Optimization Of Thermal Module Solar Photovoltaic Using CFD-Simulation

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Abstract. Photovoltaic panels can directly generate electricity by converting solar energy, but the panels temperature reduce the efficiency of photovoltaic cells. The photovoltaic thermal PVT system technology is used to improve the electrical performance. In this study, the daily and monthly global solar radiation on a horizontal surface for Iraq have been measured and presented then used with PVT water system. ANSYS software is used to simulate the water temperature differences behavior and measure the surface temperature of PVT model using the collected irradiation with the mass flow rate at 0.01 and 0.02 kg per second. The CFD results were validated with previous studies and observed a good agreement. The simulation tests apply a constant input temperature to the PVT system in all the yearly weather conditions in order to enhance the surface temperature. The results observe the PVT thermal efficiency behavior and show the maximum enhancement which is reached to 61% with the mass flowrate 0.03 kg per second and constant low input temperature.

1. Introduction

A The energy demand growing with the increase of population density produce an environmental pollution problem which become important factor affecting economic development and climate change [1]. Burning gasoline, coal, and diesel produces PM 2.5, including soot. the National Energy Strategy aims to minimize the energy-related emission to enhance the National Air Quality Standards and improve a significant strategy to achieve effective and flexible cost in addition to energy-related emission. The statistical observation of worldwide production announced that the fossil fuel resources depleting [2,3] as shown in figure 1. The consumption of the resources will present significant environmental risks, through global warming [4]. The solar energy as clean, abundant, renewable and new energy has been used widely in construction, transportation, communication and other fields [5-7]. Solar energy represents one of the most important energy sources. The solar irradiance refers to the surface at a location which represents an important input parameter.
Figure 1. future of gas and oil production [3]

To develop the solar energy, the main issue is the knowledge of solar radiation effect based on the geographical location that needed to install the devices and estimating their performances. In many countries, the data of solar radiation is not available and the not measured. For that, the present work, the Iraqi global solar radiation data have been presented and used to investigate the thermal efficiency of PVT system.

2. Literature survey

The researchers in last few decades presented numerous studies in the field of solar energy systems and developed and documented PVT systems. A few notable effective PVT system design and approaches are presented in below:

Solanki et al, [8] proposed a study to investigate the PVT solar heater system performance. They used three panels subjected in wooden duct in the lab. The panels have a 12-V, 1.5-A DC fan which is used to circulate the air. The electrical, thermal and overall efficiency of the solar heater discussed at indoor conditions. they developed genetic algorithms to maximize the energy efficiency of PVT system single channel. The main used parameters were length and depth of channel correlated with the velocity of the fluid flow. Joshi and Dhoble [9], discuss various PVT systems. They found that the heat extraction from the PV rear panel surface is crucial and PVT systems which depend on forced fluid circulations through metallic pipes.

Hussain et al, [10] presented a comparison study in global solar radiation in Iraq and developed a solar radiation data for PV potential measured at different sites. The collected data obtained from PV GIS web data.

Al-Kayiem et al, [11] presented a renewable energy outlook in Iraq. They calculated the cost of 50KW concentrated solar power based on Iraqi’s conditions and environment which is reached to 0.23 US cent/kWh

Khordelgah et al, [12] explored a PVT system component which contain electrical and thermal storage devices used for providing electricity and hot water. The presented system used for dwelling in warm location in Europe. Also, they improved the power capacity output of the solar system in addition to enhance the solar cells temperature and panel efficiency. They were able to increase the system performance by converting the solar energy to electrical power with 12% increment, and provide hot water from the system by using the solar radiation conditions.

Abdul-Ganiyu et al, [13] investigated the real-life outdoor system performance of photovoltaic-thermal (PVT) module. They studied and compared the conventional photovoltaic (PV) system in real condition in Ghana. The results observed that the average daily electrical energy produced
by PVT and PV were 2.72 KWh/KWp/day and 3.21 KWh/KWp/day respectively. The energy of electrical outputs annual performance ratios was 79.2% and 51.6% for PV and PVT respectively. Kulkarni et al, [14] compared the performance of a normal PV panel and PVT panel. They improved the PVT pane 2.17% in the electrical efficiency of 1 in comparison with the normal PV panel.

3. PVT performance and thermal efficiency

The PVT overall system performance can be calculated using PV (electricity) and PVT (heat energy) component. The PVT system thermal gain is given as:

\[ Eth = M_w \cdot c_p \cdot \Delta T \]  
(1)

where \( M_w \) represents the flow rate of water mass (kg/s), \( c_p \) is the specific heat of water (KJ/kg.C) and finally \( \Delta T \) considered the differences in temperature which expressed as:

\[ \Delta T = T_3 - T_1 \]  
(2)

where \( T_1 \) and \( T_3 \) are the inlet and outlet water temperature. The mass flow rate \( M_w \) is expressed in volumetric terms as:

\[ M_w = V_w \cdot \rho(T) \]  
(3)

where \( V_w \) is the volumetric flow rate in m³/s and \( \rho(T) \) is the density of water (kg/m³) at temperature \( T \). Both \( c_p \) and \( \rho(T) \) were assumed to be constant (\( c_p = 4.18 \text{ J/kg}_C, \rho(T) = 1000 \text{ kg/m}^3 \) throughout the analysis presented in the study. The thermal efficiency of the PVT is given as:

\[ \eta_{th} = \frac{100 \times E_{th}}{A_m \times G_p} \% \]  
(4)

The PVT system performance is influenced by many factors involving, the PV cell temperature, weather conditions, global irradiance and ambient temperature, for that in this study will concern about these two factors [15].

