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Preparing Nanofluids ($Al2O_3$) for Enhancement Performance of Photovoltaic

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HIGHLIGHTS

- The enhancement of overall efficiency at 1 g of nanofluid was 15% and in 1.5g is 18%.
- The enhancement of thermal efficiency at 1 g of nanofluid was 19% and 1.5g 27%.
- The electrical efficiency was increased at 1g of the nanofluid11% and in 1.5 g 14%.

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ABSTRACT

Photovoltaic (PV) panels produce electrical energy comparable to the cumulative amount of PV radiation generated on surface of sun. The solar modules influence on temperature of PV panel and for work with its standard specifications in Iraqi environment can be used nanofluid for cooling PV and improve performance. The developed thermal model for proposed cooling method has shown on the way to be an efficient design tool that can help engineers to reduce the time and cost of experimental testing. The improvement in temperature reduction using direct flow technique at rear sides of PV panel achieved electrical and thermal performance enhancement. The enhancement of overall efficiency at 1 g of nanofluid is showed 15% but in 1.5g nanofluid is 18%. As well as the enhancement of thermal efficiency at 1 g and1.5g of nanofluid are showed 19% and 27% respectively. So in Electrical efficiency at 1 g of nanofluid is showed 11% and in 1.5g nanofluid is 14%.The experimental results have shown that the utilization of nanofluid (Al2O3) as a result of its high thermal conductivity and tiny particle size. The coefficient of heat transfer and Nusselt number increasing with the increase of concentration of nanofluid, It can be concluded that has great impact, especially in Iraq condition where the temperature is normally high and can improve their performance and efficiency by adding nanofluid for cooling system.

1. Introduction

As a source of clean and green electricity, photovoltaic energy is of great significance for sustainable energy generation and has been increasingly used. In the previous decade, the passion for photovoltaic (PV) systems has grown owing to numerous beneficial situations resulting from these systems These attractive circumstances require unpolluted operation, unrestricted power tools, general ease of installation and noiseless activity. As a consequence, the size and amount of PV systems has grown rapidly across the world [1]. PV panels produce electrical energy comparable to the cumulative quantity of solar radiation generated on the surface of sun. Generally, this is referred to as the Worldwide Horizontal Irradiance. Other variables, such as temperature, often influence the power produced by the photovoltaic plate. However, during the activity of photovoltaic systems under evolving and complex environment conditions, faults have also been among the primary factors influencing the power generation performance of the PV device. However, efficiency has always been one of the main factors influencing the success of the PV generation system during the activity of photovoltaic systems under evolving and complex environment conditions. The most critical feature of the PV is efficiency conversion, as solar irradiation which not turned to energy is almost completely transform into heat. Performance declines as PV cell temperature increases [2]. In Iraq and in the summer season, PV temperatures exceed 80 °C, leading to a significant decrease in performancePV characteristics. In reality, extra than 80.0 per cent of the irradiation falling on PV cellis transformed to thermal energy so the reflected cooling mechanism is important for solve problems in the hot atmosphere and high irradiation. Generally, many cooling strategies are used to cool the PV panel and conquer rising temperature problems and improve its performance as water and air cooling system [3]. Photovoltaic devices may be mounted near to the point of usage, preventing transmitting losses and reducing CO2

