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Green Nanofluid from Dandelion grass (Chicory) for Cooling Photovoltaic Solar Cell

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Abstract

Theexperiment compares the effects of surface cooling by a thin film of tap water, distilled water and nanofluidwith three concentrations of 0.01%, 0.03% and 0.05% running on the front of PV module. The advantage of this cooling methodis obtaining better thermal efficiency due to decreasing the reflection loss, cleaning the PV module from dust, reducing the cost of maintenance, increasing life cycle, and decreasing the temperature of the PV modules. Data obtained from elemental composition analysis of green chicoryrevealed the presence of 23 nano size elements. The formation of potassium chloride nanoparticles was confirmed byX-Ray Diffraction,XRD, with average crystallite size 20 nm, which is in agreement with Transmission Electron Microscope, TEM, analysis. Scanning Electron Microscope**,** SEM, analysis shows the aspheric potassium chloride and other minerals nanoparticles.The potassium chloride and other elements nanoparticles are used to improve the cooling performance of PV module.The average output power of PV module increased from 3.83% to 7.95% with increasing the tap water flowrate from 0.275 to 0.85 lit/min and distilled water from 5.67% to 7.94% with flow rate of 0.75 to 0.85 lit/min compared without cooling. But for nanofluid of 0.95 lit/min with concentration of 0.01, 0.03, 0.05% nanoparticles, the average output powerwere increased from 8.023% to 8.816% by about 10%. The average improvements of daily back surface temperature of PV is found about 30% at cases of distilled water with flow rate of 0.95 lit/min and nanofluid with concentration of 0.05%.

Keywords: Chicorynanofluid**,**alserisgreen nanoparticles, cooling of photovoltaic solar cell, , potassium chloride nanoparticles.

1. Introduction

Developing clean and renewable energy has become one of the most important tasks in the field of modern science and engineering. Solar energy can be recognized as one of the most promising renewable energy sources. Photovoltaic, PV, solar systems, presently is accepted as the most important way to convert solar energy into electricity, due to pollution-free and profusely available anywhere in the world. PV systems performance in the outdoor are affected by many factors; these factors are occurred mainly by environmental features and weather conditions as irradiance, wind, temperature, humidity and dust.PV module is highly affected by ambient temperature PV module temperature increases more than the Standard Test Condition (STC) temperature, which is 25^{o}C decreasing voltage. Therefore, the output power of the PV module is reduced [1]. Increasing PV module temperature leads to PV module voltage and current decreasing. Previous researches and experiments include many studies to improve the performance of PV cell by variou cooling system design and by different cooling methods such as air, waterandnanofluids cooling.

angle for the maximum amount of direct irradiance is set out to the site's latitude [8].

Cooling techniques of photovoltaic (PV) panels in general, are analyzed and discussed. Namely, it is well known that a decrease in the panel temperature will lead to an increase in electrical efficiency, so in recent years different cooling techniques have been proposed and tested experimentally. The efficiency drops with the rise in temperature, with a magnitude of approximately 0.5 %/°C. Several cooling techniques have been tried, mostly based on active water and air cooling, as these are the simplest techniques. Other cooling techniques include conductive cooling, phase-change material cooling, etc. Increase in electrical efficiency depends on cooling techniques, type and size of the module, geographical position and the season of the year, and usually corresponds with a rise of 3-5 % in overall efficiency [9]. Finally, a perspective on the cooling techniques for PV panels will be also elaborated on and discussed, Two types of cooling can be distinguished: active cooling, which consumes energy (pump, fan, etc.,) and passive cooling, which uses natural convection/conduction to enable heat extraction:

Nanofluids are considered to be dispersed mixtures of cooling fluid and solid nanoparticles. Most of the particles used are metal oxides, for example Al_2O_3 or TiO_2 or CuO or Zn or ZnO particles. Weight percentage of dispersed particles is around 0.1-2.0 %. The particles have brownian motion through cooling fluid. Main advantages of Nano fluids are greater thermal conductivity (therefore connectivity) and somewhat greater heat capacity [10].Chicory is called dandelion grass or so-called in Egypt Alseris and is found in a large number of agricultural clover and vegetables as shown in Figure1. Despite of the plant is not desirable in the cultivation of alfalfa because it takes place from the place of Alfalfa, and the farmer

