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A COMPARATIVE ASSESSMENT OF SOLAR PHOTOVOLTAIC THERMAL (PV/T) SYSTEM WITH SOLAR PHOTOVOLTAIC (PV) SYSTEM

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Abstract

A photovoltaic thermal (PV/T) system is associated with a solar thermal collector and a photovoltaic (PV) module. PV/T systems are converting the solar energy in to electricity and thermal energy. Tropical country like India has good potential for applying this technology. In this study, a hybrid system is fabricated by using a polycrystalline silicon module as a solar collector attached with heat exchanger. The comparative study was carried out with same capacity PV module. The results show that the performance of the PV/T system is better than the simple solar PV system. PV/T systems are simple and suitable for electricity generation as well as for low-temperature heating applications.

Keywords: Hybrid photovoltaic collector, polycrystalline structure, low-temperature heating

1. INTRODUCTION

Everything around us required energy over the years earth population has increases, which led to the increase in energy. Burning of fossil fuel causes global warming and greenhouse effect, which led to the rise in temperature. India's 80% electricity demand is still being met by coal, oil and solid biomass. As India recovers from a covid -19 pandemic, it is reentering a dynamic period in its energy development. India will soon become the world most populous country and to meet the demand of energy India is focusing towards the sustainable energy source. Solar PV has high installation cost, low operational cost and maintenance cost [1], different types of solar PV systems are globally accepted. Renewable energy technologies are primarily based on Wind, Hydropower, Solar, Geothermal energy sources. Among these available renewable energy sources, Solar based ones have high potential to achieve a significant development with a reduction in carbon emission and energy savings [2]. A photovoltaic-thermal (PV/T) integrates solar thermal collector and PV module into single module. In this module, the PV modules generate electrical energy and thermal collector transfer heat from the modules and thus reduces their surface temperature and also improves their efficiency [3, 4, 5]. The installed capacity of solar PV is increasing due to its eco-friendly behaviour (Figure 1).

The concept of combining photovoltaic and thermal system is known as0020photovoltaic/thermal system (PV/T) system [6]. In consideration of both the heat and electricity production, a hybrid photovoltaic thermal (PV/T) collector is brought to produce at a time the electricity and thermal power. The outputs of PV/T depend on various parameters some as irradiance, wind speed, ambient temperature, flow rate and circulating fluid temperature etc. [7, 8, 9]. The concepts can build an environment with zero-carbon industry process. This concept of cogeneration is not a new, however it has received inadequate attention [10, 11, 12]. Martin Wolf was the first to engineer a flat plate PV/T solar collector system & analyzed the performance of combined PV/T system for domestic applications [13]. PV/T collectors limits it's use only in relatively less-temperature applications like room heating [14], domestic hot water systems [15], thermal storage [16] desalination [17], in the agricultural industry [18] and pool heating [19], etc.

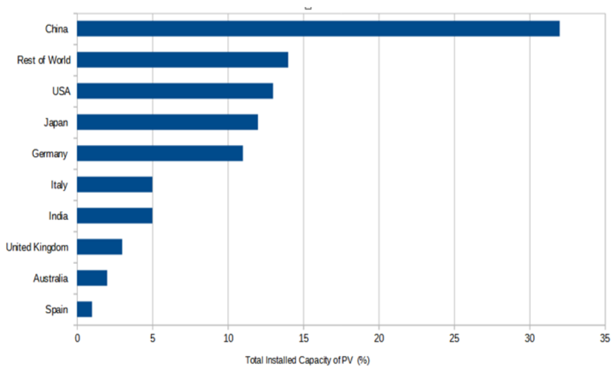

Figure 1 The projection of installation of solar PV in worldwide

The combination of these two systems provides various benefits [12] like,

1. PV cell performance and hence its overall efficiency increases, as they can be uniformly cooled through the solar thermal system.

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2. It generates more electricity per unit area of a module than the corresponding separate solar thermal collectors and PV modules. As there is a reduction in space utilization, it is mainly used in restricted roof space.
3. Lower installation cost and symmetric facade appearance. As they can be easily mounted on existing roofs with minimal modifications
4. Reduces thermal degradation of a PV panel and thermal stresses of module components hence increase the lifespan of the PV panel.

The electrical efficiency of photovoltaic panel reduces with rise in its temperature. Thus, it is necessary to maintain PV cells to its nominal operating temperature. However, this waste heat generated can be recovered with cooling techniques that cause an improvement in electrical performance. Photovoltaic Thermal system combines conventional solar thermal collector and photovoltaic module. The working principle of the PV/T system is as shown in Fig. 2. A part of a solar radiation incident on the PV/T system is converted into electrical energy, whereas remaining is converted into heat causing reduced in PV cell efficiency, which can be extracted to harvest thermal energy.