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pollution in urban centers. The cost is high and performance is low of module commercial as 15%, it is necessary for ensured the run within their peak production regime. In order to achieve the aim, it is necessary for create suitable modeling algorithm and provide model accurate for real behavior of element photovoltaic [4]. However, increase thermal conductivity for working fluid is primary limitation in development of energy and heat transfer of fluid, and high cooling systems performance [5]. Many researcher using a nanofluid such as Tiwari et al. (2018) **[6]** made an attempt to develop modified Hottel-Whillier-Bliss (HWB) equation for N-number of absolutely blanketed photovoltaic thermal- compound parabolic concentrator (N-PVT-CPC) collector. Hottel-Whillier-Bliss (HWB) equation is recommended for checking out the flat plate collectors of amazing layout on the groundwork of electricity attain and loss hassle. The Analysis is based on easy energy balance equations for each component of the device as a attribute of format and climatic parameters. Developed modified Hottel –Whillier -Bliss (HWB) equation is applicable for a broad range configure rations in unique conventional flat plates compound parabolic concentrator (FPC-CPC), really cover photovoltaic thermal-flat plate collector (PVT-FPC) and regular flat plate collector (FPC) as particular case. The characteristics curve of thermal and electrical affectivity has been residential of all conditions careful. Further, an experimental validation for N=1 has moreover been carried out beneath indoor simulation state of affairs. Asmaa A. et al. (2019) [7] furnished a assessment of the most current nanotechnology factors in photovoltaic thermal photo voltaic systems. They studied many sorts of nanoparticle and nanofluid that have been utilized until now in the literature and speedy guidelines approach rent of their preparations. Both PV/T and CPV/T gadget has study, and the applicable output have been collated at the equal time to summarize the potential benefits of rent nanofluid. Further, they spotlight crucial parameter which expanded performance for nanofluid . L. J. Hee et al. (2019) [8] beautify flat-plate photovoltaic thermal(PVT) device effectively employ water and nano fluid one at a time as fluid cooling. An efficiency contrast carried out with wonderful go with the flow cost for water as working fluid. The float rate, that influence on regular universal performance for PVT buildings, illustrate perfect efficiency at3 L/min compare with 1,2, and 4 L/min. The cease end result illustrates the thermal and electrical efficiencies for PVT laptop the use of CuO/water as a nanofluid had been elevated with the useful resource of way of 21.30% and 0.07% in contrast to the water-based system, correspondingly. The PVT system the use of Al2O3/water as nanofluid increased thermal affectivity by15.14%, then again there used to be no version in electrical effectivity between water and Al2O3/water-based systems. Sourav D. et al, (2020) [9]intended to exhibit excellent electrical and thermal factors of photovoltaic–thermal constructions and the researches in absorber graph modification, development, and applications. From the preceding overview articles, it has been concluded that the warmness electrical energy exhausted from the PV module can be in a similar fashion utilized in unique approaches and helps in accomplishing greater efficiency. Furthermore, the kinds of photovoltaic–thermal buildings such as air collector, water collector, and combi system, coupling with heat pump and their software to constructions are in addition stated. This paper additionally mentioned advantageous sketch elements like changes in the waft channel with the beneficial aid of along with fins, skinny steel sheets, roll-bond absorber, and porous media and the influence of these adjustments on the hybrid system's efficiency. Furthermore, the use of the modern-day technologies such as nanofluids, thermoelectric generators, and phase-change resources improves the common desktop performance. The function of soft-computing strategies is forecasting the effect of a number of parameters on the photovoltaic–thermal system used to be additionally discussed. Aswell as study in [10] by Salem MR. (2019) [experimentally study of PV module cooling using water and/or Al2O3/PCM mixture at different nanoparticles mass concentrations from 0 to 1% .The results illustrate that the Al2O3 at 1% concentrations compound technique (Al2O3/PCM mixture + water) better than the cooling with 100% water.

The aim of this paper is to study the behavior of the PV panel model performance and using nanofluid for cooling to examined the performance of the PV/T system. The limitations of the current study are in the circumstances of Iraq and using direct flow of action with 1 and 1.5 % nano-partical concentration.

2. Thermal Modeling

The present system is a PV module that the water collector fully covers the backend of panel as a narrow water stream flow through a shell to consist the hybrid PV/T system. Follow assumption has been made to write an energy balance equation of every component for PV/T water collectors:

1) One dimensional heat conductions are good approximation of this study.
2) The system is in quasi-steady state.
3) The PV module layers are at uniform temperature.
4) Negligible the ohmic losses of solar cell**.**
5) Thermal losses of edges for PV/T system are negligible.

The energy balance equation of proposed PV/T module conversation is:

$$\alpha c \tau g \mathrm{PF}\ G(t) = Ut\ (\mathrm{T}c - T_{am})) + \ U\mathrm{r}\ (Tc - T\bar{f}) \ + \tau g\ \mathrm{PF}\ \eta c\ G(t) \quad (1)$$

The rate available for solar energy (G (t)) on solar cells = An all heat loss from top surface of cells to ambient + rate of thermal heat withdraws by cooling fluid + rates for produced energy electrical (P_m)

From Eq. (1), the expression for solar panel temperature (T_p) is:

$$T_p = \frac{\tau g(PF\alpha c - \eta c)G(t) + U_t T_{am} + U_r \overline{T_f}}{U_t U_r} \quad (2)$$

