Experimental study of solar thermal PV collectors and its performance efficiency towards Conventional / Modern cooling techniques

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ABSTRACT: : *The Solar energy holds the capacity of long-standing sustainable energy and most of solar energy budgets originate from the price of mounting the panels and the land they sit on. The solar cells themselves only contribute roughly 20 to 22 % of the price of solar energy. Due to this, scholars/reserachers have been trying to improve the solar cell efficiency, so that a smaller amount land may be used to produce electricity from the sun. Generally solar module generates the calorific energy during photo electric conversion increases the rating of temperature of cell and lead to a decrease in the production of electricity. This occurs due, on the one hand, to the joule effect initiated by the passage of the photoelectric current advanced in the electric circuit and thermal energy, on the other hand, due to the non-absorbing partial solar radiation that established the heating of the cells of origin .The efficiency of PV panels falls by 0.41% to 0.52% for every degree increase of temperature, depending on the type of solar cells / materials used. The temperature control of PV power systems therefore becomes vital especially for areas facing consistently great temperatures to increase PV efficiency. The objective of this work is to discuss the new technical approach and methodologies, along with traditional cooling techniques to increasethermal and electrical efficiencies for different applications, in solar thermal photovoltaic energy generation systems.This review and study establishes the experimental results of on PVT solar systems. The experimental results shown the temperature and radiation variations with different collectors along with cooling and without cooling method. In future economic calculation may also be carried out based on cost of the energy in India and payback time may be reduced and calculated.*

Key Words: *Payback, photovoltaic, PVT Collectors, joule effect, Photo electric conversion*

I. Introduction

The global demand of present energy usage is increasing drastically as can be seen and oil prices that have increased significantly. The researchers are keeping their efforts to tap the renewable energy in best and efficient way. The Solar radiation incident on the photo voltaic module does not convert the total energy into Power. Only a part of 8 to 21% of incident solar radiation energy is transformed into electrical energy, depending upon the PV cell technology, material and other parameters. The balance energy is converted into heat and reduces the current of 0.4 to 0.5 % for every degree rise of temperature and reduces the electrical efficiency. This not only decreases the electricity generation efficiency but also affects the life time of PV panels. The introduction of thin-film silicon cells and group III–V materials based triple junction cells the negative temperature coefficients could have been reduced to some extent and the loss in efficiency for these materials is half of the crystalline silicon ,but these technologies are not viable commercially till now. A survey by the international Energy Solar heating and cooling programme (IEA SHC) (2006) found that, in 2004, there are about of 141 million m^2 of solar thermal collectors in its 41 associate countries. Most of the research centers and Institutions are doing research on the hybrid photovoltaic thermal collector. A solar heat collector can be pooled with a photovoltaic unit to form a mixed production unit producing simultaneously low temperature electricity and heat. Such solar collectors are termed as hybrid photo voltaic-thermal collectors. The aim is always was to increase the overall efficiency .PV collectors to absorb 75 to 80% of the incident solar radiation, but only a small portion of this converted into electrical energy dissipated as thermal energy and remaining. The electrical conversion efficiency of a solar cell for commercial application is in the range of 6-15%. In a hybrid system like photovoltaic /Thermal (PV/T) energy system, both electrical and thermal energy are produced simultaneously at the same time with single system. This can be produced by different methods and different models of the PV/T systems. This is achieved when PV panel with glazed or unglazed which convert solar radiation into electricity also functions as the absorber of the solar thermal collector. Generally PV cells are most sensitive to temperature, whenever the temperature increases after certain limit the electrical efficiency will decreases. However , if the thermal energy that causes the increment in temperature in solar cells is removed and used for other applications like space heating, water heating and drying, So that it prevents the increase of temperature in PV cells , so that overall efficiency of the PV/T system will increases. Hybrid collector performances have been studied by Sopienet .al .Bergence and Lovvik analyzed the transfer of energy between the different components of the hybrid systems PVT using the liquid like coolant. The PV-T collectors mainly categorized according to the kind of working fluid as PV-T Water and PV-T Air systems as shown in Fig. 1.

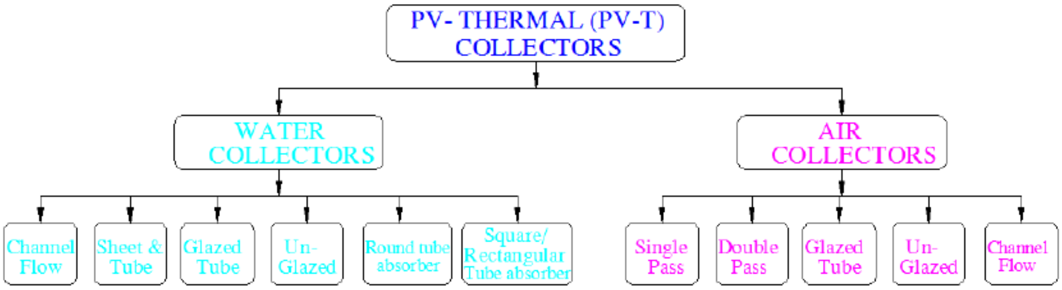


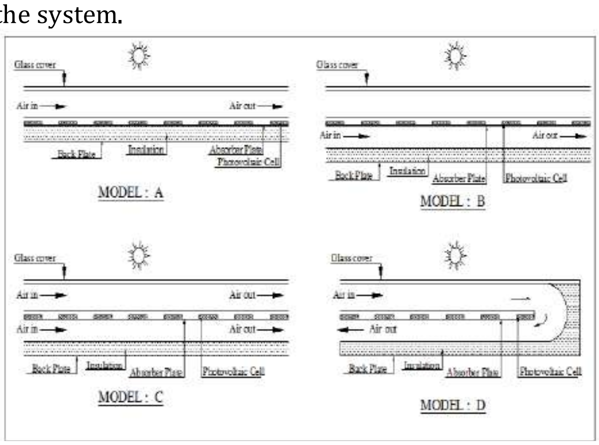
Fig. 1.Typical classification of PV–Thermal collector types.

