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Performance Improvement of Solar Photo-Voltaic Panel with Various Types of Reflectors

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***Abstract*— This paper deals the effects of a number of flat reflectors on the performance of a solar panel. A novel attempt is made to assess the photovoltaic solar module performance using I-V and P-V characteristics, open circuit voltage, short circuit current; voltage, current and maximum power with different types of reflectors and different positions of reflector namely position 1 (single side arrangement), position 2 (opposite side), position 3 (three side) and position 4 (all sides) . The reflectors are used to increase the solar irradiation that the solar PV modules are exposed and hence increase the generation of electric power. In this study, reflector materials are taken as aluminum foil, white surface paper reflectors and light blue surface paper reflectors. The performances with these are compared with the clean panel. The results show that there is significant augmentation of power with reflectors. Further, it is observed that aluminum foil increases the maximum power approximately double as compared to clean panel with reflector position 4.**

Keywords—Solar energy; Photo-voltaic system; Reflectors; PV performance

I. INTRODUCTION

Environmental concerns have motivated the researchers to explore and extract the electrical energy from renewable energy resources. Solar energy is one of the promising renewable energy resources due to several advantages associates with it such as non-polluting green source, available diverse technologies, cost effectiveness etc. The I-V characteristic of photovoltaic (PV) module is non-linear and affected by several environmental parameters. The authors [1] have studied PV performance using both side external and internal reflector. Reflectors are good modification to increase the solar irradiation and hence the solar PV efficiency. The authors [2] have used the bifacial solar panel with the reflector and achieved the maximum power and efficiency. The authors [3] have shown that accumulation of dust and soil affect the reflectance radiation, solar field efficiency and it optimized the cost of cleanliness. The authors [4] have analyzed and compared the solar panel performance without reflector and at different angle of reflector. Half of solar efficiency is claimed to be increased when angle of reflector is adjusted. The authors [5] have analyzed and investigated the performance of mono-crystalline solar panel using concentrator and reflector, and evaluated the power output and improvement has been observed during fluctuation of light due to factors like clouds etc. The structural and economic benefit of spherical silicon solar cell with semi-concentration reflectors are discussed in [6]. This setup demonstrates improvement in electrical performance of the solar cell and provides good intensity level. The authors [7] have used planar concentrator, which is a low cost method of increasing solar panel performance and efficiency. The authors [8] have used silver nano-particles for increasing efficiency of solar panel. The authors [9] have investigated intermediate reflector performance, which reduces the cell reflectance and improves the effectiveness of intermediate reflected layer (IRL), and conversion efficiency of solar cell. The authors [10] have developed multi-physics model for improving the performance of low concentration PV system. The string mismatch effect is shown in the performance of edge modules. The authors [11] have used stencil and Nano patterned back reflector for increasing the efficiency of scattering light and electrical performance of amorphous solar cells. The authors [12] have designed a thin film solar cell using new topology to increase the efficiency by proper light tapping.

With the motivation of above literature, the performance of solar PV panel with different types of reflectors is not compared to the best of author's knowledge. Therefore, the objective of this paper is to assess and compare the performance of solar PV panel with aluminum foil, white surface paper reflectors and light blue surface paper reflectors; and to prepare the comparative study.

II. EXPERIMENTAL SET UP AND DETAILS

A. PV MODULE

For the purpose, test system consists of a self-assembled 4×4 series-parallel (SP) configured PV module having area of assembled PV moudle is 0.3716 m^2. Furthermore, the specifications of mono-crystalline PV module (4×4 PV cell) are given in Table I as,

TABLE I. PV MDODULE SPECIFICATIONS

Parameter	Value
Power (W)	9.57
Open circuit voltage (V_{oc})	4.56
Short circuit current(I_{sc})	2.10
No. of cell	4×4 Module size (S×P)

B. Reflector

Reflectors are relative surfaces used for collecting and reflecting solar energy in other to boost energy production. A flate plate solar module can incorporate reflectors at the sides.

