Evaluation of oscillatory flow Photovoltaic/Thermal system in Oman

Hussein A Kazem[1], Miqdam T Chaichan[2], Jabar H Yousif[3]

Abstract: **Photovoltaic/Thermal (PV/T) system are use different observers and configurations to cool the PV, enhance thermal energy and improve both electrical and thermal efficiencies. In this paper oscillatory flow observer used with water as a cooling method for the designed PV/T in Sohar, Oman. The measurement of electrical and thermal quantities recorded for three months from September to November 2018. It is found that the average increase in temperature between inlet and outlet is 1.3 ºC. This increment will improve more in summer months. However, the peak electrical power and voltage achieved by the system are around 64 Wp and 18.3 V, respectively. The average power of the PV/T panel is 5.1% higher than average power of conventional PV panel.**

Keywords: Photovoltaic/Thermal system; solar energy; temperature; Oman.

I. INTRODUTION

There are two types of energy resources which are nonrenewable and renewable energy resources. Nonrenewable energy resources are a natural resource which can't be produces or used more than once. These resources are consumed much faster than natural can create them, for example oil, coal, natural gas and uranium also this type it can't be last forever [1, 2]. Nonrenewable resources are not environmentally friendly and can have serious effect on our health. They are called nonrenewable because they cannot be re-generated within a short span of time [3, 4], that's why the world is looking forward to finding and make available alternative resources of energy. This is because it is expected that supplies of oil and gas will face shortage soon [5]. Renewable energy is energy which comes from natural recourse which can be produced and grow or used like more than one time its unlimited resources such as a sunlight, wind energy, rain, waves energy, tides energy, ocean thermal energy and geothermal heat. They are available in plenty and by far most the cleanest sources of energy available on this planet. For example, energy that we receive from the sun can be used to generate electricity [6]. The sun is the main source of all energy on Earth, the cause of weather and climate. Solar energy is well known as the most environmentally friendly renewable energy. Before 1970's, people use to focus on fossils to produced energy, and during this year people started to research for a way to get energy direct from the sun. The development in the technology in the last few decades enables extensive and efficient use of solar energy as shown in Fig. 1 by converting it to thermal energy and electricity using thermal collector and photovoltaic (PV), respectively [7]. Solar energy is energy provided by the sun. This energy is in the form of solar radiation, which makes the production of solar electricity possible. Electricity can be produced directly from PV cells (Photovoltaic literally means "light" and "electric.") These cells are made from materials which exhibit the "photovoltaic effect" i.e. when sunshine hits the PV cell, the photons of light excite the electrons in the cell and cause them to flow, generating electricity. In use, solar energy produces no emissions. One megawatt hour of solar electricity offsets about 0.75 to 1 tons of CO_2.

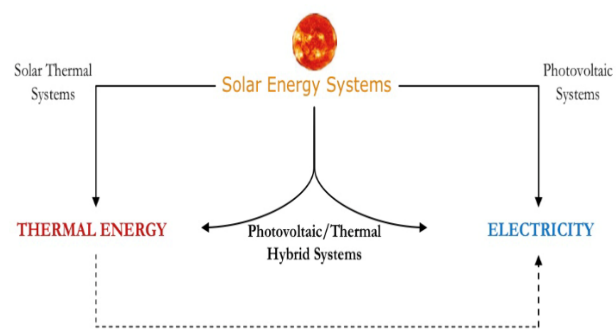

Figure 1. Solar energy systems [1]

The world is looking forward to finding and make available alternative resources of energy, this is because it is expected that supplies of oil and gas will face shortage soon [8]. Solar energy is a promising resource and can be obtained easily. However, to let the solar energy compete with oil and gas better and high efficiency equipment are required to be developed. Solar cells such as PV have recently become available at acceptable price. However, to enable better performance a tracking system can be developed to follow sun light. Tracking system needs to be designed in a way to use minimum energy. The tracking system can be design in one axis or more. Nevertheless, if more than one axis used more energy are required to run the system.

