International Journal of Research in Engineering, Science and Management
Volume-1, Issue-11, November-2018
www.ijresm.com | ISSN (Online): 2581-5792

A Review on Performance Analysis of Nano Particles on Photovoltaics

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***Abstract*: Photovoltaic thermal hybrid solar collectors, sometimes known as hybrid PV/T systems or PV/T systems combines a solar cell, which converts sunlight into electricity, along with a solar thermal collector, which captures the remaining energy and removes waste heat from the PV module. The capture of both electricity and heat allow these devices to have higher energy and thus have more overall energy efficiency than solar photovoltaic (PV) or solar thermal collector alone because dual energy from same unit area. Due to the inherent drawback of lower efficiencies of photovoltaic (PV) technologies they face some reluctance from domestic consumers for widespread acceptance. But the lower individual efficiencies of the PV/T collector compared to their individual technologies due to the low solar energy absorption and high thermal resistance between the PV cell and the cooling medium hinders the potential advantages of this hybrid technology. The efficiency of the system gradually decreases with increase in the temperature. Recently, different nanoparticles with base fluid (Nanofluid) are used in this hybrid systems for enhancement of the efficiency of the system as they act as the effective cooling medium. This review paper would give an overview of enhancements in solar PV/T systems with Nanofluid for extensive relevance in energy supply at all levels in the vicinity of future.**

***Keywords*: PV/T, nanofluid, base fluid, nano particles.**

1. Introduction

In previous era before technological Revolution, mankind was entirely dependent on the renewable sources (wind, solar, hydro and biomass) for the supply of energy for a majority of human actions (e.g., Transportation, cooking, etc.). However, over the last 150 years, the energy demand is continuously increasing globally. Therefore new methods of conservation of energy, the supply of energy as well as for the environmental protection are highly covetable. Solar energy has the greatest potential of all the sources of renewable energy. It will be one of the most important supplies of energy especially when other energy sources in the country have depleted. So, PV/T system can be a effective technology to harness both electrical and thermal energy.

A. Concept of PV/T

Combined photovoltaic-thermal system (PV/T) is considered as an appealing invention in solar technology. These systems are special kind of heat exchangers; the heat from the photovoltaic modules is extracted using various techniques. To extract the heat from the PV modules, water and air were used extensively in the beginning. The technology has grown in the last three

Decades. The concept of PV/T systems is almost five decades old. But still, the technology is not much commercialized.

B. Types of PV/T collector

PV/T systems can be classified into many types based on how the heat is removed from the system,

- PV/T liquid collector
- PV/T air collector
- PV/T Liquid and air collector
- PV/T concentrator (CPV/T)

2. Literature review

Husam et al. has experimented the effect of nanoparticles (SiC, TiO2 and SiO2) with water as its base fluid on the electrical and thermal performance of a photovoltaic thermal (PV/T) collector equipped with jet impingement have been investigated. A PV/T collector was tested indoor at set levels of solar irradiances and mass flow rates. The system consists of four parallel tubes and 36 nozzles that directly inject the fluid to the back of the PV/T collector. The electrical performance of the PV/T collector was determined based on the mean temperature of the PV/T absorber plate. The SiC/water nanofluid system reported the highest electrical and thermal efficiency. The electrical, thermal, and combined photovoltaic thermal efficiencies were 12.75%, 85%,and 97.75%, respectively, at a solar irradiance of 1000 W/m2 and flow rate of 0.167 kg/s and ambient temperature of about 30 _C. Moreover, the Pmax of PV/T with SiC nanofluid increased by 62.5% compared to the conventional PV module.

G. Narendar et al has proposed that Nanofluids of CuO and Al2O3with 0.25%, 0.5%, 0.75% and 1.0 % (by wt.) of nanoparticles are prepared using probe sonication process. The properties viz., pH value, TDS and conductivity are tested before use and after use in a heat transfer appliance named Natural circulation loop operated at various temperatures. The temperature effects on the properties of the nanofluid in the heat transfer appliance are studied. The nanofluid prepared by CuO nanofluid has less affected by temperature than the Al2O3 nanofluid. Due to this, the CuO nanoparticles less settled than the Al2O3 nanoparticlesin nanofluid and hence showed good thermal performance in the heat transfer appliance operated at various temperatures.

Jia Zenga et al. has produced the binary nanofluid contains multi-wall carbon nanotubes (MWCNTs) and silica/silver (SiO2/Ag) plamonic nanoparticles. Instead of the limited absorption property of unitary nanofluids, by mixing different types of nanofluids with different spectrally absorptive features in proper manners, the spectral absorptance of binary nanofluids can be adjusted by controlling the ratio of two components. Since MWCNTs have high absorption in infrared spectra while SiO2/Ag nanoparticles have strong absorption peaks within visible spectra, the mixed nanofluid get higher absorption within wider solar spectra. Meanwhile, the existence of MWCNTs in the working fluid remarkably improves energy transport of the binary nanofluid. Specifically, MWCNT with the volume fraction of 0.1% can enhance the thermal conductivity of about 7%.

