Design And Development Of Solar PVT System

Vishant. M. Patel[1*], H. A. Patel[2*]
1* M. Tech student, U. V. Patel College of Engineering,
2*Associate Professor, Mechanical Department, U.V.P.C.E.
Kherva, Mehsana, Gujarat, India

Abstract

The energy obtains from the solar radiation by the photovoltaic system. A made a design and fabricated of a parallel flow solar water heater with tube type aluminum absorber plate. It has been develop the design and fabrication of water collector with photovoltaic cell. And employed to study the effects of the PV cell on its performance with collector for conduction and convection effect. 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. Consequently, the working temperature of the solar cells increases considerably after prolonged operations and the cell efficiency drops significantly. The hybrid photovoltaic collector technology using water as the coolant has been seen as a solution for improving the energy performance. Through good thermal-contact between the tube type aluminum absorber plate and the PV module, both the electrical efficiency can be raised. The study was carried out to evaluate the effect of liquid tube aluminum absorber plate is used in collector with PVcell. Commercial polycrystalline PV module of 0.113-m^2 area is used for making a glazed PVT collector. An 18-W DC pump was used to circulate the water between the tank and the PV collector, Where the PVcell is mounting on the tube type absorber plate and cooled by inside water of collector and improve the performance of PVcell. Our observation is that very few studies and design appropriate recommendations are made which will aid PVT systems to improve their overall and electrical efficiency and reducing their cost, making combination of PVcell with collector.

1. Introduction

A photovoltaic thermal collector (or PVT collector) combines with the functions of a solar thermal collector and a PV module. It is converting the solar radiation to both electrical energy and heat energy. It is essentially a solar thermal module in which PV is integrated in the absorber. In this way, more solar energy is generated per unit surface area.

One example is a conventional flat plate solar heat collector with integrated PV cells on the absorber, to produce both thermal and electrical energy. For these systems, water is used as heat transfer fluid. The PV cells are pasted either directly on the absorber or interior on a cover plate with a dielectric material. This means that the only contact between the PV cells and the absorber or the cover plate is a high thermal contact. The heat transfer fluid runs inside the tube in the absorber and collects heat from the absorber. If the PV cells are pasted to the absorber, heat is also extracted from the PV cells resulting in a higher electrical efficiency of the PV cells. The heat transfer fluid can be circulated by a pump (a pumped system).

1.1Component of solar PVT system

(1) Solar thermal collector
(2) Solar photovoltaic cell

(1) Solar thermal collector: -

These collectors are better suited for moderate temperature applications where the demand temperature is 30-70° C and/or for applications that require heat during the winter months.

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. 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 [2].

(2) Solar photovoltaic cell: -

This element converts energy from sunlight directly into electricity. The more intensive is the sunlight the more electricity the solar cell produces. This electricity is later used to run the pump without other sources of energy [2]

ISSN: 2278-0181
Vol. 1 Issue 10, December- 2012

2. Radiation

2.1 Radiation terminology

2.1.1. Beam radiation:

Solar radiation that has not been absorbed or scattered and reaches the ground directly from the sun is called “direct radiation ’’or beam radiation.

2.1.2. Diffuse radiation:

Diffuse radiation is that solar radiation received from the sun after its direction has been changed by reflection and scattering by atmosphere.

2.1.3. Global solar irradiance:

Solar radiation on a horizontal surface due to both direct sun rays and diffuse radiation.

2.1.4. Irradiance:

Amount of radiant energy incident on a surface per unit area per unit Time.

2.2 Calculate the radiation

The solar water heating collector is mainly dependant of solar intensity. The solar intensity is measure by solar intensity measuring instrument. The solar collector design is main depend of solar radiation. It has made a one solar water heater with PVT system. In this system first of one make master programe.This program is based on solar equation and angle. Its angle and equation is representing below:

2.2.1 Hourly global, beam and diffuse radiation

Based on an analysis of US data, ASHRAE has given a method for estimating the hourly Hourly global, beam and diffuse radiation (clear day) falling on a horizontal surface.