The word photovoltaic comes from "photo" meaning light and "voltaic" which refers to producing electricity. Therefore, the photovoltaic process is producing electricity directly from sunlight. Photovoltaic is often referred to as PV [2]. The application of photovoltaics is very wide including water pumping, remote buildings, solar home systems, communications, satellites, space vehicles and for large power plants. Owing to this capability, the demand for photovoltaics is increasing all over the world and has begun to become economically competitive with conventional energy sources [3]. Although irradiation is the main indicator of PV potential, it is also necessary to consider secondary parameters such as PV technology, environmental parameters (wind, temperature, and humidity) which allowed us to quantify with precision the amount of electricity produced by a PV system. [4]. Temperature affects how electricity flows through an electrical circuit by changing the speed at which the electrons travel [5-6]. This is due to an increase in resistance of the circuit that results from an increase in temperature likewise, resistance is decreased with decreasing temperatures.

The power incident on a PV module depends not only on the power contained in the sunlight, but also on the angle between the module and the sun rays [7]. When the absorbing surface and the sunlight are perpendicular to each other, the power density on the surface is equal to that of the sunlight.However, tilting the surface up, causes the diffuse light to decrease. A good orientation and tilt angle of PV modules can maximize its energy potential [8]. For the best performance of the systems in the year, in most locations, fixed PV modules should be oriented to true south (in the Northern Hemisphere). In the case that there is no possibility to move the surface of the PV modules at all, the optimal tilt

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shown that nanofluid with 3.0 % wt. of particles enhances the efficiency by nearly 1.5 %, when compared with water cooling. Presumed surface of 40 W PV module is 0.35 m^2.Al-Busoul et al. [15] studied the performance of a cooled PV module by using Al2O3 and TiO_2 nanofluids with different concentrations under local conditions. It has been found that there is a significant increase in both of output power and final efficiency of all tested modules when nanofluids employed to cool down the PV module. The highest possible enhancement, under the local testing conditions, was observed for a nanofluid based on Al_2O_3 with a concentration of 0.02% by wt.

Hussein, Hashim et a. [16]presented the improvement of the performance of the photovoltaic panels under Iraqi weather conditions. The biggest problem is the heat stored inside the PV cells during operation in summer season. A new design of an active cooling technique which consists of a small heat exchanger and water circulating pipes placed at the PV rear surface is implemented. Nanofluids (Zn-H_2O) with five concentration ratios (0.1, 0.2, 0.3, 0.4, and 0.5%) are prepared and optimized. The experimental results showed that the increase in output power is achieved. It was found that, without any cooling, the measuring of the PV temperature was 76°C on 12 June 2016; therefore, the conversion efficiency does not exceed more than 5.5%. The photovoltaic/ thermal system was operated under active water-cooling technique. The temperature dropped from 76 to 70°C. This led to increase in the electrical efficiency of 6.5% at an optimum flow rate of 2 lit/min, and the thermal efficiency was 60%. While using a nanofluid (Zn-H_2O) optimum concentration ratio of 0.3% and a flow rate of 2 L/min, the temperature dropped more significantly to 58°C. This led to the increase in the electrical efficiency of 7.8%. The current innovative technique approved that the heat

wants alfalfa widely to fatten cattle. The Chicory or the throne has medical benefits. Large Seris is useful for patients with liver, sugar and diuretic. Also, Alseris is useful for kidneys as diearitic, it burns fat and is used for slimming and the amount of fiber beneficial for colon.Chicory root has a long history of human use, both as a food and as a dietary supplement to control high blood sugar levels. This activity is attributed to high amounts of the inulin-type fructans that slow down carbohydrate digestion and glucose absorption in the gastrointestinal tract [11]. Chicory plants also produce a variety of other bioactive secondary metabolites, including caffeoylquinic acids and caffeic acid derivatives as major phenolic constituents [12].

