Performance Enhancement of PV Solar System by Diffused Reflection

Rizwan ur Rahman[1], Dewan Ishtiaque Ahmed[2], Mufrad Ahmed Fahmi[3], Tithi Tasnuva[4], Md. Fayyaz Khan[5]

Department of EEE, United International University, Dhaka, Bangladesh
E-mail of corresponding author: riz282000@yahoo.com

Abstract: Various methods are being adopted to enhance the performance of a solar panel. The most common method is to track the sun for performance enhancement. Such method needs complicated control and drive circuits for implementation. Also, the power required for the tracking motor has to be provided by the solar panel and the battery system. Although better performance is achievable by the sun tracker, higher cost and frequent maintenance are required.

In this paper, performance enhancement of solar panels has been experimented utilizing diffused reflectors. Application of diffused reflectors is cheap, simple and does not require any additional equipments or devices. Simple white reflectors can be used to optimize the performance of the solar panel. Experimental results indicate appreciable enhancement in the overall output of the solar panel. For comparative study, experimental readings were simultaneously taken with i) sun tracking, ii) the panel aligned at 23.5^0 with the horizontal using diffused reflectors and iii) the panel aligned at 23.5^0 with the horizontal without diffused reflectors. Comparative results depicted for different conditions show encouraging enhancement of the performance of the solar panel.

1. Introduction

Solar panels convert light energy from the sun into electrical energy. Normally energy from the sun is received in the form of light and heat. The light energy received has different wavelengths. Photo-cells can produce output only for a particular range of frequencies of light.

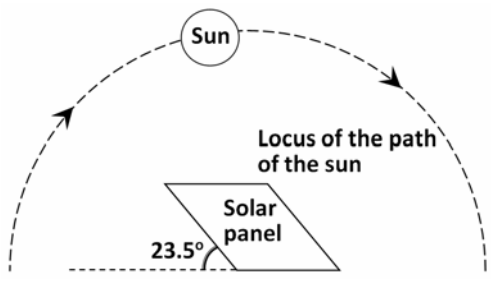

Fig. 1 Sun-Earth Geometry

The extraterrestrial solar spectrum at mean sun-earth distance can be categorized as follows [1]:

i. Ultraviolet region ($\lambda < 0.38$ mm). Percentage of solar radiation is 7%.
ii. Visible region ($0.38 < \lambda < 0.78$ mm) Percentage of solar radiation is 47.3%.
iii. Infrared region ($\lambda > 0.78$mm) percentage of solar radiation is 45.7%

Bangladesh on an average receives 4 to 6.5 kWh per square meter of solar energy every day. Solar cells have an average efficiency of 10%, which means it can convert 0.4 to 0.65 kWh per square meter of solar energy into electrical energy [2]. Unless high efficiency solar cells are invented, the only way to enhance the performance of a solar cell is to increase the intensity of light energy falling on the solar panels. Sun tracking is one of the popular methods of enhancing performance of a solar panel.

2. Different methods of performance enhancement of solar cells

The commonly used method is by sun tracking, which has some disadvantages as already mentioned. Other methods suggested here are by using good reflectors e.g. mirrors or shiny objects or using white reflectors. Highly encouraging results have been obtained by using white diffused reflectors. Increase in the intensity if light falling on the panel through white reflectors results in an increase in the short circuit current of the solar cell, which also increases the open circuit voltage, V_{OC}. This is given by the formula [3].

$$V_{OC} \approx \frac{kT}{e} \ln\left(\frac{I_{ph}}{I_{01}} + 1\right) \quad \textbf{(1)}$$

V_{OC} = Open circuit voltage
k = Boltzmann constant
T = Temperature of the device
e = Elemental charge
I_{Ph} = Photo current
I_{01} = Current due to recombination due to bulk charge carriers

Following methods may be adopted for optimizing the performance of a solar cell:

a) Reflection by a mirror:
Utilizing the reflected light from a mirror, the output current of the cell was significantly high [4]. Mirrors normally concentrate the sun beam over a small area of the panel. This results a high current density in the concentrated light beam area of the p-n-junction that creates non-uniform

current density in the panel and heated spot may be formed in the highly concentrated beam area. This may degrade the useful life of the panel. So mirrors or highly reflecting surfaces are not advisable for the purpose of performance enhancement of the solar panel.