Hourly beam radiation $\boldsymbol{I_{bn}}$ **:**

$$I_{bn} = A \exp [-B / \cos \Theta_z]$$

Hourly diffuse radiation $\boldsymbol{I_d}$ **:**

$$I_d = C\, I_{bn}$$

Hourly global radiation $\boldsymbol{I_{bn}}$ **:**

$$I_g = I_{bn} \cos \Theta_z + I_d$$

This master program made in the matlab.it is representing of beam, diffuse, global radiation at any time. And the radiation is representing by radiation program and then after radiation is calculated and generated the graph.

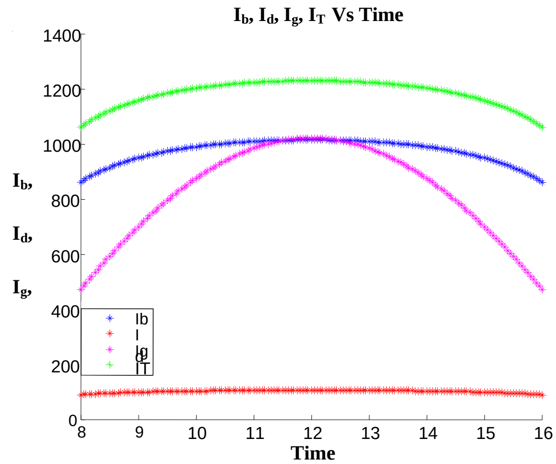

Figure 2.1 Radiation Vs Time

This master program made in the matlab.It is representing of beam, diffuse, global radiation at any time.

2.2.2 The total flux falling on a surface (I_T):

The flux I_T falling on a tilted surface at any instant is thus given by

$$I_T = I_b r_b + I_d r_d + (I_b + I_b) r_r$$

2.2.3 Incident flux absorbed by absorber plate

The amount of incident flux absorbed by the absorbed by the absorber plate is given by

$$S = I_b r_b (\tau\alpha)_b + I_d r_d (\tau\alpha)_d + (I_b + I_d) r_r (\tau\alpha)_d$$

In this chapter we make one master program in the matlab.It is representing of beam, diffuse, global radiation at any time and any location. And we find the value of radiation.

3. Thermal design of solar PVT system

3.1 Area of collector

$$q = U_t A_P (T1 - T_a)$$

$$A_P = \frac{q}{U_t\, \Delta T}$$

Where,

U_t = top los coefficient
A_P = area of collector
q = solar flux absorbed by Absorber plate = S

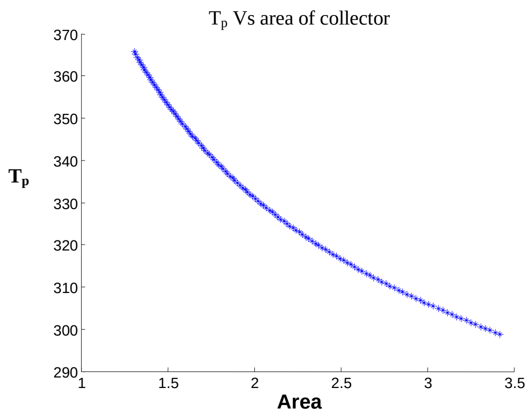

Figure 3.1 Tp Vs Area of collector

This graph is represent to change of value of collector area and observed value of plate temperature. It can observed by this graph increase the value of area of absorber plate with compare the value of absorber plate temperature is decreased because area of absorber plate is increase so that collector area is increase and heat losses is increase and temperature of plate is decreased.

Side loss coefficient:-

$$U_S = \frac{(L_1 + L_2)\, L_3\, k}{L_1 L_2 \delta}$$

Where,

L1 = length of collector (m)
L_2 = width of collector (m)
L_3 = thickness of collector (m)
U_S = 0.04 W/m^2-K
L_3 = 0.03 m
Thickness of collector = 0.010 m

Bottom loss efficient:-

$$U_b = \frac{K}{\delta}$$

U_b = 0.08 W/m^2-K

Total loss:-

$$U_l = U_t + U_b + U_s$$

U_l = 4.53 W/m^2-K

3.2 collator heat removal factor and overall loss co-efficient

An iterative procedure will be required since both F_R and U_l cannot be directly determined and the value of one is dependent on other.

