EURASIAN PHYSICAL TECHNICAL JOURNAL

2026, Volume 23, No.1 (55)

https://doi.org/10.31489/2026N1/154-161

Received: 24/09/2025 Revised: 26/12/2025 Accepted: 19/03/2025 Published online: 30/03/2026

Original Research Article

UDC 535.215.5

IMPROVE THE PHOTOVOLTAIC PANELS BY ADVANCE COOLING USING DISTILLED WATER AND COPPER NANOPARTICLES

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Abstract. *This study aimed to cool photovoltaic panels (monocrystalline and polycrystalline) using advanced cooling techniques with pure water and copper nanoparticles. The problem addressed by the current study is the high temperature in solar panels, and this problem is addressed by using one of the advanced cooling methods using nanomaterials. The high temperature harms the performance of photovoltaic panels, so cooling them is important until the high temperature leads to a decrease in their efficiency. Nanoparticles have been identified as one of the most effective methods in cooling photovoltaic panels because of their properties that can help improve the efficiency of photovoltaic panels. This study aimed to cool photovoltaic panels (monocrystalline and polycrystalline), and K – type thermometers were used to measure the side temperature. The back of each panel every half hour and the use of a Multi meter digital to measure current and voltage per half hour and a solar radiation meter to measure the intensity of solar radiation. In general, monocrystalline panels achieved better than polycrystalline panels and the best improvement of output power was when using Nano fluid at a concentration of 5%. The output power of monocrystalline and polycrystalline panels (76, 81, 85, 89W) (65.48, 70, 74.5, 76W) respectively when using distilled water and Nano fluid at a concentration of (1, 3, 5 %).*

Keywords: Photovoltaic, Thermal, Cooling, Nanoparticles, Concentration, Monocrystalline and Polycrystalline

1. Introduction

Burning fossil fuels saves 81 % of energy around the world, and the combustion of fossil fuels leads to changes in the weather, depletion of the weight layer and the emission of toxic gases that affect humanity [1]. Solar energy is an alternative to fossil fuels by generating electricity that can help reduce compared to alternative energy sources, fossil fuels have lower running costs and require less maintenance, contributing to global warming and other environmental concerns sources [2]. Photovoltaic panels are an important component of global power generation and are used in a wide range of household applications. Temperature is one of the factors most affecting the performance of photovoltaic panels [3], the performance of photovoltaic panels in factories is tested at a 25 ^{0}C temperature and solar radiation of 1000 W/m^2, which is called standard test conditions [4]. The production of solar panels changes dramatically when any change occurs in the surrounding environment [5] any increase in the temperature of the surrounding environment causes an increase in the temperature of the photovoltaic panel [6]. In addition, not all light falling on the photovoltaic panel turns into electricity [7]. A large part of the solar radiation is converted into heat that affects the performance of the panels, so they are cooled to improve their efficiency [8]. As a result, PV/T technology was developed to capture the extra heat produced by the cells in order to lower the temperature of the solar panel and increase overall energy conversion efficiency. Various fluids were utilized in the ducts on the back of the solar panels to circulate liquids and lower the temperature of the panels. or by sprinklers [9]. In the recent period, the use of nano liquids due to their heat transfer properties has increased significantly due to their thermal conductivity compared to other liquids [10]. It was used in many fields in electrical energy; photovoltaic energy has been proven effective in enhancing the photovoltaic/thermal system's efficiency in terms of testing nanoparticle concentrations, size, type, and basic fluids [11]. Adun et al. [12] used trinity nanofluids, a novel kind of liquid made up of three different kinds of nanoparticles combined with a base liquid. In water, the researchers introduced nano – Al_2O_3 – ZnO – Fe_3O_4. The greatest measured electrical efficiency was 13.75 %; the trinary PV/T system's PV panel temperature dropped by 8.81 ^{0}**C**. Govind S. Menon et al. [13] worked on evaluating hybrid photovoltaic system comprising tiny tubes mounted atop a solar panel and a plate on the back wall of the panel and cooling it using water and copper oxide nanofluids. The results showed that the average surface temperature of the board was 68.4 °C since the test was conducted during midday without cooling, which is the first case. At 12.98 %, the maximum electricity efficiency was attained. The cooling system was connected to the rear plate's wall. The second instance utilized water as the coolant, while the third case employed nano – fluid; all cases had the same operating parameters. The results showed that employing water and nanofluids increased the electricity efficiency to 14.58 % and 17.61 %, respectively. This study aimed to cool photovoltaic panels (mono crystalline and poly crystalline) through advance cooling using pure water and copper nanoparticles.