b) Tracking the sun:
Popular method for optimizing the solar panel output is by tracking the sun. It is an effective method and study shows that the panel output may be increased by 15~20% by tracking the sun. However, additional equipments and control circuits are required to track the movement of the sun. This involves additional cost [5] and consumption of additional power that is to be supplied by the panel-battery system. Besides, repair of the circuits at the site is difficult if there is a fault in the control or drive circuit. In remote areas of developing/underdeveloped countries like Bangladesh, India, Nepal, any fault in such circuits is extremely difficult to repair due to the non-availability of technical persons. If the circuit develops a fault and aligns towards west in the morning time then the total output from the panel would be at the lowest end, which would unnecessarily generate alarms of "Low Battery," "Load Disconnection," etc. The solar home system will then fail to deliver even 25% of expected output under such conditions at night.

c) White Reflector:
A white reflector reflects all the electromagnetic rays from the sun. Hence it is a good method for increasing amount of solar energy being converted to electrical energy through photovoltaic cells. In this paper, diffused reflection from white surface has therefore been used to enhance the performance of the solar cell.

3. Diffused reflection

Some of the solar rays reach the Earth's surface directly without appreciable change in the direction. Other rays undergo reflection and refraction depending on the position of the clouds, water vapors, dust particles, etc. These rays are called diffused rays. During cloudy weather there is no direct sunlight available on the solar cells.

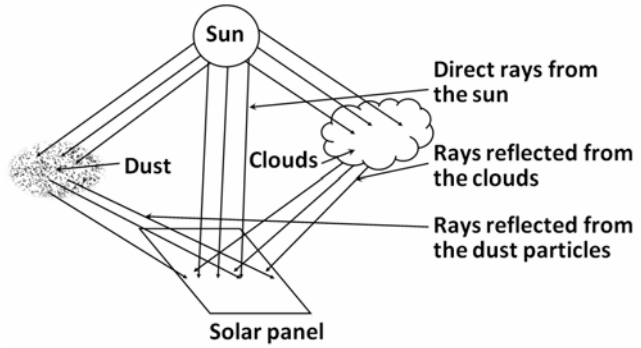

Fig. 2 Diffused sun rays falling on the panel

Most of the light is received by the panel through diffused reflection. Naturally intensity of light is less, which reduces the output of the solar cell. Also, during morning period or during sunset, depending on the position of the sun around the horizon, there is no direct sun ray falling on the panel. Diffused reflection during this period has been found effective and enhances the output of the solar cell.

4. Experimental Setup

To utilize the reflection from the diffused reflector, sheets of white foam were used with the solar panel. The solar panel was aligned at an angle of 23.5^o with the horizontal (length was aligned along east-west direction and the breadth along north-south direction) to utilize the maximum surface area of the panel for diffused reflection.

The electrical specifications of the panel were:

At STC (1000W/m^2, AM 1.5 spectrums, cell temperature 25^{o}C) nominal values

Peak Power (P_{max})	: 50.0W
Voltage (V_{mp})	: 17.0V
Current (I_{mp})	: 2.9A
Open Circuit Voltage (V_{oc})	: 21.8V
Short Circuit Current (I_{sc})	: 3.3A
Max Bypass Diode	: 6A
Max Series Fuse	: 15A

The size of the panel used was 0.835m x 0.540m.

The diffused reflectors were placed on the north-south sides of the panel at an angle of approximately 25^o with the vertical. The experimental setup is shown in the figure. The size of the diffused reflector used was 1.0m x 0.75m x 0.03m.

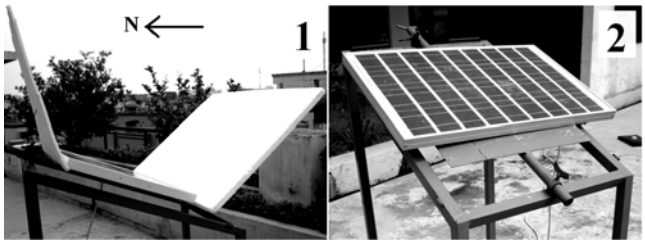

Fig. 3 Experimental Setup, (1) with and (2) without diffused reflector.

