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Impact of Reflectors on Photovoltaic Panel Performance

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ABSTRACT

A photovoltaic panel (PV) is a practical method to produce electrical energy from solar light. The solar conversion efficiency of PV panels is still low, improving it wills makes great differs of PV panels used. However, the efficiency of PV panels can be improved in many ways. One of them is to connect reflectors with PV panel. So, the aim of this research is to study the effect of three types flat reflectors (Nickel Chrome reflector; NCR, Aluminum sheet reflector; ASR and reflective glass reflector, RGR) connected with both sides of PV panels at four different tilts angles (30, 45, 60 and 90^o) on the intensity of solar radiation falling per different periods of times and to determine the impact and performance of the PV panels output. Generally, the maximum daily average of solar radiation flux incident on the PV panel (from 8:00 to 17:30) was 828.93 W.h/m^2 for NCR at a reflector angle of 30^o (RA_{30}) and the corresponded percentage increment compared to the control panel was 24.98 %. Also, at zero shade periods (ZSP) from 10:30 to 13:30, the maximum daily average value of total power was 0.758 kW, which represents 74.61 % of the daily total power for NCR at RA_{90}. The highest PV panel temperature was recorded for PV panel with NCR at RA_{90}. The rate of increase in the power resulting from the reflectors is much greater than the amount of loss of power resulting from the rise in temperature.

Keywords: PV Panel, Reflectors, Power, Performance, Solar Radiation

INTRODUCTION

Egypt lies within the subtropical regain with a high potential of solar energy, which can be considered as a reliable energy source throughout the year. The annual-average daily global irradiation values are 19.4, 18.67, and 21.78 MJ/m^2 and for diffuse irradiation they are 6.65, 6.34 and 6.23 MJ/m^2 for Cairo, Matruh and Aswan, respectively. For the normal incidence beam irradiation the annual-average daily values are 24.46 and 16.94 MJ/m^2 for Aswan and Cairo, respectively (Omran, 2000). The practical efficiency of a solar PV panel is around 17% mark (Bernt Lorentz, 2004). The improvement in efficiency production of solar energy system will make big difference in the use of PV panels, reported that the output power of the designed system and its efficiency is increases by increasing the tilt angle of the concentrator. The efficiency limit for an un-doped (monocrystalline) SI cell with optimized thickness (110 mm) was calculated to be 29.4% (Richter *et al*., 2013). The record efficiency for a monocrystalline Si homojunction cell was recently set at 25.1% (Glunz S. W. 2015). Maximum power conversion efficiency of c-Si solar cells is very close to 26.7% (Green *et al*., 2018). The results showed that the PV solar panel maximum efficiency was 0.85 at 11 o'clock with tilt angle 60^o of the concentrating mirror (AL-Hamadany *et al*., 2016). A several methods (using solar tracker, cleaning dust from PV panel, cooling technique of panel and using anti-reflecting coating etc.,) have been advanced to get beter the efficiency of PV solar panel. These methods can effectively get abeter the efficiency of PV solar panel power generation (Rupali Nazar, 2015). The rear reflection enhances a contribution of the collection efficiency to above 95% for the longer wavelengths of the thin film cell. For the wavelengths below 450 nm the collection efficiency drops below 70%, which implies that optimization of the window layer is desired (Bauhuis *et al*., 2004). One way to reduce the high cost per kWh of electricity is to enhance the performance of PV flat solar panels by implementing a reflector system for these panels, the overall output and efficiency can be improved (Mitchel *et al*., 2005, Rizk, *et al*., 2002 and Jiménez V., 2004). Reflecting mirrors concentrate the light intensity over the whole surface of the solar panel. Therefore, the output power of solar panel increases (Muhammad *et al*., 2016). Particularly, it is difficult to create considerable betterment in the performance of the PV solar cell. The efficiency of the solar cell is limited by materials used in solar cell manufacturing. Therefore, increasing the solar radiation received from the sun is the most optimized way to improve the performance of the solar cell (Adel *et al*., 2016). Experimental results show the efficiency of solar PV panel up to 32% in the case of reflectors without cooling and 52% in the case of reflectors with cooling in the total output power (Radwan *et al*., 2014). Therefore, increasing the solar radiation received from the sun is the most optimized way to improve the performance of the solar cell (Adel *et al*., 2016). Experimental results show the efficiency of solar PV panel up to 32% in the case of reflectors without cooling and 52% in the case of reflectors with cooling in the total output power (Radwan *et al*., 2014).The modified PV panel produced 15% more PV power than one-sun concentration of PV panel. During the experiments the modified PV panel was found heated with maximum operating temperature of 66^{o}C (Palaskar and Deshmukh, 2014). The aim of this

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research is to study the impact of different reflectors types and angles on the intensity of solar radiation falling on PV panel and to declare the resulted changes in PV panel performance.

