Performance Improvement Analysis and Simulation of Solar PV/T Water Collector

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ABSTRACT

The objective of this paper is to review the collection of literature available on the Photo Voltaic and Thermal Solar Collector. The review paper is presented to show the comparison of findings obtained by various research works. In solar collector, the solar energy from the sun is converted in to electrical energy by means of Photo Voltaic panel and thermal energy by converting cold water into hot water. Nowadays, solar collector is preferred in many industries and house hold applications to reduce the demand of electricity by increasing the effective utilization of solar energy coming from the sun. The selection of collector design plays vital role in the development of heat energy and electrical energy. The input process parameters such as type of collector, time, mass flow rate, flow direction, flow pattern and size of the flow tube are normally considered for the research work and the output responses like thermal efficiency and electrical efficiency are appraised by using the Photo Voltaic Thermal Hybrid Solar Collector. Normally experiments are to be conducted based on the recommendation by the Traditional and Non-Traditional techniques. The output efficiency of the solar collector is purely based on the selection of input process parameters. Based on the literature review, an investigation is essential to improve the performance of the solar collector. The authors found that input process parameters plays vital role in the quality and efficiency of the solar collector.

Keywords: Solar Collector, Input process parameters, Output responses, Optimization techniques

1. INTRODUCTION

Photovoltaic thermal hybrid solar collectors, sometimes known as hybrid PV/T systems or PVT, are systems that convert solar radiation into thermal and electrical energy. These systems combine a solar cell, which converts sunlight into electricity, with a solar thermal collector, which captures the remaining energy and removes waste heat from the PV module and thus be more overall energy efficient than solar photovoltaic (PV) or solar thermal alone.[1] A significant amount of research has gone into developing PVT technology since the 1970s.[2] Photovoltaic cells suffer from a drop in efficiency with the rise in temperature due to increased resistance. Such systems can be engineered to carry heat away from the PV cells thereby cooling the cells and thus improving their efficiency by lowering resistance.

2. PV/T collector types

PV/T collectors can be flat plate or concentrating and are classified according to the type of the working fluid used water or air).

2.1. Flat plate PV/T collectors

Flat plate PV/T collectors look very similar to the well-known flat plate thermal collectors. The only significant difference, as shown by the schematic of Fig. 1, is the PV panel which is attached on the top of the metallic absorber plate. The absorber plate with

the tubes, the PV module, the glass cover as well as the insulation.

2.2. Concentrating PV/T collectors:

PV cost is relatively high, concentrators are often used to increase the irradiance level on PV modules. A low concentrating water cooled type PV/T collector of the building integrated type, was recently investigated by Brogren et al. [2]. It incorporates PV/T string modules with low cost aluminum foil reflectors with a concentration ratio of 4.3 times. Coventry [3] developed the so called CHAPS (combined heat and power solar) PV/T collector.

It involves a parabolic trough of concentration ratio of 37 times with mono crystalline silicon cells and a two-axis tracking system At the back of the cells a tube with water and anti-freeze was attached to collect most of the generated heat produced. various engineering systems including electronic components.

Heat pipe has ability to dissipate huge amount of heat with small temperature drop along the heat pipe while providing a self-pumping capable through a porous material in its structure. A limiting factor for the heat transfer potential of a heat pipe is depends working fluid properties.

The thermo physical properties of the fluid can be improved. An innovative way to enhance liquid thermal conductivity is the dispersion of highly conductive solid nanoparticles within the base fluid. Copper heat pipe and stainless steel heat pipe as shown in figure
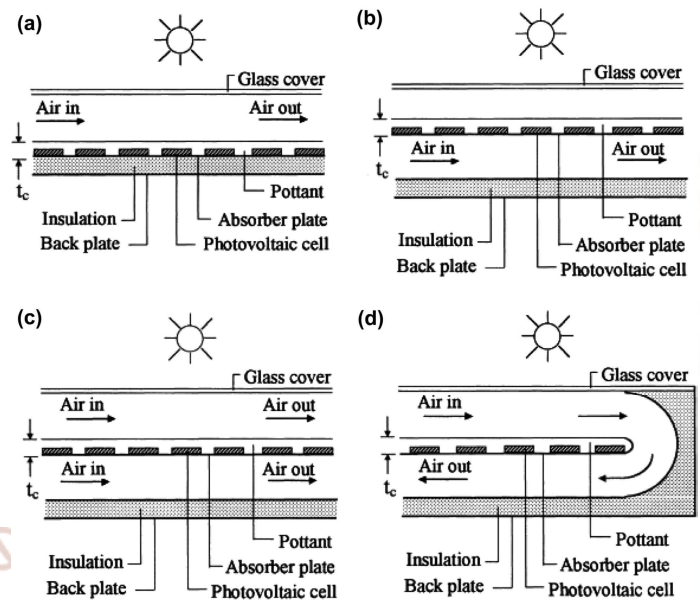

