PLC Controlled Two Axis Automatic Solar Tracking System

Md. Anwarul Abedin
Professor
Department of EEE
DUET, Gazipur, Bangladesh
Corresponding Author: *abedin14@yahoo.com*

Abstract

Use of solar energy is rapidly advancing as an important means of renewable energy resource. Solar tracking enables more solar energy to be generated because the solar panel is able to maintain a perpendicular profile to the sun's rays. The dual axis solar photovoltaic panel is characterized by the capability to move in horizontal and vertical directions. The control circuit for the solar tracker is based on LS Programmable Logic Controller (PLC). The mechanical design consists of rotary joints and two DC motors. This tracking system makes the solar photovoltaic panel more efficient by keeping the panel's face perpendicular to the sun and therefore extracts maximum solar energy resulting into increased overall efficiency. It detects the sunlight through the LDRs as a sensor and then actuates the DC motors using PLC to position the solar panel where it can receive maximum sunlight. This research study shows that if the movable structures are used in a large scale in a solar power plant, a significant amount (nearly 40%) of more energy can be produced using the same arrays. The proposed control has the capability to be installed in different regions with minor modifications.

Keywords: *Solar tracking, Two axis, PLC.*

I. INTRODUCTION

Energy is the prime factor for the development of a nation. An enormous amount of energy is extracted, distributed, converted and consumed in the global society daily. 85% of energy production is dependent on fossil fuels [1]. The resources of the fossil fuels are limited and their use results in global warming due to emission of greenhouse gases. The environmental issues are now being regarded as the most crucial problem. Therefore, the goal of obtaining good energy supplies of electric power is to be emphasized. According to that goal and considering additionally the exhaustion of the energy reserves and the global heating of the planet to promote and improve systems sourced with renewable energies is a must. A good energy source prospect for industrial continuous processes needs to be: more or less constant energy throughout the year; highly reliable and needs little maintenance; low cost to build and operate; virtually no environmental impact; modular and thus flexible in terms of size and applications; landscape friendly. A solar electric system-also known as photovoltaic (PV) systems-fulfils this entire characteristic [2].

Solar panels directly convert solar radiation into electrical energy. Solar panel is mainly made from semiconductor materials. Si used as the major component of solar panels, which is maximum 24.5% efficient [3]. Increasing the cell efficiency, maximizing the power output and employing a tracking system with solar panel are three ways to increase the overall efficiency of the solar panel [4].

Improvement of solar cell efficiency is an ongoing research work and people throughout the world are actively doing research on this. Maximizing the output power from solar panel and integrating solar tracking system are the two ways where electronic design methodology can bring success. Maximum power point tracking (MPPT) is the process to maximize the output power from solar panel by keeping the solar panel's operation on the knee point of P-V characteristics. MPPT technology only offers the maximum power that can be received from a stationary array of solar panels at a particular time; however, it cannot increase the power generation when the sun is not aligned with the system. Solar tracking is a mechanized system to track the sun's position that increases power output of solar panel 30% to 60% than the stationary system [5]. This is far more cost effective solution than purchasing additional solar panels.

In this paper, a PLC controlled two axis solar tracking system has been proposed, which shows that nearly 40% more energy can be produced using the same array if two axis tracking system is implemented.

II. DESIGN OF THE SOLAR TRACKER

Development of solar tracking system for solar panels has been ongoing for several years. As the sun moves across the sky during the day, it is advantageous to have the solar panels track the location of the sun, such that the panels are always perpendicular with the position of the sun. Available solar trackers in the market are costly to integrate with solar panel system. In the developing countries where cost is one of the major issues to integrate technologies, solar tracking prototype presented here can provide an effective solution.

The block diagram of the proposed work is given in Fig. 1. All the switching and comparison is done by the PLC itself. It gets the signal from the sensors. The sensor is composed of simple LDRs and some resistors.

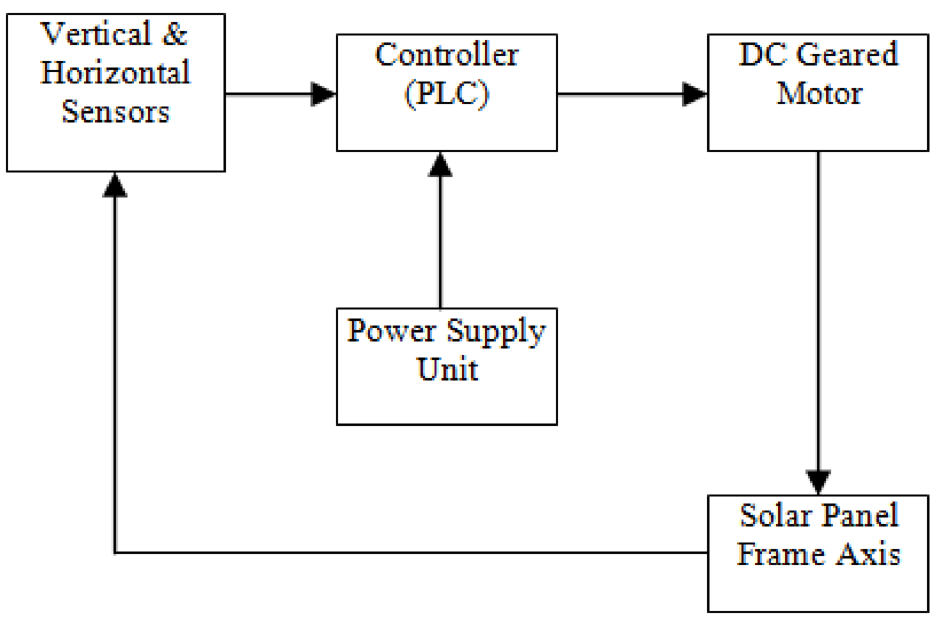


Fig. 1 Block diagram of the proposed solar tracker

The project is built using a balanced concept which is two signals from the different sensors are compared. Light Dependent Resistor (LDR) as a light sensor has been used. The two light sensors are separated by divider as shown in **Fig. 2** which will create shadow on one side of the light sensor if the solar panel is not perpendicular to the sun.

For the controlling circuit, PLC acts as a brain that controls the movement of the DC motor directly. Data received from the sensor arrangements consisting of LDRs and resistors are processed by the PLC. PLC controls the Bi-directional DC geared motor to ensure the solar panel perpendicular towards the Sun. Output relays inside the PLC control the rotation of the motor either to rotate clockwise or anticlockwise for horizontal as well as vertical axis. The solar panel that attached to the motor will be reacted according to the direction of the motors either horizontal or vertical or both. The flow diagram of the proposed solar tracker is shown in **Fig. 3.**

