Extraction of Nanoparticles from Dandelion grass (Chicory) for Cooling the Photovoltaic Solar Cell with Green Nanofluid

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ABSTRACT

The experiments have been carried out to compares the effects of surface cooling by a thin continuous film of tap water, distilled water and nanofluid (*distilled water and chicory nanoparticles*). The nanoparticles mixed with distilled water with various concentrations of nanofluids such as 0.01%, 0.03% and 0.05% running on the front of the PV module to investigate the performance of photovoltaic solar system. Data obtained from the elemental composition analysis of green chicory revealed the presence of 23 elements with nano size. The formation of potassium chloride nanoparticles was confirmed by X-Ray Diffraction, XRD, with average crystallite size 20 nm, which is in agreement with Transmission Electron Microscpe, TEM, analysis Scanning Electron Microscope**,** SEM, analysis shows the aspheric potassium chloride and other minerals nanoparticles [1]. It was found that Nanofluid has more effect on improving the panel performance than pure water. The average output power of the PV module increased from 3.83% to 7.95% with increasing the cooling flow rate of tap water from 0.275 to 0.85 L/min and distilled water from 5.67% to 7.94% with flow rate of 0.75 to 0.85 L/min compared without cooling. But for nanofluid of 0.95 L/min with concentration of 0.01, 0.03, 0.05% nanoparticles, the average output power were 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 L/min and nanofluid with concentration of 0.05%.

Keywords: *Chicory, photovoltaic system, cooling, Green nanofluid, photovoltaic performance*

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°C decreasing voltage. Therefore, the output power of the PV module is reduced [2]. 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 various cooling system design and by different cooling methods such as air, water and nanofluids cooling. 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

27

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 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 [9]. 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 [10]. 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 ZnO particles. Weight percentage of dispersed particles is around 0.1-2.0 %. The particles have brownian motion through cooling fluid. Main advantages of Nanofluids are greater thermal conductivity (therefore connectivity) and somewhat greater heat capacity [11]. 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 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 [12]. Chicory plants also produce a variety of other bioactive secondary metabolites, including caffeoylquinic acids and caffeic acid derivatives as major phenolic constituents [13].

Figure 1- Chicory herb or so-called in our country Egypt Alseris

Xu and Kleinstreuer [14] made a numerical model for water and nanofluid cooling of silicon PV cells and showed the cooling potential of nanofluid 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 nanofluids. The efficiency difference between water and nanofluid cooling is significant during higher outlet fluid temperatures, and it can be up to 1 % of total efficiency. Sardarabadi et al. [15] used copper tubing to cool down a 40W polycrystalline PV module from back side. Cooling fluid was water and two nanofluids 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 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. [16] studied the performance of a cooled PV module by using Al_2O_3 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 al. [17] 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 L/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 extracted from the PV cells contributed to the increase of the overall energy output. Mahmoud et al. [18] 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°C 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.

2. Aim and Research Significance
This work aims to investigate 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 to investigate the average increase in output power and the back surface of PV module in both cases of cooling and without cooling. The advantage of this cooling system, in addition to decreasing the temperature of the PV modules, is in obtaining better thermal efficiency due to decreasing the reflection loss, cleaning the PV solar cell from dust, reduce the cost of maintenance and increasing life cycle.

