the different temperature levels varies efficiency of solar cell. Efficiency of solar cell increases from 31^0 C 9.702 % to 12.04% at 36^0 C.After that it is decreases till 53^0 C &further it becomes 2.37 % at 58^{0}C

Keyword: *Environmental chamber; Temperature control, cell efficiency IV characteristic*

I. Introduction

The sun is immersing power source emitting light energy over a range of wavelengths. The amount of solar radiation reaching the earth surface varies greatly due to changing atmosphere which reflect, absorb and scatter the solar radiation and part of it only reaches the earth surface directly.

The local geographical feature, such as mountains, large water bodies, coastlines and plains influences the atmospheric conditions which affect the solar radiation reaching earth surface. The amount of solar radiation received at noon is maximum because the sun is directly overhead. The solar energy available at earth surface under this condition is @1000 watts /sq.meter for a clearly sky.

India has large availability of solar radiation, theoretical solar potential is about 5000 T kWh per year (i.e. ~ 600 TW), far more than its current total consumption.& has planned to go for solar PV power plants under the policy “Solar Mission” for 2010 to 2022. It has planned to generate 20,000 MW, in phases by 2022, using solar PV.

The various types of solar PV technologies available

- Homo-junction solar cell
- Hetro-junction solar cell
- p-i-n solar cell
- Cascade/Tandem solar cell

The performance of solar cell depend on the following parameters

- Spectral response
- Effect of temperature

Effects of electronic defects
Effect of metallization and cell resistance
Effect of whether condition
The effect of these parameters at field varies, than standard test conditions & need to be evaluated.

1.1 Solar cell performance Vs climate

Industrial solar cell is mainly mono and polycrystalline silicon materials. The silicon material has change in properties w.r.t. temperature and the same has been noted and proved while testing silicon solar cells.

The efficiency of silicon solar cell get reduced with increase of temperature ,it is noted that the efficiency drops by about 0.4 % for increase of 1^0C i.e. a silicon solar cell of 20% efficiency at 20^0C will reduce efficiency to 16 % only at 30^0Ci.e.at rise of 10^0C. This notable property of poly crystalline solar cell will affect the performance of application of these cells at various locations.

The India is having different climatic zones which are dominated by its temperature and relative humidity these zones hot and dry (T >30, RH <55), warm and humid (T>30, RH>55), Moderate (T 25-30, RH<75), Cold and cloudy (T <25, RH>55), Cold and sunny (T<25, RH<55). This means that a industrial solar cell when located at different climatic regions it will behave different as far as its output is concern .The studies also reviews that the increase in relative humidity will also reduce the efficiency & performance of solar installation.

1.2 Summery:

The photo voltaic characteristic of industrial poly crystalline solar cell changes with temperature at large and with humidity a little .This has impact on silicon solar cell out put. India has wide geographical variations and also the solar radiations depending on the climatic zones. A particular silicon solar cell will behave accordingly having different output. It is necessary to estimate the total output in terms of generated unit while its characteristic varies accordingly to climatic conditions. A sola cell is generally tested at 1000 W/m^2 & at 25^0 c For Indian conditions at different geographical places temperature varies from 5^0C To 50^0C which means a solar photovoltaic installation will give out put in terms of generation of units, which will vary affecting the economics of solar photovoltaic installation which will give maximum output optimizing generation cost i.e. Rs /KWh.

Therefore it is very necessary to study effect of temperature and relative humidity on performance of solar photovoltaic installation

II. Definition of Problem

2.1 Introduction

A solar photovoltaic installation consist of a solar photovoltaic array connected to a grid or off grid load through charging and storage devices .An array consists of string of solar modules and solar consists of solar cells . for an industrial applications mono and poly crystalline solar cells are used capturing 80% of market share globally , at present .

Typical silicon solar cell consists of photovoltaic P-N junction formed on surface, a front ohomic contact strip, & fingers A back ohomic contact that covers the entire back surface and an antireflection coating on front surface.

