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Solar Integrated System for Increasing Energy Efficiency

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ABSTRACT
Of the many hardships at present faced globally, one is how to minimalize energy consumption by the consumption of fossil fuels due to the adverse social & environmental influences and worth unpredictability. Thus one of the approach is to make best use of the renewable sources of energy such as energy of sun in order to adhere to the global policies of clean energy development. Our country India has raised alarms in this issue. The combination of photovoltaic with thermal collector system was assumed in the direction of converting simultaneously the solar energy into electrical energy and heat energy as well. This whole process is done to encounter the low energy obtained when the two are used independently.
Hence the concept of using the combination of thermal system with photovoltaic was to boost and optimization of PV panel efficiency. The construction of PV/T model uses water for conversion to thermal energy by the use of an appropriate technology.

Keywords
Photovoltaic PV, PV/T module Photovoltaic and thermal combined system and renewable solar energy

1. INTRODUCTION
The key featurs of this Research Paper is Numerical or we can say analytical part, which will require experimental job. The basic objective is to boost the low efficiency of energy, by the implementation of a "COMBINED PV/ T" device,[1] (Van Helden, 2004) which will be incorporated within the local atmospheric conditions in Northern States in our country India. One more objective of this work is to do analytic part on the constructed system.
To minimalize the usage of energy of fossil fuels plus to decrease ill impacts on environment, we use PV/T system[2]. In this way we can decrease pur dependency on fossil fuels and they will last longer. It also has an economic impact on the customers because this saves the bills payable by them and also development of a business area in order to generate employment.

2. PHOTOVOLTAIC SYSTEMS (PVS)
2.1. Components of PVS
A "Photo voltaic system (PVS)", which is acknowledged also by the name of "Solar cell" could be termed as a semi-conducting material apparatus which is aimed and designed in such a way so as to accomplish the transformation of electromagnetic rays of sun directly into electrical energy. In mid 70s, the photovoltaic cells started to be incorporated in such places where it was way more costly to use the power from a local grid for electricity. It was also used in far flung areas as well. In present scenario few countries for example in INDIA, for the people in general, the use of electricity from PV systems is viewed more beneficial than from the main power plants, and it is only because the technology of PV is nowadays much efficient and and more importantly it is much budget friendly than ever.
The most important components for building a basic system are as follows [7] (Y. Tripanagnostopoulos, 2004):
- A power source that is "PV Module".
- If we use a battery then we need a "Charge Controller" to avoid overcharging.
- To store this energy and use it later on we need a "Battery".
- We also require a "DC distributor panel" for CBs, switch gear protection apparatuses for protecting the system at the whole..

3. THE COMBINED SOLAR PHOTOVOLTAIC AND THERMAL SYSTEM (PV/T SYSTEM)
The name "Combined Photovoltaic and thermal system" is used when PV-cells are integrated with a thermal collector. The two techniques referred above are integrated together. The reason for this is that the photovoltaic cells' ability to perform reduces with a slight increase in the units of temperature. Thus, the integration of the device i.e., thermal collector at the backside of the panel helps in extraction of heat from the PV cell. This is done by circulating a fluid (water in this case) in the pipes which in turn will increase the cell's performing action [2] (Hasan, 2010). A cell not only produces electricity in this collector kind of system, but can also absorb the thermal energy generated. It is thus obvious that this integral solar system simultaneously generates electricity and heat energy
Known in this field, following are main types of solar collectors [8] (Zondag, 2008):
- "The one using a Fluid to collect heat".
- Ventilation type, with a heat retrieval system.".
- "Natural type using air as a collector [6] (Tripanagnostopoulos, 2003)"
- And the one using Concentrators to collect heat.
- This paper considered only water type system [7] (Y. Tripanagnostopoulos, 2004) as an amalgam water PV/T systems could be more effective to be used in the practical

conditions of seasons, specifically in areas of North India where ambient temperature is usually less than 20 degrees.