3. 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. Four methods were chosen for testing extracted ash properties.These four methods are chemical an 1 ; carried out by Inductive Coupled Plasma- .... Spectra (ICP-MS), That is a powerful tool for analyzing trace metals inenvironmental samples. A large range of elements can be detected using an ICP-MS.The benefits of using plasma compared to other ionization methods, such as flame ionization, are that ionization occurs in a chemically inert environment, preventing oxide formation, and ionization is more complete. Also, the temperature profile of the . torch is relatively uniform, reducing self absorption effects. The process can be broken down to four stages; sample introduction, ICP-MS [19], the samples described below were tested in environmental and food biotechnology laboratory by using NIST traceable reference equipment and materials (Merck KgaA, ICP Multi-Elements Standard Solution IV, LOT # HC379062) in accordance with ISO/IEC 17025:2005 requirements and the methods referenced below meet ISO/IEC 17025:2005 and accreditation requirements, Sadat University, Egypt.The mineralogical composition investigated by using X-Ray Difractometer (XRD) Bruker D2 Phaser 2nd Gen, Generator Current (mA) 10 m, Wavelength Alpha 1.54060 A°, start angle 10 and end angle 70, crystal size is calculated by scherrer equation [20,21]. The samples described below were tested in environmental geology testing laboratory by using NIST traceable reference equipment and materials in accordance with ISO/IEC 17025:2017 requirements and the methods referenced below meet ISO/IEC 17025:2017 and accreditation requirements, Sadat University, Egypt Scanning Electron Microscope (SEM) analysis. The specimens were examined with a JEOL/EO-JSM-6510 LV scanning electron microscope (Jeol JEM-2100 Scanning Electron Microscope) at Electron Microscpe, Mansoura

University, Egypt and Transmission Electron Microscpe (TEM) analysis, Perfusion or immersion fixation of the tissue using a modified solution [22]: 2.5 % buffered glutaraldehyde + 2 % paraform-aldehyde in 0.1 M sodium phosphate buffer pH 7.4, leave tissue overnight at 4°C , wash 3 x 15 minutes (min.) in 0.1 M sodium phosphate buffer + 0.1 M Sucrose , postfix 90 min. in 2 % sodium phosphate buffered osmium tetroxide pH 7.4 , wash 3 x 15 min in 0.1 M sodium p, after drying for ~15 min sections may be investigated using a transmission electron microscope . Ultrathin sections were observed at 160 kV using a JEOL JEM -2100 at Electron Microscpe Unit, Mansoura University, Egypt.

3.1 Preparation of chicory extract

Fresh chicory plant used in the study was collected from Nile Delta Clay soil in Menouf, Menoufia Governement, Egypt. Then dried according to the standard condition (under shade at low humidity at room temperature). To prepare the chicory extract, the plant was shade-dried completely, ground to powder. The Chicory powder was drenched in ethanol with concentration of 70% [23] . 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° C to convert it to ash. Figure 2 shows the chicory extract ash.

Figure 2- Chicory extract ash

3.2 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 65 cm×100 cm, 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. Figure3 shows the PV system experimental. The PV modules are south oriented at a 27o tilt angle (The best angle around the year). The load (lamp) is connected to the PV modules. The readings of voltage detected by Voltage sensor with voltage accuracy ±0.25% , current detected by ACS-712 hall effect current with current accuracy ±1.5% , PV module backsurface temperature detected by LM35 Sensor with accuracy ±0.1°C, ambient temperature and humidity detected by DHT11 Sensor with temperature accuracy ±2°C and Humidity accuracy ±5**%RH** are taken with 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 extracted 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 panel to 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.

(a) Front view

(b) Back side view
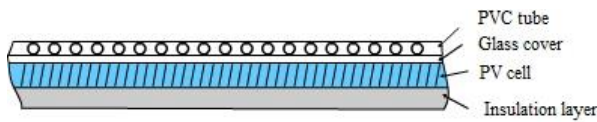
(c) Schematic diagram view

Figure 3- PV system experimental (one PV module With free front flow cooling and the other without cooling)

4. Measurements and Results

4.1 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 the chicory extract.

