A simple improvement of an off-grid solar photovoltaic panel using an integrated reflector

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Abstract. This work presents a simple demonstration of a solar photovoltaic (PV) panel integrated with mirror reflectors to increase electric energy generation. The reflector was integrated with a PV panel and its angle was adjusted to an incline to optimize sunlight collection. Current and voltage generated by PV panel was recorded by an Arduino data logger. The integrated-reflector PV panel at an appropriate incline angle of 70 degrees presented a 9.38% increased electric energy beyond that of a conventional PV panel. This result was because the reflector provided greater sunlight to the PV panel. Therefore, this method can be used to increase solar PV panel performance without the installation of additional panels.

1. Introduction

Each year, energy consumption rapidly increases due to population growth, industrial development, and economic growth [1,2], while conventional energy sources such as coal, oil, and natural gas are decreasing [3]. Alternative energy is thus proposed and considered for future development, especially solar energy [4] according to an energy policy that focuses on solar energy in Thailand [5]. Solar energy is a significant energy resource that is capable for meeting energy demands because it relies upon a free, limitless, clean, and available energy source [6]. To harvest solar energy, the solar photovoltaic system is a highly attractive technology to convert sunlight into electricity. Electricity also be stored for usability or sustainable-energy management. Moreover, energy in electric form is the most convenient to use since it can easily be converted to other energy-forms such as heat, light, and kinetic energy [7,8]. Photovoltaic systems have therefore been installed and developed in many areas and countries. Moreover, photovoltaic systems can be installed at different scales including the household, a community, and by industry [9-11]. Among these, the household and community scales are very difficult to develop due to capital limitations. Therefore, developing already-installed systems without additional installation should be considered as an alternative way to increase output.

To develop a PV system, increasing overall sunlight collection is an interesting and straightforward strategy. For example, Atif *et al*. [12] developed an open loop tracking PV system to improve electricity generation performance. The developed system showed 18% higher performance than a static PV system. However, moving component may be unsuitable for long-time stability since mechanical components require maintenance. Sornek *et al*. [13] investigated a simple method to improve building-integrated solar PV systems using Fresnel lenses to enhance sunlight collection.

They found that the developed PV system generated 7% more electricity than the conventional system. This study implies that a PV system can easily be improved using a concentrating strategy [14,15]. Similarly, Hadavinia and Singh [16] presented a simulation of a compact PV system with V-trough and compound parabolic concentrators. The simulated results indicated that both concentrators can potentially increase sunlight harvesting efficiency which resulted in improved solar PV performance compared to a flat PV system. These investigations suggest that the development of a stationary PV system using concentrating strategies can effectively and simply enhance PV performance. Concentrating strategies are an interesting method that can be promoted for rural or small-scale PV owners. This work therefore aimed to increase the electricity generation performance of a solar PV panel using a simple mirror reflector. The reflector was expected to reflect and collect more sunlight for the solar PV panel. This simple method could increase sunlight intensity on a solar PV panel and thereby improve electricity generation.

2. Experiment

A solar PV panel system integrated with two mirror reflectors (PV1) and a conventional PV (PV2, used as a reference system) were setup as shown in figure 1, at Kasetsart University Kamphaeng Saen Campus, Nakhon Pathom, Thailand (Latitude 14° 01′ 16.08″ N). The PV panels were turned southwards. The PV plate was inclined to 14 degrees to the south according to the experimental location. Both solar PV panels were silicon polycrystalline with identical characteristics of 12V30W and had an area of 35cm × 63cm. Current and voltage of each PV panel were recorded by a DIY Arduino data logger. Similarly, temperature at the PV surface was recorded by the data logger via a sensor. The DIY Arduino data logger system included an Arduino microcontroller, SD card, real time clock module, current sensor, voltage sensor, and temperature sensor. The Arduino microcontroller was programed to read the sensors and record the current, voltage, and temperature data from 9:00 to 15:00 local time. Meanwhile, sunlight intensity was measured by a handle solar power meter. Light emitting diodes (LEDs) were used to represent the external load. To improve PV panel performance, two mirror reflectors were attached at along with the PV1 length as presented in figure 1. To study the effect of the reflection of the mirror on PV panel efficiency, the reflectors were adjusted on the inclined angles of the plate from 40 degrees to 80 degrees.

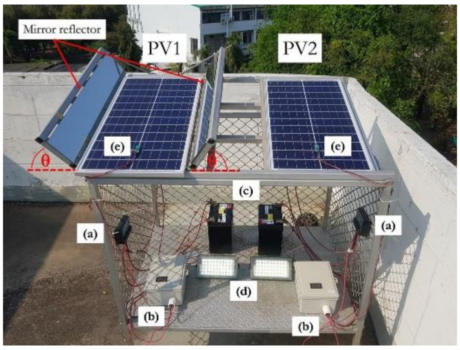

Figure 1. PV panel system setup with and without reflector: (a) charge controller, (b) Arduino data logger, (c) battery, (d) LED, and (e) temperature sensor.

