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Research Article **Physics**

Alumina Nanofluid Active-Cooling Influence on the Electrical Yield of a Silicon Solar Photovoltaic-Thermal (PVT) System

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ABSTRACT

Solar panels' temperatures have a huge impact on their electrical production. Hence, nowadays' research work focuses on the mechanical cooling of the Photovoltaic systems through different fluids which could be forced or stationary. In this research paper, we compare the effect of overheating removal between two PVT systems cooled by water and alumina nanofluid at 0.01%, 0.03% and 0.05% volumetric concentrations and a mass flow rate of 0.05 Kg/s. In addition, the reference panel that is not affected by any cooling method is involved in the comparison. The results revealed that for higher concentrations, the thermal and electrical properties will be boosted, for instance, the maximum power enhancement for concentrations 0.01%, 0.03% and 0.05% are 2.29%, 4.12% and 11.83% above the PV panel, respectively. For thermal characteristics improvement, the nanofluid-cooled PVT with a concentration 0.05%, the betterment in the cooling is by 14.25% in contrast with the reference PV.

Introduction

The humans need for energy supply keeps increasing daily, due to the raising of population while today's world suffers from the shortage of energy supplement. For example, there is an increase of energy supply by 30% between 2011 and 2013 **(Klaus et al., 2014)**. Hence, nowadays, energy production techniques have become one of the most vital research topics; as researchers of this field always seek to find new clean and more reliable energy sources, which can be continuously produced. Non-renewable energy resources, for instance oil, coal and gas are polluting and contribute to the generation of greenhouse gases like CO_2. However, solar energy acts as one of the green and cheapest origins of energy that can be facilitated to provide electricity and heat that is used in various applications. **(Kumari et al., 2022)**. One of the major benefits of PV technology is its availability everywhere, hence it could be jobbed to serve for distant and isolated areas such as deserts and islands, where no technology or electricity could be found. Seeking the maximum electricity output from a Photovoltaic (PV) system is a crucial point of research as more difficult and expensive techniques should be facilitated in the case of primary design and controlling the internal structure of the crystals in a solar cell. Hence, mechanical removal of the overheating is a promising solution to overcome this issue of electrical losses due to high operating temperatures.

Previous research work has proved that raising the operating temperature of a PV system will result in a reduction in the output efficiency of conversion and the anticipated lifetime of best performance for the PV. For instance, by comparing maximum power output (P_m) and electrical efficiency (η) at two different temperatures: 25 ℃ and 60 ℃, **(Radziemska, 2003)** obtained 13.3% and 10.3% for η, and 79.6 W and 61.28 W for power at 25 ℃ and 60 ℃. The output power of the solar cell can be decreased by about 0.4% with an increase in its temperature of 1 Kelvin **(Radziemska, 2003)**. The relation between temperature and the electrical efficiency is given by the following equation **(Evans, 1981; Sathyamurthy et al., 2021)**:

$$\eta(T) = \eta_{ref}\left[1 - \beta_{ref}(T - T_{ref})\right]$$

Where $\eta(T)$ is the electrical efficiency as a function of temperature (T). β_{ref} is the temperature coefficient (0.004 K^{-1}), the reference temperature and efficiency are T_{ref} and η_{ref} given by the photovoltaic panel's producer.

To fix the temperature at a low value of the solar panel, **(Odeh & Behnia, 2009)** employed copper pipes fixed at the back of the module to compare a PVT with a PV. There was an increase by 3% for water-cooled panel upper the not cooled one by pumping water with a flow rate of 300 liter/hour, which leads to a 16 ℃ removal in one hour of continuous cooling at average solar radiation 350 W/m². **(Moharram et al., 2013)** developed a model to calculate the time needed to cool down the PVT to a specific temperature by equating the heat quantity lost by the PVT and gained by water. Temperature reduction by front surface and both surfaces water spraying cooling for a PVT system through the active mode 0.9 liter/minute is compared with a non-cooled PV by **(Sargunanathan et al., 2020)**. The results clarified that electrical conversion efficiencies increased by 8.778%, 15.278%, and 16.895% for the not cooled PV, front surface and both surfaces cooling, accordingly. It worth mentioning that water spraying on the upper side of the PV has two contrary properties, as it can help in cleaning and cooling at the same time, on the other hand the water drops have a negative effect of increasing the optical losses of incident radiation through reflection.

