International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-6, August 2019

Effect of Temperature on Solar Photovoltaic Panel Efficiency

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Abstract: ***Solar energy is the important energy source for future. Lot of devices are used for capture the energy from solar radiation and convert into useful form of energy. Solar PV (Photovoltaic) Panels are the promising devices convert the solar radiation into electrical form of energy. The partial portion of solar energy may be converted into electricity remaining in the form heat energy. Solar PV panel performance varies with temperature increase. The PV panel temperature has effect on power and voltage. Due to increase of temperature, the photovoltaic solar cells efficiency may be decreased. The life of the panel also will be decreased. In this paper how the heat energy received from solar radiation in the form of temperature affect the solar panel efficiency was analysed by experiment conducted with solar PV panel of 50W in the real outdoor environmental condition.***

Keywords: Solar PV panel, Temperature, Power, Efficiency

I. INTRODUCTION

Solar energy is the gift for the earth. In India, many places having 250 to 300 sunny days per year. The annual average solar radiation intensity varies between 4-7 kWh/m^2/day [1]. Solar PV panels consists of solar cells basically PN junction semiconductor diode. The solar PV panel have 6 layers, Top glass, ARC (Anti Reflective Coating), PV cell, EVA (Ethylene Vinyl Acetate), rear contact (Aluminium) and Tedlar- PVF (Polyvinyl Fluoride). All the layers with aluminium metal frame. [2][3].During solar radiation, DC current is generated. The panel temperature affects the PV efficiency [4]. The temperature increase indicates power output decreases with respect to STC (Standard Testing Condition) of 25°C [5]. The solar PV panel parameters are changed due to changing the solar radiation and temperature. The solar cell performance particularly open-circuit voltage mainly depends on temperature.[6][7][8][9].The efficiency drop occurred due to temperature rise for silicon wafer based solar PV panels [10].

Revised Manuscript Received on August 30, 2019.

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Temperature and solar radiation influences on the current–voltage characteristics and efficiency [11][12]. So the temperature increase is main parameter for the efficiency and power output decrease. In this study, to find out the power output and efficiency due to temperature increase by experimental method.

II. METHODOLOGY

Using the mathematical equations and experiment to find out the performance of solar PV panel based on temperature increase**.**

Mathematical Equations

The efficiency of solar photovoltaic panel is the ratio of power output to energy absorbed by solar PV panel. Photo Electric conversion efficiency (Ƞe) is calculated using the following equation.

$$(\eta e) = P_{max} / P_{in}$$
$$= V_m \times I_m / GA$$
$$= V_{oc} \times I_{sc} \times FF / GA$$

P_{max} = Maximum power (W) from solar PV panel
V_m = Voltage at maximum power point (V)
I_m = Current at maximum power point (A)
V_{oc} = Open circuit voltage (V)
I_{sc} = Short circuit current (A)
FF = Fill Factor

Fill factor (FF) of a solar cell can be obtained from the expression [13]

$$FF = (v_{oc} - \ln(v_{oc} + 0.72)) / (v_{oc} + 1)$$
$$v_{oc} = V_{oc} / (kT / q)$$

v_{oc} = Open circuit voltage normalized to thermal voltage (V)
k = Boltzmann's constant $1.3806488 \times 10^{-23} JK^{-1}$ [14]
T = Temperature of Solar PV cell (K)
q = Elementary electron charge 1.602×10^{-19} Coulomb [14]

The typical I-V curve of a solar PV panel [15] is indicated in fig.1.

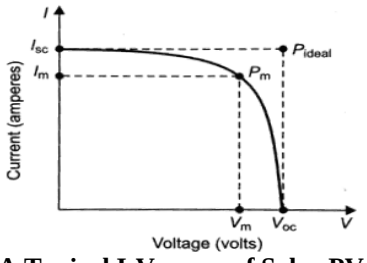

Fig.1. A Typical I-V curve of Solar PV Panel

III. EXPERIMENT

A. Experimental Setup

In this experimental study, the solar PV panel of 50W was taken and studied the performance of PV panel due to temperature increase. The experimental setup consists of 50W solar PV panel, voltmeter, ammeter, rheostat, digital thermometers. The solar PV panel (Make JP solar Chennai) having the following technical specifications.

Table.1.Technical Specifications of 50W solar PV panel at STC: 1000 W/m^2, 25°C cell temperature

1	Solar PV module type	Polycrystalline
2	Peak Power (P_{max})	50W
3	Open circuit voltage (V_{oc})	23.15 V
4	Short Circuit Current (I_{sc})	2.42 V
5	Peak Power Voltage (V_m)	20.60 V
6	Peak Power current (I_m)	2.31 A
7	No. of Cells	36
8	Solar PV cells Area(A)	0.292 m²

Table.2. Instruments used for the Experiment

Instrument	Accuracy	Range	Make
Solar Power meter	+/- 5%	0-1999 W/m^2	Tenmars TM-207
IR Thermometer	+/- 2 %	-18 to 400°C	Raytek MT4
Digital Thermometer	+/- 1°C	-50 to 110˚C	MEX TECH PM10
Multimeter	± (1.5%rdg + 4dgt) (0.7%rdg + 4dgt) on 20V & 200V	0-10A 0-1000V	MECO 9A06
Digital Anemometer	+/- 3% +/- 0.1	0 -30 m/s	WORK ZONE AVM -03

The digital thermometers were connected to top and bottom of the PV panel. The positive & negative terminals were connected to rheostat and ammeter was connected in series & voltmeter was connected in parallel. The solar power meter was used to measure the global solar radiation.