I. PV-T AIR COLLECTORS

Air collectors are mainly differentiated according to their air flow pattern. These are differentiated with respect to the flow of air above absorber, below absorber, on both sides of the absorber, in single and double pass.

H.P Garg and R.S Adhikari developed the computer simulation model and various performance parameters are calculated for single glass and double glass configurations and also various types of absorbers have been derived. His study given that system efficiency increases with increase in collector length, mass flow rate and decreases with in duct depth.

Among the air-based PV/T systems, Hegazy proposed and investigated four basic modes, with air flowing either above absorber (Model A) or below it (Model B) and on both sides of absorber in a single pass (Model C) or in double pass (Model D) that are shown in Fig. 2. The results of numerical simulations show, that under similar operating conditions , The Model A Collector has the lowest performance , while the other models exhibit comparable thermal and electrical output gains. The Model C, PV-T collector is the most suitable design for concentrating solar energy into low quality heat and high quality electrical energy. On the other hand, it is simple to be built. Mass flow rate was considered as one of the important parameters for the system.



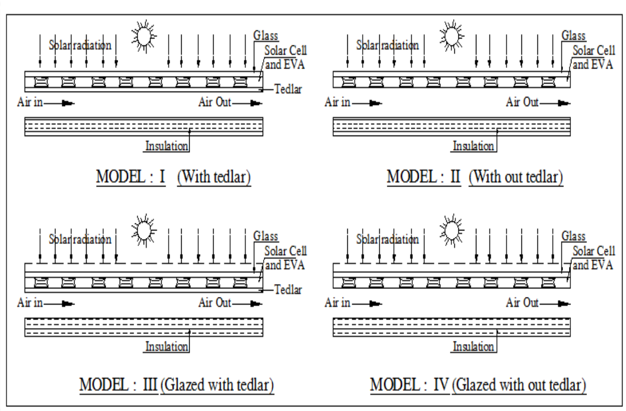


Fig. 2 Schematics of the Various types of PV-T air collector modelsFig. 3 Glazed and Un Glazed PV-T air heater with Tedlar and With out Tedlar

Tonui and Tripanagnostopoulos investigated an air system in their experiment. They did two modifications in the channel to extract much more thermal energy and make the PV much cooler to get higher efficiency. They suggested the use of thin flat metal sheet suspended at the middle or finned back wall to improve performance in the air system. Tonui and Tripanagnostopoulos studied two low cost

modification techniques to enhance heat transfer to air stream in the air channel. They used both glazed and unglazed models. They used flat plate collector and their thermal model was based on natural ventilation. They developed a mathematical model to investigate the induced air flow rate and PV/T system temperatures. They analyzed the effect of some important parameters like mass flow rate, tilt angle and ambient (inlet) temperature on efficiency. They found an optimum point for channel depth and mass flow rate, after which point the PV/T behavior is reversed.
A.Tiwari and M.S.Sodha an attempt has been made to evaluate the overall performance of hybrid PV-T air collector. The different configurations of Hybrid air collectors which are considered as glazed and unglazed PV-T air heaters, with or with outtedlar. Numerical computations have been carried out and the results for different configurations have been compared.

The thermal model for unglazed PV-T air heating system has been validated experimentally. It was witnessed that glazed hybrid PV-T without tedlar gives the finest performance. On the basis of present study, one can tell that the glazed hybrid PV-T system without tedlar, Model IV, is the best system among others with significant increase in an overall efficiency which can be used for various applications namely space heating , water heating illumination, Greenhouse and lighting. He confirmed that there is no difference in the solar cell temperature of the unglazed PV-T module, With Model I (with tedlar) and Model II (without tedlar). However, there is marginal increase in outlet air temperature in Model IV due to absence of tedlar an overall efficiency of hybrid system and solar cell efficiency increases with increase of mass flow rate of air through duct. An overall efficiency of the hybrid system decreases with an increase of the length of model due to more losses from the system there is significant increase in an overall efficiency of PV-T system if more small modules are connected in series for a given length of the system.

II.PV-T WATER COLLECTORS:

PV-T water collectors are distinguished according to water flow pattern which are differentiated to sheet and tube, channel free flow and different absorber types.

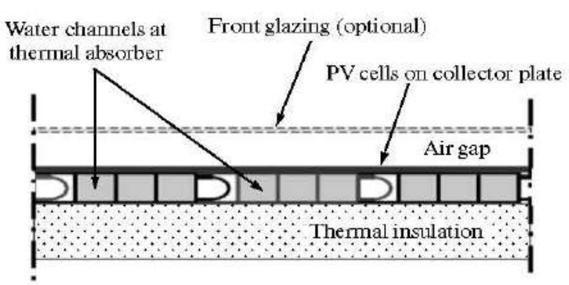


Fig. 4 (a) C/S view of PV-T collector with flat box absorber and multi water design (b) PV-T Collectors with and without glass cover

In the work of T.T. Chow et al.presented the results of investigations on experimental setup of two flatbox type PV–T collectors (Fig. 4a and 4b), one with glazing and the other without glazing. Each collector had an aperture area of 1.34 m^2 and carried a thermallyinsulated 155 liter water storage tank. Poly crystalline silicon solar cells of conversion efficiency 0.13 at standard testing conditions (STC) were used. The PV encapsulation was adhered to the upper portion of the aluminum alloy thermal absorber. The cell area was 0.81 m^2 and the packing factor was therefore close to 0.60.