(Karami & Rahimi, 2014) examined Boehmite (aluminum oxide hydroxide AlO-OH) nanoparticles (5-10 nm) water-based nanofluid and water cooling to monocrystalline solar panels. The weight concentrations of the nanofluid used were 0.01%, 0.1% and 0.3% with flow rates: 0.04, 0.08, 0.15, 0.2 and 0.3 liter/minute. The best enhancement reached 27.15% at 0.01% concentration and flow rate of 0.3 liter/minute, in comparison to 23.10% and 19.56% for 0.1% and 0.3% at same flow rate, while the water betterment was 21.98%. Indoor testing for improvement of nano ferrofluid (i.e. ferrite water-based nanofluid) is performed by **(Ghadiri et al., 2015)** at concentrations of 1% and 3%. A sun simulator provided solar radiation of 600 and 1100 W/m^2. As this type of nanoparticles is affected by the application of external magnetic field, a 50 HZ alternating field is introduced, consequently the overall improvement at 3% nanofluid concentration was 50%, compared with 45% when no magnetic field is applied over the stand-alone water cooling. **(Al-Shamani et al., 2016)** tested three different water-based nanofluids: SiC, SiO_2 and TiO_2, and water active cooling with flow rates: 0.068, 0.102, 0.138 and 0.170 Kg/s in comparison to not cooled PV panel in the outdoor conditions. The back of the PVT system is cooled down through rectangular-shaped channels that were filled by the nanofluids. The solar irradiances used in this study were 400, 600, 800 and 1000 W/m^2. The best electrical yields obtained were at 400 W/m^2 and flow rate of 0.170 Kg/s with 13.879%, 13.225%, 12.857% and 12.467% for SiC, TiO_2, SiO_2 and water, correspondingly. **(Hussein et al., 2017)** reported the cooling effect by water and zinc water-based nanofluid at five different concentrations: 0.1%, 0.2%, 0.3%, 0.4% and 0.5%. The cooling method was active through different circulation rates: 1, 1.5 and 2 liter/minute for water and nanofluid that run in a helical tube in the back side of the PVT system. Without any cooling method, the electrical conversion efficiency was 5.5%, which developed into 6.5% by reducing temperature from 76 ℃ to 70 ℃ through water cooling at 2 liter/minute, on the other hand, depending on Zn nanofluid at 0.3% concentration and the highest flow rate (i.e. 2 liter/minute) the temperature is reduced to reach 58 ℃ providing an efficiency equals to 7.8%. **(Sardarabadi et al., 2017)** tested the monocrystalline solar panel cooling of ZnO water-based nanofluid which circulated through copper pipes that are attached to a copper sheet touching the back of the panel, while the in-between is filled with a phase change material. In contrast with the two other PV and PVT (i.e. cooled by water) systems, the nanofluid-cooled PVT introduced an increase of 13% in electrical efficiency over the PV one. Copper oxide water-based nanofluid is used by **(Das & Kalita, 2018)** to cool down a multi-crystalline sola panel. The nanofluid is forced through a plate hold beneath the PV panel, this plate is composed of fifteen rectangular fins 10.5 cm × 0.5 cm × 0.5 cm. The electrical efficiencies at noon time were found to be 4.9%, 7.4% and 7.9% for the three cooling methods, in order. Multiwalled carbon nanotubes (MWCNTs) and graphene nanoplatelets water-based nanofluids at weight concentration 0.5% for both, and water are jobbed to examine the temperature reduction effect on monocrystalline solar panel's electrical yield by **(Alous et al., 2019)**, compared two identical panels: PV and PVT under the same conditions. The PVT system is cooled through passage of nanofluids in a serpentine attached to copper sheet in the back of the panel. At the peak period (i.e. 11:15 am to 3:45 pm) the enhancements of the PVT over the PV were 8.9%, 10% and 12.4% for the water, graphene and MWCNTs, successively. Another study by **(Abdallah et al., 2019)** facilitated water based MWCNTs nanofluid at different concentrations: 0.05%, 0.075%, 0.1%, 0.2% and 0.3% circulated in a serpentine with a flow rate 1.2 liter/minute; to check the improvement in efficiency compared to water-cooled PVT and not cooled PV. The best betterment in the yield of the PVT was found at 0.075% concentration. A comparative study for cooling through a copper tube at the back of PVT effect on the electrical properties is made between Al_2O_3, copper oxide (CuO), Al_2O_3-CuO (1:1) mixture nanofluids and water by **(Amalraj & Michael, 2019)**. The obtained results of this study have shown a better efficiency for cooling through Al_2O_3-CuO mixture in contrast with CuO, Al_2O_3 and water. Investigation of two distinct water-based nanofluids cooling: Al_2O_3 and TiO_2 at weight concentrations: 0.01%, 0.05% and 0.1% compared to water and non-cooled PV system was reported by **(Ebaid et al., 2020)**. The cooling type for the two PVT systems (i.e. cooled by water and nanofluids) was active by two centrifugal pumps with flow rates: 0.5, 1, 2, 3, 4 and 5 liter/minute. The heat exchanger is made of aluminum composed of 23 channels, each has dimensions: 24.5 cm × 5 mm × 3.5 mm, which filled with the cooling fluids. The results showed that the enhancement over not cooled panel of the Al_2O_3 nanofluid were 6.94%, 7.75% and 11.08%, for the TiO_2 nanofluid were 5.9%, 6.8% and 9.09% at weight concentrations: 0.01%, 0.05% and 0.1%, sequentially, while it was 2.89% for stand-alone water cooling. **(Murtadha et al., 2022)** reported that there is a gain in the electrical conversion efficiency from PVT systems by 20.2% when using alumina with a volume concentration (φ%) of 0.3% at a rate of 1.6 liter/minute turbulent flow versus 15% when the laminar flow jobbed for cooling over the non-cooled PV panel. The fluids flow was through cylindrical copper tubes attached to a copper sheet that was held in the back of the PV/T panels. From this research work and others such as **(Al-Shamani et al., 2016)**, it is found that as the solar irradiance decreases, the enhancement in the electrical efficiency will increase, as the temperature of the solar panel will be lower than it is as the solar radiation is high.

In the following context, we intend to check the improvement in the output power from three similar panels: one is not cooled, while the other two are cooled by a thermal configuration extension shown in Fig. (1) that depends mainly on a forced fluid that transfers heat through conduction. The thermal characteristics and the electrical yields for the three alumina nanofluid cooling cases: 0.01%, 0.03, and 0.05% volume concentrations are examined and compared with water cooling at the same mass flow rate for each case (i.e. 0.05 Kg/s).

Experiment construction and Methodology

The experimental setup of the system is schematically depicted in Fig. (2), representing -from right to left- the three panels: reference (PV), cooled by water (PVT-water) and cooled by Al_2O_3 nanofluid (PVT-nanofluid), collectively. Fig. (3) shows the real configuration of the experimental setup. The PV is considered as a reference (i.e. no man-made cooling effects are involved), on the other hand the second and the third PVTs are cooled from the back by water and the alumina nanofluid which are forced in the heat exchangers through fluid pumps. The temperature values are read by (DS18B20) water-proof temperature sensors, presented in Table (1). Two (FS300A G3/4) flowmeters are facilitated to every-minute recording for the flowing of the fluids in the second and third systems. For instant solar irradiance measuring, the (PSP EPLAB) solar radiation meter is employed. The electrical characteristics are evaluated by (UT89X) digital multimeters.

