Investigation on Effect of Surface Temperature Optimisation on the Performance of Solar Panel

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Abstract - *As working temperature plays a critical role in influencing solar PV's electrical output and efficiency, it is necessary to examine possible way for maintaining the appropriate temperature for solar panels. This research paper is aiming to investigate practical effects of solar PV surface temperature on output performance and efficiency. Experimental works were carried out under different radiation condition for exploring the variation of the output voltage, current, output power and efficiency. After that, the cooling test was conducted to find how much efficiency improvement can be achieved with the cooling condition. In the test condition, air and water cooling technique is used for the cooling purpose. In the air cooling technique, the cooled condition gives 40% more efficiency and power as compared to the no cooling condition. Similarly, in water cooling technique 30% more power and efficiency achieved as compared to the no cooling condition. From the above cooling technique, the air cooling technique is the more efficient cooling as compared to water cooling as the power and efficiency is more.*

***Key Words*: Solar PV1, Cooled condition2, Efficiency improvement3**

1. INTRODUCTION

Solar energy technologies include solar heating, solar photovoltaic, concentrated solar power and solar architecture, which can make considerable contributions to solving some of the most urgent problems the world now faces. The most common way of harnessing energy from the sun is through photovoltaic (PV) panels. In the continuous development of PV panel the main aim is to increase the performance and life period of the panel. By research, the increase in performance can be achieved upon the cooling of the solar panel. Hence the increase in efficiency is achieved by 40% from the normal efficiency of the panel in cooling condition. In general, the polycrystalline PV's lab efficiency is around 24% but the normal environmental efficiency is 13-15% approximately.

The researcher found that the heating of the panel causes the more reflection and the radiation incident hence deceases so the output performance decreases as the efficiency and power decreases. So the researcher effort moves on the cooling of the panel to increase the output power and the efficiency by the any method. Some researcher analysed the panel cooling by renewable energy such as the water and the wind energy. [1]John K. Kaldellis(2013) analysed that the panel surface temp affects the efficiency of the panel. He utilises the wind velocity for the cooling of the panel surface temperature which give panel efficiency increase by (0.40-0.50)%/°C. [2] D.B.Sivakumar experimented the temp over the efficiency by using the photochemical material. Hence he concluded with the efficiency increase to (5.02-7.92)%. [3] Aarti Kane investigated upon the effect of panel life period and efficiency with the temp rise of the surface of the panel. She utilises thermo electric module (TEM) and the efficiency is increased to 11.34% with temp maintained at 45.1 ^{0}C. [4] Yogesh S Bijjargi analyzed upon the cooling and no cooling of the PV panel and get the comparison result. In result the more efficiency will occur in cooling condition. [5] Nasrudin Abd Rahim uses the passive cooling method for the cooling of panel surface and get the efficiency increase by 15.5% from original efficiency. [6] Yanping Du analyzed upon the temp reduction by utilizing the Nano heat pipes in the panel surface and get the efficiency increase by 16.3% from the rated condition. [7] Zhijun Peng analyzed upon the relation between temperature and life period of the panel. He got that the cooling of the panel increases the life period of the panel by 3 years.

For reducing the working temperature of solar PV panels, some researches have been reported with possible solutions. [8] D. Prince Winston experimented on hybrid photovoltaic/thermal (PV/T) active solar and the thermal efficiency and overall efficiency increased by 25%. [9] Alberto Benato experimented upon the cooling of the panel by water cooling technique and hence the efficiency is increased by 3% from the normal one. [10] Yasamin Khanjari experimented upon the solar design and modification which leads to the increase in 12-12.4% efficiency. [11] Kasaeian et al. applied air flow for providing enforced convection to cool down solar panels' temperature and resulted in an efficiency increase of 12. [12] Both Bahaidarah and Nizetic et al. employed high cost water spray technology to cool down solar panels. Perhaps because their test locations and other test conditions were different, Bahaidarah achieved over 60% increase in electric output while Nizetic et al. got only 17%. [13] Using a simple clay pot for providing evaporative cooling water for cooling down solar panels, Ramkumar et al. made an efficiency increase of 60%. [14] Spertino et al. developed a numerical model for investigating the cooled PV performance and demonstrated the increase of electric power could be over 30%. However, although those researches have confirmed that cooled solar PV, in particular with water as cooling liquid, can effectively improve the electric output efficiency, so far no practical application has been published.

Meanwhile, a research made by Su et al. [17] which experimentally compared different fluid in the cooling system suggested that water cooled PV-Thermal system is most efficient for improving both electric and thermal performances. A review from Guo et al. [18] for various cooled PV systems has also provided a similar conclusion.

The research presented in this manuscript is aiming to investigate practical effects of solar PV surface temperature on output performance, in particular efficiency. As experimental works were carried out under different radiation condition for exploring the output efficiency, cooling test was performed to find how much efficiency improvement can be achieved with cooling condition. By analysing the variation of electric output as function of solar panel surface temperature under different conditions, effects of temperature on output efficiency were demonstrated quantitatively. Finally, a practical cooling system was proposed for residential solar PV system and the cost payback time was analysed and compared with non-cooled system, in order to assess its energy and economic benefits.