During the winter test period, the collectors were set facing south at a tilt angle of 30°. The absorptivity and emissivity of the thermal absorber were 0.91 and 0.81, respectively. The transmisivity and emissivity of the glass cover were 0.83 and 0.88, and the depth of air gap between glazing and collector plate was 0.025 m. Based on numerical models validated by experimental data, the use of glass cover at a thermosyphon type PV–T collector system has been evaluated from the thermodynamic point of view. The energetic efficiency of the glazed collector was found always better than the unglazed collector. This is for all cases examined for the six operating parameters namely wind velocity, solar radiation, cell efficiency, packing factor, ratio of water mass to collector area and ambient temperature. Hence if the system design is targeted at acquiring either higher proportion of thermal energy or more overall energy output in "quantity", the glazed system can be the better choice.

In the work of Wei He et al.presented an aluminium alloy flat box type hybrid solar collector functioned as a thermo syphon system. As illustrated by Fig. 5b the hybrid collector carried a thermally insulated 1001 water storage tank. The PV module was attached to the upper portion of the aluminium alloy flat box absorber. Poly crystal line silicon solar cells of 14.5% conversion efficiency at standard conditions were used. The constituent layers of this hybrid collector are shown in Fig. 5 a. a single glass cover was provided and separated from the PV encapsulation by an air gap. The solar cells were inserted within the encapsulated materials, which included the transparent TPT (tedlar polyester tedlar) and the EVA (ethylene vinyl acetate) layers on the top, and the EVA and opaque TPT layers underneath. The entire flat box absorber was built from a multiple of extruded aluminium alloy box structure modules. The test results on the energy performance of water type hybrid collector polycrystalline PV module on a flat box type aluminium alloy thermal absorber were very encouraging. The daily thermal efficiency was found around 80%, which is about 0.8 of that for a conventional solar thermosyphon collector system. The energy saving efficiency was found above that of the conventional system. A high final water temperature in the storage tank can be achievable after a one day exposure.

In the work T.T Chow et al the performance evaluation of a new water type PV-T collector system is presented. The thermal collection making use of the thermosyphon principle eliminates the expense of the pumping power. Figure 5 a and 5 b show the cross section views of three adjacent water tubing in a sheet and tube PV-T collector and several integrated flat box absorber modules of PV-T collector respectively.

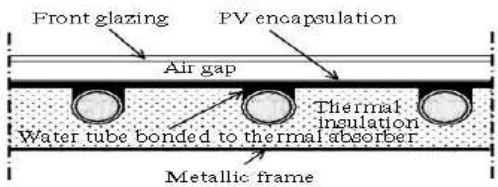


Fig 5. a) C/S view of 3 adjacent water tubing in a sheet and tube PVT Collector

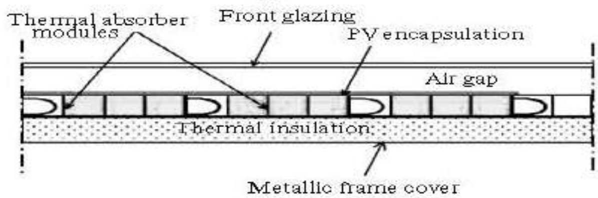


Fig 5. b) C/S view of PV-T collector showing several integrated Flat –box absorber modules

The introduced PV-T system is able to make higher energy output per collector surface area than side by side collector system. Through the numerical models established for the plain PV module, the solar hot water collector and the PVT Collector system respectively and calculations are showed that PVT system carries much economical advantages over the conventional PV module. Benefited by the financial contribution of the solar water heating system, the payback period can be shortened from 51 years to 11 years. This highly improves the business operation opportunities. It is also cost effective alternative for off grid rural households with modest electricity needs.

The existing electricity cost using PV systems is quiet several times greater than from the conventional power generation. Payback period can be shorten in the hybrid PV-T technology, which gives the energy output from the same collector surface area.

Most of the researches confirmed that the thermal efficiency can be improved by increasing the mass flow rate and lowering the inlet water temperature, packing factor and solar cell and heat loss coefficient in the PV/T system. Some of the Parameters discussed below

i) MASS FLOW RATE

Another important parameter in designing a PV/T system is mass flow rate. The convection heat transfer coefficient is sensitive to mass flow rate variations. The higher the convection heat transfer coefficient is, the higher the heat transfer rate and the lower the exit temperature. This will result in higher thermal efficiency as well as electrical efficiency. Fluid material (gas or liquid), velocity magnitude, and the geometry of PV/T thermal system are the parameters to control the mass flow rate. In general, at high mass flow rate, more heat can be removed, resulting in lower absorber plate temperature. However, if flow residence time in the channel is too short due to increase of velocity, the absorber plate temperature might not be reduced linearly as much as expected. It is believed that an optimal mass flow rate exists which allow a PV/T system to produce the highest thermal and overall efficiencies.

