Improving The Efficiency of Photovoltaic Cells by Using the Distilled Water Immersion Method

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Abstract. Photovoltaic panels can convert solar irradiance into (electrical and thermal) energy. The (PV / T) system was developed, created, and its performance tested in this experimental analysis. The main objective of this study was to design, manufacture and evaluate the work of the PV / T system as a thermal collector to enhance heat transfer, by using distilled water as a working fluid used to cool (PV / T) system. The experiment was performed with flow rate of water from (1 L / min to 5 L / min) on the PV / T collector channel. A theoretical and practical study was conducted on the effect of cooling the panels by immersing (PV) from (upper and lower) in a distilled water parallel flow forced circulation. Numerical result obtained by using Comsol Multiphysics program have been used as a computational fluid dynamic (CFD). The numerical study was conducted to determine the optimal depth of immersion of the panel to experiment with it, simulation results showed that the optimum depth of immersion is (5mm). The experimental results were conducted at the Technical Engineering College of Najaf with indoor test conditions that were controlled, Tin=20 °C, h=5mm. The results have been shown that the electrical efficiency of traditional photovoltaic panel without cooling varied between (10.5-11.6) %, while the electrical efficiency of PV/T system varied between (14.6-14.7) %.

Keywords: photovoltaic cells, mono-crystalline Silicon, Efficiency, Immersion method.

1. Introduction

In light of greenhouse gas emissions and the depletion of fossil fuel resources, solar energy is one of the most promising sources of renewable energy. Fossil fuels emit greenhouse gases into the atmosphere, polluting the environment. Fossil fuels are frequently seen as non-renewable energy sources. [1][2]. The photovoltaic cells convert from (13-20) % the incident sun radiation into electrical power and rest is lost as heat [3]. Solar panels and their main function are to generate electrical energy and reduce dependence on traditional sources of energy generation from fossil fuels, as they are considered safe and do not emit any pollutants that cause damage to the environment when they work [4]. The efficiency of photovoltaic cells decreases with the rise in temperature, as it was found that at higher temperatures, efficiency of panels reductions by (0.5%) at a temperature rise of one degree Celsius. It is very important to cool the photovoltaic cells to improve their performance and production of electrical energy [5]. Several theoretical and practical studies have been done for cooling photovoltaic cells [6]. Zhu and Si [7] used water and air to cool the photovoltaic panels. It was concluded that water-cooled photovoltaic cell produces higher electrical energy than air-cooled photovoltaic cell and that water-cooled photovoltaic cell reduce heat faster and the collector (PV/T) produces higher electrical energy.

Al-zurfi, Hazim A., et al [8] Use water technology to cool solar panels. Provided a related analysis of the principle of hybrid techniques for thermal(PV)assembly. They proposed and analyzed nine separate...
prototypes, ranging from complex to plain, to analyses the potential return. The channel thermal collector was developed with a thin metal plate comprised of tubes to provide the highest overall efficiency as a transparent structure and was placed under a PV module, according to the findings.

H. Fayaz [9]: Investigate both numerically and experimentally the effect of combining PVT and PCM techniques on thermal with electrical performance of PV panels. Using Comsol software, simulation results agree with the experimental results were tacking different flow rates from (0.5 to 3) Litter /min with a 1000 w/m². The numerical and experimental results were 12.4% and 12.28% respectively without PCM and 12.75 and 12.59% with the use of PCM. Ahmad Fudholi[10]:experimentally investigated the effect of complaining the PV panel with a solar collector. The study shows that the total exergy performance could be enhanced by using the TiO₂ as Nano-fluid with TiO₂ ranging from 0.5% and 1% with a solar radiation 500, 700 1000 w/m² and a mass flow rate ranging between 0.012 kg/s to 0.0255 kg/s. The exergy with Nano-fluid achieved 85%-89% as compared with the water based PVT at 0.026kg/sec. GökhanÖmeroğlu[11] The influence of a number of fins mounted on the base of a PV module on the process of creating turbulent air to convey heat from the PV base was determined. Fins are made of low-cost, easy-to-manufacture materials. Increasing the number of fins leads to a large increase in thermal efficiency and a minor increase in electrical efficiency, according to the CFD results. Hussein M. Maghrabie and et al. [12] The effect of air forced cooling on photovoltaic panels was investigated using an air blower connected to a rectangular channel on the back of the PV module. The results showed that when air passes over the back of the PV unit, the cell temperature drops by 11%, and when air passes over the front of the PV unit, the PV temperature drops by 10%. PV efficiency is rising at a rapid pace (8 %). Nižetić et al. [13] cooled the solar panels at the front and rear side, as the cooling led to an increase in the output electrical energy. Farhana et al [14] they studied air cooling. Work was done in PV cells of the type of polycrystalline. The comparison was made between the air-cooled photoelectric cells and the non-cooled photoelectric cells, the cooled photovoltaic cells contain an air flow channel. The results showed a decrease in temperature by (12°C) and rise in electrical energy (10%). Ahmed Amine et al. [15 -19] They studied the effect of cooling on the performance of solar panels, use water cooling methods where the solar panels were cooled by the technology of dispersing water on the front surfaces of the solar cells and the technology of cooling the solar panels by using water that touches the back side of the solar panels. The final result showed that cooling the front side of the solar panels more effective in absorbing heat than cooling the back side of solar panels. In this project, a method of immersing the solar panels in distilled water was used to decrease surface temperature of solar cells with improve their production efficiency. By using the COMSOL program to simulate the flow, the optimal depth was chosen for submerging the solar panels.