2. EXPERIMENTAL RIG AND CONDITIONS

A mono crystalline-Si solar panel(1) was used with area of 0.277m^2 and a max power output of 40W .This panel consists of 36 no of cell & each cell producing 1.02 watt power with effective radiation. The panel is placed in the plywood with covered of thermo cool. The panel got the radiation from the electric bulb (2) of 900watt and 1100watt with a combination of 200watt and 100watt bulbs. The electric bulb consumes electricity of 900watt and 1100 watt but it produces radiation of 700watt and 800watt as the at most condition. The panel and the electric bulb maintain distance of 2' with ground distance of 8". Therefore the panel receives irradiation of 700W/m^2 and 800 W/m^2. The panel is connected with a battery (5) operating with 12volt and a 3Ω resistance (4) is used for the load calculation. A switch board (3) is placed between solar panel, battery & resistance. This has 5 switches: 3 switches for DC & 2 switches for AC power supply. In 3 switches of DC power supply one for bulb, one for fan & another for power supply to the voltmeter-ammeter. In this voltmeter-ammeter is attached to measure the output voltage & current the solar panel. And also have 2 switches for AC power supply one for pump & one for 3`Ω resistance LED light. Detail specifications of the solar panel and other element used in the experiment in Table 1. The schematic diagram of the experimental set-up is shown in fig 1.

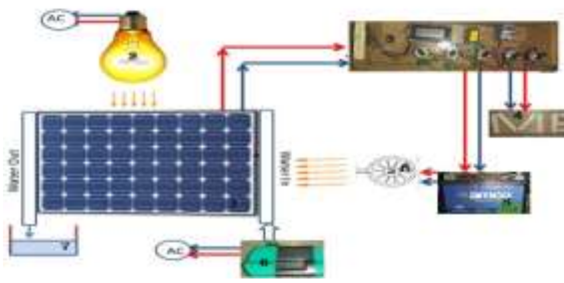

Figure 1:- Schematic diagram of experimental setup.

1. Solar Panel, 2.Electric Bulb 3. Switch Board, 4.Resistance, 5.Battery, 6.Pump, 7.Water Collection Tank, 8. DC Fan

Table no 1 Specification and components used in experimental analysis

Si No	Name	Specification
1	Plywood frame	Length- 3'4" Width- 1'3" Height- 3'
2	Solar panel	P_{MAX} = 40W Mono-crystalline panel No of cells - 36 V_{OC}= 21.6 V I_{SC} = 2.5 A V_{MP} = 17.2 V I_{MP} = 2.12 A Dimensions=(0.9144 X 0.3048 X 0.001)
3	Switches	5
4	Electric bulb	5 no of 200 watt bulb 3 no of 100 watt bulb
5	Electric pump	V_{input}= 220V I_{input}= 1.12A water flow rate= 750lit/hr
6	Battery	Voltage= 12V Current= 5A
7	Load	3`Ω resistance LED light No of LED used= 24
8	Thermocouple	4 no of K-type thermocouple sensor Temp. range- 200°C ~ 1372°C (-328°F ~ 2501°F)
9	Fan	V_{input}= 12V I_{input}= 1.12A Air flow rate= 4 m/s Diameter= 15cm or 6'

The experiment was conducted in different ways such as non-cooling and cooling condition. In the non-cooling condition the 2 types of readings has been taken such as in battery charging and without battery charging. In cooling condition also 2 types of analysis is done such as with battery charging and without battery charging. In all the cases the temperature is measured using the thermocouple arrangements placed at different location on the surface of the panel. The panel is placed in the horizontal condition and the panel receives the radiation from the bulb in the horizontal ways also. For the horizontal cause the panel assumes that there is no angle of radiation and the all the values has been zero. In the testing phenomenon the panel is placed in the perfectly environmental condition and the all the readings has been taken in the ambient environmental condition.

In the water cooling the pump is utilised where as in the fan cooling the DC fan is used for the cooling process. The cooling is done over the panel surface directly.

3. EXPERIMENTAL RESULTS AND DISCUSSION

3.1 Solar PV output performance under different radiation without cooling condition

Here in the experimental analysis, we experimented upon 2 types of radiation such as 1100W/m² and 900W/m². The experiment concludes maximum of 7.78W of power and 4.03% of efficiency and 8.28W of power and 5.01% of efficiency at charging and without charging of the battery.