ii) PACKING FACTOR

Packing factor is one important constraints in designing and studying a PV/T system , which generally means the fraction of absorber plate area covered by the solar cells. In specific applications, Vats et alstudied the effects of packing factor on energy and performed exergy analysis of a PV/ T system with air duct flow. The increase of packing factor doesn't permanently increase the electrical efficiency or energy gain . If the packing factor is raised too much the thermal exit temperature will get higher due to absorbing high amount of thermal energy so it will increase the cell temperature, which causes the decrease in electrical efficiency. Meanwhile decreasing the packing factor too much will decrease the electrical efficiency because the radiation absorber area is less. Generally speaking, a comprehensive knowledge about the variation of packing factor and its effects with different fluids in different PV/T systems still does not exist. This also opened the door for optimization of the system design. Most of the researches choose packing factor higher than 50% and less than 90%

iii) PV SOLAR CELL MATERIALS

Miles et al. presented a paper regarding the overview of the materials and methods for manufacturing PV solar cell deices. He described about different types of solar cells and their best efficiencies. They are Silicon solar cells, III-V group solar cells, thin film solar cells and dye sensitized solar cells. Silicon solar (crystalline silicon) cell ideal efficiency is 24.72% and commercial module efficiency is 18%. III-V group solar cells having 25.0% PV conversion efficiency on single junction solar cells. Thin film solar cells power conversion efficiencies around 19%. This cell is made by depositing one or more thin layers of photovoltaic material on a substrate such a metal, glass or plastic foil.

iv) EFFICIENCY

Most of the researches do their research works on different PV/T models. As some differences in the conclusions of different type of research works, at different operating conditions. In some cases Thermal efficiency (25-58%) and electrical efficiency (6.7% to 9.1%)increases with mass flow rate increment . In some cases Thermal and electrical efficiency increases with mean PV temp, decrement along with overall efficiency.

v) PVT PANEL COOLING :

Cooling of the PV Panel may classified as mentioned below.

a) Water based cooling

b) Passive cooling

It is based on PV panel cooling using water without the use of pumps. It is found effective for PV cooling provided good thermal contact between the PV and the collector system is ensured. Further the excess heat stored in water should be continuously removed or utilizedelsewhere.

c) Active cooling

PV panel cooling performance is improved as the water flow velocity is increased. However, increase in volumetric flow per unit time means increase in power consumption .Krauter found that water flow can increase the electricity generation efficiency of the panel by 8–9% along with reducing the reflection losses. The advantage of active cooling was higher heat transfer compared to both natural and forced convection of air, higher mass flow rate, heat capacity and thermal conductivity of water compared to natural and forced convection of air, higher temperature reduction. The disadvantages of this system were higher investment due to use of pumps, higher maintenance cost compared to natural and forced convection and less life due to corrosion.

d) Thermoelectric cooling

Thermoelectric cooling is based on converting additional heat generated by the panel into electricity based on Peltier effect. This process may increase the electricity generation efficiency of PV by 8–23% . The advantage of Thermoelectric cooling was no moving parts, size was compact, easy to integrate , low maintenance cost and compact size. The disadvantages of this system were Heat transfer rate depends on ambient conditions, more electrical consumption, no heat storage capacity and Low reliability.

e) Cooling using PCM

The high latent heat capacity of PCM is utilized to maintain the PV panel at a fairly constant temperature. The heat stored can later be used for space heating, water heating and other purposes. However, the initial investment with these systems is quite high. From the studies it is clear that the natural ventilation based cooling is the most ineffective method while forced water and air cooling techniques are being used around the world for PV panel cooling. PCM has an added advantage of its ability to delay the temperature rise of panel without any electricity consumption. Further, the heat stored can be reused which further enhances the system efficiency. Studies on liquid immersion cooling are lacking though it also appears promising.

f) Other cooling techniques

Heat pipe cooling is a passive cooling technique. Heat pipes combine the principles of thermal conductivity and phase transition to enhance the rate of heat transfer between two solid interfaces.Several studies are found in literature to cool PV using nano-fluid containing suspended metal particleslike MgO/water Nano-fluid , (paraffin wax mixed with Nano - SiC) , ferro fluid etc . Literature states that the electrical efficiency may be increased from 7.1% to 16.7%. Also, the system made complete use of the thermal energy added as its thermal efficiency reached to 73%.

III. ADVANTAGES OF SOLAR THERMAL ENERGY

3.1 No Fuel Cost – Solar Thermal Energy does not require any fuel like most other sources of renewable energy. This is a giant advantage over other fossil fuels whose costs are growing at a radical rate every time. Electricity prices are growingquickly in maximum parts of the world much quicker than general inflation. Price jolts due to great fuel costs are a big threat with fossil fuel energy these days.

3.2 No Pollution and Global Warming Effects – Solar Thermal Energy does not cause pollution which is one of the biggest advantages. Note the cost are connected with the equipment used to build and transport Solar Thermal Energy system.

3.3Existing Industrial Base – Solar Thermal Energy uses equipment like turbines and solar mirrors which is made in great scale at low cost by the current Industrial Base and needs no major changes in equipment and materials unlike new technologies such as CIGs Panels.

IV. APPLICATIONS OF SOLAR POWER

4.1 Concentrating Solar Power (CSP): Concentrating solar power (CSP) plants are utility-scale generators that harvest electricity using lenses /mirrors to proficiently concentrate the sun's energy. The 4main CSP technologies are concentrating photovoltaic systems (CPV), central receivers, parabolic troughs and dish-Stirling engine structures.

4.2 Solar Thermal Electric Power Plants: Solar thermal energy includes harnessing solar power for real-world applications from solar heating to electrical power production. This energy system is also used in building design and architecture to regulate the heating and ventilation in both passive solar and active solar models.

