Research Article

An Experimental Performance on Solar Photovoltaic Thermal Collector with Nanofluids for Sustainable Development

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In this article, the photovoltaic thermal collector (PVT) have designed and fabricated using nanoparticle nanofluid. The cause of this is to check out the effect of using water and water-based totally graphene nanoplatelets at an awareness of 0.05 wt% on the performance of PVT structures. Outdoor assessments have been performed at quantity along with the float prices of 0.5 L/min and 1.0 L/min for the aforementioned nanofluids, respectively, using water as a reference fluid. The results that have been analyzed from an active angle confirmed and determined that, graphene water nanofluid achieved higher in phrases of photovoltaic active conversion, than water that might generate the first-class thermal performance sooner or later of the peak period of sun radiation and high mobile temperature. The inclusion of water in the PVT collector increases average daily electrical efficiency by 7.8%, and 8.5% at flow rates of 0.5 LPM and 1.0 LPM, respectively. Furthermore, using water in the PVT collector increases average daily thermal efficiency by 24.9%, and 26.3% at flow rates of 0.5 LPM and 1.0 LPM, respectively.

1. Introduction

Renewable energy such as solar, wind, hydro, biogas, tidal, and waves plays a vital role all over the world. Solar energy is one of the eminent renewable power resources that offer future technology properly [1]. The critical software of solar strength can be labeled into two kinds: sun thermal device, which renovates sun electricity to thermal energy, and photovoltaic (PV) device, which transfigures solar electricity to electric power [2]. Usually, the structures are used after the opportunity [3]. The combined shape of sun thermal and photovoltaic (PV) is thought to be a photovoltaic thermal (PVT) system [4]. A noteworthy study which works on PVT structures has been completed in the past 50 years [5, 6]. Increasing the temperature of a solar panel by way of one degree Celsius has been shown to result as zero [7, 8], five percent lower in electric performance for silicon cells [9]. As an end result, solar panels can be cooled using an expansion of coolants, along with water and nanofluids. The following are the number of most trendy research that have been tested in this literature. Wolf [10] provided an idea of PV/T creditors for the first time and large observation has been carried out at the general performance of the module using experimental and theoretical techniques, with water-cooled flat-panel PV/T lenders, being frequently used.

Natrayan and Merneedi [11] pioneered the use of water or air as a fluid medium in a sun thermal collector. Sardarabadi et al. [12] performed a test in PVT systems using
water, due to the fact that bottom fluid and SiO₂ nanofluid at adequate concentrations. They observed that, standard overall performance come to be 3.6 percent for 1 wt percentage and 7.9 percent for 3 wt percentage whilst in evaluation to PVT water. Ghadiri et al. [13] tested diverse portions of water and ferro fluid (Fe₃O₄/water) in an indoor PVT device. In comparison to a PV gadget, the overall modified performance is proven to be 45 percent. Sardarabadi and Passandideh-Fard [14] combined three types of nanodebris (Al₂O₃, TiO₂, and ZnO) with deionized water at an attention of 0-2 wt%. The authors concluded that TiO₂ and ZnO had higher electrical performance, and ZnO had higher thermal performance.

Al-Shamani et al. [15] investigated with the glide prices on diverse nanofluids together with SiO₂, TiO₂, SiC, and water as a base fluid. According to the results, SiC had the very fantastic electric-powered performance around thirteen, fifty percent and usual performance of 81.73 percent. Soltani et al. [16] accomplished experimental research in a PVT device using a Fe₃O₄/water nanofluid. It was concluded that preferred typical performance and electricity technology had been advanced by using the use of 13% and 52%, respectively. The authors additionally confirmed that, using SiO2 stepped forward trendy, overall performance and electricity output is 3.35 percent and 54.29 percent, respectively.

Al-Waeli et al. [17] experimentally studied 3 varieties of water-based totally nanofluids consisting of Al₂O₃, CuO, and SiC on photovoltaic thermal creditors. It ends up locating that SiC had better thermal conductivity than the alternative nanofluids. Natrayan et al. [18] achieved an experiment having an observation on the silica/water nanofluid and its overall performance in a PVT system. It is determined that overall performance and exergy might be stepped forward by way of 7.9% and 24.3%, respectively. For lengthy-term stability, Ag/water nanofluid turn out to be dealt with through electric-powered explosion of wire [19, 20] and the device modified into evaluated the usage of thermodynamics, specifically power and energy performance.

