Performance Analysis of Hybrid Solar Photovoltaic-Thermal Collector

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ABSTRACT

The idea of combining photovoltaic and solar thermal collector to provide electrical and heat energy is not new, however it is an area of limited attention. Hybrid photovoltaic-thermal's have become a focus point of interest in the field of solar energy. Integration of both (Photovoltaic and thermal collector) provide greater opportunity for the use of renewable solar energy. This system converts solar energy into electricity and heat energy simultaneously. Theoretical performance analyses of hybrid PV/T's have been carried out, also the temperature of water (as a heat carrier) have been calculated for different seasons.

Keywords: Solar energy; Photovoltaic-Thermal; Seasonal performance Analysis

1. INTRODUCTION

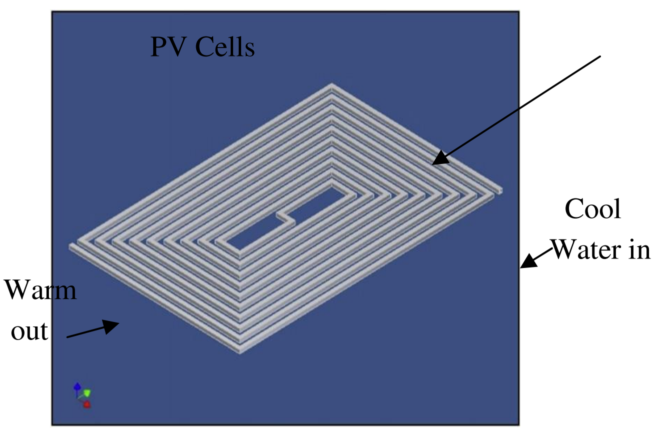
Solar energy is one of renewable energy sources which have potential for future energy application. Solar energy can generally be divided into two parts-The Photovoltaic technology which derived from solar cell and convert into electricity and Thermal solar technology which derived from the thermal collector and convert the solar energy into heat. Photovoltaic solar cells capable of changing some part of solar energy into electricity while the rest of the solar energy become waste[1].For both theoretical and practical reasons ,not all of the solar radiation energy falling on a solar cell can be converted into electrical energy. A specific amount of energy is required to produce a free electron and a hole in the semiconductor material .For example, in silicon the energy minimum is 1.1 eV and this is available in radiation having a wavelength of 1.1 micrometer. Consequently infrared radiation of longer wavelength has no photovoltaic effect in silicon but is largely observed as heat .Energy in excess of that needed to free a bound electron is simply converted into heat. The efficiency of the heated photovoltaic panel that exposed to sunlight will be decreased [6]

The latest research in this field of solar energy was to gain heat energy and decrease the temperature of photovoltaic panel simultaneously. Electrical energy and heat energy are collected separately. Photovoltaic-thermal collectors are to design to collect heat. If the temperature will reduce then definitely the efficiency of PV will increase. Water or air can be used as heat carrier. Here we used the water. This warm water can be further used for low temperature application. Florschetz suggest a model propose by Hottel-Whillier to analysis PV/T system [2].Bhargava [3] and Prakash[4] reported on effect of mass flow rate, air ducting sizing and the width of collector absorber used to the performance of the PV/T system.

Othman [5] reported the double pass PV/T collector with fins absorber shows better performance. The objective of this paper to increase the efficiency of the PV module as well as used the waste heat for low temperature application.

Experimental Set-up

The setup consists of the water based Spiral flow PV/T collector generates electricity and produce hot water simultaneously. The water based PV/T collector consists of spiral type tube upper part of which consists photovoltaic cells, as the absorber gets heat up this heat will be absorbed by the water by the conduction and it can increase the efficiency of the collector .The schematic diagram and specification of the spiral flow type Photovoltaic-Thermal collector is shown in fig.1 and table 1



Area of PV/T	$1\times1=1m^2$
Max Power (P_{max})	80W
Open Circuit Voltage(V_{oc})	21 V
Max Power current(I_{pm})	4.63 A
Efficiency (□) Solar Radiation =1000 W/m^{-2} Cell temperature = 25^oC	8 %

Fig.1 Schematic dia. of Spiral-flow PV/T **Table 1: Specification of PV/T collector**

2. PERFORMANCE ANALYSIS

In order to assess the system's performance, we should know the average solar insolation. This can be found using the following formula [7];

Avg. Solar Irradiance = Normal solar irradiance (1367 W/m^2) × cos (z) (1)

Where,

$$\cos(z) = \sin\delta \sin\varphi + \cos\delta \cos\varphi \cos[(LAT-12)\times 15] \quad (2)$$

$$\delta = 23.45 \sin[(360/365)\times(284+n)] \quad (3)$$

Where, n= no. of days

LAT = Standard time ± 4(Standard time Longitude – longitude of location) + (equation of time correction) (4)

Location of Kurukshetra is 29.96°N, 76.83°E. The average values of solar insolation for this location using the above formula for various seasons are calculated.