2. Methods of experimental work

2.1. Study location

Experimentation and evaluation of photovoltaic (PV) panels was conducted in Baghdad Al – Dora Governorate. The photovoltaic module (mono crystalline and polycrystalline) in this experiment was tilted at an angle of 30 south.

2.2. Experimental work setup

The experimental setup includes two photovoltaic panels (mono crystalline and poly –crystalline). The specifications of the panels are shown in Table 1. The purpose of using two panels is to compare the performance of the panels and to show which one is better in terms of performance. They are fixed on iron structures at an angle of 30^0. The panels were modified by adding copper tubes coated with nano – zirconia oxide with a grain size of 25nm.

Table 1. Specifications of the photovoltaic panel

	Polycrystalline, based PV module	Monocrystalline, based PV module
Maximum power	100 W	130 W
Open-circuit voltage	17 V	21.24 V
Short-circuit current	5.88 A	8.09 A
Voltage at maximum power	21.5 V	18 V
Current at maximum power	6.55 A	7.22 A
Standard test circumstances	1000 W/m^2, AM 1.5, 25 ^{0} C	1000 W/m^2, AM 1.5, 25 ^{0} C

The tubes are fixed on the back of the photovoltaic panels and measuring instruments the intensity of solar radiation using a type of energy meter (SM – 206). Measuring the ambient temperature by a temperature sensor type (DHT22) as well as measurement of current and voltage by means of a digital millimeter (SZ305) and measuring the cell temperature by a digital temperature sensor with a length of 1 meter Type (DS18B20).

2.3. Study location

To create the Nano fluid, an equivalent volume of 50 nm Cupper nanoparticles (Cu) was mixed together with clean water. To guarantee the dissociation of any aggregates, the mixes were separately guided and then further homogenized using sonication at 100 kHz and 300 W at 25 to 30 for two hours. To chill the fluids and stop overheating, the flasks were placed in an ice bath while being sonicated. Table 2 indicates the properties of nano fluids (Cu (50 nm) + DW).

Table 2. Properties of nanoparticles and distilled water

Basic fluid	ρ (kg \ m^3)	Cp (J \ kg. k)	K (W \ m. k)	β (*10^5 k^{-1})	α (*10^5) m^2/s
Distilled Water	997.1	4179	0.613	21	–
Nanoparticles Cupper (Cu)	8933	385	401	1.67	11.7

2.4 Thermo physical properties

2.4.1. Electrical Performance

The ratio of the highest electrical power of a PV module to the generation of solar radiation and module area. As shown in eq. (1) [15]:

$$\eta e = \frac{P}{A \times B} \tag{1}$$

$$P = I * V \tag{2}$$

2.4.2. Electrical performance (or PV module efficiency η_e)

The efficiency of converting sunlight into electricity, defined as the ratio of the maximum output power (P) to the product of solar radiation (B) in W/m² and the module area (A, in m²), is measured by the formula:

$$\eta e = \frac{P}{A \times I} \ ,$$

with *P* typically is representing *P* max = I mp × Vmp.

Factors Affecting Performance: The electrical output is heavily influenced by solar irradiance, ambient temperature, and cell temperature, which can significantly alter maximum power voltage.

Efficiency Range: Typical commercial PV module efficiency generally ranges from roughly 10% to over 20%, depending on the technology (mono crystalline vs. polycrystalline).

Performance Metrics: While efficiency is a measure of instantaneous conversion, performance ratio (PR) is often used to assess the overall quality of a PV plant, independent of location .

This performance index is crucial for evaluating how well a solar system converts sunlight into electricity under various environmental conditions.

2.5.3. Thermo physical properties of nanofluids

To determines the physical parameters of the nanofluids and compare the measured properties with Nanofluids. At the bulk average temperature of nanofluids, the fluid's dynamics and physical characteristics were approximated using the following equations [16 – 19]. The fraction's size (φ) can be used to calculate the nanofluid characteristics. Utilizing an Equation (3):

$$\varphi\ \% = \frac{\frac{W_{np}}{\rho_{np}}}{\frac{W_{np}}{\rho_{np}} + \frac{W_{bf}}{\rho_{bf}}} \times 100 \tag{3}$$