Sardarabadi et al. has experimentally investigated the effects of simultaneous use of a ZnO/water nanofluid and a phase change material (PCM) as coolant mediums for a photovoltaic (PV) fluid/nanofluid based collector system are investigated Experimentally.By designing and fabricating two similar photovoltaic thermal systems, one with a PCM medium (PV/T/PCM) and one without a PCM (PV/T), the experiments are performed. The measured results for surface temperature, thermal and electrical efficiency of the systems are compared with each other and with those of a conventional photovoltaic module as a reference system based on a thermodynamic viewpoint. In addition, the results for ananofluid as a working fluid are compared with those using pure deionized water. Results show that in the PCM/ nanofluid based collector system; the average electrical output is increased by more than 13% compared to that of the conventional PV module.

Ali Najah et al. evaluated the PV/T collector experimentally with different types of nanofluids (SiO2, TiO2 and SiC). The results indicated that the PV/T collector with SiC nanofluid has the highest combined photovoltaic thermal (PV/T) efficiency of 81.73% and PV/T electrical efficiency of 13.52% with the best overall energy coefficient (COE) of 0.93 has been achieved at a flow rate of 0.170 kg/s and solar irradiance levels of 1000 W/m2, followed by PV/T-TiO2 nanofluids, PV/T-SiO2 nanofluids, and PV/T-water respectively.

N. Aste et al. Evaluated that the Flat plate PV/T water based technology presents many advantages in terms of overall performance and space saving than the PV modules and the solar thermal collectors installed separately. However, the electrical and the thermal performances of the PV/T technologies are more deeply related to different influences factors, among which: the presence or absence of the air gap formed by the transparent frontal cover, the absorber configuration and the adopted PV technology. For that reasons, the proposed research is aimed to assess, under the energy point of view, a comparison between a covered and an uncovered PV/T water collectors, realized with different PV cells coupled to two aluminium roll-bond absorbers characterized also by different channel arrangements. The performance analysis is based on energy simulations carried out with two mathematical models validated on experimental data at the Test Facility of the Politecnico di Milano.

3. Experimental methodology

GT	-	Solar radiation (Wm^{-2})
Tin	-	Inlet temperature (°C)
Tout	-	Outlet temperature (°C)
Tamb	-	Ambient temperature (°C)
A_p	-	Area of the panel (m^2)
As	-	Area of the system (m^2)
CP	-	Specific heat capacity ($J\ kg^{-1}\ K^{-1}$)
Q_s	-	Energy rate (W)
I	-	Current (A)
V	-	Voltage (V)
η	-	Efficiency
ρ	-	Density (kgm−3)
φ	-	Volume fraction
P_T	-	Thermal power (W)
P_E	-	Electrical power (W)
$\dot{m}$	-	Mass flow rate (kg s−1)

Subscript
a - air
elec - electrical
fl - fluid
in - inlet
out - outlet
ther - thermal
nf - nanofluid
bf - basefluid
np - nanoparticle

As the PV/T System consists of one thermal unit for the extraction of heat energy from the hot fluid entering in the system and other is the electrical unit for the production of electricity from the PV cells. The expression for the useful collected heat in the system is given in Eq. (1):

$$Q_s = \dot{m} C_p (T_{out} - T_{in}) \quad (1)$$

Where $\dot{m}$ is the mass flow rate of the fluid ($kg\ s^{-1}$), Cp is the specific heat capacity ($J\ kg^{-1}\ K^{-1}$) and Tin, and Tout is the inlet and outlet temperature of the fluid in the system.

The equation for the overall thermal efficiency, ηther of the system is expressed in Eq. (2):

$$\eta_{ther} = \frac{Q_s}{G_T \times A_s} \quad (2)$$

Where Q_u is the useful collected heat (W), GT is the solar radiation (Wm^{-2}), and as is the surface area of the collector (m^2). The electric power is:

$$P_E = I \times V \tag{3}$$

Where I is current in ampere (A) and V is voltage in volts (V).

The electric efficiency of the system mainly depends on solar radiation (GT) and Area of the panel (A_p) is expressed in Eq. (4):

$$\eta_{elec} = \frac{P_E}{G_T \times A_p} \tag{4}$$

The overall efficiency of the system (or energy efficiency) is calculated by adding both thermal and electrical efficiency and expressed as:

$$\eta_t = \eta_{ther} + \eta_{elec} = \frac{Q_s + P_E}{G_T \times A_t} \tag{5}$$

Where At is the total collecting area of the collector and panel.