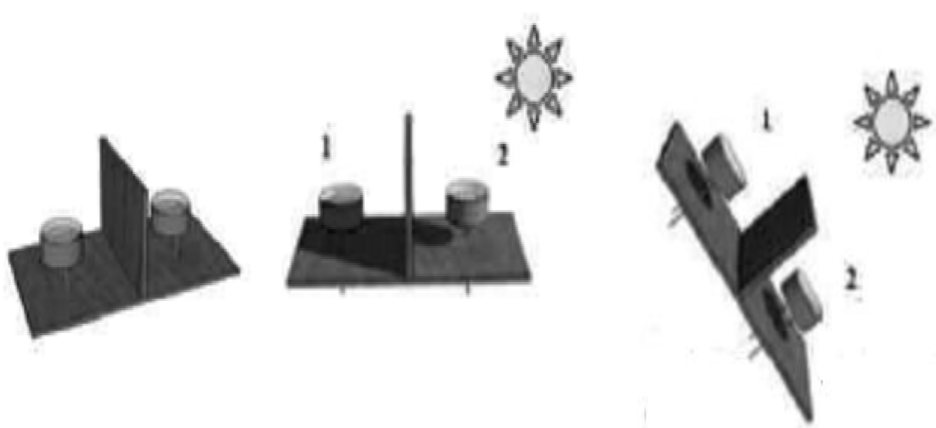


Fig. 2 LDR based light sensor

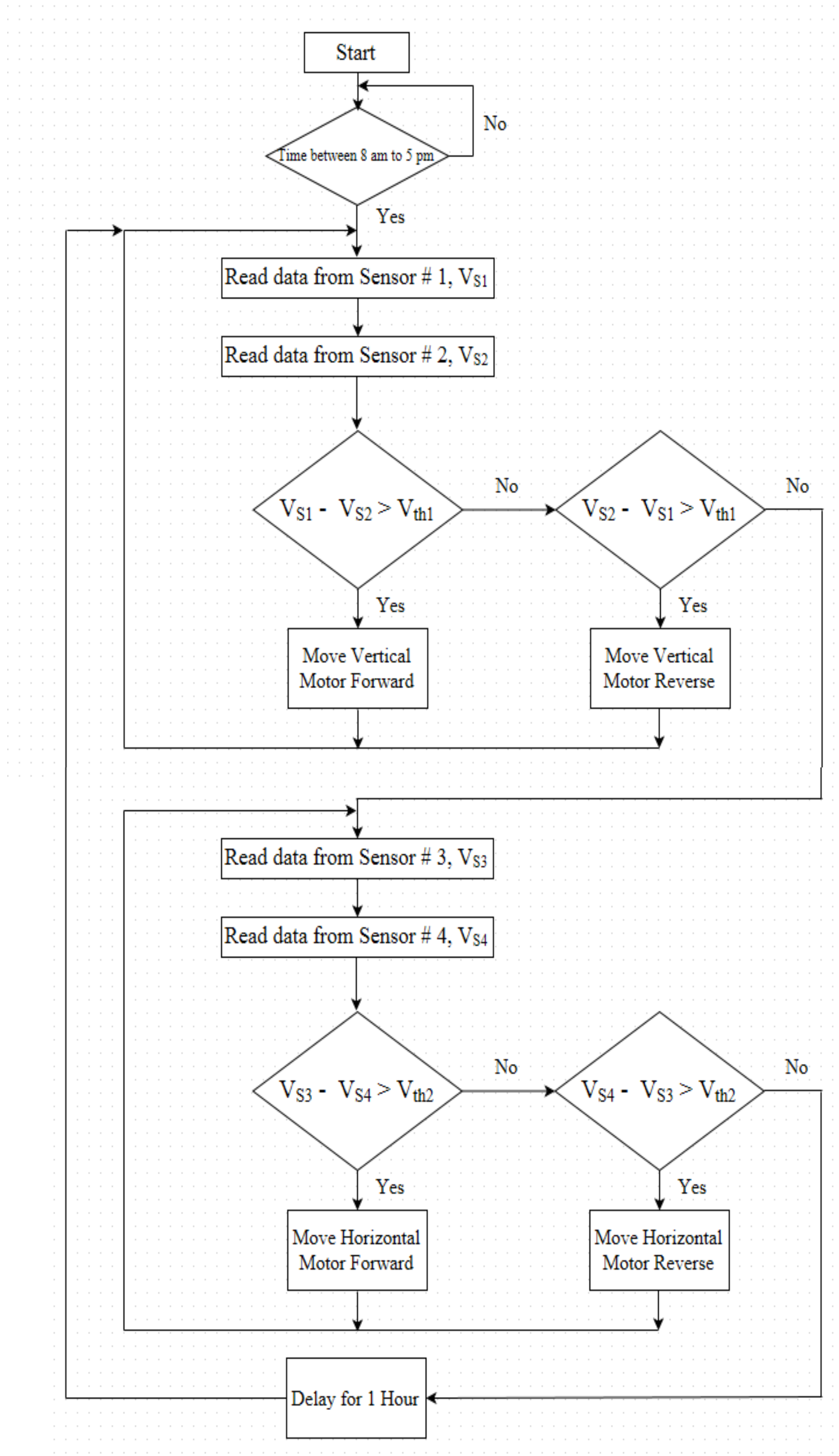


Fig. 3 Flow diagram of the proposed solar tracker

III. RESULTS AND ANALYSIS

The sole purpose of this project was to improve the efficiency of the solar photovoltaic cell applications. For that purpose we adopted the automatic solar tracking system. We conducted various experiments to find out the feasibility of improving efficiency through automatic sun tracking system and with the results, we progressed to finalize the system. Alongside, we also conducted experiments to find out the characteristic curves of the solar panel.

The system focuses mainly on the controller design. The constructed system has been tested and some data from hardware measurement have been collected and discussed. The prototype of the solar tracking system is shown in Fig. 4. A 10 watt solar panel has been used for testing and the purpose only to prove the designed system is able to operate accordingly. Therefore the surrounding effects, for instance, weather condition are not seriously considered during hardware testing.

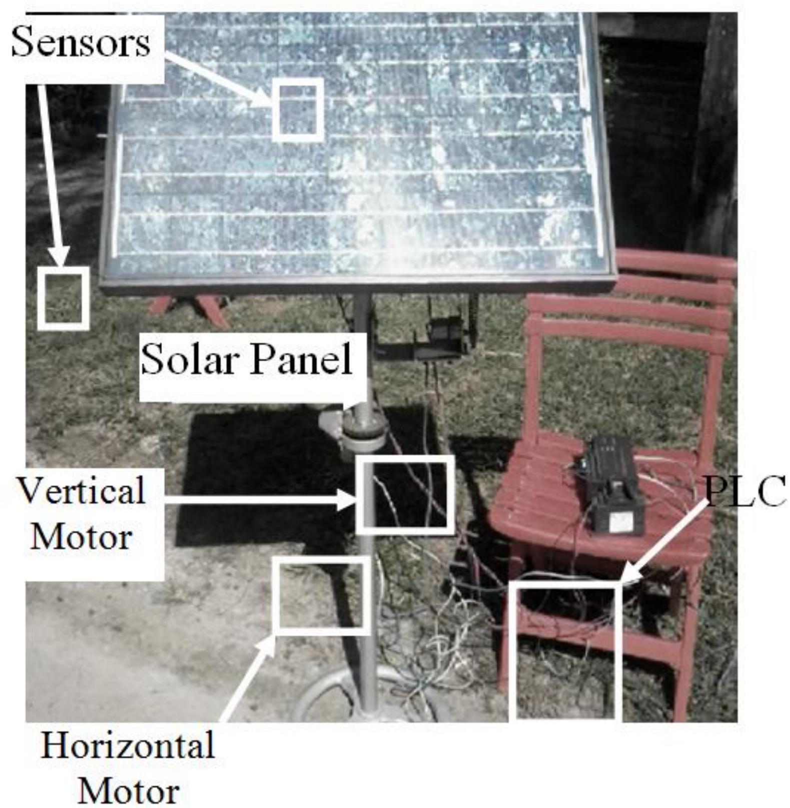


Fig. 4 Front view of the solar tracker prototype

A. The Characteristic Curves of the Solar Panel

The characteristics of the used 10 watt solar panel are mainly determined by the current voltage curve (I-V curve) and power voltage curve (P-V curve). So, we carried out the experiments to determine those curves of the panel we worked with. We gradually changed the load across the terminals of the solar panel and took reading of the current and voltage for that specific load. The I-V and the P-V curve of the used solar panel are shown in Fig. 5.