Fig. 1 Chicory herb or so-called in our country Egypt AlserisFig. 2 Chicoryextract ash

Xu and Kleinstreuer [13] made a numerical model for water and Nano fluid cooling of silicon PV cells and showed the cooling potential of Nano fluid to be somewhat greater than that of water. Electrical efficiency seems to maintain higher values even at increased temperatures when PV panel is cooled with Nano fluids. The efficiency difference between water and Nano fluid cooling is significant during higher outlet fluid temperatures, and it can be up to 1 % of total efficiency. Sardarabadi et al. [14] used copper tubing to cool down a 40W polycrystalline PV module from back side. Cooling fluid was water and two Nano fluids with silica particles. Content of particles was 1.0 % and 3.0 % of weight respectively. Maximum fluid flow was 0.011 kg/sec. It was

2.1 Preparation of chicory extract

Fresh chicory plant used in the study was collected from Nile Delta Clay soilin Menouf, Menoufia, Egypt. Then dried according to the standard condition (under shade at low humidity at room temperature). Fresh chicory were identified and authenticated by Prof.Dr. Mohamed Azzazy**,** Environmental Studies and Researches Institute, University of Sadat City, Egypt.To prepare the chicory extract,the plant was shade-dried completely,groundto powder. The Chicory powder was drenched in ethanol with concentration of 70% [18, 25, 26]. The Chicory alcohol mixture was left for 7 days in a glass jar before its filtration. Then the solvent was passed through a Whatman paper filter to a flask. After that the solvent was vaporized slowly, and the high-density liquid extract was put in the Petri dish and dried at room temperature. We put high-density chicory extract liquid in a muffle furnace at 450^o C to convert it to ash. Figure 2 shows the chicory extract ash.

2.2 PV module cooling system setup

In this experimental a PV module cooled by a thin continuous film of nanofluid running on the front of the panel has been considered. The experimental apparatus is relatively simple and consists of two polycrystalline PV modules that are used of area 65cm×100cm, the PV panel consists of 9×4 cells, which have generated 100 Watts maximum power under standard test condition (STC) and typically can generate nearly 5.8A and 17.24 V at maximum solar radiation. We will apply the cooling system in one PV module and the other module without cooling. Fig.3 shows the PV system experimental. The PV modules are south oriented at a 27^o tilt angle (The best angle around the year). The load(lamp) is connected to the PV modules. The readings of voltage, current, PV module temperature, ambient temperature and humidity are taken with extracted from the PV cells contributed to the increase of the overall energy output.

Mahmoud et al. [17, 20-23]investigated experimentally of a thermal storage system consisted of an insulated water tank, a recirculation pump and a flat plate solar collector. Additionally, the effect of adding ZnO nanoparticles to the working fluid was tested. The results showed that, the storage tank temperature is attained to about 80 ^oC in summer. The average stored energy is attained maximum to 16.11 MJ/day in summer, and minimum to 10.26 MJ/day in autumn. The average yearly stored energy is attained to about 13.69 MJ/day. Zinc Oxide nanoparticles with average diameter of 23 nm has been added to the tap water to perform the nanofluid with volume fractions of 0.05% and 0.1%. The stored energy is increased by 3.36% and 7.78% for volume fraction of 0.05% and 0.1%, also the daily efficiency is increased by 4.81% and 6.57%, for volume fraction of 0.05% and 0.1% compared to without nanoparticles.Based on the previous review, less attention of studying the cooling performance of photovoltaic solar cell using green nanoparticles [21-26].

The objective of this work is studying the cooling process by a front thin continuous film of tap water, distilled water and green nanofluid (***distilled water with chicory extract ash***)at different flow rates with various concentrations of nanoparticles and investigate the average increase in oputput power and the back surface of PV module in the cases of cooling and without cooling.

2.Experimental set-up

This study was conducted at Environmental Studies and Research Institute, University of Sadat City, Sadat City, Menoufia-Egypt, at latitude of N 30° 2' 41.1864", and longitude of E 31° 14' 8.1636", during the summer season, June, July and August 2020.

