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Fabrication and Experimental Analysis of Solar Panel Water Cooling System

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Abstract- *Photovoltaic cell generates energy from solar radiance. The electrical efficiency of photovoltaic cell decreases significantly with the increase of operating temperature of the cell and this cell produces a lot of heat while converting solar energy to electric energy. This project is all about the management of heat of PV panel through water cooling system. Generally the power produced by the panel reduces by .485% /^{0}c.When the panel temperature increases more than 25^0 C .In this project an automated water cooling system was developed which automatically sprayed water on the solar panel to prevent temperature rise and the system did monitor the cell temperature. Then a comparison was developed demonstrating the PV cell output with and without the cooling system. A photovoltaic cell having peak power of 5.0 watt was used along with other components for cooling system. This project also demonstrated if this cooling system would be effective enough to increase the overall output of the panel.*

Keywords: Solar Energy, Cooling System, Photovoltaic Panel, Solar Irradiance

1. INTRODUCTION

The use of solar energy is growing rapidly as it is clean and green energy. Solar energy can be converted to electrical energy through various method. One of the most prominent method is using PV cell to convert solar energy to electrical energy through direct solar radiance. One of the main obstacles of PV is overheating due to excessive solar radiation and high ambient temperatures. Overheating reduces the efficiency of the panels dramatically. [1]It is found that solar panel with water cooling generates more energy than the one without cooling. [2] A CFD based research also showed that the geometry and construction of the solar energy system have a major impact on how effectively the panels are cooled. [3] A research by designing a PV/T air system to study the cooling effect on the PV module with either forced or natural convection showed that PV/T air with fins gives the highest thermal output. [4] From this researches it is very clear that cooling systems are a crucial step in process of power generation from PV cells. So several processes have been followed to find an optimal solution for efficient power generation from PV cell. An automated Solar Panel water cooling system may result very efficient outcome with very few limitations.

A typical Silicon cell composed of P-N junction where boron-doped layer (P-type) & ultra-thin layer of phosphorus doped (N-type) where sunlight strikes on this junctions then the electron of the P-V cell which stimulates the current flow in the cell. Regardless of size, a typical silicon PV cell produces about 0.5 – 0.6 volt DC under open-circuit, no-load conditions.

PV panels basically faces overheating effect due to excessive solar radiation. The Ideal PV characteristics solar cell for a temperature variation between 0° to 75° shown in fig: 1which is adopted from Rodrigues [5]

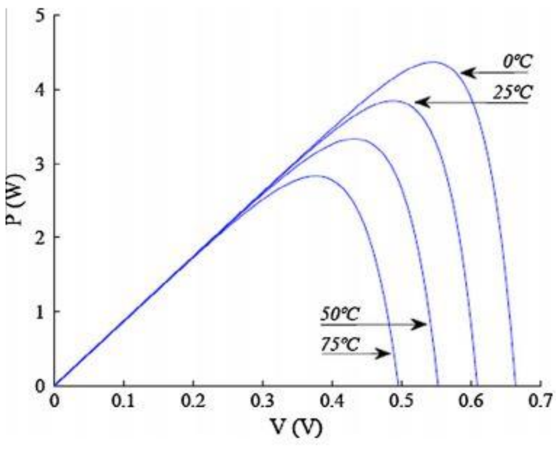

Fig.1: P-V Characteristics as a function of the temperature T_m

As most of solar cells are made by glass like objects so properties of PV panels can be regarded as glass like objects. Since the cooling of PV cells is very important part many types are used such as air-cooling system, water cooling system, hybrid cooling center which will be discussed in depth following portion. Water based cooling systems seems to have higher performance than other cooling systems. [6] In this project we used hybrid cooling system.

