International Journal of Information Technology and Management
Vol. 14, Issue No. 1, February-2019, ISSN 2249-4510

Impact by Varying PV Panel and Cooling of Glass Cover on the Performance Analysis of Composite Photovoltaic Thermal (PV/T) Solar Collector

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Abstract – Photovoltaic cells suffer from a drop in efficiency with the rise in temperature due to increased resistance Such systems can be engineered to carry heat away from the PV cells thereby cooling the cells and thus improving their efficiency by lowering resistance. Although this is an effective method, it causes the thermal component to under-perform compared to a thermal collector. Recent research showed that photovoltaic materials with low temperature coefficients. Integration of photovoltaic panel and solar thermal technologies into one single solar energy device, with dual generation of electricity and heat energy. The main aim of this research work is to improve the overall efficiency by the film type water cooling on the collector glass cover and also the take the performance of the PV panel is suitable for this system have to choose. Hence, solar collectors fabricated from locally available materials and tested in climate conditions of GIT Campus. Various parameters like isolation, temperatures at various locations, voltage, and current measured with help of calibrated Instruments.

Result shows that, integration of Hybrid solar collector with Poly Crystalline panel gives more performance compared with hybrid solar collector with Mono crystalline panel. Reason behind the performance is with poly crystalline thermal efficiency and electrical efficiency increased rather than mono crystalline used in hybrid solar collector. Here the over efficiency gives the poly crystalline is 5.11% increased rather than used the mono crystalline, Also, another result shows that when the cooling apply over the glass cover of the hybrid solar collector the overall efficiency increased 12.46 % compared with without cooling of glass cover.

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INTRODUCTION TO SOLAR ENERGY

Energy consumption increases very rapidly as the world developing. Conventional sources are not able to fulfill the today energy needs. Fossil fuels are the main conventional sources for energy production till now. The two main limitations of fossil fuels: Limited in quantity and environment pollution makes the world think for alternative energy sources. Renewable energy sources eliminate the weaknesses of conventional sources. But because of less knowledge about these sources and high initial cost of the conversion systems limits the use of these resources. From the renewable energy resources, solar energy has a huge potential for the fulfillment of today energy needs. The total solar radiation energy falling on earth atmosphere is 10^{17} watts Amount of solar radiations reaches earth is 10^{16} watts, this is 1000 times more than the world energy need. So if 5% of this energy is utilized, this is 50 times of world energy demand.

SOLAR WATER HEATER

In Solar water heater water is heated by the use of solar energy. Solar heating systems are generally composed of solar thermal collectors, a fluid system to move the heat from the collector to its point of usage.

Fig 1.1 shows the different parts of solar water heater. The system may use electricity for pumping the fluid, and have a reservoir or tank for heat storage and subsequent use. The systems may be used to heat water for a wide variety of uses, including home, business and industrial uses. Heating swimming pools, under floor heating or energy input for space heating or cooling are more specific examples.

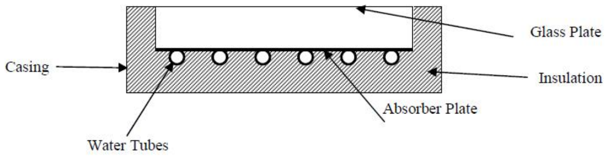

Fig 1.1: Solar water heater

SOLAR COLLECTOR [1]

Solar collectors are the devices used to convert solar energy into heat energy. Solar collector with associate absorber (absorb the solar radiation) collects and converts the solar energy into heat energy that can be used in many applications. Fig.1.2 shows the working principal of solar collector.

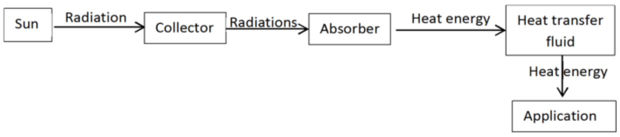

Fig.1.2. Working Principle of solar collector

In the Fig 1.3 some collectors are given which are used for to convert solar energy into heat energy with their approximate working temperature range.

