Performance of the Solar Photovoltaic Panels with Water Cooling System

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CANDIDATE'S DECLARATION

It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma

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We seek apology for any mistake that might have been in this report although we have tried hard and soul.

ABSTRACT

It is a common phenomenon that absorption of solar radiation increases the temperature of photo voltaic cells , which results in a decrease of efficiency . The objective of this research is to decrease the cell temperature in order to increase the electrical efficiency using cooling system. This cooling system has been developed based on water spraying on PV panels . About 3-4 % efficiency increment has been found in the PV panel with cooling system against the PV panel with no cooling. It has been also found that the average power output increment is about 20% per each panel.

NOMENCLATURE

I	Current at the output of the PV module (A)
V	Voltage at the output of the PV module (V)
P	Power output of the PV module (W)
A	Aperture area of the PV module (m^2)
η	Electrical efficiency of the PV module
η_i	Initial electrical efficiency
η_f	Final electrical efficiency
$\Delta\eta$	Degradation of the module efficiency
ΔP	Increment of Power output of the PV module

Contents

CHAPTER 1

INTRODUCTION

1.1 Introduction

In recent years, renewable energy is widely advocated by many countries. According to the *Clean Energy Trends 2013*[1], the global market of renewable energy reached $246.1 billion, which will be $426.1 billion in 2022. Renewable Energy includes biofuels, Wind energy and Solar PV panels. According to the *Clean Energy Trends 2013*, global market size of solar PV was $2.5 billion in 2000, which became $79.7 billion in 2012. And according to this report, global market size of solar PV will be $123.7 billion in 2022. The global installations expanded to a record of 30.9 GW in 2012, up from 29.6 GW the prior year. The photovoltaic technology has its own advantages comparing to other sources, such as, operate in noiseless mode, totally clean and green energy, highly credibility system with life span expectation between 20-30 years and very low maintenance system.

1.2 Limitation of PV module

During the operation of the PV cell, only around 15% of solar radiation is converted to electricity with the rest converted into heat. The electrical efficiency decreases when the operating temperature of the PV module increases. The ideal P–V characteristics of a solar cell for a temperature variation between 0 ^{o}C and 75 ^{o}C are shown in Fig.1.1, which is implemented from Rodrigues et al. [2].

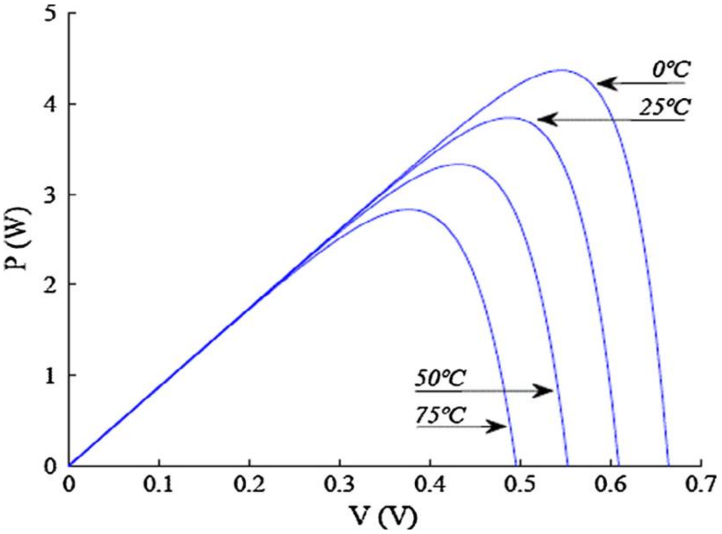

Fig 1.1: P–V characteristics as a function of the module temperature Tm. The module temperature varies between 0 C and 75 C.

Here, the parabolic lines represent the relation between the electrical power output P of the solar cell and the output voltage, V, while the solar irradiance, E, and module temperature, Tm, are kept constant. If any of those two factors, namely Tm and E, are changed the whole characteristics change. This figure represents that the maximum power output decreases with the increment of temperature.

The maximum power output decreases because of the decrement of the voltage output of PV module with the increment of the temperature, while the current output remains almost constant. The ideal I–V characteristics of a solar cell for a temperature variation between 0 °C and 75 °C are shown in Fig.1.2, which is implemented from Rodrigues et al. [2].

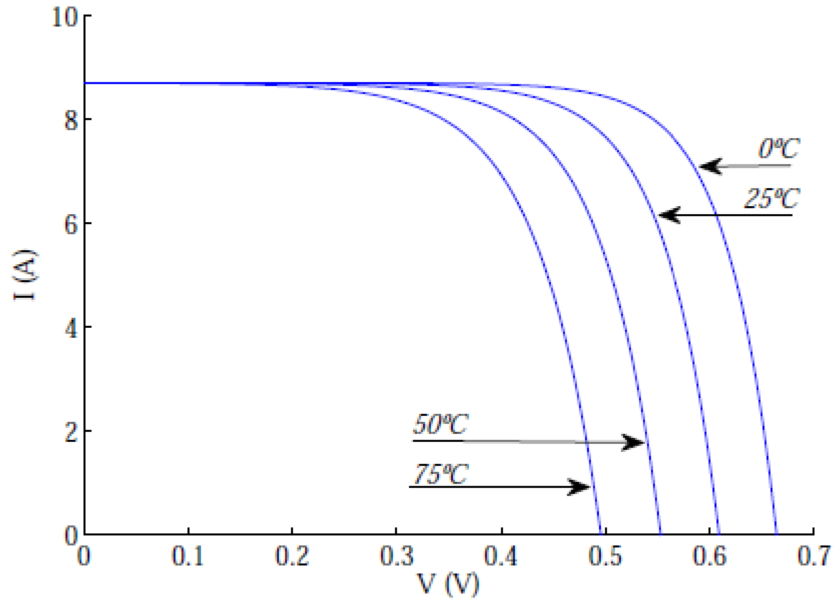

Fig 1.2: I-V characteristics as a function of the module temperature Tm. The module temperature varies between 0-75˚C