2. RELATED WORKS

Gardas and Tendolkar[7] (2012) used seven gasses for cooling in PV/thermal system; they found that hydrogen to be the best gas to maximize the output power of system.But it may seem costly process.
Garg and Datta [8] suggested several practical modifications to enhance the heat transfer in the air duct. Naphon [9] carried out a study on the performance and entropy generation of the double pass solar air heater with longitudinal fins. This study showed that the thermal efficiency of PV module increases with increasing flow rate, as the heat transfer coefficient increases with increased Reynold number.However research by Han and Park [10] and Gupta et al. [11] showed that several types of ribs in the air channel can provide better performance for heat extraction but these are also accompanied by a significant increase in frictional losses. Again in order to enhance the heat transfer from the PV module, thereby effectively reducing the operating temperature and improving the efficiency of the PV module, Prasad and Saini [12] artificially increased the roughness of absorber plate and wall of the channel. However, increased roughness of wall and absorber incurred a pressure drop penalty and, therefore, required a higher pumping power. So that may not be an ideal choice.
Tang et al. [13] found that using air as a coolant it decreased the solar cells temperature by 4.7°C and increases the solar panel efficiency by 2.6%, while using water as a coolant was found to decrease the solar cells temperature by 8° C and the panel efficiency by 3%. Therefore, cooling by water was found to be more effective than cooling by air. The experiment was performed under STC. The results also showed that the power decreased about 0.485% per the 1°C increase of the PV module temperature. Water cooling system was in a high concentration PV system to avoid the cell degradation. The Design of a hybrid PV/T solar system where water and air were both investigated in the combined system as cooling agents. The water-based cooling system was found to increase the solar cells performance higher than the air based cooling system. Air cooling system is used to increase the PV efficiency from (7-8%) to (12-14%). The design of a hybrid PV/T solar system and found that cooling the solar PV with water increases the solar cells output power by almost 50%. It is also found that cooling the solar PV panel does not allow the solar cells surface temperature to rise above 46° C when exposed to solar radiation for a period of 4 hrs. This researches shows that water cooling system is a better choice compared to other cooling systems.

3. FABRICATION PROCESS

The main fabrication process can be divided into three steps:

(i)Designing a Cooling system
(ii)Implementing in experimental setup
(iii)Getting the data by power output of solar cell

3.1 Cooling System

Since solar cell almost act as glass like material properties can be regarded as such. Since the maximum allowable temperature is assumed 35°C so cooling should start at the same point by pumping water on to the panel till the temperature drops below 35°C. The cooling system used in this project consisted with a simple water pipe porous in nature so that water could be sprayed onto the plate. The pipe was fitted on the top of the solar panel. The pipe was fitted with a 12 volt dc motor which was connected with an arduino system. When the arduino sense the panel temperature more than 35°C through LM35 sensor, it started the pump and cooling system was activated. In this process when the temperature of the solar panel goes beyond 34°C, the system stopped spraying water on the surface of the solar panel to save water.

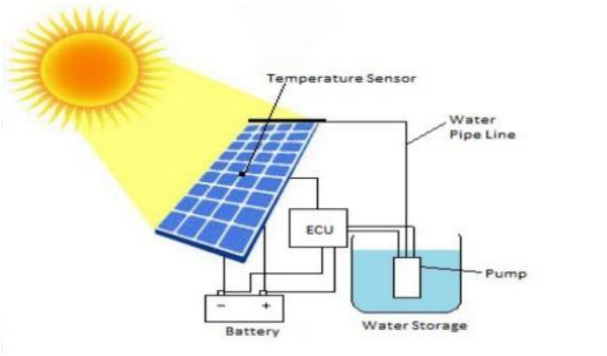

Fig.2: Schematics of cooling system

Fig.3: The cooling system

3.2 Experimental Setup

The cooling system consisted of some instruments. These components are very important to make the project a success.

3.2.1 Solar Panel

Solar panels absorb the sunlight as a source of energy to generate electricity or heat. A photovoltaic system mainly consists of an array of photovoltaic modules, an inverter, a battery for storage, some interconnection wiring and optionally a solar tracking mechanism. Photovoltaic modules use light energy (photons) from the Sun to generate electricity through the photovoltaic effect. Most modules are rigid, but semi-flexible ones are available, based on thin-film cells. The cells must be connected electrically in series, one to another. Externally, most of photovoltaic modules use MC4 connector type to facilitate easy weatherproof connections to the rest of the system. The photovoltaic cell used in this project had a peak power of 5 W, voltage of 22.5 V and current of 0.6 amp.

Fig.4: Solar Panel

3.2.2 Battery

The first Batteries in solar applications have to meet the demands of unstable grid energy, heavy cycling (charging and discharging) and irregular full recharging. Considerations for choosing a battery include cost, cycle life and installation and maintenance. Considering all situations battery used in this system was VISION CP645 and the rated voltage is 6V. The batter was used to power the control system and the water pump.