Fig.2. Photograph of Experimental setup

B. Experimental Procedure

The experiment was conducted at Chennai (Latitude 13° 4' 2.7804" N and Longitude 80° 14' 15.4212" E) on 14th May 2019 staring time was 2.48 PM and solar PV panel was exposed to sun light and taken the readings of open circuit voltage (V_{oc}), Short circuit current (I_{sc}) and ambient temperature (T_a), top panel temperature (T_1), bottom panel temperature (T_2), and wind speed by anemometer and solar radiation by solar power meter. The wind speed was from 0.176 - 4.7 m/s during the experiment. The experiments were repeated for every 3 minutes upto 3.29 PM. All the readings were noted.

IV. RESULTS AND DISCUSSIONS

Based on the input parameters taken from the experiment, calculated the fill factor (FF), power (P_{max}) and electrical efficiency (Ƞe). The following graphs were plotted based on the time. Fig.3 indicates the ambient temperature (T_a) varied from 35.5°C to 37.2°C. The top panel temperature (T_1) increased from 39.5°C to 46.2°C. The bottom panel temperature (T_2) varied from 38.2°C to 46.5°C. The average of top and bottom solar panel temperatures is the solar PV panel temperature T= (T_1+T_2)/2. It increased from 38.55°C to 44.15°C based on the time. Fig 4 shows the decrease of open circuit voltage (V_{oc}) from 19.7 V to 19 V and short circuit current (I_{sc}) decreased from 1.725 A to 1.348 A based on time. Fig .5 shows the variation of solar radiation from 633 to 754 W/m², power decreased from 27.53 W to 20.69 W and electrical efficiency decreased from 12.51% to 11.19% based on time. Fig.6 shows the decrease of open circuit voltage and short circuit current based on solar PV panel temperature.

