Solar Tracking System for a Floating Solar Panel System (FPSP)

Rhea Mae A. Cañete
Department of Electronics Engineering, Caraga State University

Alexander T. Demetillo
Department of Electronics Engineering, Caraga State University

Lovely Mae Dagsa
Department of Electronics Engineering, Caraga State University

Joshua A. Orillaneda
Department of Electronics Engineering, Caraga State University

他

https://doi.org/10.5109/7323297

出版情報：Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES). 10, pp.434-439, 2024-10-17. International Exchange and Innovation Conference on Engineering & Sciences
バージョン：

SOLAR TRACKING SYSTEM FOR A FLOATING SOLAR PANEL SYSTEM (FPSP)

Rhea Mae A. Cañete[1], Alexander T. Demetillo[1,2], Lovely Mae Dagsa[1,2], Joshua A. Orillaneda[1], Alfred Dennis B. Balamad[1,2]
[1]Department of Electronics Engineering, Caraga State University
[2]Center for Renewable Energy, Automation and Fabrication Technologies (CSU CRAFT)
Corresponding Author: lmdagsa@carsu.edu.ph

Abstract: *Photovoltaic (PV) technology is a key renewable energy source worldwide and improving its efficiency is essential. Solar trackers are effective in enhancing this efficiency. This paper discusses the design and prototyping of a solar tracking system for floating solar panel installations, aimed at increasing power output. The system employs an Arduino Uno microcontroller for control, two light-dependent resistors (LDRs) for sunlight detection, a real-time clock (RTC) for day-night detection, an L298n motor driver for motor control, and a linear actuator to adjust panel orientation. Experimental results show that the tracked floating solar panel system boosts power output by up to 28.25% compared to stationary systems. The study highlights the importance of solar tracking in optimizing PV system efficiency and overcoming the limitations of fixed installations. Statistical analysis, with a t-test P-value of 0.03, confirms the significant improvement in power harvest with the tracked system.*

Keywords: Photovoltaic (PV Technology); Solar Tracking; Real-Time Clock; LDR; Floating Solar Panel

1. INTRODUCTION

Energy plays an essential role in the development of society; it has promoted great advances and has also generated inequalities and conflicts throughout history. [1] [2] In this time of global market uncertainty one thing we do know is that the world needs energy and in increasing quantities to support economic and social progress and build a better quality of life, in developing countries. [3] In the last decades, due to industrial evolution and population growth, the world's energy demand has been continuously increasing. [4]

The increasing demand for energy in progressing civilization is leading to the exploitation of various conventional energy sources. Also, non-renewable energy sources cause the emission of greenhouse gases and other environmental damages. [5] Focusing on environmental issues and the depletion of non-renewable resources, several kinds of renewable energy have been implemented to solve the problem of energy scarcity, such as hydropower, solar power, wind power, tidal power, etc. Among the mentioned resources, solar energy possesses the greatest potential for development due to its ubiquitous nature and low maintenance costs. [6]. Solar energy is one of the most widely used forms of renewable energy, which generates electricity using photovoltaic (PV) solar cells [7].

The development of novel solar power technologies is one of many key solutions toward fulfilling a worldwide increasing demand for energy. [8] Since the integration of PV panels can contribute to reducing power transmission losses, particularly if the panels are located close to the points of consumption [9]. The idea of converting solar energy into electrical energy using photovoltaic panels holds its place in the front row compared to other renewable sources. But the continuous change in the relative angle of the sun with reference to the earth reduces the watts delivered by a solar panel. [10] At presenopticaleater parts of the sunlight-based boards are stationary & they are constantly confronted to stand out bearing; while the position of the sun continues changing in a day.[11] The Earth is in a constant rotation, so the relative position of the Sun in the sky continuously changes but can be defined utilizing solar position algorithms or optically, with enough precision. [2] Thus to get a constant output, an automated system is required which should be capable of rotating the solar panel constantly. 'The Solar Tracking System' is made as a prototype to solve the problem which is completely automated, and it keeps the panel right under the sun where we get maximum output. [11] Therefore, the solar trackers (ST) that can track the direction of the sun in real-time are ideal for improving power generation efficiency. [6]

Solar trackers move the payload towards the sun throughout the day. [8] The use of solar trackers can increase electricity production by around a third, and some claim by as much as 40% in some regions, compared with modules at a fixed angle. In any solar application, the conversion efficiency is improved when the modules are continually adjusted to the optimum angle as the sun traverses the sky. [12] One of the most common types of Solar Tracking Systems is the Single-Axis Tracking System. A single axis tracking system will be a big help for a floating solar panel system to increase the energy harvest of the solar panel compared to a solar panel with a fixed angle.