The contacting of solar cell is done by screen printing of metallic thick film paste, when a light strikes on crystalline silicon, electrons within crystal lattice are freed by the photon energy incident on it. Only photons achieving certain level of energy are converted in to free electron in semiconductor material from their atomic bond to produce electric current

A key towards effective photovoltaic cell is to convert as much sunlight as possible into electricity .These photovoltaic characteristics of current and voltage are determined by photon flux incident on semiconductor material and photon flux depend upon the spectral irradiations which is a part of sun radiation incident on earth

A bond structure of semiconductor material determines the material property which varies with climatic conditions. Therefore, while studying performance of solar cell for solar photovoltaic installations in practice, the climatic condition along with other feature like solar radiations etc. are required to be studied

2.2 Performance of solar cell

The sun is immersing power source emitting light energy over a range of wavelengths. The amount of solar radiation reaching the earth surface varies greatly due to changing atmosphere which reflect, absorb and scatter the solar radiation and part of it only reaches the earth surface directly.

The local geographical feature, such as mountains, large water bodies, coastlines and plains influences the atmospheric conditions which affect the solar radiation reaching earth surface. The total radiation at any point on the earth surface is referred as “global solar radiation” and consists of “direct radiation” and “diffuse radiation”. The direct radiation comes in direct line from the sun ,whereas “diffuse “ radiation is the scattered radiation by the dust ,water molecules ,clouds and aerosols in the atmosphere .This is also called sky radiation .The diffuse radiation is about 10 to 20 5 for clear skies and may go to 100 for cloudy skies

The location (latitude), climate and atmospheric conditions influence the spectral distribution throughout the day and the year, affecting the percentage of energy in UV, visible and near IR regions .The study of the spectral distribution during the day and the year are highly essential because solar cells respond primarily to the light photons in the visible and near –IR regions of the spectrum

The silicon solar cell shows different I-V curves of different light intensities one sun is equivalent to 1000 W/m^2 .the power output of the cell is almost directly proportional to the intensity of sunlight the important feature is that the voltage of the cell does not depend on the size and light intensity, but the current in the cell changes with the size and light intensity .to compare the performance of cell of different sizes, a parameter called “current density “is used as an index

The solar cell performance depends upon a spectral response, temperature electronic defects, metallization etc.

2.2.1 Spectral response:

The spectral response (SR) of a cell is defined as the ratio of the number of charge carriers collected by junction (i.e. photocurrent) to the intensity of the incident light at a given frequency/ wavelength. The major contribution to the 'spectral response' and photocurrent come from the base material in addition to a small contribution from the depletion region. The nature and quality of the cell are known by studying the spectral response.

It is expressed as where I_{ph} is the photocurrent and $E(\lambda)$ is the energy of the incident photon of wavelength,

$$SR\ (\lambda) = \frac{Iph(\lambda)}{qE(\lambda)}$$

The response generally begins at the band gap energy, reaches a peak and then decreases due to recombination in the diffused region. The ideal hetero-junction cell gives high and constant spectral response between the band gaps of window and absorber layer materials. The shape of SR is influenced by the quality of the two materials and the interface. If the diffusion length in the absorber is low, the carriers produced are lost through recombination, reducing the red response of the solar cell. Impurities in the window layer may create traps within the band gap leading to absorption at wavelengths above the absorption edge which tends to reduce the blue response of the cell. The effect of temperature, crystal defects and the internal resistance of the cell on its performance /efficiency is briefly mentioned.

2.2.2 Effect of temperature

The changes in ambient temperature influence the performance of the solar cell. The efficiency of the cell gets reduced with the increase of cell temperature. Voc is sensitive to temperature whereas Isc is not. Simple calculation may show that the cell
voltage and temperature are inversely related

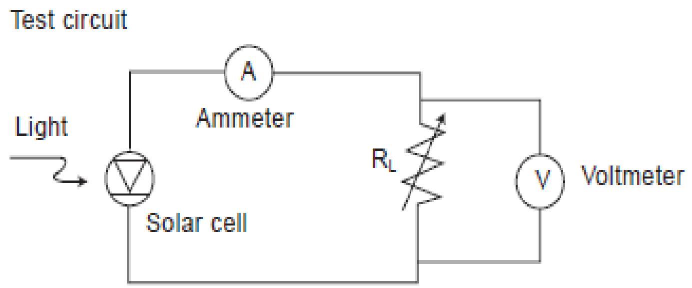
For silicon cell, (dV_{oc}/dT) is approximately equal to -2 mV/°C, which means, that the efficiency of the cell drops by about 0.4 % for increase of every one degree Celsius. A silicon solar cell of 20% efficiency at 20°C will reduce to 16% at 30°C.

$$\frac{dVoc}{dT} = \left(\frac{1}{q}\right)\left(\frac{dEg}{dT}\right) - \left(\frac{1}{T}\right)\left[\left(\frac{Eg}{q}\right) - Voc\right]$$

III. Solar PV System performance evaluation & test set up design considerations

As the weather conditions in India are changes with the climatic regions, to find out exact the effect of temperature and humidity on the performance of silicon Solar cell is the aim of this project work.