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3. Measurements and Results of Nanoparticles

3.1 Elemental composition analysis

Elemental composition analysis, Inductive Coupled Plasma-Mass Spectra (ICP-MS) of Chicory Extract (ppm) revealed presence of 23 elements, the major elements are Na 159.59 ppm, K 19.29 ppm, Ca 8.68 ppm, Mg 6.88 ppm and Al 3.11ppm. Table.1 shows the result obtained from the elements' analysis that was carried out on thechicory extract.

Table.1: Elements composition of chicory extract

Element	Na	K	Ca	Mg	Al	Cr	Zn	Fe
Weight(ppm)	159.59	19.29	8.68	6.88	3.11	2.27	1.20	0.87
Element	Sr	Bi	Ti	Mn	Ba	Pb	In	Cu
Weight(ppm)	0.85	0.63	0.56	0.33	0.32	0.24	0.15	0.138
Element	B	N	Li	Ga	Ag	Co	Cd	
Weight(ppm	0.088	0.085	0.035	0.031	0.028	0.927	0.006	

3.2Chicory extract ashanalyzes results

According to analyses conducted we found many elements in nanoparticle size such as Na, K, Ca, Mg, Zn and other elements. Data obtained revealed thatthe crystalline nature of nanoparticles was confirmed by X-ray crystallography as shown in Fig. 4. The XRD pattern indicates that the only mineral in its composition is KCL (sylvite) with average crystallite size 20 nm, the result crystal size shown had cubic structure. The TEM analysis shows that the chicory extract ash has an appropriate diameter in the range of the nano scale.The 50 nm of TEM micrograph of chicory extract ash,which explains nanoparticles with an average grain size of about (3.15 – 20.73) nm as Fig. 5. The 100 Arduino UNO microcontroller every 15 minutes starting from 9:00 am to 3:00 pm. From the observations, it is seen that there is a constant drop in voltage and current with an increase in temperature which results in a drop in power generated. In free front flow a nanofluid (chicory extract nanoparticles) with water cooling, the nanofluid is made to flow over the surface of the panel. The cooling system consists of a 0.75 inch PVC pipe of length 65 cm installed on the top end of the panel provides the nanofluid free flow on the front side of the panelto produce a film nanofluid over the PV panel. A pipe with 25 holes of 1.5 mm diameter has been installed on the top end of the panel to accommodate the flow of water uniformly over the surface of the panel. Nanofluid at room temperature added to the feeding pipe, leaves the holes, and flows over the panel as a thin-film. The flow rate is 0.95 lit/min, PVC ball valve of 0.75inch, hose nipple for connecting to nanofluid tank, for collecting nanofluid a 2-inch pipe of length 65 cm and its stopper is used. The flow of the nanofluid is controlled using the PVC ball valve.

Fig.3 PV system experimental (one PV module With free front flow coolingand the other without cooling)

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3.3Pv solar module cooling results

The cooling of PV solar module leads to decrease PV module temperature and increasing voltage and current flow, therefore the PV module power and efficiency increase. Experiments were performed in the period from 19 June 2020 to 3 August 2020 G in Environmental Studies and Researches Institute, University of Sadat City, Egypt at latitude of N 30° 2' 41.1864", and longitude of E 31° 14' 8.1636".The resultsshowsthe Pv solar module cooling using tap water experiments of volume flow rate of 0.275 to 0.85 lit/min. The distilled water experiments using volume flow rate of 0.275 to 0.95 lit/min. The green nanofluid experiments (distilled water and Chicoryextract ash) of volume flow rate of 0.95 lit/min with three concentrations of 0.01%, 0.03% and 0.05% were conducted.

3.3.1 Pv solar module cooling using tap and distilled water

In order to evaluate the performance of cooling PV module solar system with tap water, figures 7 – 9,shows the effect of increasing surface tap water flow rate on the decreasing the PV module temperature. It is observed that, the output power of the PV module increased from 3.83% to 7.95% by increasing the flow rate by about 2 times . We can see that the surface cooling of PV solar module is more effective during the period of 10:00 AM to 14:00 PM in summer and the peak cooling was happened at noon.

