Experimental Measurement of Fixed-Tilt Solar Panel and Vertical-Tilted Single-Axis Solar Tracker (VTSAT) Real-Time Solar Panel Output Power

Myo Ko Ko[1], Ei Mon[2]

[1]Ph.D candidate, Yangon Technological University, Yangon, Myanmar.
[2]Professor & Research Supervisor, Yangon Technological University, Yangon, Myanmar.

Abstract

Renewable solar energy is becoming more and more vital, and photovoltaic (PV) solar panel efficiency optimization is essential for sustainable energy generation. This study describes an experiment that uses a solar panel multimeter to measure the output power of a fixed-tilt solar panel and a vertical-tilted single-axis solar tracker (VTSAT) in real time. This measurement indicates that solar panel performance varies with several external factors, including temperature fluctuations. Perform a comparison analysis in this study between a vertical-tilted single-axis solar tracker (VTSAT) and a traditional fixed-tilt solar panel. Two 50-watt solar panels' output data were measured using a solar panel multimeter. Utilizing this comparison analysis, assess these panels' real-world performance. Determining the individual efficiency of the two solar panels will be made easier by analyzing the output figures. Moreover, the goal is to compute the daily energy production produced by every kind of solar panel under standard climatic conditions.

Keywords: Fixed-tilt solar panel, vertical-tilted single-axis solar tracker (VTSAT), temperature, solar panel multimeter.

1. INTRODUCTION

With environmental concerns and the search for sustainable energy alternatives, solar energy's boundless potential as a clean and renewable power source has attracted ever-increasing attention. Photovoltaic (PV) solar panels are at the vanguard of this new energy environment. They are incredibly efficient devices that can convert sunlight into electrical power. Recent years have seen a notable increase in the use of solar energy as a sustainable and eco-friendly power source. In order to fully utilize this plentiful resource, photovoltaic (PV) solar panels—which transform sunlight into electrical energy—are essential. However, a number of variables, such as temperature variations and sun irradiation, can affect how well solar panels function in the environment. Accordingly, accurate measurement and comprehension of the output power of solar panels in real-time are crucial for maximizing energy production and guaranteeing the dependability of solar energy systems.

The purpose of this research is to meet the demand for precise, ongoing, real-time solar panel output power monitoring. The dynamic nature of solar energy generation may not be adequately captured by traditional methods of monitoring solar panel performance, which frequently include periodic readings or modeling based on past data. In order to close this gap, we propose an experiment that uses a cutting-edge PV multimeter tester to continuously measure and record the output power of solar panels. This study has two goals. First, look into how the output power of solar panels varies in various environmental settings, such as temperature variations. Secondly, aim to offer significant perspectives on the performance attributes of solar panels, particularly in the presence of dynamic operating situations. The purpose of this experiment is to further our understanding of the behavior of solar panels in real time and how that behavior affects renewable energy systems.

2. LITERATURE REVIEW

In order to satisfy the world's expanding energy needs, solar energy has emerged as a viable and sustainable option (Jacobson et al. 2017). Due to their ongoing advancements in efficiency and affordability, photovoltaic (PV) solar panels have been instrumental in this shift (Zhang et al. 2019). The most important research and advancements in the fields of solar energy and real-time solar panel output power measurement are reviewed in this part. Due to its ability to lower greenhouse gas emissions and lessen reliance on fossil fuels, solar energy has grown significantly in recent years (Jacobson et al. 2017). Both the residential and commercial sectors have seen a sharp increase in the use of solar panels for electricity generation (IEA 2020). Due to their improved energy conversion efficiency and declining installation costs, solar photovoltaic systems are now competitively priced (Zhang et al. 2019). These developments highlight how crucial it is to assess solar panel output power precisely and in real time in order to guarantee peak efficiency and energy production. Considerable study has been done on how to improve the performance of PV solar panels in different environmental settings. Scholars have investigated how temperature, solar radiation, shadowing, and other elements affect the production of solar panels (Khalil et al. 2018). For the purpose of tracking and maximizing solar panel performance, precise real-time measurement of these factors is essential (Bourdoukan & Papathanassiou 2020). The creation of sophisticated control techniques that can optimize energy output is made easier with the use of real-time data capture (Li et al. 2016). In order to assess solar panel performance in real time, the development and application of photovoltaic multimeter testers have gained popularity recently (Ghasempour et al. 2019). Researchers and engineers can record dynamic variations in solar panel performance with these specialized instruments' benefit of continuous monitoring and recording of important parameters like voltage, current, and power output (Zhang et al. 2019). Additionally, according to Bourdoukan and Papathanassiou (2020), multimeter testers can help detect problems like defects or deterioration in solar panels.