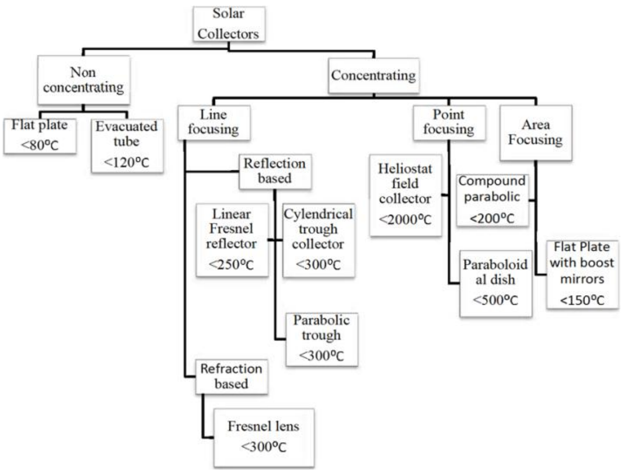

Fig.1.3. Type of Solar Collector

FLAT PLATE SOLAR COLLECTOR

Flat-plate collectors are very common and are available as liquid based and air-based collectors. These collectors are better suited for moderate temperature applications where the demand temperature is 30 ^{0}C - 70 ^{0}C and/or for applications that require heat during the winter months.

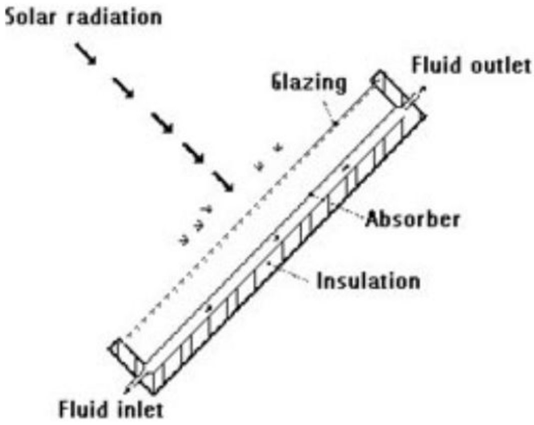

Fig.1.4. Flat Plate Liquid Collector

The air-based collectors are used for the heating of buildings, ventilation air and crop-drying. In this type of collector a flat absorber plate efficiently transforms sunlight into heat. To minimize heat escaping, the plate is located between a glazing (glass pane or transparent material) and an insulating panel. The glazing is chosen so that a maximum amount of sunlight will pass though it and reach the absorber. Figure 1.3 represents the constructional features of flat plate collectors.

WHY PVT COLLECTOR IS REQUIRED

These systems combine a photovoltaic cell, which converts electromagnetic radiation (photons) into electricity, with a solar thermal collector, which captures the remaining energy and removes waste heat from the PV module. Photovoltaic (PV) cells suffer from a drop in efficiency with the rise in temperature due to increased resistance. Such systems can be the engineered to carry heat away from the PV cells thereby cooling the cells and thus improving their efficiency by lowering resistance.

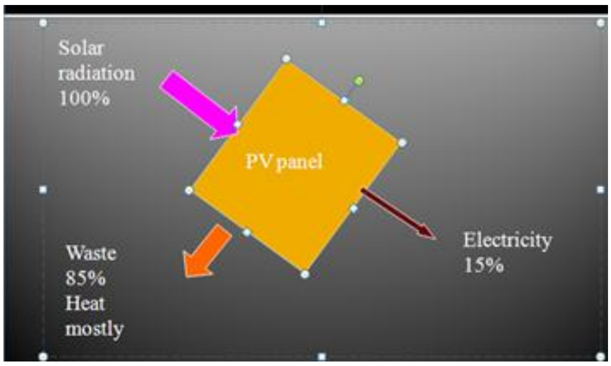

Fig.1.5. Energy Losses from PV Panel

The electricity conversion – efficiency of a solar cell for commercial application is about 6-15 %, more than 85% of the incoming solar energy is either reflected or absorbed as heat energy.