Photovoltaic Thermal/Hybrid collectors (PV/T) are an emerging technology that combines PV and solar thermal collectors by producing heat and electricity simultaneously. During the mid-1970s, people research on PV/T, with focus on PV/T collectors, and the main with increase of the PV efficiency [9-15]. The applications of solar energy can be divided into two categories, Solar Thermal system (T) and Solar Photovoltaic system (PV). By combining them into one system it results in formation of solar photovoltaic thermal (PV/T), which is a hybrid system that converts solar energy into

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electricity and heat meanwhile form one integrated system [16-20]. Figure 2 shows different classification of PV/T systems.
In this paper an oscillatory flow PV/T system installed in Sohar University in Sohar northern of Oman and tested for three months September-November 2018. The measured data used to evaluate and model the system performance. Discussion of the results are presented.

II. LITERATURE SURVEY

There is research going on for more than 80 years to increase the PV efficiency by reducing the temperature, the only problem is that with the temperature reduction there will be other reduction in the light intensity, accordingly, which is unneeded. So as a way of solving it among other methods, they combine the two systems (thermal /photovoltaic system) to produce PV/T. Many researchers investigated PV/T systems using different cooling methods [21-50].
Pratish Rawat1 *et al.* (2013) [21], Solar PV/T system's design aims to reduce the operating temperature of PV modules and to keep the electrical output at adequate level. When there is temperature change in any process, there is a loss of exergy. In comparison, exergy efficiency is lower for electricity generation using the considered PV module, ranging from 8% to 10%. It is observed that photovoltaic module temperature has a considerable effect on the various efficiencies of the system such as thermal, electrical or exergy efficiency.
Miqdam and Hussein (2016) [22], study the effect of solar Radiation on PV module in Solar region in Oman, that which was like the findings of many researchers, the found resultants of this paper shows that the impact of wind was little on the modules temperature for the tested period, voltage drop with increasing voltage, high current value and dramatic decrease of the power due to the air temperature.
Ali *et al.* (2017) [23], pointed out that cooling methods is one way to solve the reduction efficiency of PV system. Another way is by combine PV and solar thermal collectors to establish hybrid system (PV/T). Many benefits are gained through using such a method, for instance, maintaining the cell temperature, increasing the output temperature of the thermal collector, saving up space through the combination of two systems in the same area, and reducing the installation coasts.
Indra (2015) [24], indicated that as solar energy growth is widely spreading, considering the productivity of solar cells has been came as first priority. Using PV system with silicon done accordingly throughout type of crystal whether it was monoscriptal, polycrystalline and amorphous.
El-Shaer *et al.* (2014) [25], draw a conclusion on the unlimited carbon-free energy, wildly known as solar energy, in which it has the term dilute (hot regions are needed) as a problematic point. To overcome it, technology applications are used to increase the performance of the cells by using output parameters performance of mono-crystalline silicon and poly-crystalline silicon, intensity and temperature are controlled using this model.
Laxmi *et al.* (2016) [26], PV system depends upon variety parameter. As well it depends upon irradiance, temperature, shunt resistance, series resistance, identity factor, saturation current. All affect the solar cell performance.
Subarto (2013) [27], pointed out that PV materials work accurately in converting solar energy into electricity. Materials used by PV are mono-crystalline silicon, poly-crystalline silicon, microcrystalline silicon, cadmium telluride, and copper indium Seleucid.