Also, figure 10 and 11, shows the effect of increasing surface distilled water flow rate on the decreasing the PV module temperature. It is observed that, the output power of the PV module increased from 5.67% to 7.94% by increasing the flow rate by about 30 %. We can see that the surface cooling of PV solar medule is more effective during the period of 10:00 AM to 14:00 PM and the peak was happened at noon.

nm of TEM micrograph of chicory extract ash,which explains nanoparticles with an average grain size of about (5.12 – 22.18) nm as Fig 6. So we expect that the nanofluid that we prepared for cooling purposes of Photovoltaic solar cell and improving it's performance.

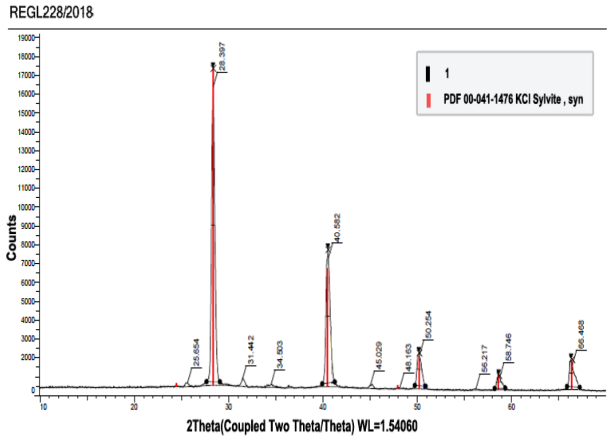


Fig.4 XRD analysis of chicory extract ash

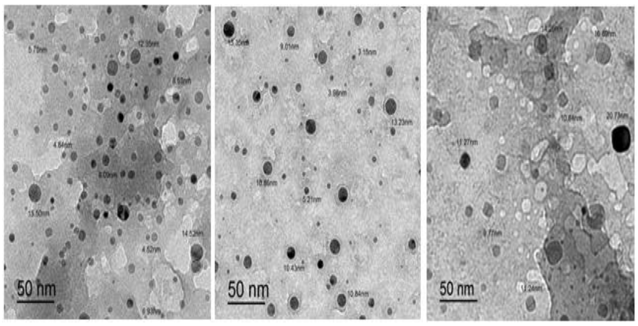


Fig. 5 50 nm TEM micrograph of chicory extract ash

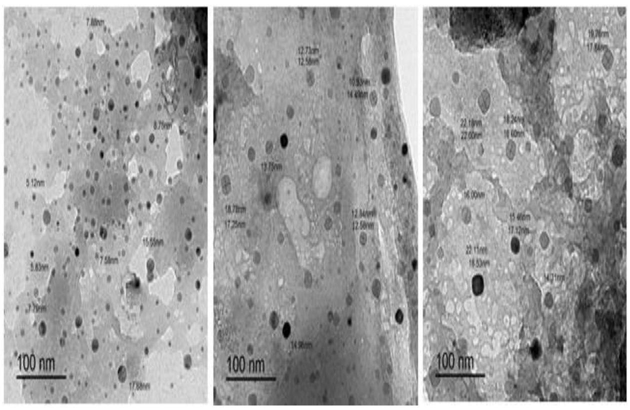
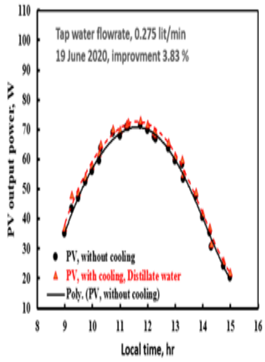


Fig. 6 100 nm TEM micrograph of chicory extract ash lit/min as shown in figures 12 - 14. The output power was increased from 8.023% to 8.816% with increasing the concentration of nanoparticles in the base fluid.