4. PHOTOVOLTAIC OR P V EFFICIENCY.

It is the ratio of the cell's output to the energy input incident from that of the sun. This equation is a main tool when we have to compare different solar devices' performance. It is dependent on various parameters like intensity and range of the light from sun and also on the PV module temperature. Hence, the efficiency of PV for a photovoltaic module can be seen as the portion of the power incident on it, and it is defined as below [4] (M. Koussa, 2012)

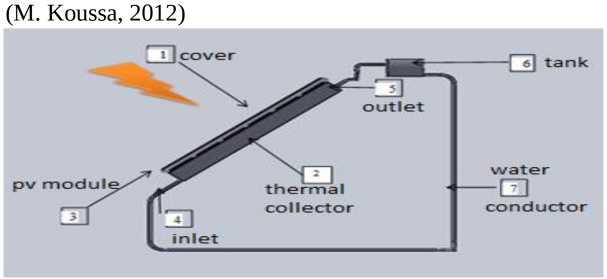

Figure 1: PV/T Collector System

$$P_{max} = FF * I_{sc} * V_{oc}$$

$$\eta_{ee} = (FF)\frac{I_{sc} * V_{oc}}{P_{in}}$$

Where the notations are defined below,

- I_{sc} is the current in Amperes
- V_{oc} is the voltage in [Volts]?
- FF is filling factor.
- P_{in} is the power at Input,($P_{in} = A_{pv} * E$)
  Where,
- E is the measure of radiation on the surface of collector [W / m^2].
- A_{pv} is the surface area of the module [m^2].
- It is important to know the efficiency of the panel in order to select the perfect panels for the system [5] (Moradi, 2013)

4.1. PV/ T Energy Efficiency Determining calculation.

The PV/ T modules are able to produce a greater amount of per unit energy and thus are much more useful and productive in comparison to the side to side P V panels and a separate solar thermal collector system. Additionally, the PV/T efficiency results may be achieved, as depending on the devices' or some hybrid systems' thermal and the electrical one [3] (Kalogirou, 2004).

$$\eta_{PV/T} = \eta_{ee} + \eta_{th} = \frac{W + Q}{H}$$

Where the symbols :

- W = mechanical work, done by the system or the electrical energy acquired.
- 'H' = energy at input
- Q = the energy supplied by heat

$\eta_{ee} = W / H$ and $\eta_{th} = Q / H$ represent the electric efficiency and heat efficiency respectively.

5. EXPERIMENTATION WORK

In the Northern India (Punjab) an experimentation process was carried out on a tested, predesigned and assembled system of PV/ T (water-based). The experimental observations were noted for consecutive seven days. It was performed in the second quarter of 2020 i.e., April, from 0800 hours in the morning to 1800 hours each day. The weather Forecast Station of 'Metrological Department of India' provided information on atmospheric temperature and solar radiation intensity. The weather station from which the following data was taken was attached to a log monitor, located on the rooftop of a building.

- Solar insolation or solar irradiation.
- Ambient temperature of that location.
- Wind speed in that particular location.

The remaining data that were taken from the experimental readings, measured manually. It includes:

- Current and Voltage in the module
- Back and the top temperature of the PV/T device.
- Temperature of fluid at inlet and outlet.

The PV/ T water based system has been thoroughly tested in order to to determine the thermal performance and electrical performance in steady terms at different working temperatures. . As a result the temperature changes at the inletting system were observed at the temperature change in outlet. Multimeters were applied to find out the voltage, the current of the load, and a small error of ± 0.30% was considered for all the observations. The water inlet temperature was not always the same due to the type of the system implemented i.e., the "Close loop system". The instantaneous temperature at the top of module panel and also at the back of panel was determined by using an infra-red gun..The PV/ T was charged to prevent PV overheating and to simulate the actual system performance using solar radiation, which is then converted into heat energy rather than electricity. This is done with the purpose of determining the system's thermal efficiency.

The whole data in this experiment, correlated to the thermal and electrical performance of the PV/ T were noted down each within a short interval of thirty minutes only. These results were then used to access the final efficiency of the solar system based on PV/T combinations.

The example for parameters measured to judge the collector's performance is displayed in Figure 02 as below.