3.2.3 Water Pump

This solar cooling system included a miniature water pump which is one of the core components of this project. This pump would activate when it received a signal from the controller. The pump used in this project was operated by a 12V motor. Water storage was also used for the proper supply of water. The pump elevated the water head and supplied it to the solar panel through spray.
Here in this system the pump was actually floating on the water reservoir and the suction pipe thus always in contact with water.

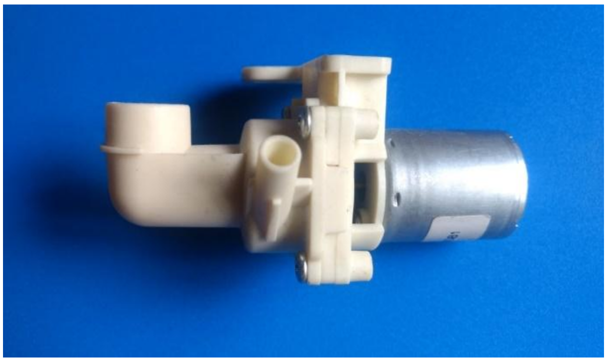

Fig.5: Water Pump

3.2.4 Controller

A microcontroller is a self-contained system with peripherals, memory and a processor that can be used as an embedded system. In this project Arduino Uno was used as microcontroller. The Arduino Uno is a microcontroller board based on the ATmega328 .It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

3.2.5 Temperature Sensor

LM35 type of temperature sensor was used in this experiment. The LM35 device has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from the output to obtain convenient Centigrade scaling. The LM35 device does not require any external calibration or trimming to provide typical accuracies of ±¼°C at room temperature and ±¾°C over a full −55°C to 150°C temperature range. It senses temperature from the solar panel and sends it to the microcontroller which will activate the water pump in a certain temperature to prevent the temperature rise.

3.2.6 Solar Radiation Meter

Solar Radiation meter is the device which measures the solar intensity of solar energy in watt per square meter unit. In this project it is used to collect the solar irradiation.

3.2.7 Digital Thermometer and Multi-meter

A multi-meter was used in this project to measure the output voltage of the solar panel. Also a digital Temperature meter was used to directly get the solar panel surface temperature.

3.3 Power Output of Solar Cell and the Control System

To measure the power output of the solar panel a multi-meter and a resistor was used. After connecting them with the solar cell circuit different values of voltage noted as well as the current values. Taking these values of voltage and current, the power output was found out. The power output was taken in two conditions. First the power output will be taken with the cooling system activated and then the power output will be noted without the function of the cooling system. Then a comparison was developed between these two conditions.

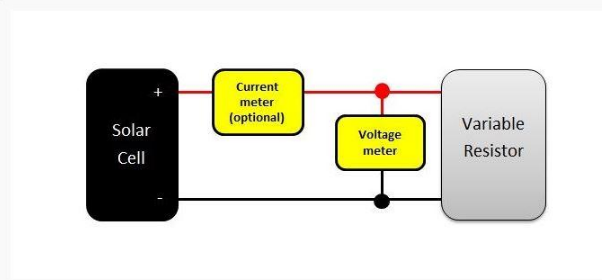

Fig.6: Power output of solar cell

The total control system consisted of a Arduino UNO, a 5V relay, 2 LM35 sensor and some connection wires. The system controlled the cooling system and it was glued to the back side of the solar panel.

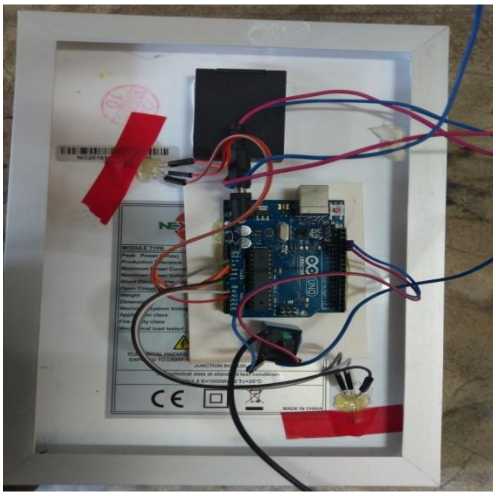

Fig.7: Control System

4. DATA COLLECTION AND ANALYSIS

These are the predetermined data that were used in this project. These data were taken form measurement and manufacture provided sheet. There data were needed for efficiency calculation.