Fig. (1): Thermal heat exchanger at the back of the PV system

Table (1): Temperature sensors distribution in the whole experimental setup

Total number of sensors	Measured parameter	Not cooled panel	Water-cooled panel	Nanofluid-cooled panel
20	**Ambient**		1	
	Back	-	2	2
	Inlet	-	1	1
	Outlet	-	1	1
	Surface	3	3	3

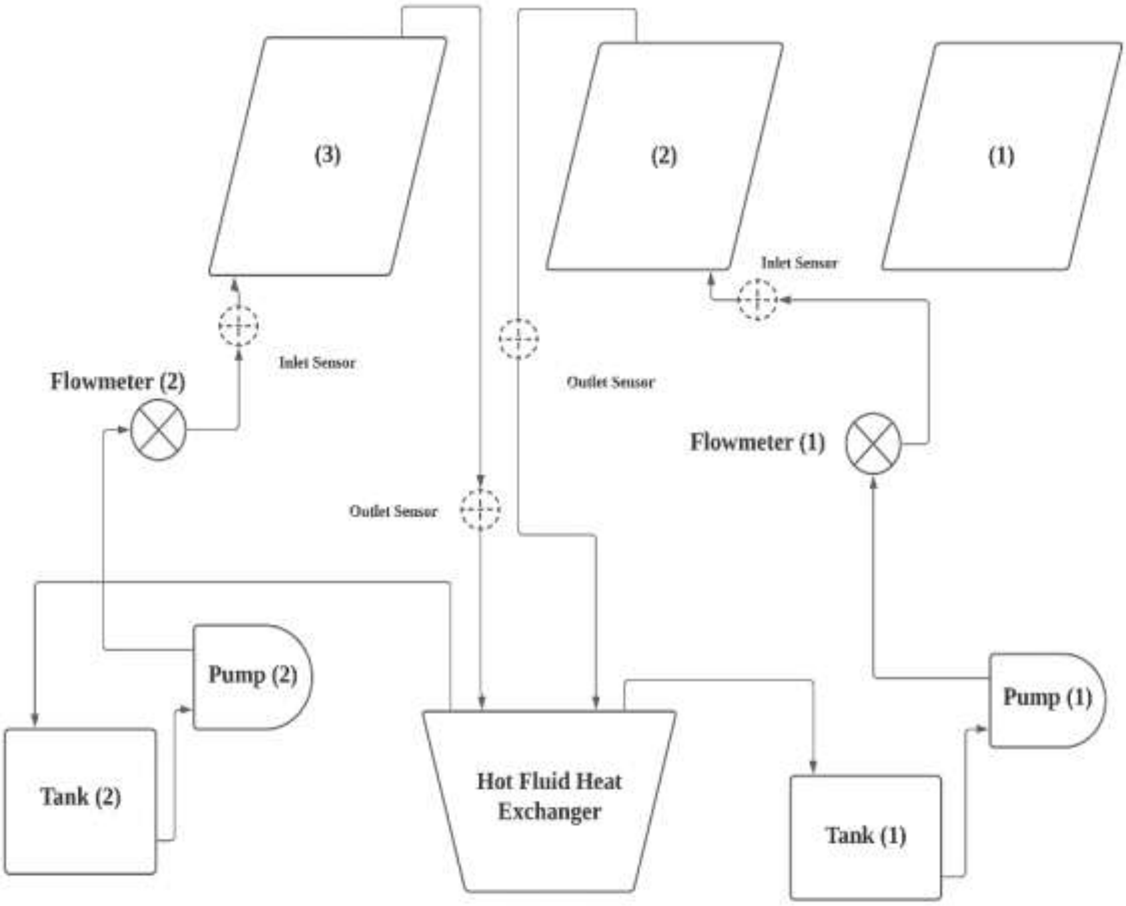


Fig. (2): Process diagram of the cooling system

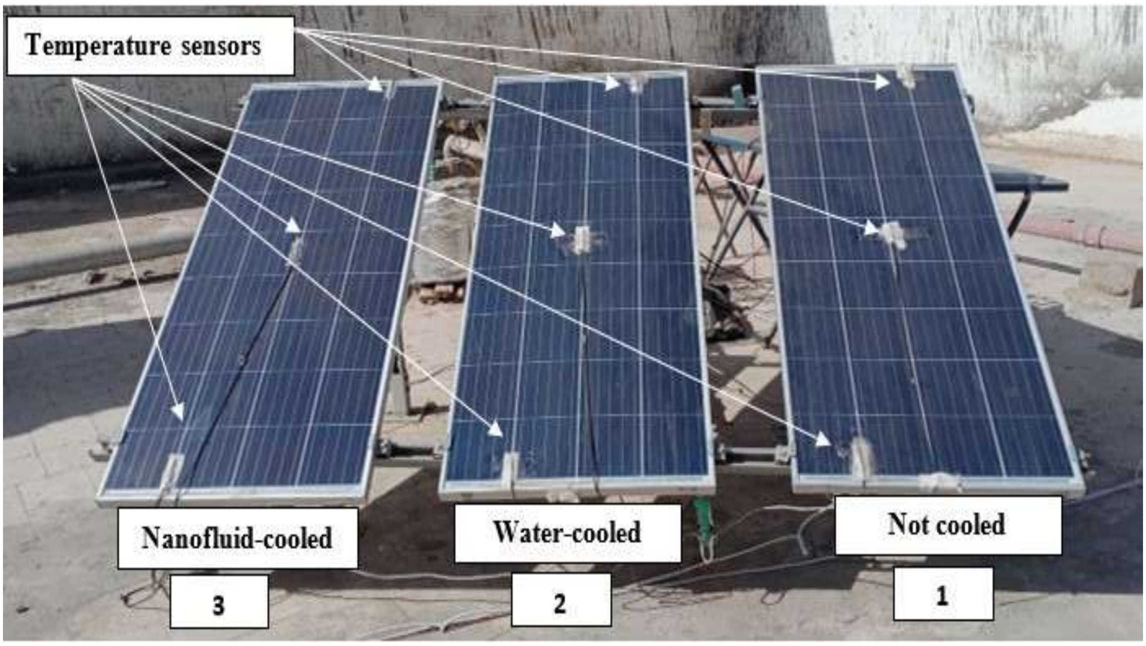


Fig. (3): Experimental setup of the system

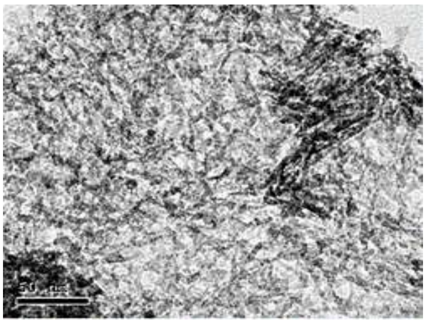
Alumina Nanoparticles and Nanofluid Preparation

The choice of aluminum oxide (Al_2O_3) as the particles to be suspended in the base fluid (i.e. water) mainly returns to their well-response to the thermal effects and good ability of heat transfer. The properties of the nanoparticles are offered in Table (2).