Assume U_l = 4.0 W/m^2

This is a reasonable assumption for collector with single glass cover and a non-selective absorber surface.

$$m_1 = \left(\frac{U_l}{K_p t_p}\right)^{1/2}$$

$$x = \frac{m_1 (w - D_o)}{2}$$

Effectiveness Ø = $\frac{\tan x}{x}$

Collector effiency factor (F')

$$F' = \frac{1}{W U_l \left[\frac{1}{U_l((W - D_o)\emptyset + D_o)} + \frac{\delta_a}{k_a D_o} + \frac{1}{\pi D_i h_f}\right]}$$

Collector heat-removal factor (F_R) =

$$F_R = \frac{\dot{m} c_p}{U_l A_p}\left[1 - exp\left(-\frac{F' U_l A_p}{\dot{m}\, c_p}\right)\right]$$

F_R = 0.83

The useful heat gain rate for the collector (q_u):

$q_u = F_R A_p [\, s - U_l(Tf_i - T_a)\,]$
q_u = 670 W
$q_l = S A_p - q_u$
q_l = 303 W

Overall loss co-efficient (q_l):-

$q_l = U_l A_p (T_{pm} - T_a)$
T_{pm} = 342 °

3.3 Water outlet temperature (T_{fo})

The water outlet temperature is obtained from the heat balance equation. Substituting

$q_u = m \times C_p (T_{fo} - T_{fi})$
T_{fo} = 339

This graph is represent to change of value of Mass flow rate and observed value of outlet temperature of water. It can observed by this graph increase the value of Mass flow rate with value of outlet temperature of water is decreased.

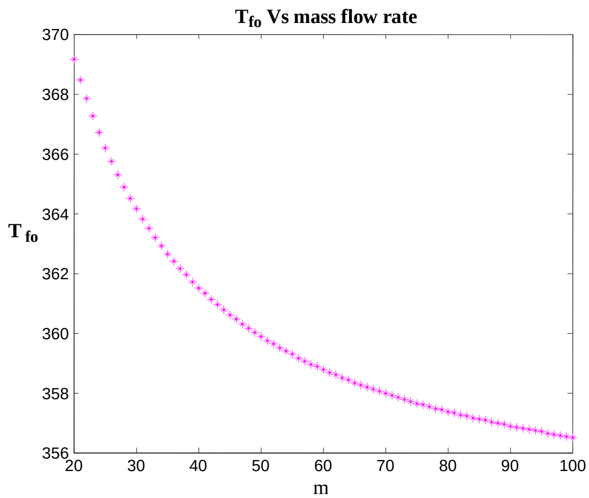

Figure 3.2 Outlet temperature of Vs Mass flow rate

3.4 Instantaneous efficiency

Instantaneous efficiency based on the absorber plate area is given by

$$\eta_i = \frac{q_u}{I_t A_p}$$

$$\eta_i = 0.4811$$

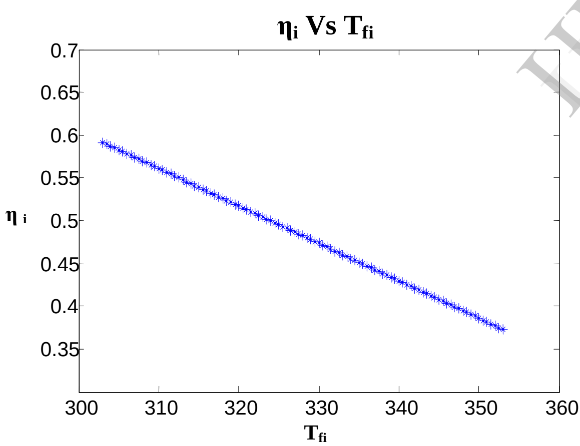

Figure 3.3 Efficiency Vs Inlet temperature of water

This graph is represent to change of value of water input temperature and observed value of efficiency. We observed by this graph when the value of inlet temperature of water is increase then efficiency is decrease.