This test turned into carried out with varied concentrations and glide regimes. The intention of this check is to draw interest to the use of carbon nanomaterials in improving the general performance of PVT systems. To the greatness of the author’s understanding, graphene nanoplatelet nanofluid grows to be experimentally explored in this paper for nonconcentrating PVT tool and evaluates its typical overall performance. The authors examined in contrast the electric and thermal efficiency of water and the use of nanofluids on a PVT collector.

2. Analytical Methodology

Two kinds of energy analysis were carried out in this study such as electrical and thermal performance of PVT collector [21] as given below.

2.1. Electrical Energy Analysis. The electrical efficiency of a PV/T system is typically used to decide its electric overall performance [22]. The most viable performance at a given solar intensity is received, through dividing the maximum appropriate electric-powered energy output of the PV module, with the useful resource of the sun intensity accomplishing the PV module’s glazing surface [23].

\[ \eta_{\text{elec}} = \frac{P_{\text{max}}}{Q_s}, \]

where \( P_{\text{max}} \) is the maximum electrical energy output from the PV module and may be calculated using Equation (2).

\[ P_{\text{max}} = I_{mp} V_{mp}, \]

where \( I_{mp} \) denotes the maximum current (amps) and maximum voltage (volts) of the panel.

\[ Q_s = A_{col} I_G, \]

where \( A_{col} \) is the area of the collector (m²) and \( I_G \) is the solar intensity (W/m²).

2.2. Thermal Energy Analysis. The term thermal efficiency is commonly used to describe the thermal performance of a

<table>
<thead>
<tr>
<th>Specification</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>( P_p )</td>
<td>260 W</td>
</tr>
<tr>
<td>( V_{mp} )</td>
<td>30.18 V</td>
</tr>
<tr>
<td>( I_{mp} )</td>
<td>7.96A</td>
</tr>
<tr>
<td>( V_{oc} )</td>
<td>36.72 V</td>
</tr>
<tr>
<td>( I_{sc} )</td>
<td>8.99A</td>
</tr>
<tr>
<td>( T_{lc} )</td>
<td>0.045K⁻¹</td>
</tr>
<tr>
<td>Single-cell dimension</td>
<td>156 mm × 156 mm</td>
</tr>
<tr>
<td>Single-module dimension</td>
<td>1640 mm × 992 mm × 35 mm</td>
</tr>
</tbody>
</table>
PV/T system [24]. The low temperature heat is created from the rear side of the solar panel (as shown by the equation below).

\[ \eta_{\text{ther}} = \frac{Q_u}{Q_i}, \]  

where \( Q_u \) is the rate of useful low temperature heat attained by the solar panel, which can be drawn from

\[ Q_u = mC_p \Delta T = mC_p(T_o - T_i), \]  

where \( m \) is mass flow rate of the fluid (Kg/s), \( C_p \) is specific heat capacity of the fluid (kJ/kg K), \( \Delta T \) is difference in temperature (K), \( T_o \) is the outlet fluid temperature (K), and \( T_i \) is the inlet fluid temperature (K) [25].

2.3. Experimental Methodology. A photovoltaic thermal sun collector is made from a storage tank, a nano fluid tank, a water pump, a temperature gauge, and a pressure gauge [26]. The outdoor dimensions of the PV/STSC tool are 1640 mm in period, 992 mm in width, and 35 mm in peak, with serpentine copper tube diameter and top of 6.35 mm and 1600 mm, respectively [27]. The technical characteristics of the PV panel evaluated in these studies are confirmed in Table 1. A storage tank with an indoor diameter of 300 mm and a top of 500 mm becomes built out of chrome steel [28]. Glass wool insulation with a thickness of 0.07 m was put around the storage tank's perimeter and associated pipes. The flow rate of the HTF, as well as the system's intake and outlet pressure differential, was monitored with a rotameter and a pressure gauge. The temperature of the heat transfer fluid, as well as the system's current and voltage, was measured every 30 minutes. The experimental testing facilities are depicted in Figure 1.
The experiment was carried out from June to August 2020, with the system-oriented East-West. The photographic view of experimental setup is shown in Figure 1. Schematic view of the architectural design details is displayed in Figure 2. Preparation of nano fluid and its related things are depicted in Figure 3.