Table 1- Elements composition of chicory extract

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

4.2 Chicory extract ash analyzes 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 that

the crystalline nature of nanoparticles was confirmed by X-ray crystallography as shown in Figure 4. The XRD pattern indicates that the only mineral in its composition is KCL (sylvite) with average crystallite size 20 nm calculated by scherrer equation [20, 21], 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 Figure 5. The 100 nm of TEM micrograph of chicory extract ash, which explains nanoparticles with an average grain size of about (5.12 – 22.18) nm as Figure 6. So we expect that the nanofluid that we prepared for cooling purposes of Photovoltaic solar cell and improving it's performance.
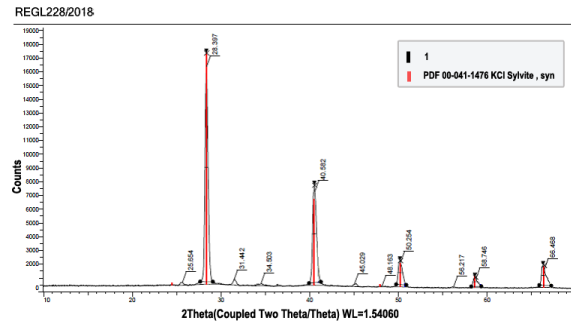

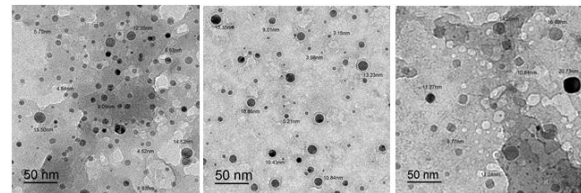Figure 4- XRD analysis of chicory extract ash

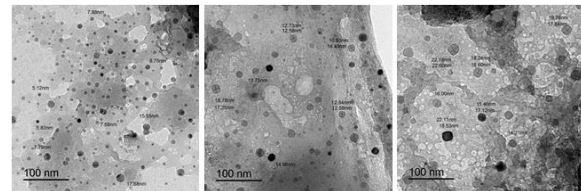Figure 5- 50 nm TEM micrograph of chicory extract ash

Figure 6- 100 nm TEM micrograph of chicory extract ash

4.3 PV solar module cooling results

The experiments were carried out for the PV solar module cooling using tap water experiments of volume flow rate ranging of 0.275 to 0.85 L/min. The distilled water experiments using volume flow rate within the range of 0.275 to 0.95 L/min. The green nanofluid experiments (distilled water and Chicory extract ash) of volume flow rate of 0.95 L/min with

three concentrations of 0.01%, 0.03% and 0.05% were conducted.

4.3.1 PV solar module cooling using tap and distilled water

In order to evaluate the performance of cooling PV module solar system with tap water, the results are plotted in figures 7 to 9 to indicate 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 time period of 10:00 AM to 14:00 PM in summer and the peak cooling was occurred at noon.
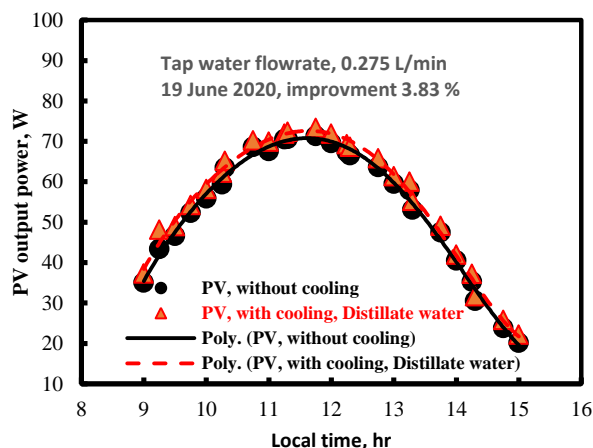
Figure 7- PV cooling module using tap water with flow rate of 0.275 L/min with average power error without cooling =4.64 and average power error with cooling =4.81
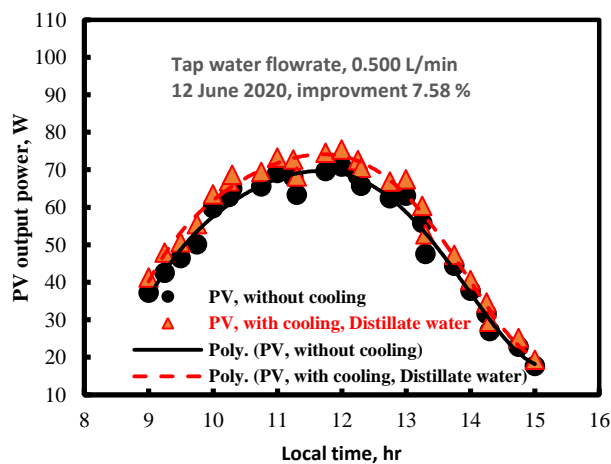