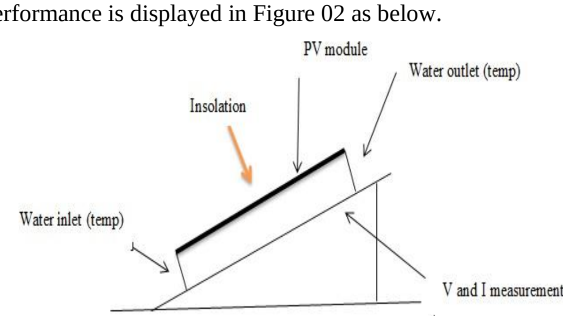

Figure 2: Schematic representation of different parameters measured during the experiment

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6. RESULTS AND DISCUSSIONS

Generally because of the overheating of the cells and the lack of circumjacent temperature to cool them, Photovoltaic cells do not have significant energy efficiency. Thus the PV cells can be cooled off and heat is recovered simultaneously at the rear of the PV module by installing a thermal solar collector. Verily, the solar collector returns maximum of the energy which is moved through the module and which in all probability be lost, now retrieve this heat energy for effective and constructive applications. In this scene, the solar thermal collector cooled the PV cells as shown in figure 03 below, with in and out fluid flow within the absorber.

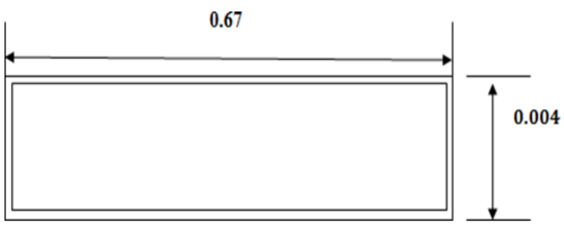

Figure 3: Schematic representation of the collector side of PV/T

The heat produced in the cells is absorbed by the water and is utilized to restraint the temperature of the PV module. The periodic variation of the room air temperature, temperature of inflow and outflow, solar irradiation for week are recorded. During the test of this system, the maximum hot water temperature of 44.50 was acquired whilst the environmental temperature was about 038.84.

After 30 minutes of experimental day, the whole value was recorded (from 15th to the 21th of April 2020). The curves for efficiencies shown in the following graphs were drawn on basis of the figures obtained in seven days (week). Figures given below depict the different efficiency outcomes of the collector over the time from day one to the finishing day of experiment. The graphic results illustrate electric and thermal values at some point in the day.

DAY 01

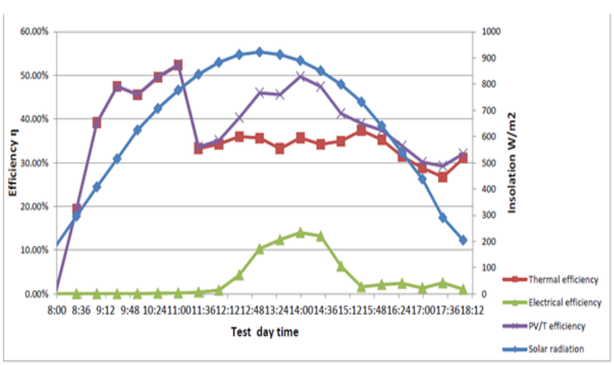

Figure 4: Graphical representation of test results of different efficiencies (i.e., 1. thermal efficiency, 2. electrical 3. energy efficiency of PV/T) and solar radiation, in accordance of first day

Plot in figure 04 depicts the efficiencies of main four typical parameters (i.e., electrical, thermal and PV/ T efficiency, and solar radiations) with time calculated on Day 01. It was seen that since 8 O'clock to 11 O'clock, PV/T and Thermal efficiencies exhibit an increasing fluctuation which attained its maximum at 54%. After that it started to decrease and settled down to 34% at11:30am. On the contrary, at 12 o'clock onwards to about 1800 hours, the aforesaid efficiencies started to increase continually and decreased gradually. It could be seen that the PV/T efficiencies were dominating the thermal efficiencies.

Conversely, the solar radiations showed a tendency which is parabolic with gradual increase up to 54.53 % from 0800 hours in the morning to about12 pm. It was seen that it gradually dropped to 12% between the internal of 1230 hours to 1800 hours.

And ultimately, the electrical efficiency was zero from start time of experiment, i.e., 08:00am to about 11: 26am. It then gradually reached to 12.5% from 11:40 to 1400 hours. Then again it considerably dropped to 1.98% from 1430 hours to 1500 hours. It then became constant till 1800 hours.

The first pinnacle was noticed at 11am and the PV module was used to read the generated current from the load connection on the circuit. In the preparation for the experiment, the electric and thermal efficiency curves show the performance of the normal operating system before. We also took a notice that as the thermal efficiency starts to fall, the temperature at the inlet start to rise from 17˚ to 19˚.