1.3 PV Module with Cooling System

It is a well-known fact that the efficiency conversion of solar energy to electrical energy using photovoltaic cells is limited by several factors. Firstly, conversion efficiency falls as the temperature of the photovoltaic cells rise and secondly, the conversion efficiency increases with good solar radiation. It is seen that in rainy season the efficiency of solar PV module is poor due to the lack of insolation. One of the ways to increase efficiency is to decrease the temperature of module with a cooling system, while having good solar radiation. In this study, a cooling system is designed to examine the performance of PV module with comparatively low temperature, and to compare it to the performance of PV module of same characteristics with comparatively high temperature. As a coolant medium, water is available, less costly and has good heat capacity. So as the coolant medium, water is used in this system.

CHAPTER 2
LITERATURE REVIEW

2.1 Literature on PV System

A lot of theoretical and experimental works have been done to improve the performance of the PV solar system.

A hybrid PV/T solar system was designed by Akbarzadeh and Wadowski [3] and they found that cooling the solar photovoltaic panel with water increases the solar cells output power by almost 50%.

Chaniotakis [4] made a hybrid PV/T solar system where water and air were both examined in the combined system as cooling means. It is found that the water-based cooling system increases the solar cells performance higher than the air based cooling system.

An integrated combined system of a photovoltaic (PV) panel was designed by Dubey and Tiwari [5] with a thermal solar water heater. This system has been tested in outdoor condition of New Delhi. They measured the efficiency of the solar PV panels under three different cases, namely Case A – the absorber of the solar collector is fully covered by the PV module, Case B – the absorber is 50% covered by the PV module, and Case C – the absorber is partially covered by PV module, i.e., 30%. Dubey and Tiwari [5] discovered that there is a substantial increase in the efficiency of the solar collector from 33% to 64% from Case A to Case C.

Batoul [6] considered the influence of the air flow on the performance of the PV module by Computational Fluid Dynamics (CFD). The model of the panel was developed in such a way that air can pass under the panel to maximize cooling by natural convection. It was found that geometry and the construction have a great effect on the panel efficiency.

Kluth [7] used water as coolant to increase the efficiency of module. Two small prototypes was made. One was cooled by spraying water using fan and other was remained in solar radiation without spraying water. It was found that the module that was sprayed with water gives more energy than the module that was not sprayed. But this method is not very effective because the panel is not fully covered by water.

Tang et al. [8] made a micro-heat pipe array for solar panels cooling. The cooling system contains of an evaporator section and a condenser section. The heat from the sun vaporizes the liquid inside the evaporator section and then the vapor flows through the condenser section. Then, the condenser section is cooled by either air or water. Therefore, the heat pipe can transfer the heat from solar panel to air or water depending on the system. Using air as a coolant was found to decrease 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.

Fujii et al. [9] experimented on PV panels by made a reservoir of water under the panel. Two PV panel was taken for this experiment, one was with reservoir and other was without reservoir. The reservoir was fulfilled by 20litre water. When the temperature of water exceeded 40˚C, the water was drained out and the reservoir was filled with 20litre water again. The total power consumption of solar module with water-cooled equipment was about three percent higher than that of normal solar module in summer.

2.2 Scope of Present Work

It is concluded from above literature review that using water as a cooling agent is found to be more effective than using air. So our objective to construct a cooling system to get more power output from the PV panels using water as a coolant.
In this experiment, the performance characteristics of the solar PV panels will be examined using water cooling system. The test will be carried out with the six PV panels, situated at the campus of IUT, Gazipur.

CHAPTER 3

DESIGN CONCEPT

3.1 General Discussion

The Photovoltaic panel can work effectively where the solar radiation can be available along the day. Our panels are situated a place where the solar radiation is available along the day. The cooling system is designed so that the water can be sprayed on the panel and this sprayed water can cover all the aperture area of the PV panel. To measure the power output, the panel should be connected with a load.

Usually PV panels are following types:

- Monocrystalline silicon
- Multicrystalline/ Polycrystalline silicon
- Amorphous silicon
- Thermophotovoltaics

Monocrystalline silicon PV panel:

These panels are made from pure monocrystalline silicon. In these cells, the silicon has a single continuous crystal lattice structure with almost no defects or impurities. The main advantage of monocrystalline cells is their high efficiency, which is typically around 15%. The disadvantage of these cells is that a complicated manufacturing process is required to produce monocrystalline silicon, which results in slightly higher costs than those of other technologies.

Multicrystalline/ Polycrystalline silicon PV panel:

Multicrystalline cells are produced using numerous grains of monocrystalline silicon. In the manufacturing process, molten polycrystalline silicon is cast into ingots, which are subsequently cut into very thin wafers and assembled into complete cells. Multicrystalline panels are cheaper to produce than monocrystalline ones because of the simpler manufacturing process required. They are, however, slightly less efficient, with average efficiencies being around 12%.

