Performance Comparison on Glazed and Unglazed Solar PV/T Water Collectors

M. Manikandana[1] D. S. Vidhyasagarb[2] A. J. Infant Jegan Rakeshc[3] M. Sridharand[4]
[1,2,3]PG Student [4]Assistant Professor
[1,2,3,4]Department of Mechanical Engineering
[1,2,3,4]Saranathan College of Engineering, Tiruchirappalli -12 India

Abstract— Simultaneous generation of electrical and thermal energy from a solar based device known as Solar PV/T. Now a day's many researchers are focusing on performance improvement of such PV/T. In this work performance variation of single PV/T were experimented in terms of glazed and unglazed. Experiments conducted in terms of four different cases and results were compared. Experimental result shows that efficiency of lower half covered PV/T is greater than upper half covered PV/T. Similarly efficiency unglazed PV/T system is greater than glazed PV/T system. Experimental results suggested glazed system during off summer season and unglazed system during summer season.
Key words: Solar, PV/T, Glazed, Unglazed, Lower Half, Upper Half

I. INTRODUCTION

Solar PV/T collector is a device which converts solar energy into thermal energy and electrical energy. Photovoltaic technology is able to convert solar radiation in to electricity with an efficiency ranging from 5% to 25%, meaning that significant part of the incident solar energy is reflected or converted in thermal energy. This means the photovoltaic cell temperature increases to decreases the electrical efficiency. So the surface temperature of the PV cell maintained constantly to increases the electrical efficiency. Water is the mostly used as the common coolant of the flat plate collector because it efficiency is higher than the any other fluid. The glazed and unglazed PV/T collector has been used in these experiments. The unglazed collector is used to produces the more effectively but the collector losses are quite higher.

Many numbers of researches is to be made on the flat plate collector but what is the efficiently worked on the systems. Finding the optimum operating conditions to improving the electrical efficiency of the system to changing the solar cell material. 40% is the maximum efficiency of the solar photovoltaic cell. Dye sensitized solar cells and the polymer cells are the developed solar cells. However, today a new area has emerged incorporating both the methods of glazed and unglazed flat plate collectors of energy conversion, which can be called photo thermo conversion. To produce both the heat energy and the electricity simultaneously is called as the hybrid photovoltaic thermal collector.

Both of the heat and power are produced simultaneously and it seems a logical idea to developing by the two different techniques. The approach of research development in PV–thermal system is detailed in this paper. Solar thermal energy collectors is having special kind of characteristics to produce the heat energy from the solar radiation are special kind of heat exchangers that convert solar radiation into thermal energy through a transport medium and/or moving fluid. Classification of various solar collectors are illustrate in Fig. 1. The solar collector is the major component of a solar device system. This is a device which absorbs the incoming solar radiation, converts it into heat energy, and transfers it through a fluid (usually air, water, or oil) for useful purpose/applications.

On the other part, the thermal efficiency of a PV/T collector is lower. For a traditional system for many reasons a part of solar energy is converted into electricity. The optical factor is much weaker and the global coefficient of the is higher emissivity of the modules. On the other hand glazed collector is to increase the thermal efficiency and the unglazed collector is to increases the electrical efficiency of the system. Because of the unglazed systems are in the open to the atmosphere therefore the panel temperature is reduced. The PV cell temperature maintained constantly a low is to improve efficiency.

II. LITERATURE REVIEW

P.G. Charalambous in his research work conducted in this paper presents a review of the available literature on PV/T collectors. In this review is discussed on the various parameters are affecting the performance of the PV/T collectors. In this paper description of water and the air collectors to evaluate the output. The parameters affecting PV/T performance like covered and uncovered PV/T collectors, optimal mass flow rate, absorber-plate parameters and absorber to fluid thermal conductance and configuration design types are elaborately discussed. In performing the exergy analysis, it was reported that the glazed and unglazed PV/T collector produces the largest available total energy.

