EXPERIMENTAL INVESTIGATION OF POTENTIALITY OF NANOFLUIDS IN ENHANCING THE PERFORMANCE OF HYBRID PVT SYSTEM

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ABSTRACT

The power from sun caught by earth is nearby 1.8×10^{11}MW which is obtained by utilizing sun's energy by photovoltaic cells appears to be a good substitute then the conventional fuels. The efficiency of the system declines due to the heat confined in photovoltaic cells throughout the operation [1]. Enhancing the efficiency of Sun power generation by engaging nanofluids in PV/T systems is achieved by recent improvement in the nanotechnology field. In our work Nano fluids are employed as coolants to lower the PV panel temperatures and thus the system efficiency increases. This study comprehensively analyses the effectiveness of Zinc nanoparticles in different base fluids i.e. water, water (75%) & ethylene glycol (25%) and water (75%) & propylene glycol (25%) to enhance the electrical and thermal efficiency of the PV/T system. Other parameters like flow rate, concentration of nanoparticles by volume and sonication time are kept constant throughout the experiment. The experiments were performed on an indoor setup and to replicate the solar irradiance a solar simulator was engaged as per previous year's metrological data. It is perceived that the extreme change in electrical efficiency is 2.6% and maximum change in thermal efficiency observed is 31% as compared to conventional system.

Keywords: Nano fluids, photovoltaic cells, nanoparticles, sonication time, electrical efficiency.