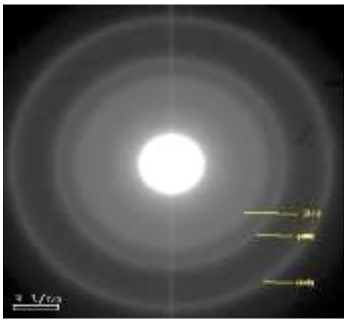
Table (2): Physical properties of Al_2O_3 nanoparticles

Property	Al_2O_3
Color	white
Form	powder
Purity	99%
Shape (TEM)	semi-spherical
Particle size (nm)	30±5
Density (g/cm^3)	3.880 (Teng & Hung, 2014)
Thermal Conductivity (W/m.K)	40.0 (“CRC Handbook of Chemistry and Physics, 57th Edition,” 1977; Grünewald, 1976)
Specific Heat (J/Kg.K)	779.2195 (“CRC Handbook of Chemistry and Physics, 57th Edition,” 1977; Popa et al., 2017)

Preparation of the alumina nanoparticles and investigation of their features are performed by NanoGate Company, Cairo, Egypt. The analysis of Transmission Electron Microscopy (TEM), Selected Area Electron Diffraction (SAED) and X-ray Diffraction (XRD) are presented in Error! Reference source not found.) and Fig. (5) The average particle’s size of alumina is less than 30 nm with a semi-spherical shape, from TEM analysis in Error! Reference source not found.)a and the XRD investigation is presented in Fig. (5). It was found that the diffraction peaks $2\theta \approx 19.0°$, $37.5°$, $39.5°$, $46.0°$, $61.0°$ and $67.7°$ have appeared. They refer to (111), (311), (400), (511) and (440) directions of Miller indices (hkl), respectively. The previous results agree with the XRD analysis by **(Ansari & Husain, 2011; Mahmoud et al., 2022)**. Moreover, the results showed that the nanoparticles have a hexagonal structure. The SAED picture shown in Error! Reference source not found.)b had brightest circles at (311), (400) and (440) that corresponds to aluminum oxide nanoparticles. The preparation of the nanofluid is accomplished through the two-step method. In this way, initially, the nanopowder is prepared and then dispersed into the base fluid (i.e. distillated water) with the help of intense magnetic agitation by the ultrasonic waves by the (JY99-IIDN) sonicator, consequently, the suspension of nanoparticles and the nanofluid stability against agglomeration boosts. However, the latter is the most economic and easier one **(Yu & Xie, 2012)**. In contrast, the first method which is expensive **(Zhu et al., 2004)**. Several factors influence the thermal conductivity of a nanofluid (K_{nf}) **(Akilu et al., 2016; Ali & Salam, 2020)** such as type of the nanoparticle dispersed in the base fluid, its thermal conductivity, shape, and size which inversely proportional (i.e. as the size decreases the thermal conductivity increases) **(Ali & Salam, 2020)**. In addition, as the concentration of the nanofluid and its temperature (T_{nf}) expands, the thermal conductivity increases; due to the increment of the nanoparticles' Brownian motion **(Sharma et al., 2022)**.



(a) TEM of Al_2O_3



(b) SAED of Al_2O_3

Fig.(4): TEM (a) and SAED of Al_2O_3 (b)

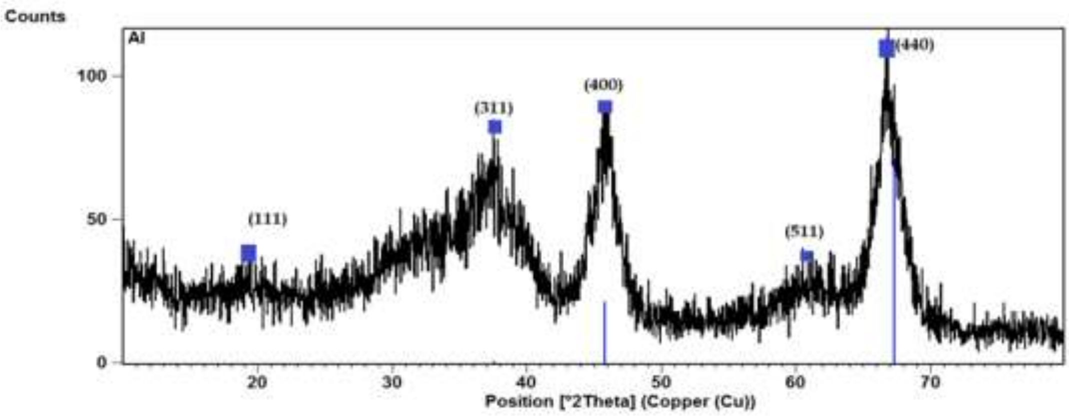


Fig. (5): XRD analysis for alumina nanoparticles

Results and Discussion

In the same location and under similar conditions in 2021 a study is performed by **(Ibrahim et al., 2023)** using the same PV/Ts, while the main difference is that the mass flow rate was constant (i.e. 0.05 Kg/s), since the volume concentration of the alumina nanofluid varies. The solar modules have different outputs of power and conversion efficiencies at various weather circumstances that estimated through the Power-voltage (P-V) characteristic curves **(Yahyaoui, 2018)**. The mean temperatures of the three solar panels and the surrounding ambient are measured every minute using the temperature sensors. After quarter an hour of starting the circulation of the fluids (i.e. cooling), the values of current and voltage are recorded for the three panels by changing the load resistances. Therefore, the maximum power (P_{max}) is calculated from the highest point of the P-V curve.

On this day (i.e. 20-09-2021) the average solar irradiance is 733 W/m^2 at the time of recording the values current and voltage to study the P-V characteristic curve. The maximum power values recorded are 84.42, 84.87 and 86.36 W for the first, second and third panels, respectively, as can be noted from Fig. (7). The cooling process started at 01:26 PM, however, the interval between 01:13 PM and 01:25 PM shows that the temperatures of the three panels are

Case 1: Concentration = 0.01%

approximately asymptotic, due to no participation of either cooling ways. The modification due to heat removal appears after 01:26 PM. From Fig. (6), the average measured surface temperatures for the PV, water-cooled PVT and nanofluid-cooled PVT are 65.68 °C, 61.71 °C and 58.29 °C, correspondingly. In addition, the second and third PVTs' temperatures become equal after 14 minutes of stopping the fluids circulation at 02:04 PM.