Niccolò Aste, in his experimental work conducted a PVT technology presents many attractive features for a wide application in the building sector since it is able to produce electricity and thermal energy at the same time with better overall performances and reduced surfaces in comparison with the two separated solar technologies. However the effectiveness of the PVT modules is most evident when they are integrated in complex systems, capable of fully exploiting their multi-functionality (e.g. heat pump coupling, multi-storage interconnection, etc.). For that reason, the research work presents a mathematical model for energy simulation of PVT systems, which takes in account all factors and parameters involved in the energy performance of an uncovered hybrid collector; the model can be easily implemented in any performance calculation tool in order to carry out technical–economic assessment of PVT systems. The experimental calibration and validation of the proposed model was performed in outdoor conditions on a commercial PVT product, at the Test Facility of the Politecnico di Milano University, and finally the model was ran supposing the application in three different locations. The validation of the developed simulation model shows a good agreement with monitored data also if a mismatch occurred due to an assembling defect of the tested commercial PVT component.

An experimental work has been conducted by Shyam to calculate the performance analysis on the PV/T system connected in series. Earlier developed theoretical model has been maintained by performing the experiment in a clear dry surface area. The annual energy gain and the exergy gains, carbon di oxide mitigation, energy matrices and carbon credit of the system have also been discussed. The energy pay-back time was found to be 1.50 and 14.19 years for the overall exegy based systems. Carbon credits earned in a year were Rs. 6331.70 for overall thermal energy gain and Rs. 657.30 for the overall exergy gain. For the past 30 years, the cost of one unit of electricity was estimated to be Rs. 1.54 on overall thermal energy basis however it was Rs. 14.46 on overall exergy basis.

T.T. Chow in his theoretical work conducted an in order to improve the energy performance of the photovoltaic system, much effort has been spent on the research and development of hybrid PVT (photovoltaic-thermal) technology using water as the coolant. The fin performance of the thermal absorber is known to be one crucial factor in achieving a high overall energy yield of the collector. Its design is primarily for natural circulation and for domestic water heating purpose. Our test results showed that a high final hot water temperature in the collector system can be achieved after a one-day exposure. A numerical model of this photovoltaic-thermo siphon collector system was also developed and the model accuracy was verified by comparison with measured data.

Swapnil Dubey in his theoretical work conducted a In this paper, an integrated combined system of a photovoltaic (glass–glass) thermal (PV/T) solar water heater of capacity 200 l has been designed and tested in outdoor condition for composite climate of New Delhi. An analytical form of expression has been derived for a characteristic equation for photovoltaic thermal (PV/T) flat plate collector, for different conditions as a function of design and climatic parameters. The testing of collector and system were carried previously.

Patrick Dupeyrat in his theoretical work conducted a paper deals with the design of a single glazed flat plate Photovoltaic–Thermal (PV–T) solar collector. First, the thermal and electrical performances of several single glazed flat plate PV–T concepts based on water circulation are investigated, using a simple 2D thermal model, then different ways of improvement are presented. It mainly consists in focusing on the heat transfer between PV cells and fluid, and also on the optical properties of materials. Thus, the most appropriate concept configuration has been identified and suitable material properties have been selected. A prototype collector has been designed, built and tested. A high thermal efficiency was reached at zero reduced temperature.

Javad Yazdanpanahi, in his theoretical work conducted a in this paper, the exergy efficiency of a solar photovoltaic thermal (PVT) water collector is investigated experimentally and numerically. An experimental setup of PVT water collector is constructed and its operating parameters are measured. The measured parameters include solar radiation intensity, wind speed, ambient temperature, solar cells temperature, fluid inlet and outlet temperature, open circuit voltage, short circuit current, maximum power point voltage and maximum power point current, respectively. The numerical simulation of PVT water collector is carried out with the use of one-dimensional steady thermal model and four-parameter current–voltage model.

