

Comparison of Power Output from Solar PV Panels with Reflectors and Solar Tracker

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Abstract

In this paper, performance enhancement of solar Photo Voltaic (PV) panels has been experimented utilizing diffused reflectors and solar-tracker in other to determine the one with higher power output. An intelligent solar tracker and diffused reflector augmented systems were designed, developed and installed to compare the power output that can be generated from each of them when standing alone; and which system will achieve higher power output so as to reduce the number of PV panels required at any given time especially when cost is a major factor. For this comparative study, experimental readings were simultaneously taken from the panel, with sun tracker and the panel with diffuse reflectors aligned at 23.5° with the horizontal. Experimental results indicate appreciable increase in the overall power output of the solar panels. It is discovered that the power output of the panel with reflectors was higher from about 11 am till 2 pm, while the panel with tracking was higher at other times. The average power output of the system for a day is about the same. Looking at the cost of fabrication and the complexity of the tracking system, the reflector system is the better option.

Keywords: Diffuse Reflectors, Performance enhancement, Power output, Solar PV panels, Tracking system.

1. Introduction

Fossil fuel is causing our world a lot of havoc in terms of environmental pollution and degradation. Fossil fuels are non renewable energy sources. Renewable energies sources are intermittent, low density and the initial cost of equipment needed is usually high. In other to justify the shift from fossil fuel energy sources to renewable energy sources, the performance of the renewable energy collector has to be improved upon. The main source of renewable energy on earth is the sun and one the renewable ways to harvest the energy of the sun is through the solar PV panels. PV panels are arranged in the sun and connected together in other to generate electricity. The electricity generated depends on the sun intensity and its the angle of incidence of the panels. With reflectors, the collecting area is increased, while with the solar tracker, the angle of incidence of the Sun on the PV panel is reduced, thereby increasing the power output for each particular system. Several works has been done in this area. Rizk and Nagrial (2000) showed that implementing different types of reflectors in solar energy systems, will dramatically improve energy production by means of concentrating and intensifying more sunlight onto a solar cell. Rizwan et al. (2009), experimented performance enhancement of solar panels using diffused reflectors and sun tracking. Their results showed that there is no need for sun tracking if diffused reflectors are installed with the panel. Antara et al. (2010) utilized various types of reflectors at a designed angle which increased the output power of each individual panel in different weather conditions. They concluded that by implementing reflector with the panel, the power output of a solar panel can be increased, and the aluminum finish reflector improved solar cell output than the other reflectors used. McFee (1975) was among the first people to construct automatic solar tracking systems, in which an algorithm was developed to compute the total power received and flux density distribution in a central receiver solar power system. Semma and Imamru (1980) used a simple microprocessor to adaptively adjust the positions of the solar collectors in a photovoltaic concentrator such that they pointed toward the sun at all times. Kalogirou (1996) proposed a one-axis tracking system which contains three light-dependent resistors (LDRs). Gadewadikar, (1997) made solar tracking system using a microprocessor that controls the tracking system which involves a stepper motor. Microprocessor was used to control the tracking system by interfacing with others components. Khalifa and Al-Mutawalli (1998) developed a two-axis sun tracking system to enhance the thermal performance of a compound parabolic concentrator. The system was designed to track the sun's position every three to four minutes in the horizontal plane and every four to five minutes in the vertical plane. Yousef (1999) developed a sun tracking system in which the nonlinear dynamics of the tracking mechanism were controlled using a fuzzy logic control algorithm implemented on a PC and supported by an interfacing card consisting of a sensor data acquisition function, motor driving circuits, signal conditioning circuits and serial communications. Roth et al. (2004) designed and constructed a sun tracking system. Jong Kiun Kiet, (2006) created a Miniature Solar Tracker. This solar tracker was microcontroller based

and single- axis tracking systems using DC motor. The objective of this paper is to design and develop solar power output enhancement systems and compare the output to know which is better in sub - Sahara Africa.