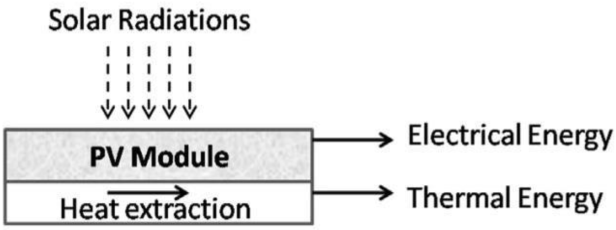

Figure 2 Basic concept of PVT system [20]

2. MATERIALS AND METHODS

The experiments were carried at tropical climatic conditions of Malegaon city.

Experimental Setup

The solar PV/T system was constructed using 37 W capacity poly-Si solar panel. The area of panel is 0.1954 sq. m. Solar PVT water system was constructed by providing copper tubes placed at the back of panel.

Working

The sunlight gets absorbed by the PV/T System the panel gets heated up. Water will flow through the pipes (thermal collector) attached to the PV system which is supplied from the overhead tank, the water in the pipe extracts heat from the PV cell and the hot water flows into the storage tank. This hot water gets heated further because of the solar radiation falling on the transparent storage tank and it will heat up the water already present in the storage tank. By using thermocouple, temperature of hot water is measured whenever the temperature is dropped below the atmospheric temperature, the water will get re-circulated inside the PV/T system and remaining water will be extracted for domestic purposes.

Design Analysis Our Design mainly consists of following parts:

1. PV/T system
2. Heat exchanger
3. Storage Tank

PV/T System

PV/T System as mentioned above, both solar heat and photo-voltaic have traditionally existed as separate systems in many applications. According to Abdullah 2018, research began in the 1970s to combine solar thermal design and solar photovoltaic into a single integrated system called a photovoltaic / thermal (PV/T) solar collector. The main advantages of photovoltaic/Thermal systems are i) Increased efficiency of solar cells and can be cooled by solar heat system ii) Reduction of land use. The photovoltaic cells experience an efficiency drop for rise in temperature and can be minimized with a solar thermal system using photovoltaic thermal design. The image of the PV/T model is shown in Fig. 3. The characteristics of the solar panel used in this study are mentioned in Table 1.

Figure 3 Image of the PV/T System

Table 1 Specification of the Solar PV module

Parameters		
Model No	Eldora -20P	
Nominal Power, Pmpp (0 ~+ 4.99 Wp)	18	20
Nominal Voltage, Vmpp	17 V	17.15 V
Nominal Current, Impp	1.08 Amp	1.18 Amp
Open Circuit Voltage,Voc	21.25 V	21.44 V
Short Circuit Current, Isc	1.17 Amp	1.27 Amp
Module Efficiency (%)	9.21	10.23
Temperature	- 40 °C (min) - + 85 °C (max)	
Length	552mm	
Width	354mm	
Height	18mm	
Weight	2.8 kg	
Cells	36 no's Poly-crystalline solar cut cells; 2 or 3 bus bars	
Back Sheet	Polymer	
Frame	Aluminum	

Storage tank

Generally, most of the storage tank is cylindrical or rectangular but in this we are using cylindrical storage tank. Because, it reduces the losses due to low surface area. The total capacity of the storage tank is 20 litres. Firstly, we made two holes of 6 mm through which two copper pipe has been adjusted. These copper pipe has been attached to container through soldering. This container is of 1 kg which is attached on a circular type ring inside the cylindrical container. Inside the container there is 1400 ml distilled water which is used for store thermal energy collection. The image of storage tank is shown in Fig. 4.

Figure 4 Image of Storage Tank

Heat Exchanger

It is copper and mild steel made heat exchanger used to absorb heat that transmit from outer surface of the panel to inner surface of the panel. The heat exchanger fluid absorb heat and stored in to the storage tank. a forced circulation is flow is maintained by submergible dc pump motor that improve the capacity of heat exchange. The image of heat exchanger is shown in Fig. 5.

Figure 5 Image of heat exchanger

3. RESULTS

Temperature profile of tank storage water

The following graphs represent the profile of tank temperature at different periods of time and the ambient temperature at that time. We find the tank temperature graph is increases with respect to time and we achieve peak temperature at 2:00 PM and the ambient temperature is also increase with respect to time. The temperature variation of the storage tank is shown in Fig. 6.

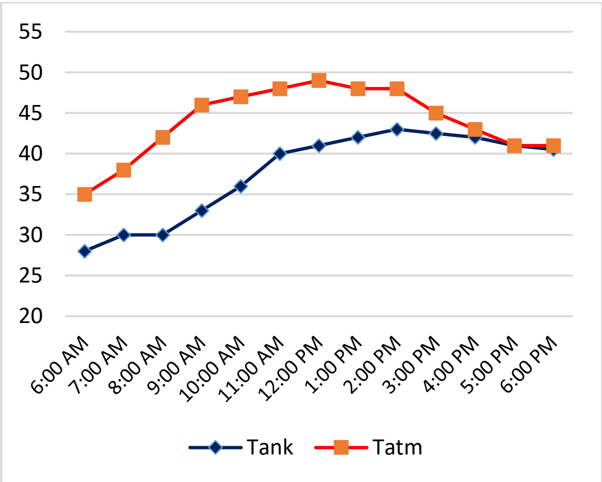

Figure 6 Temperature profile of storage tank water

Temperature profile of PV module surface

Figure 7 represent the temperature profile of photovoltaic (PV) photovoltaic thermal (PV/T) with respect to ambient temperature. The maximum surface temperature on PV panel was achieved in between 55 to 60 ˚C at 2:00 AM. And with PV/T the temperature is near about same as PV approximate 55 ˚C, at that the same time ambient temperature is lower than up to 10 ˚C.