3.4 Power improvement results of Pv module cooling

Surface cooling of PV solar module using nanofluid at flow rate of 0.95 lit/min with nanoparticles concentration of 0.01%, 0.03% and 0.05% were illustrated in Fig. 15. The result showed that the increase in PV output power from 8.023% to 8.816% by about 10% .

3.3.2 Pv solar module cooling using Nanofluid



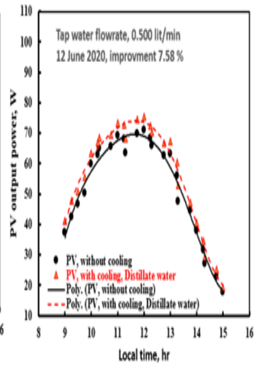
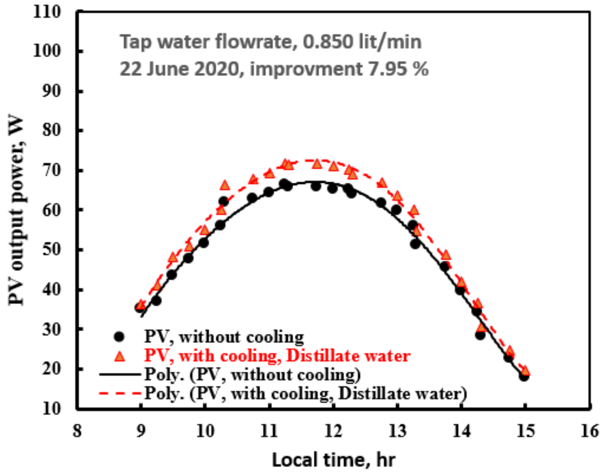


Fig. 7 PV cooling module using tap water with flow rate of 0.275 lit/min *Fig. 8 PV cooling medule using tap water with flow rate of 0.50 lit/min*

Surface cooling of PV solar module with nanofluid with concentration of 0.01, 0.03, 0.05% were performed at flow rate of 0.95



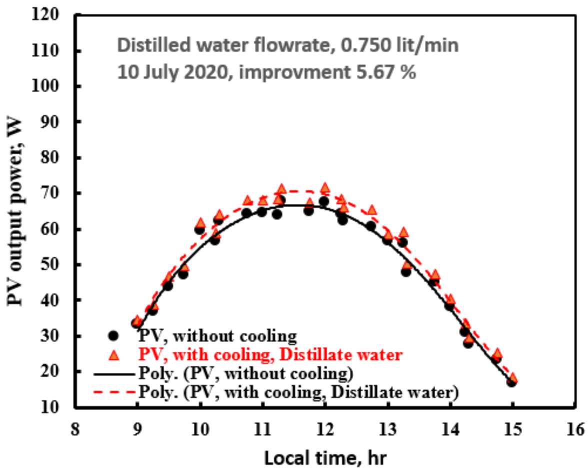
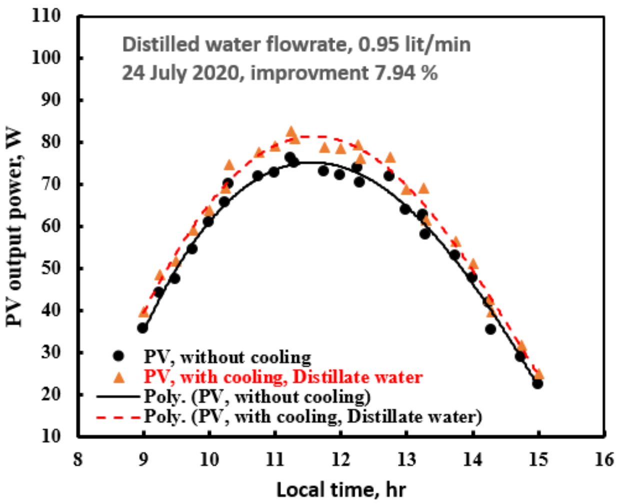


Fig. 9 PV cooling medule using tap water with flow rateof 0.85 lit/min *Fig. 10 PV cooling medule using distilled water with flow rate of 0.75 lit/min*