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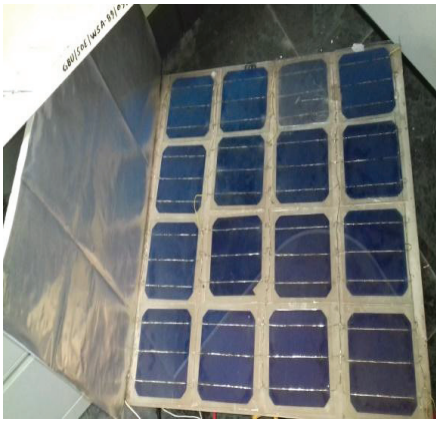
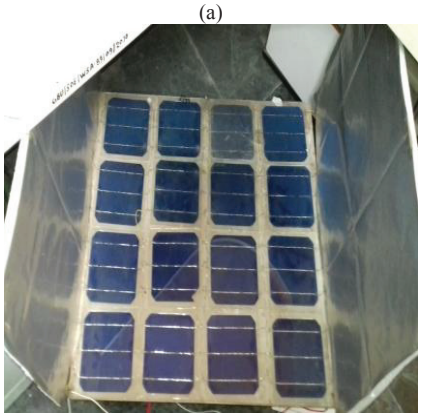
The idea is to increase the sunlight intensity on the surface of the panel by reflecting sunlight that would normally have missed the panel. Reflectors are normally mounted at an optimum angle and height to gain exposure to sunlight that can be reflected to the panel. Area of reflector A= 38 m^2 is taken**.** The common reflectors are the flate surface. Various reflector material used here are as aluminum, white surface, and light blue surface.

C. PV module with aluminum foil reflector

The solar PV module is designed to have four reflectors i.e. one on each side. In this case, the reflector is a flat plate made of aluminum foil. The clean solar PV module and the diffuse reflector system are shown in Fig.1 as,



(a)



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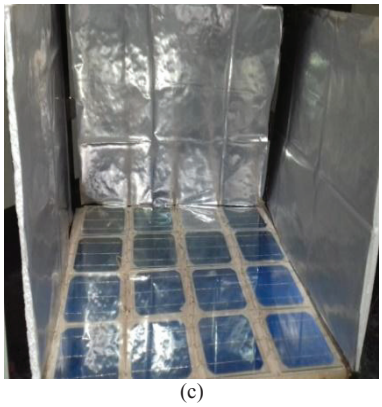

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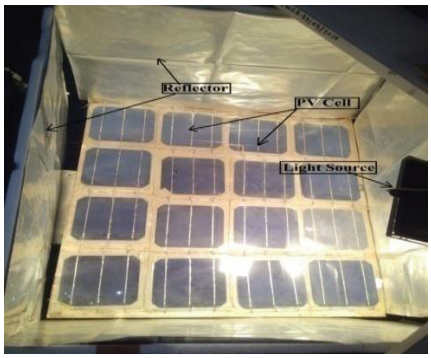


(d)

(a) single side reflector arrangement (b) opposite sides reflector (c) Three sides reflector (d) All sides reflector

Fig. 1. Solar PV module with diffuse aluminum reflector

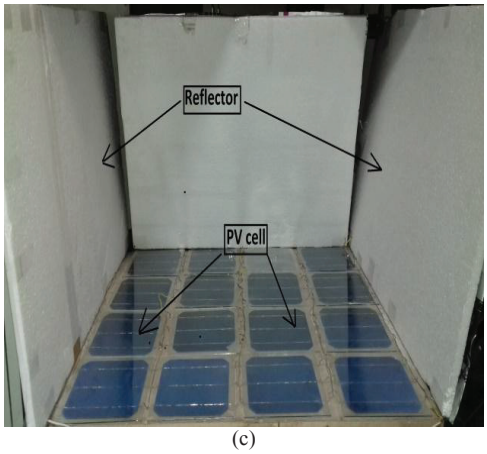
Reflecting properties depend upon the size and optical properties of the reflector. Optical properties of Aluminum reflector is, Refractive index (n=1.0972), Extinction coefficient (K= 6.7943), Chromatic dispersion ($dn/d\lambda$ = 3.5414 μm^{-1}). Area of reflector is A= 38 m^2.

D. PV module with white surface reflector

The clean solar PV module along with the diffused white surface paper reflector system are shown in Fig. 2.