To calculate the density of Nanofluids, the following equation was used (4):

$$\rho_{nf} = (1 - \varphi)\rho_{bf} + \varphi\, \rho_{np} \tag{4}$$

The specific heat capacity of Nanofluids was evaluated as follows:

$$C_P, nf = \frac{(1-\varphi)\rho_{bf}\, c_{bf} + \varphi\, \rho_{np}\, c_{np}}{p_{nf}} \quad (5)$$

To determine nanofluids' theoretical thermal conductivity, the following equation was used:

$$K_{nf} = k_{bf}\left[\frac{K_{np}+2K_{bf}+2\varphi\,(K_{np}-K_{bf})}{k_{np}+2K_{bf}-\varphi(K_{np}-K_{bf})}\right] \quad (6)$$

To determine nanofluids' theoretical thermal viscosity, the following equation was used:

$$\mu_{nf} = \frac{\mu_{bf}}{(1-\varphi)\ 2.5} \quad (7)$$

3. Results and discussion

3.1. Solar radiation and ambient temperature

Fig. 1 shows solar radiation per half hour on experimental days from 8:30 AM to 2:00 PM we notice that solar radiation increases from early morning until it reaches a peak in the middle of the day and decreases throughout the afternoon Fig. 2 shows the ambient temperature and the temperature begins to rise gradually until reaches its peak at 1:30 PM.

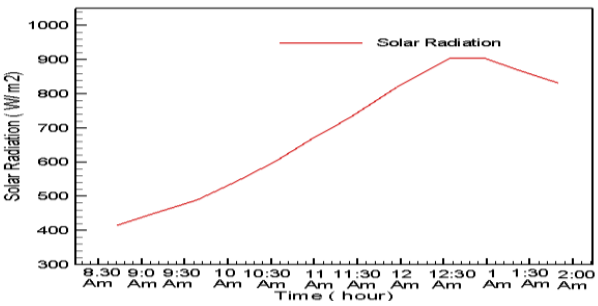


Fig.1. Solar radiation

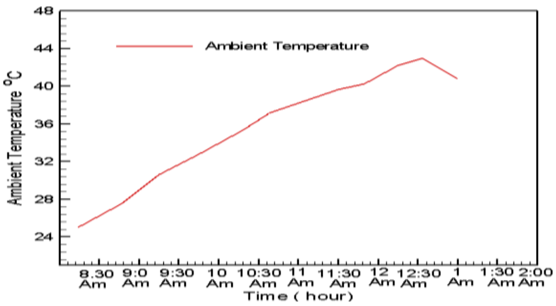
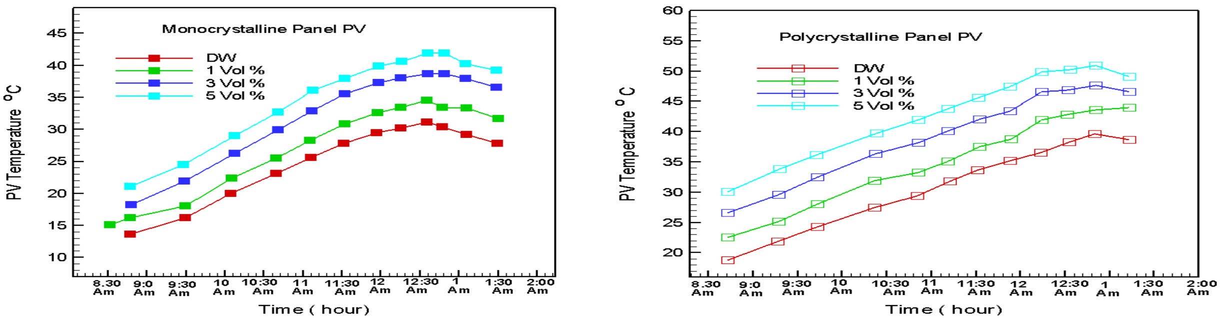


Fig.2. Ambient temperature

3.2. Effect of Nano fluidics of Temperature PV panel

The fig. 3 shows the temperatures of the cooled monocrystalline and polycrystalline photovoltaic panels. It is shown that when using Cu and water, the temperature of the panel decreases. At a concentration of 5 %, the minimum temperature is recorded, and at a concentration of 1 %, 3 % and distilled water.



a) b)