MATERIALS AND METHODS

Four PV panels were placed on the roof of testing and research station for tractors and farm machinery, Alexandria (Latitude 33.74 N and 72.83 E) on a rack facing south with a fixed tilt angle of 31°. Experiments were conducted from 1th May 2018 to 30th June 2018 between 8:00 am and 5:30 pm day time. Global and diffuse radiation on the horizontal surface, temperatures, output of voltage and current of PV panel at corresponding experiment conditions were recorded in 30 minutes of time interval. A PV panel of 150 Watts was used. Its specifications are given in table 1.

Table1. PV panel specifications

Item	Rating
V_{oc}	21.6 V
I_{sc}	9.25 Amps
Rated current	8.333 Amps
Rated voltage	18 V
Maximum power point(MPP)	150 Watt
Temperature of PV panel	25 ^{o}C
Area	0.9425 m^2
Max serial fuse	15 Amps
Temperature coefficient of I_{sc} (%/^{o} C)	+ 0.06
Temperature coefficient of V_{oc} (%/^{o} C)	- 0.36
emperature coefficient of P_M (%/^{o} C)	- 0.5

A solar power meter (model: SPM-1116SD) was used to measure global solar radiations on the horizontal surface every 30 minutes of time interval. The Arduino-Uno Mega 328 board used with computer software as a device for measuring and recording temperature every 30 minutes during the experimental period. Nine temperature sensors were used (six sensors for panels with reflectors, two sensors for PV panel without reflectors and one sensor for measure ambient temperature). The used temperature sensors were digital sensor at a typical / maximum ± 0.25 °C / ± 0.5 °C, and its range from 0 °C to +1024 °C. In addition, the thermocouples type was MAX6675 and 12-bit design serial K-type.

A DC voltmeter and ammeter were used to measure voltage and current at various loading conditions. Four digital multi-meters (300W) with accuracy of: +1% for DC current and + 0.09% for the DC volt were used.

Three types of reflectors were used in this study (Nickel Chrome reflector; NCR, Aluminum sheet reflector; ASR and reflective glass reflector; RGR). The dimensions of the reflectors are 147cm by 66 cm. Two reflectors of same type were assembled at the longitudinal direction of the PV panel at both sides. Four reflectors angles were used; 30, 45, 60 and 90^{o} which represented as follow RA_{30}, RA_{45}, RA_{60} and RA_{90} respectively. Fig. 1 shows the reflectors as assembled with the PV panels.

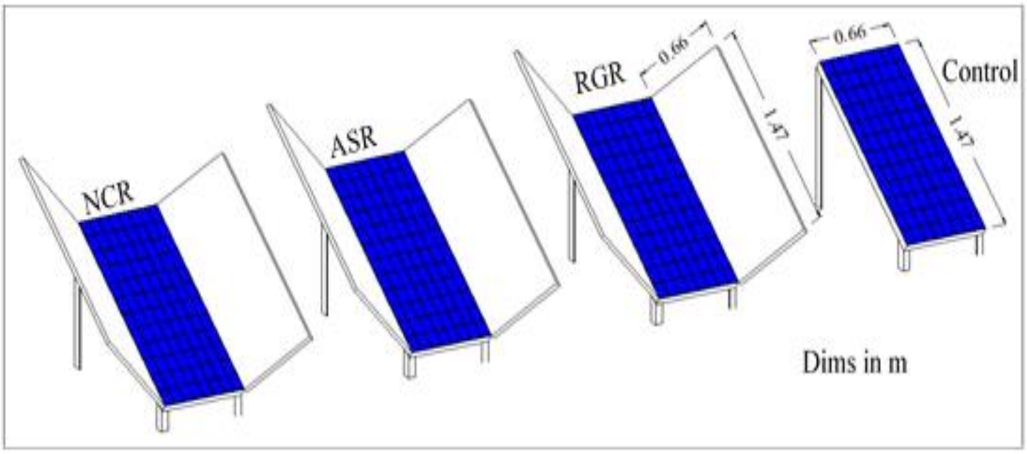

Fig.1. Schematic of panels with the three reflectors types and the control panel.