Solar cell length=23 cm=0.23 m

Solar cell breadth= 16 cm=0.16m

Area of the cell= (0.23×0.16) m^2 = 0.0368 m^2

Maximum output= 5W

Open circuit voltage= 22.5V

By these basic measurements data were recorded from 22[th] to 24[th] October in between 10 am to 1pm on the roof-top of Mechanical Engineering Department Building, CUET.

4.1 Calculation

Area of solar cell= (0.23×0.16) m^2=0.0368m^2

When cooling system was not activated,

Sum of solar irradiance=31590 W/m^2

Sum of power=17.4814W

Number of observations=49

Average solar irradiance= $\frac{31590}{49} W/m^2$= 644W/m^2

Average power= $\frac{17.4814}{49} W$= 0.35676W

Solar intensity on the PV panel= (644×0.0368) W=23W

Efficiency of the solar panel when cooling system was not activated= $\frac{0.35676}{23} \times 100\%$ =1.55%

When cooling was activated,

Sum of solar irradiance=34228W/m^2

Sum of power=20.6734W

Number of observations=50

Average solar irradiance= $\frac{34228}{50} W/m^2$= 684 W/m^2

Average power=$\frac{20.6734}{50} W$ =0.41347 W

Solar intensity on the PV panel= (684×0.0368) W = 25W

Efficiency of the solar panel when cooling system was activated=$\frac{.41347}{25} \times 100\%$ = 1.66%

Increase in solar panel efficiency= $\frac{1.66-1.55}{1.55} \times 100\%$ =7.10%

4.2 Analysis of Data

From the calculated data above, it is seen that, without cooling system the overall efficiency of the solar PV cell is 1.55% and when cooling was implemented on the panel it increased to 1.66%. from these data, the overall efficiency was increased to 7.10% for 1000 ohm load.
Through the experiment and calculated data, it indicates that if the temperature is controlled to a certain limit, the efficiency of the PV panel increases. From figure-8 it has been seen that, the output power has increased with the increase if irradiation. But the amount is significantly large in case of with cooling system which is clearly visible. Figure-9 indicates the solar panel surface temperature. The cooling system did not allow the surface temperature to increase much. But without cooling system, the surface temperature increased significantly and it caused the overall output lower than solar cell with cooling system.

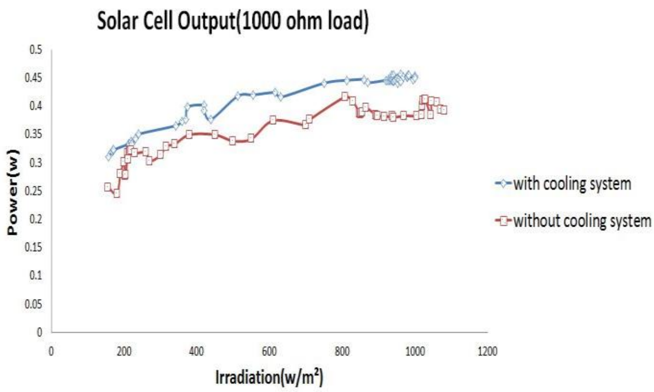

Fig.8: Solar Cell output of 1000 ohm load

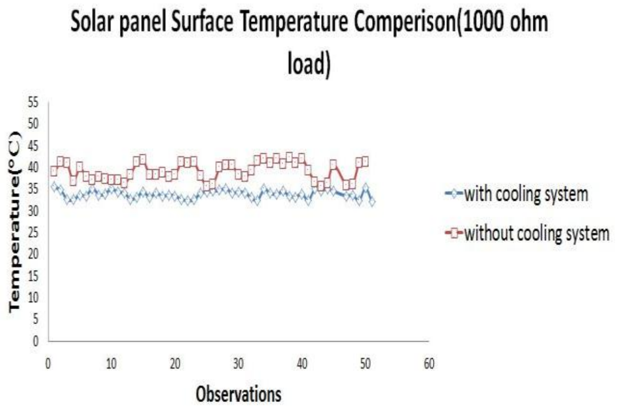

Fig.9: variation in surface temperature for solar panel with cooling system and without cooling system

The figure-10 shows the relationship among power, temperature and radiance. It is seen from the graph that, temperature increase makes a negative impact on the power production. On the other hand, radiance makes a positive impact. With the increase of radiance, power increases. The cooling system made the most use of the radiance to produce power and thus solar cell with cooling system increased the efficiency up to 7.10%.The system also helps to prolong the solar panel life span as high temperature reduces the cell life span and damages the cell significantly faster.