Fig No. 3.1



3.1 Test set up and design considerations

While testing silicon solar cell at different temperature and humidity following parameters needs to be studied

1. equivalent circuit of solar cell
2. solar radiation incident on solar cell
3. Voc & Isc
4. Imax & V max
5. Ambient temperature & solar cell temperature
6. Relative humidity

To test the solar cell in the above conditions an environmental chamber requires to be created having consideration which can measure above parameters

1. A solar cell of size 156 x 156 mm (as specified by IEC 6125) should be able to be tested.
2. The chamber should measure chamber temperature ,solar cell surface temperature & ambient temperature
3. Incident solar radiation on solar cell at given location
4. Humidity inside & outside chamber should be measure and can be varied.
5. Output of solar cell should be measure at light and at dark
6. A chamber design with above considerations is shown in fig

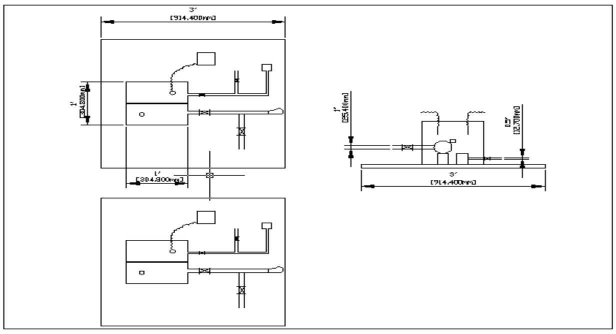


Fig No. 3.2

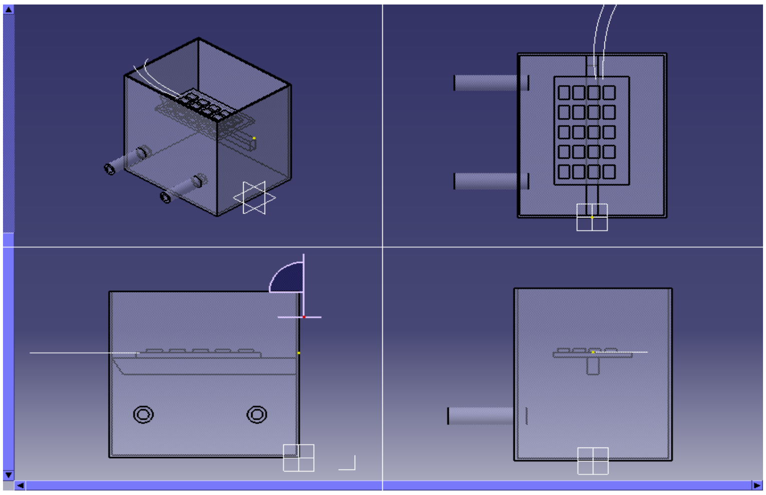


Fig No. 3.3

3.2 Manufacturing of test set up

Chamber was manufactured as per drawings.

3.2.1 The test set up includes following features

3.2.2 Supporting table design:

Supporting table is manufactured from mild steel pipes , by fabricating pipes in decided dimensions with the help of welding machine . a simple attachment is used to change the tilt angle as per requirement this table must support the chamber and other equipments used .

3.2.3Design and construction of environmental chamber

Environmental chamber is constructed from transparent glass, for the surroundings walls and for base glass having 6 mm width and for top cover glass of 4 mm width is used. The all pieces of surrounding walls are fabricated or paste with each other and also with base plate in well manner with help of silicon gel.

At the center of chamber two supporting plates are attached to allow a location for the solar cell which is going under test. One hole having diameter 12 mm and another 6 mm is produced on one wall, opposite to this wall another 12mm hole is produced.

For top cover 4 mm glass is used and two holes of 6 mm are developed to allowed hygrometer sensor from one hole and carried out connections from solar cell to outside chamber, gasket is used to create a base for top cover and also to reduce leakage from chamber.

3.2.4 Air blower

Air blower is used to produce hot air, this hot air is then forced in to chamber as per requirement to increase or decrease the temperature of chamber .Simple air blower is taken and air from surrounding is heated in to it and further passed through the air circuit in to chamber by using by- pass valve and main valve.