3. MATERIALS AND METHOD

The main solar energy source for this experiment was a 50-watt polycrystalline solar panel. The position and tilt of the solar panels with respect to the sun determine how much electricity they produce. The primary factor affecting how skewed the panels are is often latitude. For solar panels in Myanmar to capture solar energy as efficiently as possible, they must be oriented and tilted at the ideal angles. In Myanmar, south-facing solar panels receive the maximum amount of sunlight during the day. This is the ideal orientation for them. Furthermore, the ideal tilt angle for solar panels in Myanmar is usually about 15 degrees, which allows them to efficiently collect sunlight while taking seasonal variations in the sun's angle into account. We can increase the energy generation capacity of solar panels and promote the development of sustainable energy solutions in Myanmar by precisely positioning them in accordance with these characteristics [5].

Fig (1) The optimal tilt angle in Myanmar is 15 degrees to the south

Maximum Power	50W
Open Circuit Voltage	22V
Short Circuit Current	3.28A
Voltage at Max Power	18V
Current at Max Power	2.78A
Max System Voltage	600V DC
Number of Cells Per Module	36
Product Dimensions (cm)	67x50.5x3.4

Fig (2) Specifications of 50-watt polycrystalline solar panel

The mounting system will be moved by the motor or actuator in response to the sensors, ensuring that the solar panels are always facing the sun during the day. Sensors are always determining where the sun is in the sky during the day. There will be a difference in light intensity on one light sensor compared to another if the sun is not shining directly on the tracker. This difference can be used to calculate the angle at which the tracker needs to be angled in order to face the sun perpendicularly.

Single-axis trackers are implemented in various ways. These consist of polar-aligned single-axis trackers, slanted single-axis trackers, vertical single-axis trackers, and horizontal single-axis trackers. A vertical-tilted single-axis solar tracker (VTSAT) is a vertically rotating device with a tilt parallel to a horizontal position. Furthermore, compared to horizontal trackers, these trackers have superior energy collection.

Fig (3) Vertical-tilted single-axis solar tracker (VTSAT)

Fig (4) Sunrise and Sunset positions of two solar panels

To measure the open circuit voltage (V_{oc}), maximum voltage (V_{mp}), maximum current (I_{mp}), and power maximum (P_{max}) of a solar panel, a multimeter is utilized. With two appropriately long crocodile clip cables and two PV connection cables, the photovoltaic panel multimeter just has to be attached to the solar panel in order to operate. Without the need for additional batteries, the multimeter is powered directly by solar panels.

Fig (5) Solar Panel Multimeter

The temperature of the solar panel is measured using an infrared (IR) thermometer. It is imperative to have an infrared (IR) thermometer in order to take accurate temperature measurements in a range of situations. These thermometers enable quick and precise surface temperature measurements from a distance. They are primarily utilized in commercial and industrial situations. Among tools for measuring temperature, infrared thermometers are special because they can rapidly scan an area and identify temperatures without coming into direct contact.

Fig (6) Infrared (IR) thermometer

4. RESULTS AND DISCUSSION

For the experiment, there were days with clear skies and days with clouds. The measurements of P_{max}, V_{max}, I_{max}, V_{oc}, solar panel temperature, and energy production are made between a fixed-tilt solar panel and a vertical-tilted single-axis solar tracker (VTSAT).