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THERMAL MODELING OF HYBRID PVT COLLECTOR

In order to write the energy balanced equation the following assumption have been made.

- The heat capacity of photovoltaic/thermal (PV/T) collector has been neglected in comparison with the heat capacity of water in the storage tank.
- There is no temperature stratification in the water of the storage tank due to forced mode of operation.
- One dimension heat conduction is good approximation for the present study.
- The system is in quasi-steady state.
- The ohmic losses in the solar cell are negligible.

The energy balance equations for each component of (PV/T) solar water heating system are as follows,

(i) For Solar Cells of PV Module (Glass-Glass)

$$\alpha_c \tau_c \beta_c I(t) W dx = [U_{t\,c,a}(T_c - T_a) + h_{c,p}(T_c - T_P)] W dx + \tau_c \eta_c \beta_c I(t) . W dx \quad - (1)$$

(ii) For Blackened Absorber Plate Temperature Below the PV Module (Glass-Glass)

$$\alpha_p (1-\beta_c)\tau_g^2 I(t) + h_{c,p}(T_c - T_p) = h_{p,f}(T_p - T_f) \quad -(2)$$

(iii) For Water Flowing Through an Absorber Pipe Below the PV Module (Glass-Glass)

The energy balance of flowing water through absorber pipe is given by,

$$m_f C_f \frac{dTf}{dx} dx = F' h_{p,f}(T_p - T_f) W dx \quad (3)$$

The rate of thermal energy available at the end of absorber PV module (glass-glass) is evaluated as,

$$Q_{u,m} = A_m F_{Rm}(PF_2(\alpha\tau)_{m,eff} I(t) - U_{L,m}(T_{fi} - T_a)) \quad -(4)$$

(iv) The Rate of Thermal Energy Available at the End of First Collector

Following Tiwari [12], the rate of thermal energy available from the first flat plate collector can be evaluated as,

$$Q_{u,c1} = A_{c1} F_{Rc1}((\alpha\tau)_{c1,eff} I(t) - U_{L,c1}(T_{f01} - T_a)) \quad -(5)$$

$$\text{Here,} \quad T_{f01} = T_{fi} + \frac{Qu,m}{mfCf}$$

(v) The Rate of Thermal Energy Available at the End of Second Collector

An expression for the rate of thermal energy available at the end of second collector will be as follows

$$Q_{u(m+c1+c2)} = m_f C_f (T_{f03} - T_{fi})$$

$$Q_{u,c2} = A_{c2} F_{Rc2}((\alpha\tau)_{c2,eff} I(t) - U_{L,c2}(T_{f02} - T_a)) \quad (6)$$

$$\text{Here,} \quad T_{f02} = T_{fi} + \frac{Qu,m}{mfCf} + \frac{Qu,c1}{mfCf}$$

On solving the Eqs. (4), (5) and (6) we get,

$$Q_{u(m+c1+c2)} = [A_m F_{Rm} PF_2(\alpha\tau)_{m,eff}(1 - k_1) + A_{c1} F_{Rc1}(\alpha\tau)_{c1,eff}(1-k_2) + A_{c2} F_{Rc2}(\alpha\tau)_{c2,eff}] I(t) - [A_m F_{Rm} U_{L,m}(1 - k_1) + A_{c1} F_{Rc1} U_{L,c1}(1-k_2) + A_{c2} F_{Rc2} U_{L,c2}](T_{fi1} - T_a) \quad (7)$$

Where, $k_1 = [\frac{Ac1F\,Rc1\,UL,c1}{mfCf} + \frac{Ac2FRc2\,UL,c2}{mfCf} - \frac{Ac1F\,Rc1\,UL,c1Ac2FRc2\,UL,c2}{(mfCf)2}]$ and

