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Research Paper

PERFORMANCE EVALUATION OF PHOTOVOLTAIC CELL WITH AND WITHOUT THERMAL SINK

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The following paper presents concisely the operation principles of photovoltaic cells and their main parameters. The efficiency of photovoltaic (PV) cell drop as their operating temperature increases especially under high insolation levels. The aim of the paper is to improve the performance of PV cell by dissipating excess heat, there by maintaining effective temperature of the cell which will enhance performance of the system. The work also deals with the comparing of the performance of PV cell with and without heat sink. During the study an optimum performance temperature was determined and heat sink mechanisms are used to maintain the determined temperature in PV cell.

Keywords: Fin, Heat sink, Photovoltaic (PV) cells, Temperature

INTRODUCTION

In the past two decades, photovoltaic (PV) cells production and demand has rapidly increased due to both the concern of fossil fuels depletion and cleaner, non-polluting ways of energy production. Based on converting solar energy into electricity, photovoltaic modules comply with both requests, having no net CO_2 emissions (Corina, 2010). Energy policies throughout the world have had a big impact on solar power plants development, leading to a constant increase in the use of PV technology (Tonui, 2006). However, the main limitation in the power output of photovoltaic cells resides in the conversion efficiency. Physical limitations, such as the available wavelength spectrum for conversion, lead to a maximum theoretical efficiency achievable for each type of photovoltaic cell (Winter, 1991). Another factor which lowers their efficiency is the cell's operation temperature.

The main aim of the paper is to compare the performance of PV cell with and without heat sink. During the study an optimum performance temperature, is determined and heat sink mechanisms are used to maintain the determined temperature of PV cell.

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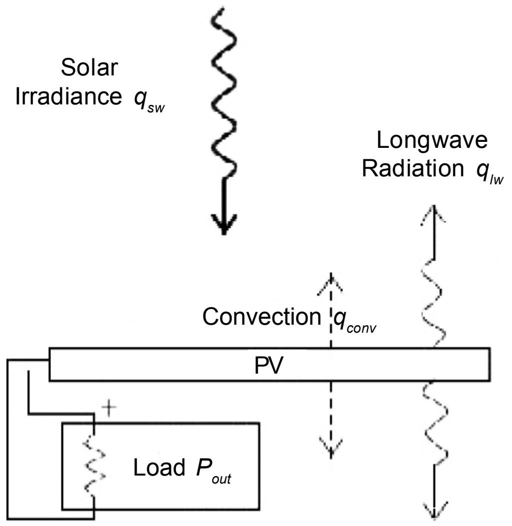
PHOTOVOLTAIC CELL WORKING AND MAIN PARAMETERS

Solar cells, or photovoltaic cells, transform light, usually sunlight, into electric current. Few power-generation technologies are as clean as photovoltaic (PV) (Figure 1). As it silently generates electricity, PV produces no air pollution or hazardous waste, PV cells are semiconductor.

Figure 1: Principle of Photovoltaic Cell



Two important steps are involved in the principle of working of solar cell. These are,

- Creation of pairs of positive and negative charges (called electron hole pairs) in the solar cell by absorbed solar radiation.
- Separation of the positive and negative charges by a potential gradient within the cell.

CONVERSION EFFICIENCY

The maximum conversion efficiency of PV cell,

$$\eta_{\max} = \frac{V_m I_m}{I_t A_c}$$

where V_m = Maximum^{Voltage}

I_m = Maximum^{Current}

I_t = Total Incident solar flux

A_c = Area of cell

EXPERIMENTAL WORK

Specification of PV Cell Module (Figure 2)

- Length of the PV cell module is 35.5 cm.
- Width of the PV cell model is 34 cm.
- Glass thickness on the top is 0.3 cm.
- No of cells 9.
- Maximum output power (P) is 8 Watt.