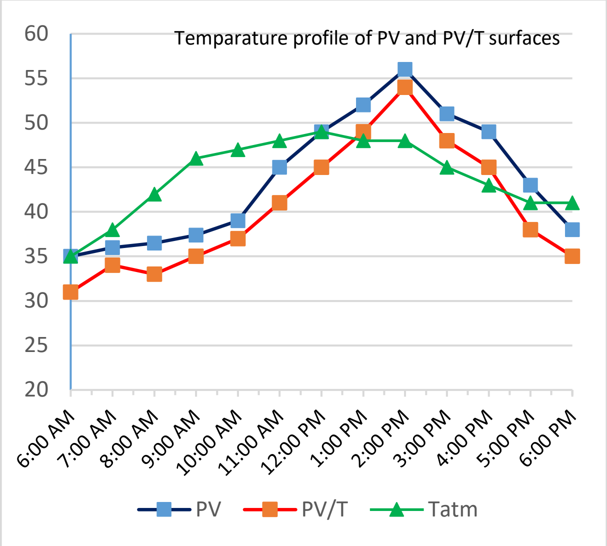

Figure 7 Temperature profile of PV module surface

Electricity generation

The daily electricity generation by PV module is about 3806.4 Wh. However, the daily electricity generated by the PV/T module is 3889.1 Wh. However, 3W pump is used in PV/T system for water circulation, total electricity consumption by water circulation is about 48Wh/day. The net electricity generation by the PV/T is 3841.1 Wh. The additional daily heat stored in the tank water is about 192.28 KJ. The details of electricity generation of PV and PV/T systems are mentioned in Table 2.

Table 2 The average daily electricity generation

Time	Voltage (V)		Current (Amp)	
	Solar PV	PV/T	Solar PV	PV/T
1:00 AM	0.2	0.24	0.01	0.01
2:00 AM	0.9	0.93	0.01	0.01
3:00 AM	1.4	1.5	0.04	0.05
4:00 AM	2.5	2.6	0.1	0.13
5:00 AM	6.2	6.3	0.32	0.35
6:00 AM	18	18.1	1.12	1.125
7:00 AM	18.3	18.4	1.12	1.122
8:00 AM	18.5	18.55	1.13	1.132
9:00 AM	18.6	18.61	1.15	1.152
10:00 AM	18.8	18.82	1.18	1.181
11:00 AM	18.9	19	1.2	1.22
12:00 AM	19.1	19.12	1.24	1.23
1:00 PM	19.2	19.24	1.25	1.26
2:00 PM	19.4	19.42	1.26	1.27
3:00 PM	19.3	19.4	1.24	1.25
4:00 PM	19	19.1	1.21	1.23
5:00 PM	18.9	19	1.18	1.2
6:00 PM	9	9.1	0.4	0.42
7:00 PM	1.4	1.9	0.01	0.03
8:00 PM	0.3	0.5	0.09	0.09
9:00 PM	0.1	0.1	0.04	0.05
10:00 PM	0.1	0.1	0.01	0.01
11:00 PM	0.1	0.1	0.01	0.01
12:00 PM	0.1	0.1	0.01	0.01

Economic assessment of the system

The total cost of the PV/T system is about Rs 6680. The detail of the component cost is mentioned in Table 3.

Table 3 Economic Assessment of the PV/T System

Sr. No.	Economic Assessment	Price (Rs)
1	Solar Panel	1400
2	Mild Steel Rectangular Pipe	700
3	Mild Steel L Angle Pipe	300
4	Container	800
5	Fevicol	100
6	Vetra	60
7	Thermocol	130
8	Brazing Welding	500
9	Soldering	200
10	Thermometer	280
11	Cotton	100
12	Rope	70
13	Sticky Tape	30
14	Pump	100
TOTAL Cost of the PV/T system		6680

Renewable power generation systems are sustainable systems but it's environmental impact should be reduced in near future [21, 22]. After the End-of-Life of electronics waste will become problematic [23, 24]. The Ecological Footprint assessment should be examined all the available PVT systems that can provide better understanding of sustainable system design of PVT and also helps to achieve the UN goal of sustainability [25, 26, 27, 28, 29].

4. CONCLUSIONS

The PV/T system can generate electricity as well as heat simultaneously. It is more efficient than conventional PV system because it is cogeneration type system. However, it's costlier than conventional Solar PV system due to the use of heat exchanger and storage tank. PV/T system is useful for water and air heating also. It reduces the requirement of fuel for air or water heating. It works efficiently even in winter also. It has Endless amount of energy available free of cost. The PV/T systems are more efficient than conventional PV systems.

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