Improve the performance of solar modules by reflectors

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Abstract. Solar energy is one of the most significant renewable energy sources, in both its applications thermal and photovoltaic, world needs. Iraq is one of the countries with the abundance of this type of energy, where annual solar activity reaches about 2000kWh / m² / year on the horizontal surface. In the present work a solar collectors with V-trough concentrator system were designed and fabricated with geometric concentration ratios two suns to get an extra electric output power. The experiment was carried out in Al-Zwraa Company in Baghdad. The main results indicated that the solar concentrator system caused to increase the short circuit current due to increase the amount of incident solar radiation on the solar modules, and thus increase in output power. As a comparison with reference module, the gain in output power, at solar noon, exceeded 48%. It can be concluded that the use of V-Trough concentrator system coupled with solar module systems can result in a favourable cost-benefit ratio.

Keywords: CPV, V-trough reflector.

1. Introduction:

Solar photovoltaic (PV) technology is a very attractive renewable energy option for clean energy generation but is limited in use due to its prohibitively high cost. However the cost of PV power generation has decreased substantially over the last two decades, and now stabilized.

There are several ways by which the PV material consumption/watt of generated power can be reduced. Some of these include concentrator PV technologies. In the PV concentrator technology, the use of optical concentrators replaces the expensive PV cell area by cheaper reflector material, hence reducing the material consumption. Compared to the non-concentrating PV, the required area of the solar cell is reduced by the factor of concentration ratio, providing significant reduction in the cost of PV system. Although the concept of use of solar PV concentrator with PV modules/cells is simple but it is difficult to implement, especially for high concentration ratio. Based on the above concepts, V-trough concentrator is an attractive option to reduce the price of the PV electrical power using conventional solar PV cells. V-trough’s are static concentrators, wherein the light intensity is boosted by placing reflectors to the sides of the PV module. Since, these are the non-imaging type of concentrators hence, diurnal tracking of the sun is not required and the added cost of the V-troughs is low as they are simple to manufacture.

The V-trough with plan Reflectors is one of the types of CPV system. Reflectors are an optical Device with cheap and suitable technology to concentrate the light and increase the amount of sunlight
onto the panel [1]. Reflectors are Lower cost, Superior efficiency, less materials availability issues, Ease of recycling, Ease of rapid and high local manufacturing content [2].

PV/T system with and without reflectors has been studied by Kostic et al [3]. These studies show the positive effect of reflectors made of AL sheet and AL foil, considering the additional cost of about 10% for the reflectors, there is an energy gain in the range 20.5–35.7% in the summer period. The present work aims at measuring the effect of V-Trough reflector on the output power of array solar system in Iraqi environment.

2. V-Trough solar concentrator
V-trough geometry is defined by two parameters: the Geometric concentration ratio and the trough angle or vertex angle (Ψ) (the angle between reflector and the column on PV). The geometric concentration ratio is the ratio between the area of aperture plane (A) and area of the absorber plane a as shown in figure 1, which can be expressed by [4]:

\[ C = \frac{A}{a} = \frac{W_{ape}}{W_{abs}} \quad \ldots \ldots \ldots \ldots \ldots (1) \]

Where the \( W_{ape} \) is the aperture width and \( W_{abs} \) is the absorber width (width of the PV module). The geometric concentration ratio in the system at vertex angle equal 30° is two suns.

![Figure 1. A- PV module, B- V-PV module [5].](image)

An early study by Bannerot and Howell [6] had suggested that static V-trough collectors could achieve an annual average concentration ratio of over 1.2 for locations with a high diffuse solar fraction, and might be suited to applications where the reflectors were off setting the cost of expensive solar absorbers such as photovoltaics. Tabaei and Ameri [7], investigated the aluminum foil and stainless steel reflectors can increase power output around 8.5%-14% of polycrystalline solar panel. The average output power for PV panels with aluminum foil reflector and water film concurrently is represented about 50% improvement in power generation. The effects of V-trough geometric
parameters such as slant height of the reflectors and vertex angle on the trough optical performance in terms of effective concentration ratio and irradiance distribution were investigated to determine the optimum design. Results show that the optimum vertex angles of the V-trough concentrator for 1.5, 2, 2.5 and 3 are 30, 30, 22, and 19, respectively [5]. Shneishil [8], study the effect of one and two reflectors on V-trough concentrator on PV output power theoretically and experimentally. The increase on insolation at noon is 61% and 120% respectively, who’s showed a good performance of solar cell.

