Utilization of the thermal energy potential in photo voltaic solar panels

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Abstract

Over recent years, electricity generation using photovoltaic (PV) solar panels has become a more and more reliable technology in the area of green energy. The investment break-even period of this installation type is about 8-12 years. The typical PV solar panel transforms only about 15-16% of the solar energy. A large amount of solar energy is transformed into heat, which lowers the panel's efficiency. The heat leading decreases the PV–cell temperature, raises the produced electrical energy and can be used as a thermal energy for other applications.

This article analyzes the effects of the PV–cells cooling and of the potential thermal energy utilization. An experimental approach is used. The utilization of the excessive solar energy amounts in combined PV/ T panels may significantly reduce the break-even period by raising the PV panel efficiency. Additional income from the produced thermal energy would also be available.

Keywords: Combined Photo Voltaic/ Thermal (PV/ T) Solar Panel, PV Solar Panel, Improved Panel Efficiency, Thermal Energy Potential Utilization, Comparison of Both Panels Types

1. Introduction

In the recent years investments in the field of photovoltaic plants becomes more and more reliable. Payback period of 8 – 10 years is now real, but any new technology that lowers it is welcome. Combined photovoltaic/thermal (PV/T) collectors are devices that simultaneously convert solar energy into electricity and heat. Big amount of thermal energy may be produced to turn to profit and break payback time. A different types of flat water cooled PV/T collectors, reviewed by Zondag et al. [1], are shown schematically in Fig. 1. They are: A) sheet and tube, B) channel, C) free flow and D) two-absorber type. Collector typically consists of a PV module on the back of which an absorber plate (a heat extraction device) is attached. PV modules convert solar radiation into electricity with peak efficiencies in the range of 5–20%.

The purpose of the absorber plate is twofold. Firstly, to cool the PV module and thus improve its electrical performance and secondly to collect the thermal energy produced, which would have otherwise been lost as heat to the environment. This collected heat could be used, for low temperature applications such as domestic hot water production for showers and washing.

Another approach in water cooled PV/T collector construction is using of concentrator. As reported by Charalambous et al. [2]. A low and a high concentrating type PV/T collectors are developed. In Brogren et al. [3] a low concentrating water cooled type PV/T collector is presented. It incorporates PV/T string modules with low cost aluminum foil reflectors with a concentration ratio of 4.3 times. Coventry [4] developed the so called CHAPS (combined heat and power solar) PV/T collector. It involves a parabolic trough of concentration ratio of 37 times with mono-crystalline silicon cells and a two-axis tracking system.

Tripanagnostopoulos et al. [5] constructed and tested covered and uncovered PV/T collector systems with both water and air as the working fluids. The performance of these collectors was boosted by diffused reflectors made of flat aluminum sheets. The electrical efficiency of the basic polycrystalline silicon (pc-Si) PV/T model was found to be 3.2% higher than that of the simple pc-Si PV module. Lalovic [6] built a PV/T collector using amorphous silicon photovoltaic cells and its performance was tested. The diameter of the copper tubes was 12 mm and tube spacing was 12 cm. The aluminum fins were bonded to the PV panels by means of a silicon-based adhesive (such as Dow Corning 282 [6]) which has good thermal conductance and which stays stable and elastic at all temperatures. The transmittance-absorptance product (sa) for the hybrid collector was reported to be rather low, i.e. 0.53.

A possibility to offer a new approach to build combined PV/T by using standard PV flat panels is proposed here. This paper presents an experimental study of energy production measurements, by using water cooled, flat plate PV/T collectors. Two standard thin layer photovoltaic panels are tested. One of them is transformed to combined PV/T – type by simple way, with low price and minimum intervention.