Heat transfer modes and equivalent thermal network are illustrated in Figure 1

For backend panel:

$$U_{con}(T_p - T_s) = h_r A_p(T_s - \overline{T}_f) \quad (3)$$

The conduction heat transfers of cells at backend panel = rate of Thermal heat withdraw by cooling fluid [12]
Eq. (3), is shown a panel backend temperature (T_s) as

$$T_s = \frac{T_p U_{con} + \overline{T_f} h_r A_p}{U_{con} + h_r A_p} \quad (4)$$

For water flowing through the duct [12]:

$$Q_{usf} = \dot{m}_f c_{p,f} \Delta T_f = U_{con}(T_p - T_s) \quad (5)$$

The rate of enthalpy change of water Q_{usf}= rates of heat withdraw of cells to flow fluid

$$\text{So} \qquad T_{f,o=} \Delta T_f + T_{f,i} \quad (6)$$

The overall heat transfer coefficients (U_t) evaluated as:

$$U_t = \left(\frac{L_{cell/2}}{A_P K_{cell}} + \frac{L_{EVA}}{A_P K_{EVA}} + \frac{L_{glass}}{A_P K_{glass}} + \left[\frac{\left(\frac{1}{4F \in_g \sigma A p T_{sky}^3} \right) + \frac{1}{ha}}{\left(\frac{1}{4F \in_g \sigma A p T_{sky}^3} \right) \times \frac{1}{ha}} \right]^{-1} \right)^{-1} \quad (7)$$

T_{sky} is sky temperature (= 0.0552 (Tam)1.5), K.
And the overall heat transfer coefficients (U_r) at rear panel is evaluated as:

$$U_r = U_{con} + h_{conv} \quad (8)$$

$$U_{con} = \left(\frac{L_{cell/2}}{Ap.K_{cell}} + \frac{L_{EVA}}{Ap.K_{EVA}} + \frac{L_{td}}{Ap.K_{td}} \right) \quad (9)$$

Mean fluid (water) Temperature is

$$\overline{T_f} = \frac{T_{fo} + T_{fi}}{2} \quad (10)$$

Convective coefficient at front surface (ha) of PV panel due to wind speed Vw [11] is

$$h\text{a} = 5.7 + 3.8\, Vw \quad (11)$$

Convective coefficient at the backend surface (h_{con}) of PV panel due to cooling fluid velocity Vw, which can calculate from the following formula of Nusselt number (Nu) [11] is:

$$\text{Nu} = 0{:}0239\ \text{Re}^{0.805} \quad (12)$$

$$\text{Then } h_{conv} = \frac{Nu * Kf}{D_h} \quad (13)$$

Kf is water conductivity and $D_h$is the hydraulic diameter of the fluid stream.
maximum power output from PV panel is [11]:

$$P_m = V_m I_m \quad (14)$$

And, the instantaneous electrical efficiency (ηe) for solar module and thermal efficiency (ηth) are[11]:

$$\eta\text{e} = \frac{P_m}{A_p\ G} \quad (15)$$

$$\eta\text{th} = \frac{\dot{m} c_p\ (T_o - T_i)}{A_p\ G} \quad (16)$$

Several investigators have represented overall efficiency, when testing the PVT arrangement [11], through the following Equation:

$$\eta_{ov} = \eta_{th} + \eta_{ele} \quad (17)$$

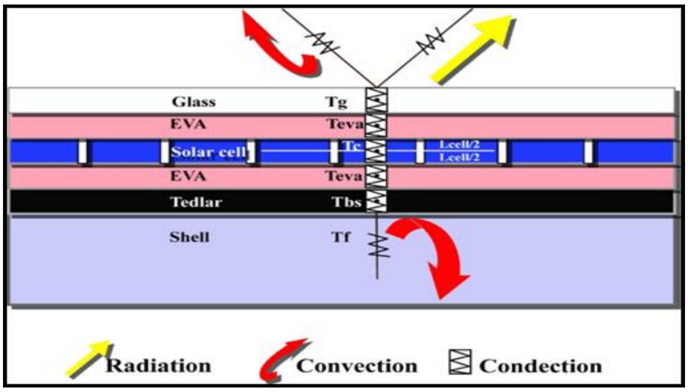

Figure 1: Heat transfer modes and equivalent thermal network

Physical Properties of the Nanofluid

The thermal properties of the working fluids are changed due to the influence of. The Nano properties depend on concentration of nanoparticles and fluid temperature.