The graphs which we obtained are the expected ones. From the I-V curve, we can find that the maximum voltage that our panel can attain is 20.5 V, which is also known as the open circuit voltage and the maximum current of the panel is 0.55 A, which is known as the short circuit current of the panel. Also we can see from the P-V curve that the maximum power output of our solar panel is almost 9.05 Watt attainable at a load of approximately 30 ohm. So, for this specific panel, we need to use a load closer to 30 ohm to get the maximum power output from the panel.

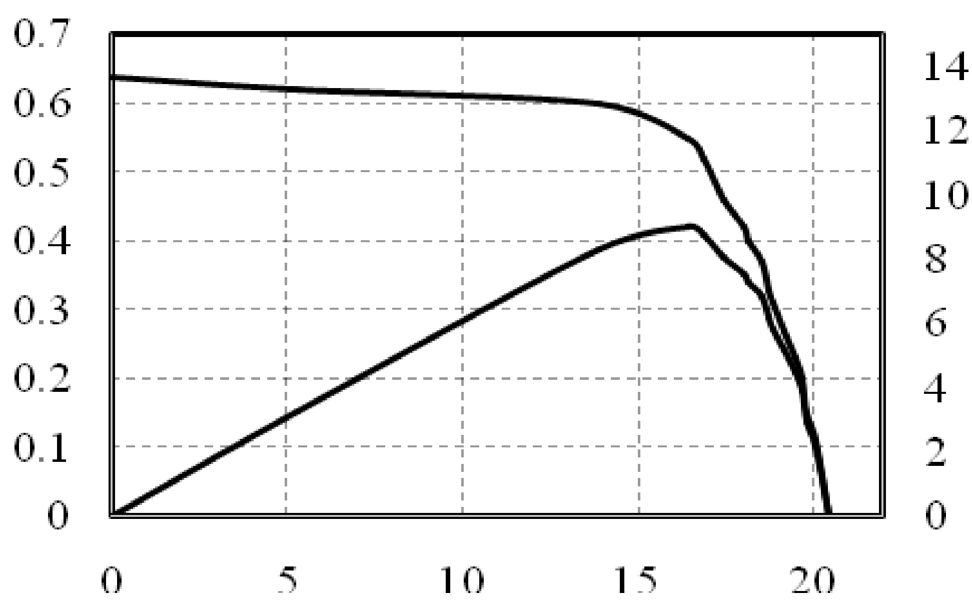


Fig. 5 I-V and P-V curve of the used solar panel

B. Comparison Characteristics of Movable and Fixed Panel

The experiment was performed in March and the first comparison curve was available at 9:00 AM because of the installation situation of the movable panel and the fixed panel. I-V and P-V characteristics of the panel are shown in Fig. 6. Because the movable panel is directly faced to the sun, it generated more electric power and its peak power is higher than fixed panel. It is to be mentioned here that the fixed panel was tilted 23.5□ from horizontal axis and facing south.