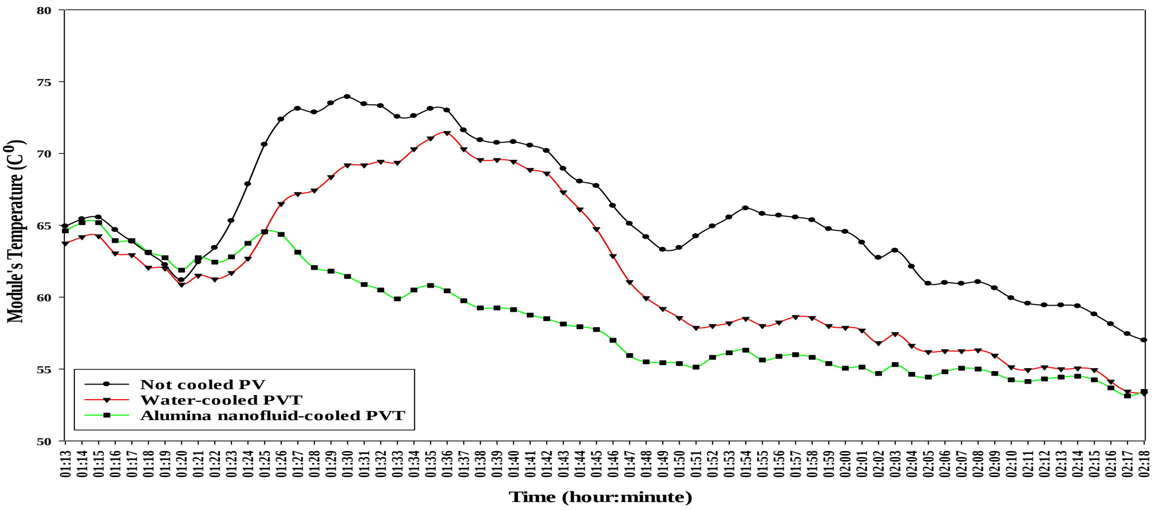


Fig. (6): Operating temperatures behavior of the three panels [20-09-2021]

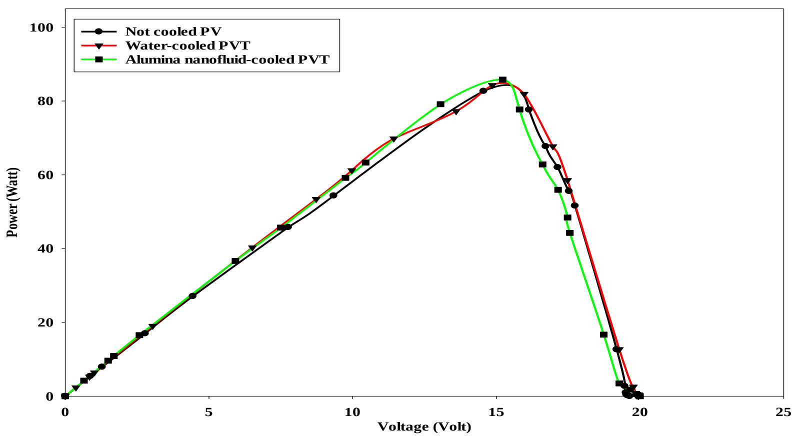


Fig. (7): P-V characteristic curves of the three panels [20-09-2021]

Case 2: Concentration = 0.03%

For φ% = 0.03% and the same mass flow rate 0.05 Kg/s the thermal properties of the three solar modules are studied from 12:42 PM, by which the cooling process takes place, to 02:05 PM. The median surface temperature of the nanofluid-cooled PVT is 56.43 °C, contrasted to 65.43 and 63.02 °C for the PV and water-cooled PVT. The mean solar irradiance is 852 W/m^2 at the time of electrical properties evaluation. It can be noticed in Fig. (9) that the PV system the maximum power was 86.70 W, while for the PVTs cooled through water and alumina the P_{max} values were 87.16 and 90.28 W.

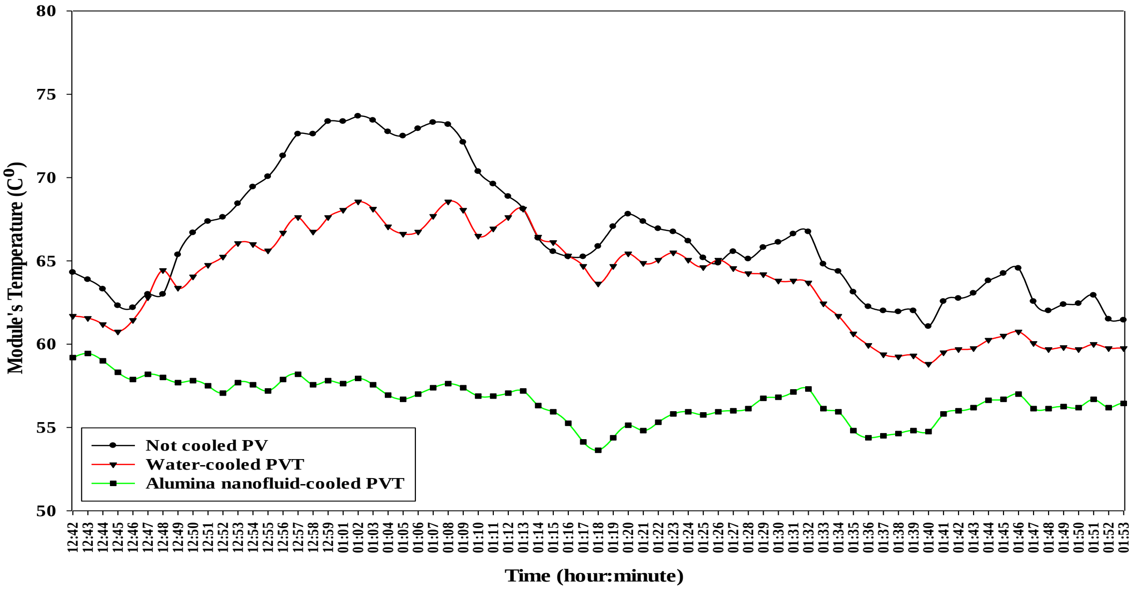


Fig. (8): Operating temperature behavior of the three panels [07-09-2021]