4. Results and discussion

4.1. Model validation

PVT system temperature of outlet water collected from CFD-ANSYS simulation software observed a good response. In order to validate the simulation results of PVT system design, the present work calculate the thermal efficiency of the PVT water collector and compared results with previous studies. The results observe a significant difference between the researcher results and published previous works. The results show that the temperature of outlet water can be reached to the value that can reduce the cell temperature and enhance the solar panel efficiency. While, the thermal efficiency will increase based on the correlation of system cooling parameters. The CFD-ANSYS simulation software provide an accurate data response as shown in table 1. Lowering the temperature of PVT water collector provides an effective cooling process by water flow rate. Reduce the cell temperature provide a significant enhancement to the PVT system efficiency and improve the output power of the PVT system.
Table 1. A comparison between previous studies and present study

| References            | Thermal efficiency (%) | Collector design                                           |
|-----------------------|-------------------------|------------------------------------------------------------|
| Present study         | 61.36                   | Dual absorber                                              |
| Misha et al, [16]     | 59.6                    | Dual oscillating absorber                                   |
| Yang et al, [17]      | 58.35                   | Water collector (parallel circular pipes)                  |
| Dubey and Tay [18]    | 39.4                    | Parallel plates                                            |

correlation between temperature and solar irradiation

Iraq naturally has abundant sunshine which produce solar radiation. The total solar radiation on horizontal surface in Iraq varies from 41 CWEERV17/day in the north to 5.6 KWH/h17/day in the south while the direct normal solar radiation varies from 5 to 7 KWh/m2/day. The total solar irradiation correlation in horizontal surface correlated with the temperature shown in figure 2.

![Figure 2. Correlation between the total solar irradiation in Iraq](image)

As shown in the figure, the curves provide a great relationship observation between the monthly ambient temperature and solar radiation. Polynomial Linear Regression shown in below:

for solar radiation: $y = -84.289x^2 + 1055x + 2794.7$, $R^2 = 0.9803$
for temperature: $y = -0.7x^2 + 9.8104x + 5.0682$, $R^2 = 0.9346$

4.2. the global solar radiation

The hourly and monthly values of the global solar radiation on horizontal and inclined surface will be presented in this section. The comparison between them gives a difference between 589 to 773 in 12am, in July and December respectively. Figure 3 shows the comparison of monthly irradiation with time on horizontal plane in Iraq. Also, it has found that the maximum solar radiation is in July.
4.3. The Water Mass Flow Rate Effect Based On Irradiation Change

The solar irradiation level effect observes an increment in the system thermal performance with respect to the water mass flow rate. Table 2 presents the temperature differences with respect to water mass flow rate of system inlet and outlet which can be seen the clear reduction in temperature due to increment of mass flow rate.

**Table 2. Temperature difference between water inlet and outlet**

| time | Mass 0.01kg/s | Mass 0.02kg/s |
|------|--------------|---------------|
|      | Tin   | Tout | Δt  | Tin   | Tout | Δt  |
| 10   | 19.8  | 23.1 | 3.3 | 18.8  | 20.4 | 1.6 |
| 11   | 19.8  | 22.3 | 2.5 | 17.8  | 19.5 | 1.7 |
| 12   | 20.4  | 23.6 | 3.2 | 18.4  | 20.2 | 1.8 |
| 13   | 20    | 23.3 | 3.3 | 18    | 19.9 | 1.9 |
| 14   | 19.4  | 22.7 | 3.3 | 18.4  | 20.3 | 1.9 |

Therefore, the thermal efficiency increases when the flow of water increases. Also, the solar irradiation level will be increased and the differences in water temperature between the inlet and outlet will be reduced. The differences in water inlet and outlet temperature will affect the thermal efficiency. Figure 4 presents a clear effective changes in the value of solar irradiation correlated with thermal efficiency and the mass flow rate values.
The results of the present work show that the thermal efficiency will increases with respect to mass flowrate while the irradiation with time affect the thermal efficiency value.

5. Conclusion

In the present work, the PVT system performance with dual absorber was presented and evaluated. The CFD ANSYS software is used to analysis the system numerically based on Iraqi weather conditions. The PV system performance was compared with previous studies. The main finding of current research study is that highest value of the PVT thermal system efficiency can be reach to 61% when using 0.03 kg/s of water mass flow rate and the maximum solar irradiation is 588 v/m².

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