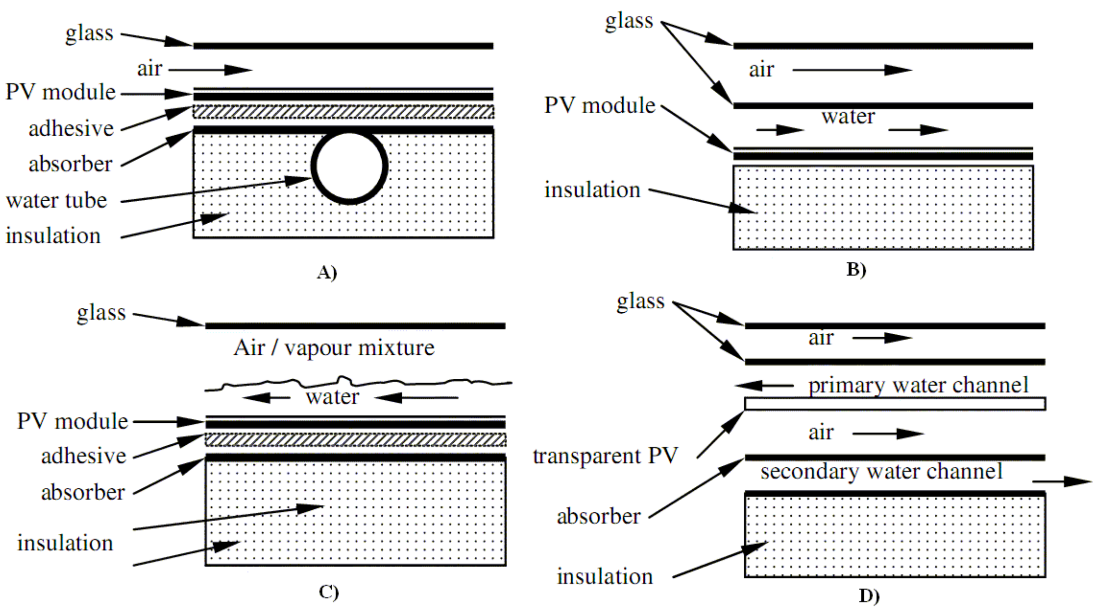

Figure 1 – Different types of water cooled flat PV/T collectors

2. Methodology

An installation for testing of photovoltaic (PV) solar panels was created recently at the Technical University of Sofia, branch Plovdiv (Fig. 2). The main parts of the installation are a combined PV/T solar panel 1 and ordinary photovoltaic solar panel 12 (their photography are shown on the Fig. 3). A circulation pump 2 is used to move the cooling fluid through the combined panel and the thermostat tank 3 - it is used to maintain a constant temperature through the PV/T panels. PT100 Signal Conditioner 5 is used to measure the temperature. The signal is sent then to a data logger 6 and treated by means of a Laptop or personal computer 7. An integrated solarimeter/ anemometer 8 is used to measure the global solar radiation and the wind velocity. The pyrheliometer 9 is measuring the direct solar radiation by means of the sun following system (sun tracker) 10 and the direct solar radiation measurement unit 11. The current/ voltage signal conditioners 13 are utilized to measure the gained electrical power from the sun.

The PV solar panel is of the type ASI®-F 32/12 Solar Module for 12 V-Applications and Grid-Connection. The ASI®- Technology with its special stacked-cell design on the basis of silicon thin film guarantees years of unfaltering high performance (SCHOTT Solar company). Each type of module is ready for mounting, and all parts, from the frame to the junction box, are designed for easy and inexpensive system integration. The typical uses of this module include 12 V stand-alone applications such as lighting systems, solar home systems, displays, light and guidance systems, telecommunications, driving systems (e.g. water-pump plants, gates), robots, and mobile applications (e.g. campers). Through the connection of higher system voltages, the modules are also excellently suited for the implementation of grid connected photovoltaic systems. Some of the technical data of the panel is shown in Table 1.