The single-axis solar tracking system can indeed be helpful. In this system, an Arduino Uno microcontroller manages the tracking process using inputs from two light-dependent resistors (LDRs) to detect sunlight. A real-time clock (RTC) helps determine the time of day for adjusting the panel's position. The L298n motor driver controls the linear actuator, which adjusts the panel's orientation to follow the sun from east to west. This setup ensures that the solar panel maintains an optimal angle relative to the sun, thereby increasing power output compared to stationary panels.

This study focused on prototyping a single-axis solar tracking system for a floating solar panel system.

The study aims to design and prototype a single-axis solar tracking system for a floating solar panel system

which specifically, the study is subjected to consider the following questions:
(i) Can a solar tracking system increase the power output of a floating solar panel? and (ii) Is it possible to design and prototype a solar tracking system for a floating solar panel system? This intends to show the potential of developing and prototyping a single-axis solar tracking system for a floating solar panel system aimed (i) to design and prototype a solar tracker system for a floating solar panel system, and (ii) to increase the power output of a floating solar panel system using a solar tracker system.
The development of this solar tracker for a floating solar panel system will help increase the power output of a floating solar panel system. This will also lessen the hassle in positioning the floating solar panels manually because a solar tracker is designed to automatically position the solar panel in the area where the sun is facing.
For the scope and limitation, the researcher limited the design and prototyping of a single-axis solar tracking system for a floating solar panel system to the following: (i) This single-axis solar tracking system is designed for a floating solar panel system; (ii) This system will only track the position of the sun; and (iii) This solar tracker system is a horizontal single-axis solar tracking system that moves from east to west and vice-versa.

2. METHODOLOGY

To meet the objectives of the following methods were implemented: conceptualization and prototyping; acquisition of the components required for the system; program algorithm development of different subsystem; development of the machine and hardware components assembly; testing and evaluation of the machine; data gathering; and finalization and writing of manuscript.

2.1 System Overview

The block diagram of the system is shown Figure 1. It has a microcontroller board that processes data received from the two sensors and the real timeclock (RTC). The motor driver controls the direction of the linear motor. The linear motor will move the panel from east-west direction. The power source of the system will be taken from the solar panel.

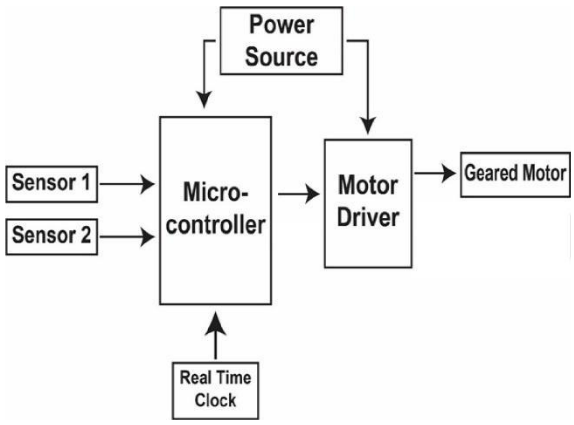

Fig. 2. Block Diagram of the System

2.2 System Flowchart

In this solar panel tracking system, a Real-Time Clock (RTC) serves the crucial function of determining whether it is daytime or nighttime. During daylight hours, the system enters its tracking mode to optimize solar panel orientation for maximum sunlight capture. This process is facilitated by two Light Dependent Resistors (LDRs) strategically positioned along the east-west axis.
These LDRs continuously monitor the ambient light intensity from both the east and west directions. If the east LDR detects a higher intensity of light compared to the west LDR, the system activates the motor to adjust the solar panel's position towards the east. Conversely, if the west LDR records a higher light intensity, the panel adjusts westward accordingly.
The motor driving the solar panel continues to adjust its position until both LDRs report equal light intensity. This state indicates that the panel has achieved alignment with the azimuth position of the sun, maximizing the efficiency of solar energy collection.
In summary, the system uses an RTC to synchronize its operation with daylight hours, employs LDRs to detect and compare light intensity from east and west directions, and adjusts the solar panel orientation dynamically to face the direction of maximum sunlight, thereby optimizing energy harvesting throughout the day

