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IMPROVEMENT IN SOLAR PANEL EFFICIENCY USING SOLAR CONCENTRATION BY SIMPLE MIRRORS AND BY COOLING

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ABSTRACT

Concentrated photovoltaic technology (CPV) uses optics such as mirrors and lens to focus sunlight on solar cells for the sake of generating electricity. CPV has advantage over nonconcentrated photovoltaic as less number of solar cells are required for the same power output. Along with duration and intensity of sunlight, temperature also has great effect on the performance of PV module as high temperature significantly reduces output power.
This research paper explains a practical approach to enhance the efficiency of solar panel by the use of mirrors and cooling mechanism. These reflectors are cheap, easy to handle, simple enough to use and need no extra equipment or devices to use. But CPV operate efficiently in concentrated light as long as the solar cells are kept cool by means of some heat sinks. Experimental results indicate appreciable enhancement in overall output of solar panel. Experimental readings obtained from a) without reflectors and without cooling b) with reflectors and without cooling c) with reflectors and with cooling are compared. Corresponding results obtained from different conditions showing improvement in efficiency up to 32%in case (b) and 52% in case (c) are tabled and plotted.

Keywords*: Efficiency improvement, passive cooling, simple mirrors, concentrated photovoltaic, four sun technology.*

I. INTRODUCTION

Energy is the fundamental need for mankind today. It ensures better quality of life. For daily use uninterrupted energy has become a necessity for humanity now a days. As blood is to body electricity is to economy of any country so without it economy will tremble and it will be very hard to sustain it. All over the world energy is one of the leading issues and every country is looking for energy resources as its demand is increasing sharply. Non-renewable energy resources are either too expensive or damaging the environment and also they are eventually going to end in near future. That's why the world is moving towards renewable energy resources which are naturally replenished in a relatively small period of time. Though hydroelectric is very cheap renewable energy source but it is not available to all places in the world while on the other hand solar has the potential to take over the whole power generation [1],[13-14]. From over the centuries, sun is providing energy in both forms: light and heat. Today, solar energy is used to produce electricity by using photovoltaic cells.

II. PRINCIPAL OF SOLAR CELL

Solar cells are made up of semiconducting materials, such as silicon, which are doped with different impurities [7]. This produces unequal distribution of free electrons (n-type) on one side of junction and excess of holes (p-type) on other side of junction. Solar light has photons which hit the solar panel and excite the loosely bound electrons which are designed to move only in one direction in solar cells and thus electron-hole pairs are created in respective junctions and electricity is obtained in external circuit.

Whatever the size is, a typical solar cell produces 0.5-0.6 volt DC under no load and open circuit condition. The current and voltage (power) ratting of a PV cell mainly depends on its efficiency, size (surface area) and is proportional to the intensity of light striking the surface of cell. For example, under peak sunlight conditions, a typical commercial PV panel of surface area 160 cm^{-2} (25 $inch^{-2}$) will produce 2 watts peak power. If the intensity is 60 percent of peak it will produce about 1.2 watts. So intensity adds a lot to efficiency [8]. Extensive research shows

that output of a PV cell can be increased by two methods: fabrications and passive devices [26]. Passive devices are used widely to enhance the efficiency as fabrication is expensive one.

III. EFFECT OF IRRADIANCE

Efficiency of solar cell is greatly affected by the amount of solar irradiance. It is one of the most dynamic factors which change the solar array performance [9]. It is measure of amount of solar radiation from the sun striking on specific surface.

It is commonly expressed in watts per square meter (W/m^2). Under ideal conditions a solar panel should receive an irradiance of 1000 W/m^2 but unfortunately this is not true in most environments. Irradiance depends on geographical position, angle of sun to solar panel and amount of energy wasted by reflection from dust particles or from fog or clouds.

Therefore change of irradiance means change of output performance of solar panel.

IV. TEMPERATURE EFFECT

Conducting materials consist of free electrons and some electrons are held tightly by the nucleus of atoms. When irradiance increases, more packets of photons strike the panel and this energy is absorbed by the atoms and electrons and they collide with each other emitting more electrons from the atoms and thus raising the temperature. Increase in temperature leads to increase in resistance to the flow of current. Efficiency is also dependent on temperature. At high temperature output performance of solar panel reduces as compared to a lower temperature [10]. According to estimation for every degree rise in temperature, efficiency of PV module decreases 0.5 percent. PV modules are usually manufactured at 25°C (77°F) and can be operated above 20°C.