Amorphous silicon PV panel:

Generally, the main difference between these panels and the previous ones is that, instead of the crystalline structure, amorphous silicon panels are composed of silicon atoms in a thin homogenous layer. Additionally, amorphous silicon absorbs light more effectively than crystalline silicon, which leads to thinner cells, also known as a thin fi lm PV technology.

The greatest advantage of these cells is that amorphous silicon can be deposited on a wide range of substrates, both rigid and flexible. Their disadvantage is the low efficiency, which is on the order of 6%. Nowadays, the panels made from amorphous silicon solar cells come in a variety of shapes, such as roof tiles, which can replace normal brick tiles in a solar roof.

Thermophotovoltaic PV panel:

These are photovoltaic devices that, instead of sunlight, use the infrared region of radiation, i.e., thermal radiation. A complete thermophotovoltaic (TPV) system includes a fuel, a burner, a radiator, a longwave photon recovery mechanism, a PV cell, and a waste heat recuperation system. TPV devices convert radiation using exactly the same principles as photovoltaic devices. The key differences between PV and TPV conversion are the temperatures of the radiators and the system geometries. In a solar cell, the radiation is received from the sun, which is at a temperature of about 6000 K and a distance of about 150 $\times 10^6$ km. A TPV device, however, receives radiation, in either the broad or narrow band, from a surface at a much lower temperature of about 1300 – 1800 K and a distance of only a few centimeters. Although the blackbody power radiated by a surface varies at the fourth power of the absolute temperature, the inverse square law dependence of the power received by the detectors dominates. Therefore, although the power received by a non-concentrator solar cell is on the order of 0.1 W/cm^2, that received by a TPV converter is likely to be 5– 30 W/cm^2 , depending on the radiator temperature. Consequently, the power density output from a TPV converter is expected to be significantly greater than that from a non-concentrator PV converter.

In this experiment, the panels that used are monocrystalline panels.

3.2 Experimental Setup

There are two stages in this experiment

1. Comparison of efficiency of two selected solar cells
2. Comparison between the PV panel without cooling system and the PV panel with the cooling system

Comparison of efficiency of two selected solar cells:

This experiment was performed in July, 2014. The experiment was performed to ensure that the two selected PV panels provide almost the same power output and efficiency. Each of the PV panels was connected to a bulb of 24V and 30W. This experiment was performed from 12:45 P.M. to 4:00 P.M. For measurement of the insolation, a pyranometer is placed on the top of the panels. A voltmeter is installed in parallel and an ammeter is in series with each panel to measure voltage and current respectively. A thermometer is set on the surface of each panel to measure temperature.

Comparison between the PV panel without cooling system and the PV panel with the cooling system:

In this step we applied cooling system on one of the selected panels. This experiment was performed in September, 2014 using a controlled water flow rate of 24 liter/min. The cooling process was repeated each 20 minutes, where the cooling period of PV cells was 5 minutes each. Experiment was started from 11:20 A.M. till 2:00 P.M. where cooling process was started at 11:30 A.M. The remaining components are installed in the same way of previous experiment.

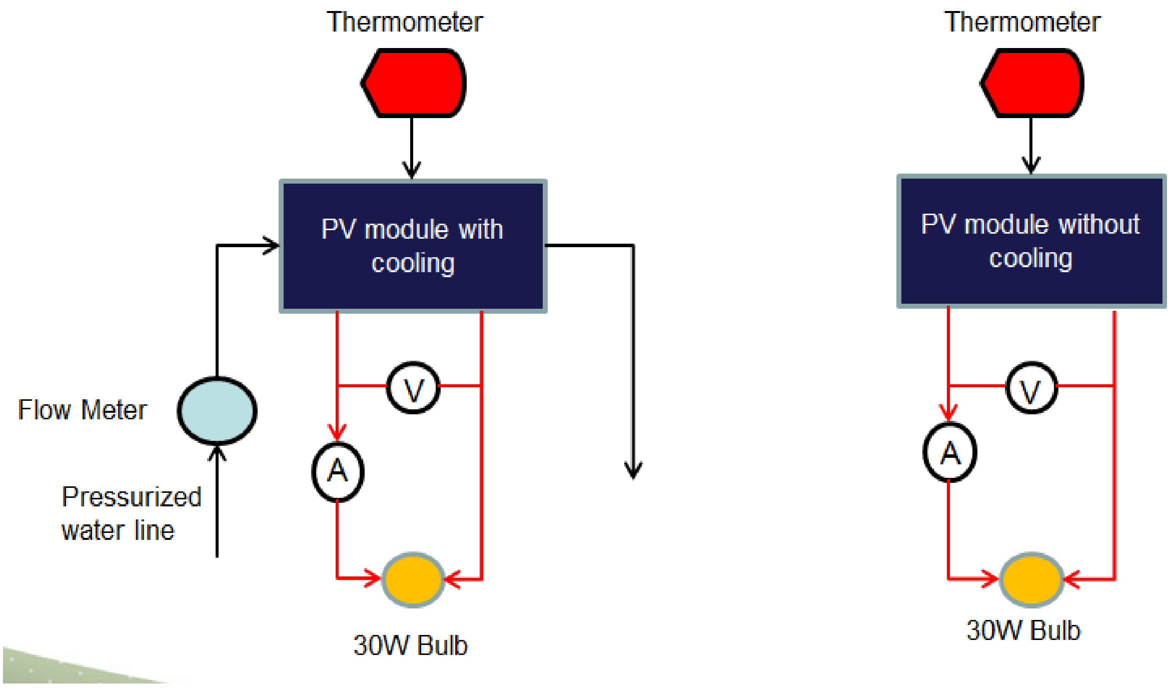

Fig.3.1 : Schematic Diagram of the Experimental Setup

3.3 Components of the Experiment Setup

Components are used in this experiment as follows:

- Two PV modules of 75 W peak-output each
- Flow meter gauge
- Water supply pipe
- A pipe having small holes for water spray
- Thermometer
- Pyranometer
- Voltmeter
- Ammeter
- Load

The Various components that we used in this experiment are discussed below in details:

Solar PV Panels:

For the experiment, two panels were selected of same characteristics. The panels are monocrystalline silicon panels. The aperture area of the PV panel is $0.63m^2$.