$k_2 = [\frac{Ac2FRc2\,UL,c2}{mfCf}]$

(vi) Energy Balance for Complete Water Heating System

The rate of thermal energy available at the outlet of second collector is fed into insulated storage tank, and then the energy balance of whole system will be,

$$Qu(m+c1+c2) = Mw\,Cw \frac{dTw}{dt} + (UA)tk\,(Tw - Ta) \quad (8)$$

The above equation can be solved by assuming Tfi = Tw, due to perfectly insulating connecting pipes. Using Eq. (7) the tank water temperature can be obtained by as,

$$(\alpha\tau)_{eff} I(t) - (UA)eff(T_w - T_a) = Mw\,Cw \frac{dTw}{dt} + (UA)_{tk}(Tw - Ta) + m\,Cw(T_w - T_a)$$

$$\text{Or,} \quad \frac{dTw}{dt} + a\,T_w = f(t)$$

Where,

$$a = [(UA)_{eff} + (UA)_{tk} + m_w C_w]/M_w C_w$$

$$f(t) = \frac{(\alpha\tau)_{eff} I(t) + [(UA)_{eff} + (UA)_{tk} + m_w C_w] + T_a}{M_w C_w}$$

On solving the above differential equation the expression for tank water temperature can be obtained as,

$$T_w = \frac{f(t)}{a}(1 - e^{-at}) + T_{w0}\,e^{-at} \quad - (9)$$

(vii) Energy Analysis

The energy analysis is based on the first law of thermodynamics, and the expression for total thermal gain can be defined as,

$$\sum Q_{u,\,total} = \sum Q_{u,\,Thermal} + \sum Q_{u,\,electrical}/0.38 \qquad -(10a)$$

Overall thermal output from a PV/T system = thermal energy collected by the PV/T system + (Electrical output / çpower) where, çpower is the electric power generation efficiency for a conventional power plant. This is so because electrical energy is a high-grade form of energy which is required for operation of DC motor. This electrical energy has been converted to equivalent thermal by using electric power generation efficiency as 0.38 for a conventional power plant .

In the case of withdrawal from tank the thermal energy output from the tank can be written as,

$$Q_{u,thermal} = mw\, C_w\, (T_w - T_a) \qquad -(10b)$$

ANALYSIS OF HYBRID SOLAR SYSTEM

Proposed set-up of the Experiment:

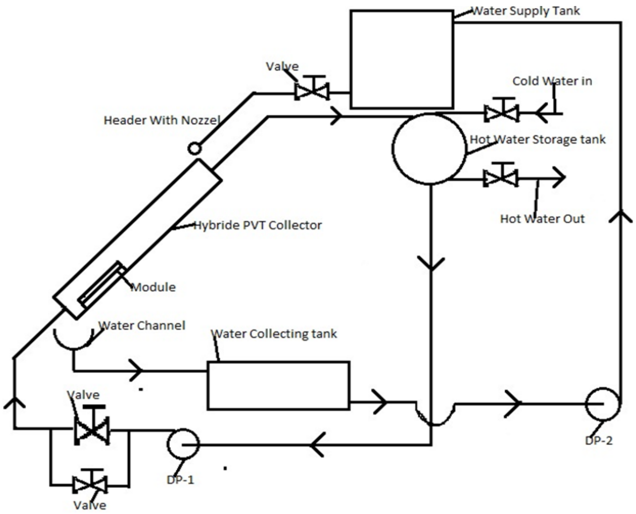

Fig.2.1 Line diagram of Proposed set-up of the Experiment

Series connected glass cover was used in collector. Thermal losses through the collector backs are mainly due to the conduction across the insulation (thickness of bottom side insulation 6 cm and side insulation thickness 1.5 cm). The absorber plate surface which is the most important part of the solar water heater consist of a circular cross sectional liquid tube made of copper material. The distance between glass cover and absorber plate is 3 cm and thickness of collector is 10 cm.