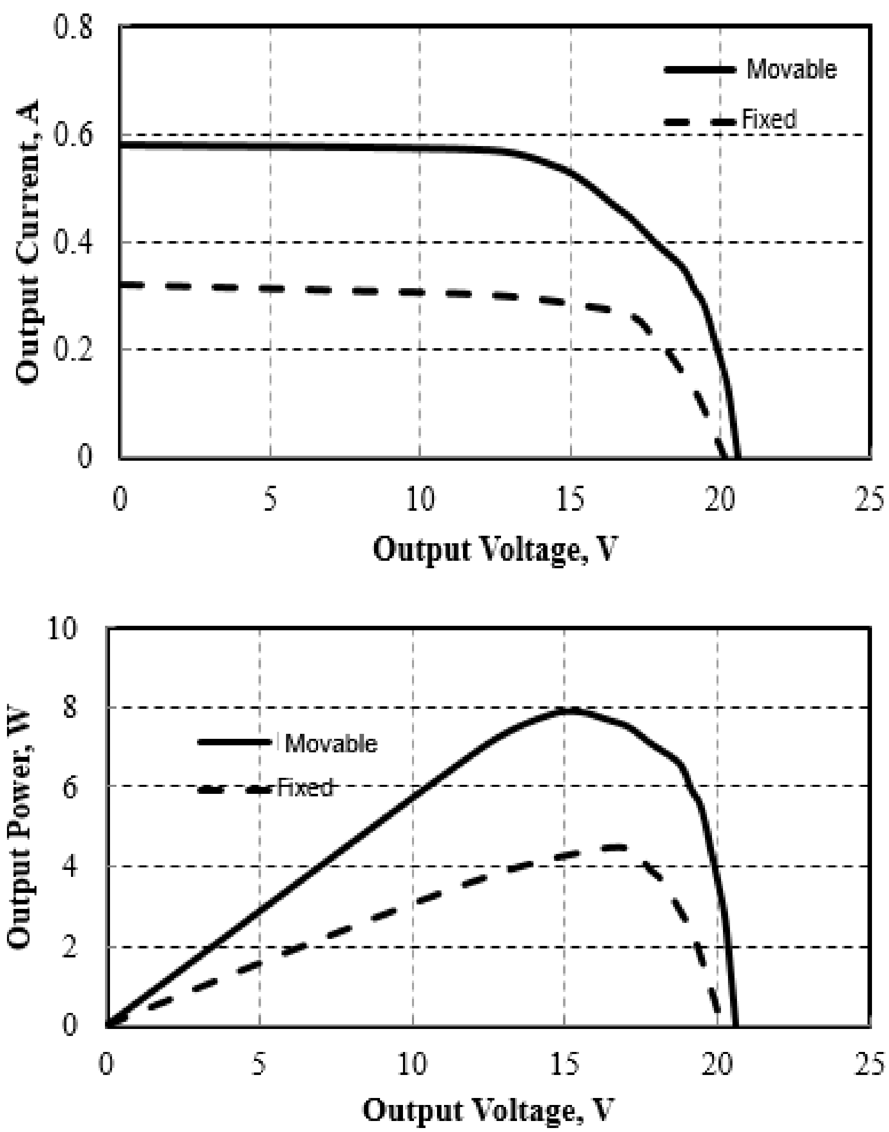


Fig. 6 I-V and P-V Char. of Movable and Fixed PV Panel at 9:00 AM

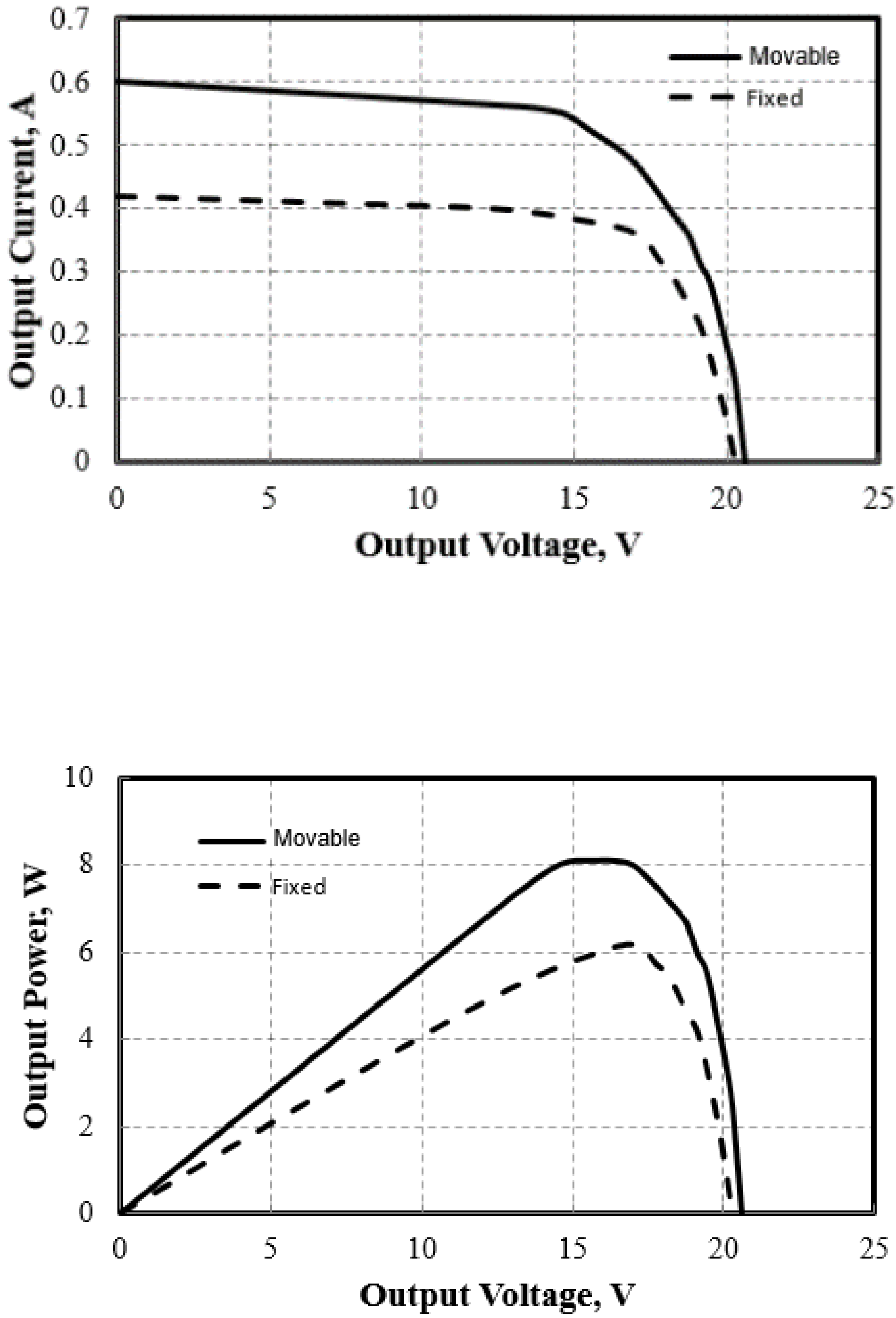


Fig. 7 I-V and P-V Char. of Movable and Fixed PV Panel at 10:00 AM

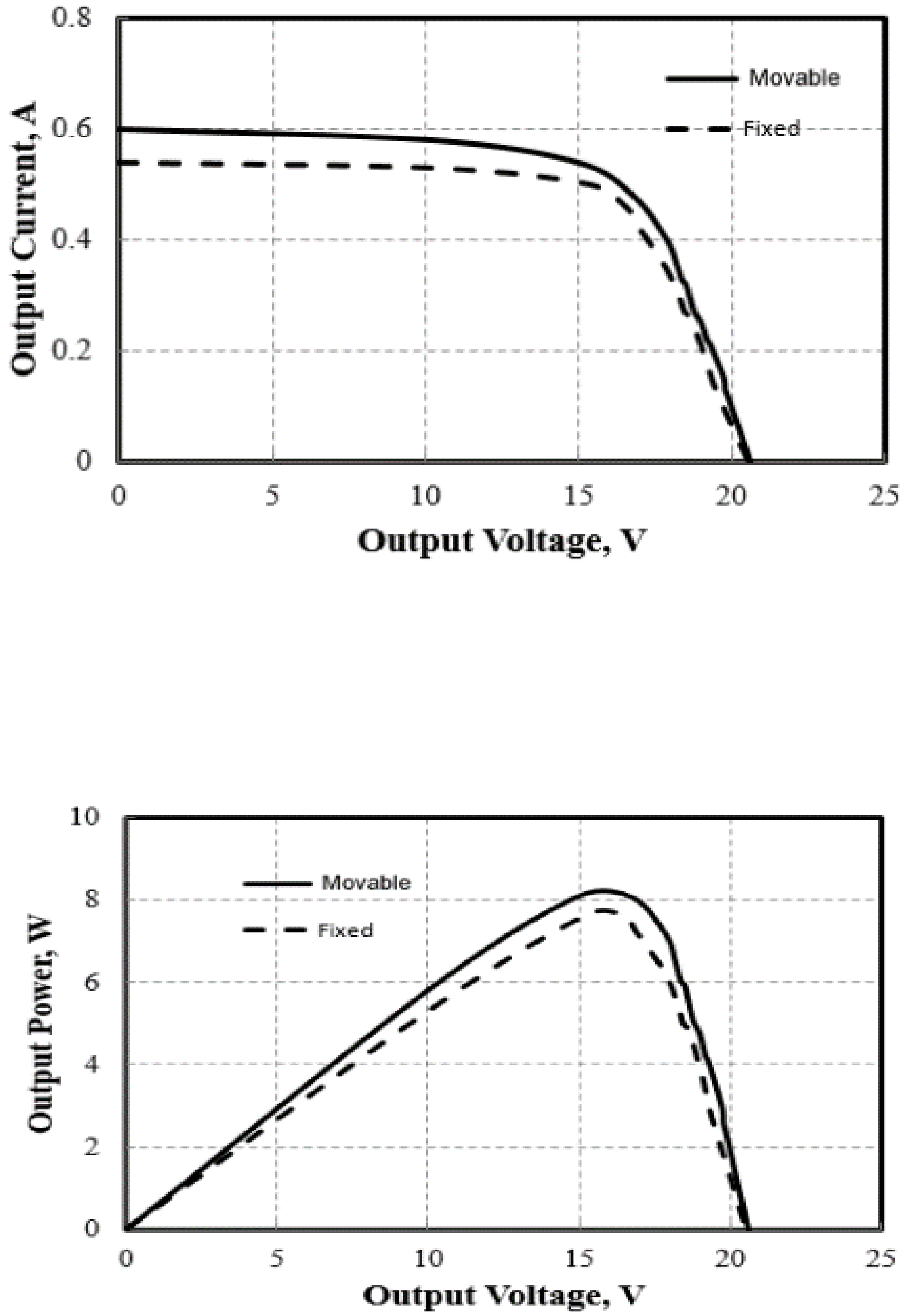
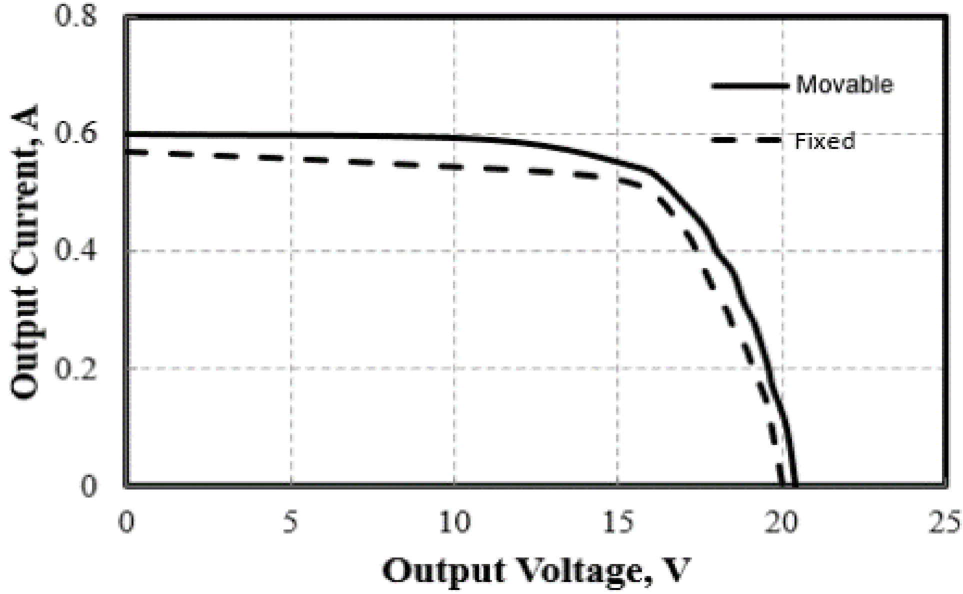