The specific characteristics of the PV panels are as follows:

Model:		BP275F
Nominal Peak Power (P_{max}):		75.00W
Voltage @ maximum power (V_{mp}) :		17 V
Current @ maximum power (I_{mp}) :		4.45 A
Short-circuit current (I_{sc}):		4.75 A
Open-circuit Voltage (V_{mp}):		21.4 V
Co-efficient of voltage:		– 0.0022 Volt/cell/°C
Co-efficient of current:		8.9 mA/cm^2/°C
Dimension:	Length:	1188 mm
	Width:	530 mm
	Depth:	43.5 mm
	Weight:	7.5 kg

Front cover: toughened glass 3 mm in thickness

Cell specifications: 36 series connected 125 mm mono-crystalline silicon pseudo square cells.

Flow Meter Gauge:

For the measurement of the water flow rate, a water flow meter is used. The water flow remains constant and it is 24litre/min.

Fig. 3.2: Water Flow Gauge

Water Supply Line:

For the water supply to spray on the PV panels, a pressurized water supply line from the IUT campus is used in this experiment. The water supply line in IUT campus is pressurized, which is supplied from the pump house of IUT.

Pipe for water spray:

A pipe of 0.5 inches diameter and 1188mm length has been used in this experiment for spraying water over the panel. The pipe has 170 holes of 1.5mm each in diameter and 7 mm away from one center to another. The pipe is G.I. pipe and it is opened at one end and welded at other.

Fig. 3.3: Pipe for Spraying Water

Thermometers:

Two thermometers are used in this experiment to measure the surface temperature of PV modules.

Pyranometer:

The Pyranometer is used for the measurement of solar radiation received by the aperture area of the panel.

Fig.3.4: Pyranometer

Voltmeter and Ammeter:

For measurement of the voltage and current at the output of the PV panels, voltmeter and ammeter are used respectively. For each panel, there is one voltmeter and one ammeter has been used. The connection of voltmeter with PV output is in parallel and ammeter is in series.

Load:

In this setup, one bulb of 24V and 30W has been used as a load for each panel.

The following images gives a partial view of setup:

Fig. 3.5: Installed setup in IUT Campus

CHAPTER 4

METHOD OF ANALYSIS

4.1 Performance Test: Related Terminologies

The following parameters to be recorded for the performance test:

- Temperature of the surface of the panel(T)
- Insolation (G)
- Aperture area (A)
- Output voltage (V)
- Output current (I)

4.2 Performance Test: Comparative Study

To compare the performances between the four experimental setups the data obtained from the experiment are to be plotted in graphs:

- Power output vs. Time
- Temperature vs. Time
- Efficiency vs. Time

4.3 Equations

- Efficiency of the PV module:

$$\eta = \frac{V \times I}{G \times A} = \frac{P}{G \times A}$$

Where, I= Output current (A)

V= Output voltage (V)

G= Insolation (W/m²)

A= Aperture area (m²)

P= Power Output(W) = V×I

- Degradation of cell efficiency:

$$\Delta\eta = \frac{\eta_i - \eta_f}{\eta_i} \times 100$$

Where, $\Delta\eta$= Percentage of degradation of cell efficiency

η_i= Initial efficiency

η_f= Final efficiency

CHAPTER 5

RESULTS AND DISCUSSION

5.1 Experimental Data

For comparison of efficiency of two selected solar cells:

The following data is taken in 08 July, 2014: For module 1

No. of Observation	Time	Insolation, G(W/m²)	Voltage, V (Volt)	Current, I(A)	Power, P (W)	Temp. of surface, T (°C)	Efficiency, η (%)
1.	12:45pm	350	16.2	1.1	17.82	43	8.08
2.	1:00pm	625	18.2	.8	14.56	48	3.7
3.	1:15pm	700	17.2	1.3	22.36	46	5.07
4.	1:30pm	640	18.58	.8	14.9	43	3.7
5.	1:45pm	470	17.8	.9	19.8	41	6.69
6.	2:00pm	450	17.5	.7	12.25	43	4.32
7.	2:15pm	475	17.88	1.5	26.82	43	8.96
8.	2:30pm	550	18	1.3	23.4	48	6.75
9.	2:45pm	760	17.9	.8	14.32	52	3
10.	3:00pm	700	18.25	1.2	21.9	47	4.97
11.	3:15pm	690	17.9	1.8	32.22	51	7.41
12.	3:30pm	600	17.65	1.5	26.48	50	7.0
13.	3:45pm	200	16	.4	6.4	41	5.07
14.	4:00pm	460	17.25	1.7	29.33	46	10.12

For module 2:

No. of Observation	Time	Insolation, G(W/m²)	Voltage, V (Volt)	Current, I(A)	Power, P (W)	Temp. of surface, T (°C)	Efficiency, η (%)
1.	12:45pm	350	15.7	1	15.7	43	8.6
2.	1:00pm	625	17.5	.8	14.0	48	3.55
3.	1:15pm	700	18.35	1.1	20.2	46	4.58
4.	1:30pm	640	18.33	.7	12.83	42	3.18
5.	1:45pm	470	17.63	1.2	21.16	41	7.14
6.	2:00pm	450	15.47	.7	10.83	42	3.82
7.	2:15pm	475	17.38	1.5	26.07	45	8.71
8.	2:30pm	550	17.95	.8	14.36	48	4.14
9.	2:45pm	760	17.8	.6	10.7	52	2.23
10.	3:00pm	700	18.05	1.5	27	48	6.12
11.	3:15pm	690	17.8	1.7	30.26	52	6.96
12.	3:30pm	600	16.3	1.2	19.56	50	5.17
13.	3:45pm	200	16	.4	6.4	41	5.07
14.	4:00pm	460	17.35	1.7	29.5	46	10.2

For Comparison between the PV panel without cooling system and the PV panel with the cooling system:

This experiment was performed in 15 September,2014: For Module without Cooling System

No. of Observation	Time	Insolation, G(W/m²)	Voltage, V (Volt)	Current, I(A)	Power, P (W)	Temp. of surface, T (°C)	Efficiency, Ƞ (%)
1.	11:20am	800	17.5	.9	15.45	52	3.06
2.	11:25am	780	17.86	.2	17.86	52	3.63
3.	11:30am	750	14.73	.5	7.365	54	1.56
4.	11:35am	550	16.53	2.2	36.37	46	10.5
5.	11:40am	650	17.97	1.5	26.96	50	6.6
6.	11:45am	870	17.48	1.8	31.46	53	5.74
7.	11:50am	550	13.4	2.1	28.14	49	8.12
8.	11:55am	230	15.4	.8	12.32	44	8.5
9.	12:00pm	450	16.01	2.4	38.42	45	13.55
10.	12:05pm	280	14.75	.9	13.28	44	7.52
11.	12:10pm	500	15.9	.8	12.72	45	4.04
12.	12:15pm	400	11.2	2	22.4	42	8.9
13.	12:20pm	600	17.3	2.3	39.8	43	10.5
14.	12:25pm	770	17.85	2.3	41	44	8.45
15.	12:30pm	750	17.45	2.3	17.51	48	3.7
16.	12:35pm	550	16.53	2.2	36.37	46	10.5

For Module without cooling system (Cont.)

No. of Observation	Time	Insolation, G(W/m²)	Voltage, V (Volt)	Current, I(A)	Power, P (W)	Temp. of surface, T (°C)	Efficiency, η (%)
18.	12:40pm	450	16.01	2.4	38.42	45	13.55
19.	12:45pm	500	13.5	1.5	20.25	38	6.4
20.	12:50pm	770	17.85	2.3	41	42	8.45
21.	12:55pm	650	17.45	2.3	40.13	44	9.8
22.	1:00pm	600	17.3	2.3	39.8	47	10.5
23.	1:05pm	810	17.16	2.1	36	50	7
24.	1:10pm	750	17.45	2.3	17.51	53	3.7
25.	1:15pm	600	17.51	1	17.51	51	4.6
26.	1:20pm	650	16.7	1	16.7	51	4.07
27.	1:25pm	810	17.16	2.1	36	50	7
28.	1:30pm	770	17.85	2.3	41	42	8.45
29.	1:35pm	650	17.45	2.3	40.13	44	9.8
30.	1:40pm	600	17.3	2.3	39.8	47	10.5
31.	1:45pm	770	17.85	2.3	41	49	8.45
32.	1:50pm	750	17.45	2.3	17.51	53	3.7
33.	1:55pm	600	17.51	1	17.51	51	4.6
34.	2:00pm	650	16.7	1	16.7	51	4.07

For module with cooling system

No. of Observation	Time	Insolation G(W/m²)	Voltage, V (Volt)	Current, I(A)	Power, P (W)	Temp. of surface, T (°C)	Efficiency, η (%)
1.	11:20am	800	17.5	.9	15.45	52	3.06
2.	11:25am	780	17.86	.2	17.86	52	3.56
3.	11:30am	750	14.73	.5	7.365	54	1.56
4.	11:35am	550	20.55	2.4	49.32	27	14.2
5.	11:40am	650	20.47	1.5	30.71	33	7.5
6.	11:45am	870	19.55	1.3	25.41	41	4.63
7.	11:50am	550	15.75	2	31.5	41	9.1
8.	11:55am	230	17.62	.8	14.1	27	9.73
9.	12:00pm	450	18.3	2.2	40.26	31	14.2
10.	12:05pm	280	16.89	1	16.89	32	9.6
11.	12:10pm	500	17.9	.8	14.32	35	4.5
12.	12:15pm	400	16.43	2.1	34.5	28	13.7
13.	12:20pm	600	19	2.4	45.6	36	12.1
14.	12:25pm	770	20.05	2.4	48.58	42	10
15.	12:30pm	750	18.5	1.9	35.15	46	7.4
16.	12:35pm	550	20.55	2.4	49.32	27	14.2

For -module with cooling system (cont.)