The Nano fluid volume concentration is defined as [14]:

$$\phi = \frac{Vol_{np}}{Vol_t} \quad (18)$$

The viscosity is calculated by

$$\mu_{\mathrm{nf}} = (1 + 2.5\phi)\mu_{\mathrm{f}} \quad (19)$$

The thermal conductivity of Nano fluid mixture is derived by Maxwell for spherical particles:

$$k_{nf} = \left(\frac{k_p + 2k_f + 2(k_f - k_p)\phi}{k_p + 2k_f - (k_f - k_p)\phi}\right) k_f \quad (20)$$

The Nano fluid density for all volume concentration is [9]

$$\rho_{\mathrm{nf}} = (1 - \phi)\rho_{\mathrm{f}} + \phi\rho_{\mathrm{p}} \quad (21)$$

The specific heat of Nano fluid is calculated from this equation for all volume concentration [14]:

$$(c_p)_{nf} = (1 - \phi)(c_p)_f + \phi(c_p)_p \quad (22)$$

Enhancement can be calculated from this formula

$$enhancement\ of\ effecincy = \frac{\eta withnano - \eta with\ withoutnano}{\eta withnano}\ \% \quad (23)$$

Expanded uncertainty $\vec{U}$ is obtained in equation

$$U_c = \sqrt{\left(\frac{\partial f}{\partial x}\right)^2 \cdot U_{x^2} + \left(\frac{\partial f}{\partial y}\right)^2 \cdot U_{y^2}}$$

$$U_c = \sqrt{\frac{(R_{Norm_a}/2)^2 + (R_{Uni_b}/3)^2 + \cdots}{\mathrm{P}} + \left(\frac{Syst_{Norm_c}}{2}\right)^2 + \left(\frac{Syst_{Uni_d}}{2}\right)^2 + \cdots}$$

Then, according to equation and Cov Factor ,

$$U = \mathrm{Cov}_{\mathrm{Factor}} \cdot U_c.$$

Here, $\mathrm{Cov}_{\mathrm{Factor}}$ = 1 97 (coverage factor)

$$\vec{U} = 1\ 97 \cdot U_c,$$

3. PV Experimental Work

To measure the real temperature of the model module based on the performance of the PV plate. The input structure was composed of radiation, wind speed, air temperature and relative humidity. Two panels used in this work. The panel specifications are given in the Table I. One of the PV panels was changed to allow cooling fluid (water) to flow on the back of the module, the aluminum plate was manufactured as a jacket with a depth of 8 mm and mount at back for photovoltaic panel. The device as seen in Figure. 2.