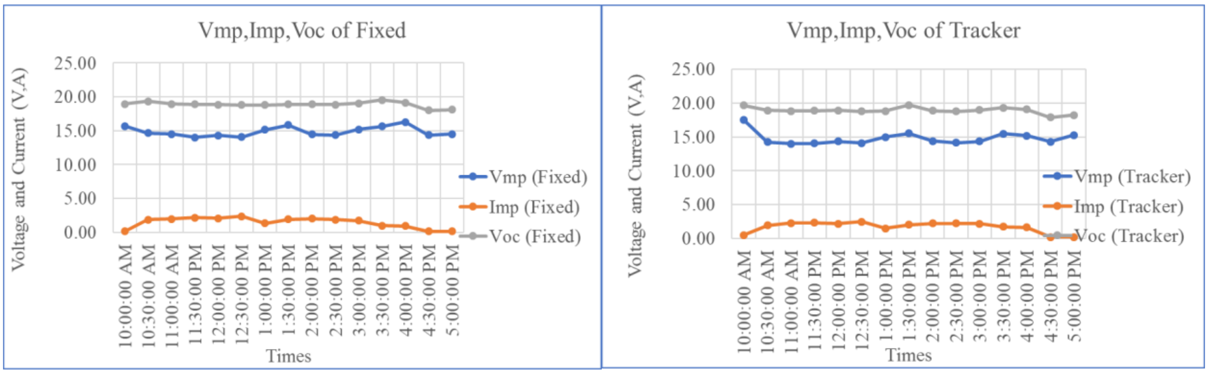

Fig (7) V_{mp}, I_{mp}, V_{oc} Comparison between Fixed and Tracker (Day 1 Cloudy)

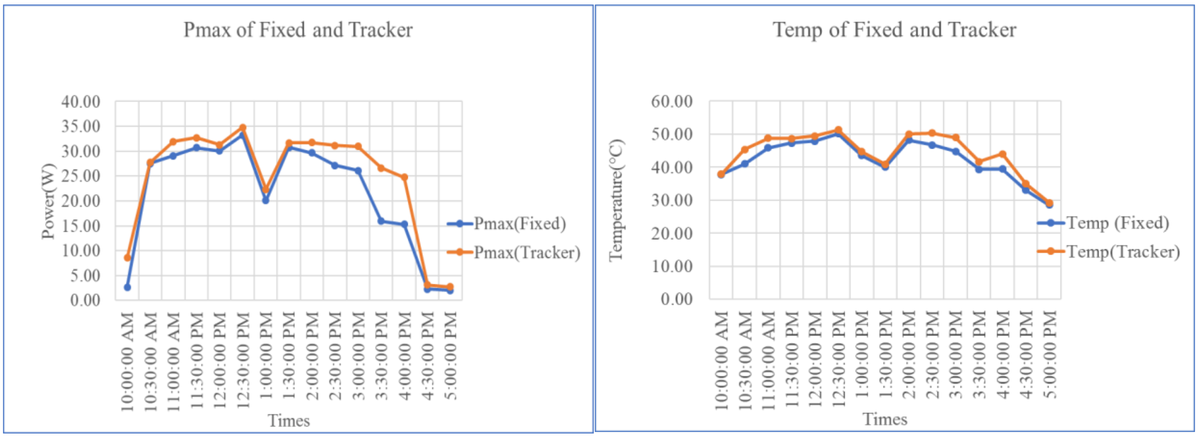

Fig (8) Power and Temperature Comparison between Fixed and Tracker (Day 1 Cloudy)

Only in antemeridian and postmeridian conditions is a vertically tilted single-axis solar tracker (VTSAT) more efficient than a fixed-tilt solar panel. 33.25 watts is the fixed-axis maximum power output at 12:30 p.m., and 34.80 watts is the maximum power output that is tracked at 12:30 p.m. The fixed-axis minimum power output is 2.03 watts at 5:00 p.m.; 2.74 watts is the tracking minimum power output at 5:00 p.m. At 12:30 p.m., the highest temperature of a fixed tilt is 50.11 degrees Celsius. At 12:30 p.m., a solar tracker's highest temperature is 51.33 degrees Celsius.