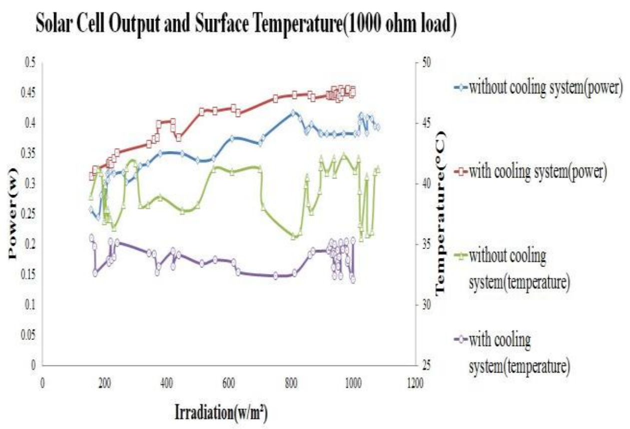

Fig.10: The overall change in power in different irradiation and temperature

5. CONCLUSION

In this research, the performance of PV panels was enhanced by developing an efficient cooling system. The comparison had been made between the output from the PV panels with and without using the cooling system. The objective was to cool the PV panel with the least amount of water and energy. A non-pressurized cooling system was developed based on spraying the PV panels by water. The experimental setup developed to create an effective model that significantly improved the output of the PV cell and to study the influence of cooling on the performance of PV panels. But this system can also be a part of hybrid cooling system which can be implemented in solar power plant. Again there was no option of reusing the water. So for optimal output reuse in the next iteration can be done. In overall the system consumed much power than the solar panel actually could have been produced, but the same system can be implemented in much larger solar panel system and then the cooling system would be beneficial and efficient for the solar cell.

6. REFERENCES

[1] Akbarzadeh A.Wadowski T., *Heat-pipe-based cooling systems for photovoltaic cells under concentrated solar radiation*, Applied Therm. Eng.16(1):81-7,1996

[2] Kluth A., *Using water as a coolant to increase solar panel efficiency, California State science fair, California*, USA, April 2008.

[3] Batoul H., *Flow simulation improves photovoltaic solar panel performance, Technical Report, Schueco International*, Paris, France, September 2008.

[4] Tonui JK, Tripanagnostopoulos Y., *Improved PV/T solar collectors with heat extraction by forced or natural air circulation*. Renew Energy;32:623–37, 2007

[5] Rodrigues EMG, Mel´cio Mendes VMF, Catala˜ o JPS. *Simulation of a solar cell considering single-diode equivalent circuit model. In: International conference on renewable energies and power quality*, Spain, 13–15 April,

[6] Chaniotakis *E. Modelling and analysis of water cooled photovoltaics*, M.Sc. thesis, Faculty of Energy System and Environment, Department of Mechanical Engineering, University of Strathclyde, Glasgow, Scotland; 2001.

[7] Gardas and M V Tendolkar: "Design of Cooling System for PV Panel for Increasing its Electrical Efficiency", *International Journal of Mechanical and Production Engineering (IJMPE)*, p. 63-67, 2012

[8] Garg HP, Datta G. *Performance studies on a finned-air heater*. Energy;14:87–92, 1989

[9] Naphon P. On the performance and entropy generation of the double-pass solar air heater with longitudinal fins. Renew Energy;30:1345–57, 2005

[10] Han JC, Park JS. *Developing heat transfer in rectangular channels with rib turbulators*. Int J Heat Mass Transfer;31:183–95, 1988

[11] Gupta D, Solanki SC, Saini JS. *Heat and fluid flow in rectangular solar air heater ducts having transverse rib roughness on absorber plates*. Solar Energy;51:31–7,1993

[12] Prasad BN, Saini JS. *Optimal thermohydraulic performance of artificially roughened solar air heaters.* Solar Energy;47:91–6, 1991

[13] Tang X, Quan Z, Zhao Y. *Experimental investigation of solar panel cooling by a novel micro-heat pipe array*. Energy Power Eng;2:171–4, 2010

8. NOMENCLATURE

Symbol	Meaning	Unit
PV	Photovoltaic Panel	-
CFD	Computational Fluid Dyanmics	-
STC	Standard Test Condition	-
P	Power	(Watt)
V	Voltage	(V)