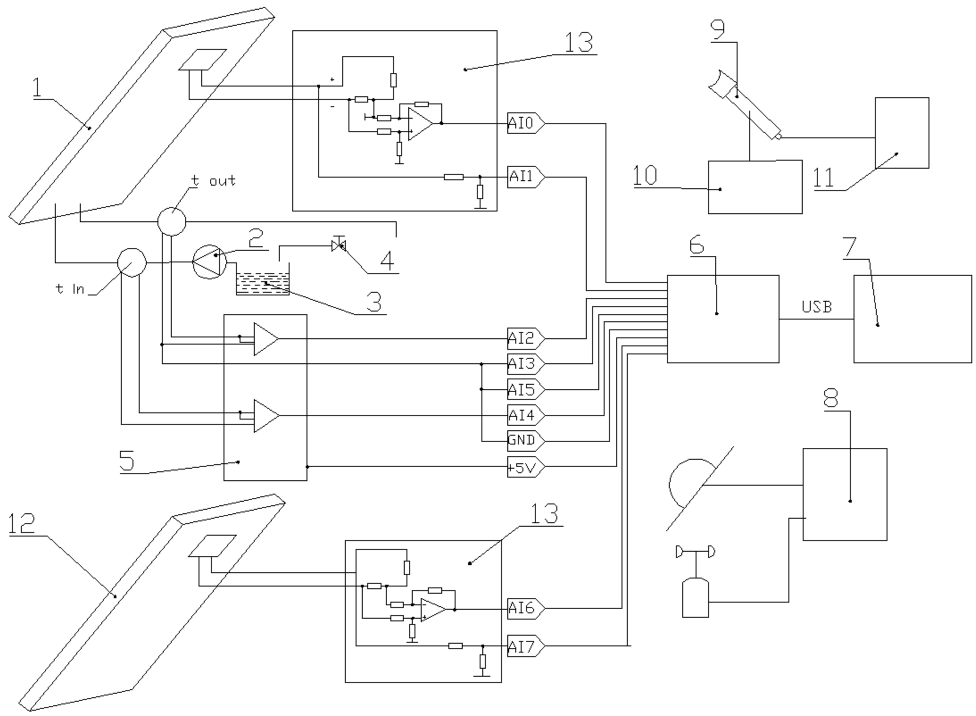

Figure 2 – Installation setup

Table 1 – Technical data of the Solar Module for 12 V-Applications ASI®-F 32/12 [7]

	Technical data	
Parameter	**Dimension**	**Value**
Initial Nominal Power	Wp	39,3
Nominal Power Pnom	Wp	32,2
Voltage at nominal power Umpp	V	16,8
Current at nominal power Impp	A	1,92
Short-circuit current Isc	A	2,5
Open-circuit voltage Uoc	V	22,8
Max. DC system voltage	V	600
Weight	kg	6.2

The combined PV/T solar panel 1 consists of PV solar panel of the type ASI®-F 32/12 Solar Module and an additional construction to cool it (Fig. 4). It has an aluminium pipe with diameter of 7,4 mm and aluminium foil. The backside is then covered by the FIBRAN insulation panel.

The described installation is used to measure the electrical power gained by both panels. Additionally the thermal power production is measured, too. The main goal is to compare the efficiency of the different panels. The quantity of the gained thermal energy by the PV/ T panel is important, too.

Figure 3 –View of PV and PV/ T panels

Figure 4 – View of the cooling part of the PV/ T panel

3. Results

The experiment was carried out during 2 days – 26 and 27 of May 2010. There were done 7 tests. Every test had duration of about 15 min. The following parameters were measured: intensity of the global solar radiation by means of the integrated solarimeter, ambient temperature, flow rate, inlet and outlet fluid temperature trough the PV/T panel, produced electrical power from the PV panel and produced electrical power from the PV/T panel. The produced thermal power from the PV/T panel, the ratio of produced electrical power by PV/T panel to PV panel and the ratio of produced thermal to electrical power by PV/T panel were calculated. All the mentioned parameters are shown in Table 2.

Table 2 – Main results from the experimental work

Parameter	**Test 1**	**Test 2**	**Test 3**	**Test 4**	**Test 5**	**Test 6**	**Test 7**
Date	26.05.10	26.05.10	26.05.10	27.05.10	27.05.10	27.05.10	27.05.10
Start time	10:32 h	11:52 h	12:12 h	09:59 h	10:30 h	10:55 h	11:26 h
Intensity of global solar radiation	860 W/m²	860 W/m²	860 W/m²	845 W/m²	865 W/m²	872 W/m²	872 W/m²
Ambient temperature	28,4 °C	29,0 °C	29,5 °C	28,4 °C	28,0 °C	28,0 °C	28,0 °C
Flow rate	0,48 l/min	0,29 l/min	1,58 l/min	0,83 l/min	0,83 l/min	0,83 l/min	0,83 l/min
Inlet fluid temperature	22,38 °C	21,58 °C	18,01 °C	31,15 °C	40,29 °C	35,37 °C	44,35 °C
Outlet fluid temperature	30,80 °C	34,48 °C	23,39 °C	35,93 °C	44,56 °C	40,56 °C	48,54 °C
Fluid temperature difference	8,42 °C	12,89 °C	5,38 °C	4,78 °C	4,27 °C	5,19 °C	4,19 °C
Mean fluid temperature	26,59 °C	28,03 °C	20,7 °C	33,54 °C	42,43 °C	37,96 °C	46,45 °C
Produced electrical power (PV panel)	31,47 W	30,75 W	30,11 W	30,09 W	30,47	31,34 W	31,27 W
Produced electrical power (PV/ T panel)	32,45 W	31,80 W	31,13 W	30,93 W	31,22	32,59 W	32,06 W
Produced thermal power (PV/ T panel)	284,4 W	262,02 W	592,56 W	277,87 W	248,18	301,86	243,47 W
Ratio of produced electrical power by PV/ T panel to PV panel	103,09 %	103,42%	103,36%	102,81 %	102,44 %	103,99 %	102,52 %
Ratio of produced thermal to electrical power by PV/ T panel	9,04	8,52	19,68	9,23	8,14	9,63	7,79