V. COOLING

Based on the study of Akbarzadeh and Wadowaski [15], under concentrated solar radiation the performance of solar cell reduces 50% when its temperature rises from 46^0C to 84°C. Therefore, an efficient cooling system is quite essential to maximize solar cell's efficiency and to prevent the cell from degradation and damage. Photovoltaic panels can be cooled actively or passively. The difference between active and passive is that active system requires some external power source to run while passive system needs no additional power source [11-12].

VI. EXPERIMENTAL SETUP

The proposed following approach of improving solar panel efficiency is based on experimental data (readings and graph) obtained from three different methods. All these readings were recorded during three bright sunny days of month April. A mono crystalline solar panel made of silicon semiconductor was used for this experiment. An iron made frame was designed with space for solar panel and for three mirrors.

In this experimental technique active cooling system was used for improving efficiency of PV module.
A PVC plastic pipe with holes at the bottom was fixed over the solar panel frame which was further fed from a rubber pipe from a water tank which was filled by an electric motor. One mirror from above and two from sides were reflecting solar radiation on the solar panel which was placed in the middle. This technique can be named as four sun technology also. This analysis is based on following three methods i.e. a) without mirrors and without cooling b) with mirrors and without cooling c) with mirrors and with cooling.

VII. RESULTS

Table I. change in currnet, voltage and power w.r.t concentration and cooling

Voltage	Current	Power	Concentration
12.98	1.91	24.84	Without
15.02	1.92	28.838	1 mirror
15.43	1.93	29.625	Plus cooling
16.11	1.94	31.253	2 mirrors
16.50	1.94	32.011	Plus cooling
16.71	1.95	36.929	3 mirrors
16.91	2.23	37.709	Plus cooling

This table is giving information about how the performance measures of solar cell are changing with respect to change in environmental conditions which in this case are changing concentration and cooling step by step. It can be clearly seen from the experimental readings that without concentration solar panel is not even producing its rated power i.e. 30 watts. Just by adding a mirror increases its output power approximately 4 watts. Similarly output power goes on increasing by increasing concentration and cooling.

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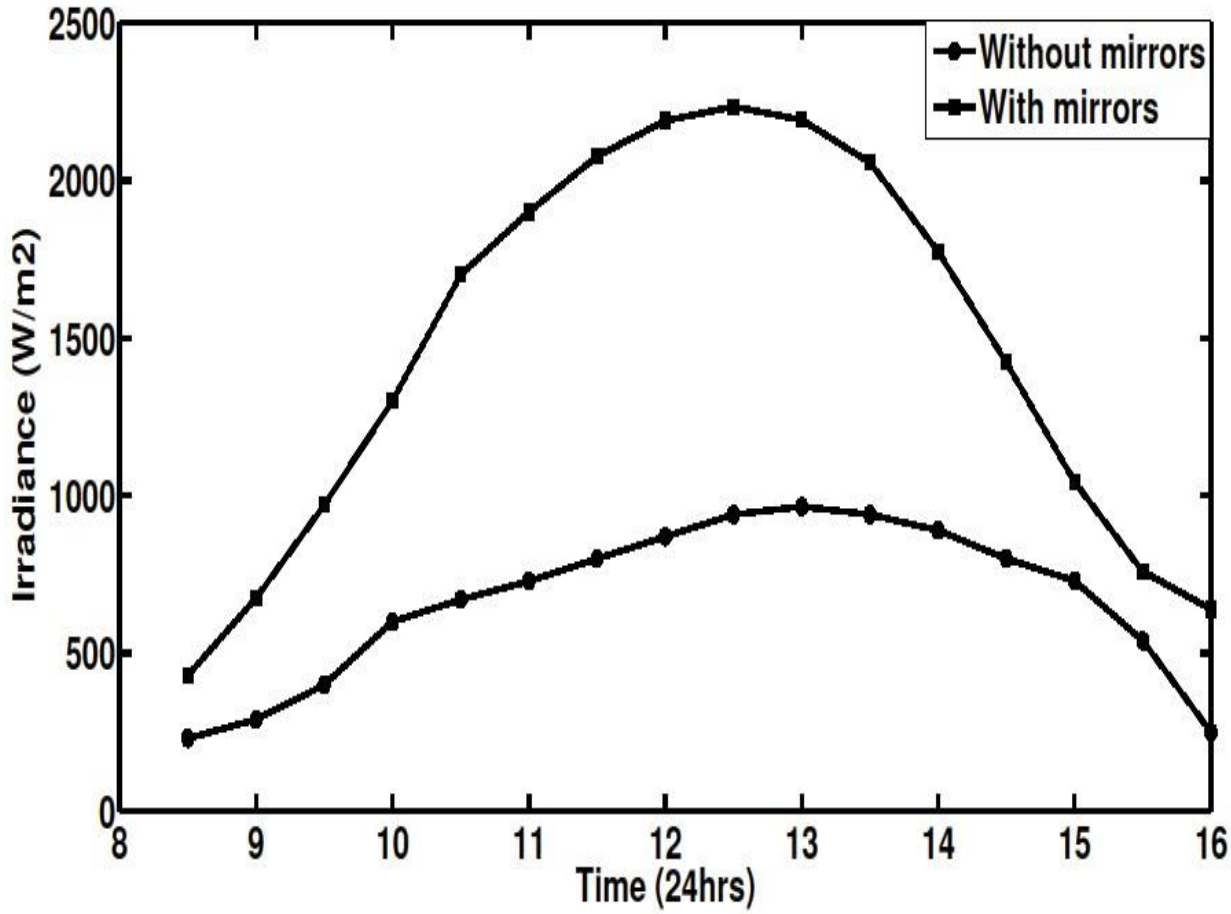