2. Design and Development

2.1 Description of the Components

Solar Panels: These are PV modules that converts photons in Solar rays to direct-current (DC) and voltage. The amount of current generated by a PV panel depends on its efficiency, its size (surface area) and the intensity of sunlight striking the surface at that moment. Table 1, gives the specification of the solar PV panels used in this experiment.

Table 1: Specification of solar PV panel

Maximum power output, Pmax [W]	20.00
Open circuit voltage, Voc [v]	26.70
Short circuit current, Isc [A]	0.80
Nominal operating voltage, Vdc [v]	12
Cell type	Mono-crystalline

Reflectors: Reflectors are reflective surfaces used for collecting and reflecting solar energy in order to boost energy production. A flat solar panel can incorporate reflectors at the sides. The idea is to increase the sunlight intensity onto the panel by reflecting sunlight that would normally have missed the panel, thereby increasing the panel's surface area. Reflectors are normally situated at an optimum angle to gain the greatest exposure to sunlight that can be reflected to the panel. The common reflectors are the flat surface and the parabolic shapes. Various materials are used as reflectors such as mirrors, aluminum, stainless steel, chrome film, silver surface, and white surfaces to mention but a few. The solar PV panel and the diffuse reflector system is shown in Figure 1 below.



Figure 1: Solar PV panel with diffuse reflector system

Solar Tracker: A solar tracker is a device that orients PV panels toward the sun. The sun's position in the sky varies both with the seasons of the year and time of the day as the sun moves across the sky daily. Equipment depending on solar power works best when pointed at or near the sun angle of incidence, so a solar tracker will increase the effectiveness of such equipment. In flat-panel photovoltaic (PV) applications, trackers are used to minimize the angle of incidence between the incoming sunlight and a photovoltaic panel which will typically lead to an increase in electricity generation capacity of the PV panel. There are different types of solar trackers such as the time based and the intelligent type. There is single axis tracker and also dual axis tracker (Siew, 2008). The tracker used here is the intelligent type makes use of sensors to detect the position of the sun over the length of a day and thus the system knows the direction to which the panel will face. This system is basically a single-axis active tracker. The solar PV panel with tracking system is shown in figure 2.

2.2 Design

In this section the design of the diffuse reflectors and solar tracking system is carried.

2.2.1 The Reflector Design

The solar PV panel is designed to have four reflectors, one on each side. The reflector is a flat plate made of aluminum. The panel is oriented facing south. The analysis of the reflectors designs are given below.

The W-E Configuration Analysis

The proposed solar PV and reflector system is shown in Figure 2. The reflector is inclined from vertical at a specified angle. Introducing trigonometric principle of similar triangles, the optimum inclination angles of the solar PV and reflector is obtained using the incident angle of the sun at solar noon as contained in Table 2.

Table 2: The values of solar height angle for different days (Solar position locator (ESRL, 2012))

Date	Sept. 28	Sept. 29	Sept 30	Oct. 1	Oct. 2
Solar height angle ($^{\circ}$)	79.71	80.10	80.49	80.88	81.27