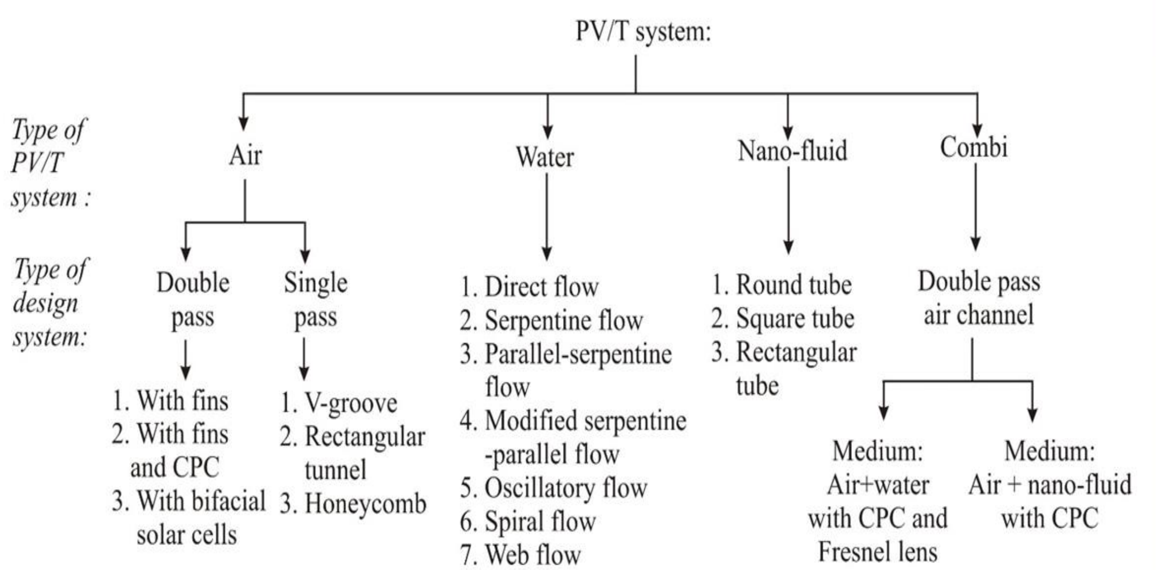

Fig. 2. Classifications of PV/T systems

Table 1: Comparison of PV/T literature survey.

Authors/reference	Year	Location	PV Type	Thermal collector type	Colling type
Mustafa Kaya [28]	2013	UAE/outdoor	_	Water collector with glass tedler	_
Lv et al. [29]	2013	China/indoor	Monocrystalline Si	Tube-Plate Collector	_
Musallam Ahmed Tabook et al. [30]	2014	Malaysia	Polycrystalline silicon	Water collector with glass tedler	_
H. Jouhara et al. [31]	2015	UK	-	water/ glycol	-
Ahed Hameed Jazz [32]	2017	Malaysia	Polycrystalline silicon	water	a jet impingent
Amna A. Alzaabia et al. [33]	2004	UAE	a polycrystalline	Water Hybrid Photovoltaic Thermal	-
M. Hajji, et al [24]	2014	Morocco/ Indoor	Monocrystalline Si	integrated with a tube-and-sheet	water
Athukorala A. U. et al. [35]	-	Sri Lanka/ indoor	-	-	-
Haiping et al [36]	2015	China	-	Numerical - Compound parabolic concentrator	water
Slimani et al. [37]	2015	Algeria/outdoor	Monocrystalline	Air Collector	air
Hongbing Chen et al. [38]	2011	UK	Monocrystalline Amorphous hybrid	Air Water Dual	Air Water
Swapnil Dubey [39]	2013	Singapore	-	(PVT) collectors.	water/air
Ali.H Al-Waeli et al. [23]	2017	Malaysia/outdoor	Monocrystalline	Hybrid Photovoltaic Thermal	Nanofluid and Nano-PCM
Ali.H Al-Waeli et al. [40]	2019	Malaysia/outdoor	Monocrystalline	PV/T collector	Air water
Indra Bahadur Karki et al. [41]	2015	Nepal/outdoor	polycrystalline	-	air
A. El-Shaer et al. [25]	2014	Egypt	mono-crystalline and poly-crystalline silicon	-	-
Laxmi Kant Dwived et al. [42]	2016	India	Monocrystalline Si	-	air
Hussein A Kazem [43]	2019	Oman	Monocrystalline Si	PV/T collector	Water

The following points are highlighted from table 1:

- In literature it is found that there are more than four types of cooling solar cells air, water and phase change material PCM. However, adding nano particles produce: Nanofluid and Nano-PCM. In addition, sometimes the PV/T system has mixed cooling (air/water, air/PCM, nanofluid/PCM, etc.).
- The types of cooling that have a greater impact is the efficiency of the solar cell is water and air. However, adding nano particles will enhance the heat transfer.
- The parameters that have been investigated related to the cooling type, thermal collector type, PV type and efficiency but there are few studies that investigates all these parameters together.
- Only few studies have models for cases and parameter (i.e. voltage, current, power or efficiency).
- Monocrystalline silicon type PV the most commonly used type of PV modules in PV/T systems within this range of research.
- Type of configuration provided in the study is assumed to be standalone in case it was not mentioned.