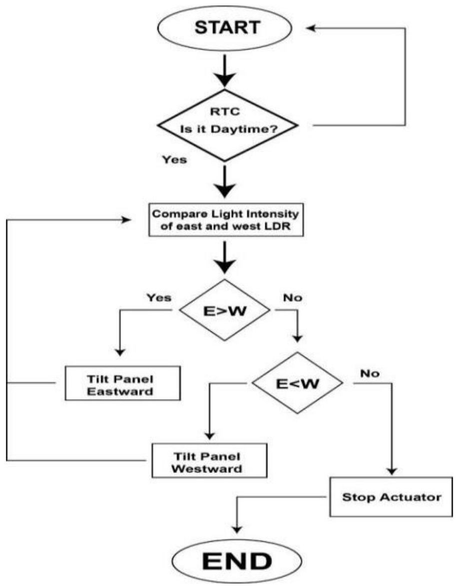

Fig. 1. System Flowchart

2.3 Software Aided System Design

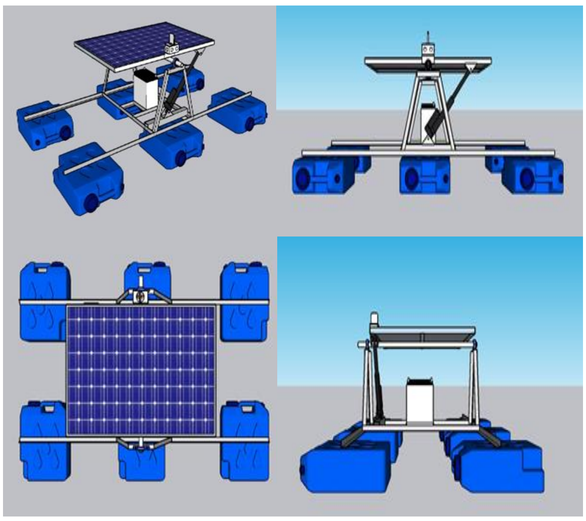

Fig. 3. 3D Model Design of the System

Figure 3 shows the different perspective view of the Solar Tracking System for a Floating Solar Panel System Prototype. The researcher used Sketch-up 2020 in designing the 3D model of the system.

2.4 Construction

To ensure the effectiveness and strong structure of the floating solar tracker system, design of the floating solar panel system is considered. The system is composed of 6 water containers to serve as floaters of the system. The sensors were placed on top of the solar panel for better light detection. The linear actuator was installed below the solar panel to make the panel tilt easily in eastward or westward direction.

Fig. 5. Actual Design of the System

2.5 Data Analysis

To determine if there is a significant difference between the two setups, a t-test was performed. This statistical test is appropriate for comparing two sets of data from different setups. We set our significance level to 0.05 and formulated the null hypothesis as follows:

Null Hypothesis (H_0): There is no significant difference in power harvest between the two setups.

2.6 Calculation on average power and the percent error of the harvested data

Equation (1) the formula used to calculate the average power recorded.

$$P_{avg} = \left(\frac{P_1 + P_2 + P_3 + P_4 + P_5 + P_6 + P_n}{n}\right) \qquad Eq. (1)$$

And for the calculation of percent error:

% Error = ((Ideal – Actual)/ Ideal)/ 100 *Eq.* (2)

3. DATA RESULTS AND ANALYSIS

This section provides valuable insights into the performance of the developed system.

3.1 RTC Module Testing

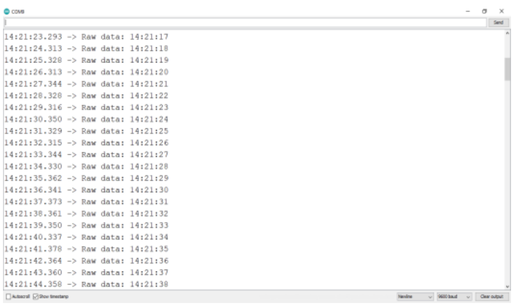

Fig. 4. RTC Module Results

The RTC module is tested to govern its assigned function. The test conducted to this module by means of comparing its time generated from the real standard time. In assessing the RTC module, the exactness of the time needs to be considered. Determining the hours generated by the module is essential. The time generated by the RTC is shown in Figure 5. The value of hour and minutes is accurately the same with the standard time.

3.2 Testing between (i) Fixed Ground Solar Panel System and (ii) Ground Solar Panel System with Solar Tracker integration during partly cloudy weather condition

The data gathered in testing a stationary solar panel system with a weather condition of partly cloudy having a temperature of 32 degrees and a of humidity 64 percent at Butuan City.