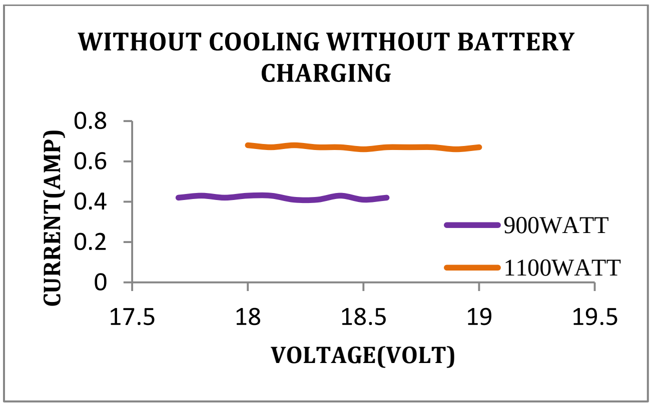

FIG no 2 Graph between Voltage and Current at Without Cooling Without Battery Charging gives more current at 1100W/m².

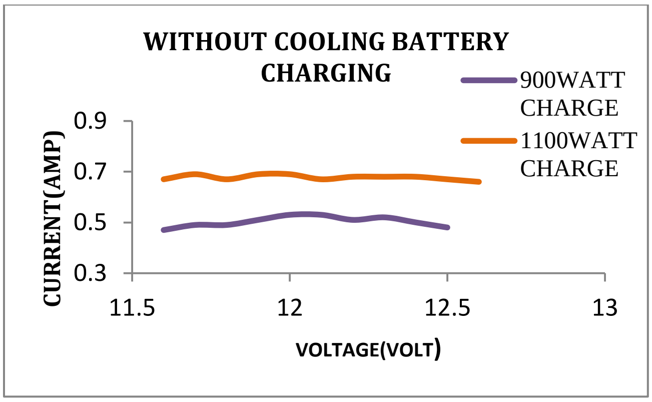

Fig no 3 Graph between Voltage and Current at Without Cooling With Battery Charging gives more current as compared at 1100W/m² to 900W/m²

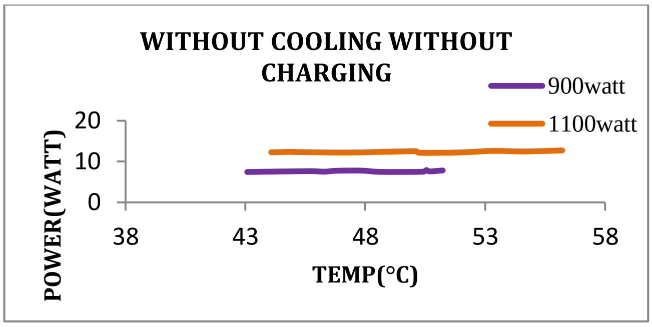

Fig no 4 Graph between Temp and Power at Without Cooling Without Battery Charging gives more power at 1100W/m²

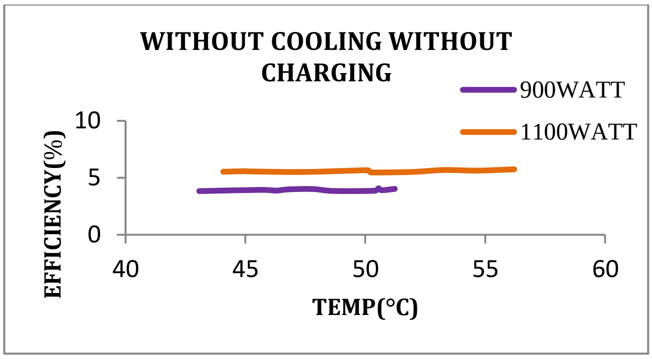

Fig no 5 Graph between Temp and Efficiency at Without Cooling without Battery Charging 1100W/m² gives more efficiency

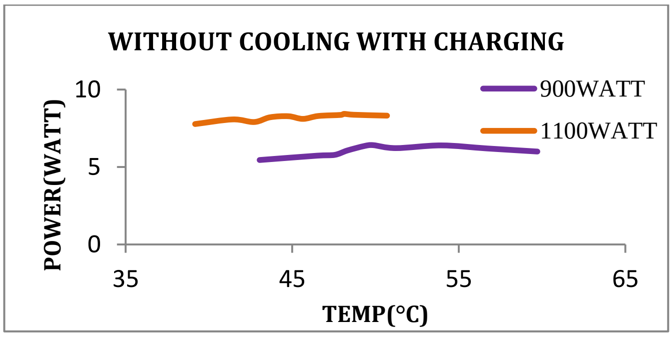

Fig no 6 Graph between Temp and power at Without Cooling with Battery Charging. we achieve more power at 1100W/m²

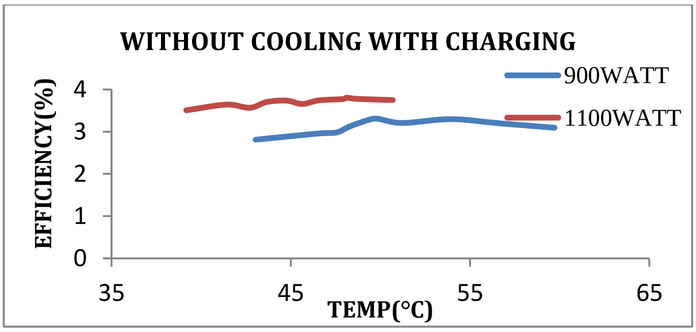

Fig no 7 Graph between Temp and Efficiency at Without Cooling with Battery Charging

It can also be seen from those figures that the surface temperature always keeps increase with radiation, and the stable surface temperature is always obviously higher than the maximum efficiency temperature.