(a)

(b)



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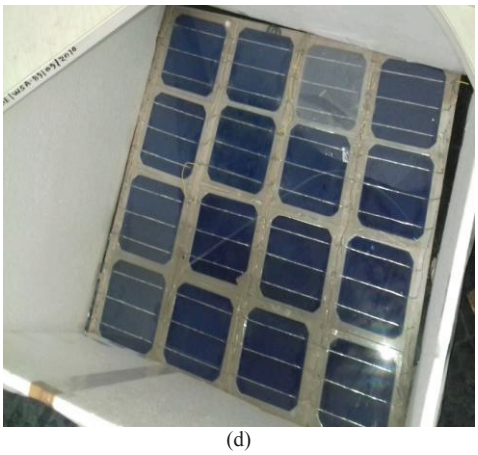


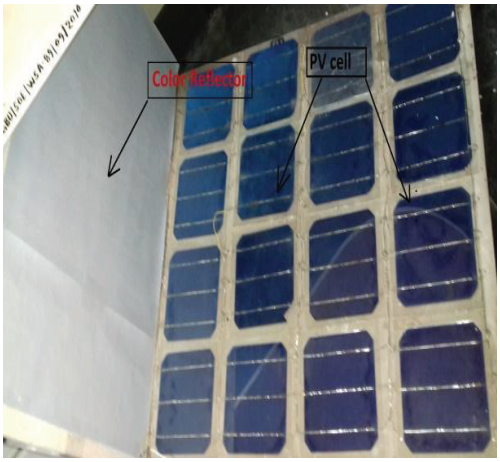
(d)

(a) single side reflector arrangement (b) opposite sides reflector (c) Three sides reflector (d) All sides reflector

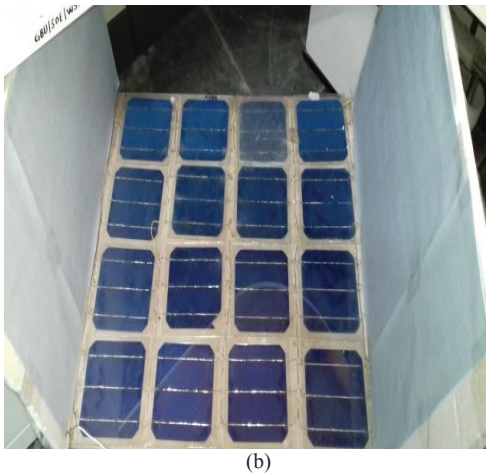
Fig. 2. Solar PV module with diffuse white surface paper reflector

E. PV module with light blue surface reflector

The light blue surface paper reflector having light wavelength is good for reflection purpose. The clean solar PV module along with the diffused light blue surface paper reflector system are shown in Fig.3.

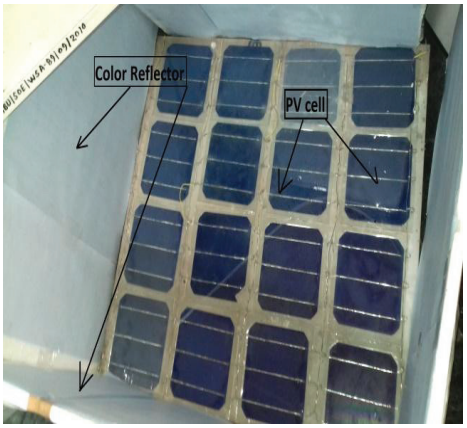


(a)



(b)

(c)



(d)

(a) single side reflector arrangement (b) opposite sides reflector (c) Three sides reflector (d) All sides reflector

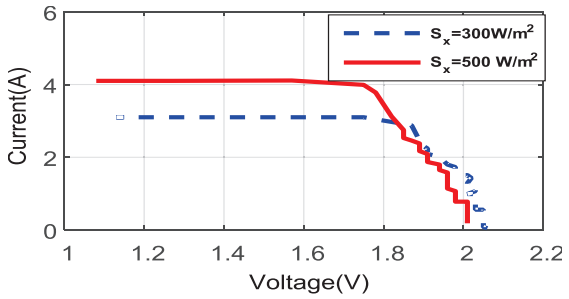
Fig. 3. Solar PV module with diffused light blue surface paper reflector:

III. Results and Discussion

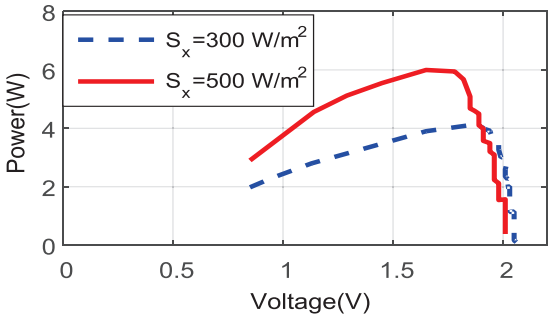
The I-V and P-V curves are plotted for assessing the effect of reflector. The effect of reflectors on the PV has been studied in detail. In this study Various type of materials are used as reflectors such as aluminum, white surface, and light blue surface to mention. Each reflector mounted, one on each side of the panel is considered.