3.2.5 Steam injector

Steam injector is used to provide steam inside the chamber which resulted to increase or decrease the humidity of chamber which is important part of our study .In steam injector water is heated and steam is produced by using electric energy, and passed through copper tubing in to chamber. Perfect insulation is applied on this copper tube to avoid any loss and to avoid condensation of steam while passing through copper tube and then supplied into chamber with help of bypass valve and main valve

3.2.6 Temperature sensor

To measure the temperature of chamber accurately an instrument is attached to chamber which preciously shows exact values of humidity and temperature inside the chamber. This instrument known as thermo-hygrometer made by Mextech company having wide temperature range from -50 ^{0} c to 70 ^{0} c with accuracy +/- 2 ^{0} c.

3.2.7 Thermocouples

A non-contact type thermocouple is used, for measure temperature of solar panel.

3.2.8 Air circuit

Air circuit is made from PVC pipe which is capable to work under high temperature conditions and successfully carried the air which is heated in blower. This pipe is connected to blower through a special arrangement which interconnect the blower and the PVC pipe easily.

Figure 3-12

Humidity circuit is made of 6 mm copper tube ,as copper is capable to work under high temperature as we are passing the steam through this circuit it is essential to material to sustain high temperature condition . All joints are soldered carefully to avoid the sharp changes in pipe

3.2.9 Variable resistance

The variable resistance is used in the circuit of solar cell to controlling the voltage and current as per requirement by using this we can vary the current and voltage

The value of variable resistance used is 47K**.**

3.3 Data collection

The data collected from field test and the variable such as temperature, humidity, solar flux, Voc, Isc, Imax, Vmax are measured and is collected in the following format table

Temperature: - o C, Solar Flux: - mw /Cm^2

Solar Panel Temperature: - ^{0}c Date

Table No. 3.1

IV. Analysis and performance evaluation

The solar cell was tested for the field conditions for 15 days in the month of June and July .The reading table is given as below

4.1 Data representation:

The analysis is carried out based on performance evaluation of solar cell by measuring solar flux ,Voc, Isc ,Imax ,Vmax Power input etc

Place: Department of Physics, Shivaji University, Kolhapur (Terrace)

4.2 Analysis of current and voltage characteristic for the different weather conditions

By using the data plotted for cases from 1 to 26 we can find out the values of I_{max}, V_{max} and I_{sc} V_{oc},