Mean solar height angle = 80.5°

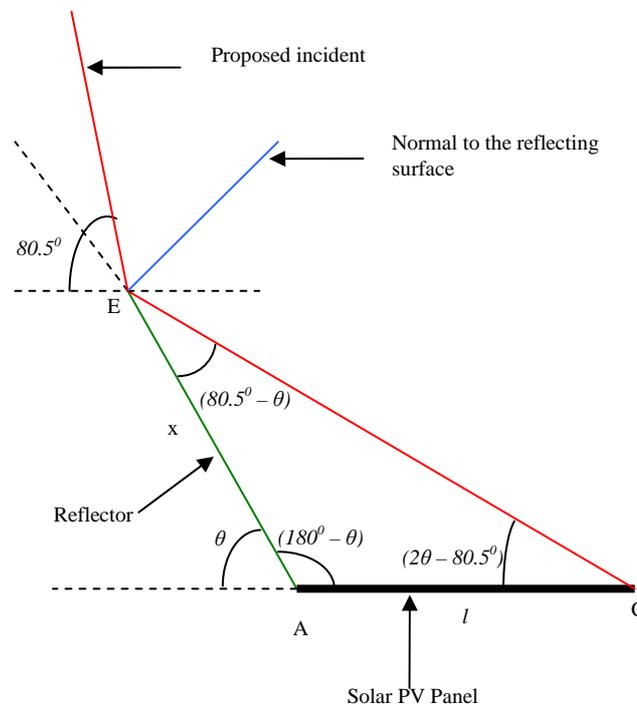


Figure 2: W-E configuration of the reflectors and the panel

where x = length of diffused reflector

l = length of solar panel

θ = the angle the reflector makes with the horizontal plane

Using Sine rule in triangle ABC,

$$\frac{l}{\sin(80.5 - \theta)} = \frac{x}{\sin(2\theta - 80.5)} \tag{1}$$

$$x = \frac{l \sin(2\theta - 80.5)}{\sin(80.5 - \theta)} \tag{2}$$

By iteration, and using values for θ from 45° to 60° , and a reflector to solar PV length ratio of 1, i.e. $x = l = 36\text{cm}$, then the corresponding value of $\theta = 53.7^{\circ}$.

The N-S Configuration Analysis

The proposed solar PV and reflector system is shown in Figure 3. The same mean solar height angle as in the previous analysis is being used.