3.2.1 For (i) Fixed Ground Solar Panel System

For table 1, the panel was exposed to the sun for about 2 hours and 45 min with an angle elevation of 13 degrees.

Table 1. Harvest data for Fixed Solar Panel System

Time (mins)	Voltage (V)	Current (I)	Power (W)
15	18.02	2.06	37.1212
30	18.73	3.12	58.4376
45	18.45	3.73	68.8185
60	18.95	4.28	81.106
75	19.24	4.8	92.352
90	19.09	4.52	86.2868
105	19.24	4.06	78.1144
120	19.5	3.63	70.785
135	19.12	3.41	65.1992
150	20.01	3.09	61.8309
165	19.76	2.05	40.508

3.2.2 For (ii) Ground Solar Panel System with Solar Tracker Integration

The data gathered in testing a solar panel system that was set on the ground attached with a solar tracker with a weather condition of partly cloudy having a temperature of 32 degrees and a humidity of 64 percent at Butuan City Agusan del Norte.

Table 2. Harvest data Solar Panel with Solar Tracker Integration

Time (mins)	Voltage (V)	Current (I)	Power (W)
15	19.82	2.56	50.7392
30	20.04	3.59	71.9436
45	20.18	4.14	83.5452
60	19.9	4.32	85.968
75	19.6	4.4	86.24
90	19.64	4.33	85.0412
105	19.75	3.95	78.0125
120	19.8	3.89	77.022
135	20.18	4.19	84.5542
150	20.02	4.13	82.6826
165	19.83	4.08	80.9064

Table 2 shows the data of the voltage and current produced by the solar panel that was checked every 15 mins. We started the test at around 8:00 in the morning due to the weather conditions.

Figure 6 below shows a visualization of the results of the stationery and with solar tracker setups for better comparison.

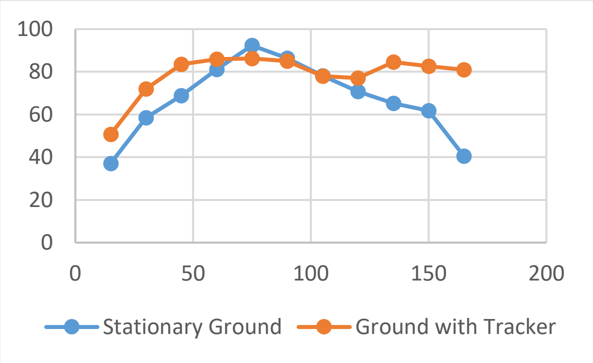

Fig. 6. Stationary vs. with solar tracker system set-up (On the Ground)

Table 3. Comparison results between (i) Stationary Ground Solar Panel System and (ii) Ground Solar Panel System with Solar Tracker integration

Parameters	Stationary	With Tracker
Mean	67.3236	78.786
Variance	305.15	105.90
Observations	11	11
Hypothesized Mean Difference	0	
P(T<=t)	0.0377	

Table 3 indicated the solar panel system with solar tracker integration outperforms the stationary solar panel system in terms of average power output. This suggests that integrating a solar tracker can significantly enhance the efficiency and performance of a solar panel system by optimizing sunlight capture throughout the day. The increased current and power output indicate improved energy generation potential with the use of solar tracking technology.

Using t-test to analyze the data sets, we obtained a p-value of 0.0377. Since this value is less than the 0.05 significance level, we reject the null hypothesis. This indicates that the two setups yielded significant difference in terms of power harvest.

3.3 Testing between (i) Stationary Floating Solar Panel System and (ii) Floating Solar Panel System with Solar Tracker integration during partly sunny weather condition

The test involved comparing two types of solar panel systems under controlled conditions. Specifically, it evaluated a fixed floating solar panel system against a floating solar panel system equipped with an integrated solar tracker. The testing was carried out during partly sunny weather with a temperature of 32 degrees Celsius and a humidity level of 75 percent.

For accuracy, the test was conducted on the same day and at the same time for both systems. The duration of the test was four hours, from 1:00 PM to 5:00 PM. Throughout this period, the performance of the solar panels was monitored and recorded every 15 minutes to ensure precise data collection and facilitate a thorough comparison of the two systems.