	Avg. Solar Irradiation (W/m²)		
Seasons	**9:00 to 11:00**	**11:00 to 13:00**	**13:00 to 15:00**
Summer (Mar-Jun)	1027.61	1231.35	1133.16
Monsoon (Jul-Sep)	854.5	1064.3	943
Winter (Dec-Feb)	634.38	839.38	758.82

Table 2: Value of Avg. solar irradiation for different seasons in different time periods

To find the total heat available to the PV/T in summer (March-June) for time period 9:00-11:00 a.m:

$A = 1\times 1 = 1\ m^2$

$$Q = I_b r_b \times A = 1027.61\ W \quad (5)$$

This is the amount of power available to the PV/T collector. PV cells convert only 8% of this power into electricity; the remaining power available in the form of heat and this heat increase the temperature of PV/T .increasing temperature decrease the efficiency of the PV cell .To maintain the temperature at the normal ambient temperature we can extract this heat from PV by the use of water as heat carrier

We can determine the temperature of warm water also as.

$Q' = 1027.61\times 0.92 = 945.4\ W$

This is the amount of heat available to the absorber. Using this heat for 2 hours i.e. 9:00-11:00 a.m. for 2.8 Kg of water at 35°C (room temperature of water in summer), we can determine the temperature of warm water attained in the system [8];

$Q' =$ mass of water$\times$ $[C_{pw} (100-T_w) +$ Latent heat of vaporization $+ C_{ps} (T_s - 100)] / (2\times60\times60)$ (6)

$945.4 = \{2.8\times1000[4.18 (100-35) + 2257 + 2 (T_s – 100)]\} / (2\times60\times60)$

Therefore, $T_s = 51.1°C$

For summer in 11:00a.m-13:00p.m time period, here we used the 3.3 Kg of water

$T_s = 71.4°C$

For summer in 13:00p.m-15:00p.m time period, here we used the 3.1Kg of water

$T_s = 46.2°C$

In a similar way, T_s can be found for monsoon and winter season to ascertain the steam temperature. However, in case of monsoon season (July-September), the room temperature of water is taken as 25°C and 10°C for winter season (December-February).

3. CONCLUSION

Thus, from the table below we can conclude that maximum solar intensity is received during summer season and also, the amount of warm water obtained highest in this season.

And it will also increase the efficiency of the PV cells by extracting the extra heat from the panels through the water as heat carrier.

Table 3 Various Values of PV power and temperature of water at different season

	Summer(Mar-Jun)			Monsoon(Jul-Sep)			Winter(Dec-Jan)		
	9:00-11:00	11:00-13:00	13:00-15:00	9:00-11:00	11:00-13:00	13:00-15:00	9:00-11:00	11:00-13:00	13:00-15:00
Avg. Irradiance (W/m²)	1027.61	1231.35	1133.16	854.5	1064.3	943	634.3	839.38	758.82
Total power available to PV panel (W)	1027.61	1231.35	1133.16	854.5	1064.3	943	634.3	839.38	758.82
Q´ (Watts)	945.4	1132.84	1042.5	786.1	1065.2	867.56	583.6	772.22	698.11
Mass of water (Kg)	2.8	3.3	3.1	2.3	3.1	2.6	1.7	2.2	2
Temp. of warm water (T_s in °C)	51.1	71.4	46.2	45.1	51.7	16	19.2	47	38
Avg. temp. of warm water (T_{s2} in °C)	56.2			37.6			34.73		

4. NOMENCLATURE

C_{pc} = Specific heat of coolant, KJ/Kg °C

C_{ps} = Specific heat of steam, KJ/Kg °C

T_s = Temperature of steam, °C

C_{pw} = Specific heat of water, KJ/Kg °C

T_w = Temperature of water at room temperature, °C

Z = Zenith angle

δ = Declination angle

Φ = Latitude

LAT = Local Apparent Time (hours)

I_b = Beam Radiation, W/m^2

r_b = Tilt factor

A = Area of PV/T panel, m^2

Q = Heat incident on PV/T collector, Watts (W)

Q′ = Heat received by the absorber tube, Watts (W)

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