III. Experimental setup

The PV/T collector used in this study is made up of stainless-steel material which has good thermal conductivity; heat transfer rate increase. Moreover, it is easy to weld. The pipe is designed in rectangular shape, which allows to cover more area of the collector while maintaining reasonably lower depth. The configuration of the pipe is a direct flow illustrated in figure 3. Beneath the thermal collector a glass wool insulation material was employed to ensure to heat leakage. Both panels were installed and fixed in an area without shading. The thermal collector system is used to facilitate between hot and cold water to ensure cold water is used to cooldown the PV/T. The mass flow rate of water was set for 0.02 kg/s.
Figure 3 is a photo of PV and PV/T panels located on the surface roof of faculty of engineering in Sohar University. The module is PLM-100/12 polycrystalline silicon solar module with high efficiency crystalline cell, it produces considerable power even if it exposed to weak light. The PV highest specifications are: 100 W, V_{oc}=21.7 V, and I_{sc}=6.38 A, respectively.

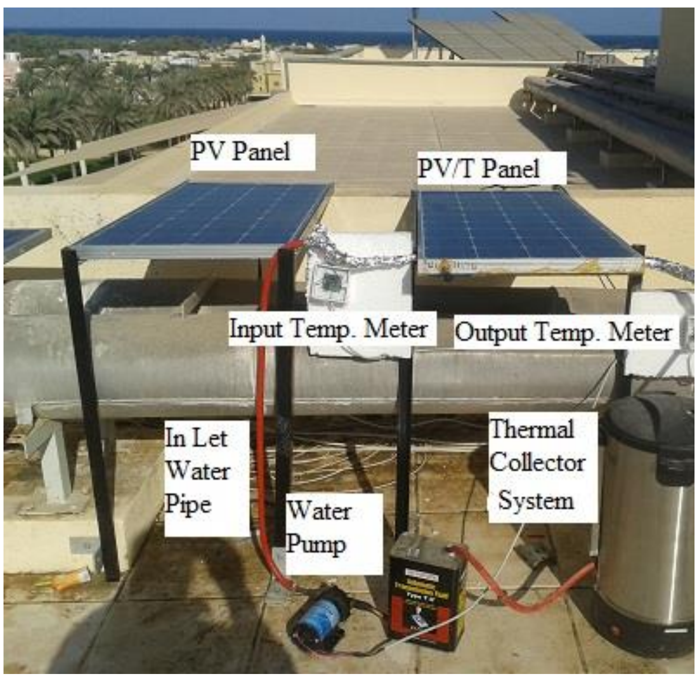

Figure 3. PV/T experimental setup.

As shown in Figure 3, two meters are fixed at the input and the output of the coper tube to measure the inlet and outlet water temperature. The meter's type is W1209 temperature control switch, the temperature value is displayed in ℃ via 3-digit seven segment displayers. Furthermore, different sensors, data acquisition and accessories has been installed for more accurate measurements of temperature, solar radiation, current, voltage and power.