4.3 Photovoltaic: Photovoltaic or PV technology employs solar cells or solar photovoltaic arrays to convert energy from the sun into electricity. Solar cells harvest direct current electricity from the sun's rays, which can be used to power equipment or to restore batteries. For greater applications, cells are generally assembled together to form PV modules that are in turn arranged in solar arrays. Solar arrays can be used to power revolving and spacecraftsatellites and in isolated areas as a source of power for remote sensing, and cathodicshield of pipelines.

4.4 Passive Solar Energy: It concerns building design to maintain its environment at a comfortable temperature through the sun's daily and annual cycles. Greenhouses Sunspaces and solar closets are another ways of arresting isolated heat gain from which warmed air can be taken.

4.5 Solar Lighting: The usage of natural light to deliver illumination to balance energy use in electric lighting systems and cut the cooling load on HVAC systems. Daylighting features window orientation, exterior shading, include building orientation, saw tooth roofs, light shelves, skylights, and light tubes.

4.6 Solar Cars: A solar car is an electric vehicle powered by energy obtained from solar panels on the surface of the car which convert the sun's energy directly into electrical energy. Research teams have focused their efforts on enhancing the efficiency of the vehicle, but many have only adequate room for one or two people.

4.7 Solar Power Satellite: A solar power satellite (SPS) is a proposed satellite built in high Earth orbit that uses microwave power transmission to beam solar power to a very big antenna on Earth where it can be used in place of traditional power sources. The benefit of placing the solar collectors in space is the unobstructed view of the sun, unaffected by the day/night cycle, weather, or seasons.

4.8 Renewable Solar Power Systems with Regenerative Fuel Cell Systems: NASA has recognized the special advantages of regenerative fuel cell (RFC) systems to distribute energy storage for solar power systems in space. RFC systems are exclusively qualified to offer the necessary energy storage for solar surface power systems on the moon or Mars during long periods of darkness, i.e. during the 12-hour Martian night or 14-day lunar night. And in the course of applying the NASA RFC Program, researchers recognized that there are severaluses in industry, transportation ,government, and the military for RFC systems.

Objective of the work:

The objective of this study is to examine the quantitative energy output of PVT collectors that use different type of solar collectors along with reflectors and with out reflectors in the climatic conditions of Hyderabad ,india. The cooling of panel is also done to increase the power output and comparison has been done with and without cooling for the tropical climatic conditions.

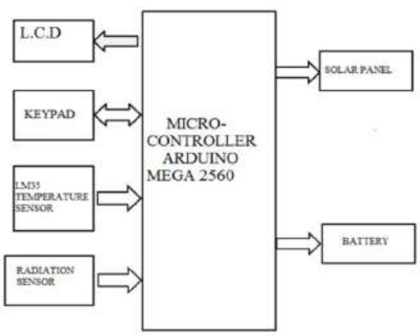
V) EXPERIMENTAL SETUP:

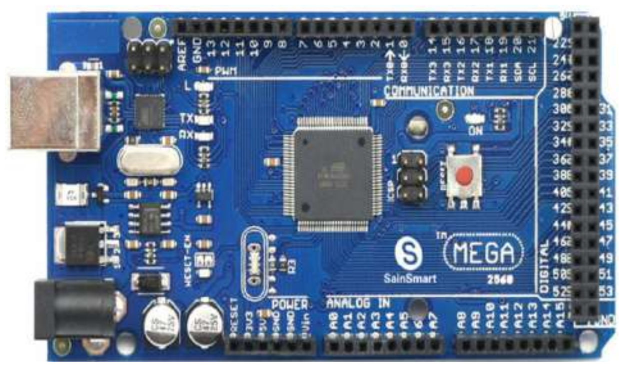
Figure 6 (a) and 6 (b) shows the experimental rig and each system consists of flat plate collector of area consists of size 0.6 m x 0.8 m with components like pyranometer, battery, Arduino Mega 2560, Heat sink, Battery and Keyboard. In this study we used the different solar concentrators to increase Solar light. The purpose of these concentrators is to concentrate the light falling on a large area to smaller areas. Large mirrors or other devices are used in the facilitation of the task. Thus, the overall(electrical and thermal) efficiency of solar cells, can be improved. You not only get more energy but also save money. Solar panel output power may be improvedthrough a light concentrator like a Fresnel lens or mirror. Study also be done by collecting IR rays. Traditional solar cells aren't able to absorb the infrared part of the sun's rays. The infrared part of solar radiation to allow conventional photovoltaic cell to harvest this previously untapped energy.

6. a) PV-T Collectors with and without Reflector6. b) PV-T Collectors with and without Reflector