Adnan Ibrahim in his theoretical work conducted a Flat plate photovoltaic/thermal (PV/T) solar collector produces both thermal energy and electricity. This paper presents the state-of-the-art on flat plate PV/T collector classification, design, performance evaluation of water, air and combination of water or air based. The discussion over the development of a PV/T solar collector on Integrated Photovoltaic (IPV) and the Integrated Photovoltaic/Thermal (IPVT) applications are performed. The Different design features and performance of flat plate PV/T solar collectors have been compared and discussed and the future research and development (R&D) works have been elaborated.

III. EXPERIMENTAL SETUP

PV panel is a type of heat exchanger to producing the electrical energy. Storage tank is stored the cold water and used to supply the water to the collector. The water is flowed to the flat plate collector it would raises the temperature of water. In the valves they are controlling the mass flow rate. In a straight flow collector area is 2000 mm^2 and their distance between the tubes is 100mm where tube diameter is 12.74mm tube is fixed in a straight flow tube. The number of tube is placed in a straight flow collector is nearly around 9 tubes to be fixed in a collector.

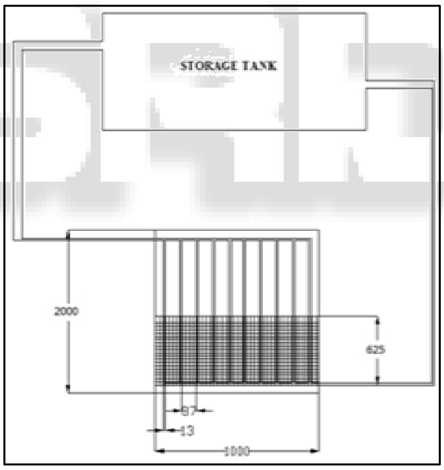

Fig. 1: Lower half covered glazed and unglazed PV/T collector

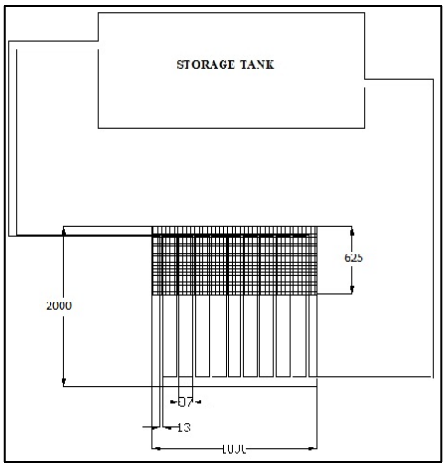

Fig. 2: Upper half covered glazed and unglazed PV/T collector.

PV panel is having the area of 610x650 mm which is placed lower half of the flat plate collector. Which means the water is flowed to the collector it collects the heat from the both PV and flat plate collector. The lower half covered flat plate collector is having the higher electrical efficiency. Because the cold water is directly contact to the PV panel, it collects the heat from the panel to improve the panel efficiency.

Another case of the collector is having the upper half covered by PV panel. It has the lower efficiency when compared to the lower half covered collector. Because of heat removing capacity of the water is low. Cold water is directly entered the lower portion of the flat plate collector, therefore the cold water temperature is increases. Then the water is reaches the PV panel covered area, it collects the heat from panel with lower efficiency. Because of the cold water temperature is quite higher, so the heat removing capacity of water is low.

Then this configuration will be on experimented by the without glass. In this method is used for only the summer period, it is having the higher efficiency but the losses of collector is higher. Which means the top side of the collector is not covered, so the heat loss of the collector is higher. The overall efficiency of the collector is higher because of the heat absorption rate of the collector is higher. The electrical efficiency of the panel is low, because of heat energy affect the PV panel. Temperature of the panel increases efficiency of the panel is decreases.