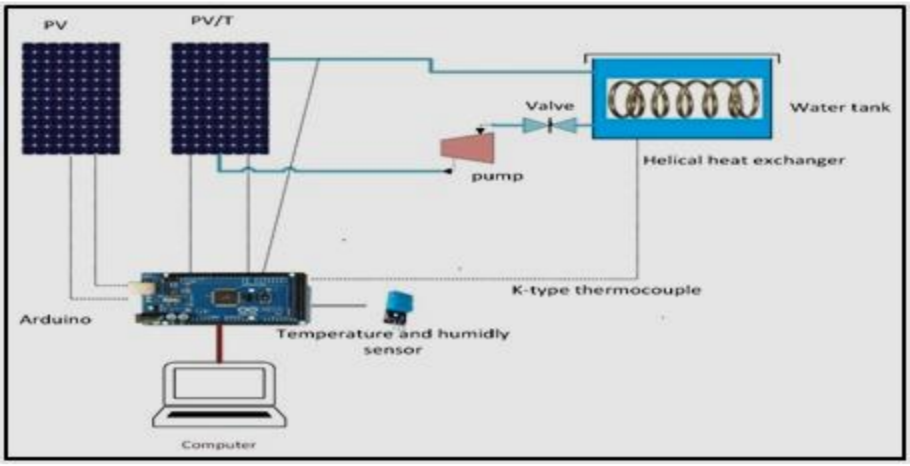

Figure 2: Schematic diagram of proposed PVT arrangement

4. Preparing of Aluminum Trioxide (Al2O_3)

Alumina (Al_2O_3) is utilized in many applications because of it's a variety of import and useful property. The chemical composite for aluminum and oxygen and mainly generally utilized ceramic material among other ceramic materials such as zirconia, aluminum nitride, silicon carbide, etc. Application of alumina such as biomedical implant, catalyst support and fire retardant, absorbent, polymer matrix composites, insulator and in electronic field, clinical fields, etc. The motive of alumina mainly widely attractive utilized materials in several applications for great property suchas chemical and thermal stability, good wear resistance, high hardness, relatively good strength, high melting point, and chemical resistance and good electrical. Alumina may be synthesized at many phases including delta alpha, gamma, and beta. Every of these phases may be attained at many temperatures through synthesize for alumina. All phase has own feature that different of applications utilized. Though, with these phases, alpha alumina is mainly steady structures and popular amongst researchers for superior properties for example high hardness, high stable, transparency and high insulations [13]. The basic unit cell structures for alpha alumina is hexagonal. Whilst internal crystal structures for alpha-alumina of oxygen is in closes packed hexagonal and aluminum in of octahedral site in center of nanotechnology \University of Technology\Baghdad \Iraq. The cooling organization needs 13 liters of water. The SDS (stabilizer) is dissolved as a stabilizer for amino oxide and mixed with a regular mixer for ten quarts, every ten grams are added to one liter of water. The nanomaterial is mixed with different concentrations once (1 g, 1.5 g) with the ultrasound device for a quarter of an hour and each liter separately to achieve the number 13 liters for three concentrations. The readings are taken with thermal conditions for one day only, and each concentration is separately from the other to find out the difference that occurs in the temperature. Properties of nanofluids Shown in Table II.

Table 1: Test results of deep beam specimens

MODEL	SR-100S
Maximum power	111.1W
Open circuit voltage	20.44V
Short circuit current	8.039A
Rated voltage	14.94V
Rated current	7.441A
Short circuit current temperature coefficient	0.15A\C
Open circuit Voltage temperature coefficient	0.021V\C
No. of series cells	32
No. of parallel cells	1
Module efficiency	12.8%
Module Area	0.87m^2

Table 2: Properties of nanofluid components

Mixture component	ρ (Kg/m^3)	Cp (J/kg k)	k (W/m k)	β*10^5 (k^{-1})	α*10^5(m^2/s)
Water (Base fluid)	6.2	997.1	4179	0.613	21
Aluminumoxide Al_2O_3	3970	765	40	0.85	131.7

Figure 3: Prepared Nanomaterials

5. Results and Discussion

In this study, the solar panel is applied using nanofluid for cooling at concentration 1,1.5 g. The results obtained of the photovoltaic panel and the Nano fluid system are shown in this section. Figure 5 shows flow chart of experimental set up. Figure 6 shows a relationship efficiency increase with increase of concentrations rate from 12 to 13.8%. Figure 7 and Figure 8 shows the thermal efficiency and electrical efficiency increases with increase of concentrations rate so this mean a power output is improvement. Figure 9 shows a Power of PV at different concentration that illustrated a maximum power at 1.5 g and minimum at without cooling. From this study the result showed an enhancement of overall efficiency at 1 g of nanofluid is showed 15% but in 1.5g nanofluid is 18%As well as the enhancement of thermal efficiency at 1 g and1.5g of nanofluid are showed 19% and 27% respectively, So in Electrical efficiency at 1 g of nanofluid is showed 11% and in 1.5g nanofluid is 14%. The results of efficiencies showed in Table III. The limitations of the current study are in the circumstances of Iraq a direct flow of action. There are no conditions and limits in this work. It is a quasi - steady state assumption in the present analysis. Direct flow selection for several barriers between the fluid and the solar panel and there is no increase in the thermal resistance. Low density helps the transition process and helps with cooling. The current comparison study may be compared with that published in [10] as shown in Table IV.