DAY. 02

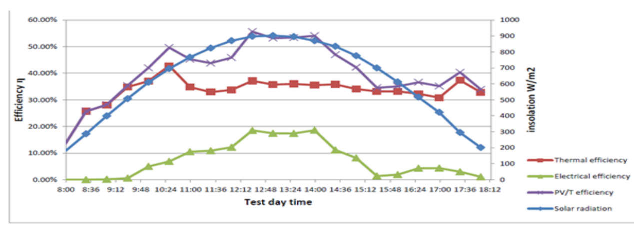

Figure 05: Graphical representation of test results of different efficiencies (i.e., 1. thermal efficiency, 2.electrical 3. energy efficiency of PV/ T) and solar radiation, in accordance of second day

On day 02 the results were much more expressive than on day 01, when the designed pv/ t reacted to solar radiations as expected.. The plotted results depicted in Figure 05 reveals that at 0800 hours in the morning to about 1020 hours , Thermal efficiencies & PV/T efficiencies showed an increase until a value of 45.50% was achieved. It was again later on decreased a bit at about 1100 hours till 1220 hours. Alternatively, at 12:13 to 18:12 hours, the aforesaid efficiencies increased repeatedly and then gradually decreased with the observation that PV/T efficiency was being dominant to thermal efficiency.

The solar radiations again demonstrate the parabolic trend but with a gradual increase from 8 am upto 12:48 pm.It was observed that it later on continually decreased and droped down to about 11.5% at 18: 12 pm.

Finally the electrical efficiency was again zero percent from start up to 9;35 am. After that it was observed that it steadily rose up to 1400 hours and then severely dropped down at 1400 hours up to 3:30pm. The pinnacle for the electrical efficiency was found to be 18.9%.

DAY 03

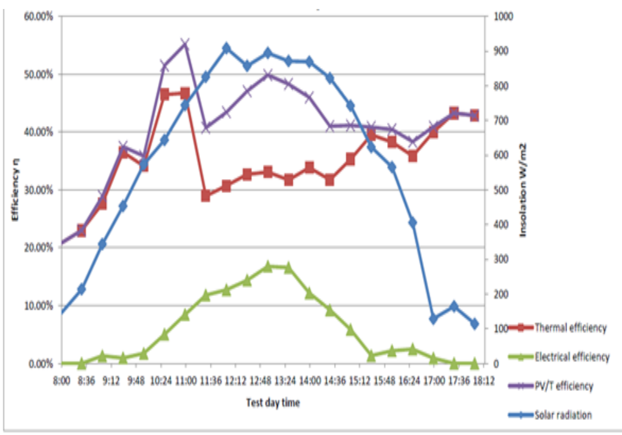

Figure 6: Graphical representation of test results of different efficiencies (i.e., 1. thermal efficiency, 2.electrical 3. energy efficiency of PV/ T) and solar radiation, in accordance of third day

Plot in figure 04 shows again that the effectiveness of key 4 typical parameters (i.e., efficiency in case of electric output, thermal output and solar radiation) of PV/ T. has been calculated with the time on third day. The thermal efficiency diagram reveals a deep decline from 49% at 9;30am to approximately 34% at 10:30am.

For the electrical efficiency it could been seen that the graph reaches to its peak value of 14.19% at about 13.26pm. . The thermal efficiency was 34% at 10:28 and it increased to 36.5% at the last stage of the day at about 6 pm.

Also the PVT efficiency cure shows the exact powerful peak along with a greater value of efficiency. Finally it was observed that when we compare day 01 and day 02 electrical efficiency with day 03 electrical efficiency, the electrical efficiency was becoming efficient more quickly with a higher value of 15.87%.at somewhere in the middle of the experimental duration.