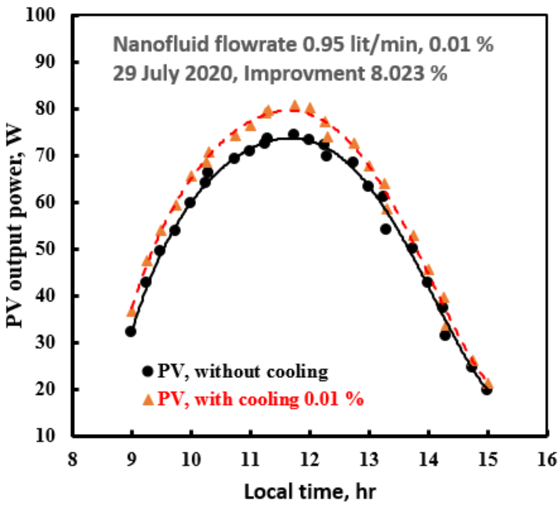
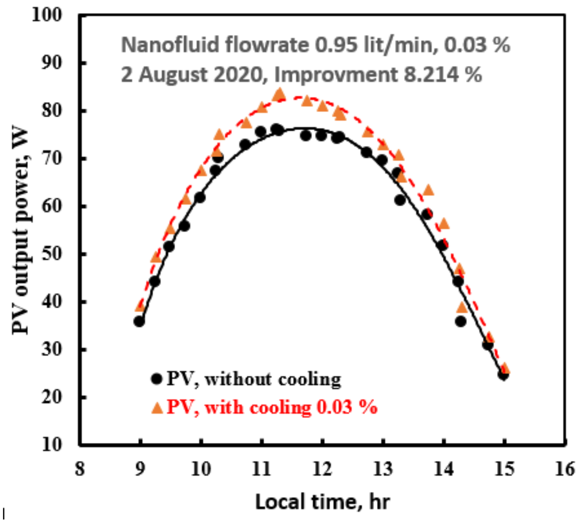


Fig. 11 PV cooling medule using distilled water with Fig. 12 PV cooling medule using nanofluidwith

flow rate of 0.95 lit/minconcentration of 0.01%



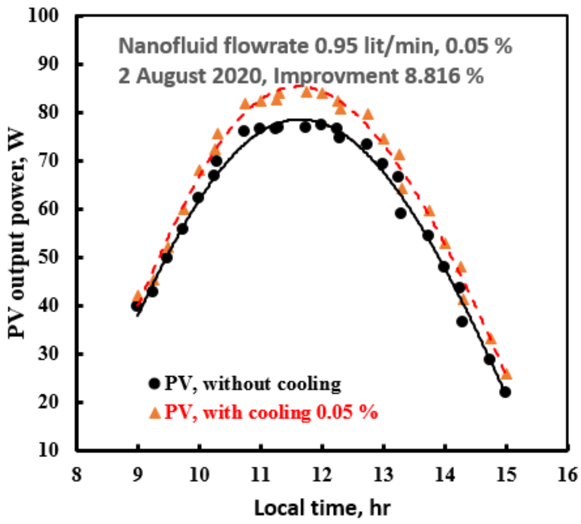
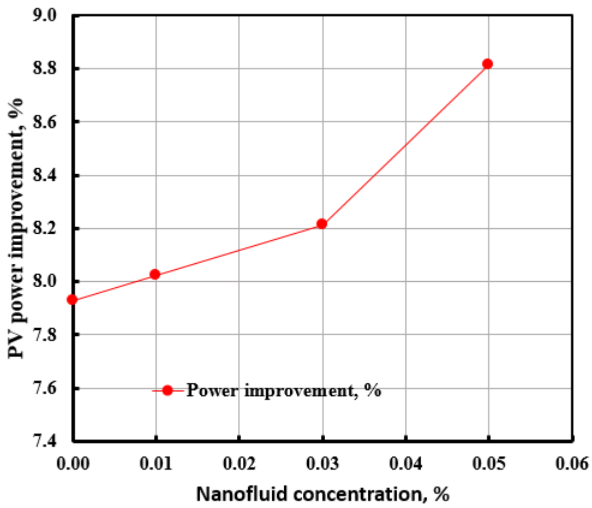