From the entire above graph we concluded that the higher irradiation gives more power and more efficiency. But it depends upon the panel surface temperature which directly affects the panel output voltage and current. From the variation of the voltage and current the power and efficiency varies. The higher the panel surface temperature reduces the panel power and efficiency.

From the experiment, we concluded that the panel surface temperature affects the power and efficiency of the panel. So we must cool the panel surface temperature by using and cooling medium.

3.2. Solar PV performance under cooled condition

3.2.1 Air cooling technique

In the cooling procedure, a DC fan is installed to give airflow over the panel as the atmospheric air flows. The air flows reduce the temp of solar panel so it becomes the optimum condition for receiving the irradiation.

In the cooling condition also 4 experiments has been conducted as of the no cooling condition. Here also 900W and 1100W of electrical power supply was given to the electric bulb. In the 900W supply of electricity supply to experiments were conducted such as with battery charging and without battery charging condition. In 1100W of power supply, with battery charging and without battery charging the experiments were continued.

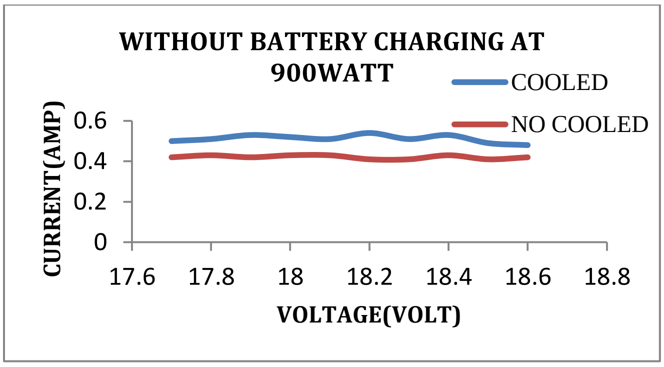

Fig no 8 Graph between Voltage and Current at 900W without Battery Charging

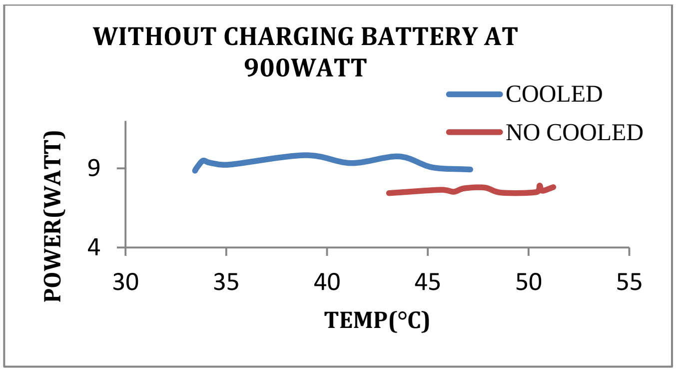

Fig no 9 Graph between Power and Temp at 900W without Battery Charging

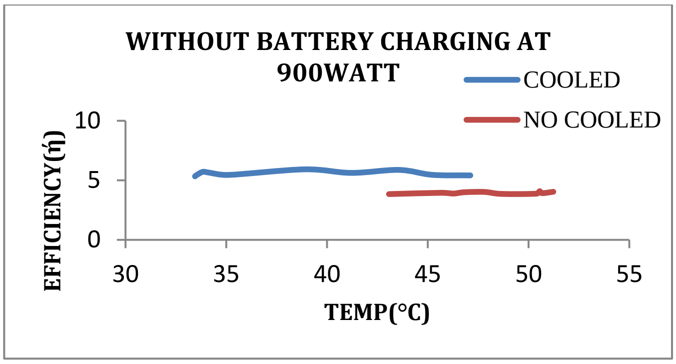

Fig no 10 Graph between Efficiency and Temp at 900W without Battery Charging

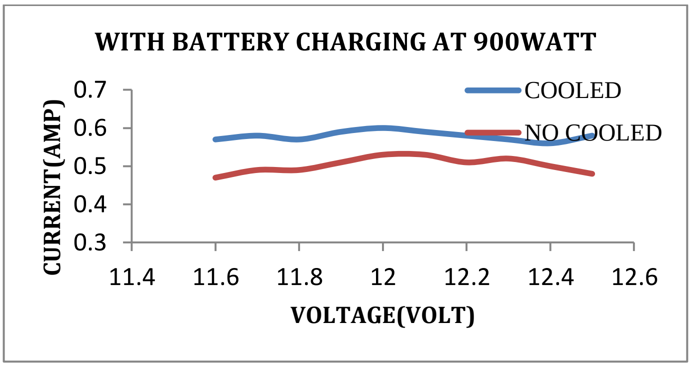

Fig no 11 Graph between Voltage and Current at 900W with Battery Charging

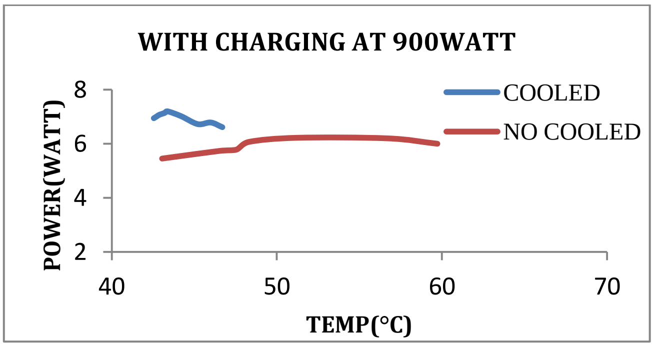

Fig no 12 Graph between Power and Temp at 900W with Battery Charging

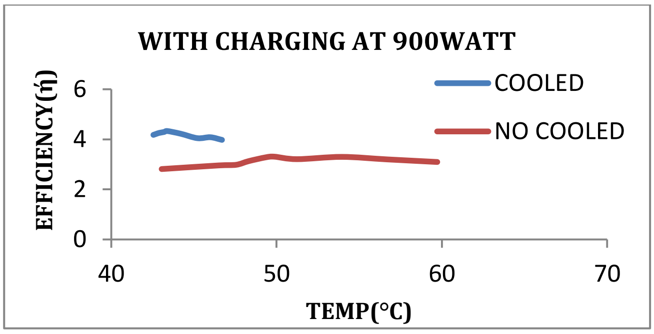

Fig no 13 Graph between Efficiency and Temp at 900W with Battery Charging

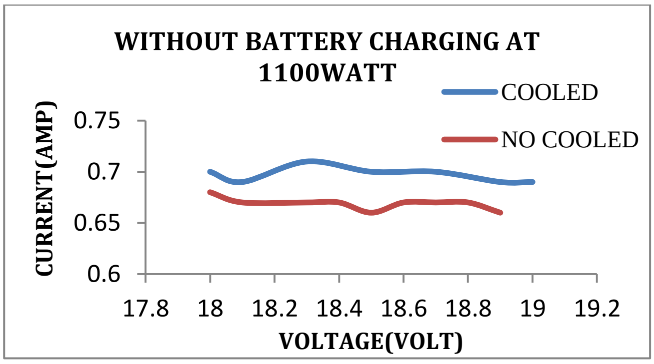

Fig no 14 Graph between Voltage and Current at 1100W without Battery Charging

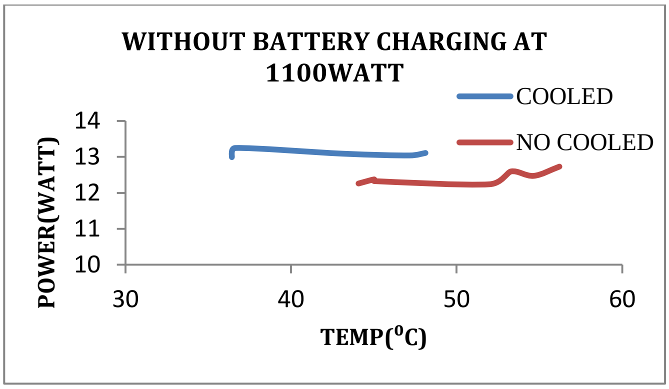

Fig no 15 Graph between Power and Temp at 1100Wwithout Battery Charging

The experiment is done with the irradiation of 800W/m².From the above graph in the charging of the battery in cooled condition gives more efficiency as compared to the non-cooled condition.