DAY 04

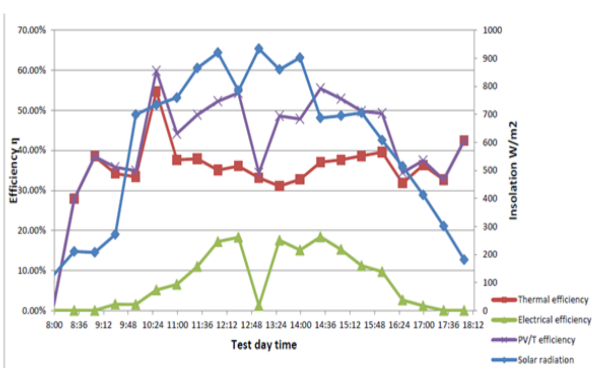

Figure 7: Graphical representation of test results of different efficiencies (i.e., 1. thermal efficiency, 2.electrical 3. energy efficiency of PV/T) and solar radiation, in accordance of fourth day

The observations of day 04 as in Figure 07 was same as day 05 as shown above, but with some slight differences on the instant at which the electrical efficiency showed up. Moreover, the thermal efficiency was seen to be declined a bit. Some small changes in case of the solar radiations were also observed. The parabolic line in the plot of electrical efficiency, observed from 9:40 am to 15:30 was because of the solar radiations. On the contrary, the thermal efficiency was observed to reach to its peak between 9:30am and 10:30am and it was noted as 49%. Then it started to decline and again after some time it started escalate to 43% from 11:30am to 1800 hours.

The highest value of the PV/ T efficiency was also found at 11 a.m. It was also noted. In addition, due to the projection angle of the sun facing the panel, the parabolic increase in decrease in solar radiation observed between 8:00 am and 18:30 was observed.

DAY 05

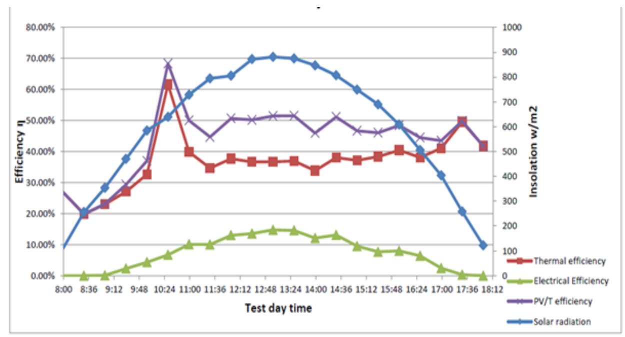

Figure 8: Graphical representation of test results of different efficiencies (i.e., 1. thermal efficiency, 2.electrical 3. energy efficiency of PV/T) and solar radiation, in accordance of fifth day

Now as can been seen from Figure 08, the electrical efficiency started to increase at a quick pace. This reason for this behaviour is the considerable amount of solar radiations (insolation). This tendency was observed in-between 9 am to 17;25. After this it was noticed that it changed its trend and finally touched its top value of 13.2%. The behaviour of thermal efficiency curve can be best explained by the fact that we used a system here which is close looped system. It showed its highest value of 63% at 10:30am.

The PV/ T efficiency increased repeatedly and gradually decreased at 11:00am to 1800 hours. And so did the thermal efficiency but again PV/ T efficiency was dominant over later one. This trend continued till the electrical efficiency was dropped down to zero.

DAY 06

The results on Figure 09 as shown below are totally different. The Solar radiations dropped from 902 W/m^2 at 12pm to about 785.1 W/m^2. Because of this dramatic slip was observed in the electrical efficiencies and also in PV/ T efficiencies at about 12:30pm. Now with the increase in the temperature at the inlet, a decline in thermal efficiency was noticed. After this, it showed more or less constant feature, reaching its peak value of 56% on 10:10.am. The fluctuating trend in the curve of electrical efficiency was observed. It stayed at a very low figure in comparison. But in comparison with the past five day observations, it was found out to be much higher - 16%.

Also, from 8 O'clock to 09:30am, the electrical efficiency was about zero percent but gradually it reached to a value of 12.90% in-between 10 O'clock to 12:30.pm. and finally it again severely declined to zero percent at 12:48pm. Then it again increased at a sharp rate and reached to its pinnacle at 13:24 with a highest point at 18.89% and after that it gradually declined again till 1800 hours.