Figure 8- PV cooling module using tap water with flow rate of 0.50 L/min with average power error without cooling =4.58 and average power error with cooling =4.91
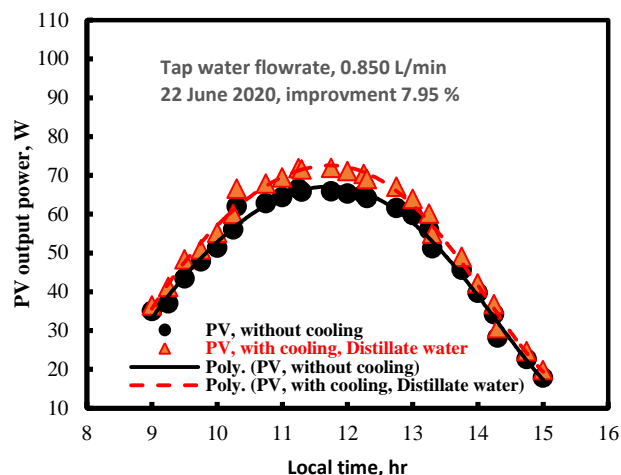

Figure 9- PV cooling module using tap water with flow rate of 0.85 L/min with average power error without cooling =4.39 and average power error with cooling =4.75

The effect of increasing distilled water flow rate on the decreasing the surface temperature of PV solar module is shown in figures 10 and 11. It is observed that, the output power of the PV module increased from 5.7% to 7.4% by increasing the flow rate by 30 %. This means that the surface cooling of PV solar module is more significant during the period of 10:00 AM to 14:00 PM and the peak was occurred at noon.
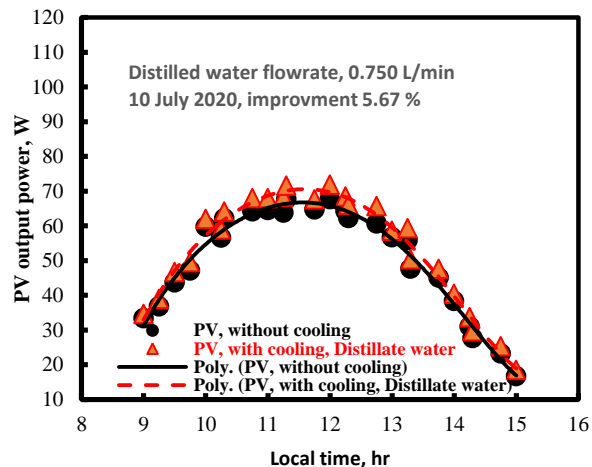

Figure 10- PV cooling module using distilled water with flow rate of 0.75 L/min with average power error without cooling =4.39 and average power error with cooling =4.63
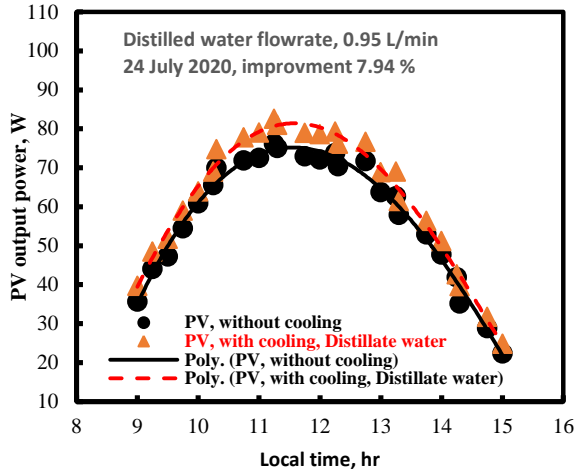
Figure 11- PV cooling module using distilled water with flow rate of 0.95 L/min with average power error without cooling =5 and average power error with cooling =5.39