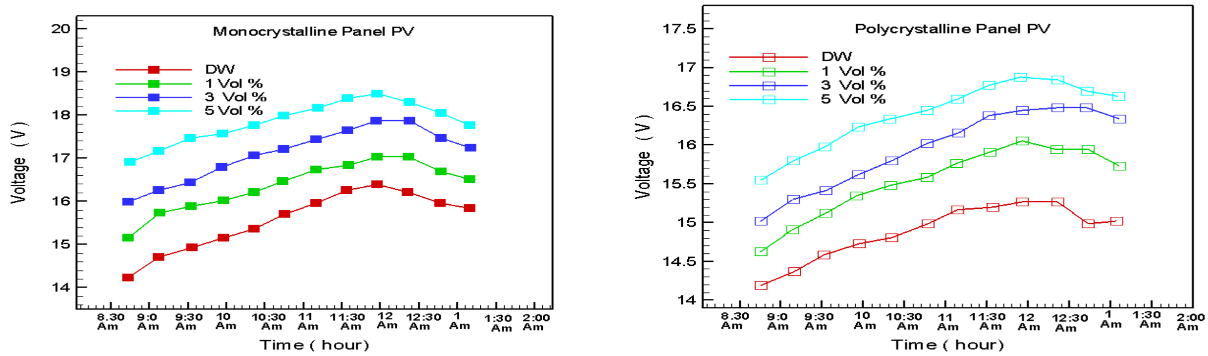
Fig.3. Monocrystalline (a) and polycrystalline (b) panel PV surface Temperature with cooling at various Cu concentration values and distilled water

The reason for the decrease in temperature is that the addition of nanoparticles at different concentrations leads to heat transfer due to its high thermal conductivity.

3.3. Effect of Nano fluidics of Temperature PV panel

Photovoltaics consume about 20% of solar radiation and convert the rest into heat. Fig. 4 displays voltage over time when cooling using distilled water and Cu (50 nm) at three concentrations of monocrystalline and polycrystalline panels.

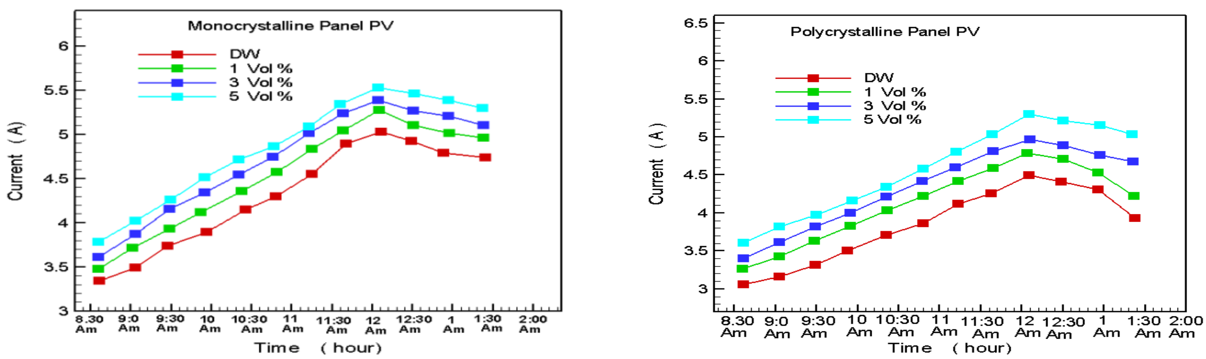
We notice a noticeable increase in voltage and it increases more and more than the increase in nanofluid concentrations and less Bima when using water distilled in cooling, decrease the voltages when by increasing temperature significantly and increase slightly with increasing solar radiation over time, and use of nanofluids in cooling led to lowering the temperature of the board and thus increasing the voltage.



a) b)

Fig.4. a) monocrystalline and b) polycrystalline panel Variations of voltage with cooling at various Cu concentrations values and distilled water.

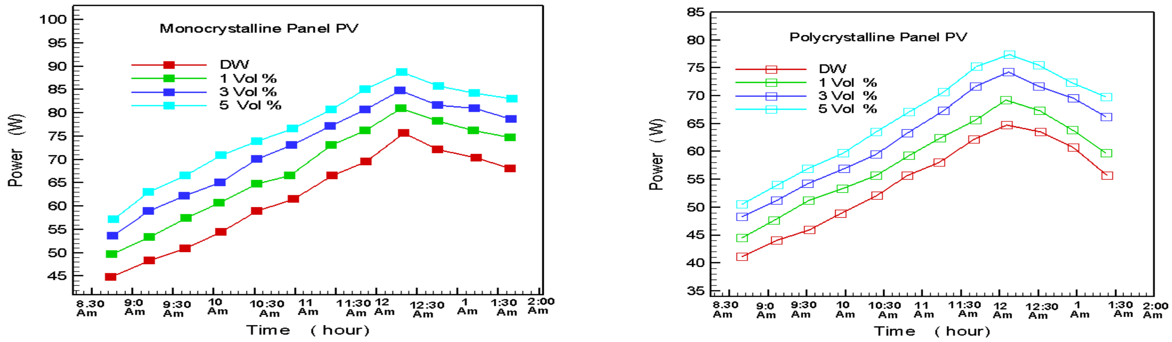
Fig.5 shows the electric current when cooling with distilled water and Cu (50 nm) at three concentrations of 1, 3, 5% mono crystalline and polycrystalline panels We note an increase in electric current for two reasons: 1 – Increasing solar radiation, which leads to the flow of more and more electrons; 2 – cooling using distilled water and Cu (50 nm) at three concentrations of 1, 3, 5 %.