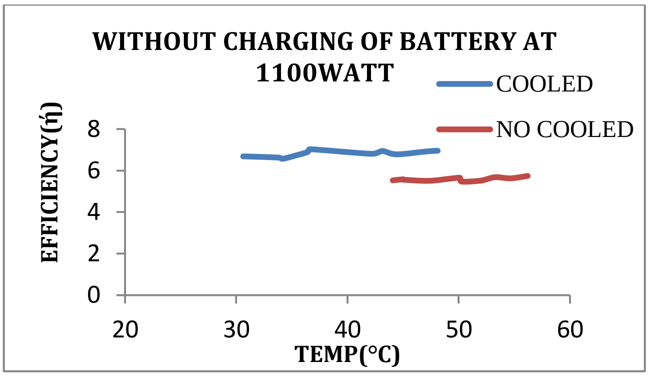

Fig no 16 Graph between Efficiency and Temp at 110Wwithout Battery Charging

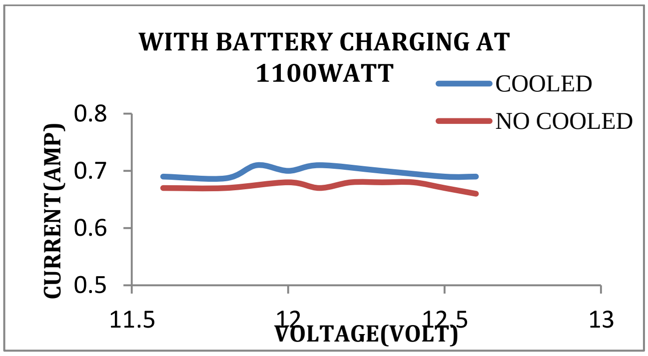

Fig no 17 Graph between Voltage and Current at 1100W with Battery Charging

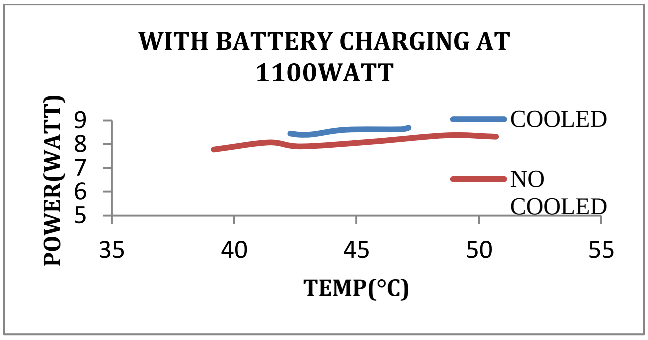

Fig no 18 Graph between Power and Temp at 110Wwith Battery Charging

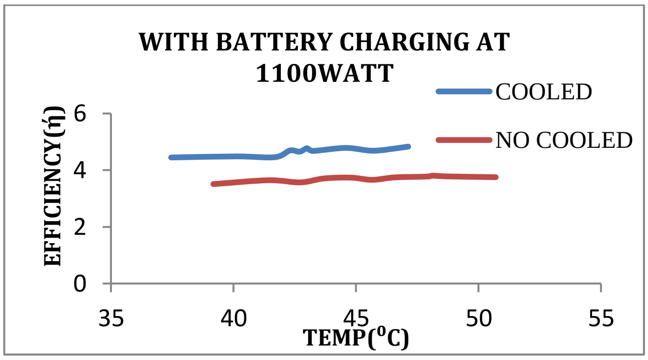

Fig no 19 Graph between Efficiency and Temp at 1100W without Battery Charging

From the above graph, here we got more efficiency as compared to the low irradiation.

3.2.2 Water cooling technique

In the cooling procedure, a pump is installed to flow the water above the panel surface with varying flow rate of water. The water flow reduces the temp of solar panel also reduces the irradiation losses due to reflection. The water flows 2 way of technique.in the 1st way the layer wise water is flows on the panel, in the 2nd the quick water flows technique i.e. the water flow on the surface of the panel without layer formation. The water was in the room temperature i.e. 25°C. The pump has the water flow rate 750 l/h with consuming 220 Volt from the power supply. With effectively running of 2 hr continuously the efficiency or change in temp happens.

In the cooling condition, we also conducted 4 no. of conditions as the no cooling condition. Here also 900Watt and 1100Watt of electrical power supply were given to the electric bulb. In the 900Watt supply of electricity supply to experiments were conducted such as with battery charging and without battery charging condition. In 1100Watt of power supply, with battery charging and without battery charging the experiments were continued.