Figure 2: Photovoltaic (PV) Cell Module

Specification of PV Cell

- Number of cells = 9
- Length of each cell = 8 cm
- Breadth of the cell = 8 cm
- Power output from each cell = 0.888 W
- Thickness of the cell = 300 μm
- Cell material = Single Crystal Silicon (semi-conductor)
- Thermal conductivity (K) = 4.31 W/m K

Figure 3: Photovoltaic (PV) Cell

HEAT SINK CALCULATION

The heat sink (fin) was provided to dissipate the heat and to maintain the optimum PV cell temperature at 42 °C for its maximum power output.

The heat generated,

$Q = UA\,(t_s - t_f)$

where, $U = 1 \Big/ \frac{1}{h_s} + \frac{L_1}{k_1} + \frac{L_2}{k_2}$

To find excess heat (Q) in PV cell temperature at 42 °C and 46 °C.

$Q = UA\,(t_s - t_f)$

The amount of heat that must be dissipated to maintain the optimum temperature of PV cell,

$Q = Q_2 - Q_1$

where,

Q = Amount of heat to dissipated.

Q_1 = Amount of heat present at 42 °C.

Q_2 = Amount of heat present at 46 °C.

FIN CALCULATION

Calculations are done to find out area of copper fin to dissipate 0.439 W of excess heat.

Heat transfer through rectangular fin is given as,

$Q_{fin} = (T_b - T_\infty)\,(h\,P\,k\,A)^{0.5}$

The parameter ml is used to find, short or long fin,

If, ml < 5 it is a short fin

ml > 5 it is a long fin

where, $m = \sqrt{\frac{hP}{kA}}$

l = length of fin

Heat transfer through short fin is given,

$Q_{fin} = (T_b - T_\infty)\,(h\,P\,k\,A)^{0.5}$ tan H x (ml)

To find number of fins (n) use to dissipate heat

$$n = \frac{Q_{Total\ heat\ to\ be\ dissipated}}{Q_{Heat\ dissipated\ by\ one\ fin}}$$

Therefore 6 number of copper fin are required to dissipate excess heat from each single cell as shown in Figure 4.

Figure 4: Photovoltaic (PV) Cell Module with Thermal Sink (Fin)

EXPERIMENTAL DATA

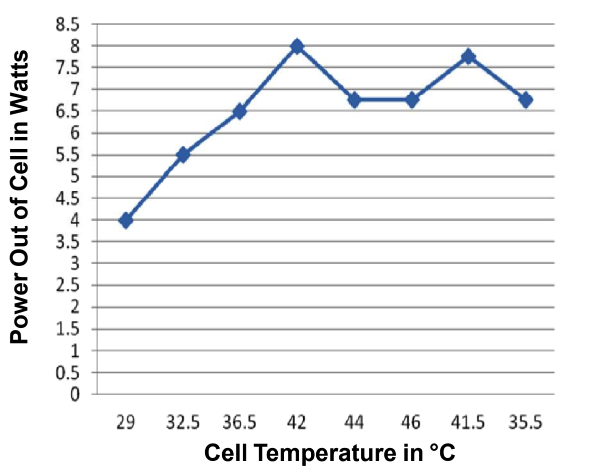
I. Performance Evaluation of Photovoltaic (PV) Cell Without Heat Sink (Fin)

The experiment was conducted for three days from morning 9 a.m. to evening 4 p.m., the variation in power output of PV cell module is as shown in Table 1.

Table 1: Temperature and Power Values with Respect to Time

Time in Hrs	Ambient Temp. (T_a) °C	Cell Temp. (T_1) °C	Output (*P*) in W
9 a.m.	26	29	3 to 5
10 a.m.	28.5	32.5	5 to 6
11 a.m.	30.5	36.5	6 to 7
12 noon	32	42	8
1 p.m.	34	44	8 to7.5
2 p.m.	34.5	46	7.5 to 7
3 p.m.	32	41.5	7 to 7.5
4 p.m.	30	35.5	7

Figure 5: The Variation of Cell Output with it's Temperature is Shown Below



RESULTS AND DISCUSSION

When ambient temperature increases from a minimum of 26 °C to maximum of 35 °C, the PV cell module temperature also increases.