IV. Result and Discussion

A. Glazed System

Time (h)	$I_c(t)$ (W/m^2)	$T_{a\,(°C)}$	$T_{fi1(°C)}$	$T_{fo1(°C)}$	$T_{cell(°C)}$	$I_{SC(A)}$	$V_{OC(V)}$	$I_{L(A)}$	$V_{L(V)}$
10:00	600	29	33	33	44	1.4	18.9	1.1	16.8
11:00	660	30	36	39	54	1.6	18.7	1.4	16.8
12:00	720	32	40	44	57	1.7	18.3	1.4	16.1
13:00	680	32	45	48	58	1.7	18.2	1.4	16.4
14:00	600	34	49	53	62	1.6	18.1	1.3	16.2
15:00	460	33	53	56	56	1.4	17.9	1.3	8.6
16:00	280	33	53	54	51	0.8	17.6	0.6	4.3

Table 1: Hourly measured parameters of a hybrid (PV/T) water heating system on 07th December 2016 Glazed system.

Time (h)	$I_c(t)$ (W/m^2)	$T_{a(°C)}$	$T_{fi1(°C)}$	$T_{fo1(°C)}$	$T_{cell(°C)}$	$I_{SC(A)}$	$V_{OC(V)}$	$I_{L(A)}$	$V_{L(V)}$
10:00	660	29	33	34	51	1.6	18.8	1.4	16.8
11:00	760	31	38	40	56	1.8	18.5	1.5	16.9
12:00	800	32	42	46	59	1.9	18.3	1.7	16.6
13:00	780	33	48	53	60	2	18.1	1.6	16.3
14:00	620	34	52		60	1.8	17.9	1.6	16.2
15:00	500	33	53	56	58	1.6	17.8	1.4	16.2
16:00	300	33	55	55	50	0.9	17.6	0.6	8.5

Table 2: Hourly measured parameters of a hybrid (PVT) water heating system on 08th December 2016 Glazed system.

B. Unglazed System

Time (h)	$I_c(t)$ (W/m^2)	$T_{a\,(°C)}$	$T_{fi1(°C)}$	$T_{fo1(°C)}$	$T_{cell(°C)}$	$I_{SC(A)}$	$V_{OC(V)}$	$I_{L(A)}$	$V_{L(V)}$
10:00	722.6	34	34	34	42	1.4	19.2	1.1	17
11:00	859.4	33	37	40	46.7	1.6	18.6	1.4	17.5
12:00	937.5	35	42	46	48.6	1.8	18.3	1.4	17.4
13:00	917.9	33	45	48	55	1.8	18.2	1.4	17.3
14:00	820.3	34	47	51	56	1.5	18.1	1.4	17.2
15:00	761.7	34	49	54	56.7	1.3	17.9	1.3	17.1
16:00	605.5	34	51	53	53	0.9	17.1	0.6	17.1

Table 3: Hourly measured parameters of a hybrid (PVT) water heating system on 14th June 2017 Unglazed system.

Time (h)	$I_c(t)$ (W/m^2)	$T_{a\,(°C)}$	$T_{fi1\,(°C)}$	$T_{fo1\,(°C)}$	$T_{cell(°C)}$	$I_{SC(A)}$	$V_{OC(V)}$	$I_{L(A)}$	$V_{L(V)}$
10:00	722.6	34	33	34	44	1.4	19.5	1.1	17
11:00	859.4	33	39	41	45	1.6	18.6	1.4	17.6
12:00	937.5	35	44	48	48	1.8	18.3	1.4	17.9
13:00	917.9	33	45	51	57	1.8	18.4	1.4	17.5
14:00	820.3	34	49	52	59	1.5	17.4	1.3	17.2
15:00	761.7	34	51	54	60	1.3	16.3	1.3	17.1
16:00	605.5	34	53	53	54	0.9	16.8	0.6	19

Table 4: Hourly measured parameters of a hybrid (PVT) water heating system on 15th June 2017 Unglazed system.