Figure 2.2 Solar PVT system set-up

The water tank is provided to collect the heated water. The capacity of tank is 30 litre with protecting insulation. Four valves are provided for circulation of water in collector. There are two valves for water inlet and outlet and other two valves are provided on liquid tube to measure the mass flow rate and maintain water overflow. All valves are made from brass material. Two plastic pipes are used for circulating the water between water tank to collector and collector to water tank by using pump and the pipes of pump are joined with tube by clamping. The D.C pump of 12 Watt is used in the collector. The collector water is circulated by pump. In this system, 8 switches thermocouple is used to measure the different temperature of collector.

The angle protector is provided in PVT collector construction to set the angle using angle protector. It is made from M.S. bar.

Figure 2.3 Voltmeter and Ammeter

Figure 2.4 Pyrenometer and Anemometer.

RESULT AND DISCUSSION

Measurement of Test Series

Preliminary measurements determined that first fractions of solar radiation at about 9:00 AM of local time. Distillate output and temperature augmentation in the time span before 9:00 AM and after 5:00 PM proved to be negligible. For this reason, the following parameters will be measured in an interval of one hour from 9:00 AM local time to 5:00 PM.

Parameter to be measured

- ► Solar Radiation [W/m2]
- ► Water inlet temp [°C]
- ► Water outlet temp [°C]
- ► Ambient temperature [°C]
- ► Heat gain (Q)
- ► Thermal efficiency (η_{TH})
- ► Overall efficiency (η_{OVER})

Heat gain (Q) =m*C_p (T_0-T_1)

Q= heat gain

m= mass flow rate

C_p = specific heat 4.187

T_O= Outlet water temp (°C)

T_1= inlet water temp (°C)

Thermal efficiency (ηi) = m*C_p (T_0-T_1)/A*G

A= AREA OF COLLECTOR (M^2)

G= Solar Radiation [W/m^2]

The electrical output of the FP-PVT, the and the solar PV module was calculated using equation where P is the electrical output (W), I is the measured current (A) and V is the measured voltage (V). The electrical conversion efficiency of the two systems was calculated using equation , where Ac is the area of the collector aperture and G the incident solar radiation (W/m2) on aperture.

P = V* I

Electrical efficiency (η_e) =P/A*G

The total instantaneous output of both PVT collectors was calculated by adding the thermal and electrical output and the overall efficiency calculated using equation

Overall efficiency (η_{over})=P*Q/A*G

EFFICIENCY WITH HYBRID SOLAR COLLECTOR

Table-1 Experimental Observation of Hybrid solar collector with Mono-PV (photovoltaic panel)

TIME(T)	Insolation (w/m^2)	T1	T0	T=T_0-T_1 (°C)	Heat gain(Q)	THERMAL EFFICIENCY η_{th} %	Overall Efficiency η_{over}%
9AM	360	28	30	2	12.56	5.82	5.82
10AM	592	30	35	5	31.40	8.84	10.46
11AM	740	32	40	8	50.24	11.32	13.20
12AM	817	39	50	11	69.09	14.09	15.95
13PM	940	48	64	16	100.49	17.82	19.63
14PM	915	45	59	14	87.93	16.02	17.87
15PM	825	42	51	9	56.52	11.42	13.24
16PM	624	40	45	5	31.40	8.39	10.54
17PM	485	35	38	3	18.84	6.47	8.40

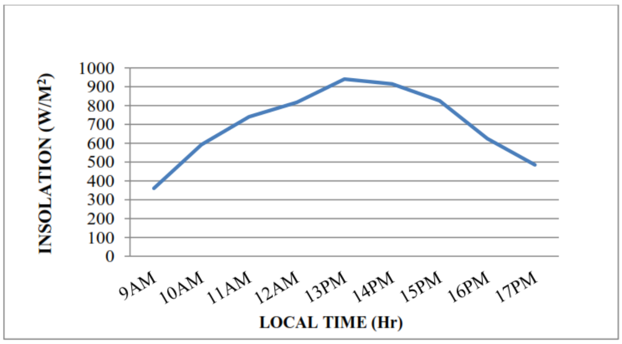

Fig 3.1 Relation between local time and insolation for Mono-PV panel

Fig 3.1 show relation between local time (Hr) and Insolation (w/m^2). All the figures show that, Insolation increases from morning 9:00 AM to 1:00 PM noon due to increase of solar radiation and then decrease from 1:00 PM to evening 5:00 PM due to low sunshine hours. Here, average highest sunshine hours obtained during 1:00 PM of 940 (w/m^2) and lowest sunshine hours obtained during morning 9:00 AM of 360 (w/m^2).