A. PV performance clean module without reflector

A clean PV module is analyzed under two level of irradiation (300 and 500 W/m^2). For each irradiation level the I-V and P-V curves are plotted for clean panel without reflector. The I-V and P-V curves are obtained as shown in Fig.4 as,



(a) I-V characteristics



(b) P-V characteristics

Fig. 4. I-V and P-V curve of clean panel without reflector.

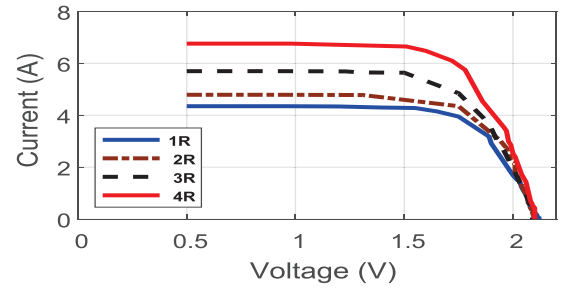
The given graphs are used for calculating the electrical parameter and maximum power of the PV module. It is observed that the value of short circuit current I_{sc} = 4.15 A at irradiation 500W/m^2 and max. Power P_{max}= 6.09 W. The obtained parameter are shown in Table II as,

TABLE II. PARAMETER OF CLEAN PV MODULE WITHOUT REFLECTOR

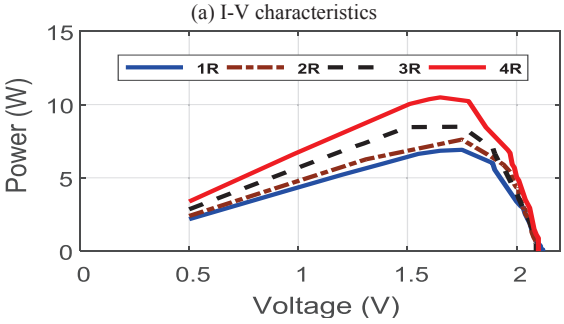
Irradiation (W/m^2)	I_{sc}	V_{oc}	I_m	V_m	$P_{max.}$
500	4.15	2.05	3.26	1.87	6.09
300	3.09	2.08	2.25	1.89	4.21

B. PV performance with aluminum foil reflector

The I-V and P-V curves are plotted for aluminum reflector and at different irradiation level (500 W/m^2 & 300 W/m^2), obtained curves are shown in Fig.5-6 as,

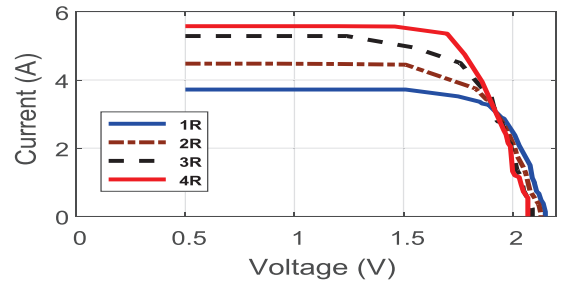


(a) I-V characteristics

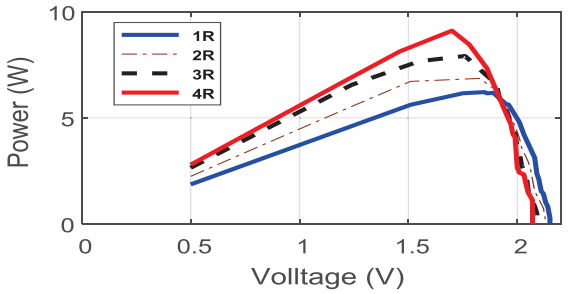


(b) P-V characteristics

Fig. 5. I-V and P-V curve with aluminum reflector at 500 W/m^2.



(a) I-V characteristics



(b) P-V characteristics

Fig. 6. I-V and P-V curve with Aluminum reflector at 300 W/m^2.