The following equations and procedure were used to calculate the PV panel and PV panel with reflector parameters (Helmy *et al*. 2014).

The maximum power was calculated using the measured maximum current and the maximum voltage.

$$p_{max} = I_{max} \text{ x } V_{max} \quad \ldots\ldots(1)$$

The following relation was used for the calculation of PV panel efficiency,

$$\eta_M = \frac{p_{max}}{G \text{ x } A} \quad \ldots\ldots(2)$$

$$increasing\ power\ (\%) = \frac{p_{MR} - p_M}{p_M} \quad \ldots\ldots(3)$$

$$increasing\ in\ module\ efficiency\ (\%) = \frac{\eta_{MR} - \eta_M}{\eta_M} \quad .(4)$$

Where:

A	Actual area of PV panel	p_M	Output of PV panel
G	Global solar irradiance	p_{MR}	Output of PV panel with reflector
I_{max}	maximum current	p_{max}	Maximum power
V_{max}	maximum volt	η_{MR}	Efficiency of PV panel with reflector
η_M	PV panel efficiency		

RESULTS AND DISCUSSION

Reflectors types and tilt angles via the solar radiation flux incident on the PV panels

The results in Fig. 2 indicated that the solar radiation flux incident on the PV panel recorded on the PV panels with reflectors was a higher compared to the PV panel without reflector. The difference of solar radiation between the three types of reflectors was very small at the day time from 8:00 to 10:00 am and from 15:00 to 17:30 and the maximum solar radiation for the three types of reflectors was recorded from 10:30 am to 14:30.