INTRODUCTION

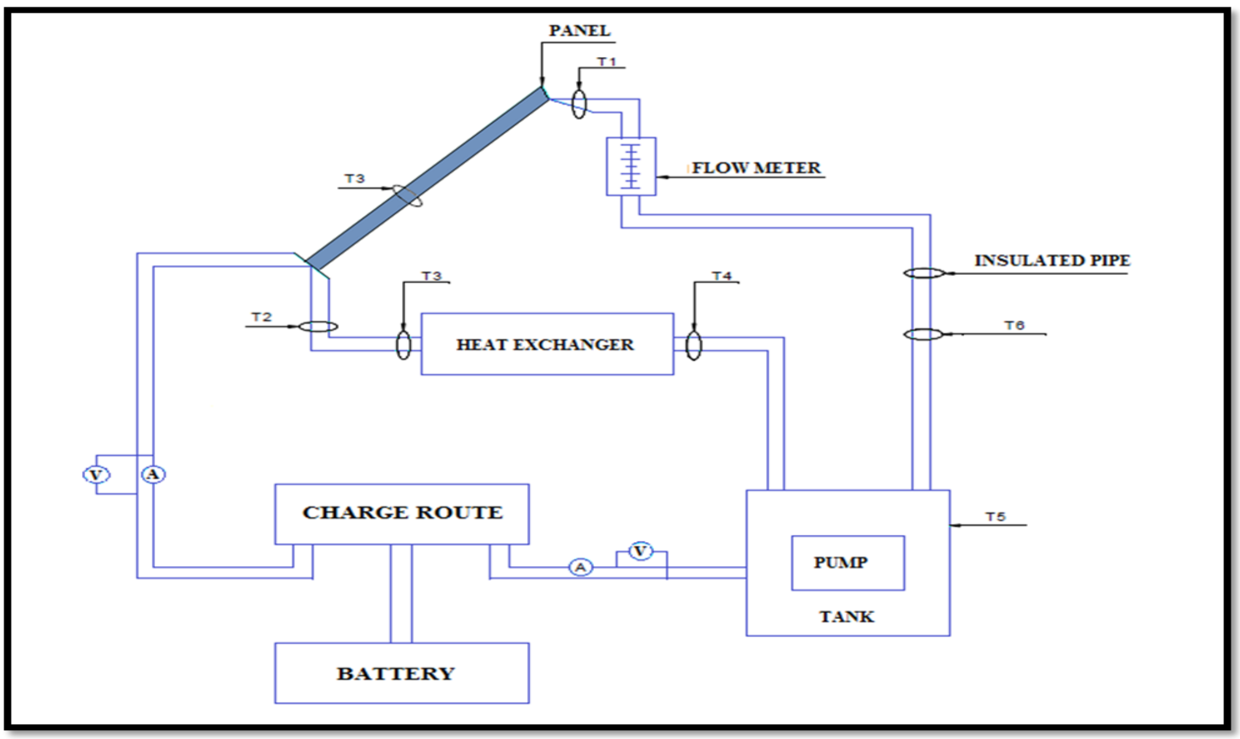
The escalation of world's population has led to an increased demand of resources including water, electricity, and housing. Consumption of fossil fuels has also increased in order to meet the human demands resulting in environmental degradation. Scientists and researchers are putting their efforts to look after some alternate eco-friendly/rechargeable energy sources which are cost-effective and less polluting. Also, solar energy is one the optimum energy sources, there are two possible ways that can be used to extract the solar energy. Through semiconductors, photovoltaic panels was made that transform energy of light straightly to DC current. For evolving countries, particularly the ones situated in humid and temperate regions, solar radiation is the ultimate source of energy with tremendous potential. Photovoltaic cells are eco-friendly and uncontaminated source for power production and have an extensive kind of application. *Khanjari et al*.(2016) considered pure water and Alumina-water nanofluid as coolant. The result showed that by increasing the volume fraction of nanoparticles the heat transfer coefficient and efficiency was enhanced. For alumina-water the extreme increase percentage of heat transfer coefficient was 12%. Rising the heat transfer coefficient pertaining to the velocity at the inlet of fluid in the range of 8-10% at volume fraction 5% in association to clean water for alumina-water nanofluid [1]. *Al-Shamani et al.*(2016) different types of nanofluids (SiC,TiO2 and SiO2) were used in PV/T accumulator. The investigation outcomes exhibited that the highest PV/T electrical efficiency of 13.52% obtained in case of PV/T collector with SiC nanofluid. For PV/T-TiO2 nanofluids, PV/T-SiO2 nanofluids, and PV/T-water thermal photovoltaic (PV/T) efficiency of 81.73% was accomplished at a flow rate of 0.170 kg/s and 1000 W/m2 of solar irradiance levels, correspondingly [2]. *Yun and Qunzhi* (2012) prepared MgO-water nanofluid has been and used above PV panel of silicon so as to diminish solar cells heat. The transmittance of light, temperature of solar cells, optical properties and temperature dropped from inlet to outlet and output power of solar cells had been compared for different mass concentration of fluid produced. The concentrations and particle size of the nanofluid utilize was almost 0.02wt%, 0.06wt% and 0.1wt%, 10 nm respectively. The designed PV/T system having a 2mm thick liquid layer had efficiency above 60%. Also, compared to that of traditional PV system there was no gain in electrical efficiency but relatively higher overall efficiency accomplished [3]. *Michael and Iniyan* (2015) improved photovoltaic thermal collector performance by using copper oxide – water (CuO/H2O) nanofluid as a coolant, which was made by sealing a copper sheet to the silicon cell directly. From the experimental data they observed that .05% volume fraction of nanofluid made a significant improvement in the thermal efficiency up to 45.76% compared to water [4]. *Rajeb et al.* (2016) showed that higher performance is achieved in comparison with ethylene glycol using pure water as a base fluid. In appraisal to Al2O3/ ethylene glycol, Al2O3/water and Cu/ethylene glycol consuming Cu/water contributes the best electrical and thermal efficiency. It is perceived that energy output of electrical and thermal energy for Monastir (Tunisia) weather condition is greater than that of Iran and France [5]. Sardarabadi et al. experimentally studied the effect of TiO_2, Al2O3 and ZnO nanofluids with base fluid water. The volume fraction of each nanofluid is taken as 0.2wt% and the size of the nanoparticle was 20nm for Al_2O_3 about 10-30nm for TiO_2 and for ZnO 10-25nm. The results showed the enhancement in electrical efficiency of the PV/T system for TiO2 6.54% for Al_2O_3 it was 6.36% and for ZnO it was 6.46% [6].The researchers have also tried to configure in detail the effects of properties of nanofluids on various system parameters such as electrical efficiency and thermal efficiency of the system. Nanofluid as a coolant in popular researchers have concentrated on employing the nanofluid flows beneath PV cells to harvest their heat and diminish the

COMPONENTS	DESCRIPTION

temperature. After studying the works it can be clearly perceived that the altered systems have been considered to explore the effects of nanofluids as a coolant in the systems.

EXPERIMENTAL SETUP

We have performed the comparative study of zinc nanoparticles with different base fluids. The



effects of thermal and electrical output are equated with each other from the first law of thermodynamics viewpoint. This study enables us to check the employability Zinc based nanofluid as an alternative to other nanofluid which are relatively costlier. Instruments and the flow chart of circuit is shown in figure 1.