The measured voltage, current and power of the module with load variations are helpful to plot the I- V and P- V curve. The given characteristics are shown with different positions of aluminum reflector around the PV module, the results show that reflectors affect the maximum output power of PV module.

It is also observed that the short circuit current I_{sc}= 4.35 and P = 6.90 W at position 1 (one reflector), I_{sc}= 4.79 A and P=7.61W at position 2 (two reflectors), I_{sc}= 5.70 A and P= 8.48 W at position 3 (three reflectors), I_{sc}= 6.76 A and P= 11.55W at position 4 (four reflectors) of the reflector at irradiation of 500W/m$^{2.}$.

At irradiation of 300W/m^2, I_{sc}= 3.72 A and P= 6.35W at position 1, I_{sc}= 4.48 A and P= 6.95 W at position 2, I_{sc}= 5.29 A and P= 7.92W at position 3, I_{sc}= 5.58 A and P= 9.05W at position 4 of the reflector. Calculated electrical parameters are shown in Table III-IV as

TABLE III. COMPARISON OF PARAMETERS FOR ALL POSITION OF ALUMINUM REFLECTOR AT 500W/M^2

Position of reflector	I_{sc}	V_{oc}	I_m	V_m	$P_{max.}$
1	4.35	2.12	3.95	1.75	6.90
2	4.79	2.10	4.35	1.75	7.61
3	5.70	2.09	4.85	1.75	8.48
4	6.76	2.10	6.72	1.72	11.55

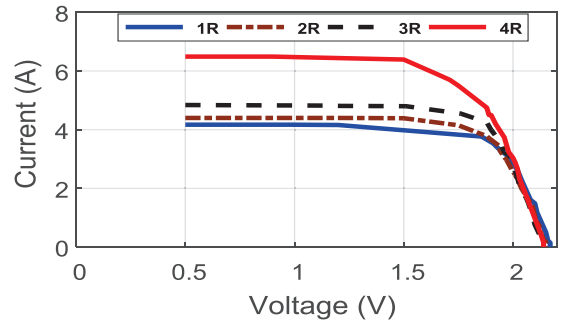
TABLE IV. COMPARISON OF PARAMETERS FOR ALL POSITION OF ALUMINUM REFLECTOR AT 300W/M^2

Position of reflector	I_{sc}	V_{oc}	I_m	V_m	$P_{max.}$
1	3.72	2.15	3.36	1.89	6.35
2	4.48	2.13	3.95	1.76	6.95
3	5.29	2.09	4.50	1.76	7.92
4	5.58	2.08	4.85	1.86	9.05

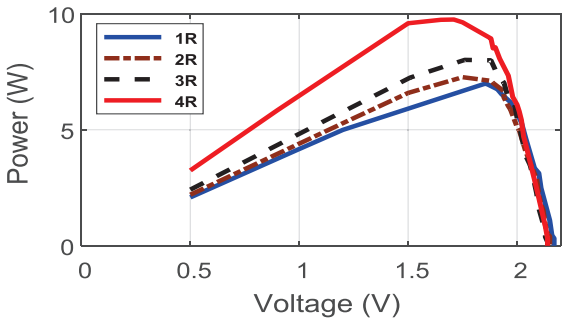
C. PV performance with white surface reflector

The measured voltage, current and power of the module with load variations are helpful to plot the I-V and P-V curve. These curves are plotted for white surface paper reflector at different irradiation level (500 W/m^2 & 300 W/m^2), obtained curves are shown in Fig.7-8 as,

It is observed that the short circuit current I_{sc}= 4.17 A and P = 6.74W at position 1, I_{sc}= 4.40 A and P= 7.10W at position 2, I_{sc}= 4.84 A and P= 7.46 W at position 3, I_{sc}= 6.49 A and P= 9.62W at position 4 of the reflector at irradiation 500W/m$^{2.}$.