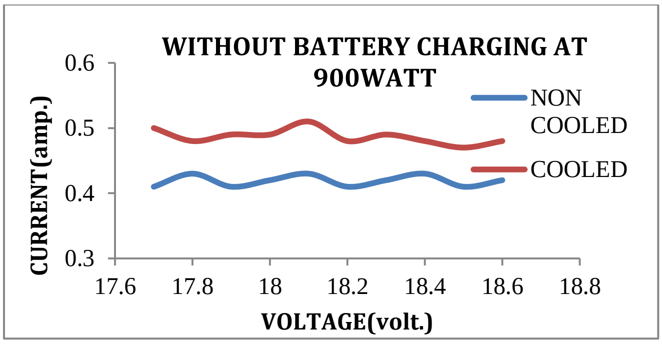

Fig no 20 Graph between Voltage and Current At 900Watt without Battery Charging

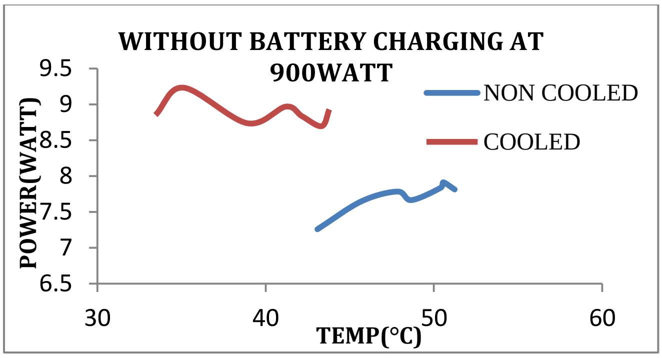

Fig no 21 Graph between Power and Temp At 900Watt without Battery Charging

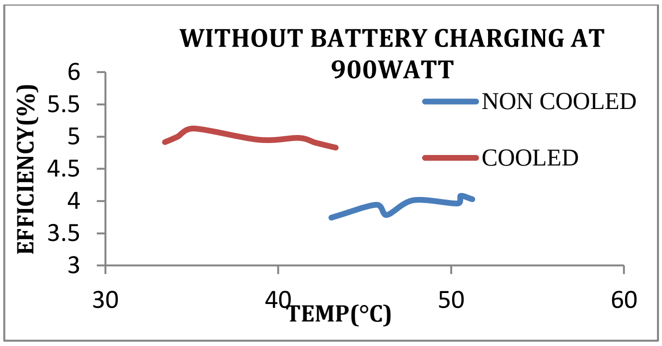

Fig no- 22 Graph between Efficiency and Temp At 900Watt without Battery Charging

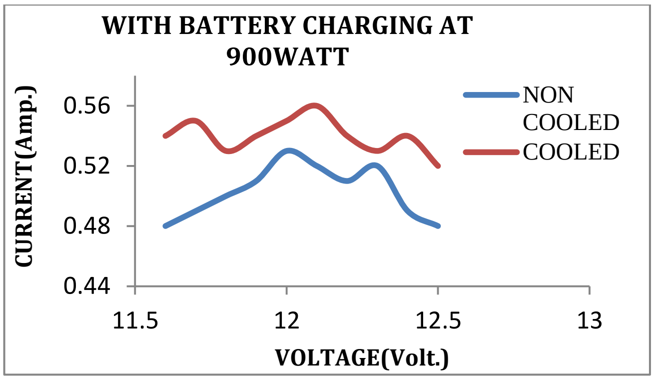

Fig no 23 Graph between Voltage and Current At 900Watt with Battery Charging

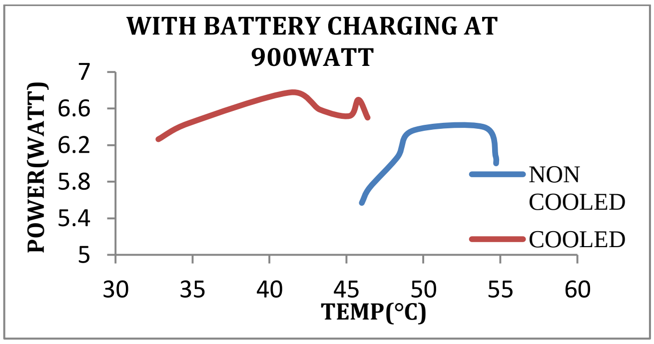

Fig no 24 Graph between Power and Temp At 900Watt with Battery Charging

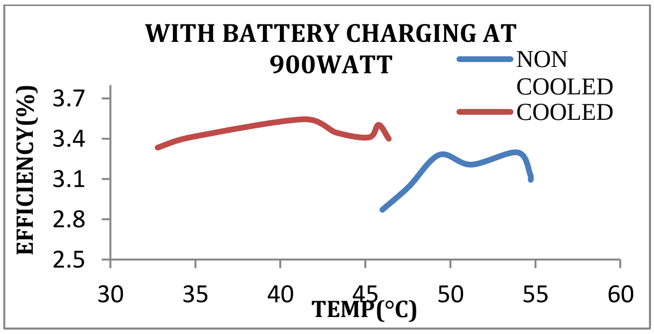

Fig no 25 Graph between Efficiency and Temp At 900Watt with Battery Charging

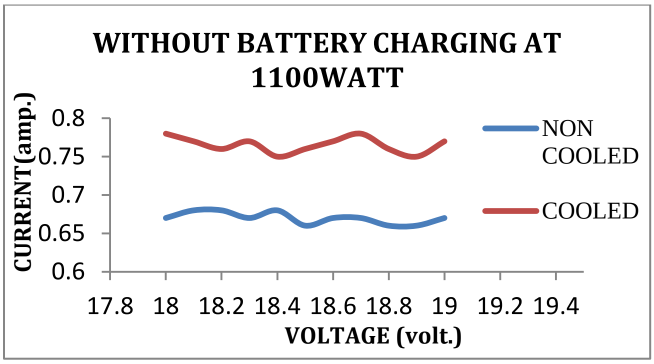

Fig no- 26 Graph between Voltage and Current At 1100Watt without Battery Charging