Figure 2.1 PV/T CROSS SECTION

Traveling through the adiabatic section the vapor reaches the condenser region where condensation rejects the latent heat of the fluid to the sink. The condensed liquid is pumped back against an adverse pressure gradient to the evaporator by a combination of the capillary pumping action and/or bulk forces.

This fluid circuit is repeated during the normal operation of the heat pipe and can continue as long as there is sufficient vapor pressure and capillary pressure to support its operation. Simple heat pipe as shown Figure 2.1.At the evaporator end the liquid recedes into the wick pores and hence the menisci in the pores at the vapor interface are highly curved. Whereas the liquid menisci at vapor interface in the condenser end are almost flat. This difference in the interface curvature of the menisci at the vapor interface coupled with the surface tension of the working fluid causes a capillary pressure gradient at the liquid-vapor interface along the length of the pipe. This capillary pressure gradient pumps the working fluid against various pressure losses such as friction, inertia and against bulk body forces. This axial variation of pressure is illustrated in Figure 2.

### 2.3 Parametric studies of PV/T

Packing factor one of the important parameters in designing and studying a PV/T system is packing factor, which generally means the fraction of absorber plate area covered by the solar cells. In specific applications such as buildings, Vats et al. [27] studied

the effects of packing factor on energy and performed energy analysis of a PV/T system with air duct flow. Fig. 4 demonstrates the efficiency behaviors of different PV cell materials due to change in packing factor. For example, Fig. 1a shows the thermal and electrical annual energy variations caused by changing of packing factor in each PV cell modules.

The overall annual thermal energy and energy variations are shown in Fig. 1b and c respectively at two different packing factors in each PV cells. The increase of packing factor doesn't always increase the annual energy gain or electrical efficiency. In the figure above, the effect of higher packing factor on the annual thermal efficiency and annual exergy analysis is also shown. If the packing factor is raised too much the thermal exit temperature will get higher due to absorbing high amount of thermal energy so it will increase the cell temperature, which causes the decrease in electrical efficiency. Meanwhile decreasing the packing factor too much will decrease the electrical efficiency because the radiation absorber area is less.

In the study of Wu et al. [25] on PV/T hybrid system, the energy analysis showed that the energy efficiency behaves quite irregularly .For example, according to the Fig. 2, the lower energy   efficiency happens in packing factor equal to 0.8 in the experiment when they had three packing factors as 0.7, 0.8 and 0.9. The higher energy efficiency is related to the packing factor equals to 0.9.In Fig. 5, we show the packing factors that different researchers have been used. It is obvious that most of the researchers chose the packing factors higher than 50% and less than 90%.Generally speaking, a comprehensive knowledge about the variation of packing factor and its effects with different fluids in different PV/T systems still does not exist. This also opened the door for optimization of the system design.