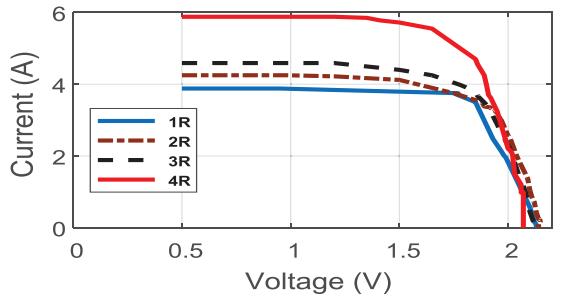


(a) I-V characteristics

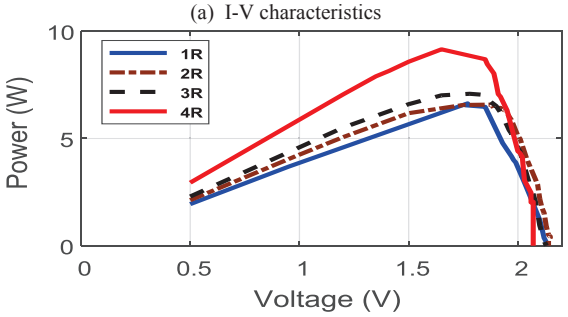


(b) P-V characteristics

Fig. 7. I-V and P-V curve with white surface reflector at 500 W/m^2.



(a) I-V characteristics



(b) P-V characteristics

Fig. 8. I-V and P-V curve with white surface reflector at 300 W/m^2.

At irradiation of 300W/m^2I_{sc}=3.88 A and P= 6.19 W at position 1, I_{sc}= 4.25 A and P= 6.34 W at position 2, I_{sc}= 4.59 A and P =7.03 W at position 3, I_{sc}= 5.88 A and P= 8.91 W at position 4 of the reflector Calculated electrical parameter are shown in Table V-VI as,

TABLE V. COMPARISON OF PARAMETERS FOR ALL POSITIONS OF WHITE SURFACE PAPER REFLECTOR AT 500W/M^2

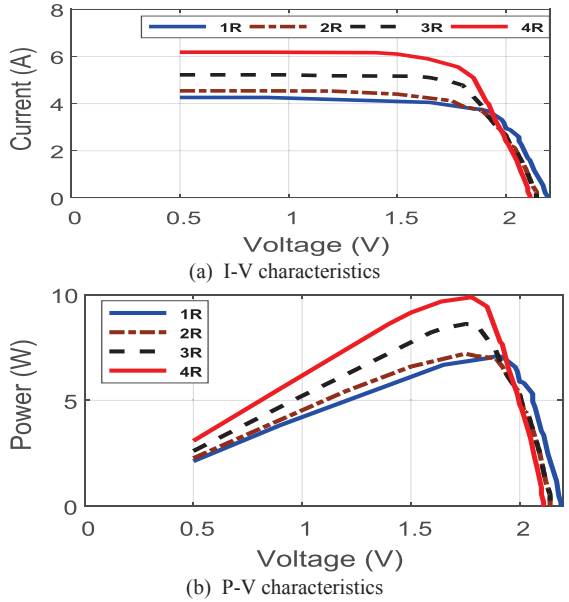
Position of reflector	I_{sc}	V_{oc}	I_m	V_m	$P_{max.}$
1	4.17	2.17	3.53	1.91	6.74
2	4.40	2.15	3.78	1.88	7.10
3	4.84	2.14	4.25	1.85	7.56
4	6.49	2.14	5.60	1.72	9.62

TABLE VI. COMPARISON PARAMETER ALL POSITION OF WHITE SURFACE REFLECTOR AT 300W/M^2

Position of reflector	I_{sc}	V_{oc}	I_m	V_m	$P_{max.}$
1	3.88	2.13	3.35	1.85	6.19
2	4.25	2.14	3.43	1.85	6.34
3	4.59	2.13	3.80	1.85	7.03
4	5.88	2.14	5.35	1.65	8.91

D. PV performance with light blue surfac reflector

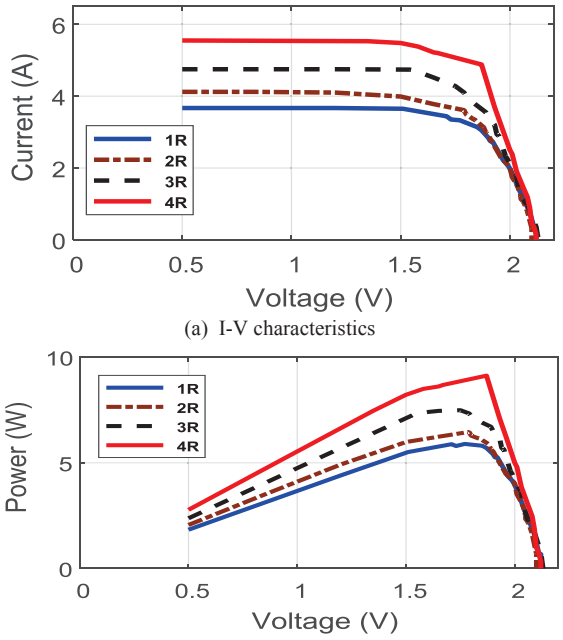
The I-V and P-V curves are plotted at light blue surface paper reflector at different irradiation level (500 W/m^2 & 300 W/m^2), obtained curves are shown in Fig. 9-10 as,