3.3.1 For (i) Stationary Floating Solar Panel System

Table 4. Harvest data for Fixed Floating Solar Panel System

Time (mins)	Voltage (V)	Current (I)	Power (W)
15	18.79	2.08	39.0832
30	18.85	2.33	43.9205
45	18.89	2.42	45.7138
60	18.79	2.82	52.9878
75	18.91	2.86	54.0826
90	19.73	3.42	67.4766
105	19.81	4.27	84.5887
120	20.53	4.88	100.1864
135	19.97	4.46	89.0662
150	20.10	3.96	79.5960
165	20.00	3.50	70.0000
180	20.00	3.60	72.0000
195	20.00	3.31	66.2000
210	19.95	2.50	49.8750
225	19.30	1.07	20.6510
240	19.09	0.61	11.6449

3.3.2 For (ii) Floating Solar Panel System with Solar Tracker integration

Table 5. Harvest data for Floating Solar Panel System with Solar Tracker integration

Time (mins)	Voltage (V)	Current (I)	Power (W)
15	19.83	3.07	60.8781
30	19.81	3.13	62.0053
45	19.95	3.67	73.2165
60	20.01	3.83	76.6383
75	19.97	3.98	79.4806
90	20.52	4.54	93.1608
105	20.83	4.70	97.9010
120	20.87	4.72	98.5064
135	20.17	5.27	106.2959
150	20.36	4.74	96.5064
165	20.21	4.31	87.1051
180	20.19	4.45	89.8455
195	20.18	4.15	83.7470
210	20.21	3.18	64.2678
225	19.65	1.44	28.2960
240	19.73	0.85	16.7705

Figure 7 below visualizes the results for the stationary and solar tracker setups for comparison.

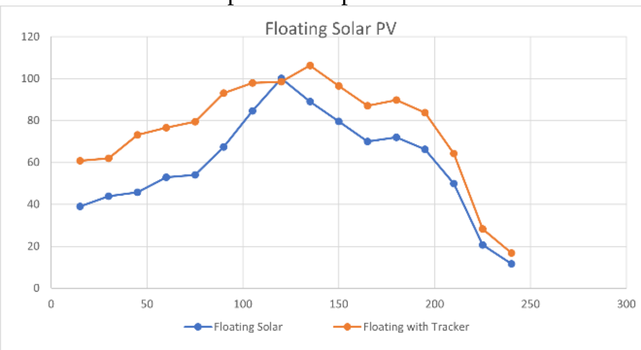

Fig. 7. Stationary vs. with solar tracker system set-up (Floating Solar)

Table 6. Comparison between (i) Stationary Floating Solar Panel System and (ii) Floating Solar Panel System with Solar Tracker integration

Parameters	Stationary	With Tracker
Mean	59.192	75.913
Variance	583.314	624.01
Observations	16	16
Hypothesized Mean Difference	0	
P(T<=t)	0.0318	

Table 6 indicated the solar panel system with solar tracker integration outperforms the stationary solar panel system in terms of average power output.

A t-test yielded a p-value of 0.0318, which is less than the 0.05 significance level. As a result, we reject the null hypothesis. This suggests that the two setups yielded significant difference in terms of power harvest.

3.4 Angle Elevation of the Solar Panel

A test was conducted using an angle meter that was installed on a phone. The angle of the solar panel was checked every 30 minutes from 11:00 AM- 2:00 PM. This test was conducted to check the percentage error of the angle elevation of the panel. The best angle of the solar panel should be 90 degrees or perpendicular with respect to the sun's rays for the maximum exposure to the sunlight.

Table 7. Data Gathered on the Angle Elevation of the Solar Panel

Time	Actual Angle Reading of the Solar Panel	Solar Panel Ideal angle with respect to the Sun's position	Error (%)
11:00	13	19°	31.58%
11:30	13	16°	18.75%
12:00	-13	-17°	23.53%
12:30	-17	-20°	15.00%
01:00	-18	-24°	25.00%
01:30	-18	-30°	40.00%
02:00	-19	-37°	48.60%

Equation (2) was used to get the percentage error of the angle elevation of the solar panel.

Table 7 shows the data gathered on the angle elevation of the solar panel with respect to the sun rays. Using the Equation (2), the percentage error of the actual angle elevation of the solar panel with respect to the ideal angle elevation of the solar panel was calculated. And based on calculations, the lowest percentage error of the angle elevation of the solar panel is 15% while the highest percentage error is 40%.

4. CONCLUSIONS

4.1 Conclusion

As a conclusion, the objectives of the study have been successfully achieved. The study focused on developing a solar tracking system tailored for a floating solar panel setup. This system utilizes two Light Dependent Resistors (LDRs) to accurately track the position of the sun throughout the day, thereby optimizing the solar panel's orientation for increased power output. A linear actuator mechanism is integrated with the solar panel to facilitate precise movements and ensure alignment with the sun's position.