Fig.I Hourly changing Irradiance

Table II. hourly comparison of three methods

Time	Without mirrors and cooling	With Mirrors and without cooling	Three mirrors plus cooling
8:30 AM	19.17	25.12	22.7848
9:00 AM	20.01	26.58	24.7756
9:30 AM	20.60	28.00	26.5125
10:00 AM	21.21	28.40	30.4433
10:30 AM	22.05	27.50	32.1758
11:00 AM	23.63	28.05	34.6399
12:00 PM	24.44	30.81	36.4188

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12:30 PM	24.91	30.91	37.6444
01:00 PM	24.80	32.26	37.709
01:30 PM	24.20	31.80	36.66
02:00 PM	23.44	29.94	35.5450
02:30 PM	22.26	29.45	32.2936
03:00 PM	20.22	29.34	30.0969
03:30 PM	19.81	27.87	27.6212
04:00 PM	19.02	27.56	26.0064
04:30 PM	18.09	27.10	25.3455

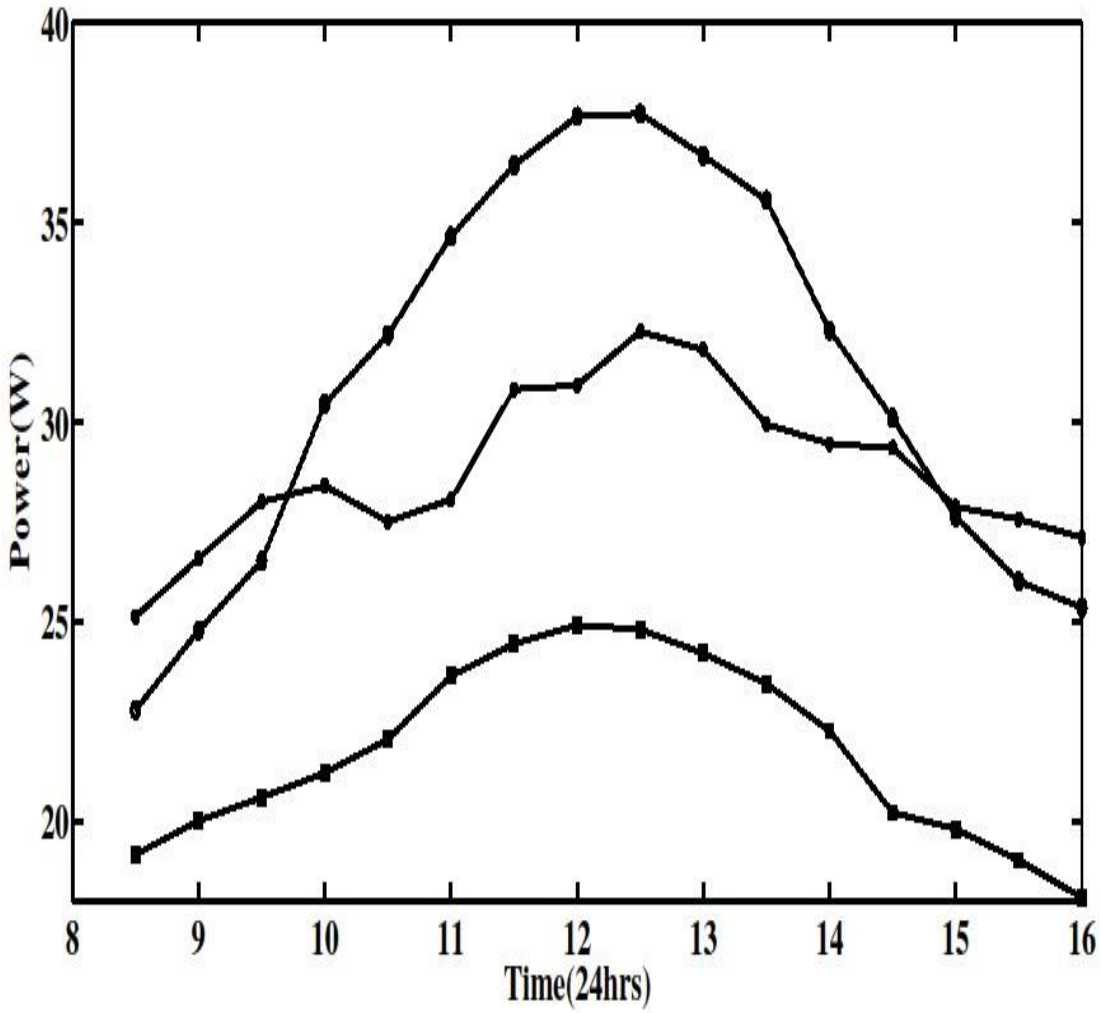

Fig II. Hourly changing power output of solar panel under three different conditions a) without mirrors and without cooling b) with mirrors and without cooling c) with mirrors and with cooling