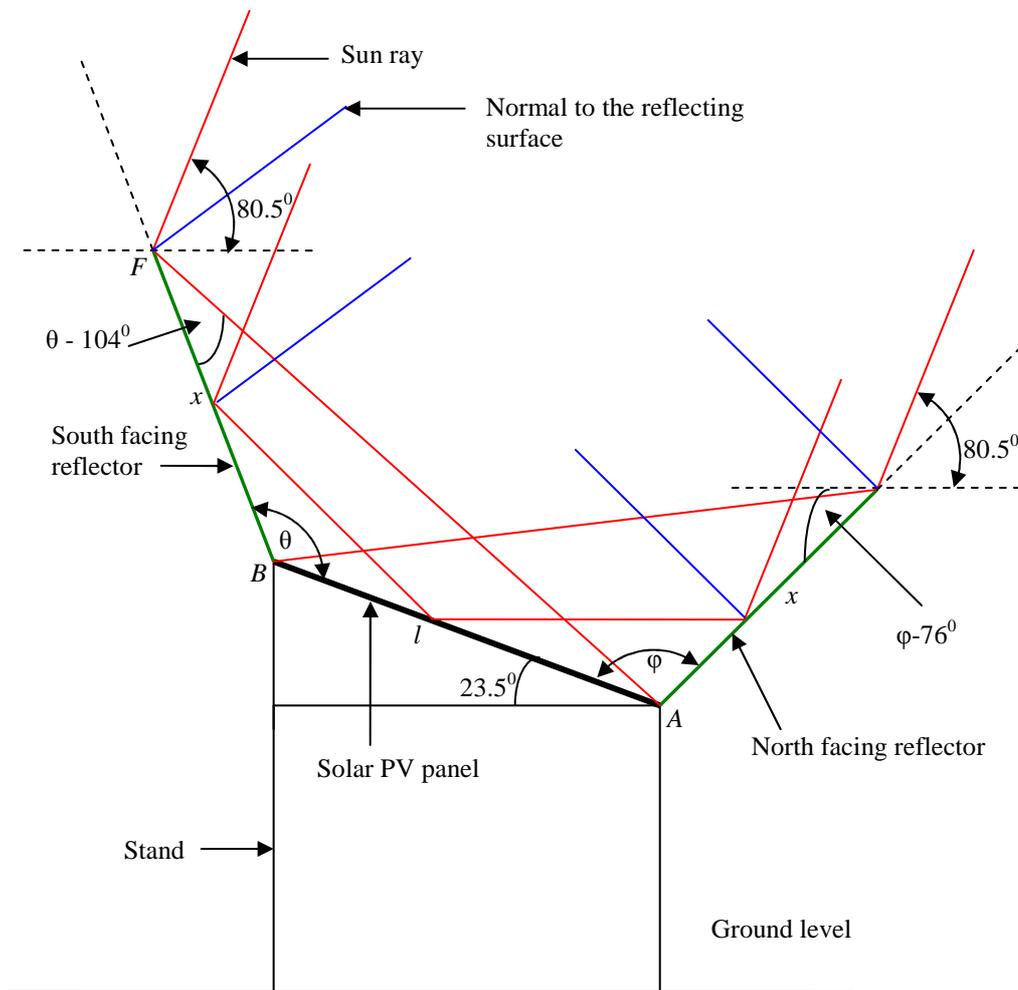


Figure 3: N-S configuration of the reflectors and the PV panel analysis

where x = length of diffused reflectors

l = width of solar panel

ϕ = angle between the North facing reflector and solar panel

θ = angle between the south facing reflector and solar panel

Using Sine rule in, triangle ABF ,

$$\frac{l}{\sin(\theta - 104)} = \frac{x}{\sin(284 - 2\theta)} \quad (3)$$

$$x = \frac{l \sin(284 - 2\theta)}{\sin(\theta - 104)} \quad (4)$$

Using iteration, values of x were generated using varying values of θ from 125° to 140° . Thus, using the obtained from iteration and using a reflector to solar PV panel length ratio of 1, i.e. $x = 29.5\text{cm}$, then the corresponding value of $\theta = 129.3^\circ$ i.e. 105.8° from the horizontal.

Using Sine rule in triangle EFG ,

$$\frac{l}{\sin(\phi - 76)} = \frac{x}{\sin(256 - 2\phi)} \quad (5)$$

$$x = \frac{l \sin(256 - 2\varphi)}{\sin(\varphi - 76)} \quad (6)$$

Similarly by iteration, the value of $x = 29.5\text{cm}$, then the corresponding value of $\varphi = 110.7^\circ$ i.e. 45.8° from the horizontal.

2.2.2 Solar Tracker

Basically the tracking system is a mechanism that moves the solar panel to the appropriate position to face the sun as the earth rotates. The intelligent type of tracking system involves the use of sensors that detects the position of the sun through out a day and thus the system knows the direction to which the panel will face. This system is basically a single-axis active tracker. In building this system, the following components were used: the micro-controller, the motor, the battery and the solar PV panel.

Micro-Controller

The micro-controller, Figure 4, is the brain of the tracker, and it controls the tracking system. Basically, it receives input from the sensors, specifying the position of the sun and in response, it sends signal to the motors that are connected to the solar panel to move to the panel to the position of the sun in which optimum solar rays could be received. The micro-controller is made up of software and hardware components. The software component is basically computer programs that decode the input signals and sends out appropriate signal in response to the inputs to control the tracking system. It is connected to the sensors and the motors. The hardware executes the command.

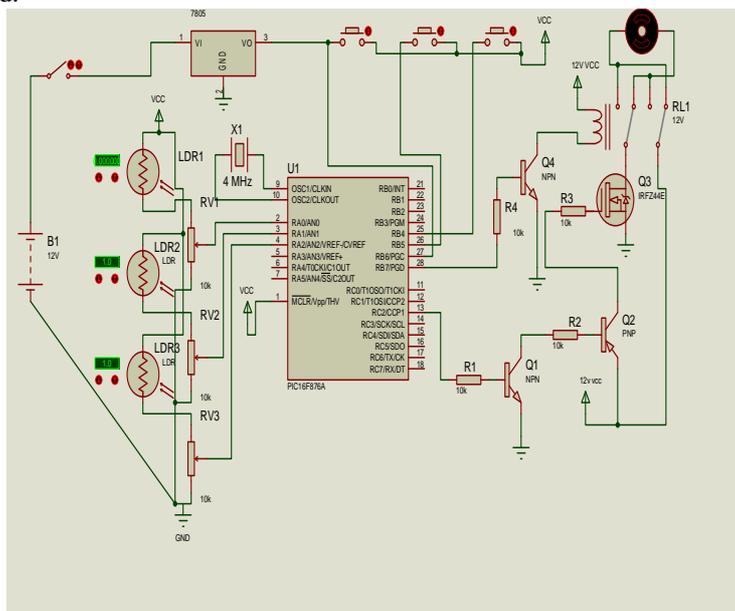


Figure 4: Micro-controller circuit diagram

Motor

The motor is the prime mover in the system, which moves the solar panel into appropriate position. A 12V, 3amps DC gear motor is used. It is connected to the panel.