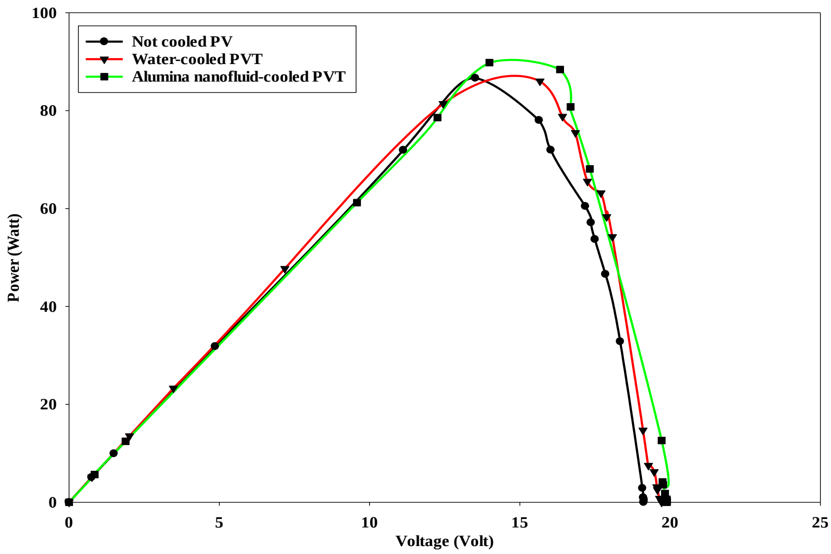


Fig. (9): P-V characteristic curves of the three panels [07-09-2021]

Case 3: Concentration = 0.05%

Moving on to the 0.05% volume concentration, the mean surface temperature of the nanofluid-cooled PVT is 60.06 °C in contrast with 65.75 and 70.04 °C for the first and second panels. The moderate solar irradiance is 950 W/m^2 at the time of examining the electrical characteristics of the system.

As illustrated in Fig. (11), the values of P_{max} witnessed 89.68, 95.82 and 100.29 W for the non-cooled PV, water-cooled PVT, and alumina nanofluid-cooled PVT. The maximum power of the third panel is enhanced by 11.83% compared with the PV, while for the second panel the improvement is 6.84% over the first panel.

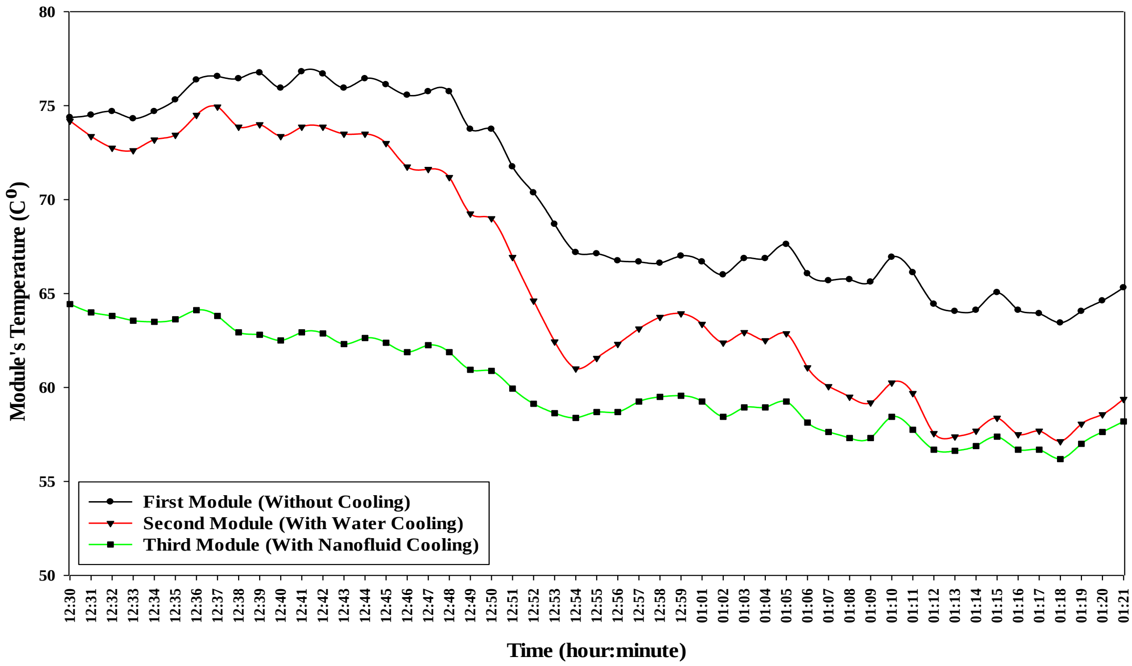


Fig. (10): Operating temperature behavior of the three panels [28-08-2021]

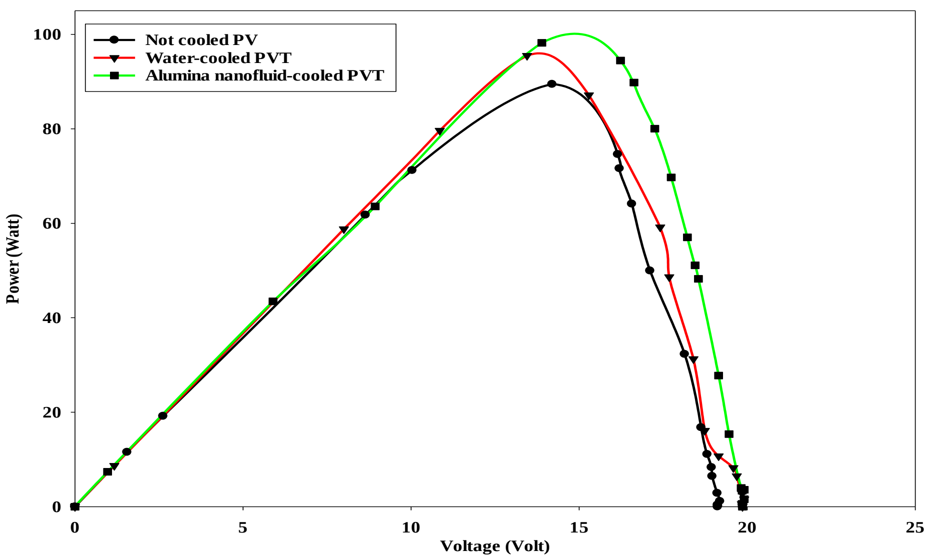


Fig. (11): P-V characteristic curves of the three panels [28-08-2021]

From the maximum power point, the electrical conversion efficiency (η) is calculated through the following relation **(Goetzberger et al., 1998; Kalogirou, 2014)**:

$$\eta = \frac{P_{max}}{A \times I}$$

Where A is the area of the PV system is 1.0064 m^2, and I is measured in W/m^2 representing the average incident solar radiation during the measuring interval.