Fig. 8 I-V and P-V Char. of Movable and Fixed PV Panel at 11:00 AM



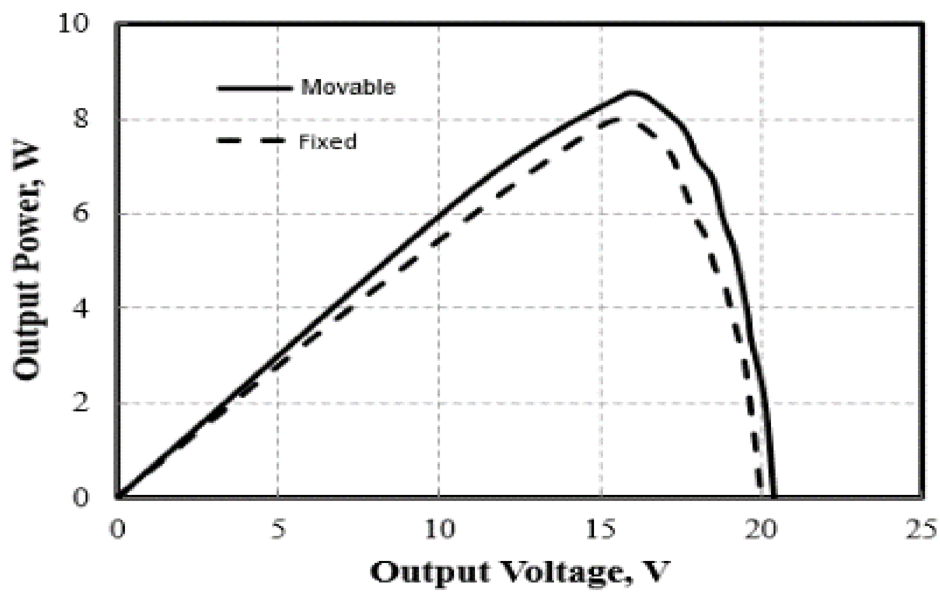


Fig. 9 I-V and P-V Char. of Movable and Fixed PV Panel at 12:00 PM

The obtained I-V and P-V curves at 10:00 AM are shown in Fig. 7. It shows the increasing of the fixed panel power in comparison with 9:00 AM whereas the movable panel has a little change in its generating power and still it is greater than fixed panel by 24.11% increment in power.

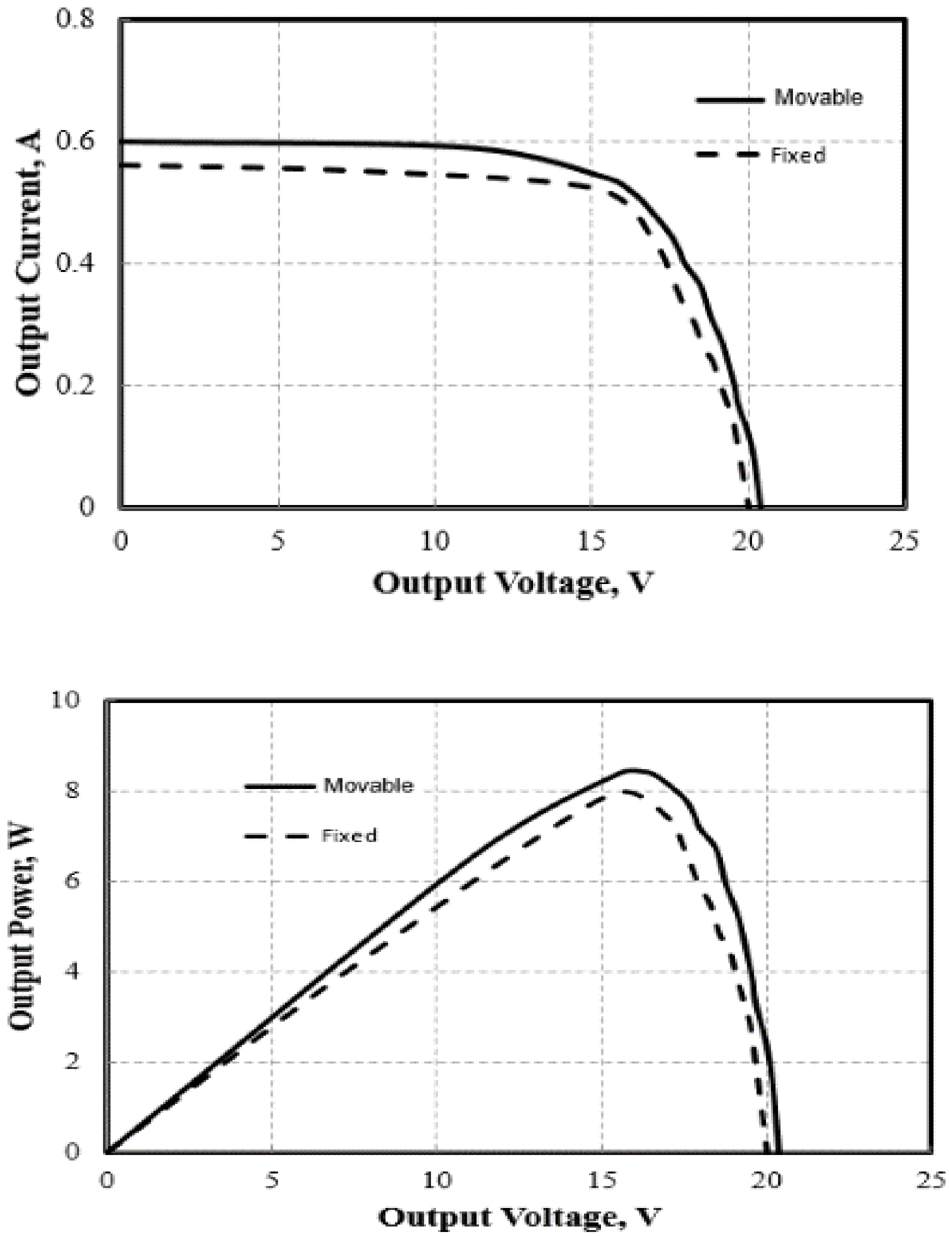
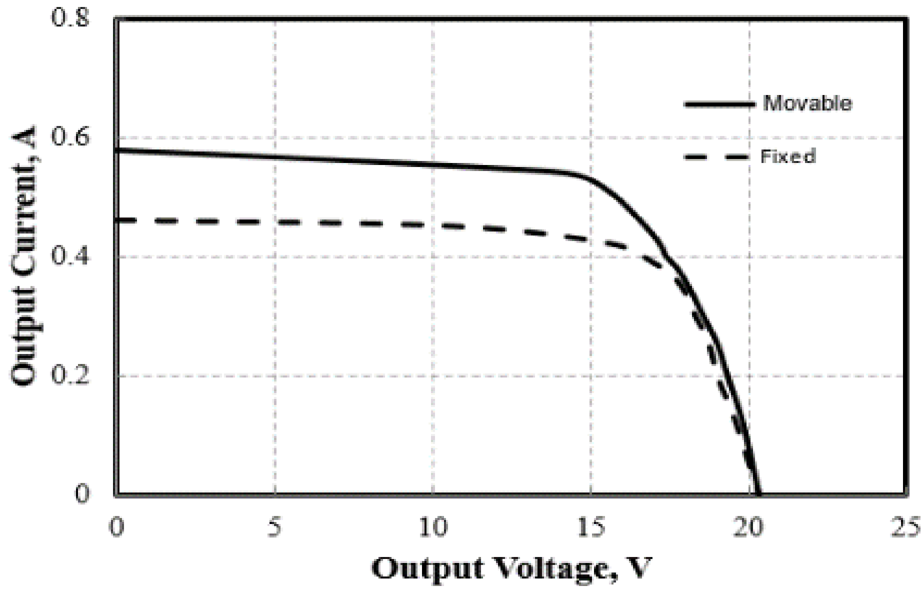