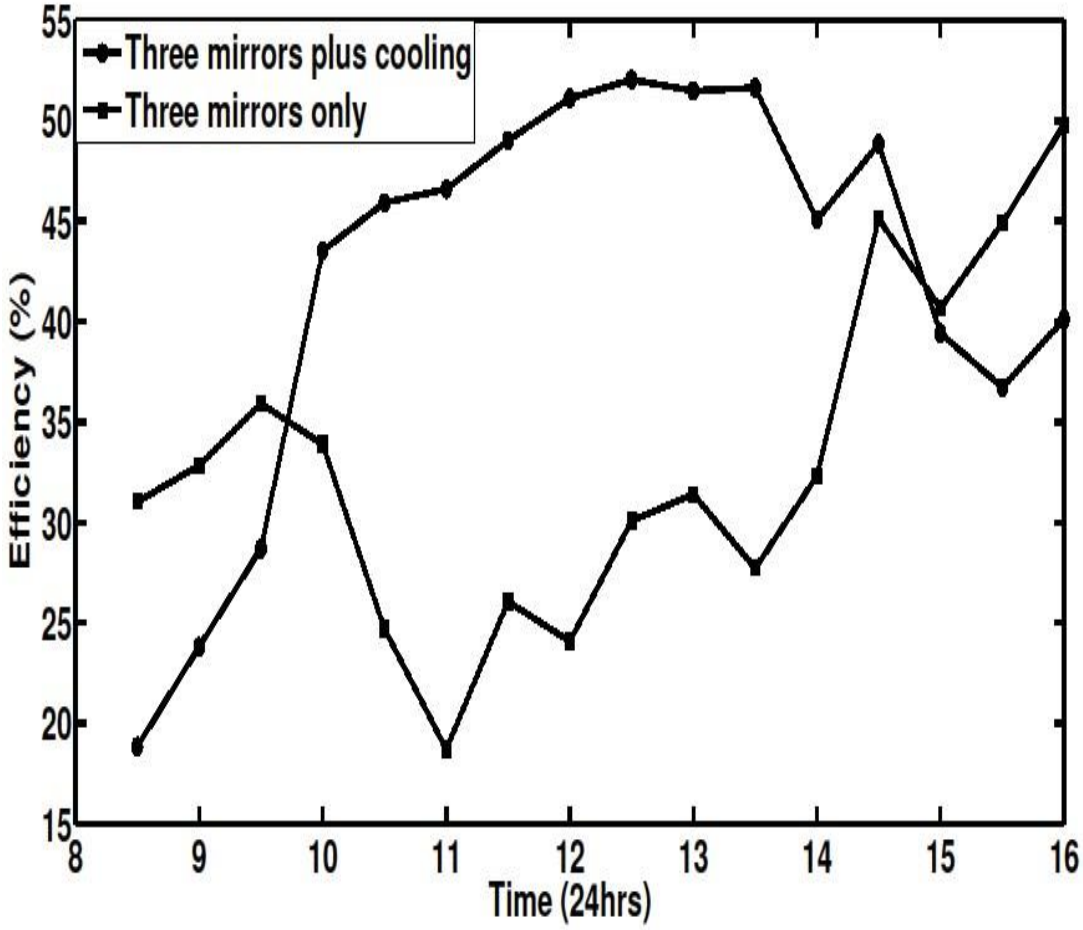

Fig III. Percentage improvement in solar panel efficiency using a) three mirrors without cooling b) three mirrors plus cooling

VIII. DATA ANALYSIS

A. Without mirrors and without cooling

Though this method was practiced by most of the people from all over the world a few years ago but now a days this method is almost losing its value due to its low efficiency. The curve from fig.2 clearly shows that output power by using solar panel without mirrors and without cooling is not only far less than other two methods but also less than its rated power. Solar irradiance, most of the time in this case is also round about 750w/m^2.

B. With mirrors and without cooling

Efficiency of solar panel can be increased by increasing solar irradiation on solar panel. As we have seen from the graph that irradiance is continuously changing with respect to time so output power largely depends on irradiation. As earth has only one sun so reflecting mirrors can also be named as sun. So here in this case solar radiations from four suns are striking on solar panel and the results are also encouraging. Second Curve of fig.2 and first curve of fig.3 is showing the corresponding output characteristics of this method. In fig.2 from 8:30 AM11 AM curve follows an increasing trend but then up to 1:30 PM follows a decreasing trend. This is because in these peak hours as irradiance received is at its maximum so temperature effect dominates in these hours of the day and power output decreases. Collisions between atoms and electrons are hindering the flow of current and thereby increasing

resistance which eventually leads to increase in temperature and cause reduction of output power. It can also be verified from Fig.3 that efficiency of solar panel during these hours is less than the other hours of the day but at the same time its efficiency is better than using solar panel without mirrors and without cooling.
Approximately, on average 32% efficiency was improved by this method.

With mirrors and with cooling