The results of the test 6 are presented on Figs. 5 and 6. Fig. 5 shows the produced electrical power by PV and PV/ T panel on 27.05.10 starting at 10:55 h and Fig. 6 presents the produced electrical and thermal power by PV/ T panel on 27.05.10 starting at 10:55 h. It is obviously that the cooled PV/ T panel produces more electricity. Additionally the temperature of the cooling fluid is raised.

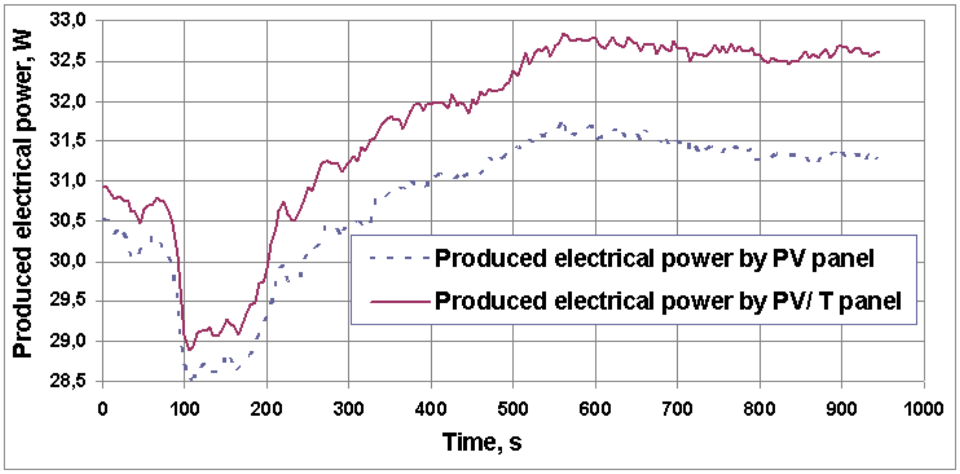

Figure 5 – Produced electrical power by PV and PV/ T panel on 27.05.10 (starting at 10:55 h)

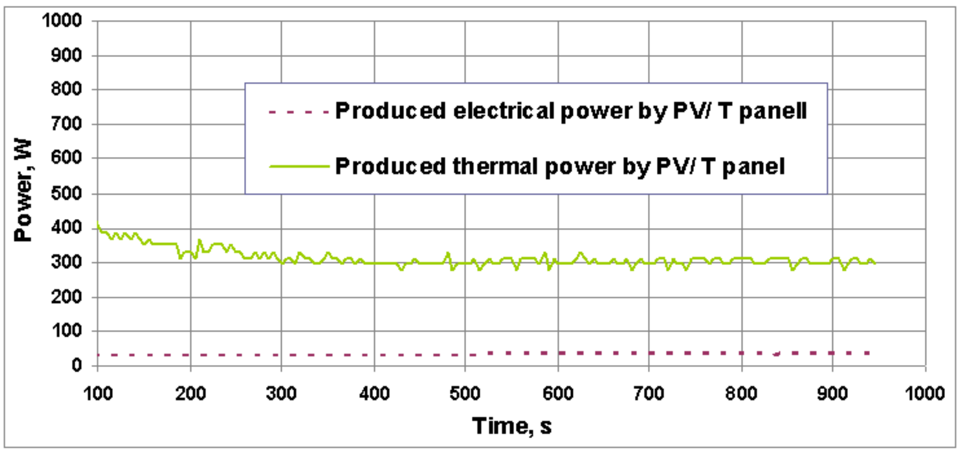

Figure 6 – Produced electrical and thermal power by PV/ T panel on 27.05.10 (starting at 10:55 h)

The ratio of the produced thermal to electrical power by PV/ T panel is presented on Fig. 7. A good stability of the produced electrical power as well as of the produced thermal energy in a relative large temperature interval is remarkable. The same stability is to be shown on Fig. 8 where the ratio of produced electrical power by PV/ T panel to PV panel is presented.