2. Configure a photovoltaic cell cooling system

The cooling system uses water as a cooling liquid that is important and suitable for lowering the temperature of the panels. First part of the cooling system, which is the main part, is the photovoltaic cells that are required to be installed and lowered its temperature when the system is running. The third part of the system contains water guides to the base of the (PV/T) system. The fourth part is the pump used to pump the water through the thermal collector channel, and the finish fifth part is the sun simulator consists of 12 lamps of halogen the capacity of each one is 500W installed in the steel structure and placed above the (PV/T) panel’s system 1mof distance. The entire system was installed on a steel structure that can be moved at any height and any angle; the photograph of the experimental setup is shown in Figure 1. The schematic diagram of the complete experimental setup is shown in Figure 2. This unit's specifications are given in Table 1, Figure 3 PV module respectively.
Figure 1. Components of the cooling system photovoltaic cells.

Figure (1) shows the parts of the cooling system, the photovoltaic cells with complete assembly of the cooling system, the photovoltaic panels that were used, their power (60 watts). At the bottom of the complex a heat exchanger made of acrylic was placed that cools the hot water returning from cooling the photovoltaic plate. The temperature of the incoming and outgoing water and the temperature of surface of the photovoltaic cells and the base of the photovoltaic plate were calculated by means of sensors (thermo cables of type k). The fall of solar radiation on the photovoltaic panels was measured by a solar meter. At the inlet of the water, the flow meter is installed in order to control the amount of flow.

The experiment was performed using solar simulator under indoor test conditions of laboratory. The simulator consists of 12 halogen lamps with a power of 500W each, and the solar radiation intensity is controlled by a variable voltage. Before collecting data, (PV / T) system was exposed to radiation of 1000 Watt/ m² for 30 min to ensure that system’s conditions reached a steady state. The change in voltage is recorded at different volume flow rates using electric loads. The water volume flow rate was set at a range of 1 to 5 L / min. The temperature of a system were recorded every 1 minute by a thermocouple attached to the Data Logger device and afterwards used to calculate the system’s (thermal and electrical) efficiency. Its water was forced to flow around the PV/T system using an 8W DC pump and a heat exchanger in a closed loop arrangement to keep the fluid cold.

**Table 1.** Specifications of solar cells

| Solar Module Typical Performance Characteristics |
|--------------------------------------------------|
| Peak power                                      | 60(w) |
| Max power current (I m p)                       | 3.35 (A) |
| Max power volt (V m p)                          | 18 (V)  |
| Parameter                        | Value               |
|---------------------------------|---------------------|
| Open voltage (Voc)              | 21 (V)              |
| Short current (Isc)             | 3.68 (A)            |
| Stander test condition (STC)    | 1000 w/m², 25°C     |

**Figure 2.** Diagram of the (PV/T) System with its all Parts.

**Figure 3.** (Mono crystalline) photoelectric cell (PV).

**3- Methodology of the system**

Under laboratory test conditions, the experiment was carried with using a sun simulator. Simulator consists of halogen lamps, each lamp has a power (500 watts), and a variable voltage control unit is controlled by the intensity of solar radiation. For a period of (30 minutes) the cooling system of the photovoltaic panels was exposed to solar radiation of (1200 watts / m²). Utilizing electric loads, the voltage difference is recorded at various flow rates. From (1-5) litter / min, the water flow rate is
adjusted, through the thermocouple sensors that were connected to the data logger device, the temperature of the cooled PV panels and the non-cooled photovoltaic panels were determined. About the photovoltaic cells cooling system the water was pumped using a DC pump and the water was cooled using a heat exchanger in a closed system. Calculate the total efficiency of the cooled photovoltaic cells, the energy was measured. The electrical efficiency is the main part of the solar energy research system. The electrical efficiency of Cells ($\eta_c$) indicates the maximum power of the PV module, according to the amount of absorbed solar irradiance by the solar cells, where it can be expressed in the equation below as the following \[16\]

$$\eta_c = \frac{pmax}{G \times Ac}$$

Were $\eta_c$ represent electrical efficiency and $P(max)$ is max power, is solar of the radiation, $Ac$ represent area of the collector.

Expression of electrical efficiency ($\eta_{el}$), according to of the temperature is given for PV panel, will be the equation of electrical efficiency as below :

$$\eta_{el} = \eta_r (1 - \beta (T_C - T_r))$$

Where $\eta_{el}$ is the (electric efficiency) of PV ($\eta_{el} = 0.15$), $\beta$ is the [coefficient ($\beta = 0.0045\text{oC}$)], $T_C(\text{oC})$ is the (cell temperature) and $T_r (\text{oC})$ is the (reference temperature).