Figure.1 Line diagram of the experimental setup

Hybrid PV/T Panel	300W, Collector area 1.44m^2
Battery	Amaron; 12V, 100Ah
Pump	Metro; 165-250Volts, Power: 12 W H_{max} = 1.5-2.8 m of water
Flow meter	Capacity:- 0-2 LPM
Data logger	E&E, 8 channel datalogger
Infrared Thermometer	HTC; MT4 Range: -50 to 550 °C
Heat Exchanger	Air cooled fin type
Thermocouple	Range 0 to 500 °C Nickel-Chromium (K type)/Metal wire
Solarimeter	Tenmars electronics; TM 206
Solar Simulator	Halonix; 49 Halogens of 150 watts each
Charge Controller	Sukam; MPPT Charge controller

Table.1 shows the components of experimental setup

Material	**Properties**			
	Specific Heat (J/Kg-K)	**Density (Kg/m^3)**	**Thermal Conductivity (W/m-K)**	**Particle size**

Zinc Powder	376.81	7140	1.16	240
Ethylene Glycol	337	1110	0.285	-
Propylene Glycol	323	1051	0.147	-

Table.2 Shows the Material specifications

METHODOLOGY

- By the two-step process nanofluids were prepared.
- Zinc nano powder of APS 50 nm was bought from Sisco Research Lab Pvt Ltd.
- 3 different solutions of concentration 0.3% by volume was prepared with Zn nanoparticles in 3 different base fluids; Water, Water (75%) with Ethylene Glycol (25%) and Water (75%) and propylene Glycol (25%).
- In each case sonication was performed in an Ultra sonic bath for 2 hrs. to produce colloidal solutions.
- A closed circuit for the flow of nanofluid was established with the heat exchanger and a pump in between as shown in figure 1.
- Thermocouples are attached at different points to measure the temperature.
- Setup was then run at a constant flow rate of 2 lpm (0.03kg/s) and the readings were taken at intervals of 30 min.
- Intensity of radiation was varied after every half an hour, starting from 700W/m^{2}to 900 W/m^2 to simulate the outdoor conditions.

Governing Equations

After taking all the readings, thermal and electrical efficiencies of the hybrid PV/T system would be evaluated to investigate the effect of nanofluids.

Applying Energy balance and assuming steady state:-

$$E_{in} = E_{out}$$

which implies,

$$\dot{E_{in}} = \dot{E}_{el} + \dot{E_{th}} + \dot{E_{loss}} \quad (1)$$

where **E_{el}** the output electrical power,

E_{in} is solar irradiation the incident,

E_{loss} is the energy loss for the control volume.

E_{th} the useful thermal energy gained from the collector

E_{th} can be evaluated through a simple analysis of energy as:-

$$E_{th} = m_f.C_{p,f}.(T_{f,out} - T_{f,in}) \quad (2)$$

where: -

$T_{f,in}$ and **$T_{f,out}$** represent the inlet temperature and outlet temperature of fluid from the collector

C_{pf} is the specific heat of fluid,

m_f is mass flow rate of the fluid through the collector, respectively.

Following empirical relations are used to evaluate the thermo physical properties of nanofluids:

- For Density of the mixture:

$$\rho_{nf} = \varphi\rho_n + (1-\varphi)\rho_{bf} \quad (3)$$

And

$$\rho_{bf} = \emptyset\rho_{f1} + (1-\emptyset)\rho_{f2} \quad (4)$$

- For the Specific Heat Capacity of the mixture:

$$C_{p,nf} = \frac{\varphi.(\rho_n.C_{p,n}) + (1-\varphi).(\rho_{bf}.C_{p,bf})}{\rho_{nf}} \quad (5)$$

And

$$C_{p,bf} = \frac{\emptyset.(\rho_{f1}.C_{p,f1}) + (1-\emptyset).(\rho_{f2}.C_{f2})}{\rho_{bf}} \quad (6)$$

where n, bf and nf signify subscripts, nanoparticles, base fluid, and nanofluid correspondingly and ρ is the density [8].

φ is the ratio (volumetric) of nanoparticles in a solution of suspension of the fluid (base) that can be considered as follows:

$$\varphi = \frac{m_n/\rho_n}{m_n/\rho_n + m_{bf}/\rho_{bf}} \quad (7)$$

where m_f and m_n are the mass of the fluid and nanoparticles respectively.