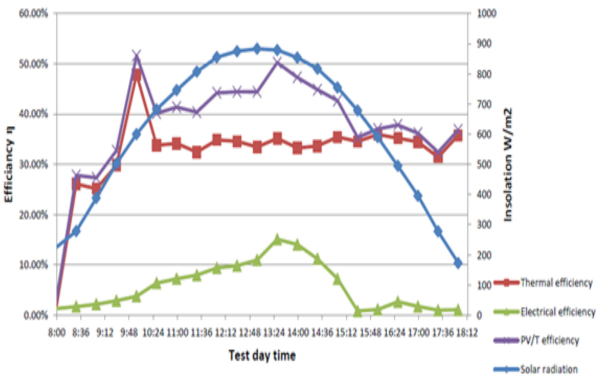

Figure 9 Graphical representation of test results of different efficiencies (i.e., 1. thermal efficiency, 2.electrical 3. energy efficiency of PV/T) and solar radiation, in accordance of sixth day

DAY 07

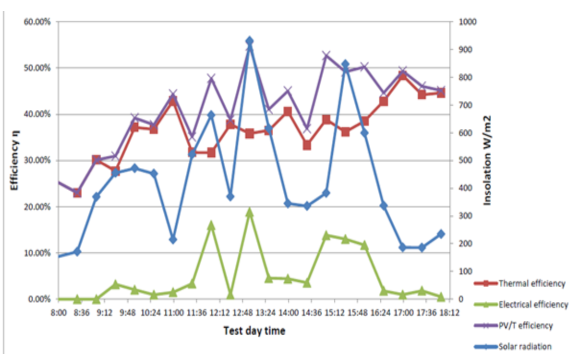

Figure 10: Graphical representation of test results of different efficiencies (i.e., 1. thermal efficiency, 2.electrical 3. energy efficiency of PV/ T) and solar radiation, in accordance of seventh day

The figure 10 depicts the observations for day 07. Several peaks are noticed which are related to the different parameters mentioned. The solar radiations plunged at 12:00pm, and thus electrical efficiency curve showed a peak at this time. Again at 1300 hours a higher peak in the pattern was observed. In comparison with the thermal efficiencies, the electrical efficiencies were cot constant. Also they were low as well. Of the two peaks observed at 12pm and 13:00, the higher peak has a value of 19.19% and it was obtained at 13;00 pm.

In a broader view, we can say that during all the seven days, the variation of electrical efficiency was in-between 0% to 19.19%. The variation of thermal efficiencies was 0.76% - 63% & between 1% to 68% for the PV/ T efficiency. The PV/ T has an average of 41.45% efficiency. All the Figures (graphical representations) above depict it in a best possible scenerio. It is also noted that during the period of testing we found that the water temperature was increased to a peak value of 43.

7. CONCLUSION

Cogitation of low energy efficiency on the world and especially in India the system's payback range increases and the value of the energy produced in the PV module also increases. This research was first motivated by the creation, construction and the testing of a solar system that can solve a low energy efficiency problem. Researchers in the field of existing PV/ T systems (water as a fluid) have shown that electrical efficiency improvements are slightly, but that overall PV/ T efficiency increases greatly as this system combined with the thermal collector functions simultaneously. Description was given of design aspects and construction part.

The power efficiency of the photovoltaics (PV/ T) was derived from the "Output Power" to the "Incident solar radiation" ratio. The ratio of "Output Heat" to "Solar radiation" cab be determined in considering the water-based PV/ T's temperature or thermal efficiencies. The modal has shown that thermal efficiencies are better. This ha shown that when estimating the PV/ T efficiencies, this thing cannot be overlooked. It has also been shown that using the wayer to refresh the PV T system enhances the electrical effectiveness and reduces solar radiation on the PV module. It is also displayed in different graphs.

In addition, even though the results still have to be improved, because PV/T operations synchronise the PV/ T module with the thermal absorber, a considerable yield of total PV/ T efficiencies were achieved. This fact that PVT improves energy efficiency, would boost the attractiveness, competition and affordability of PV/ T collectors in global markets and use of renewables worldwide.

8. RECOMMENDATIONS

There should be several approaches to the future work in this area, particularly on the system itself. When an open loop system on equivalent water was used by the system, the idea of utilising a coolant to absorb the heat created should have fulfilled the electric performance expectations at a specific temperature. The subsequent heat capacity of the water, as it might vary by ambient temperature, must be seen to estimate the mass flow rate. Instead of using some cheap adhesive, the sealing between the P V module and that of the absorber ought to be done correctly, probably better if the materials match to the extent they are selected. The time (Month) and the duration ore than 7 days as done here) of experiments should also be expanded to have a sharp and broader view across all the four seasons of a year.

In order to ensure the greatest efficiency with various orientations in the PV/T module, Max. Power Point Tracking can also be implemented for this system.

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