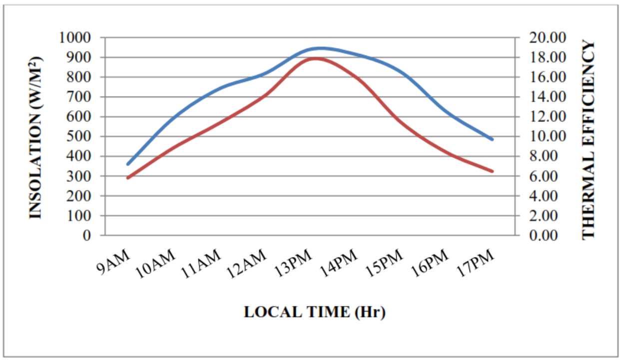

Fig 3.2 Relation between local time, insolation and thermal efficiency for Mono- PV panel

Fig.3.2 shows relation between Local Time (Hr), insolation (watt/m^2).and thermal efficiency of solar collector. average highest thermal efficiency gained by solar collector at 1 PM of 17.82 % and least at 9 AM 5.82% .

EFFICIENCY WITH HYBRID SOLAR COLLECTOR

Table-2 Experimental Observation of Hybrid Solar collector with Poly-PV (photovoltaic) panel

TIME(T)	INSOLATION (W/M²)	T_1	T_o	$T=T_o-T_1$ (°C)	Heat gain(Q)	THERMAL EFFICIENCY η_{th}%	Overall Efficiency η_{over}%
9AM	430	25	28	3	18.84	7.30	7.30
10AM	595	26	32	6	37.68	10.56	12.93
11AM	835	30	39	9	56.52	11.28	13.49
12AM	975	37	51	14	87.93	15.03	17.15
13PM	990	48	66	18	113.05	19.03	21.27
14PM	930	45	56	11	69.09	12.38	14.61
15PM	840	40	49	9	56.52	11.22	13.31
16PM	610	42	48	6	37.68	10.30	12.53
17PM	455	43	45	3	18.84	6.90	8.77

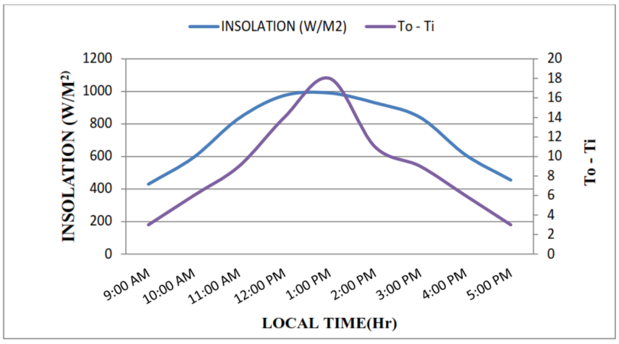

Fig 3.4 Relation between local time, insolation and temp overall efficiency for Poly- PV panel

Fig.3.4 shows relation between Time (Hr), Insolation (w/m^2) and Temperature difference of water outlet and inlet. In all the figures, they show that, by increasing insolation temperature difference is also increase. Because, When solar energy striking the collector, it comes in contact with pipes in which water is flowing, hence latent heat of vaporization is gained by water and water temperature increase. Due to increase of water temperature at outlet, difference of water temperature at inlet and outlet is increase. It is very desirable for design of any collector. Average temperature difference gained at 1 PM of 18°C.