3. Experimental setup
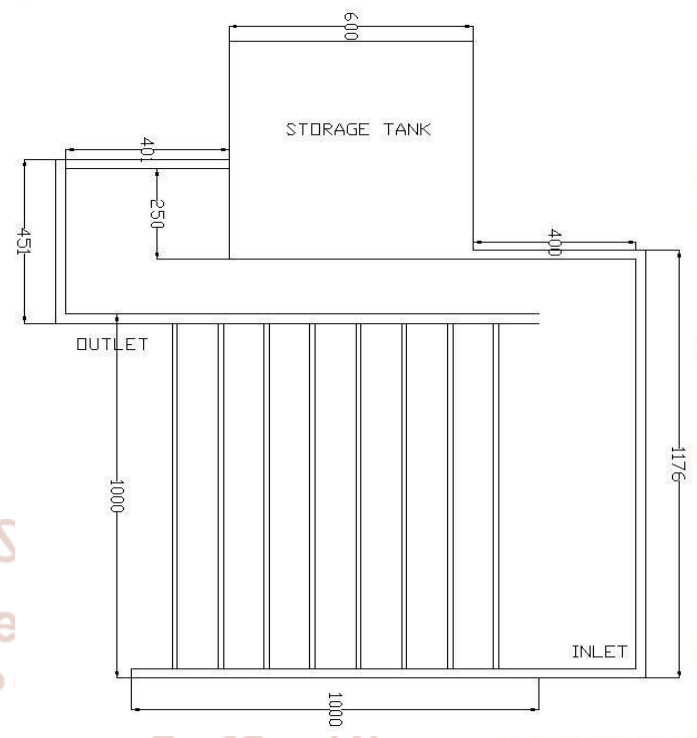
3.1.1 Schematic diagram of a PV/T system
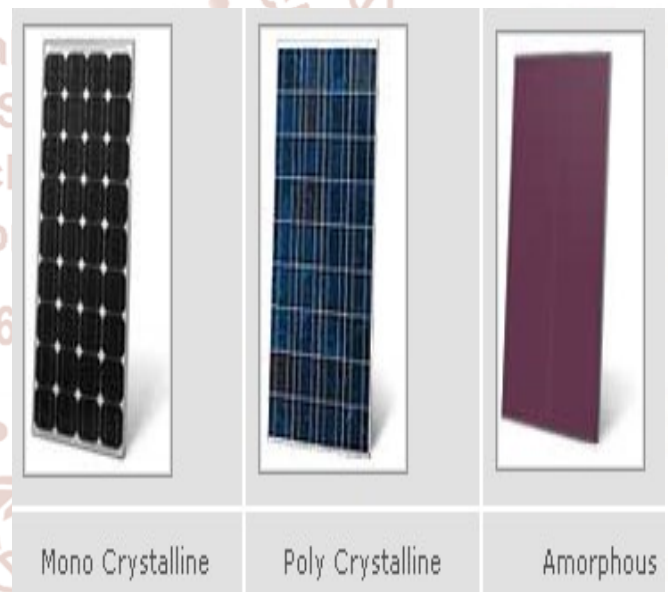

Fig: 3.1.2 PV Module

3.2. PHOTOVOLTAICS:

Photovoltaic (PV) is a method of generating electrical power by   converting sunlight into direct current electricity using semiconducting materials that exhibit the photovoltaic effect. A photovoltaic system employs solar panels composed of a number of solar cells (PV cells) to supply usable solar power. The photovoltaic cell is the basic building block of a PV system. Individual cells can vary in sizes from about 1cm to about 10 cm across. Most cells are made

with silicon today. Silicon must be purified. This is one of the biggest expenses in the production of solar cells.

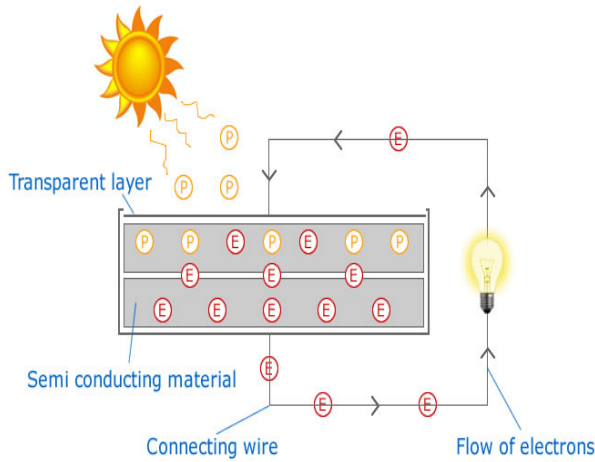**Figure 3.2.1: working principle of PV cell**

4. EFFICENCY CALCULATION

4.1 EFFICIENCY OF FLAT PLATE COLLECTORS:

The solar collector efficiency η is defined as:

$$\eta = \frac{\text{actual useful energy collected}}{\text{solar energy incident on the collector}}$$

$$\eta = \frac{Q_u}{I_T A_C}$$

Where,

Q_u = rate of useful heat collected from the collector

I_T = total solar radiation incident on the collector per unit area and time

A_C = aperture area of the absorber

Thus instantaneous efficiency of the flat plate collector is given as:

$$\eta = F_R(\tau\alpha)_e - F_R U_L \frac{(T_i - T_a)}{I_T}$$

τ = transmittance of the cover plates

α = absorptance of the black absorber surface

T_i = inlet fluid temperature

T_a = ambient temperature

The collector heat removal factor may be calculated from the following equation:

$$F_R = \frac{\dot{m}C_p}{U_L A_c}\left(1 - \exp\left[-\frac{U_L A_c F_p}{\dot{m}C_p}\right]\right)$$