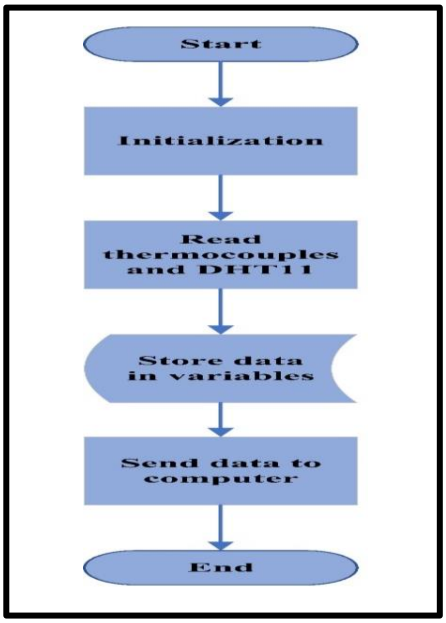

Figure 5: Flow chart of experimental setup

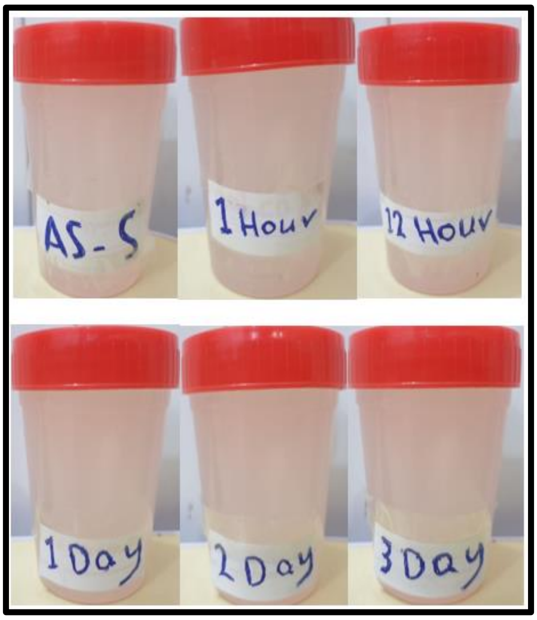

Figure 4: Prepared Nanomaterials with stabilizer

Table 3: Results of Efficiencies

Base fluid	Over all effecincy	Thermal effecincy	Electrical effecincy
Without Naonfluid	11%	42%	10%
With Naonfluid 1g	13%	52%	11.2%
With Naonfluid 1.5 g	13.5	58%	11.75%