3. Results and discussion

Figure 2 presents the power output of the solar PV panels versus duration period of dairy solar energy. It was found that PV1 exhibited higher power output than PV2 reference for reflector incline angles of 40, 50, 60, and 70 degrees. These results suggest that the reflector reflected more sunlight onto the PV panel. Thus, the PV panel integrated with the mirror reflectors is able to generate more electricity by collecting more sunlight. However, PV1 at an incline angle of 80 degrees showed lower power output than the PV2 reference. This effect was caused by shading of the reflector itself. This behavior implies the importance of considering shading. The power output trend shows that both PV1 and PV2 presented low power outputs at 9:00 and 15:00 because the sunlight rays diverged from the normal line of the PV panel. For quantitative evaluation of electricity generation of the PVs, the total generated electrical energy over 6 hours was calculated from the area under the power-time curve of figure 2, as listed in table 1. It is evident that the PV1 generated more electricity than PV2 for most angles with the exception of 80 degrees.

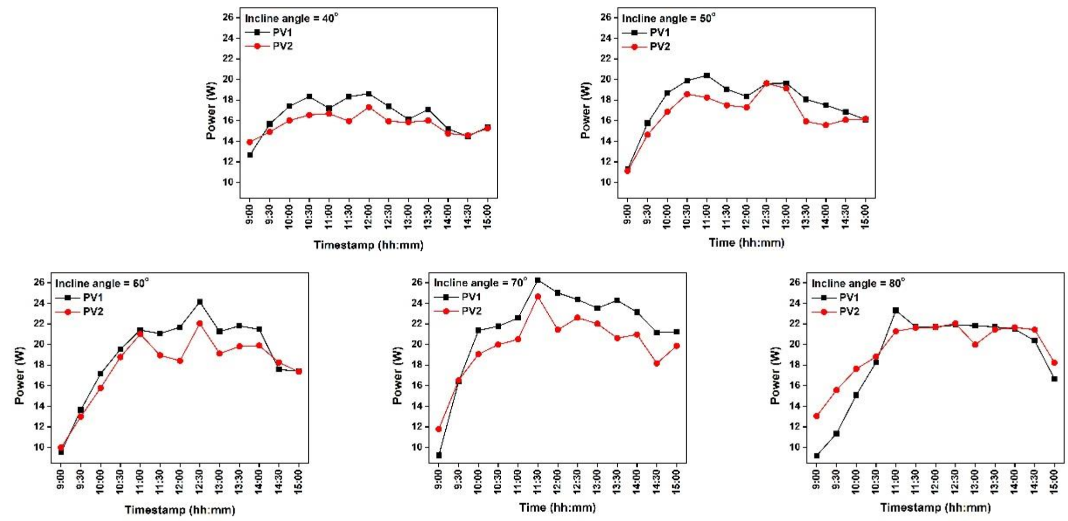

Figure 2. Power output of PV1 integrated with reflectors at different angles compared to PV2.

Table 1. Total generated electrical energy, sunlight energy, and average temperature for the PVs.

Incline angle (°)	Generated electric energy (kJ)		Total sunlight energy (kJ)		Temperature (°C)	
	PV1	PV2	PV1	PV2	PV1	PV2
40	359.9	340.6	3,814.5	3,782.5	46.3	46.5
50	391.6	365.7	3,321.7	3,258.2	49.4	48.4
60	421.6	393.8	3,195.3	3,164.5	47.5	46.9
70	477.2	436.3	3,914.3	3,872.9	48.9	48.3
80	417.0	429.8	3,808.8	3,767.6	47.5	47.6

Increased sunlight energy also resulted in higher temperatures for PV1. Higher temperatures can reduce electricity generation, resulting in lower efficiency. Yet the average temperature was insignificantly different between PV1 and PV2, indicating little temperature effect on electricity generation. Thus, the small increase in temperature might not be considered in this case, while sunlight energy was the significant factor for electrical energy generation. These results indicate that the PV panel integrated with reflectors can increase electricity generation. To evaluate the performance of PV integrated with reflectors, the total generated electricity was compared between PV1 and PV2 at the same angle, as shown in figure 3. It is found that PV1 exhibited a maximum performance around 9.38% higher than the conventional PV2 at an incline angle of 70 degrees, which is in agreement with another report [16]. This can be interpreted that solar PV panel integrated with reflectors at an appropriate incline angle can be used to increase electricity generation. This method can potentially produce more electricity without installation of additional panels, and should be considered for PV applications with low-cost management. However, the large scale of the solar farm must be considered on the economic analysis including to the maintenances cost during life time of PV panels.

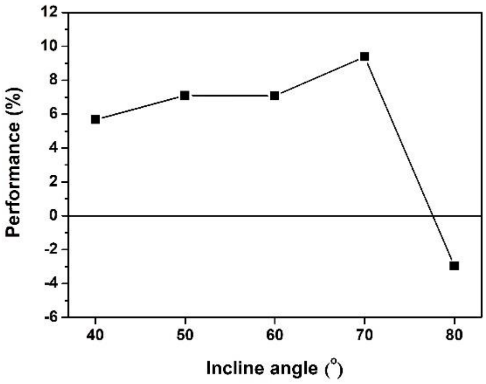

Figure 3. Performance evaluation of PV1 compared to PV2 at the same incline angle.

4. Conclusion

This work presented a simple method to improve electricity generation of solar PV panels using the integrated-mirror reflectors. The reflectors were integrated with the PV panel and its incline angle was adjusted to optimize sunlight collection. It was found that the PV panel integrated with the reflectors at an appropriate angle of 70 degrees presented the greatest improved electricity generation of up to 9.38% compared to a conventional-reference solar PV panel. The increased electricity generation occurred because more sunlight was reflected onto and collected by the PV panel. Therefore, this method can be used to increase solar PV panel performance without the installation of additional panels.

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