4.2.1 I-V curve for temperature region 30^{0}C 1 to 39^{0}C

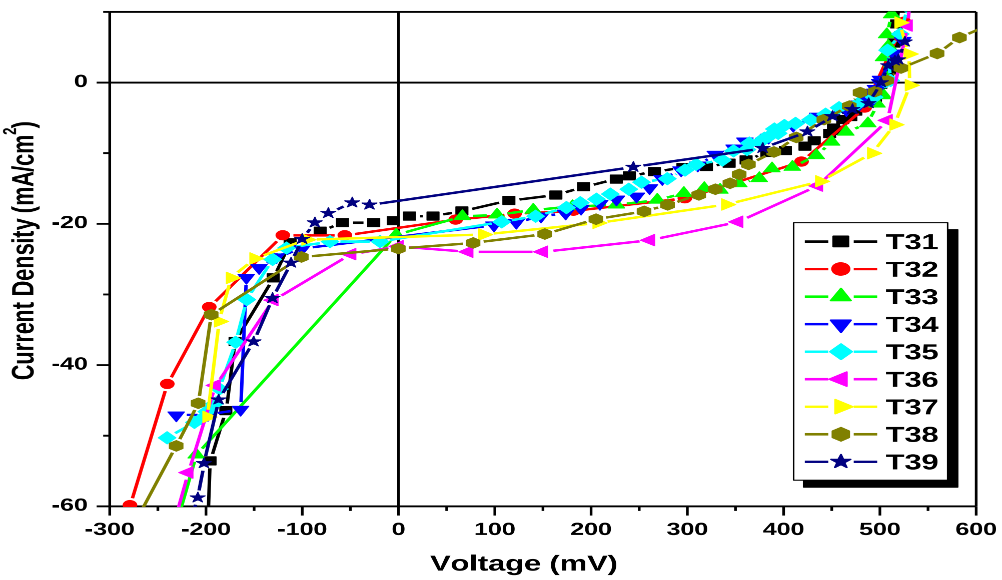


Fig No.4.1

4.2.2 I-V curve for temperature region

Sr No.	1	2	3	4	5	6	7	8	9
Voc									
Isc									

40^{0}C to 48^{0}C

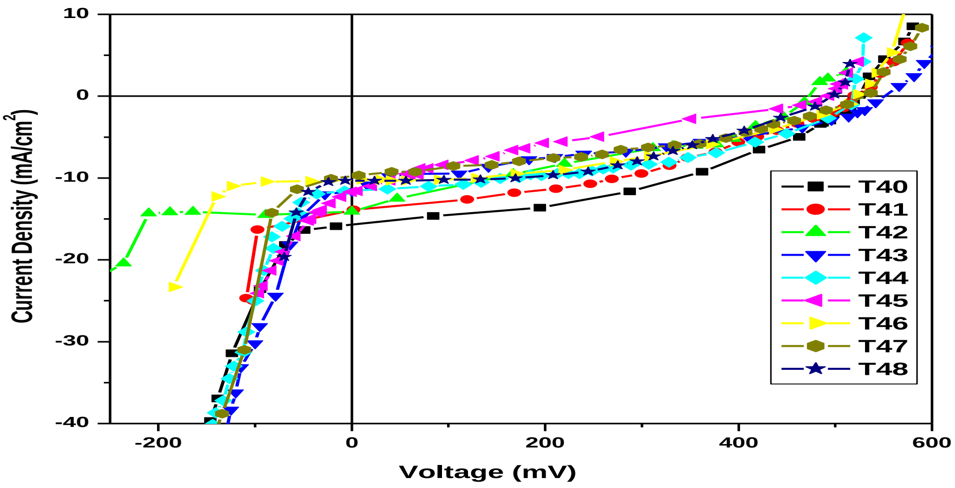


Fig No.4.2

4.2.3 I-V curve for temperature region

49^{0}C to 58^{0}C

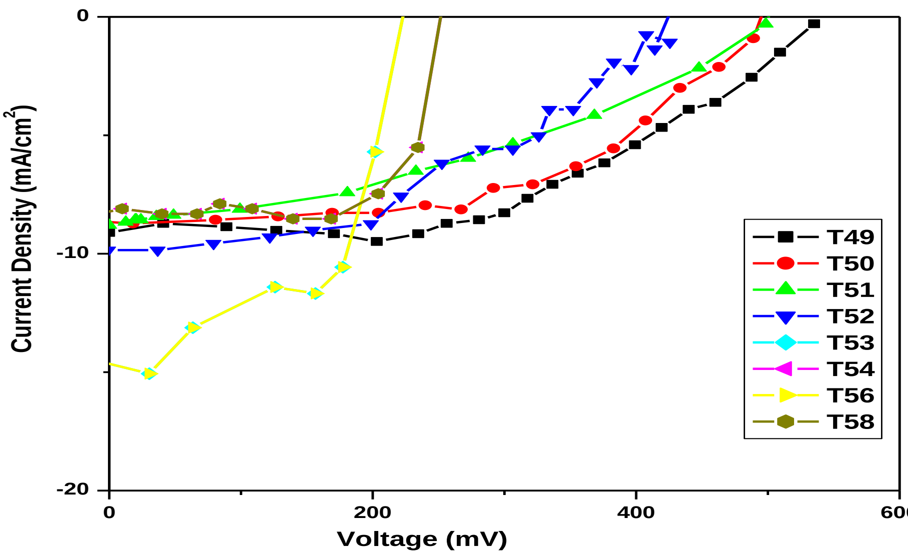


Fig No.4.3

4.2.4 Variation of current mA /cm^2 w.r.t. temperature

The variation of current intensity w.r.t. temperature is shown in following table's range of temperature 31^{0}C to 54^{0}C

After studying all above data it is found that total variation of current intensity w.r.t. temperature is 33.41 % for the range of temperature 31^0 C to 54^{0}C

Table no. 4.1

Voltage	Temperature 31^0C Imin	Temperature 39^0C Imax	Imax-Imin	Imax-Imin/Imin	% variation
100	16.7	19.5	2.81	0.17	16.8
200	14.4	17.4	3.06	0.21	21.32
300	11.6	12.3	0.61	0.05	5.24
400	9.5	6.4	3.11	0.49	48.