Fig. 13 PV cooling medule using nanofluid withFig. 14 PV cooling medule using nanofluid with concentration of 0.03%concentration of 0.05%



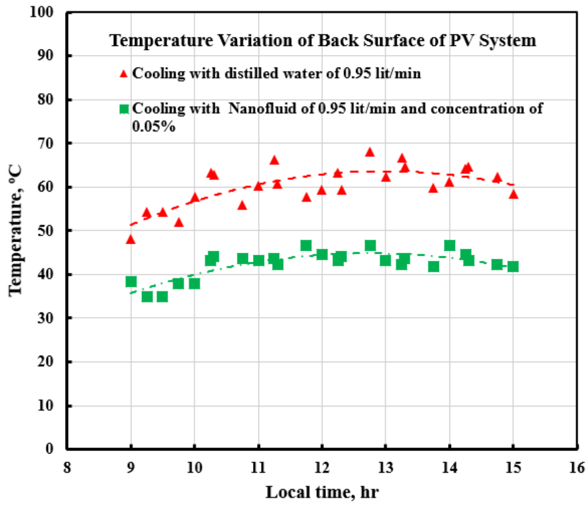


Fig. 15 PV output power percentage improvementFig. 16 Back surface temperature with time for the best coaling improvement.

general, increasing of nanoparticle concentration have higher heat transfer rate, because of higher thermal conductivity, uniform distribution and properly homogenous suspended in the water.

4.Conclusion

In this study a PV module solar system was cooled by a front thin continuous film of tap water, distilled water and nanofluid with various concentration of chicory extract ash of 0.01%, 0.03% and 0.05%. Based on the experimental results, the output power generated by the PV modules have been studied. The comparison has

3.5Back surface temperature of solar PV systems with cooling

The variation of back surface temperature is directly proportional to the thermal conductivity of the nanofluid. The Fig. 16 shows the daily variation of back surface temperature with time for distilled water and nanofluid. The best improvement with cooling of solar PV systems in cases of distilled water with flow rate of 0.95 lit/min and nanofluid with concentration of 0.05% nanoparticles. The results indicate that the daily surface temperature of the nanofluid cooling yields the lowest one and the daily average improvement is about 30%. In

3. The average output power with cooling by nanofluid of 0.95 lit/min with concentration of 0.01, 0.03, 0.05% was increased from 8.023% to 8.816% by about 10% .
4. The daily average decreased of back surface temperature of PV solar moduleis found about 30% atthe cases of nanofluid with concentration of 0.05% nanoparticles compared with distilled water at the same flow rate of 0.95 lit/min.

been made between the output from the PV modules with and without using the cooling system. The following results are obitaind,

1. The average output power of the PV module increased from 3.83% to 7.95% with increasing the flow rate of tap water from 0.275 to 0.85 lit/min.
2. The average output power of the PV module increased from 5.67% to 7.94% with increasing the flow rate of distilled water from 0.75 to 0.85 lit/min by about 30 %.

5. Abbreviations

Ag	Silver	*Li*	Lithium
Al	Aluminum	*Mg*	Magnesium
B	Boron	*Mn*	Manganese
Ba	Barium	*Na*	Sodium
Bi	Bismuth	*nm*	Nanometer
Ca	Calcium	*PV*	Photovoltaic
Cd	Cadmium	*Si*	Silicon
Co	Cobalt	*Sr*	Strontium
Cr	Chromium	*STC*	Standard test condition
Cu	Copper	*TEM*	Transmission Electron Microscop
Fe	iron	*Ti*	Thallium
Ga	gallium	*TiO2*	Titanium dioxide
In	Indium	*XRD*	X-Ray Diffraction
K	potassium	*Zn*	Zinke
KCL	Potassium chloride (sylvite)	*ZnO*	Zinc oxide

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