4. Nanofluid thermal properties density

The density (kgm_{-3}) of the nanofluid mainly depends on volume fraction, density of nanoparticle and basefluid and is expressed by the Eq. (6):

$$\rho_{nf} = \varphi\rho_{np} + (1 - \varphi)\rho_{bf} \tag{6}$$

A. *Specific heat capacity*

The most acceptable equation about the specific heat capacity of the nanofluids is given by the Eq. (7):

$$C_{p,nf} = \frac{\varphi(\rho C_p)_{np} + (1 - \varphi)(\rho C_p)_{bf}}{\rho_{nf}} \tag{7}$$

Where φ is the volume fraction of nanoparticles. Eq. (7) takes into consideration the product of density-specific heat capacity and not only the specific heat capacity as other literature formulas.

5. PV/T system

A. *Schematic diagram*

The PV/T system has working fluid circulating the system which absorbs the heat from the PV panels and take them to the heat exchanger. The PV/T system is closed type so that the water in the system is reused.

B. *PV/T module*

The PV/T module has the following layers in order.

1) Glazing 2) PV module 3) Absorber plate 4) Absorber coil 5) Heat insulation

C. *Instruments used*

1) DC pump
2) Solar power meter
3) Ammeter
4) Thermal image camera Psychrometer
6) Heat exchanger
7) Thermocouples

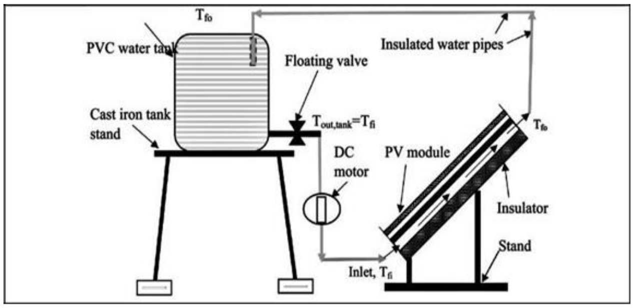


Fig. 1. Schematic diagram of PV/T

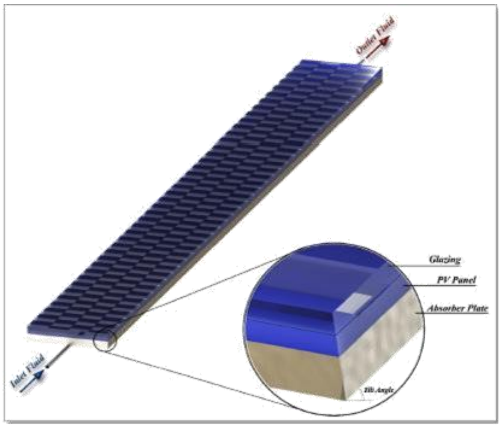


Fig. 2. PV/T module setup

D. *Physical parameters affecting PV/T collector*

1) Wind speed
2) Air space resistance
3) Azimuth angle
4) Tube spacing
5) Slope
6) Shading
7) Dust on top cover

E. *PV/T with nano fluid*

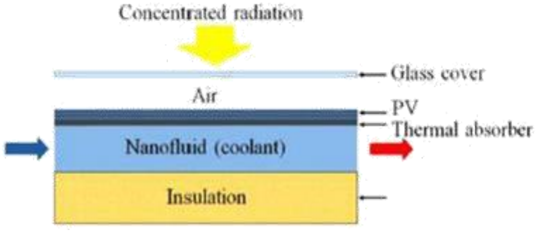


Fig. 3. Cross section of PV/T

The working fluid of the PV/T system can be Nanofluid(basefluid with nano particles) which are prepared by the suitable methods .Nano materials are particles which have size