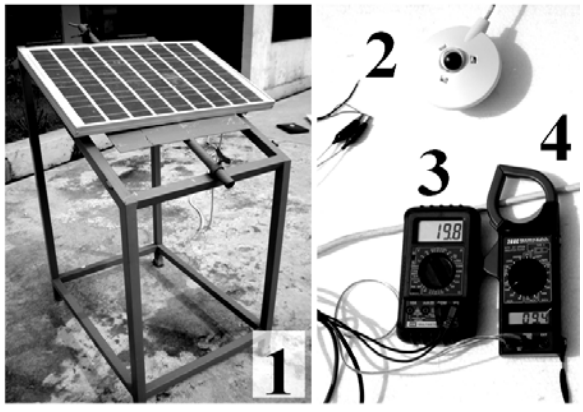

Fig. 4 (1) Panel (2) Pyranometer (3) Ammeter (4) Voltmeter

5. Results

Experimental data recorded are shown in the graphs of Figures: 5, 6, 7, 8 and 9. Enhancements in output short circuit current were recorded for both sunny and cloudy weathers.

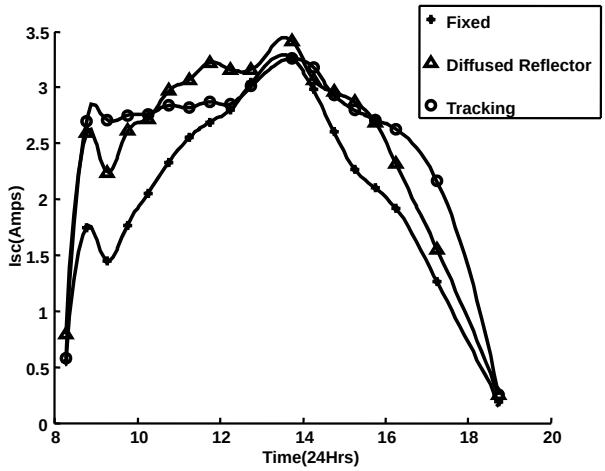

Fig. 5 Short circuit currents Vs. Time of solar panel aligned at 23.5^o (with horizontal), diffused reflector and tracking (sunny day)

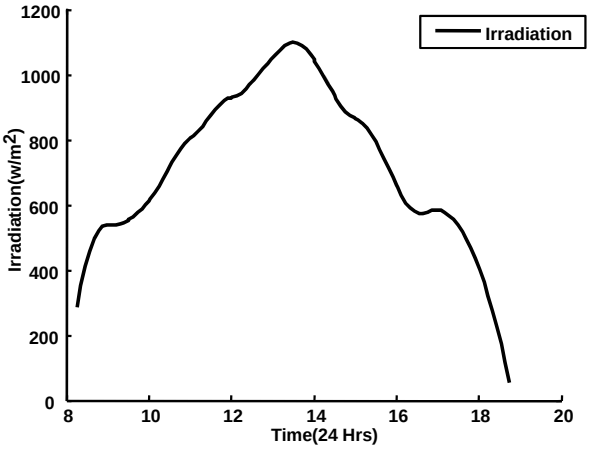

Fig. 6 Solar Irradiation vs. Time measured on pyranometer (sunny day)

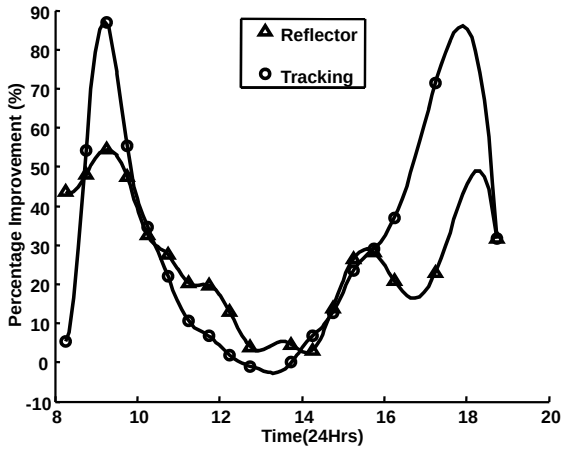

Fig. 7 Percentage improvement of solar panel using diffused reflector and tracking with respect to 23.5^o fixed panel (sunny day)