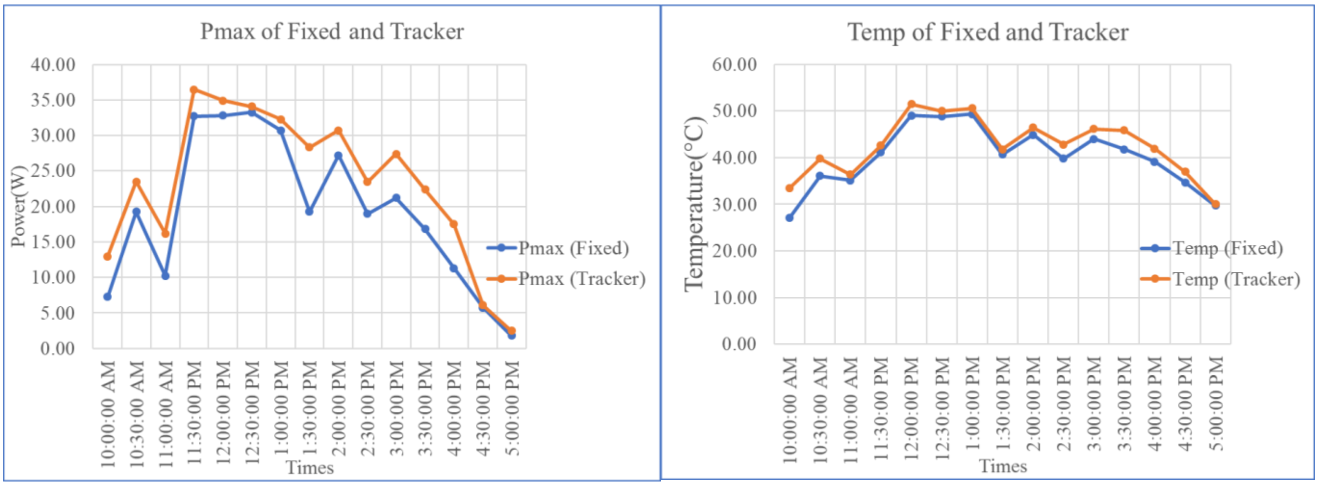

Fig (9) Power and Temperature Comparison between Fixed and Tracker (Day 2 Cloudy)

The uneven pattern of sun irradiation on partially cloudy days is caused by the high number of passing clouds in the morning and evening. At about 12:30 pm, the fixed-axis maximum power output is 33.25 watts. Tracking 36.94 watts of maximum power output at 11:30 a.m. At 5:00 p.m., the fixed-axis minimum power output is 1.79 watts. The lowest power output that is monitored at 5:00 p.m. is 2.48 watts. A fixed tilt reaches its maximum temperature of 49.33 degrees Celsius around 1:00 p.m. A solar tracker's maximum temperature is 51.44 degrees Celsius at 12:00 p.m.