Table no. 4.2

Voltage	Temperature 40^0C Imax	Temperature 48^0C Imin	Imax-Imin	Imax-Imin/I min	% Variation
100	14.11	10.21	3.9	0.38	38.20
200	13.41	9.66	3.75	0.39	38.82
300	11.24	7.44	3.8	0.51	51.08
400	7.31	4.15	3.16	0.77	76.14

Table no. 4.3

Voltage	Temperature 49^0C	Temperature 54^0C	Imax-Imin	Imax-Imin/Imin	% Variation
100	9.9	8.79	1.12	0.13	12.74
200	9.52	8.65	0.87	0.11	10.06
300	8.25	5.55	2.7	0.49	48.65

4.3 Performance evaluation:

The performance of solar cell w.r.t. temperature, humidity and power input are calculated and the fill factor and the efficiency for the respected temperature humidity and solar power input are compared as following

4.3.1 Plot of Isc (mA/cm^2) Vs Voc (volt)

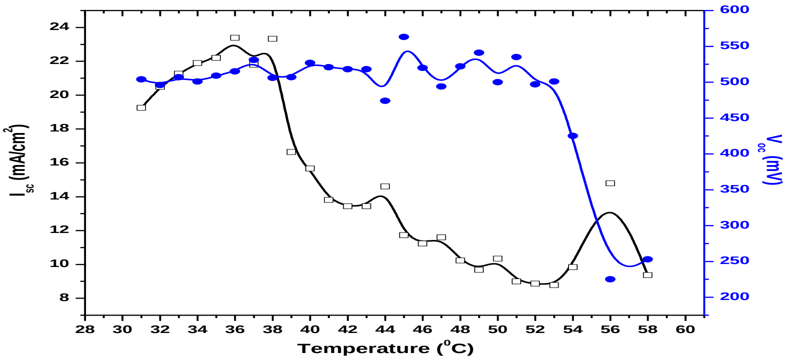


Fig No.4.4

Fig 4-4 shows the current intensity of solar cell increases from 31^0 C (11.55 A/cm$^{2)}$ to 37^0 C (18 mA/cm$^{2)}$ after that it is decreases till 53^0 C (6mA/cm^2) further it becomes (8mA/cm^2) & the open circuit voltage at31^0 C (504 mV$^)$ to 40^0 C (527mV$^)$ after that it is decreases till 56^{0}C (225mV) further it becomes (253mV) at 58^{0}C

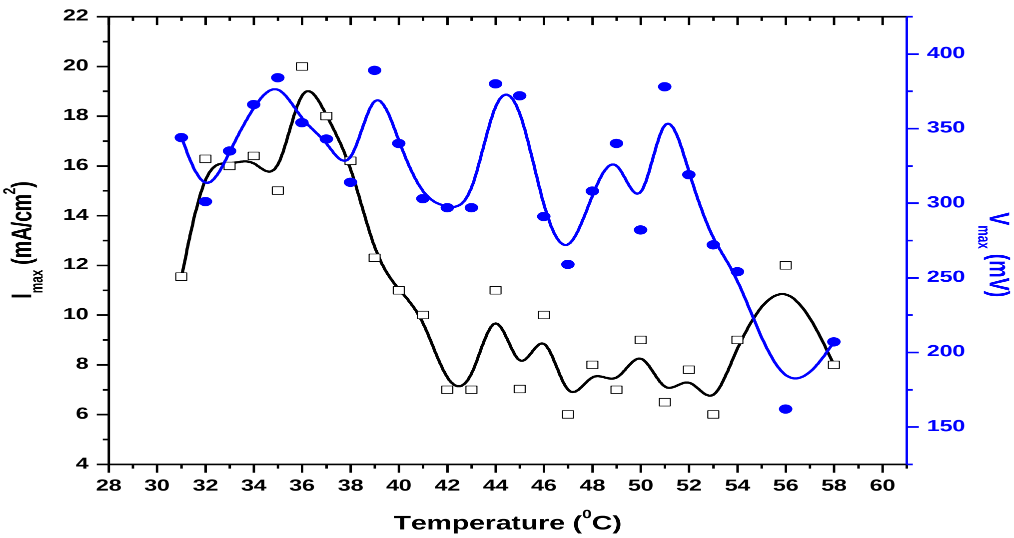


Fig No.4.5

Fig 4-5 shows the current intensity of solar cell increases from 31^0 C (11.55 mA/cm$^{2)}$ to 37^0 C (18 mA/cm$^{2)}$ after that it is tremendously decreases till 53^0 C (6mA/cm^2) further it becomes (8mA/cm^2) at 58^{0}C.& the circuit voltage solar cell increases from 60 % humidity (344 mV$^)$ to 44 % humidity (380 mV$^)$ after that it is decreases till 30 % humidity (162 mV) further it becomes (207 mV) at 29 % humidity