<u>DESIGN AND CONSTRUCTIONOF PROJECT MODEL</u>

FUNCTIONAL BLOCK DIAGRAM

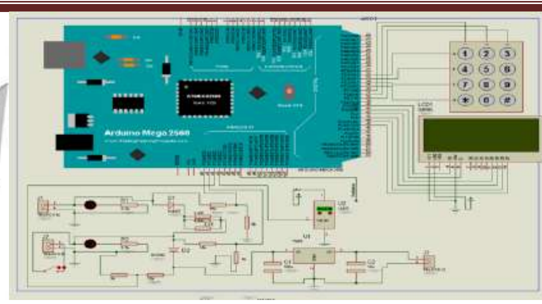




Arduino Mega 2560

Thermopile Pyranometer **LCD 20*4 Diagram**

HEAT SINK

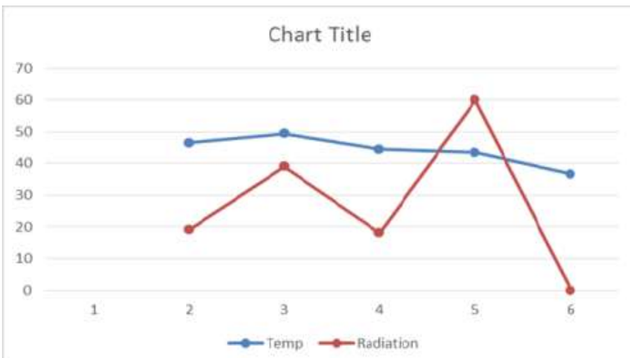


SCHEMATIC DIAGRAM

RESULTS AND DISCUSSION

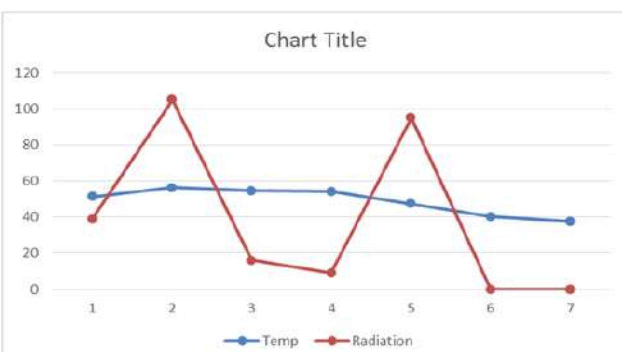
5.1.1 Solar Panel Readings Without Any Collectors Attached To it

S.No	Time	SP (V)	BT (V)	T(oC)	Radiation
1	12:00	16.15	15.06	46.5	19
2	13:00	16.61	15.88	49.43	39
3	14:00	16.19	15.17	49.51	18
4	15:00	17.17	16.44	43.43	60
5	16:00	13.4	12.6	36.64	0



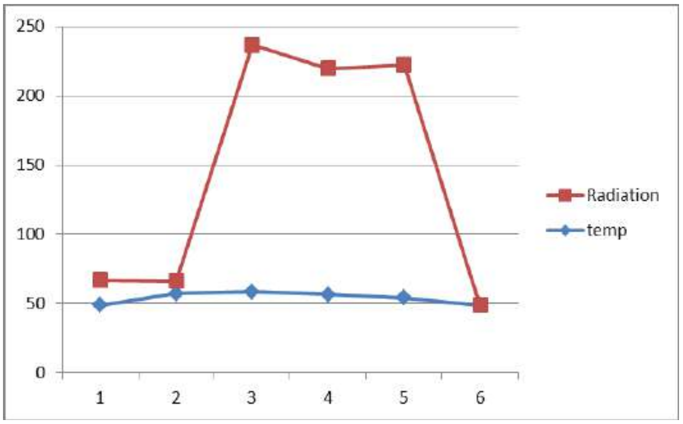
5.1.2 Solar Panel Readings With Flat Plate Collectors Attached To it at Various Angles

S.NO	Time	SP(V)	BT(V)	Temp(oC)	Radiation
1	10:30	16.87	15.89	51.19	39
2	11:30	17.32	15.49	56.16	105
3	12:30	16.09	15.01	54.63	16
4	13:30	15.7	14.53	54.19	9
5	14:30	15.49	14.1	47.32	95
6	15:30	14.34	13.12	40.14	0
7	16:30	15.52	14.51	37.59	0



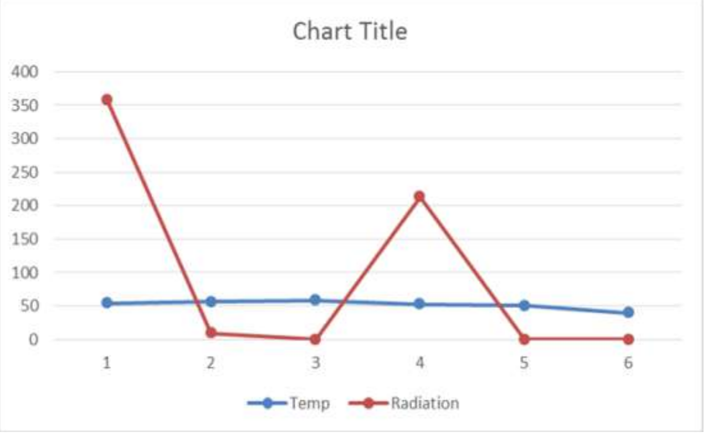
5.1.3 Graph of Solar Panel Readings With Flat Plate Collectors Attached To it at 30 degrees

S.No	Time	SP (V)	BT (V)	Temp	Radiation
1	10:15	17.01	16.07	48.8	18
2	11:15	16.56	15.63	5.06	9
3	12:15	16.45	15.47	58.42	178
4	13:15	15.84	14.79	56.52	163
5	14:15	15.37	14.22	54.18	168
6	15:15	15.21	14.02	48.72	0



5.1.4 Solar Panel Readings With Flat Plate Collectors Attached To it at 45 degrees

S.No	Time	SP	BT	Temp	Radiation
1	11:00	17.03	6.27	54.01	358
2	12:00	16.9	16.15	55.71	9
3	13:00	16.86	16.11	58.05	0
4	14:00	16.97	16.23	52.11	213
5	15:00	16.71	16	50.23	0
6	16:00	16.72	15.85	39.19	0