$\emptyset$ is the ratio (volumetric) of fluids in the fluid (base) solution which might be evaluated by:

$$\emptyset = \frac{m_{f1}/\rho_{f1}}{m_{f1}/\rho_{f1} + m_{f2}/\rho_{f2}} \quad (8)$$

where m_{f1} and m_{f2} are the masses of the fluids, used to prepare the base fluid.

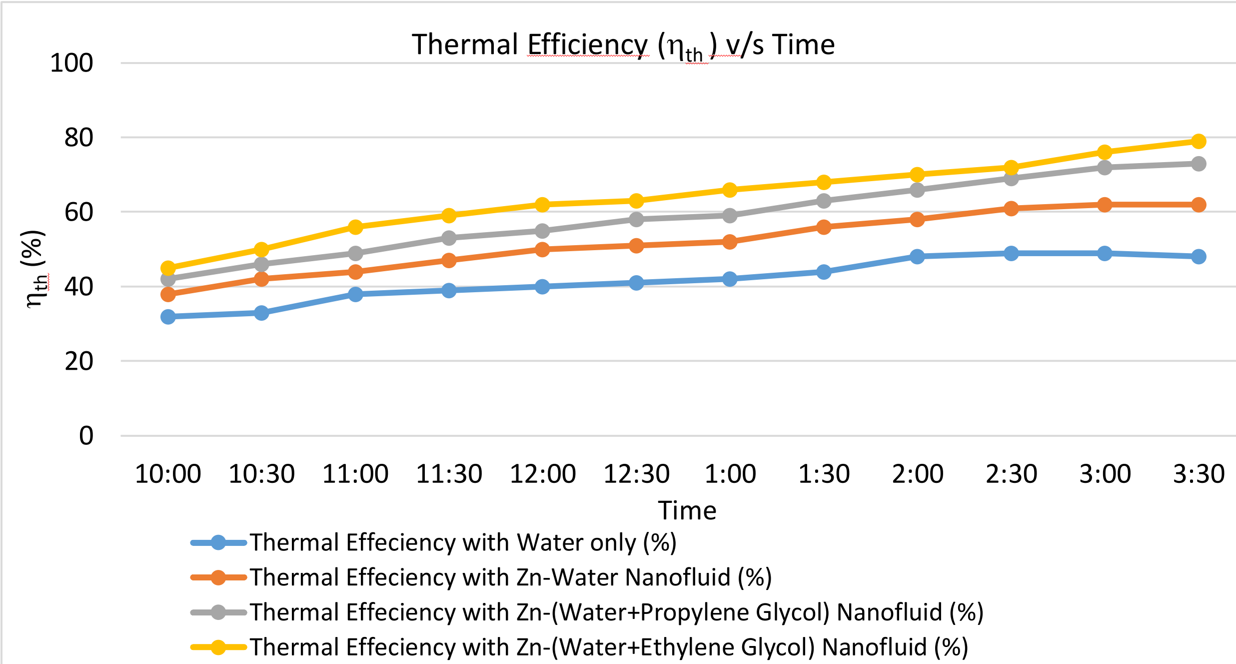
- Thus thermal efficiency can be expressed as:

$$\eta_{th} = \frac{\dot{E_{th}}}{\dot{E_{in}}} \quad (9)$$

- The electrical efficiency might be stated as:-

$$\eta_{el} \equiv \frac{\dot{E_{el}}}{\dot{E_{in}}} = \frac{V_{oc} \times I_{sc} \times FF}{\dot{G_{eff}} \times A_c} \quad (10)$$

Where,



- Short circuit current $\mathbf{I_{sc}}$.
- Open circuit voltage $\mathbf{V_{oc}}$.
- **FF** is fill factor (for polycrystalline PV panels the value of fill factor is **0.89**).
- $\mathbf{G_{eff}}$ is the mean of the radiation incident evaluated from solar power meter.
- A_c is the area of collector.