Fig. 10 I-V and P-V Char. of Movable and Fixed PV Panel at 1:00 PM



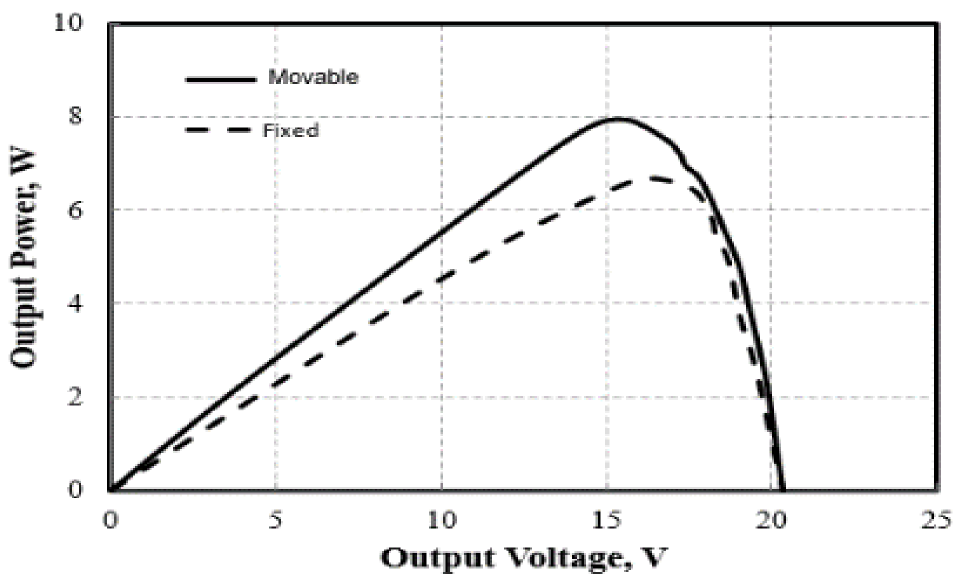


Fig. 11 I-V and P-V Char. of Movable and Fixed PV Panel at 2:00 PM

From 11:00 AM to 2:00 PM (Fig. 8 to Fig. 11), the power curves of the fixed panel become closer to the movable panel. Because of the sun motion close to south, both movable panel and fixed panel are faced to the south where the movable panel still generates more power (5.47% to 12.61% higher).

Because the sun height starts to decrease after 2:00 PM, the generated power by the fixed panel starts to decrease. The generated power in both PV-panels decrease but in the movable panel, the slow rate of decreasing is observed. As the Fig. 12 (at 3:00 PM) and Fig. 13 (at 4:00 PM) show, by the sun motion to the sunset, the generated power reduces in both PV-panels but the movable PV-panel still generates more power than the fixed one.

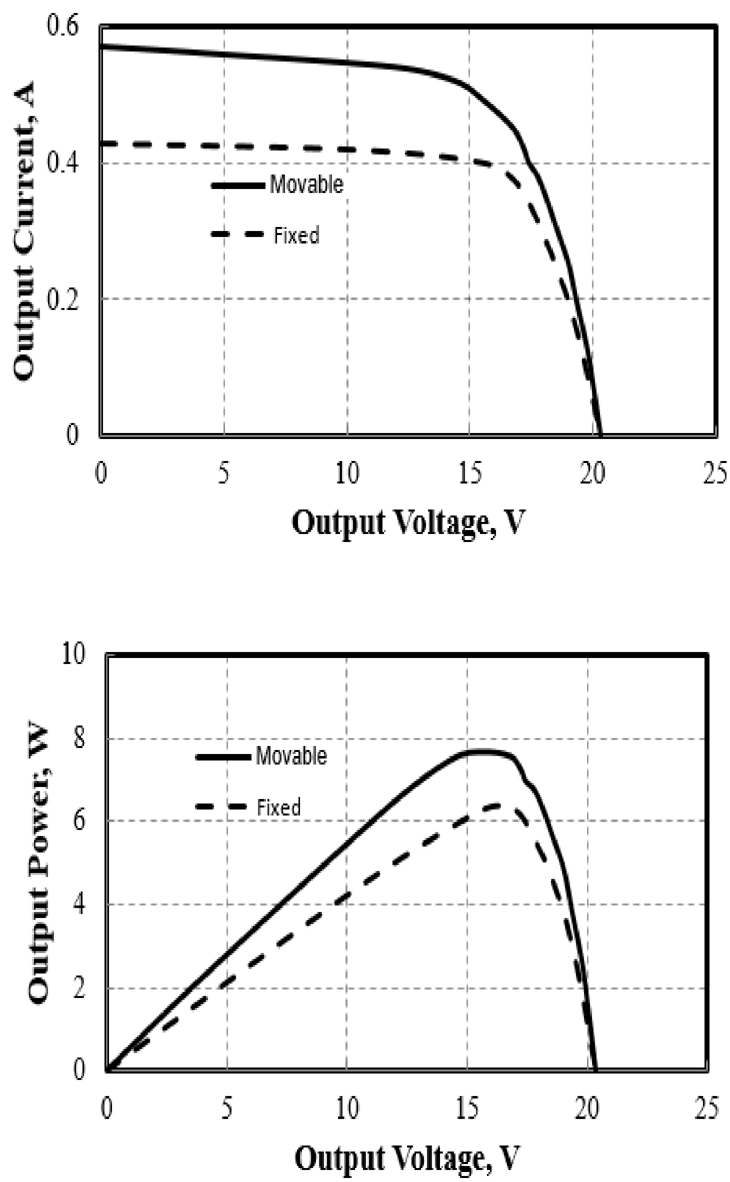
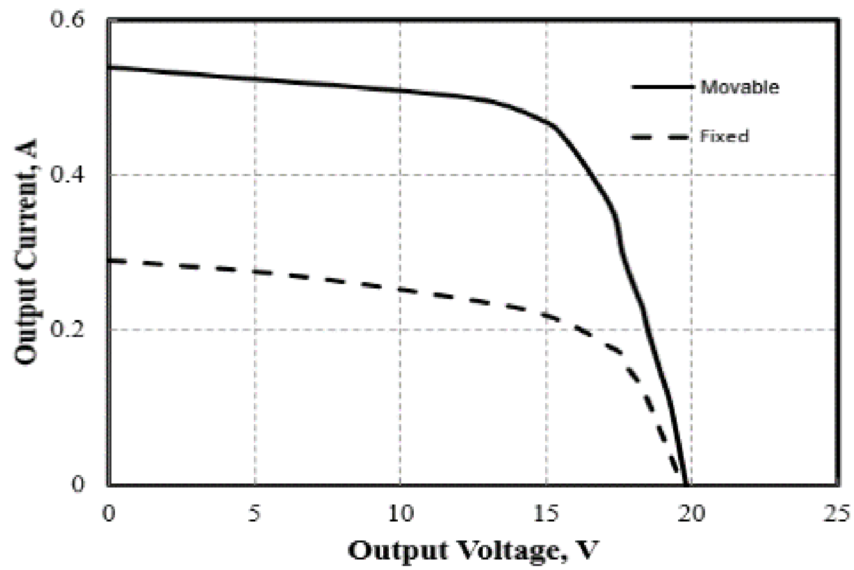