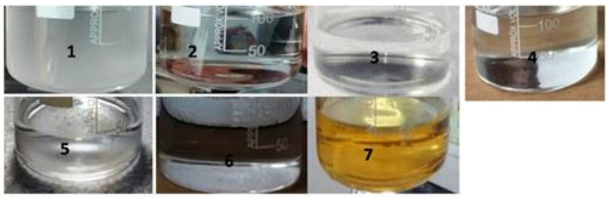
Table 1
Result and discussion

Authors	Nanomaterial Type /BaseFluid	Nanoparticles concentration wt.%	Electric power enhancement	Thermal energy gained	Remarks
Rostami et al.(2017)	Fe_2O_4 Water	1–3%	17%	33%	The study investigated the effects of a Fe_2O_4-water nanofluid on the electrical and thermal efficiencies Of a PV/T system. The study was conducted indoor using solar simulator
Sardarabadi Et al. (2017)	Al_2O_3 TiO_2 ZnO Water	2.37–7.48% 0.38–3.8% 1.93–4.11%	23.2% 23.5% 23.5%	85% 105% 110%	The experimental and numerical study was conducted to evaluate thevarious metal oxides nanofluids Coolant effect. ZnO/water nano-fluidhad the highest thermal efficiency in comparison with the other two nanofluids
Khelifa et al (2015)	Al_2O_3 SiC Water	4% 4%	19%	62%	A microchannel heat sink was used in new designed technique where a SiC 4% nanofluid is applied to cool down a PV/T system
Al-waeli et al. (2017)	Cu_9S_5 Water	0.23–0.92%	21%	40%	A fluid based spectral splitting filter was provided toa concentratingPV/T collector with in this Work. The maximum overall efficiency inthis case was increased to 34.2% compared with the case without filter which was 17.9%
Manikandan and Rajan et al. (2015)	Sand Propylene glycolwater	0.5–2%	–	16.5%	The study was conducted to investigate the thermos-physical properties of prepared surfactant-free, sand-propylene glycol-water nanofluids for solar energy collection.The thermal conductivity was enhanced by 16.3% and the viscosity was reduced by 47% when 2 vol.% of sand-PG water nanofluid at 28 _C was used
Aste et al. (2017)	Ag Al_2O_3 Water	3.4% 3%	3.9% 1.83%	12.4% 4.45%	A CFD study conducted to evaluate the cooling effect of two studied nanofluids on a PV/T System.
Sardarabadi et al (2017)	ZnO Water	0.2%	9.5%	42%	The authors studied two cases: using nanofluid and PCM to cool PV/T system and compared the results with water only
Hassani et al.(2016)	Ag–SiO_2 + CNT Water	0.026%	19%	60%	The authors used Ag-SiO_2 and CNT In water. These materials were used due to its sun light absorbing properties
zeng et al. (2017)	SiO_2 Water	0.02%	–	9.7%	A CFD study focused on changing the nanomaterial sizes. The thermal conductivity showed 20% Enhancement . The system maximumexergetic efficiency was defined at a specific nanofluid flow velocity and nano-SiO_2 concentration

in the range of 10^{-9}m. There are various types of base fluids and nanoparticles used.

F. Base fluids

The basefluid is an active medium which circulates the heat energy throughout the system, the basefluid should be cheap, effective and non-corrosive.



(1: Al_2O_3 Nanofluid, 2: Coconut oil, 3: Distilled Water, 4: Transformer Oil , 5: Glycerine, 6: Ethylene Glycol, 7: Rice Bran oil)

Fig. 4. Different types of basefluids

6. Performance analysis

A. Mass flow rate

Mass flow rate plays major role in heat transfer by the nanofluid, the temperature of the PV module decreases with increase in the mass flow, thus increasing the efficiency of the system.

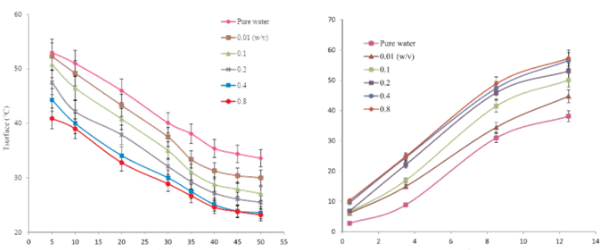


Fig. 5. Variation of the average temperature of the PV module surface by time at different concentration of nanofluid (Q=12.5m^3/h)

B. Concentration

The concentration of the nano particles is the % wt of the nano particles in the base fluid. The increase in the concentration of the nano particles increase the conductivity of the nanofluid and increase the viscosity of the nanofluid.

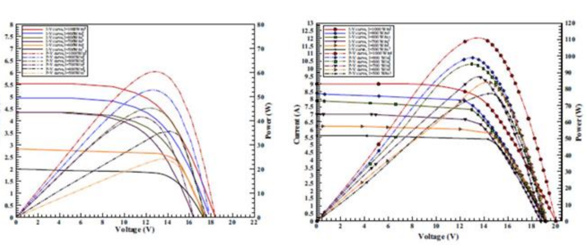


Fig. 6. IV and PV Characteristics before and after using nano fluid

7. Conclusion

The nano particles.The high surface to volume ratio of nano particles is their major advantage, thus the PV/T water collector with nanofluids are better than other methods. The experimental results showed that a PVT/ nanofluid system can improve the electrical output by 7% .In this study, it is found out that the PV/T collector performance can be greatly increased by conventional PV unit. This value is 2% for the electrical output, compared to that of the PVT/pure water system. The following factors are to be considered when the system is integrated with nano particles: 1) thermal conductivity of nano particles 2) size of particle 3) concentration of nano particles 4) mass flow rate 5) base fluid. The preparation process of nano particles involves great effort and attention. The advancement of the material science in future may lead to ease of production of the nanoparticles.

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