1) Case 1: Flat Plate Collector with PV Mounted At the Bottom (Glazed System)

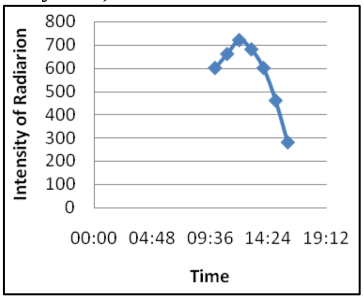

Fig. 3: Time Vs Intensity of Radiation

2) Case 2: Flat Plate Collector with PV Mounted At the Top (Glazed System)

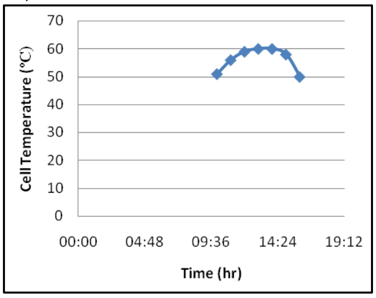

Fig. 4: Time Vs Cell Temperature

3) Case 3: Flat Plate Collector with PV Mounted at the Bottom (Unglazed System)

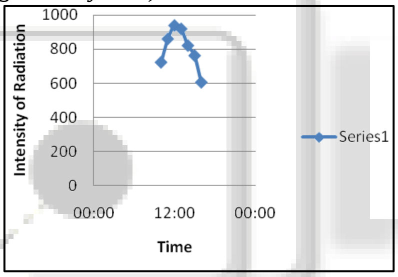

Fig. 5: Time Vs Intensity of Radiation

4) Case 4: Flat Plate Collector with PV Mounted At the Top (Unglazed System)

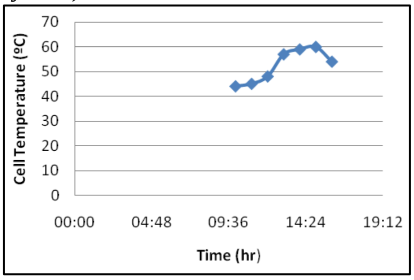

Fig. 6: Time Vs Intensity of Radiation

5) Case 1: Flat Plate Collector with PV Mounted At the Bottom (Glazed System)

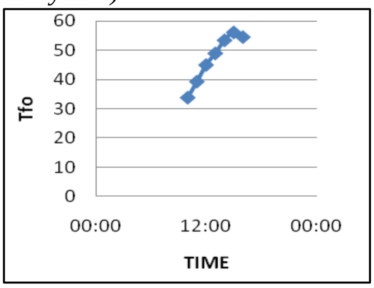

Fig. 7: Time Vs Collector outlet (Tfo)

6) Case 2: Flat Plate Collector with PV Mounted At the Top (Glazed System)

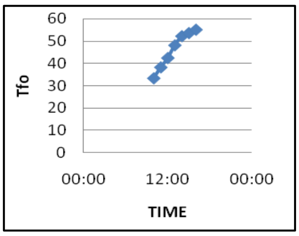

Fig. 8: Time Vs Collector outlet (Tfo)

7) Case 3: Flat Plate Collector with PV Mounted At the Bottom (Unglazed System)

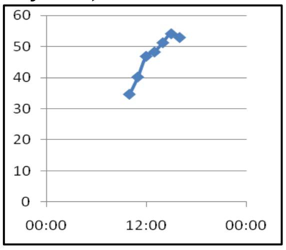

Fig. 9: Time Vs Collector outlet (Tfo)

8) Case 4: Flat Plate Collector with PV Mounted At the Top (Unglazed System)

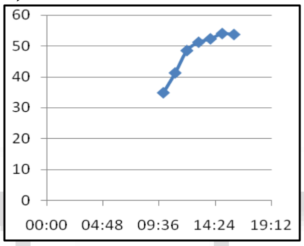

Fig. 10: Time Vs Collector outlet (Tfo)

V. CONCLUSION

Thus comparison between glazed and unglazed PV/T collector is made. The unglazed PV/T collector is having the higher electrical efficacy than the glazed system and the glazed system is having higher thermal efficacy. The Performance of lower half covered PV/T collector is more efficient than upper half covered PV/T collector. Performance of unglazed PV/T collector is higher than glazed PV/T collector.