IV. Results and Discussions:

In this section two types of solar cells PV and PV/T were evaluated by covering all aspects, along with comparisons between the two technologies. Measurement of system performance has been collected for three months 2 September-1 November 2018, to investigate the impact of solar radiation and temperature on current, voltage, and efficiency of the PV module and PV/T systems. Furthermore, modeling of the system has been implemented in MATLAB software to predict and analyze the PV/T performance for Sohar, Oman.
The productivity of the solar cells increases by increasing the angles and density of the solar radiation. The PV depends on the sunlight and not the resulting heat (high temperature). Figure 4 shows one typical day describe the effect of temperature on the (PV) and (PV/T) module. The experimental results show that an increase in temperature effect the PV negatively. High temperature decreases the efficiency of the solar PV. On the other hand, the low temperature will increase the efficiency of the solar PV. Using water as cooling method for PV within the PV/T will enhance electrical and thermal power productivity and improve the electrical and thermal efficiencies.
The distinction in outlet and inlet temperatures shows more heat is being exchanged to the gatherer because of raise of PV cell temperature ascend after some time. This heat does not, really, compare to the sun-based irradiance. Albeit sun-oriented force affects last heat proficiency, it doesn't really control the heat gain waveform. The ambient temperature and sun-oriented irradiance amid the testing time frame were extensively low because of estimations being taken in November. In addition, the adjustment in outlet and inlet temperatures may not be at ideal conditions which is a result of the heat system, which is straightforward, shabby and not exceptionally effective. The PV/T system is set up in such approach to demonstrate how basic heat segments could prompt changes in electrical execution of the PV module, which are represented in figures 4, 5, 6, and 7. The electrical voltage, current and power of the PV/T are outlined in figures 5, 6, and 7, separately.

V. Conclusions

In this paper the installed PV/T has been tested in Sohar, Oman where it is connected to the grid. An oscillatory flow observer with an immediate stream design was utilized as the gatherer for the PV/T system. Correlation between the proposed PV/T and a regular PV was made by estimating the electrical performance, current, voltage and power, of the two panels, while being set beside one another. The conclusions of this study and investigations are summarized as follows:

1. Water-based PV/T system create higher electric higher current, voltage and power comparing with the conventional PV system.
2. The improvement in voltage waveform due to the PV/T cooling is higher than the current. However, the overall improvement appears clearly in the power waveform.
3. The oscillatory flow observer cools the PV of the PV/T and increase the outlet temperature. However, more increase in the length of the observer produce more heat enhancement.

Conflict of Interests
"The authors declare that there is no conflict of interests regarding the publication of this paper".

Acknowledgment

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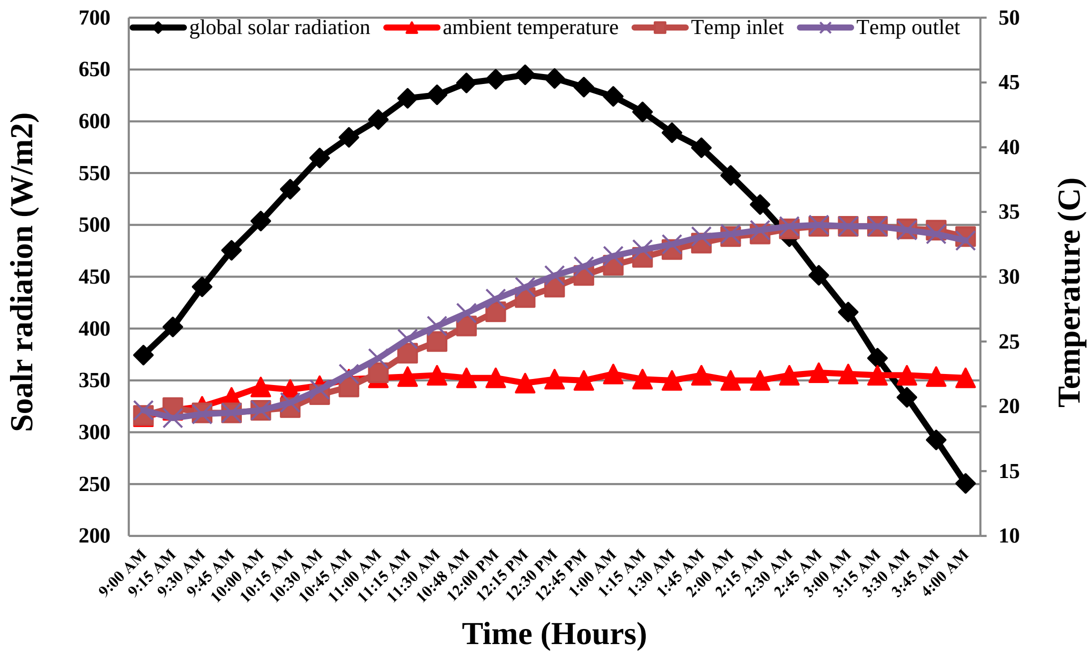