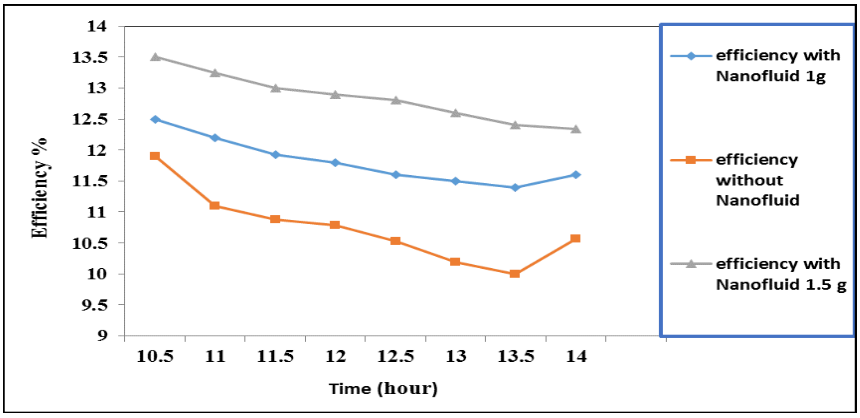

Figure 6: Efficiency of PV with time

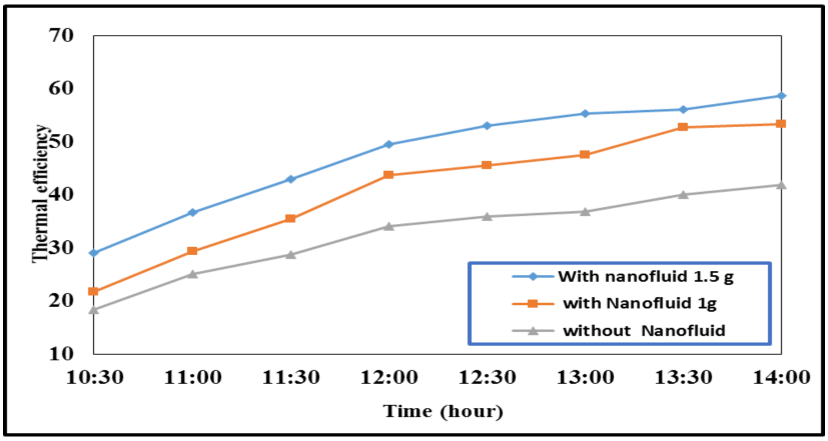

Figure 7: Thermal efficiency at different concentration

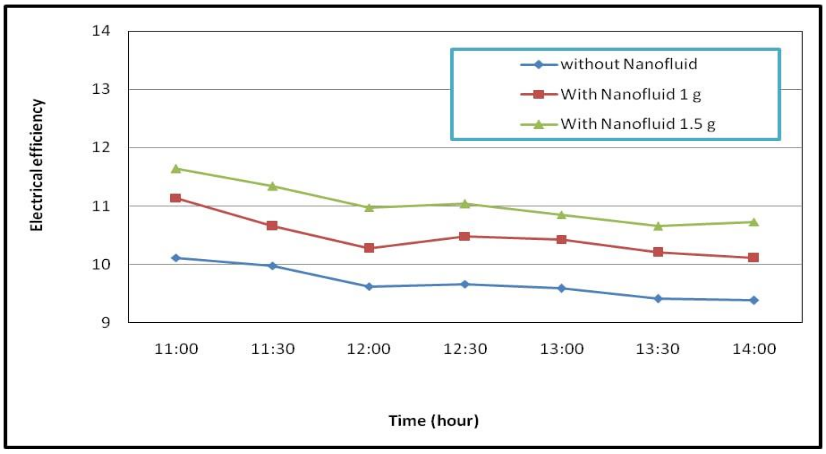

Figure 8: Electrical efficiency at different concentration

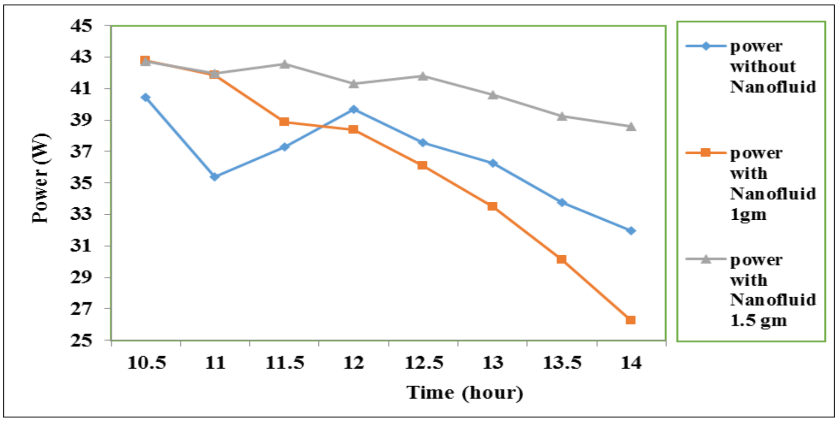

Figure 9: Power at different concentration

Table 4: Comparison of this study with results in [12]

	Nanofluid using	Efficiency	Improvement when Temp. Reduce
This Study	AL_2O_3	58 to 42%	66°C reduce to 43°C
Ref.[10]	AL_2O_3	41%	57°C reduce to 30°C

6. Conclusions

The experimental results have shown that the utilization of nanofluid (Al2O3) as a result of its high thermal conductivity and tiny particle size. The heat transfer coefficient and the Nusselt number are increasing with the increase of concentration of nanofluid, It can be concluded that the solar modules can't work with its standard specifications in Iraqi environment and can the influence of temperature on the PV panel performance has great impact, especially in Iraq condition where the temperature is normally high and can improve their performance and efficiency by adding nanofluid for cooling system. The developed thermal model for proposed cooling method has shown to be an efficient design tool that can help engineers to reduce the time and cost of experimental testing. The improvement in temperature reduction using direct flow technique at the rear side of the PV panel achieved electrical and thermal performance enhancement. The contribution of this paper is improvement of efficiency of PV when using Nanofluid AL_2O_3. So in future work can be used other nanofluid material.

Symbol	Significance
U_t	The overall heat transfer coefficients
T_{sky}	Sky temperature
U_r	The overall heat transfer coefficients at rear panel
$\hbar a$	Convective coefficient at front surface
Vw	Wind speed
T_f	Mean fluid (water) Temperature
Nu	Nusselt number
h_{con}	Convective coefficient at the backend surface of PV panel
Kf	Water conductivity
D_h	Hydraulic diameter of the fluid stream
$Syst_{Uni}d$	$Syst_{Uni}d$ = uniformly distributed systematic components
ϕ	Nano fluid volume concentration
μ_{nf}	Viscosity
k_{nf}	Thermal conductivity
ρ_{nf}	Nano fluid density
$(c_p)_{nf}$	The specific heat of Nano fluid
U_c	Combined uncertainty
U	Expanded uncertainty
P	Number of samples
R_{Norma}	Normally distributed random components
R_{Unib}	Uniformly distributed random components
$Syst_{Normc}$	$Syst_{Normc}$ = normally distributed systematic components

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Author contribution

All authors contributed equally to this work.

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of interest

The authors declare that there is no conflict of interest.

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