3.5 Temperature of PVcell

For convection and conduction effect:

Thermal conductivity of cell k_c =145

Area of PVcell A_1 =0.113

Thickness of cell L_C = 0.001mm

Temperature of PVcell =

$$Tc_3 = \frac{L_c q_u + k_c A_1 T_p + h_p L_C T_{in}}{A_1\ (h_p L_c + K_c)}$$

$$Tc_3 = 337°$$

4. Experimental set up

A schematic view of the constructed single flow with single glass cover water heater with PVcell is shown in figure 4.1. In this study the PVcell is mounted on two different location of absorber plates were used. The liquid tube type absorber plates were made of aluminum material with black coating. Dimension and plate thickness for absorber plate were 1090 mm x 460 mm and 1.3 mm and glass cover is 5 mm thickness was used as glazing.

Single pass 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 aluminum material. The distance between glass cover and absorber plate is 3 cm and thickness of collector is 10 cm. types-I the PVcell is mounted on absorber plate. And type-II the PVcell is mounted 25 mm above absorber plate.

Figure 4.1 Solar PVT system set-up

The water tank is providing for collect the heated water. The capacity of tank is 20 liter with protecting insulation.

Four valves are providing for circulation of water in collector. There two valves are water inlet and outlet valve and other two valves are providing on liquid tube its measure the mass flow rate and maintain overflow water. All valves are made in brass material.

Two plastic pipes are used circulating the water between water tank and collector and collector to water tank by using pump and Its pipe is join with tube are clamping.

The 18 watt D.C pump is used in the collector. The collector water is circulated by pump. In this system to measure the temperature by using 10 switches 4-pole thermocouple with different temperature of collector. The angle protector is providing in PVT collector construction and to set the angle by using angle protector. It is made in M.S. bar. Solar radiation is measure by pyrenometer and velocity of air is measure by anemometer.

5. Results and discussions

Collector performance tests were conducted on days with clear sky condition. The collector slope was adjusted to 38˚, which is considered suitable for the geographical location of Mehsana (23.40˚ N, 72.60˚ E). The collector efficiency improvements for single-pass type solar water heater with PVT system were calculated using Eq.

The thermal efficiency and electrical efficiency of a PVT collector are, respectively, given by:

$$\eta_t = \frac{mC(T_{out} - T_{in})}{I_g A_p}$$

$$\eta_e = \frac{V_m I_m}{I_g A_p}$$

Where m and C are, respectively, the mass flow rate and specific heat capacity of the coolant, A_P the collector aperture area, T_{in} and T_{out} the coolant temperatures at the inlet and outlet, Ig the incident solar irradiance normal to surface.

5.1 Performance on PV cell with conduction effect and convection effect

Experimental studies had been performed during the on day (15.10.2012) period. And constant water mass flow rates 0.02 kg/s is also investigated at the experiments.

Table 5.1 Experimental reading for m = 0.02 kg/s with conduction effect

No	Time	I (w/m^2)	Tin (ºc)	To (ºc)	V (volt)	I (amp)	P (kw)	η_{Th} (%)
1	10:30	566	38.5	39.9	16	0.4	6.4	0.4136
2	11:00	581	38.9	40.4	15.9	0.4	6.4	0.4317
3	11:30	616	39.7	41.3	15.7	0.4	6.3	0.4343
4	12:00	639	39.5	41.2	15.7	0.39	6.1	0.4448
5	12:30	676	39.9	41.7	15.2	0.4	6.1	0.4452
6	1:00	689	39.9	41.8	15.1	0.4	6.0	0.4611
7	1:30	690	40.3	42.2	15.3	0.39	6.0	0.4604
8	2:00	689	40.9	42.8	15.2	0.39	5.9	0.4611