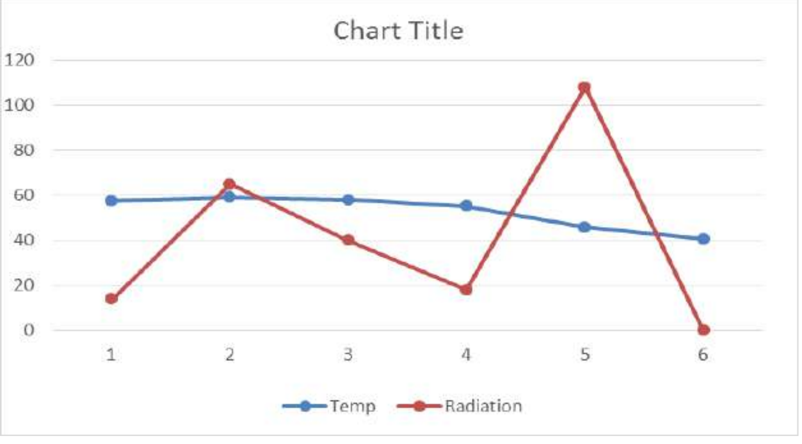
5.1.5 Solar Panel Readings With Flat Plate Collectors Attached To it at 60 degree

S.No	Time	SP	BT	Temp	Radiation
1	11:00	17.32	16.56	46.4	178
2	12:00	17.15	16.41	48.81	208
3	13:00	16.45	16.28	46.01	228
4	14:00	15.64	14.82	47.7	0

5	15:00	16.93	16.19	44.02	213
6	16:00	16.65	15.86	40.01	303

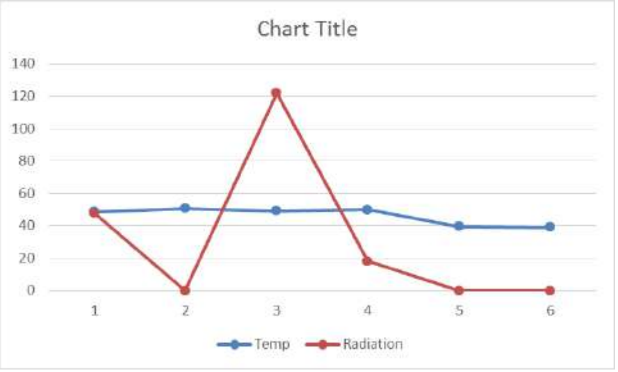
5.1.6 Solar Panel Readings With Parabolic Collectors Attached To it at 30 degrees

S.No	Time	SP	BT	Temp	Radiation
1	11:00	16.99	16.23	57.55	14
2	12:00	16.84	16.02	59.06	65
3	13:00	16.69	15.94	57.92	40
4	14:00	16.73	16.22	55.16	18
5	15:00	17.26	16.48	43.87	108
6	16:00	15.68	14.92	44.61	0



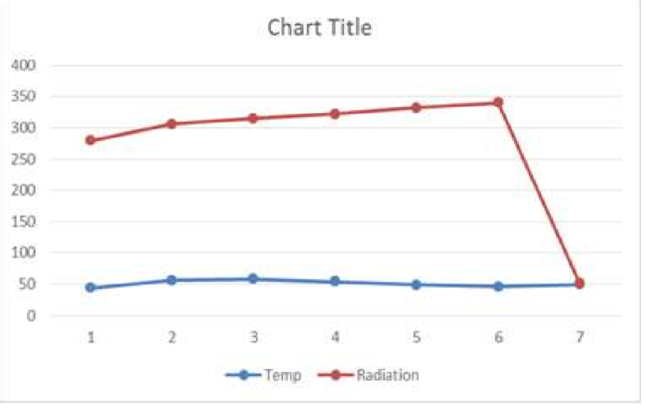
5.1.7 Solar Panel Readings With Parabolic Collectors Attached To it at 45 degrees

S.No	Time	SP	BT	Temp	Radiation
1	11:00	17.17	16.41	48.82	48
2	12:00	17.11	16.35	50.73	0
3	13:00	17.16	16.39	49.21	122
4	14:00	17.19	16.43	49.85	18
5	15:00	17.64	16.86	39.69	0
6	16:00	10.2	9.4	39.03	0



5.1.8 Solar Panel Readings with Parabolic Collectors Attached To it at 60 degrees having Honey Comb Cooler

S.No	Time	SP	BT	Temp	Radiation
1	10:00	17.17	16.44	43.43	279
2	11:00	17.32	15.49	56.16	306
3	12:00	16.45	15.47	58.42	315
4	13:00	17.03	16.27	54.01	322
5	14:00	17.15	16.41	48.81	332
6	15:00	17.26	16.48	45.87	340
7	16:00	17.13	16.39	49.21	52