VI. PHOTOGRAPH

Fig. 11: Lower half covered PV/T Collector

Fig. 12: Upper half covered PV/T Collector

REFERENCES

[1] Adnan Ibrahim, Recent Advances In Flat Plate Photovoltaic/Thermal (PV/T) Solar Collectors, Renewable and Sustainable Energy Reviews 15 (2011) 352–365.
[2] H. A. Zondag, The Thermal And Electrical Yield Of A Pv-Thermal Collector, Solar Energy Vol. 72, No. 2, Pp. 113–128, 2002.
[3] H. P. Garg, Some Aspects of A PV/T Collector/Forced Circulation Flat Plate Solar Water Heater with Solar Cells, Energy Convers. Mgmt Vol. 36, No. 2, Pp. 87-99, 1995
[4] Javad Yazdanpanahi, Experimental Investigation Of Exergy Efficiency of A Solar Photovoltaic Thermal (PVT) Water Collector Based On Exergy Losses, Solar Energy 118 (2015) 197–208.
[5] Jie Ji, A Sensitivity Study of A Hybrid Photovoltaic/Thermal Water-Heating System with Natural Circulation, Applied Energy 84 (2007) 222–237.
[6] J.K. Tonui, Improved PV/T Solar Collectors with Heat Extraction by Forced or Natural Air Circulation, Renewable Energy 32 (2007) 623–637.
[7] Lj.T. Kostic, Optimal Design of Orientation of Pv/T Collector with Reflectors, Applied Energy 87 (2010) 3023–3029.
[8] Niccolo Aste, Design, Modeling And Performance Monitoring Of A Photovoltaic–Thermal (PVT) Water Collector, Solar Energy 112 (2015) 85–99.
[9] Niccolò Aste, Performance Monitoring And Modeling Of An Uncovered Photovoltaic-Thermal (PVT) Water Collector, Solar Energy 135 (2016) 551–568.
[10] Patrick Dupeyrat, Efficient Single Glazed Flat Plate Photovoltaic–Thermal Hybrid Collector for Domestic Hot Water System, Solar Energy 85 (2011) 1457–1468.
[11] P.G. Charalambous, Photovoltaic Thermal (Pv/T) Collectors: A Review, Applied Thermal Engineering 27 (2007) 275–286.
[12] Shyam, Performance Evaluation Of N-Photovoltaic Thermal (PVT) Water Collectors Partially Covered By Photovoltaic Module Connected In Series: An Experimental Study, Solar Energy 134 (2016) 302–313.
[13] Swapnil Dubey, Thermal Modeling Of A Combined System Of Photovoltaic Thermal (Pv/T) Solar Water Heater, Solar Energy 82 (2008) 602–612
[14] Swapnil Dubey, Analysis Of Pv/T Flat Plate Water Collectors Connected In Series, Solar Energy 83 (2009) 1485–1498.
[15] S.A. Kalogirou, Hybrid Pv/T Solar Systems for Domestic Hot Water and Electricity Production, Energy Conversion and Management 47 (2006) 3368–3382.
[16] S.A. Kalogirou, Industrial Application of Pv/T Solar Energy Systems, Applied Thermal Engineering 27 (2007) 1259–1270.
[17] T.T. Chow, Hybrid Photovoltaic-Thermosyphon Water Heating System For Residential Application, Solar Energy 80 (2006) 298–306.
[18] T.T. Chow, Energy and Exergy Analysis of Photovoltaic–Thermal Collector with and Without Glass Cover, Applied Energy 86 (2009) 310–316.
[19] Wei He, Hybrid Photovoltaic and Thermal Solar-Collector Designed For Natural Circulation of Water, Applied Energy 83 (2006) 199–210.
[20] V.V. Tyagi, Advancement in Solar Photovoltaic/Thermal (Pv/T) Hybrid Collector Technology, Renewable and Sustainable Energy Reviews 16 (2012) 1383– 1398.
[21] Xingxing Zhang, Review Of R&D Progress and Practical Application of the Solar Photovoltaic/Thermal (Pv/T) Technologies, Renewable and Sustainable Energy Reviews 16 (2012) 599– 617.