RESULTS

Figure.2 Thermal Efficiency (η_{th}) v/s Time graph

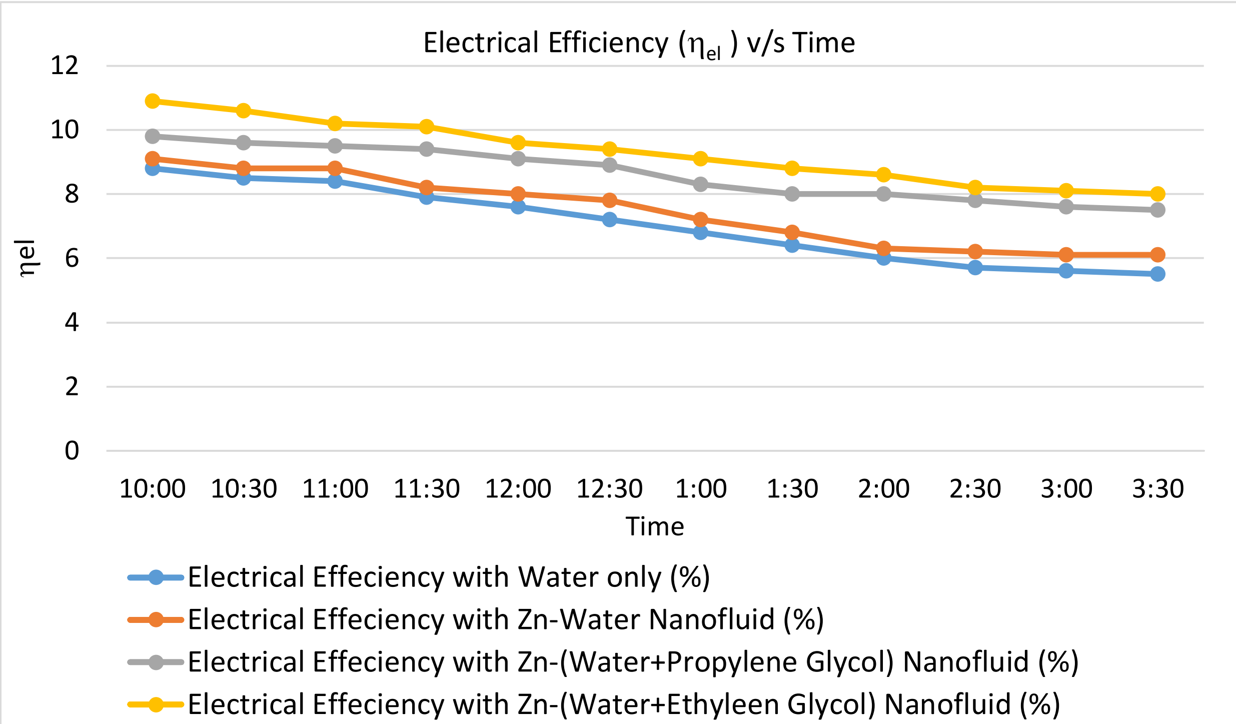


Figure.3 Electrical Efficiency (η_{el}) v/s Time

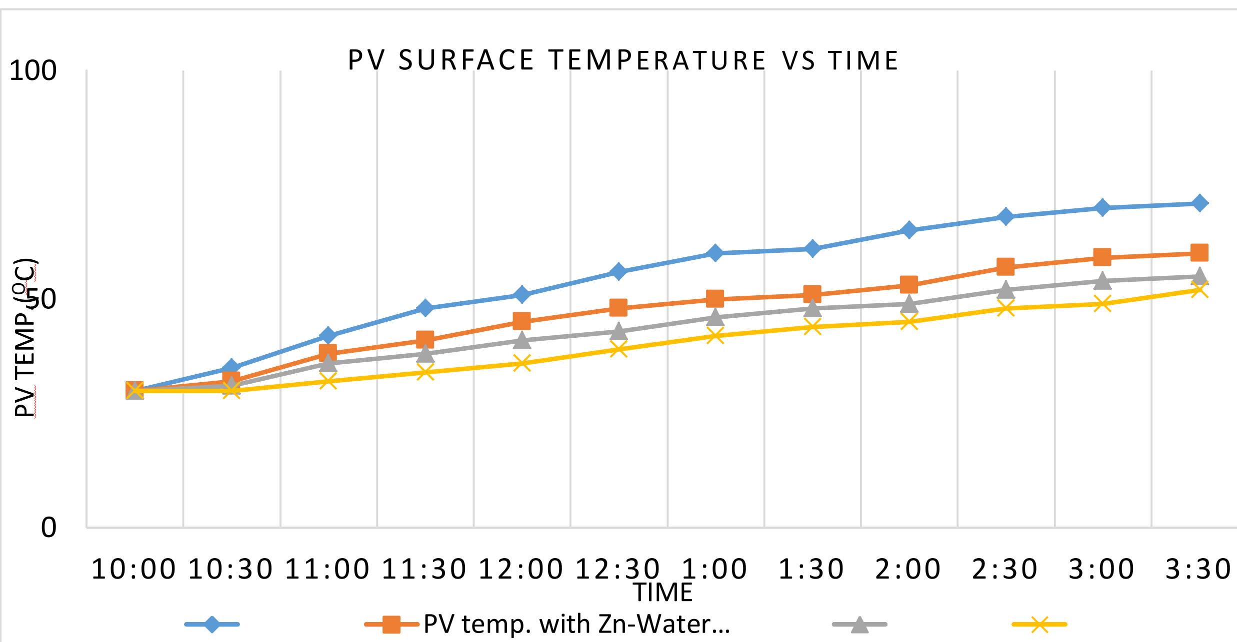


Figure.4 Variation of PV surface temperature with Time

ERROR INVESTIGATION

For both electrical and thermal efficiencies an Error investigation is executed. Table 3 signified the uncertainties related with the measuring equipment of the experimental operation.

If R is related to 'n' independent linear parameters as

$R = R\,(v_1, v_2, v_3 \ldots v_n)$, the ambiguity of function R might be evaluated as:

$$\delta R = \sqrt{\left(\frac{\delta R}{\delta v_1}\delta v_1\right)^2 + \left(\frac{\delta R}{\delta v_2}\delta v_2\right)^2 + \cdots + \left(\frac{\delta R}{\delta v_n}\delta v_n\right)^2} \quad (11)$$

Where δR show the ambiguity of function R, δv_i signified ambiguity of parameter v_i, and $\delta R/\delta v_i$ is the partial derivative of R with respect to the parameter V_1 [7].

Equipment and model	**Measurement section**	**Accuracy**
Current multimeter	Current	±(0.8%+1)A
Voltage multimeter	Voltage	±(0.5%+1)V
Rotameter	Mass flow rate	± 1kg/hr
Infrared thermometer	surface temperature of PV	0.14°C
Thermocouple	Fluid temperatures	±0.15-0.25°C
Mercury thermometer	Temperature (Ambient)	±0.5°C
Power meter (Solar)	Solar radiation Incident	±10 W/m^2

Table.3 shows accuracy of various components

Using the above equation (11) and recalling Eq (10), from the table solar input and the electrical/ thermal outputs fractional uncertainties are considered, by considering the maximum uncertainties for each parameter based on the following equation the maximum fractional uncertainty of the electrical efficiency can be calculated as:

$$\eta_{el} = f(G, P_{el}) = \frac{\delta\eta_{el}}{\eta_{el}} = \pm\sqrt{\left(\frac{\delta V}{V}\right)^2 + \left(\frac{\delta I}{I}\right)^2 + \left(\frac{-\delta G}{G}\right)^2} = \pm 0.019$$