Battery

The tracker needs a power source to keep it running due to the irregularity of the power received from the solar panel. A 12V rechargeable battery is used; the battery as it is connected to the tracking system is also connected to the output of the solar panel to keep it charging.

3. Results and Discussion

Solar PV panels with diffused reflectors and solar tracker were constructed in order to determine the system that will produce the higher power output. They were both placed in the sun close to each other to have the same sky condition as practicable enough. Readings were taken on both systems simultaneously for comparison. The longer axis of the panel is aligned horizontally in the east – west direction, facing south. The reason behind this kind of placement is to utilize the maximum area of the panel for diffused reflection. The reflectors were fixed to the four sides of the solar PV panel.

For the solar tracker, the solar PV panel is attached to the tracker to track the sun as it rises from the east to set at the west. The open circuit voltage (Voc) and short circuit current (Isc) of the solar panel of the two systems were measured concurrently with two multi-meters. Figures 5 and 6 are the plots of the performance of the two systems on a sunny and cloudy day respectively. In Figure 5, the reflector system is higher between 10 am and 2 pm and lower at other times. This is because the angle of incidence of the sun on the solar PV panel and reflectors is minimum.

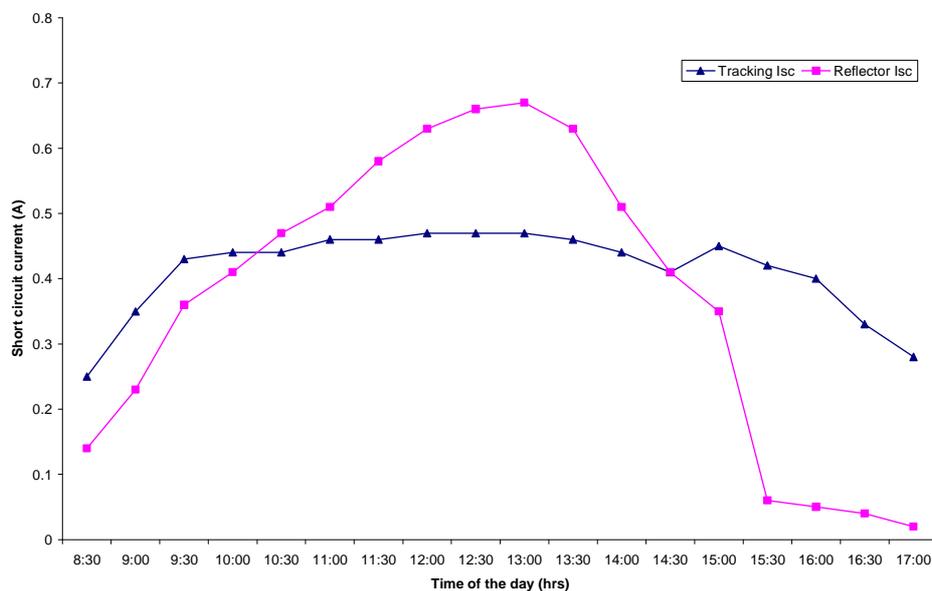


Figure 5: Short circuit current of the solar PV panels vs. time of the day (sunny day)

What was noticed during the experiment in the system with diffuse reflectors is that the east and west reflectors were blocking the sun thus casting shadow on the solar PV panel during rising and setting of the sun, thus causing loss of power during these periods. On a cloudy day, there is no much difference in the solar power output as seen in Figure 6.