4.3.2 PV solar module cooling using Nanofluid

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 L/min as shown in figures 12 to 14. The output power was increased from 8.023% to 8.816% with increasing the concentration of nanoparticles in the base fluid.
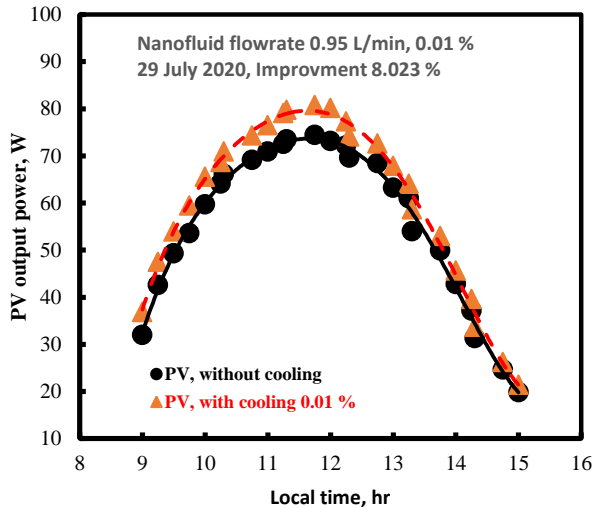

Figure 12- PV cooling module using nanofluid with concentration of 0.01% with average power error without cooling =4.85 and average power error with cooling =5.23
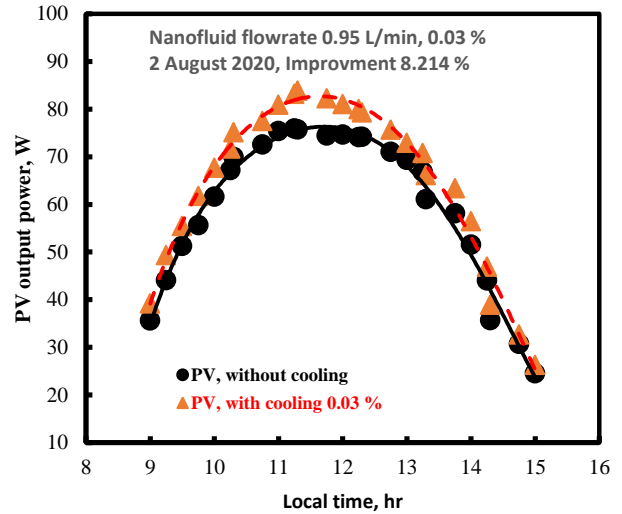

Figure 13- PV cooling module using nanofluid with concentration of 0.03% with average power error without cooling =5.15 and average power error with cooling =5.57
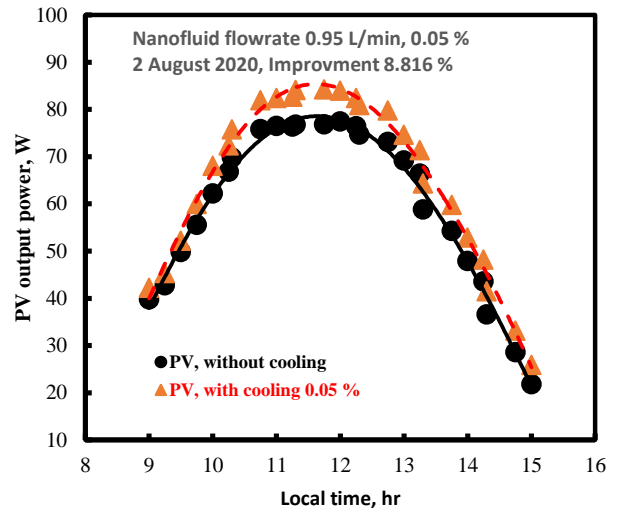