It was noted that, when the ambient temperature was 32 °C, the PV cell temperature was 42 °C and PV cell module generated its maximum power output of 8 W.

When the ambient temperature went beyond 32 °C, the PV cell module temperature also increased to 46 °C and as seen from the Table 1 the power output decreased.

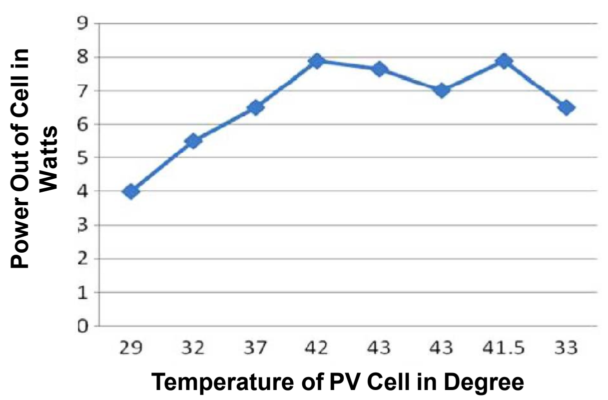
II. Performance Evaluation of Photovoltaic (PV) Cell with Heat Sink (Fin)

The experiment was conducted for three days from morning 9 a.m. to evening 4 p.m. on June 4, 2012, and the variation in power output of PV cell module was shown in Table 2.

Table 2: Temperature and Power Values with Respect to Time

Time in Hrs	Ambient Temp. (T_a) °C	Cell Temp. (T_1) °C	Output (*P*) in W	Fin Temp. (t_s)
9 a.m.	26	32	3 to 5	29
10 a.m.	28	33	5 to 6	30
11 a.m.	30.5	38.5	6 to 7	33.5
12 noon	32	42.5	7.8 to 8	35
1 p.m.	33.5	42.5	7.8 to 8	38
2 p.m.	34.5	44	7.3 to 8	38.5
3 p.m.	33	42	7.8 to 8	34.5
4 p.m.	30	38	6 to 7	33

Figure 6: Variation in Power Output



Results Observed

As seen from the result in Table 2 and graph, it is evident that for almost the same ambient conditions the cell with heat sinks never excuded 44 °C and the maximum power output repeated four times as shown in the Table 2.

CONCLUSION

Based on the experiment and results obtained, the following conclusions are made. When the ambient temperature increases from 32 °C to 35 °C, the PV cell module temperature also increases from 42 °C to 46 °C, thereby decreasing it's power output.

When PV cell module perform with heat sink (fin), Maximum power out of PV cell module was maintained by dissipating excess heat due to temperature rise of 5 °C. Thus the maximum power output was maintained by incorporating the fins which act as heat sink devices.

REFERENCES

1. Blok K (2007), *Introduction to Energy Analysis*, Techne-Press.
2. Cengel Y A (2008), *Introduction to Thermodynamics and Heat Transfer*, 2nd Edition, McGraw-Hill.
3. Corina Martineac (2010), "Temperature Influence on Conversion Efficiency in the Case of Photovoltaic Cells", 10th International Conference on Development and Application Systems, Suceava, Romania.
4. Luque A (2003), *Handbook of Photo-Voltaic Science and Engineering*.
5. Masters G M (2004), Renewable and Efficient Energy Power Systems.
6. Tonui J K (2006), "Improved PV/T Solar Collectors with Heat Extraction by Forced or Natural Air Circulation", *Renewable Energy*, Vol. 32, No. 4, pp. 623-637.
7. Winter C J (1991), "Solar Power Plants", *Fundamentals, Technology, Systems, Economics*, Springer-Verlag.