3. Results and Discussion

The collected data is averaged and provided for further computations and examination at every 15 seconds. The trial days’ climatic parameters, solar intensity, and ambient temperature have been accumulated and displayed in Figure 4. The distribution of sun radiation for the duration is a bell form, with the highest rate at 12:00 pm being 1017.07 W/m² and the lowest values being 307.18 W/m² at 7:00 am and 229.29 W/m² at 17:00 pm, in step with this graph. The day-by-day common place ambient temperature climbs from 29.36°C at 09:00 A.M. to 34.23°C at 17:00 P.M. The consequences of electrical energy on water and nanofluid waft charges of 0.5 and 1.0 litres in line with minute are shown in Figure 5. Electrical energy grew with time until 12 pm because of developing solar intensity, however, then declined. The common electrical electricity for water is with glide quotes of 0. 5 LPM and 1.0 LPM have become around 46.43 W and 50.34 W, respectively. Similarly, the common electric-powered electricity for water primarily based graphene nanofluids with 0.05 percent concentrations of 0.5 and 1.0 LPM of water and 0.05% nano with 0.5 LMP of water, 0.5% LMP of water, 1.0% LMP of water, and 1.0% nano with 1.0 LMP of water, 1.0% nano with 1.0 LMP of water.

Figure 6 depicts the impact of electrical efficiency on water and nanofluid with different flow rates. The day-by-day common place ambient temperature climbs from 29.36°C at 09:00 A.M. to 34.23°C at 17:00 P.M. The consequences of electrical energy on water and nanofluid waft charges of 0.5 and 1.0 litres in line with minute are shown in Figure 5. Electrical energy grew with time until 12 pm because of developing solar intensity, however, then declined. The common electrical electricity for water is with glide quotes of 0. 5 LPM and 1.0 LPM have become around 46.43 W and 50.34 W, respectively. Similarly, the common electric-powered electricity for water primarily based graphene nanofluids with 0.05 percent concentrations of 0.5 and 1.0 LPM of water and 0.05% nano with 0.5 LMP of water, 0.5% LMP of water, 1.0% LMP of water, and 1.0% nano with 1.0 LMP of water, 1.0% nano with 1.0 LMP of water.

Figure 7: Heat energy gained of the water and nanofluid with different flow rates.

Figure 8: Thermal efficiency of the water and nanofluid with different flow rates.
electrical efficiency for water flow rates of 0.5 and 1.0 LPM was around 13.03 percent and 14.19 percent, respectively. Additionally, the average electrical efficiency of water-based graphene nanofluids with 0.05 percent concentrations of 0.5 and 1.0 LPM was 14.92%, and 15.93%, respectively. Electrical efficiency, like electrical power, and coolant flow rate increased [29]. Figure 7 exposed that, the heat energy gained of the water and nanofluid with different flow rates.

Thermal overall performance of PVT collector with water primarily based on nanofluids has been located at particular drift charges. As seen from Figure 8, maximum thermal overall performance for water at 0.5 LPM turn out to be 56.7%, and 61.2%, respectively. Similarly, a bent had been found for 1.0 LPM for water-based totally graphene nanofluids with 0.05% attention modified into determined to be 66.3% and 69 and 5%, respectively. Thermal normal performance of PVT device changed into more first-class through increasing flow charge due to the reality at higher glide fee temperature distinction among inlet and outlet of PV/T device becomes extra due to excessive warmth absorption of nanofluid from tool [29].

4. Conclusion

The overall performance of a PVT collector accomplished through water and graphene nanoplatelets-water nanofluid with a concentration of 0.5 wt% has achieved in this experimental studies. It changed into tested from the factor of view of the first regulation of thermodynamics at regular coolant together with the flow prices of 0.5 L/m and 1.0 L/m, which may be compared. The use of water in the PVT collector complements not unusual each day electric-powered performance with the aid of 8.5%, while using water-based totally graphene nanofluids inside the PVT collector boosts common each day thermal overall performance thru manner of 26.3%.

Data Availability

The data used to support the findings of this study are included within the article. Should further data or information be required, these are available from the corresponding author upon request.

Disclosure

This research was performed as a part of the Employment of College of Engineering and Technology, Mettu University, Ethiopia.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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