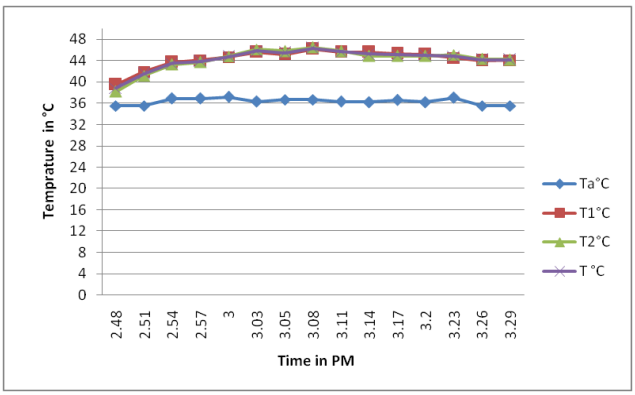

Fig.3.Variation of solar panel temperatures based on time

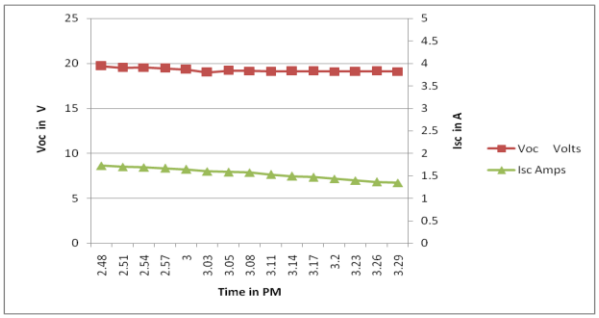

Fig.4.Variation of open circuit voltage and short circuit current based on time

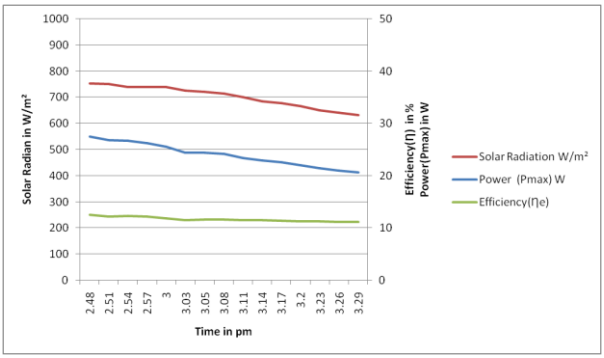

Fig.5. Variation of solar radiation, power & efficiency based on time

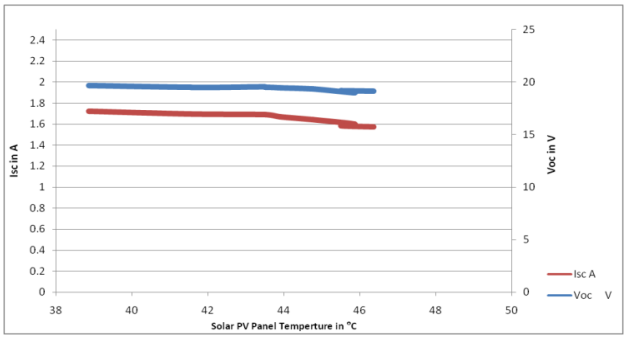

Fig.6.Variation of V_{oc} and I_{sc} based on solar PV panel temperature

V. CONCLUSION

The effect of temperature of solar PV panel was successfully demonstrated by the experiment. The total experimental setup was done at Chennai with solar PV panel, ammeter, anemometer, rheostat and digital thermometers. The efficiency of solar PV panel is about 15 % at STC condition of solar PV panel temperature at 25^{o} C and solar radiation of 1000 W/m^{2}. From the experiment, found that the efficiency was 12.51 % at the solar PV panel temperature of 38.55 ^{o} C & solar radiation of 754 W/m^{2} and it decreased to 11.09% at the Solar PV panel temperature of 44.15^{o}C & solar radiation of 633 W/m^{2}. From this experiment we observed the voltage, current; power and efficiency of solar PV panel were decreased based on solar radiation and solar PV panel temperature. Finally found that the temperature increase is the main factor for the decrease of efficiency. So the cooling of PV panel is a good solution to decrease the temperature and increase power output and efficiency. Future work, the experiments may be conducted with cooling arrangements of solar PV panel either by passive or acting cooling methods for increase the efficiency by decreasing the solar PV panel temperature.

REFERENCES

1. K. Sudhakar, M. Rajesh, and M. Premalatha. " A Mathematical Model to Assess the Potential of Algal Bio-fuels in India", Energy sources, Part A: Recovery Utilisation and Environmental effects, 34(12), pp 1114-1120, 2012
2. Rahman, M. M., Hasanuzzaman, M., & Rahim, N. A.,"Effects of various parameters on PV-module power and efficiency", Energy Conversion and Management, 103, pp 348–358, 2015
3. Hiren, D. Raval , "Improvement in energy efficiency of solar powered reverse osmosis by modification in membrane morphology and recovery of thermal energy from solar photovoltaic panel(PhD Thesis)", chapter 4, pp 52-56, October 2016 https://shodhganga.inflibnet.ac.in/bitstream/10603/118235/6/15chapter%204.pdf
4. Sudhakar, K., & Srivastava, T,"Energy and exergy analysis of 36 W solar photovoltaic module", International Journal of Ambient Energy, 35(1), pp 51–57,2013
5. P K Dash, " Effect of Temperature on Power Output from Different Commercially available Photovoltaic Modules", International Journal of Engineering Research and Applications,Vol 5, Issue1(Part 1), pp 148-151, January 2015
6. A.El-Shaer1, M. T. Y. Tadros2, M. A. Khalifa, " Effect of Light intensity and Temperature on Crystalline Silicon Solar Modules Parameters" , International Journal of Emerging Technology and Advanced Engineering, Volume 4, Issue 8, pp 311-318, August 2014
7. Green, M. A,"General temperature dependence of solar cell performance and implications for device modelling", Progress in Photovoltaics: Research and Applications, 11(5), pp 333–340,2003, doi:10.1002/pip.496
8. Meneses-Rodríguez, D., Horley, P. P., González-Hernández, J., Vorobiev, Y. V., & Gorley, P. N, "Photovoltaic solar cells performance at elevated temperatures", Solar Energy, 78(2), pp 243–250,2005,
9. Gonzalez, M. C., & Carrol, J. J, " Solar cells efficiency variations with varying atmospheric conditions", Solar Energy, 53(5), pp 395–402,1994,
10. Ye, Z., Nobre, A., Reindl, T., Luther, J., & Reise, C. " On PV module temperatures in tropical regions", Solar Energy, 88, 80–87,2013, doi:10.1016/j.solener.2012.11.001
11. Radziemska.E, "The effect of temperature on the power drop in crystalline silicon solar cells", Renewable Energy, 28(1), pp 1–12,2003, doi:10.1016/s0960-1481(02)00015-0 ,
12. Malik, A. Q., & Damit, S. J. B. H, "Outdoor testing of single crystal silicon solar cells", Renewable Energy,28(9), pp 1433–1445,2003, doi.org/10.1016/S0960-1481(02)00255-0
13. Chetan Chetan Singh Solanki, " Solar Photovoltaics (Book)" – Third Edition", PHI Learning pvt Limited, New Delhi, pp 98-99,2017
14. https://www.pveducation.org/pvcdrom/appendices/constants
15. Chetan Singh Solanki, " Solar Photovoltaic Technology And Systems (Book)", PHI Learning pvt Limited, New Delhi, pp 59-83,2013