Fig. 12 I-V and P-V Char. of Movable and Fixed PV Panel at 3:00 PM

This comparison illustrate that the movable photovoltaic panel with sun tracking capability can significantly increase the absorbed energy that increases the generated electric power.



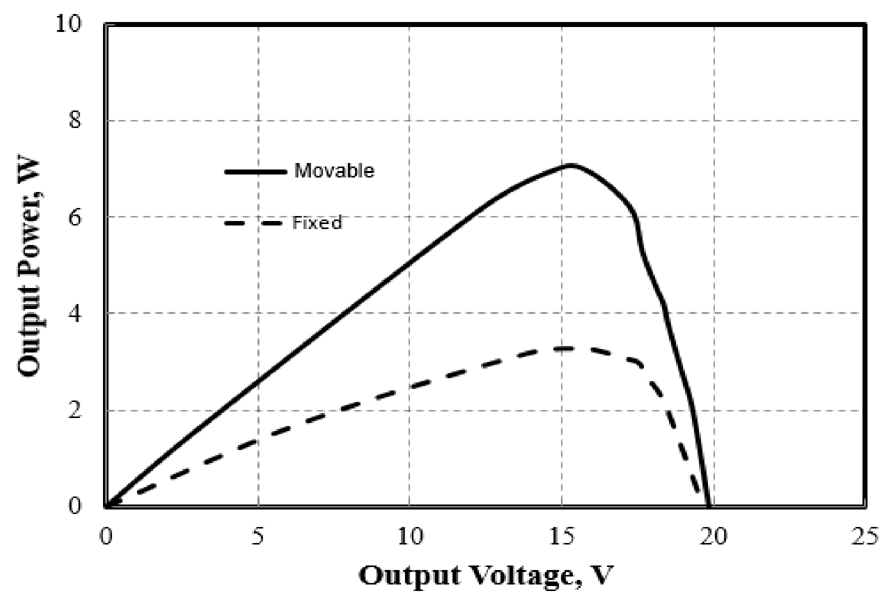


Fig. 13 I-V and P-V Char. of Movable and Fixed PV Panel at 4:00 PM

Fig. 14 shows the current-voltage characteristics of the movable PV panel during the day and current generated by this panel has a small variation during the day (about 18%) where Fig. 15 shows the same characteristics for the fixed PV panel and a large variation (more than 81%).

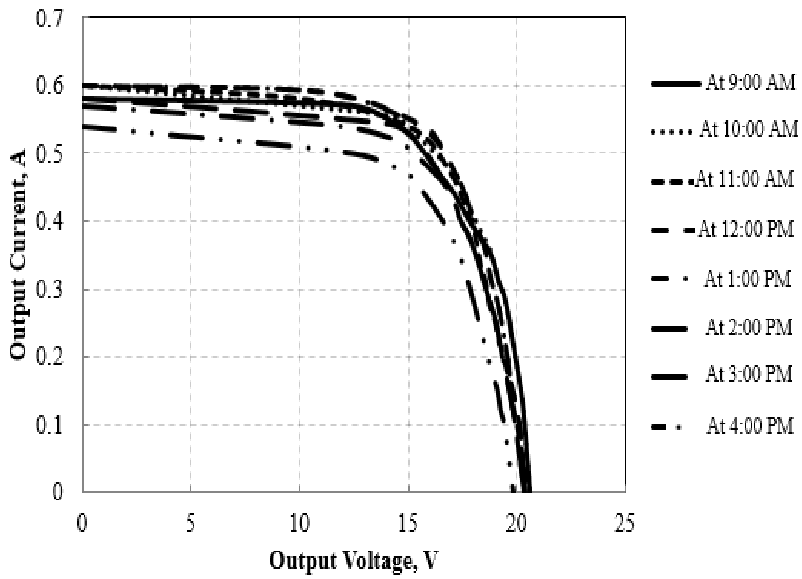


Fig. 14 I-V Curves of the Movable PV Panel between 9:00 AM & 4:00 PM

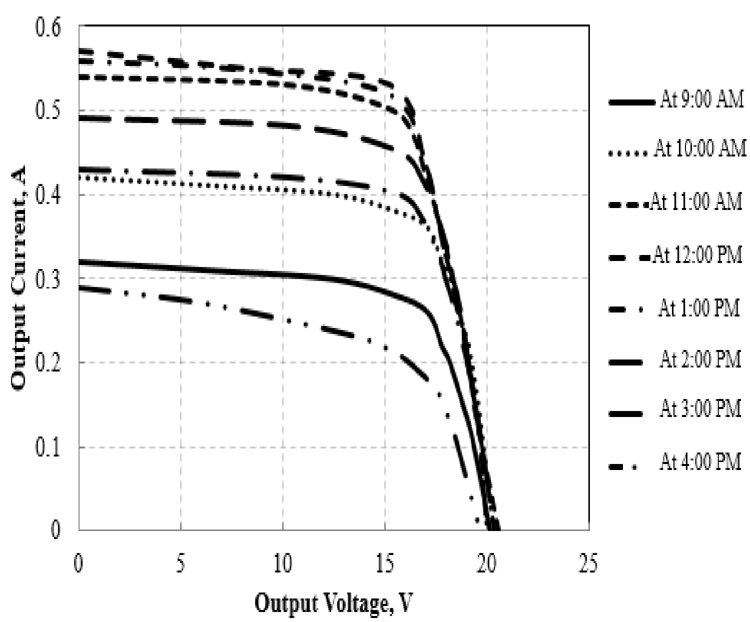


Fig. 15 I-V Curves of the Fixed PV Panel between 9:00 AM & 4:00 PM

Fig. 16 and Fig. 17 show the power curves of both movable and fixed PV-panels and it shows that the generated power by the movable panel has less variation in compare with fixed panel during the day. It can be concluded that in terms of electric power supply, by using the movable photovoltaic panel the power quality will be higher and by using the fixed panel, the large power variation should be dumped due to a larger energy storage unit.