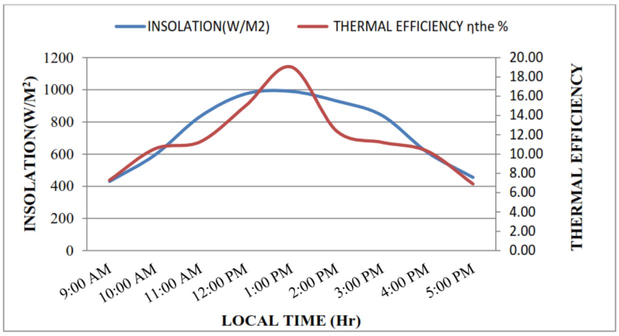

Fig 3.5 Relation between local time, insolation and thermal efficiency for Poly-PV panel

Fig.3.5 shows relation between Local Time (Hr), insolation (watt/m^2).and thermal efficiency of solar collector. Average highest thermal efficiency gained by solar collector at 9AM of 19.03 % and least at 5PM 6.90 %

Table-3 Compression between overall Efficiency of Hybrid Solar collectors with Different PV (Photovoltaic panel)

TIME (T)	heat gain(Q)	Without Cooling		heat gain(Q)	With Cooling	
		Thermal efficiency η_{th} %	Overall Efficiency η_{over} %		Thermal efficiency η_{th} %	Overall Efficiency η_{over} %
9AM	18.84	7.30	7.30	18.84	7.48	7.48
10AM	37.68	10.56	12.93	37.68	12.08	14.50
11AM	56.52	11.28	13.49	56.52	13.18	15.58
12AM	87.93	15.03	17.15	94.21	16.48	19.10
13PM	113.05	19.03	21.27	119.33	19.67	22.53
14PM	69.09	12.38	14.61	75.37	14.11	17.26
15PM	56.52	11.22	13.31	56.52	12.56	15.60
16PM	37.68	10.30	12.53	43.96	12.63	16.45
17PM	18.84	6.90	8.77	12.56	5.44	10.08
AVERAGE	55.13	11.56	13.48	57.22	12.62	15.40

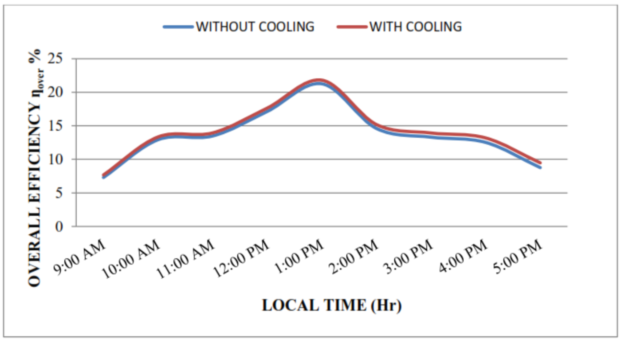

Fig.3.6 Relation between local time and overall efficiency

Fig 3.6 show comparison of without and with cooling of hybrid solar PVT collector .here shows that the thermal efficiency is the higher than the without cooling .here also shows that the overall efficiency is higher than the without cooling. Average increase of overall efficiency of 12.46 %

by the with cooling compared with the without cooling of glass cover of the hybrid solar collector.

CONCLUSION

Following points were concluded from the dissertation work of single and double flat plate collector with photovoltaic panel.

- This system is not only used to heat the water but also increase electrical efficiency, improvement in PV panel and also increase overall efficiency of flat plate collector.
- Solar insolation is increase from morning 9 am to 1 pm noon and decrease after 1 pm in hybrid solar collector.
- Hybrid solar collector with mono crystalline panel Thermal efficiency is 11.13 % and with poly crystalline panel is 11.56 %,hence the With poly crystalline panel possess slightly higher thermal efficiency compared with mono crystalline panel used in hybrid solar collector.
- overall efficiency of hybrid solar collector with Mono crystalline is 12.79% and with Poly crystalline is 13.48 %, hence hybrid solar collector with Poly crystalline panel possess higher overall efficiency (combination of thermal and electrical) compared with Mono crystalline panel.
- Overall efficiency of hybrid solar collector with glass cooling is 15.40 % and without glass cooling is 13.48 %,hence hybrid solar collector with glass cooling possess higher overall efficiency compared with without glass cooling.