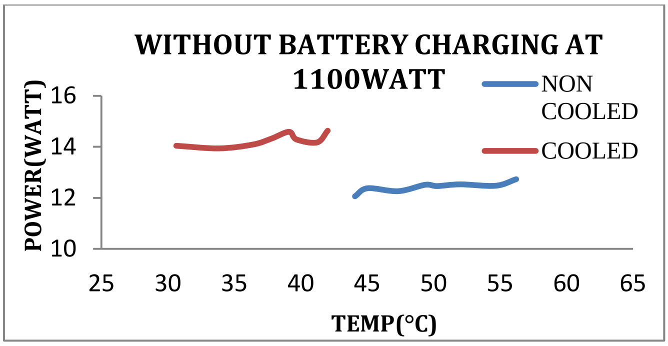

Fig no- 27 Graph between Power and Temp At 1100Watt without Battery Charging

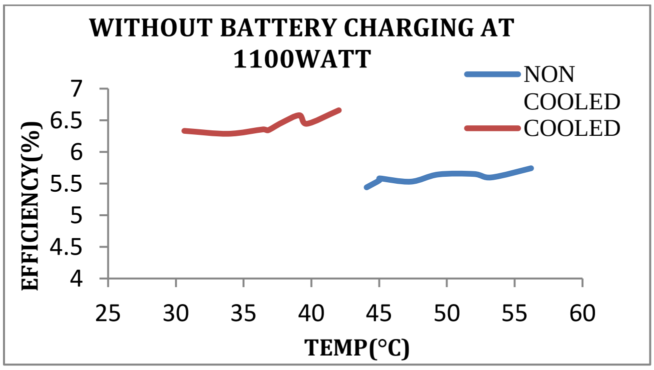

Fig no-28 Graph between Efficiency and Temp At 1100Watt without Battery Charging

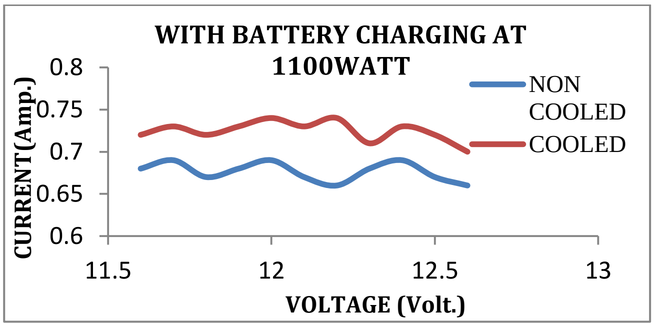

Fig no -29 Graph between Voltage and Current At 1100Watt with Battery Charging

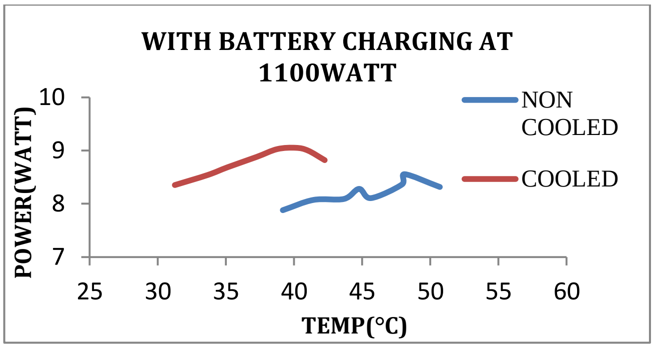

Fig no-30 Graph between Power and Temp At 1100Watt with Battery Charging

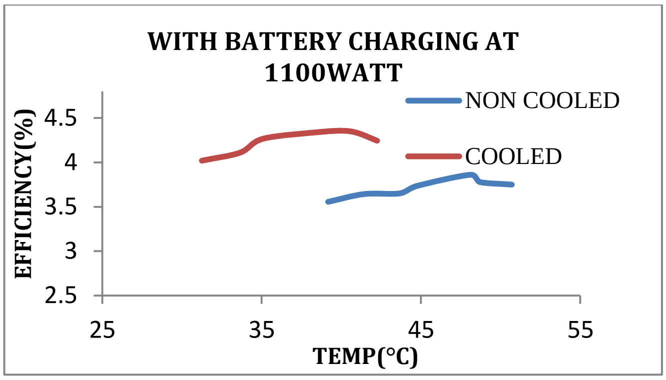

Fig no- 31 Graph between Efficiency and Temp At 1100Watt without Battery Charging

From the above graph in the charging of the battery in cooled condition gives more efficiency as compared to the non-cooled condition.

From the above analysis also we found that the water cooling technique gives lesser efficiency than the air cooling technique.

4. Conclusions

In this research, effects of solar PV surface temperature on output performance have been experimentally investigated under different radiation condition for exploring variation of output voltage, current, output power and efficiency. A cooled case for solar PV performance has been also performed by using air and water cooling technique. With those investigations, the following conclusions have been derived.

1. The cooling improves the panel voltage and current at both without charging and with charging condition. The cooling improves the payback life period of the panel by reducing the operating surface temperature.

2. In this research with ice for providing cooling function on the back of solar PV panel, the efficiency of solar PV can have an increasing rate of 47% with cooled condition.

3. In the cooling consideration, the air cooling technique will be the effect cooling from the water cooling technique as there is no layer is formulated.

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BIOGRAPHIES

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