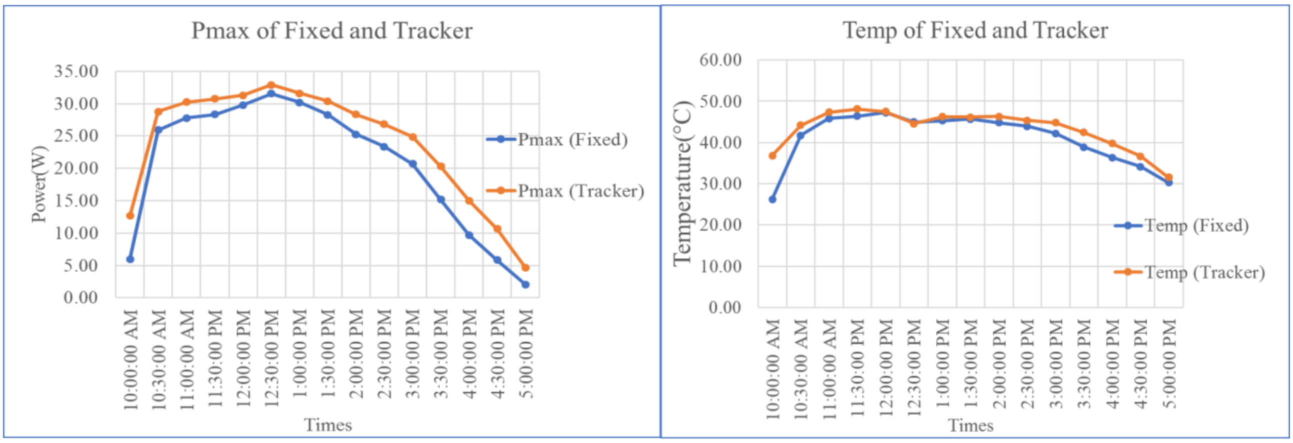

Fig (10) Power and Temperature Comparison between Fixed and Tracker (Day 3 Clear Sky)

At 12:30 p.m., the fixed-axis maximum power output is 31.52 watts. The highest power output of 32.89 watts was measured at 11:30 a.m. At 5:00 p.m., the fixed-axis minimum power output is 2.04 watts. At 5:00 p.m., the tracked minimum power output is 4.69 watts. The maximum temperature of a fixed tilt is 47.82 degrees Celsius at 12:00 p.m. A solar tracker's maximum temperature is 48.17 degrees Celsius at 11:30 a.m.

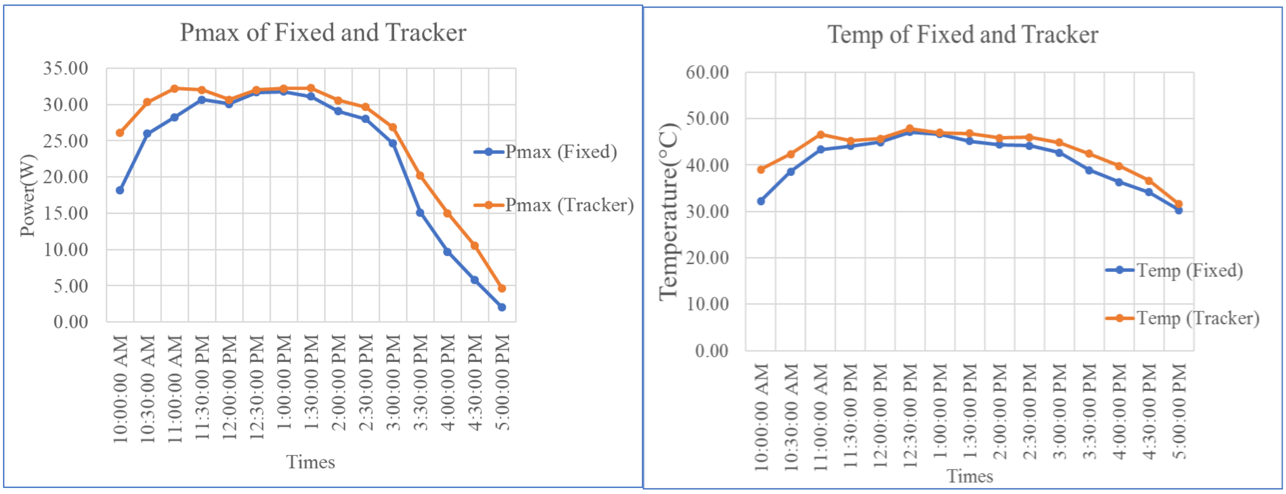

Fig (11) Power and Temperature Comparison between Fixed and Tracker (Day 4 Clear Sky)

At 1:00 p.m., the fixed-axis maximum power output is 31.76 watts. At 1:30 p.m., the maximum power production that is monitored is 32.25 watts. At 5:00 p.m., the fixed-axis minimum power output is 2.01 watts. The lowest power output that is monitored at about 5:00 p.m. is 4.63 watts. The maximum temperature on a fixed tilt is 47.11 degrees Celsius at 12:30 p.m. The maximum temperature recorded by a sun tracker is 47.89 degrees Celsius at 12:30 p.m.