$\dot{m}$ = mass flow rate of the fluid

C_p = heat capacity of fluid

The plate efficiency factor Fpis defined as

The plate efficiency factor (Fp) for a tube in plate type of collector may be calculated from the following equation:

$$F_p = \frac{1/U_L}{W\left[\frac{1}{\pi D h_{fi}} + \frac{m_t}{\pi D K_t} + \frac{1}{C_b} + \frac{1}{U_L[D + (W - D)F]}\right]}$$

Where

W = center to center tube spacing

D = outside diameter of the tube

h_{fi} = tube to fluid (film) heat transfer coefficient

K_t = thermal conductivity of the tube

C_b = bond conductance (= Kb b/t)

Kb = bond material thermal conductivity

b = bond width

t = bond thickness

mt = tube thickness

F = fin efficiency factor given as:

$$F = \frac{\tanh[a(W - D)/2]}{a(W - D)/2}$$

Efficiency of solar cell:

$$\eta = \frac{\text{incident radiation}}{\text{power radiation}}$$

Typical standard test condition for efficiency measurement

Irradiance 1000w/m2 or 800 w/m2

4.2. Effect of mass flow rate on the PVT collectors

The mass flow rate through the collectors and into the designated channels indirectly affects PV module cooling. The effects of the mass flow rate on the absorber collectors are shown in Figs. 9–11. The mass flow rates used in this analysis (0.011– 0.041 kg/s) were later applied under various solar radiation levels. The results show that increasing the mass flow rate simultaneously decreased the PV temperature of the PVT collectors at all solar radiation levels. At the same mass flow rate, the PV temperatures in-creased in the solar radiation level. Figs. 5–9 show that from 0.011 kg/s to 0.041 kg/s mass flow rates and under 500 W/m2 solar

Fig4.2.2. Changes in PV efficiency with the mean PV temperature of the PVT absorber collectors under 600 W/m2 of solar radiation.
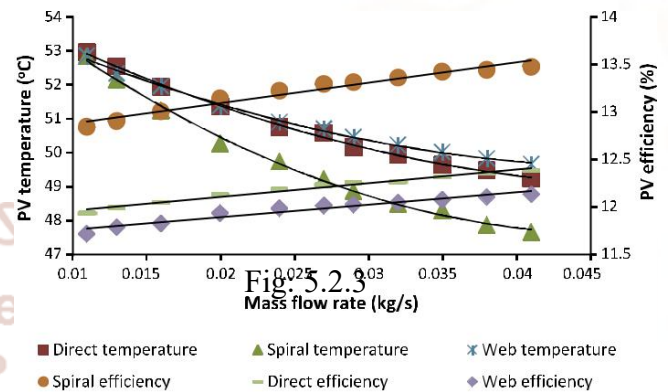

Fig: 4.2.4 Changes in PV efficiency with the mean PV temperature of the PVT absorber collectors under 700 W/m2 of solar radiation.
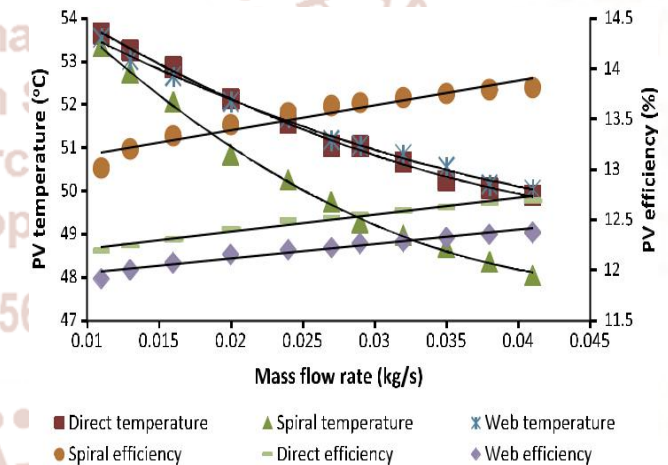

Fig: 4.2.5

Fig:4.2.5 Changes in PV efficiency with the mean PV temperature of the PVT absorber collectors under 800 W/m2 of solar radiation.