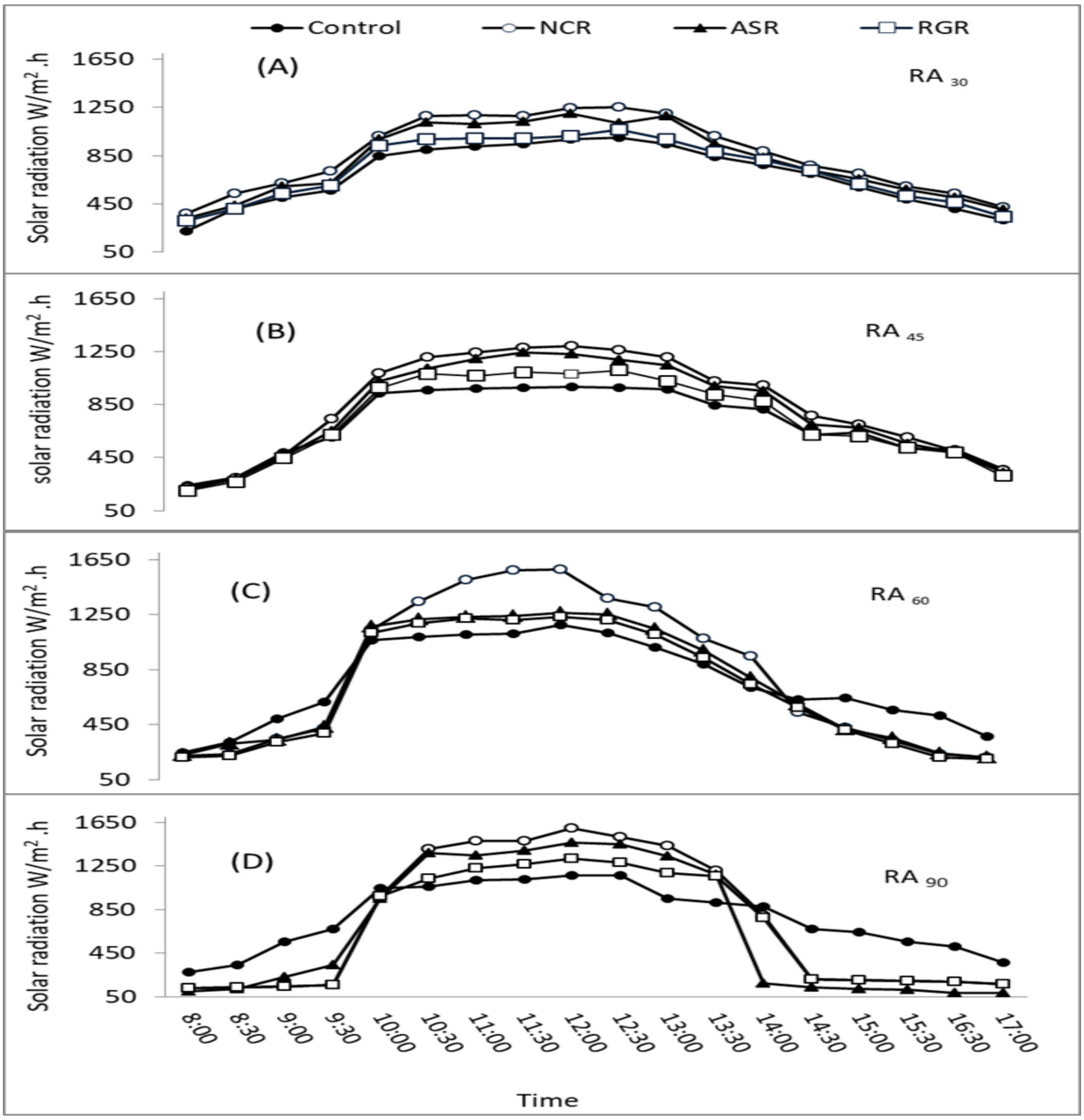

Fig. 2. Reflectors types and tilt angles via the solar radiation

Fig. (2-A) represents the average solar radiation flux incident on the PV panel at RA_{30} for all reflectors types and the control. The daily average total solar radiation at the day time from 8:00 am to 17:30 were 828.93,778.21 and 707.12 W h/m^2 for NCR, ASR and RGR respectively, compared with the control which was 663.24 W h/m^2. The highest increasing percentage of solar radiation received compared with the control was 24.98 % for NCR.

Fig. (2-B) represents the average solar radiation flux incident on the PV panel at RA_{45} for all reflectors types. The daily average total solar radiations during the day time from 8:00 am to 17:30 were 813.93, 771.93 and 711.86 W. h/m^2 for NCR, ASR and RGR respectively, compared with the control which was 682.35 W. h/m^2. The highest solar radiation received was by the NCR and it was higher by a value of 19.28 % compared with the control.

Fig (2-C) represents the average solar radiation flux incident on the PV panels at RA_{60} for all reflectors types. The daily average total solar radiation during the day time from 8:00 am to 17:30 were 790.32, 718.08 and 685.73 W. h/m^2 for NCR, ASR and RGR respectively, compared with the control which was 730.63 W. h/m^2. The highest solar radiation values received was by the NCR was 8.17 % compared with the control.

Fig (2-D) represents the average solar radiation flux incident on the PV panel at RA_{90} for all studied reflectors types and the control. The daily average total solar radiation during the day time from 8:00 am to 17:30 were 713.49, 636.82 and 631.38 W.h/m^2 for NCR, ASR and RGR respectively, while, the control panel was 749.57 W.h/m^2. In general, the solar radiation flux incident on the PV panel with reflectors decreased compared to the control because both reflectors sides have shade on a large part of the PV panel at the beginning and end of the day (from 8:00 to 10:00 am and from 15:00 to 17:30).

Reflectors types and tilt angles via daily total power

The results in Fig. 3 showed the total power of PV panels with reflectors at different tilt angles and the control PV panel during the day time from 8:00 to 17:30. As shown in the results, the maximum daily total power was recorded for the PV panel with NCR compared to the PV panel with ASR and RGR at RA_{30}, RA_{45}, RA_{60} and RA_{90}. These results are corresponding with the results of solar radiation flux incident on the surface of the tested panels.