No. of Observation	Time	Insolation, G(W/m²)	Voltage, V (Volt)	Current, I(A)	Power, P (W)	Temp. of surface, T (°C)	Efficiency, η (%)
18.	12:40pm	450	18.3	2.2	40.26	31	14.2
19.	12:45pm	500	15.96	1.5	23.94	30	7.6
20.	12:50pm	770	20.05	2.4	48.58	36	10
21.	12:55pm	650	19.95	2.3	45.9	28	11.2
22.	1:00pm	600	19	2.4	45.6	36	12.1
23.	1:05pm	810	18.7	2	37.4	42	7.3
24.	1:10pm	750	18.5	1.9	35.15	46	7.4
25.	1:15pm	600	20	1.1	22	28	5.82
26.	1:20pm	650	19.27	.9	17.34	34	4.23
27.	1:25pm	810	18.7	2	37.4	40	7.3
28.	1:30pm	770	20.05	2.4	48.58	42	10
29.	1:35pm	650	19.95	2.3	45.9	28	11.2
30.	1:40pm	600	19	2.4	45.6	36	12.1
31.	1:45pm	770	20.05	2.4	48.58	38	10
32.	1:50pm	750	18.5	1.9	35.15	46	7.4
33.	1:55pm	600	20	1.1	22	28	5.82
34.	2:00pm	650	19.27	.9	17.34	34	4.23

5.2: Result of Comparison of Two Selected PV panels

Comparison of the power output and efficiency of two selected PV panels are shown in Fig. 5.1 and 5.2 respectively. It can be seen from these figures that selected two panels gives almost same efficiency and output power. It is also found in these graphs that when temperature increases, efficiency and power output decrease. The maximum temperature of the surface of the module raised up to 52 ˚C.

5.3: Result of comparison of the PV module with cooling system and PV module without cooling system

Comparison of the power and efficiency of PV module with cooling system and PV module without cooling system are shown in Fig: 5.3 and Fig: 5.4. It can be seen from this figures that the PV module with cooling system gives better efficiency and power output than those of PV module without cooling system. It is also found that a rise in the solar cells temperature by 10˚C from 27˚C-46˚C results in decreasing efficiency of the cells from 12.1 to 7.4%, which is equivalent to the degradation of panel efficiency 38.84%.

By this experiment, it is found that the power output from the panels can be increased about 20%.