(a) I-V characteristics

(b) P-V characteristics

Fig. 9. I-V and P-V curve with light blue surface reflector at 500 W/m^2.



(a) I-V characteristics

(b) P-V characteristics

Fig. 10. I-V and P-V curve with light blue surface reflector at 300 W/m^2.

It observed that the short circuit current is I_{sc}= 4.26 A and P = 6.65 W at position 1, I_{sc}=4.54 A and P= 6.69 W at position 2, I_{sc}= 5.22 A and P= 7.42 W at position 3, I_{sc}= 6.18 A and P= 9.52W at position 4 of the reflector at irradiation 500W/m^2. . At irradiation 300W/m^2 I_{sc}=3.67 A and P= 5.88 W at position 1, I_{sc}= 4.12 A and P= 6.12 W at position 2, I_{sc}= 4.75 A and P =6.95W at position 3, I_{sc} = 5.55 A and P= 8.58 W at position 4 of the reflector. Calculated electrical parameter are shown in Table VII-VIII as,

TABLE VII. COMPARISON PARAMETERS FOR ALL POSITIONS OF LIGHT BLUE SURFACE PAPER REFLECTOR AT 500W/M^2

Position of reflector	I_{sc}	V_{oc}	I_m	V_m	$P_{max.}$
1	4.26	2.19	3.72	1.80	6.65
2	4.54	2.15	3.70	1.80	6.69
3	5.22	2.18	4.16	1.79	7.42
4	6.18	2.11	5.34	1.78	9.52

TABLE VIII. COMPARISON PARAMETER ALL POSITION OF LIGHT BLUE SURFACE REFLECTOR AT 300W/M^2

Position of reflector	I_{sc}	V_{oc}	I_m	V_m	$P_{max.}$
1	3.67	2.13	3.32	1.77	5.88
2	4.12	2.11	3.43	1.79	6.12
3	4.75	2.13	3.89	1.79	6.95
4	5.55	2.13	4.99	1.72	8.58

E. Comparative analysis of reflector system

In this section detail comparative analysis is done with the help of results for various types of reflectors. For comparison purpose, different irradiation level and position 4 are considered to present the difference among them. Table IX presents the comparative results.

TABLE IX. COMPARE MAXIMUM POWER WITH DIFFERENT REFLECTOR AT 500W/M^2 AND 300 W/M^2

Types of reflector	Irradiation (W/m^2)	Power (W)
Aluminum foil	500	11.55
White surface		9.60
Light blue surface		9.52
Clean panel		6.10
Aluminum foil	300	9.05
White surface		8.91
Light blue surface		8.58
Clean panel		4.21

From Table IX shows results, the salient point of this investigation is that configuration of PV module are more beneficial many materials are considered for reflector influence. And after comparative analysis considered the three various type of reflectors, aluminum foil, white surface reflector and light blue surface reflector, aluminum foil reflector are more effective and use full in increased the power of PV module. The comparative study is concerned at the different irradiation level, after aluminum foil reflector considered the analysis of white surface reflector, it reduce the minutely power as compare with the aluminum foil.

IV. CONCLUSION

A comparative study of the effect of three types of reflector deployed on the self- assembled PV module at different irradiation level and installed reflectors is carried out. A detailed study has been carried out on the basis of various performance parameters. The results using I-V and P-V characteristics show that reflector have significant increase in the power of the PV module. Following are the notable point of this study,

- In investigation, aluminum foil reflector is more effective to produce the power of the PV module at different irradiation level.
- For white and light blue surface reflector, it is less effective compared to aluminum foil reflector.
- Comparative study with clean module without reflector and with reflector at different irradiation level is also carried out.

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