3. Experimental

3.1 System description:
The system consists of array of three poly-crystalline (pc-Si) solar modules and V-Trough reflectors, which consists of six sheets of Aluminum foils called cpv1, cpv2 and cpv3 with total area (3*1.48m*0.67m) as shown in figure 2. There is a single PV module without reflectors as a reference. The characteristics of the PV module are listed in table 1.

![Figure 2. CPV system.](image)

| Parameter | Value       | Parameter            | Value       |
|-----------|-------------|----------------------|-------------|
| \(P_{max}\) | 330 W       | Dimensions           | 1958mm*1992mm*50 mm |
| \(I_{SC}\)  | 9.28 A      | Temperature coefficient \(V_{OC}\) | 0.31V/°C |
| \(V_{OC}\)  | 45.9 V      | Temperature coefficient \(I_{SC}\) | 0.41mA/°C |

Table 1. The characteristics of Sharp solar module 330 W.
3.2 Measurements

The experiment was implemented normally from 9 Am to 13 Pm in August/2017. During the experiment duration, ambient temperature (Ta), module temperature (Tm), short circuit current (Is), open circuit voltage (Voc), wind speed and direct with and without reflected solar irradiance (Id &Idr respectively) were hourly measured and recorded. The recorded values of temperature, Voc, Is, and Id with presence of reflectors represent the average value of three modules. Four K-type thermocouples are used to measure the temperatures of PVC modules and reference module. The geometric concentration ratio in the system at vertex angle equal 30° was two suns.

4. Results and Discussion

In the present work each of ambient temperature (Ta) and module temperature with and without reflectors (Tm &Tr respectively) were measured. The results indicated that the temperature of the reference module was increased and reached, approximately, the twice value of the ambient temperature as show in figure 3. This figure also shows that the module with reflectors had the highest mean value of temperature. This is due to interaction of light with PV material and converts a part of incident power into heat. The amount of released heat proportional with amount of incident radiation.

Another important factor that contributes in output power of PV system is the irradiance. The direct incident radiation per unit area of reference solar module (Id) was measured for one hour periodically. The result was predicted. The levels of irradiance were increased with sun elevation as demonstrated in figure 2. This figure, also, shows that the levels of this irradiance rises with using V-Trough reflectors (Idr).

![Figure 3. Variation of Ta, Tm, and Tr with day time. Figure 4. Variation of irradiance with day time.](image-url)
From figure 4 it is appear that the reflectors raise the irradiance to, approximately, double value. It is known that and according to the band theory in semiconductor the electrons leave the equivalent band toward valance band when it received photon with energy equal or more than energy gap and the number of free electrons increase with increase of incident photons and thus increase the output current of PV device. This fact is demonstrated in figure 5 by reflectors action. In this figure the current value of module with reflectors is greater than that for reference module (Im). The increment in current levels leads to improve the performance of PV solar module. This result appears the importance of using reflectors with PV solar systems. On the other hand there was dropping in output voltage of PV module with presence of V-Trough reflectors (Vr) as shown in figure 6. This drop is due to rises in module temperature by reflectors.

The voltage decrease of a silicon cell is typically 2.3 mV per 1 °C. The temperature variation of the current or the fill factor are less pronounced and usually neglected in the solar cell system design. Accordingly, only the voltage variation with temperature is allowed for in practical calculations, and for individual module consisting of \( N_c \) cells connected in series is set equal to [9]:

\[
V_{oc} = V_{oco} - (2.3 N_c T_c) \quad \quad \quad \quad \quad \quad (2)
\]

Where \( V_{oco} \) is the open circuit voltage under standard test conditions, \( N_c \) is the number of cells inside the module and \( T_c \) is the cell temperature. Based on the values of \( V_{os} \) and \( I_s \) the output power of each reference module and that with reflectors was calculated. The results indicated that there was a gain in power due to V-Trough reflectors as demonstrated in figure 7. This gain was 48% at solar noon and, as average, 42.6% along day time.
Figure 7. Output power for both modules with (Pr) and without reflectors (Pm).

According to above results, it can be predicted that the area of high-cost solar module can be reduced to, approximately, fifty percent by using low-cost reflectors.

5. Conclusion

From the present work, it can be concluded that:

1. The solar reflectors cause to rise the incident radiation levels and thus increase the PV module short circuit current.

2. The solar reflectors cause to rise the temperature of PV module and thus decrease in its output voltage.

3. The percentage of current increases more than the percentage of droop in voltage and thus there was gain in output power.

4. The use of V-Trough concentrator system coupled with solar module systems can result in a favourable cost-benefit ratio.

5. PVC project is promised in Iraqi environment.

6. References:

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