Results obtained from this method were encouraging as for about 6 hours of the day its output power is far greater than the method explained in section *B*. It can be observed form the fig.2 that only for a single hour of morning from 8:30 AM9:30 AM and one hour in the evening from 3:30 PM-4:30 PM its output is less than the second method. The reason of this low power and low efficiency is that because for performing this method cooling was started at sharp 8:30 AM and ended at 4:30 PM as already discussed in previous sections that when electrons absorbs sufficient heat energy they collide with each other and with other atoms thus producing free electrons. During these hours although solar panel is receiving same amount of solar energy from the sun as the method in section *B* but at the same time in this method cooling is removing away some of heat energy from the solar panel so making it less efficient than using mirror and without cooling method only for two hours. This method was approximately 20% more efficient than second one and 52% more efficient from the first one.

IX. CONCLUSION

The results of the experiment for improving efficiency of solar panel using mirrors and cooling were come out to be highly encouraging. Using mirrors plus cooling is better than the other two as efficiency is approximately 52% in this case. Output power from simple solar panel without using mirrors was 24 watts and from solar panel with mirrors and cooling was 37.709 watts which means instead of purchasing new solar panel one can obtain 52 percent more power from the same solar panel using this technique.

X. FUTURE RECOMMENDATIONS

Of all the other two methods, last one was efficient but it still needs to be improved. One can enhance its efficiency beyond 52 percent by following these recommendations.
Stop cooling solar panel in the early and last hours of the day. This will definitely increase further output power.
As this whole experiment was without following maximum power point tracking technique (MPPT).So one can combine these two techniques to improve efficiency

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