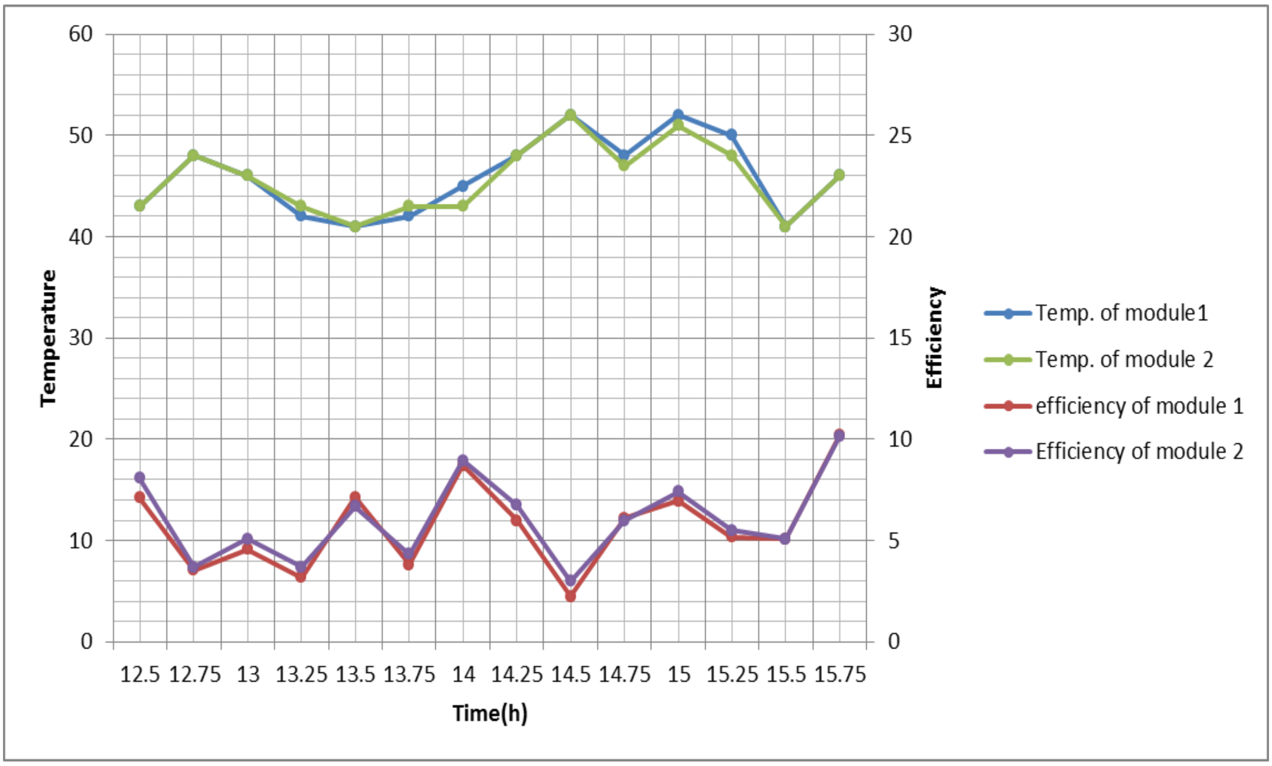

Fig. 5.1: PV module temperature and efficiency vs. time graph

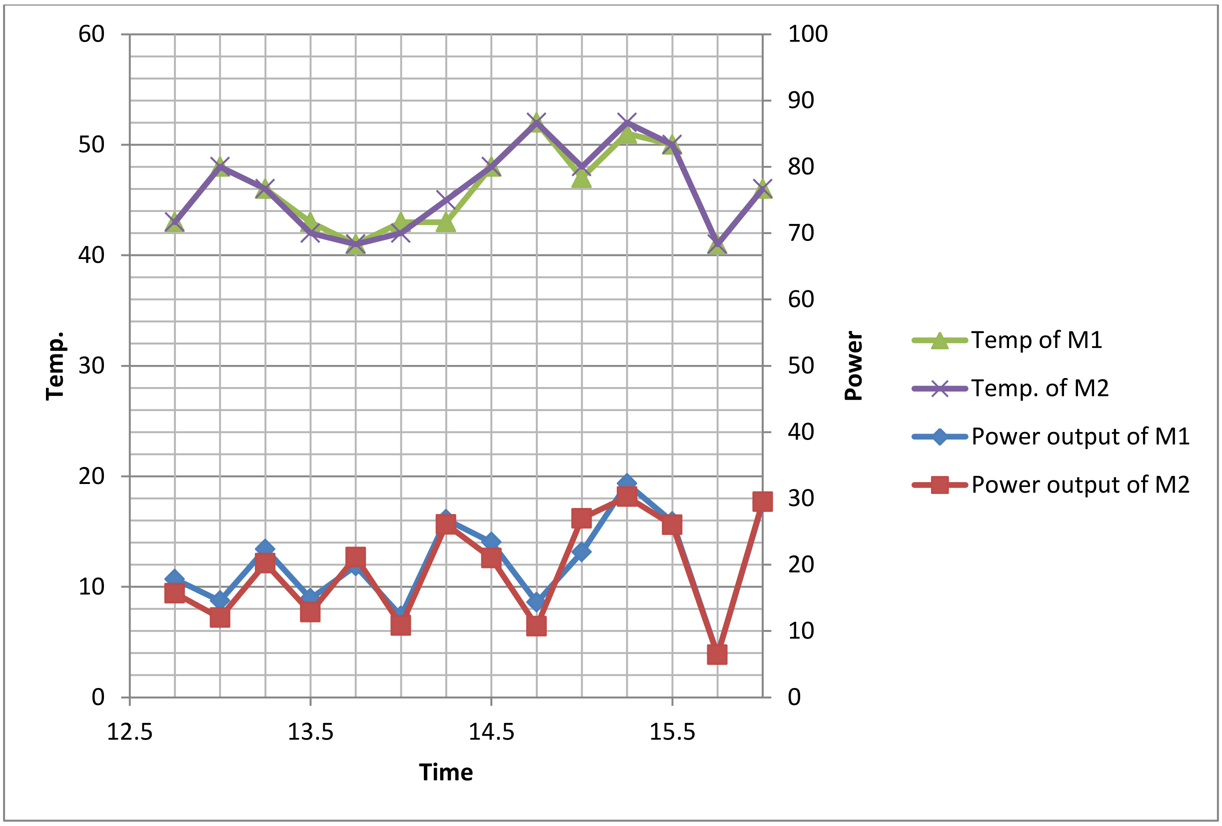

Fig. 5.2: Temperature and Power output vs. Time Graph

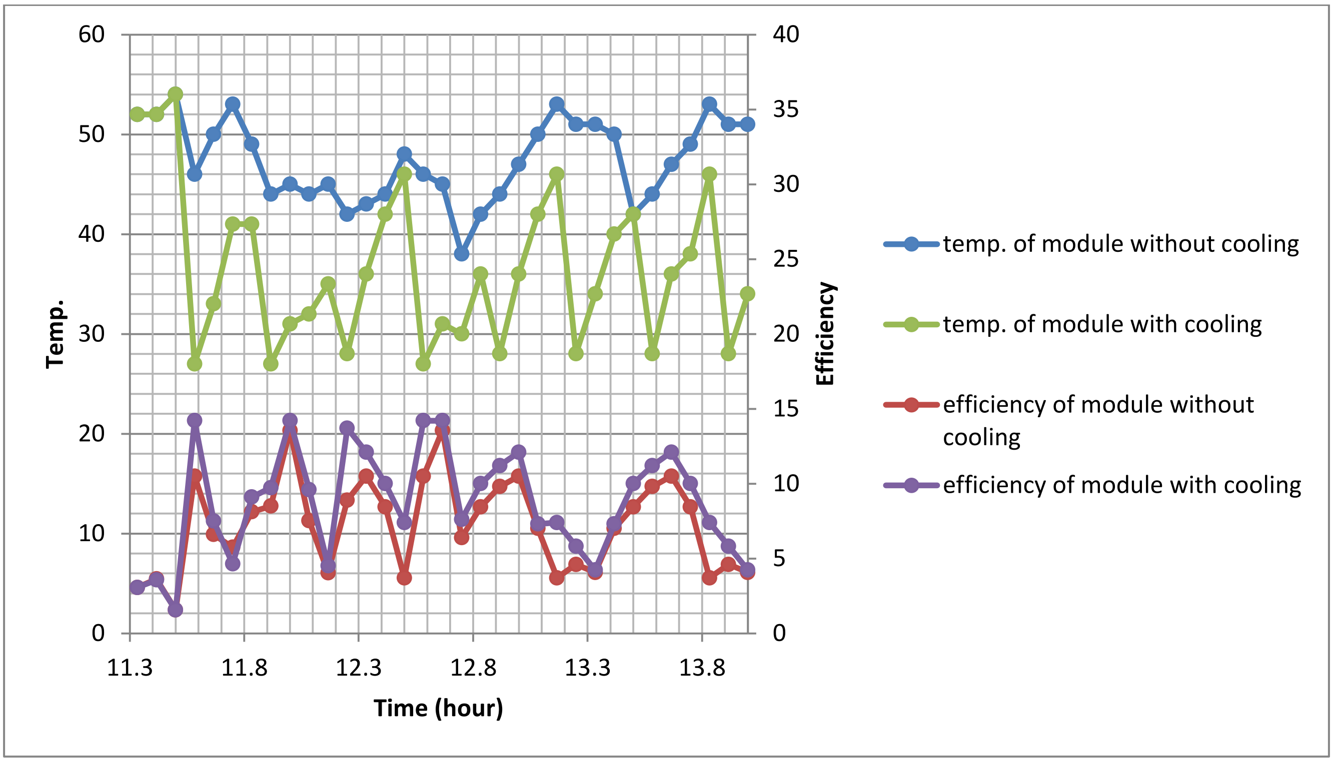

Fig. 5.3: Temperature and Efficiency vs. Time Graph

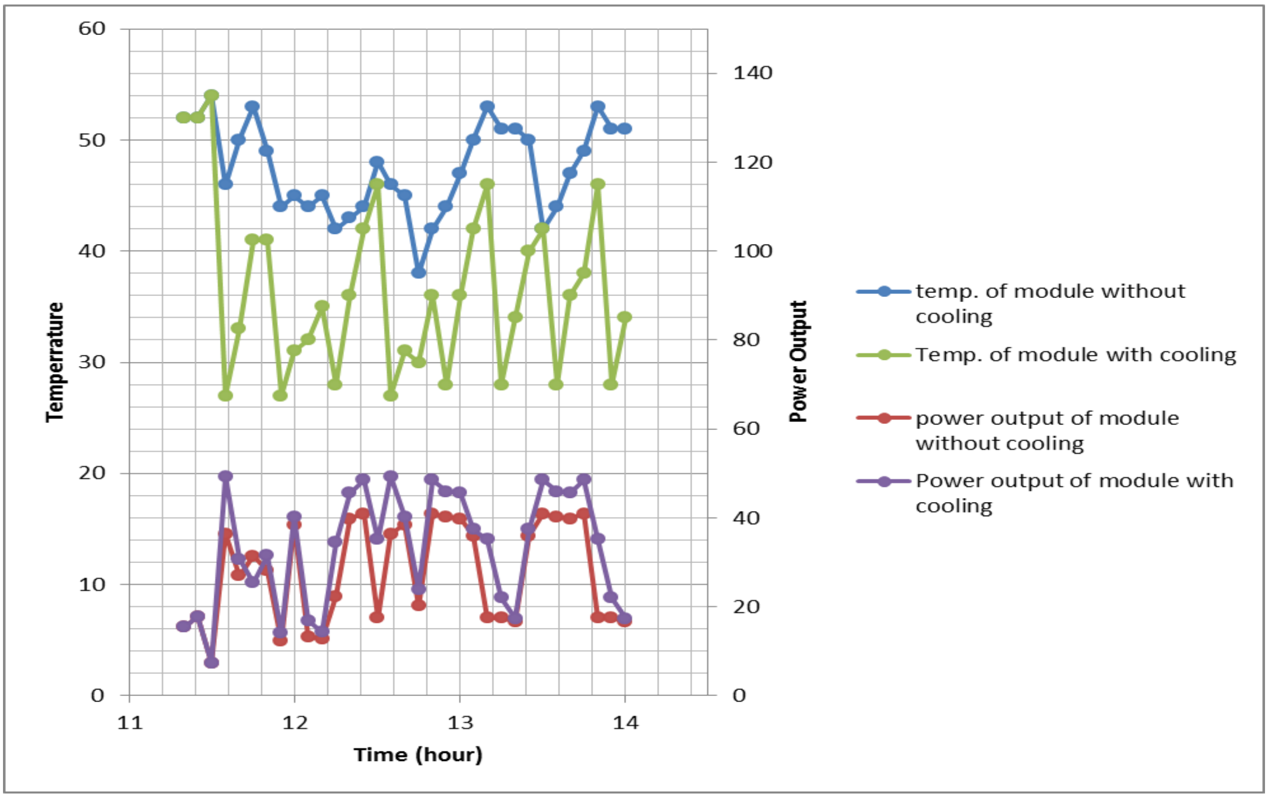

Fig. 5.4: Temperature and Power Output vs. Time Graph

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1: Conclusions

The implementation of the water cooling system on the PV module shows variations in the parameters related to it. From our experimental analysis we can come to a conclusion mentioned here:

- ❑ It is possible to cool the PV panels using the proposed cooling system.
- ❑ The cooling system will be running every time for 5 min, in order to decrease the module temperature. The average cooling rate has been found 3.6˚C/min.
- ❑ By this research, it is clearly seen that efficiency of PV panels can be increased by precise cooling.
- ❑ The power output can also be increased by cooling.

6.2: Recommendations

From the experimental analysis of the project PV solar energy system is found very significant in terms of net power output and efficiency. The following recommendations are propounded for the better investigations of the system:

- ❑ The study of the system should be conducted in the summer season of the year to get the better performance.
- ❑ The electrical efficiency of the PV module should be measured under different load conditions to get accurate result.
- ❑ For more accurate and detail results Data logger can be installed in the experimental setup.
- ❑ The cooling water can be re-circulated to reduce the amount of wastage of water.

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