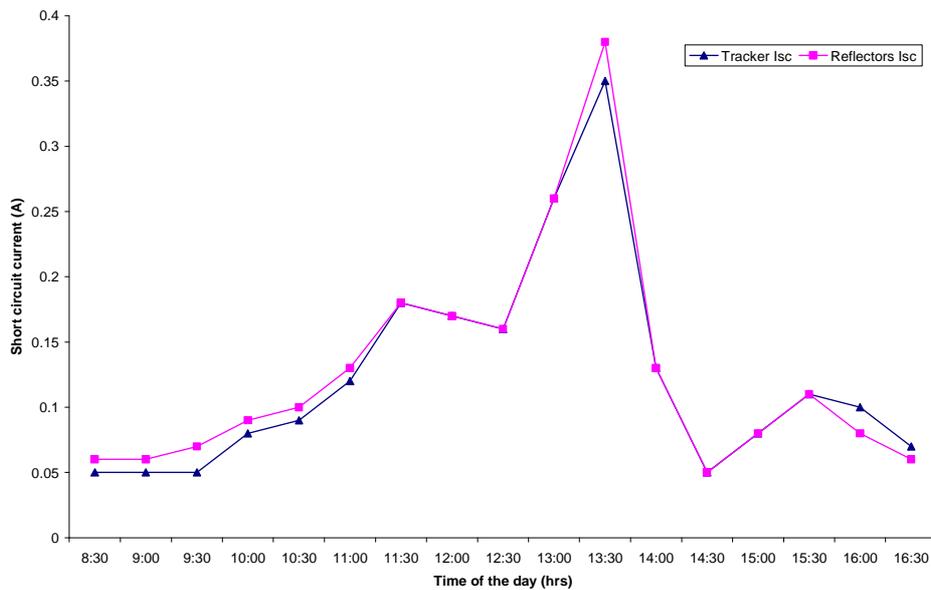


Figure 6: Short circuit current of the solar PV panels vs. time of the day (cloudy day)

Figure 7, is the plot of daily average short circuit current and shows solar PV panel with tracker producing slightly higher power than the solar PV panel with reflectors.

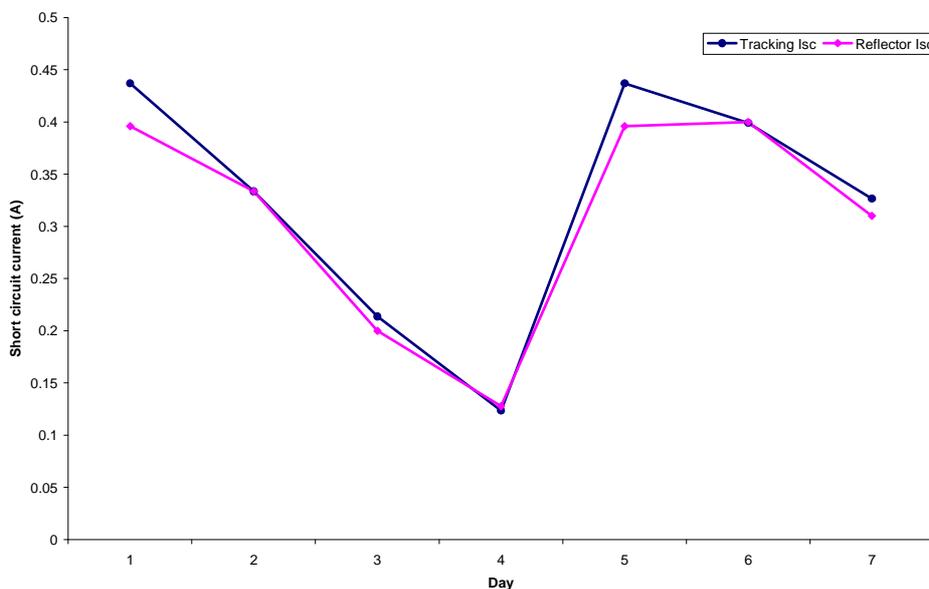


Figure 7: Average daily short circuit current

4. Conclusion

The system of solar PV panel with diffuse reflector and tracker has been designed, developed and tested. It is discovered that the east – west oriented reflectors were blocking the sun ray up till 10 am in the morning and from 2pm in the afternoon till sunset. This could be the reason why the short circuit current of the tracker is higher than that of the diffuse reflector system during these periods. From this experiment, it can be concluded that it is better to use diffuse reflectors to improve the power output of a solar PV panel because it is cheaper and less complicated.

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