REFERENCES

1. Rama subba Reddy Gorla (1997). Finite element analysis of a flat plate solar collector, Finite Elements in analysis and design, 24, pp. 283-290

2. HO-Ming Yeh, Chill-Dong Ho and Chun-hung Chen (1999). The Effect of solar collector aspect ratio on the collector efficiency of sheet- and –tube solar fluid heaters, 2, No. 2, pp. 61-68

3. N.K .Vejan S. Furboand L.J. Shah (2004). Development of 12.5m^2 solar collector panel for heating plants, Solar Energy Materials and Solar Cells, 84, pp. 205-223

4. Viorel Badescu (2007). Optimal control of flow in solar collectors for maximum exergy extraction International Journal of Heat and Mass Transfer, 50, pp. 4311-4322

5. Adnan Sozen, Tayfun Menlik, Sinan Unvar (2008). Determination of efficiency of flat-plate solar collectors using neural network approach, Expert Systems with Applications, 35, pp. 1533-1539

6. Alireza Hobbi, Kamran Siddiqui (2009). Experimental study on the effect of heat transfer enhancement devices in flat-plate solar collectors, International Journal of Heat and Mass Transfer, 52, pp. 4650-4658

7. S. Farahat, F. Sarhaddi and H. Ajam (2009). Exergic optimization of flat plate collector, Renewable Energy, 34, pp. 1169–1174

8. Naiem Akhtar, S.C. Mullick (2012). Effect of absorption of solar radiation in glass-cover(s) on heat transfer coefficients in upward heat flow in single and double glazed flat-plate collectors, International Journal of Heat and Mass Transfer, 55, pp. 125–132

9. S. C. Solanki, Swapnil Dubey, Arvind Tiwari (2009). "Indoor simulation and testing of photovoltaic thermal (PV/T) air collector, "Applied Energy, 86, pp. 2421-2428.

10. G. N. Tiwari (2008). Thermal modeling of a combined system of photovoltaic thermal (PV/T) solar water heater. Solar Energy 82, pp. 602–612

11. Y. B. Assoa, C. Menezo, G. Fraisse, R. Yezou, J. (2007). Brau study of a new concept of photovoltaic-thermal hybrid collector.Solar Energy, Volume 81, Issue 9, Pages 1132-1143

12. G. N. Tiwari and Swapnil Dubey (2008). Life Cycle ANALYSIS AND Carbon Credit Earned by Hybrid PV/T Solar Water Heater for Delhi Climatic Conditions, Open Environmental sciences, 2, pp. 15-25

13. PatrickDupeyrat, Christophe Ménézo, Harry Wirth, Matthias Rommel (2011). Improvement of PV module optical properties for PV-thermal hybrid collector application. Solar Energy Materials and Solar cells. Volume 95, Augest 2011 Pages 2028-2036

14. Moharram K.A. et. al. (2013). Enhancing the performance of photovoltaic panels by water cooling, Ain Shams Eng J.

15. Abdultawab Qahtan, Nila Keumala, S. P. Rao, Zulkiflee Abdul-Samad (2011). Experimental determination of thermal performance of glazed façades with water film, under direct solar radiation in the tropics, Building and Environment, 46, pp. 2238-2246

BOOKS:

1. Rai G. D. (2010). “Solar Energy”, 10th reprint, Khanna Publications, New Delhi.

2. Sukhatme S. P. (2010). “Solar Energy”, 3rd edition., 7th reprint, Tata McGraw Hill, New Delhi

WEBSIDES:

1. www.google.com

2. www.encyclopedia.com

3. http://sel.me.wisc.edu/publications-theses.shtml

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