Figure 14- PV cooling module using nanofluid with concentration of 0.05% with average power error without cooling =5.18 and average power error with cooling =5.62

4.4 Power improvement results of PV module cooling

Figure 15 shows the 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 the increase in PV output power from 8.023% to 8.816% by about 10%.
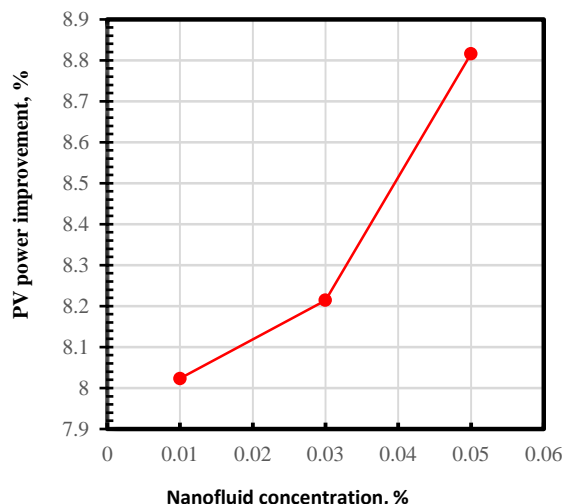
Figure 15 PV output power percentage improvement

4.5 Back surface temperature of solar PV systems with cooling

The variation of back surface temperature is directly proportional to the thermal conductivity of the nanofluid. Figure 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 L/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 general, increasing nanoparticle concentration have a higher heat transfer rate, because of higher thermal conductivity, uniform distribution and properly homogenous suspended in the water.
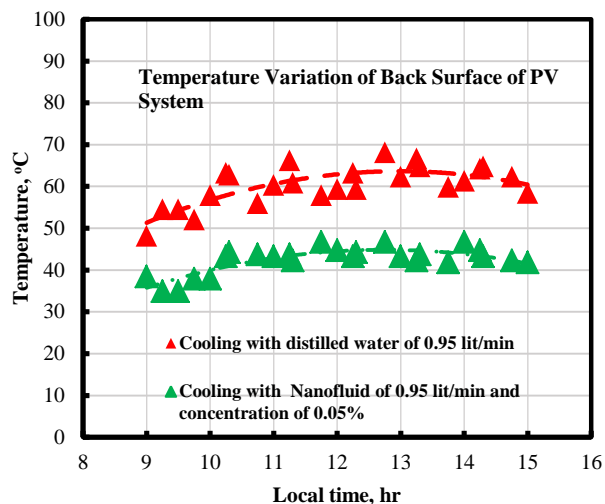

Figure 16 Back surface temperature with time for the best coaling improvement

5. Conclusions

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

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 L/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 L/min by about 30 %.
3. The average output power with cooling by nanofluid of 0.95 L/min with concentration of 0.01, 0.03, and 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 module is found about 30% in the cases of nanofluid with concentration of 0.05% nanoparticles compared with distilled water at the same flow rate of 0.95 L/min.

6. Abbreviations

Ag	Silver
Al	Aluminum
B	Boron
Ba	Barium
Bi	Bismuth
Ca	Calcium
Cd	Cadmium
Co	Cobalt
Cr	Chromium
Cu	Copper
Fe	iron
Ga	gallium
In	Indium
K	potassium
KCL	Potassium chloride (sylvite)
Li	Lithium
Mg	Magnesium
Mn	Manganese
Na	Sodium
nm	Nanometer

PV	Photovoltaic
Si	silicon
Sr	Strontium
STC	Standard test condition
TEM	Transmission Electron Microscope
Ti	Thallium
TiO2	Titanium dioxide
XRD	X-Ray Diffraction
Zn	Zinke
ZnO	Zinc oxide

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