Table 5.2 Experimental reading for m = 0.02 kg/s with convection effect

No	Time	I (w/m^2)	Tin (ºc)	Tout (ºc)	V (volt)	I (amp)	P (kw)	η_{Th} (%)
1	10:30	574	34.5	36	14.9	0.4	6.0	0.4369
2	11:00	591	34.9	36.5	14.9	0.4	6.0	0.4527
3	11:30	616	34.7	36.4	14.8	0.4	5.9	0.4614
4	12:00	647	35.5	37.3	14.7	0.4	5.9	0.4652
5	12:30	676	35.9	37.8	14.5	0.4	5.8	0.4699
6	1:00	689	36.9	38.9	14.4	0.4	5.8	0.4853
7	1:30	688	37.3	39.3	14.2	0.4	5.7	0.486
8	2:00	688	38.9	40.9	14.1	0.4	5.6	0.486

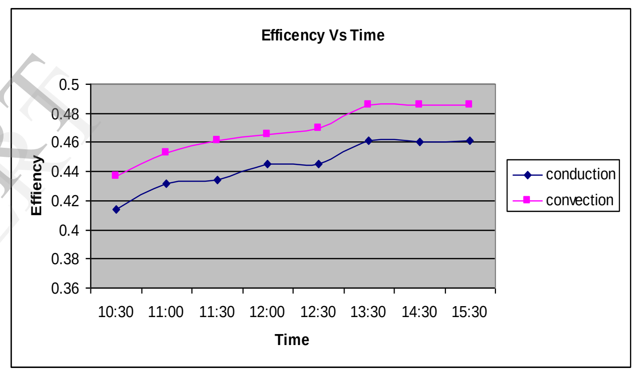

Figure 5.1 Efficiency Vs time

It is representing that the thermal efficiency of convection effect is high comparing to conduction effect. The effect of conduction is 41.36% to 46.11% and the effect of convection is 43.69% to 48.60% respectively.

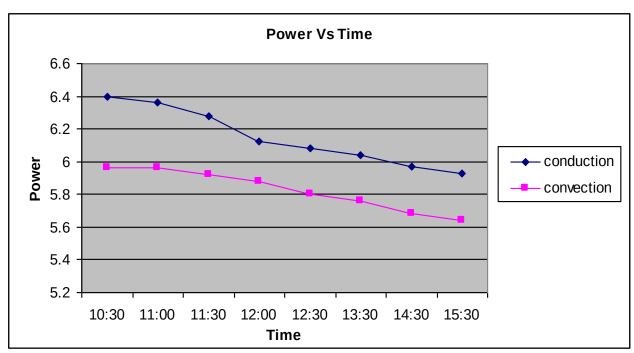

Figure 5.2 Power Vs Time

This graph is representing the effect of PV cell on collector with power Vs time. It is representing that the power of convection effect is low comparing to conduction effect. The effect of conduction is 6.4W to 5.9W and the effect of convection is 6.0W to 5.6W respectively.

5.2 Performance on PV cell constant mass flow rate with variation of inlet temperature.

Experimental studies had been performed during the on day (11.10.2012) period. And constant water mass flow rates 0.01 kg/s is also investigated at the experiments.

Table 5.3 Constant mass flow rate with variation of inlet temperature

No	Time	I (W/m^2)	Tin (ºc)	Tout (ºc)	V (Volt)	I (Amp)	P (w)	η_{Th} (%)
1	10:30	650	38.5	41.9	14.2	0.4	5.68	0.4373
2	11:00	656	39.9	43.3	14.1	0.4	5.64	0.4333
3	11:30	646	41.7	45.0	13.8	0.4	5.52	0.4271
4	12:00	653	43.5	46.7	13.7	0.4	5.48	0.4097
5	12:30	666	45.9	49.1	13.6	0.4	5.44	0.4017
6	1:00	689	47.9	51.2	13.4	0.4	5.36	0.4004
7	1:30	696	49.3	52.6	13.4	0.4	5.36	0.3964
8	2:00	733	51.9	55.3	13.2	0.4	5.28	0.3878