5. CONCLUSION

The average surface temperature of the panels may be seen to rise with an increase in power output, according to the tracking and fixing systems. Both panels were generating a similar, almost equal amount of power output at midday. Throughout the day, a vertical-tilted single-axis solar tracker (VTSAT) generates more power than a fixed-tilt solar panel, which will shorten the time it takes for the technology's initial investment to pay for itself. It was also observed that the panel's performance is significantly impacted by the degree of cloudiness in the surrounding environment. Even on bright days, there are clouds in the sky that eventually obstruct the sun's light.

REFERENCES:

1. Bourdoukan, Paul, and Stelios Papathanassiou. "Performance Analysis and Modeling of Photovoltaic Systems Under Real Operating Conditions." IEEE Transactions on Sustainable Energy, vol. 11, no. 4, 2020, pp. 2382-2391.
2. Ghasempour, Reza, et al. "Real-time Monitoring and Fault Detection in Photovoltaic Systems Using Multimeter-Based Technique." IEEE Transactions on Industrial Electronics, vol. 66, no. 8, 2019, pp. 6345-6352. IEA. "Renewables 2020: Analysis and Forecast to 2025." International Energy Agency, 2020.
3. Jacobson, Mark Z., et al. "100% Clean and Renewable Wind, Water, and Sunlight All-Sector Energy Roadmaps for 139 Countries of the World." Joule, vol. 1, no. 1, 2017, pp. 108-121.
4. Khalil, Abdul Rahim A., et al. "Review on the Effects of Environmental Factors on Photovoltaic Performance." Renewable and Sustainable Energy Reviews, vol. 81, 2018, pp. 2142-2150.
5. Mark Z. Jacobson∗, Vijaysinh Jadhav, Department of Civil and Environmental Engineering, Stanford University, Stanford, CA 94305-4020, USA, Solar Energy 169 (2018) 55–66, World estimates of PV

optimal tilt angles and ratios of sunlight incident upon tilted and tracked PV panels relative to horizontal panels.
6. Li, Yang, et al. "Data-Driven Photovoltaic Maximum Power Point Tracking Using a Hammerstein-Wiener Model." IEEE Transactions on Industrial Electronics, vol. 63, no. 12, 2016, pp. 7439-7447.
7. Zhang, Qian, et al. "A Review of Solar Photovoltaic Panel Performance Enhancement Techniques." Renewable and Sustainable Energy Reviews, vol. 104, 2019, pp. 159-172.
8. R.G. Vieira a,n , F.K.O.M.V. Guerra a , M.R.B.G. Vale a , M.M. Araújo, “Comparative performance analysis between static solar panels and single-axis tracking system on a hot climate region near to the equator”, R.G. Vieira et al. / Renewable and Sustainable Energy Reviews 64 (2016) 672–681.
9. M. Mahendran, H.L. Ong, G.C. Lee and K. Thanikaikumaran, “An Experimental comparison study between Single-Axis Tracking and Fixed Photovoltaic Solar Panel Efficiency and Power Output: Case Study in East Coast Malaysia”.
10. Zhimin Li , Xinyue Liu , Runsheng Tang, “Optical performance of vertical single-axis tracked solar panels”, Z. Li et al. / Renewable Energy 36 (2011) 64e68.
11. D. Yogi Goswami, “Principles of Solar Engineering”, International Standard Book Number-13: 978-1-4665-6379-7 (eBook - PDF).