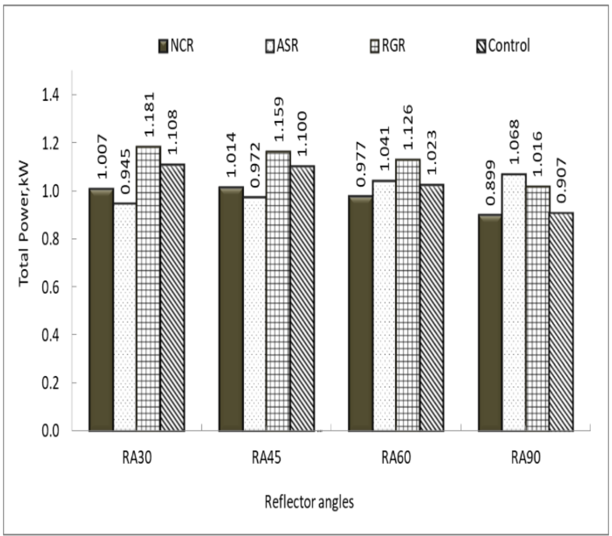

Fig. 3. Reflectors types and tilt angles via daily total power

It was also founded that, the PV panel with reflectors has a greater total power than the control at different reflector angles except the RA_{90}. This was due to the reflector with RA_{90} at the beginning and end of the day shades a part of the PV panel. Therefore, the daily total power for the control was more than the total power for the PV panel with reflectors at RA_{90}.

Effect of reflectors types and tilt angles on PV panel temperature

Fig.4 shows the effect of reflectors type and angle on PV panel temperature. The temperature was higher for the PV panels with all reflectors types and at all tilt angles than the control one. The highest PV panel temperature was received for the NCR followed by ASR and the last was RGR at RA_{90}. The highest PV panel temperature values were 52.3, 56.1, 60 and 61.5^{o}C for NCR compared to the control at RA_{30}, RA_{45}, RA_{60} and RA_{90} respectively. The results proved that, increasing the PV panel temperature due to the use of reflectors relatively decreased the power obtained.