a) b)

Fig.5. monocrystalline and b) polycrystalline panel Variations of current with cooling at various Cu concentrations values and distilled water.

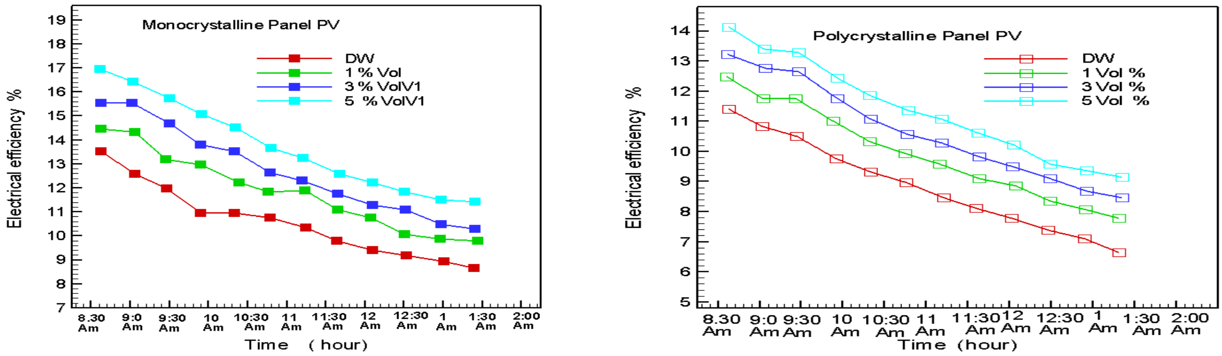
The fig. 6 displays the electrical power when using distilled water and Nano fluid Cu (50 nm) at three concentrations of 1, 3, 5 %. The electrical power also increases with the increase in solar radiation, where more and more electrons are emitted and more current and voltages are generated, in addition to that, the addition of nanofluids Cu (50nm) affects the productive capacity, as it increases with increasing concentration, as the highest value of the produced capacity was at a concentration of 5 % and the lowest value when using distilled water.



a) b)

Fig.6. Monocrystalline (a) and polycrystalline (b) panel electrical power with cooling (water and various values of Cu concentrations nano fluid as cooling fluid).

Fig. 7 shows the electrical efficiency when cooling with distilled water and nanofluid Cu (50nm) at three concentrations of 1, 3, 5 %



a) b)

Fig.7. Monocrystalline (a) and polycrystalline (b) panel electrical efficiency with cooling (water and various values of Cu concentrations nano fluid as cooling fluid).

The efficiency depends on solar radiation and the panels' temperature. We note that the efficiency values decrease over time as a result of increasing the temperature of the panel and that adding Cu (50 nm) leads to heat withdrawal and thus improves its efficiency.

4. Conclusions

1. The comparison showed that monocrystalline panels perform better than polycrystalline panels in all conditions.

2. Output power for mono crystalline panels was higher than that of polycrystalline panels due to cooling by Nano fluids and distilled water

3. The results showed the performance of nanofluids in cooling the photovoltaic panels, reducing their temperature and increasing the electrical efficiency of the three concentrations compared to distilled water due to their high thermal conductivity.

4. The comparison showed that the best performance was achieved during the cooling of photovoltaic panels using copper nanofluids at a concentration of 5 %.

Conflict of interest statement

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

CRediT author statement

Sultan **Kh.F.**: Writing – original draft, Investigation, Formal analysis, **Jaddoa A.A.:** Methodology, Formal analysis, Writing –review & editing, Fadel,**H.S.:** Supervision, Funding acquisition, Conceptualization**.** The final manuscript was read and approved by all authors.

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