Table (3): Thermal and Electrical Properties of the three solar panels

Volume Concentration (%)		**0.01%**			**0.03%**			**0.05%**	
Panel Type	**PV**	**PVT_w**	**PVT_n**	**PV**	**PVT_w**	**PVT_n**	**PV**	**PVT_w**	**PVT_n**
Maximum Power (P_{max})	84.42	84.87	86.36	86.70	87.16	90.28	89.68	95.82	100.29
Maximum Power Enhancement (%)	-	**0.53%**	**2.29%**	-	**0.53%**	**4.12%**	-	**6.85%**	**11.83%**
Electrical Efficiency (η)	11.44%	11.50%	11.70%	10.11%	10.16%	10.52%	9.37%	10.02%	10.49%
Efficiency Enhancement (%)	-	**0.52%**	**2.27%**	-	**0.49%**	**4.05%**	-	**6.93%**	**11.95%**
Average Temperature (°C)	65.68	61.71	58.29	65.43	63.02	56.43	70.04	65.75	60.06
Temperature Enhancement (%)	-	**6.04%**	**11.25%**	-	**3.68%**	**13.76%**	-	**6.13%**	**14.25%**

Conclusions

In this research work, three similar multi-crystalline solar panels are compared in terms of their electrical and thermal properties in the natural weather conditions. The first panel is not cooled, while the second and the third ones are cooled down by water and alumina nanofluid, sequentially. Here are the main findings of this experimental work:

- The Alumina nanofluid-cooled systems (i.e. PVTs) introduced better improvement in all cases in comparison to the water-cooled and non-cooled PV/T.
- For constant mass flow rate, as the concentration of the nanofluid increases, the development in the electrical and thermal characteristics will be noticeable.
- The electrical power yield and the conversion efficiency are strongly related because the incident solar irradiance and area of the solar panel are constants.
- The electrical conversion efficiency advance was shown to have its best result at 0.05% volume concentration for the nanofluid with 11.95% over the PV yield.
- Best heat removal appears because of φ% = 0.05% concentration of the alumina nanofluid compared

with water cooling. This owing to the fact that the thermal characteristics such as thermal conductivity and heat capacity boost as the volume concentration of the nanoparticles rise.

- The temperature betterments of nanofluid cooling over the not-cooled panel are 11.25%, 13.76% and 14.25% for nanofluid concentrations of 0.01%, 0.03% and 0.05%, correspondingly.

References

Abdallah, S. R., Saidani-Scott, H., & Abdellatif, O. E. (2019). Performance analysis for hybrid PV/T system using low concentration MWCNT (water-based) nanofluid. *Sol. Ener.*, 181: 108-115.

Akilu, S., Sharma, K. V., Baheta, A. T., & Mamat, R. (2016). A review of thermophysical properties of water based composite nanofluids. *Ren. Sust. Ener. Rev.*, 66: 654-678.

Ali, A. R. I., & Salam, B. (2020). A review on nanofluid: preparation, stability, thermophysical properties, heat transfer characteristics and application. *SN Appl. Sci.*, (Vol. 2).

Alous, S., Kayfeci, M., & Uysal, A. (2019). Experimental investigations of using MWCNTs and graphene nanoplatelets water-based nanofluids as coolants in PVT systems. *App. Therm. Eng.*, 162:

Al-Shamani, A. N., Sopian, K., Mat, S., Hasan, H. A., Abed, A. M., & Ruslan, M. H. (2016). Experimental studies of rectangular tube absorber photovoltaic thermal collector with various types of nanofluids under the tropical climate conditions. *Ener. Conv. Manag.*, 124: 528–542.

Amalraj, S., & Michael, P. A. (2019). Synthesis and characterization of Al_2O_3 and CuO nanoparticles into nanofluids for solar panel applications. *Res. Phys.*, *15*.

Ansari, S. A., & Husain, Q. (2011). Immobilization of Kluyveromyces lactis β galactosidase on concanavalin A layered aluminium oxide nanoparticles - Its future aspects in biosensor applications. *J. Mol. Cat. B: Enz.*, *70*(3–4).

CRC Handbook of Chemistry and Physics, 57th Edition. (1977). *Soil Sci. Soc. Amer. J.*, *41*(4).

Das, D., & Kalita, P. (2018). Performance Improvement of a Novel Flat Plate Photovoltaic Thermal (PV/T) System Using Copper Oxide Nanoparticle—Water as Coolant.

Ebaid, M. S. Y., Al-busoul, M., & Ghrair, A. M. (2020). Performance enhancement of photovoltaic panels using two types of nanofluids. *Heat Trans.*, *49*(5):2789-2812.

Evans, D. L. (1981). Simplified method for predicting photovoltaic array output. *Sol. Ener.*, *27*(6).

Ghadiri, M., Sardarabadi, M., Pasandideh-Fard, M., & Moghadam, A. J. (2015). Experimental investigation of a PVT system performance using nano ferrofluids. *Ener. Conv. Manag.*, *103*.

Goetzberger, A. (Adolf), Knobloch, J., & Voss, B. (1998). *Cryst. Silic. Sol. cells*. Wiley.

Grünewald, H. (1976). Handbook of Chemistry and Physics. Weast. CRC Press, Cleveland (Ohio) 1975.

Hussein, H. A., Numan, A. H., & Abdulrahman, R. A. (2017). Improving the Hybrid Photovoltaic/Thermal System Performance Using Water-Cooling Technique and Zn-H2O Nanofluid. *Inter. J. Ph. Ener., 2017*.

Ibrahim, A., Ramadan, M. R., Khallaf, A. E. M., & Abdulhamid, M. (2023). A comprehensive study for Al_2O_3 nanofluid cooling effect on the electrical and thermal properties of polycrystalline solar panels in outdoor conditions. *Env. Sci. and Poll. Res*.