4.4 Relation between temperature, and efficiency.

From above all result it is seen that the relation between temperature and solar cell efficiency is as below

Fig 4-6 shows the efficiency of solar cell increases from 31^0 C 9.702 % to 12.04% at 36^0 C after that it is decreases till 53^0 C &further it becomes 2.37 % at 58^{0}C

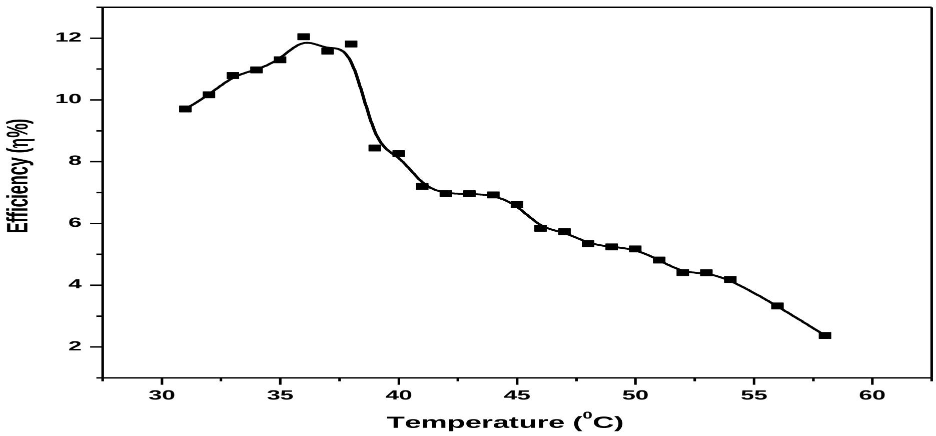


Fig No.4.6

V. Recommendations and Conclusion

This chapter gives the effective conclusion beneficial for industry to find out relation between weather conditions i.e. temperature and humidity and variation in efficiency of solar cell.

5.1 Conclusion

Analysis of performance of industrial solar cell depending on the temperature and humidity carried out with the help of environmental chamber, by changing the conditions inside the environmental chamber shows the variation in energy conversion efficiency of solar cell.

Inside conditions are obtained by using air blower and steam injector. Which varies inside conditions i.e. temperature and humidity from ambient to 58^0C and 60% respectively. Variable resistance, voltmeter and ammeter are used to measure the concern output parameters like Isc, Voc and Imax, Vmax for various input conditions.

From the analysis, it is confirmed that as temperature increases in the range of 31^0c to 58^0c efficiency of single crystalline solar cell is also varies. The light conversion efficiency of single crystalline solar cell shows 9.702 % efficiency at 31^0c as increase in temperature the conversion efficiency increases and it reaches up to 12.0459 % at 36 ^{0} c temperature however, further temperature increases from 36 ^{0} c the conversion efficiency decreases slowly & it goes up to 6.60 at 45 ^{0}c

Further increase in temperature from 45 ^{0}c there is continuously decrement in conversion efficiency & we found that at 58^0c the single crystalline silicon solar cell shows 2.37061 % conversion efficiency.

From all above study we can conclude that the used single crystalline silicon solar cell vapour shows maximum conversion efficiency at 36 ^{0} c i.e. 12.0459 %

The outcome of the studies can be applied to solar cell field with respect to temperature and humidity at specific locations.

For a given location at Kolhapur at University lab the % variation in efficiency is observed up to 33.42% ,which shows that the efficiency of given solar cell dropped 32.42% with rise in solar cell surface temperature.

5.2 Applications

Avery important conclusion in quantifying the field of solar PV power plant can be drawn based on the application of theory and experimentation proposed & carried out as above

5.3 Future Scope

Performance can be checked for elevated temperatures also.

a. More study will be done on the different humidity levels and lower temperatures

b. For different types of solar cells, performance of solar cell can be studied.

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