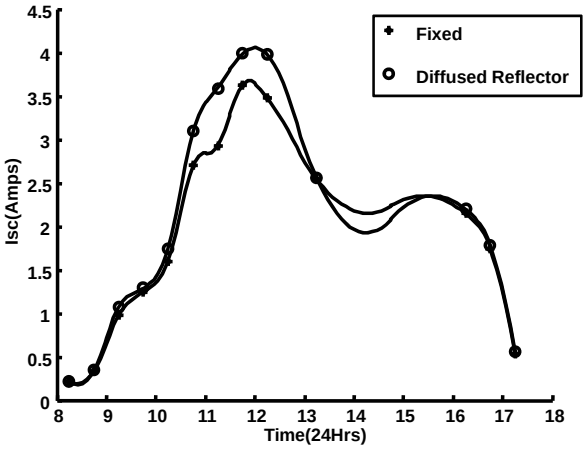

Fig. 8 Short circuit current Vs. Time of solar panel aligned at 23.5^o (with horizontal) and with diffused reflector (on a cloudy day)

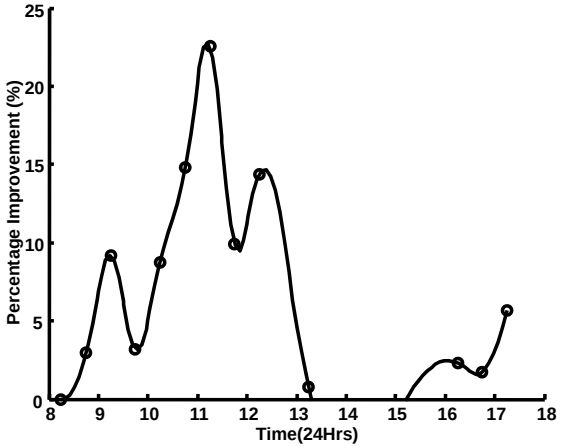

Fig. 9 Percentage improvement of solar panel using diffused reflector aligned at 23.5^o (with horizontal) (cloudy day)

For sunny day, the percentage improvement in short circuit current is appreciably high with respect to fixed panel position. In the morning hours and in the afternoon hours, diffused reflection produced higher improvements in I_{SC} compared to I_{SC} with sun-tracking. This is a significant observation. Even in cloudy weather, diffused reflection produced higher I_{SC} with respect to fixed panel position. For a sunny day, the percentage improvement is as high as around 25%.

6. Comments on the results

It is quite interesting to note that on a sunny day, early in the morning i.e. from 8AM to 10 AM, the panel short circuit current is nearly equal to that of the panel current with sun tracking. Highly encouraging result can be noticed from 11AM to 2PM when the short circuit current exceeded the sun tracking current. The result is significant which implies that if properly installed and if the surface of the diffused reflector is clean, then there is no need for sun tracking to enhance the performance of the solar cell. Although from 4 o'clock in the afternoon, the sun tracking current is slightly higher, but the overall performance with diffused reflector is quite encouraging. This is due to the fact that light rays, after diffused

reflection, are scattered all over the surface of the panel that yielded better output short circuit current.

Curves in figure 5 show the outputs of solar cell under different conditions. When compared to the short circuit current produced by the panel when the panel is fixed at 23.5^0 with the horizontal with that of reading with diffused reflector, then the output of the panel with diffused reflector may be assumed to be excellent.

Also for scattering of light by diffused reflector, in cloudy weather also panel short circuit output current shows higher values than that of panel output without reflector.

It may be mentioned that during experimental readings, the transition time between each set of readings was less than 0.5 minute and during this transition period, pyranometer readings remained fairly constant. However, considering the unpredictable motion of the patches of clouds and personal error, the percentage improvement may further be reduced by 5% (in each case) from the percentage improved short circuit current shown in Table-1 and 2 respectively.

7. Conclusions

Highly encouraging results have been obtained by erecting diffused reflectors along N-S edges of the solar panel. This gives a new dimension towards performance enhancement of a solar panel by a very simple method and with a very cheap device. These diffused reflectors are sheets of white foam which are very light in weight and very easily available at a very nominal price. No heavy structure is needed for installation of such reflectors. Supporting structure made of bamboo can be used for installation of diffused reflectors. The only negative side for such reflector is: it is subjected to twist and deformation in the gusty wind. In that case, the reflector may be made of thin strip in the form of a louver. Experimental readings obtained with diffused reflector show that there will be no need of sun tracking if diffused reflectors are installed with the panel. Only maintenance requirement is that the reflectors have to be cleaned regularly for giving optimum performance.

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