Kalogirou, S. A. (2014). Solar Energy Engineering: Processes and Systems: Second Edition. *Sol. Ener. Eng.: Proc. Sys.: Second Edition*.

Karami, N., & Rahimi, M. (2014). Heat transfer enhancement in a hybrid microchannel-photovoltaic cell using Boehmite nanofluid. *Int. Comm. Heat Mass Trans., 55*.

Klaus, J., Olindo, I., Smets, A., van Swaaij, R., & Miro, Z. (2014). Solar energy. Fundamentals, technology, and Systems. *Green Ener. Tech*.

Kumari, S., Pandit, A., Bhende, A., & Rayalu, S. (2022). Thermal Management of Solar Panels for Overall Efficiency Enhancement Using Different Cooling Techniques. *Int. J. Env. Res.*, 16:(4).

Mahmoud, S. A., Elsisi, M. E., & Mansour, A. F. (2022). Synthesis and electrochemical performance of α-Al2O3 and M-Al_2O_4 spinel nanocomposites in hybrid quantum dot-sensitized solar cells. *Sci. Rep., 12*(1).

Moharram, K. A., Abd-Elhady, M. S., Kandil, H. A., & El-Sherif, H. (2013). Enhancing the performance of photovoltaic panels by water cooling. *Ain Shams Eng. J., 4*(4): 869–877.

Murtadha, T. K., Dil Hussein, A. A., Alalwany, A. A. H., Alrwashdeh, S. S., & Al-Falahat, A. M. (2022). Improving the cooling performance of photovoltaic panels by using two passes circulation of titanium dioxide nanofluid. *Cas. Stud. in Therm. Eng., 36*.

Odeh, S., & Behnia, M. (2009). Improving photovoltaic module efficiency using water cooling. *Heat Trans. Eng., 30*(6), 499–505.

Popa, C. V., Nguyen, C. T., & Gherasim, I. (2017). New specific heat data for Al_2O_3 and CuO nanoparticles in suspension in water and Ethylene Glycol. *Int. J. Ther. Sci., 111*:108–115.

Radziemska, E. (2003). The effect of temperature on the power drop in crystalline silicon solar cells. *Ren. Ener.*

Sardarabadi, M., Passandideh-Fard, M., Maghrebi, M. J., & Ghazikhani, M. (2017). Experimental study of using both ZnO/ water nanofluid and phase change material (PCM) in photovoltaic thermal systems. *Solar Ener. Mat. Sol. Cells, 161*.

Sargunanathan, S., Ramanathan, K., Mohideen, S. T., & Suresh, S. (2020). Enhancing the Performance of the Standalone Rooftop SPV Module during Peak Solar Irradiance and Ambient Temperature by the Active

Cooling of the Rear Surface with Spraying Water and the Front Surface with Overflowing Water. *Int. J. Ph. Ener., 2020*.

Sathyamurthy, R., Kabeel, A. E., Chamkha, A., Karthick, A., Muthu Manokar, A., & Sumithra, M. G. (2021). Experimental investigation on cooling the photovoltaic panel using hybrid nanofluids. *Appl. Nano sci.* 11(2).

Sharma, R., Chauhan, P., Sharma, A. K., Katiyar, A., Singh, H. K., Rinawa, M. L., & Kumar, P. M. (2022). Characterization of ZnO/nanofluid for improving heat transfer in thermal systems. *Mat. Tod.: Proceed.*, *62*: 1904–1908.

Teng, T. P., & Hung, Y. H. (2014). Estimation and experimental study of the density and specific heat for alumina nanofluid. *J. Exp. Nano sci.*, *9*(7).

Yahyaoui, I. (2018). Advances in Renewable Energies and Power Technologies - Volume 1: Solar and Wind Energies.

Yu, W., & Xie, H. (2012). A review on nanofluids: Preparation, stability mechanisms, and applications. *J. Nano mat.* (Vol. 2012).

Zhu, H. T., Lin, Y. S., & Yin, Y. S. (2004). A novel one-step chemical method for preparation of copper nanofluids. *J. Coll. Inter. Sci.*, *277*(1).

دراسة تأثير التبريد بإستخدام مائع أكسيد الألومنيوم على العائد الكهربي من ألواح الطاقة الشمسية – المبردة

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تتحكم درجات الحرارة الخاصة بالألواح الشمسية في قدرتها على إنتاج الكهرباء. لذا تهدف الدراسة الحالية الى تطوير التبريد بالطرق الميكانيكية للخلايا الشمسية من خلال سوائل التبريد المختلفة و التي من الممكن أن تكون ثابتة أو متحركة. حيث تم دراسة تأثير إزالة ارتفاع درجة الحرارة بين لوحين طاقة شمسية متطابقين تحت تأثير التبريد بالماء و مائع أكسيد الألومنيوم بتركيزات حجمية تساوي ٠.٠١ ٪ ، ٠.٠٣ ٪ و ٠.٠٥ ٪ ، و بمعدل تدفق كتلي للموائع (الماء و أكسيد الألومنيوم) يساوي ٠.٠٥ كجم/ ثانية. ومقارنة النتائج بلوحة شمسية غير مبردة لمعرفة قيمة الطاقة المفترض الحصول عليها دون القيام بأي نوع من أنواع التبريد (بالأخذ في الإعتبار أن الألواح الثلاثة متطابقة و يتم مقانتها في نفس الظروف). وكشفت النتائج أنه كلما زادت التركيزات الحجمية لجسيمات النانو في المائع الأساسي (الماء) ، فسوف يتم تعزيز الخواص الحرارية والكهربائية للخلايا المبردة بمائع أكسيد الألومنيوم ، على سبيل المثال ، الحد الأقصى لزيادة الطاقة عن طريق التركيزات الحجمية: ٠.٠١ ٪ و ٠.٠٣ ٪ و ٠.٠٥ ٪ هي ٢.٢٩ ٪ و ٤.١٢ ٪ و ١١.٨٣ ٪ مقارنة بلوحة الطاقة الشمسية الغير المبردة علي الترتيب. أما بالنسبة للخصائص الحرارية ، فإن مائع أكسيد الألومنيوم و الذي له تركيز حجمي يساوي ٠.٠٥ ٪ أظهر تحسن في التبريد بمقدار ١٤.٢٥ ٪ بالمقارنة باللوحة الغير مبردة.