4. Conclusions

An experimental work to measure the electrical power of two different PV panel types is implemented. The following conclusions can be drawn on the base of the work done.

- the PV/ T panel, which is cooled by means of a fluid has higher efficiency than the other panel (Fig. 5);
- a thermal power is gained in the PV/ T panel (about 9 times more than the electrical power)– Fig. 6;
- the production of thermal energy is relative high (8-9 times more than the electrical power) in the whole temperature interval (20 till 50°C);
- the effect of the better electrical production in the PV/ T panel is relative stable in a long temperature interval (Fig. 8);
- the cooled PV/ T panel produces in the whole temperature interval about 3% more electricity than the PV panel (Table 2);

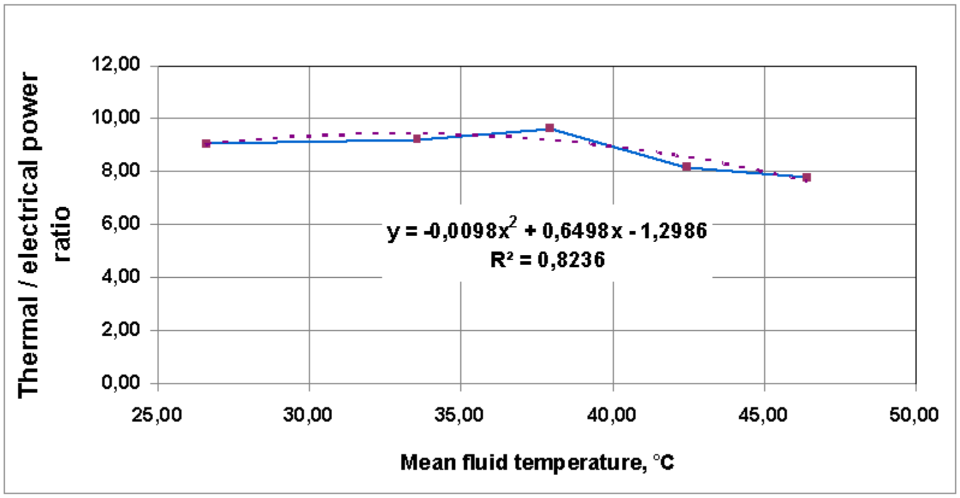

Figure 7 – Ratio of produced thermal to electrical power by PV/ T panel

- than lower the working temperature of the panel is, so higher the gained thermal power is (the gained thermal power is about 2 times more at work under the ambient temperature – test 3, Table 2).

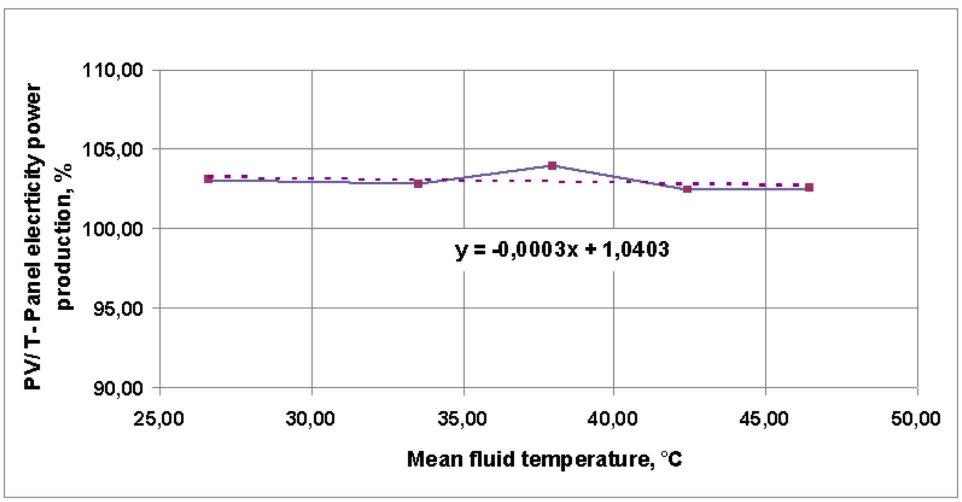

Figure 8 – Ratio of produced electrical power by PV/ T panel to PV panel

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