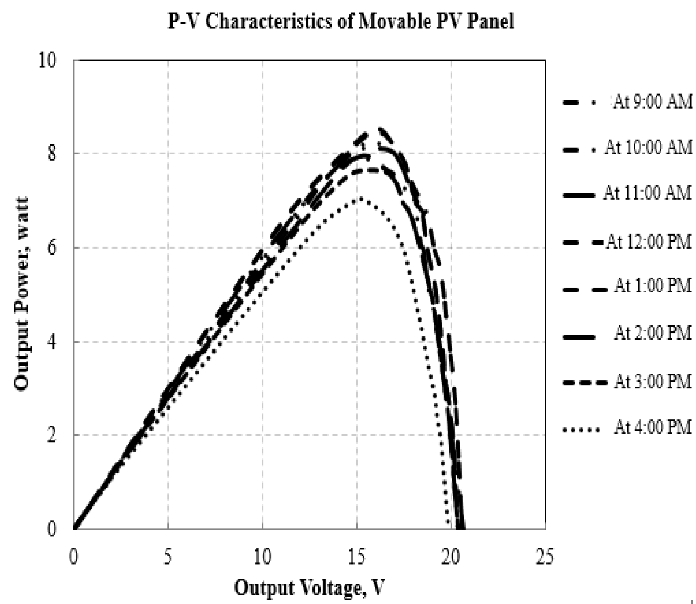


Fig. 16 P-V Curves of the Movable PV Panel between 9:00 AM & 4:00 PM

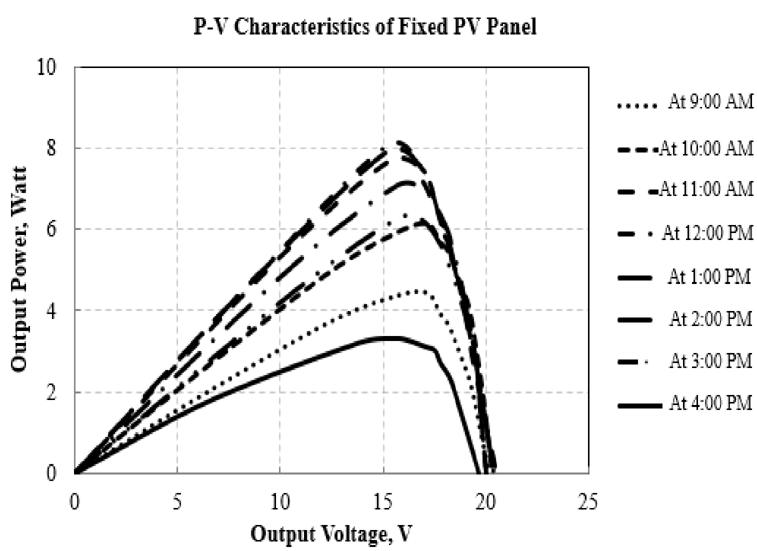


Fig. 17 P-V Curves of the Fixed PV Panel between 9:00 AM & 4:00 PM

With the assumption of using a maximum power point tracker (MPPT) to absorb the maximum power from both arrays, and using one hour as power sample time, the absorbed electric energy is calculated for both arrays and the results are shown in Table I and in Fig. 18 respectively.

TABLE I

Test Results of Measuring the Output Power

Sampling Time	Array Type		Increment Rate (%)
	Movable	Fixed	
9:00 AM	7.91	4.45	77.80
10:00 AM	8.11	6.16	31.77
11:00 AM	8.10	7.68	5.47
12:00 PM	8.51	8.07	5.43
1:00 PM	8.44	7.91	6.64
2:00 PM	7.96	7.07	12.61
3:00 PM	7.64	6.28	21.72
4:00 PM	7.01	3.29	113.23
Absorbed Energy During the Test (Wh)	63.67	50.90	25.10

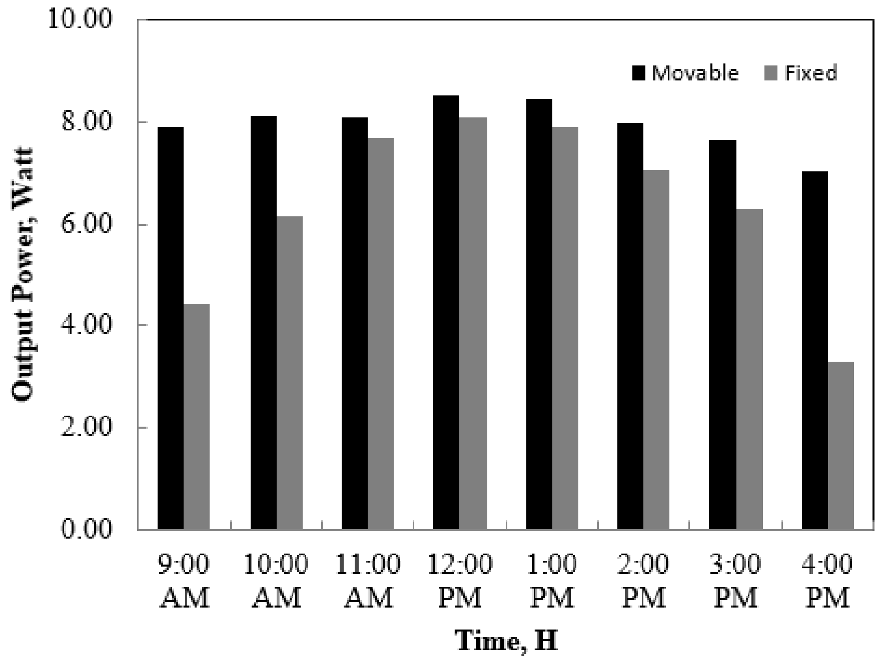


Fig. 18 The Maximum Output Power of Movable and Fixed PV panels

CONCLUSIONS

The test result shows that using a PV panel with sun tracking capability can increase the absorbed energy more than 25% in comparison with the fixed PV panel. Also, this type of array can supply the electric energy with small variation and better power quality during the day. Moreover, the motion of the tracking structure for a small period of time (24 minutes in day) consumes a small amount of energy (less than 10 watt-hours) to follow the sun path in the sky where the total efficiency of the converter is high.

This research study also shows that if the movable structures are used in a large scale in a solar power plant, a significant amount (nearly 40%) of more energy can be produced using the same arrays. The increased investment due to the usage of movable PV-arrays and their maintenance will be justified due to increasing of the output power. Manufacturing of the structure in large amount will reduce the cost. Therefore, this type of trackers can be manufactured, used, and serviced in solar power plants with lower cost.

ACKNOWLEDGMENT

This work was supported by "University Teachers' Research Fund" of University Grants Commission Bangladesh and Department of Electrical & Electronic Engineering, Dhaka University of Engineering & Technology, Gazipur.

REFERENCES

1) J. Wilcox, "Grand challenges in advanced fossil fuel technologies," Frontiers of energy research, Vol. 2, Article 47, November 2014.

2) L. D. Partain, Solar Cells and Their Applications, John Wiley & Sons, New York, 1995.

3) M. A. Green, E. Mary, D. Archer and R. Hill, Clean Electricity from Photovoltaics, Imperial College Press, UK.

4) A.Anuraj and R Gandhi, "Solar Tracking System Using Stepper Motor," International Journal of Electronic and Electrical Engineering, Vol. 7, Number 6, pp. 561-566, 2014.

5) K. Saxena and V. Dutta, "A versatile microprocessor based controller for solar tracking," Photovoltaic Specialists Conference, pp. 1105–1109, 1990.