The temperature decreased from 50.20 LC to 47.76 LC and PV efficiency simultaneously increased from 11.07% to 11.42%. When solar radiation was increased to 800 W/m2, temperature dropped from 53.5 LC to 50 LC, whereas PV efficiency increased from 11.91% to 12.37%. For the direct flow absorber as (Fig. 10) and referring to Figs. 5–8, at solar radiation of 500 W/m2 and when mass flow rate increased from 0.011 kg/s to 0.041 kg/s, PV temper-ature dropped from 50.11 LC to 47.18 LC, and PV
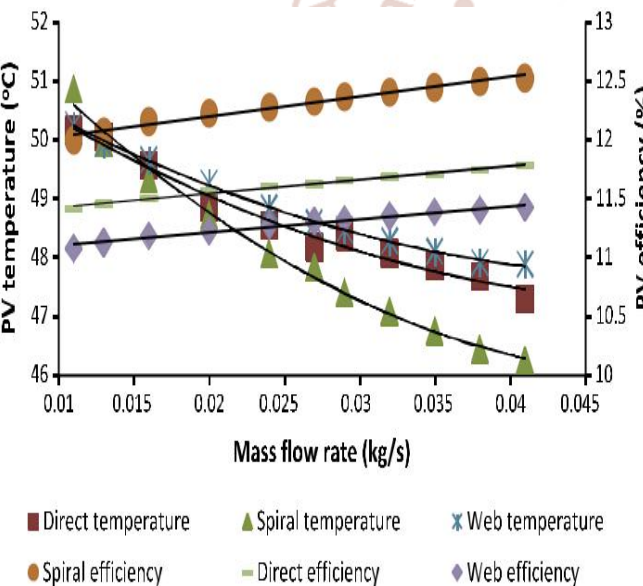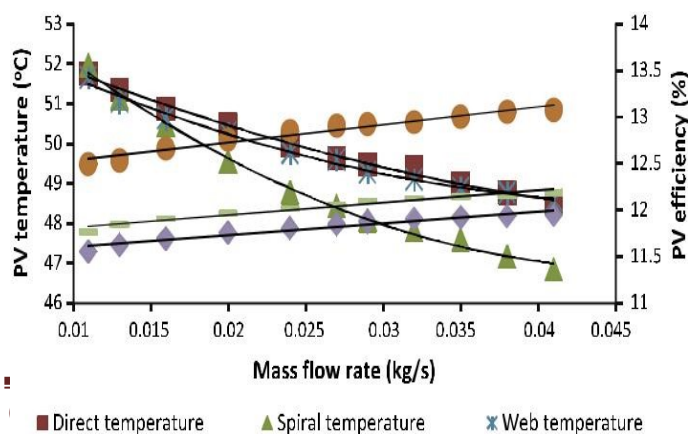

Fig. 4.2.1. Changes in PV efficiency with the mean PV temperature of the PVT absorber collectors under 500 W/m2 of solar radiation.

efficiency in-creased from 11.41% to 11.78%. The same result was obtained when the solar radiation increased to 800 W/m2: temperature de-creased from 53.6 LC to 49.8 LC, whereas PV efficiency increased from 12.19% to 12.69%.

5. TABULATION

Result of PV module and PV/T system Flow under various mass flow rates and solar radiations

Table : 5.2.3 Mechanical Energy

Timing	Mass flow rate	T in	Tout
10	0.011	26	32
11	0.013	26	38
12	0.015	26	38
1	0.016	27	39
2	0.018	28	38
3	0.017	28	38
4	0.016	28	38

Table : 5.2.3 Electrical Energy

Timing	V 1	I 1	Voc	Ioc
10	17	0.4	17	0.6
11	16	0.3	18	0.7
12	15	0.3	17	0.8
1	16	0.4	17	0.8
2	16	0.5	17	0.9
3	7	0.6	18	0.7

6. CONCLUSION:

The efficiency of photovoltaic panel is sensitive to operating temperature and decreases when the temperature of the PV increases. Therefore, the PV/T hybrid systems are one means used to improve the electrical efficiency of the panel. In the study, the photo voltaic panel temperature significantly reduced by 15–20% due to the flow of water through the manifold to the rear of the PV panel (recalling that it is about 60 _C to 80 _C in the conventional photovoltaic solar panel)

For all previously stated, we can say that our objective is to get a more effective exploitation of solar energy by the advantage materials and technical means used (galvanized steel, water) that reduce costs and required installation area, and of the part photovoltaic simply we get a better performance of the Collector. For which reason its use does not change, with the removal of the thermal energy produced What's used in various other applications exist (water heating, drying, air conditioning, etc.).

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