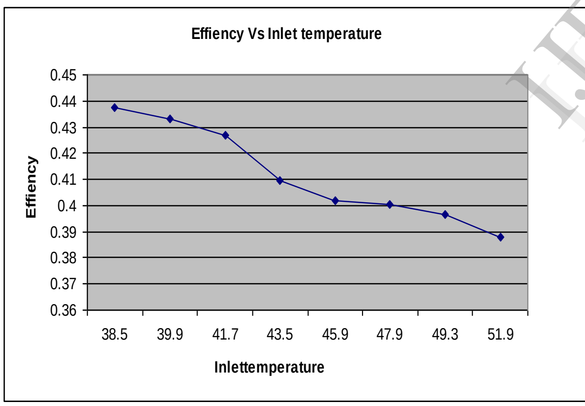

Figure 5.3 Efficiency Vs inlet temperature

This graph is representing of performance of collector with PVcell with constant mass flow rate and variation of inlet temperature. When inlet temperature is increase by 38.5º to 51.9º so that efficiency is decrease 43.73% to 38.78% respectively.

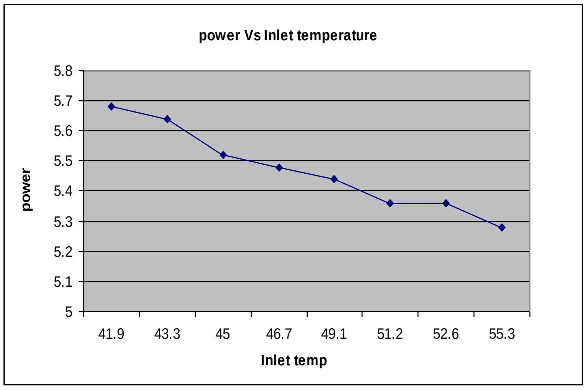

Figure 5.4 power Vs Inlet Temperatures

This graph is representing of performance of collector with PVcell with constant mass flow rate and variation of inlet temperature. When inlet temperature is increase by 38.5º to 51.9º so that power output is decrease by 5.68 kW to 5.28 kW because temperature difference is reduce.

5.3 Performance on PVcell inlet temp Constant with variation of mass flow rate

Experimental studies had been performed during the on day (12.10.2012) period. And variation of mass flow rates 0.01 kg/s, 0.02 kg/s, 0.03 kg/s are also investigated at the experiments.

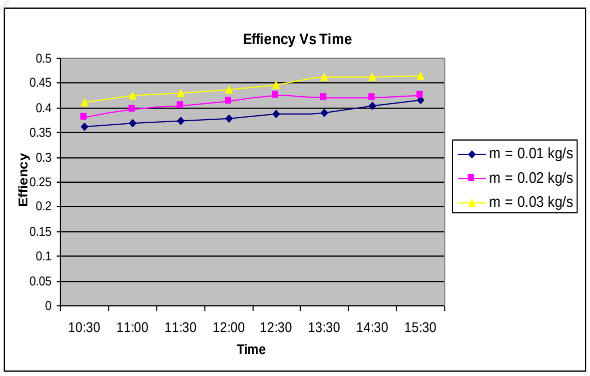

Figure 5.5 Efficiency Vs time

This graph is representing the performance of PV cell with variation of different three mass flow rates of 0.01 kg/s, 0.02kg/s, 0.03 kg/s and inlet temperature is constant. When mass flow rate is 0.01kg/s so that the efficiency is increase 36.15 % to 41.69%,mass flow rate is 0.02 kg/s so that the efficiency is increase 38.07% to 42.63%,mass flow rate is 0.03 kg/s so that efficiency is increase 41.04% to 46.38%.