Figure 4. Comparison of ambient temperature, T_{inlet}, and T_{outlet} with respect to solar radiation,

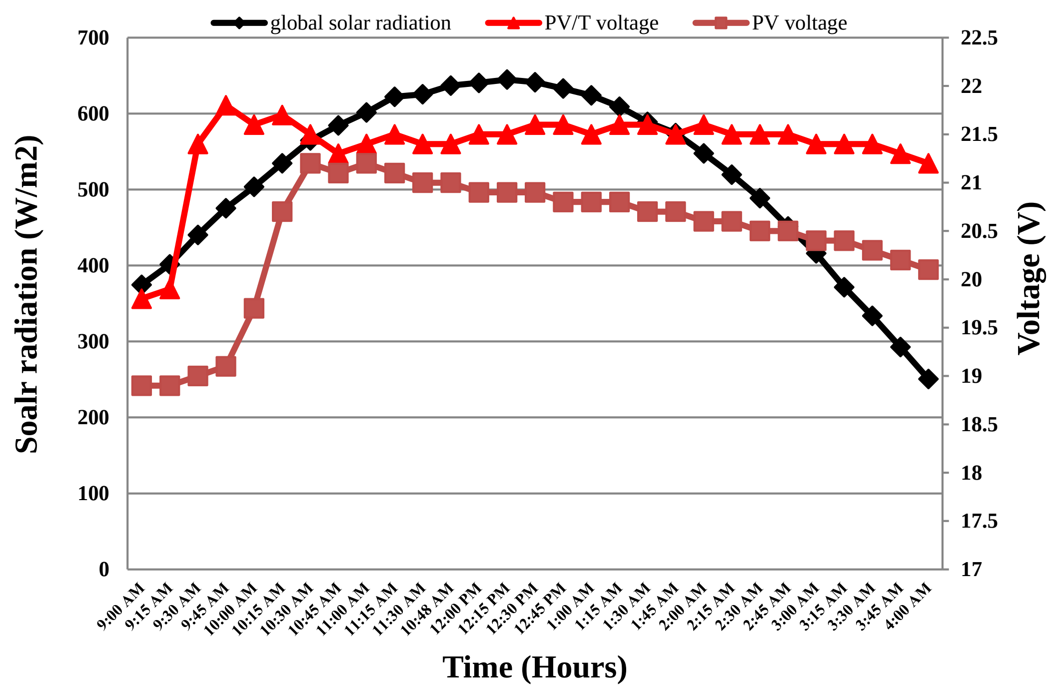

Figure 5. Solar radiation, temperature and PV/T voltage.