Where $\eta_r$ is the (reference efficiency) of PV module ($\eta_r = 0.15$), $\beta$ is the [temperature coefficient ($\beta = 0.0045\text{oC}$)], $T_C(\text{oC})$ is the (panels temperature) and $T_r (\text{oC})$ is the (reference temperature). The rate of electrical energy generated from PV/T system is given as \[17\].

$$E_{ele,net} = (\eta_r \times A \times \text{photovoltaic cells} \times I)$$

4. RESULTS AND DISCUSSION

Applied all experiments on the final design of the PV/T system, The testing has been performed in Technical College of Engineering, Najaf-Iraq (Indoor Test Condition) for the PV/T system under a constant of (Solar Radiation) and (Ambient Temperature) respectively with different volumetrically flow rates to predict in the temperatures of [PV module, (PV/T) system and water Inlet and Outlet] at the testing, for PV module, PV/T system can be calculated the (electrical) efficiency. A mass flow rate that passes through the collector by designed channels directly by the CNC machine, therefore, affects the cooling of the PV unit and increases the convection heat transfer coefficient. This effect due to an increase in the volume flow rate to the absorber collector and can be seen in Figure 4 and Figure 5 . The test has been conducted with indoor conditions, whereby the temperature of input $T_i$ and ambient $T_a$ were constants for every test. The volumetric flow rates comprised of 1 to 5 L/min, have been used in this testing which was later applied with solar radiations for indoor test conditions, were selected (600,700,800,900 and 1000 W/m2). The results showed that rises the volumetric flow rate simultaneously reduced the temperature of base and surface ($T_b$, $T_s$) respectively for the PV/T system, besides, reduced the temperature of outlet water ($T_{out}$) at any irradiance levels. For the same mass flow rate.
heat from the panel’s absorbed by water passing from above and below of PV panel through the thermal collector channel which is pre-designed and engineered by CNC machine, thus it will affect the cooling of the panel. Effect is caused by change in the flow rate inside the thermal channel collector of PV/T system and can be seen in figure 4 and figure 5. Pumping supplied from 1 to 5 LPM, have been used in this testing which later applied with a solar radiations for indoor test condition, where selected (600-1000) W/m². The results indicated that raising the flow rate reduced the temperature of the PV/T system while also lowering the temperature of the output water Tout at any solar radiation levels while maintaining the same mass flow rate.

**Figure 4.** Variations in Water (PV/T) System Base Temperature Over Flow Rates Under Different Solar Irradiance

| Volume flow rate (LPM) | Base temperature (°C) |
|------------------------|-----------------------|
| 0                      | 36                    |
| 1                      | 35                    |
| 2                      | 34                    |
| 3                      | 33                    |
| 4                      | 32                    |
| 5                      | 31                    |
| 6                      | 30                    |

**Figure 5.** Variations in (PV/T) System Electrical Efficiency with Different Solar Irradiance Over Flow Rates

| Flow rate (Litter /min) | Ele. eff. (PV/T) @ G=1000 (w/m²) | Ele. eff. (PV/T) @ G=900 (w/m²) | Ele. eff. (PV/T) @ G=800 (w/m²) |
|-------------------------|----------------------------------|----------------------------------|----------------------------------|
| 0                      | 14.25                            | 14.65                            | 14.75                            |
| 1                      | 14.3                             | 14.66                            | 14.76                            |
| 2                      | 14.35                            | 14.67                            | 14.77                            |
| 3                      | 14.4                             | 14.68                            | 14.78                            |
| 4                      | 14.45                            | 14.69                            | 14.79                            |
| 5                      | 14.5                             | 14.7                             | 14.8                             |
| 6                      | 14.55                            | 14.71                            | 14.81                            |
At lower mass flow rates, this behaviour is readily visible. As shown in figure 4 of the PV/T system at flow rate (1 - 5) LPM with solar radiation of 600 W/m² indicated temperature decreased from 32.1°C to 29.2°C simultaneously increased the electrical PV/T efficiency from 14.52% to 14.72% as shown figure 5. Radiation rise up to 1000 W/m², the temperature decreased from 35.5°C to 30.3°C as shown in figure 4, the electrical PV/T efficiency increased from 14.291% to 14.642% as shown in figure 5.

5- Conclusion

This research is a test of the water (PV/T) design method as the heat exchanger medium. The indoor test conditions for the experiment are prepared for the thermal collector channel connected to the PV panel. At a controlled surrounding condition, the experiment is conducted under a solar radiation setting from (600 W/m² to 1000 W/m²). The fluid volume flow rate also is varied from (1 Litter /min to 5) L/min. The analysis of this study is focused on the (electrical) efficiency. Radiation increased up to 1000 W/m², the temperature decreased from 35.5°C to 30.3°C and the electrical PV/T efficiency increased from 14.291% to 14.642%. Volume flow rate plays an important for the cooling effect on PV solar cells by reducing both the PV module base temperature and outlet water temperature from the thermal collector channel. Based on the tests carried out on the PV/T system thermal collector, both efficiencies have been shown to increase as the volumetric flow rate increase. Therefore, as the volumetric flow rate rise, total efficiency (PVT efficiency) increase simultaneously.

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