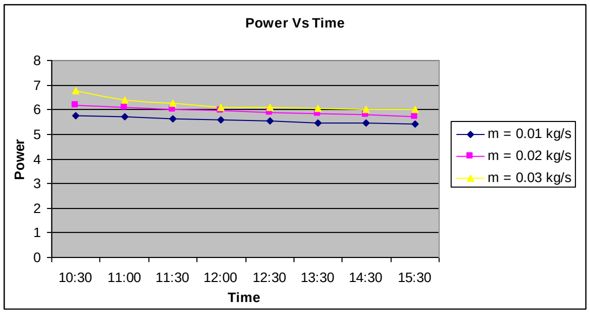

Figure 5.6 Power Vs Time

This graph is representing the performance of PV cell with variation of different three mass flow rates of 0.01 kg/s, 0.02kg/s, 0.03 kg/s and inlet temperature is constant. When mass flow rate is 0.01kg/s so that the power output is decrease 5.76W 5.40W, mass flow rate is 0.02 kg/s so that the power output is decrease 6.20w to 5.72w mass flow rate is 0.03 kg/s so that efficiency is decrease 6.76w to 6.00w.

5.4 Performance on PV cell with different temperature effect

Experimental studies had been performed during the on day (15.10.2012) period. And constant water mass flow rates 0.02 kg/s is also investigated at the experiments.

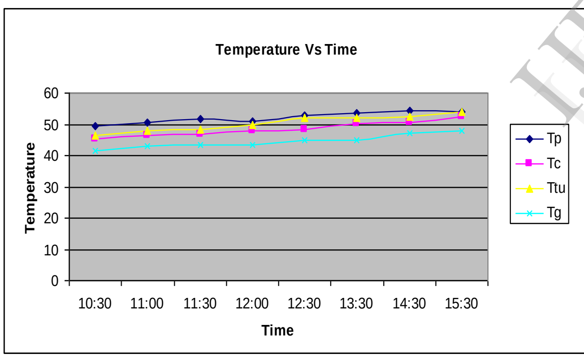

Figure 5.7 Temperature Vs time

This graph is representing to temperature Vs time effect. It is represent that the temperature of plat is high compare to temperature of cell, tube, glass cover and the temperature of glass cover is low compare to other temperature.

6. Conclusion

From above experiments following results have obtained.

(1) In this dissertation work, we check the performance of PVT system with various mass flow rate based on the result obtained, it can be concluded the thermal efficiency of convection effect is high comparing to conduction effect and the power of convection effect is low comparing to conduction effect for PVT system.
(2) When inlet temperature is increase then efficiency and power output is decrease for PVT system with constant mass flow rate and variation of inlet temperature.
(3) When mass flow rate is increase then efficiency and power output is increase with respect to time for PVT system.
(4) The temperature of plate is high compare to temperature of cell, tube, glass cover and the temperature of glass cover is low compare to other temperature for PVT collector.

7. References

[1] Wei He, Tin-Tai Chow , Jie Ji, Jianping Lu, Gang Pei, Lok-shun Chan, "Hybrid hotovoltaic and thermal solar-collector designed for natural circulation of water", *Applied Energy 83 (2006)* 199–210.

[2] Chii-Dong Ho , Ho-Ming Yeh, Tsung-Ching Chen, "Collector efficiency of upward-type double-pass solar air heaters with fins attached", *International Communications in Heat and Mass Transfer 38 (2011)* 49–56.

[3] Wei He, Tin-Tai Chow , Jie Ji, Jianping Lu, Gang Pei, Lok-shun Chan, "Hybrid photovoltaic and thermal solar-collector designed for natural circulation of water", *Applied Energy 83 (2006)* 199–210.

[4] G.N. Tiwari, R.K. Mishra , S.C. Solanki, "Photovoltaic modules and their applications: A review on thermal modelling ", *Applied Energy 88 (2011)* 2287–2304.

[5] Gajendra Singh , Shiv Kumar , G.N. Tiwari , "Design, fabrication and performance evaluation of a hybrid photovoltaic thermal (PVT) double slope active solar still ", *Desalination 277 (2011)* 399–406.