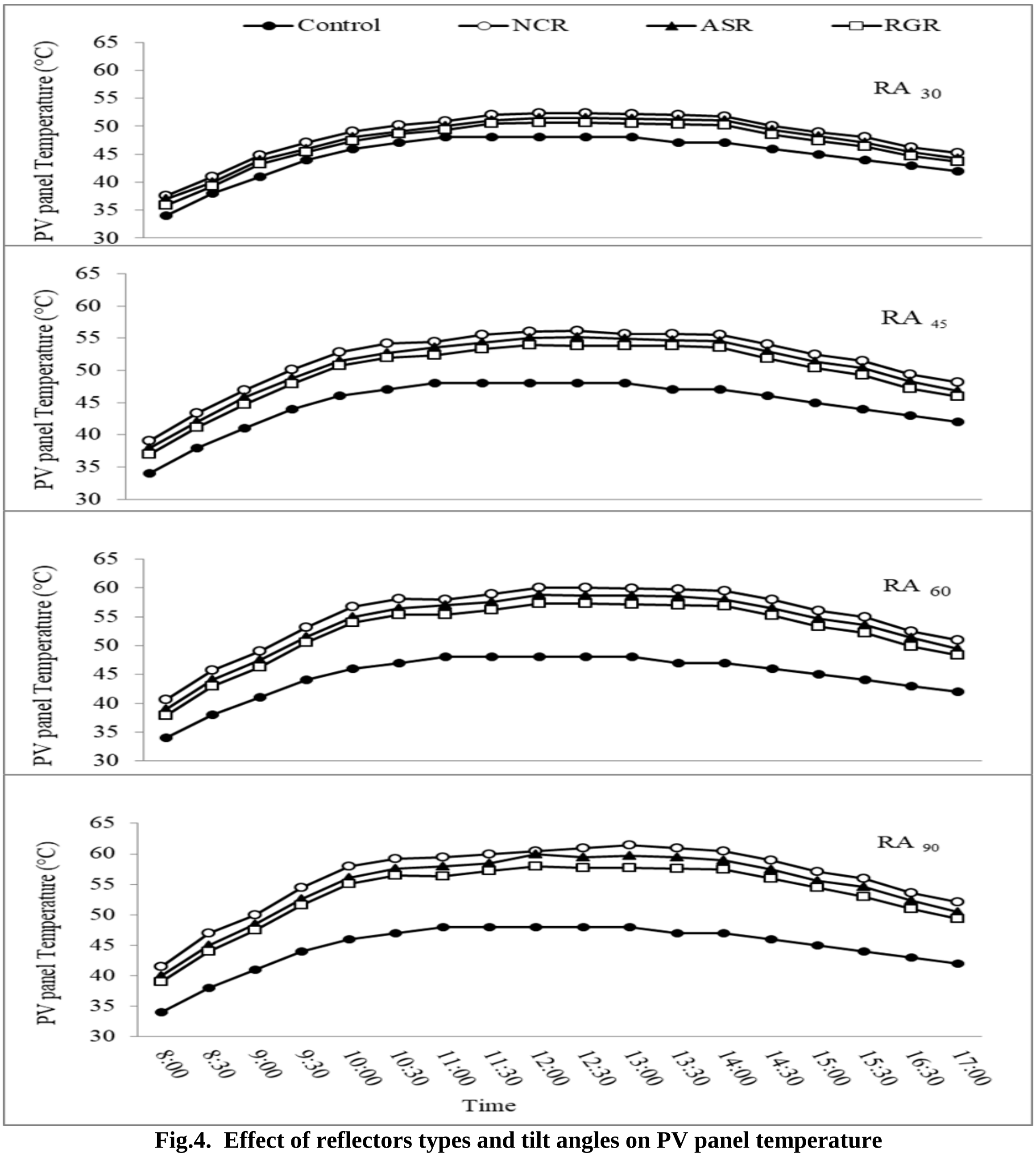

Fig.4. Effect of reflectors types and tilt angles on PV panel temperature

Reflectors types and tilt angles via total power at zero shade period

Fig. 5 shows the effect of the reflector type and angle on the PV panel total power at the day time from 10:30 am to 13:30 pm which represents a zero shade period (ZSP) compared with the control. The highest value of the total power for the three studied types of reflectors at different angles was for the NCR at the ZSP. The maximum values of total power for the PV panel with NCR, ASR and RFR at RA_{90} were 0.758, 0.715 and 0.643 kW respectively, compared with the control PV panel (0.563 kW) at ZSP. Also, at ZSP the maximum daily average value of total power which was 0.758 kW represents 74.61 % of the daily total power for NCR at RA_{90}.

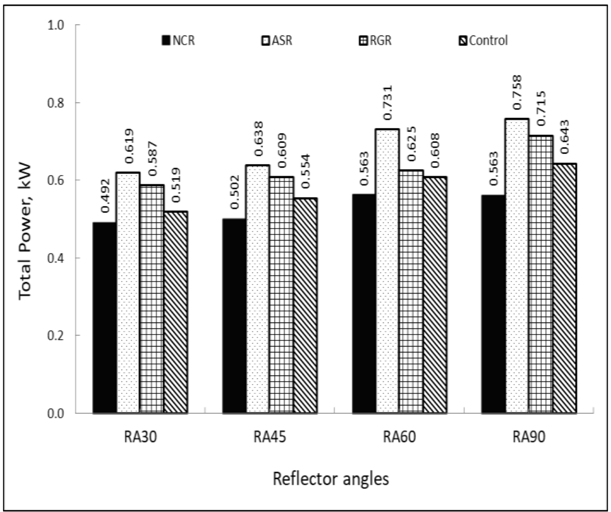

Fig.5. Reflectors types and tilt angles via total power at zero shade periods

Fig.6 results indicated the maximum increase in power during ZSP was recorded for PV panel with NCR compared to the PV panel with ASR and RGR at different angles. The highest percentage increment compared to the control panel in power was 34.76 % for NCR and RA_{90} during ZSP.