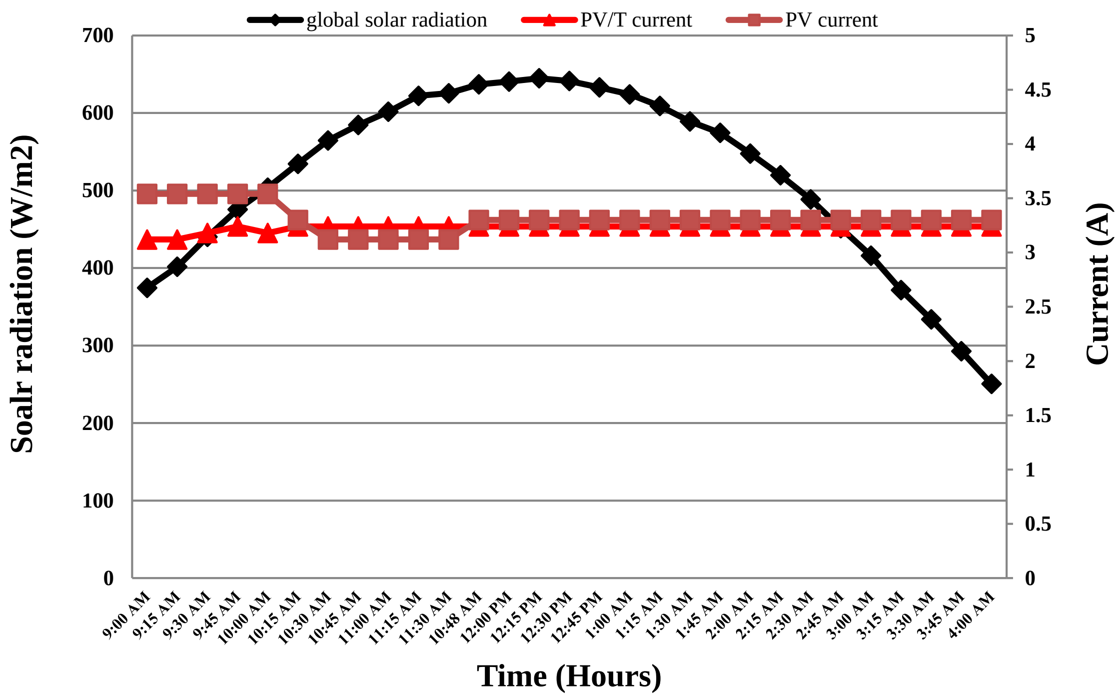

Figure 6. Solar radiation, temperature and PV/T current.

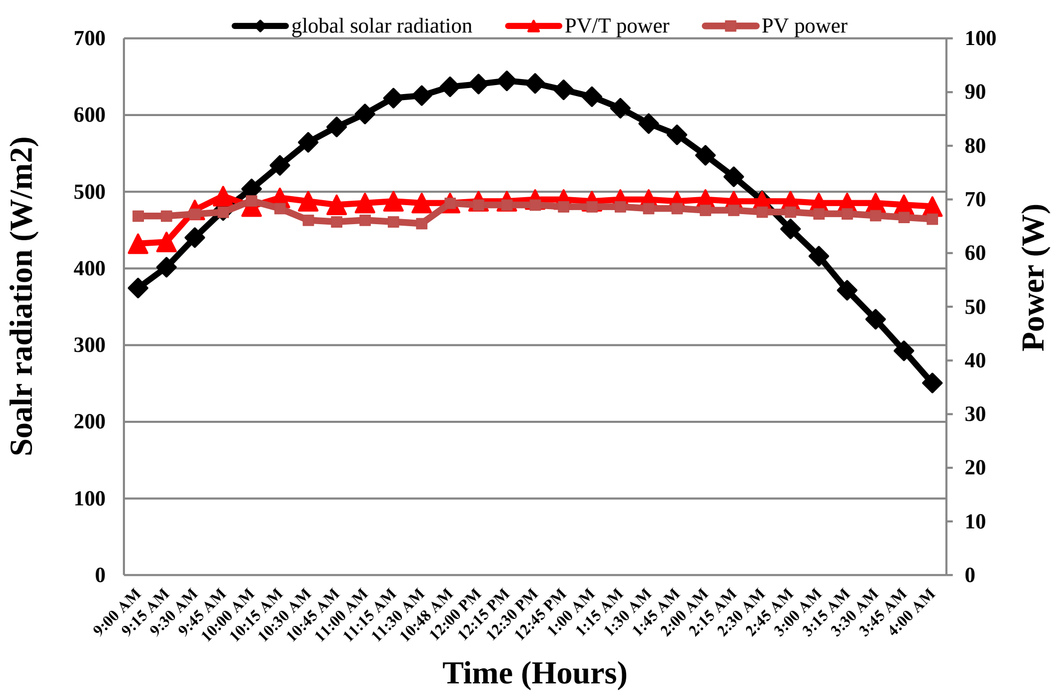

Figure 7. Solar radiation, temperature and PV/T power.