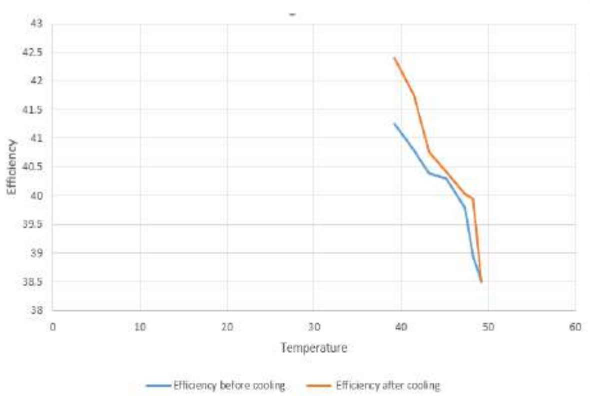
In this work "Solar Panel cooling system" has been introduced to design an intelligent system capable of monitoring Solar panel temperature. The microcontroller is used to run the entire cooling system automatically, when the temperature reaches above 42^0 C the sensor senses the temperature and send this information to the microcontroller. The micro controller then activates the relay to switch the water pump to circulate the water on the panel until the temperature reaches below 42^0 C. The panel temperature indicated in LCD display.This work may also extended by using more sensors like rain sensor for automatic wiper operation and a wireless communication can be implemented to get the solar panel temperature and Voltage values. The cooling technique also be used to reduce the joule effect with small amount of water and a non-pressurized cooling system has been developed based on spraying the PV panels by water once in a while. A cooling rate model has been established to fix how long it will take to cool the PV panels via water spraying to its operating temperature. A mathematical model can be developed to determine the heating rate of the PV panels, in order to determine when to start cooling. An experimental systemwasestablished to validate both models, i.e., the heating and the cooling rate models, experimentally, and to study the effect of cooling on the performance of PV panels.

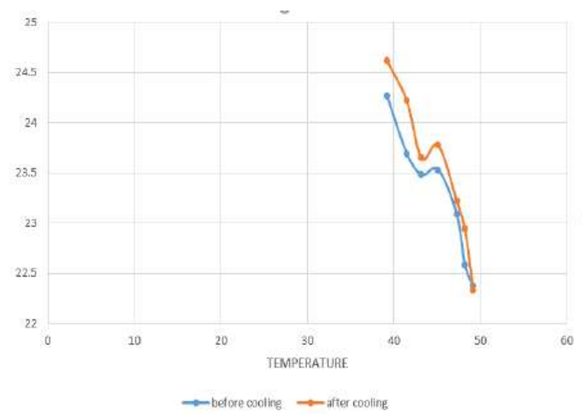
Without cooling of solar panel:

S.NO	Temperature in °C	Voltage (V)	Current (I)	Power P= V*I	Efficiency (η)
01	39.21	16.66	1.43	23.10	39.82
02	41.17	16.02	1.40	22.42	38.66

After cooling the solar panel:

S.NO	Temperature in °C	Voltage (V)	Current (I)	Power P= V*I	Efficiency (η)
01	49.15	15.95	1.40	22.33	38.5
02	48.25	16.16	1.43	22.94	39.95
03	47.30	16.24	1.42	23.22	40.04
04	45.14	16.40	1.45	23.78	40.43
05	43.15	16.54	1.43	23.65	40.77
06	39.21	16.98	1.45	24.62	42.40





Temperature Vs Efficiency **Temperature VS Power**

From the above table and graph it was clear that after cooling solar panel with water the efficiency is increased from 39.82 to 42.40.

Conclusions :

Literature review from the research papers states that PV-T water systems are more efficient than PV-T air systems, because the high heat conductivity ,high heat capacity and high density resulting in high volume transfer. But using water, required more modifications to enable water tight and corrosion free construction. PVT water systems are further expensive than PVT air systems due to added cost of the thermal unit with the pipes for the water circulation. The maintenance costs for air based system are cheaper than the water based. But the sheet and Tube geometry is considered as the one with high efficient and less expensive in water based PV/T for practical applications.On the other hand Research paper concluded that Silicon solar (crystalline silicon) cell ideal efficiency is 24.7% and commercial module efficiency is 18%. III-V group solar cells having 25% PV conversion efficiency on single junction solar cells. Thin film solar cells power conversion efficiencies around 19%.

When solar panel is not attached with any kind of reflectors we observed that the maximum radiation obtained is 39 mW/sq cm at temperature of 49.43^{0} C but subsequently Observed that drop in the output of battery and radiation even though there is an increase in temperature this is due to photo voltaic effect of PV cells. Later the solar panel is attached with Flat plate Collectors at angle 15^{0} the maximum radiation obtained is 105mW/sq cm at temperature of 54.16^{0} C and at an angle of 30^{0} that the maximum radiation obtained is 178mW/sq cm at temperature of 58.43^{0} C.When solar panel is attached with Flat plate Collectors at an angle 45^{0} that the maximum radiation obtained is 358mW/sq cm at temperature of 54.01^{0} Cand at angle of 60^{0} we observe that the maximum radiation is 228 mW/sq cm at temperature of 46.0^{0} C

When solar panel is attached with Parabolic Collectors at 30^{0} we observe that the maximum radiation obtained is 108 mW/sq cm and at temperature of 44.61^{0} Cbut subsequently we observe drop in the output of battery and radiation is observed even as the temperature rises.• When solar panel is attached with Parabolic Collectors at 45^0 the maximum radiation obtained is 122 mW/sq cm at temperature of 49.21^0 C and at an angle of 60^0 C and honey comb cooler incorporated to it we observed that the maximum radiation obtained is 325 mW/sq cm at temperature of 58.42^0 C.

The work was also carried by cooling solar panel along with cleaning of the PV panels automatically in hot and dusty regions with temperature sensors using the proposed cooling system. The cooling rate for the solar cells is 2^0 C/min based on the concerned operating conditions, which means that the cooling system will be operated each time for 5 min, in order to decrease the module temperature by 10^0 C. The outcome of the cooling rate model has shown decent agreement with the experimental measurements. In future work both the heating rate and the cooling rate models have been validated experimentally. The PV panels yields the highest output energy if cooling of the panels starts when the temperature of the PV panels reaches the maximum allowable temperature (MAT), i.e., 45^0 C. The Maximum allowable temperature is a conciliation temperature between the output energy from the PV panels and the energy desirable for cooling

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