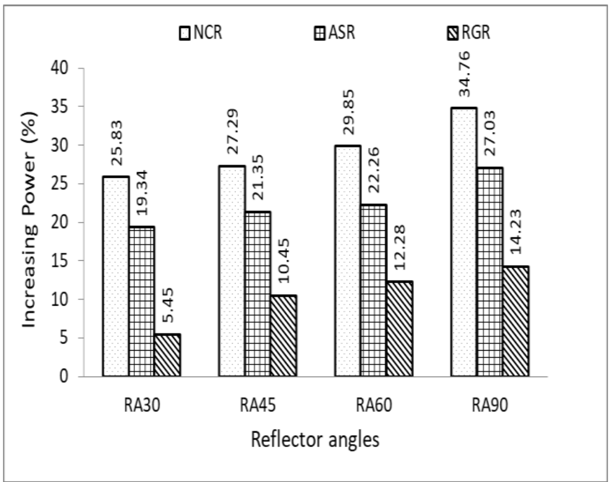

Fig.6. Reflector types and tilt angles via increasing power at ZSP

Discussion

The discussion of the above results recorded that the values of solar radiation for PV panels with reflectors are mostly higher than the PV panel without reflector. The power gradually increases from morning to noon, however, it starts decreasing in the afternoon. In fact, the highest improvement of PV panel occurs with the reflector during the mid-day, when solar intensity goes higher. So, improvement in this part of the day is more beneficial as compared to morning and afternoon. With fixing the PV panel reflectors at certain angles, sun rays falling on it are not fully reflected on PV panel surface at the period from 8:00 to 10:00 am and from 2:30 to 17:30 and increasing the shading from the reflector on the PV panel surface those makes the modified PV panels performance less than the control PV panel especially with the RA_{90}. To utilize this condition, the reflectors should be tracked from morning to evening continuously along East-West direction beside using a proper reflector type and angle to produce power and maximizing the efficiency more than its rated output. Meanwhile, the life of PV cell will be decreased due to overheating of PV cells and components. Cooling of the modified PV panel is required to increase life of PV cell and PV panel.

CONCLUSION

Several conclusions could be drawn from the investigations of the effect of reflectors types on the performance of PV panels. The use of plane reflector for improving the performance of the PV panel has shown impressive results. Using of plane reflectors are easy in installation, making the usage of solar panel more feasible, inexpensive, reducing the overall cost of electricity generation and improving the performance of the PV panel. Another advantage is increasing the PV panel output power considerably during mid-day. An increase of 20–37 % in solar radiation received on the PV panel was observed with the use of reflectors. A corresponding increase in power output was also recorded. The conversion efficiency seems to be showing considerable increase with the use of different studied reflector types and angles.

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تأثير العواكس على أداء الألواح الفوتوفولتية

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الألواح الفوتوفولتية هي وسيلة عملية لإنتاج الطاقة الكهربائية من ضوء الشمس. لا تزال كفاءة تحويل الطاقة الشمسية من الألواح الفوتوفولتية منخفضة، لذا فان العمل على تحسين كفاءة نظام إنتاج الطاقة الشمسية من الالواح الفوتوفولتية سوف يحدث فرقا كبيرا في استخدامها. ويمكن تحسين كفاءة الألواح الفوتوفولتية بطرق عديدة منها استخدام عواكس مسطحة على جانبي الألواح الفوتوفولتية. ويهدف هذا البحث إلى دراسة تأثير استخدام ثلاثة أنواع من العواكس: عاكس النيكل كروم (NCR) ، عاكس صفائح الألمنيوم (ASR) وعاكس الزجاج العاكس (RGR) وأربع زوايا عاكسة (30 ، 45 ، 60 و 90^o) على شدة الإشعاع الشمسي الساقط على الألواح الفوتوفولتية في فترات زمنية مختلفة. لتحديد تأثيرها على ناتج الألواح الفوتوفولتية. حيث بلغ أقصى متوسط إشعاع شمسي يومى متجمع على الالواح الفوتوفولتية 828.93 واط .س/م2 مع عاكس النيكل كروم NCR عند زاوية عاكس قدرها 30^o (RA_{30})، وكانت أعلى نسبة للزيادة فى الإشعاع الشمسي المتجمع على الوحدة المعدلة هي 24.98% بالمقارنة بالكنترول. أيضًا ، في فترة الظل الصفري (ZSP) من الساعة 10:30 إلى الساعة 13:30 ، كان الحد الأقصى لمتوسط القيم اليومية لإجمالي الطاقة هو 0.758 كيلوواط ، وهو ما يمثل 74.61٪ من إجمالي الطاقة اليومية للـ NCR عند RA_{90}. وكانت أعلى درجة حرارة مسجلة للوحدة مع NCR عند RA_{90}. وكان معدل الزيادة في القدرة الناتجة عن العواكس أكبر من مقدار فقدان الطاقة الناتج عن ارتفاع درجة الحرارة.