In the Experiment, 1.9% is the maximum ambiguity of electrical efficiency.

likeways, the maximum uncertainty for thermal efficiency is calculated as:

$$\eta_{th} = f(G, T_{in}, T_{out}, \dot{m}) = \frac{\delta\eta_{th}}{\eta_{th}} = \pm\sqrt{\left(\frac{\delta T}{T}\right)^2 + \left(\frac{\delta\dot{m}}{\dot{m}}\right)^2 + \left(\frac{-\delta G}{G}\right)^2} = \pm 0.029$$

In the experiments the extreme total uncertainty for all parameters is less than 3%. Which confirms the dependability of the data measured.

CONCLUSIONS

- Thermal and Electrical efficiency obtained of the hybrid PV/T system is highest when it's cooled by Zn-(Water+Ethylene Glycol) nanofluid and least in the case when its only cooled by water.
- The maximum change in electrical efficiency observed is **2.6%** and maximum change in thermal efficiency observed is **31%.**
- Electrical efficiency of the Hybrid PV/T system decreases with time, as the operation time of the solar panel increases its resistance increase, current generating capacity decreases and hence its power generation capacity.
- Thermal efficiency of the Hybrid PV/T system increases with time as the operation time of the panel increases because more temperature difference is obtained across the heat exchanger.
- PV Panel surface temperature also is least in case of Zn-(water+Ethylene Glycol) Nanofluid cooled hybrid system and maximum in the case of water cooled system.
- PV surface temperature increase with time in all the 4 cases of cooling because of its continuous operation.
- Zn-(Water+Ethylene Glycol) Nanofluid gives most drop in surface temperature as compared to other 3 liquids/coolants. During our experiment the maximum temperature

difference between water cooled and Zn-(Water+Ethylene Glycol) Nanofluid cooled PV Panel is 19^0C.

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