Tests were conducted to assess the effectiveness of the solar tracking system. Experimental validation indicates that the tracked system floating solar panel system enhances power output by up to 28.25% compared to stationary floating solar panel systems. This improvement underscores the significant energy gains made possible by dynamic solar panel orientation.

This study contributes to the advancement of solar energy technologies by providing a practical solution to enhance the efficiency of solar panel systems. Traditionally, stationary solar panels are limited in their ability to maximize power generation due to fixed positioning.

In summary, the developed solar tracking system represents a viable alternative for maximizing the energy yield of solar panel installations. By enabling panels to track the sun's path throughout the day, this technology enhances overall energy harvesting capabilities and represents a promising advancement in renewable energy applications. Statistical analysis demonstrated a significant improvement in power harvest with the tracked system compared to the untracked system. The t-test results, which yielded a P-value of 0.03, confirm that the tracked solar panel system significantly increased power harvest relative to the untracked system.

4.2 Recommendations

This study focuses on the capability of the solar tracking system to improve the power output of a solar panel system. So, one of the possible recommendations for the future enhancement of a Single Axis Solar Tracking System is a more sensitive light sensor to have a more accurate tracking of the sun's light and to have a lesser percentage error in terms of the angle elevation of the solar panel with respect to the sun's rays. The maximum tilt angle of this solar tracking system is only limited to around 20-25 degrees, that's why it is recommended to have a linear actuator with longer stroke for a higher maximum tilt angle that will help in maximizing the exposure of the solar panel to the sun's rays. And the single-axis solar tracking system can be innovated into a much better solar tracking system which is a dual-axis solar tracking system. The dual-axis solar tracking system is designed to move the solar panel horizontally and vertically which will locate the position of the sun more accurately than the single-axis tracking system.

5. REFERENCES

[1] "Energy Transitions: History, Requirements, Prospects - Vaclav Smil - Google Books." [Online]. Available: https://books.google.com.ph/books?hl=en&lr=&id=vLuT4BS_25MC&oi=fnd&pg=PR5&ots=_ECBVHCY89&sig=-SlinsGAOxhwWylxXFCilNq_m4I&redir_esc=y#v=onepage&q&f=false. [Accessed: 11-Nov-2020].

[2] J. A. Carballo, J. Bonilla, L. Roca, and M. Berenguel, "New low-cost solar tracking system based on open-source hardware for educational purposes," Sol. Energy, vol. 174, no. July, pp. 826–836, 2018, doi: 10.1016/j.solener.2018.09.064.

[3] "The importance of energy | Imperial." [Online]. Available: https://www.imperialoil.ca/en-CA/Company/About/The-importance-of-energy. [Accessed: 11-Nov-2020].

[4] A. Pérez et al., "No 主観的健康感を中心とした在宅高齢者における 健康関連指標に関する共分散構造分析 Title," BMC Public Health, vol. 5, no. 1, pp. 1–8, 2017.

[5] "India projected to be on track to achieve Paris climate agreement target: US expert, Energy News, ET EnergyWorld." [Online]. Available: https://energy.economictimes.indiatimes.com/news/renewable/india-projected-to-be-on-track-to-achieve-paris-climate-agreement-target-us-expert/68229428. [Accessed: 11-Nov-2020].

[6] Z. Hua, C. Ma, M. Ma, L. Bin, and X. Pang, "Operation characteristics of multiple solar trackers under typical weather conditions in a large-scale photovoltaic base," Energy Procedia, vol. 158, pp. 6242–6247, 2019, doi: 10.1016/j.egypro.2019.01.463.

[7] M. S. Rahman and T. Sadi, "Development of a 10 kW Solar Photovoltaic Power Plant for Bonwary Lal Govt. High School," in Proceeding of International Exchange and Innovation Conference on Engineering & Sciences (IEICES), Interdisciplinary Graduate School of Engineering Sciences, Kyushu University, 2023, pp. pp.13-20.

[8] E. Kabir, P. Kumar, S. Kumar, A. A. Adelodun, and K. H. Kim, "Solar energy: Potential and future prospects," Renew. Sustain. Energy Rev., vol. 82, no. September, pp. 894–900, 2018, doi: 10.1016/j.rser.2017.09.094.

[9] W. HENNI, W. L. RAHAL, D. RACHED and A. BOUKORTT, "Thickness optimization of Al2O3 tunneling layer in CBTS solar cells using SCAPS software," in Proceeding of International Exchange and Innovation Conference on Engineering & Sciences (IEICES), Interdisciplinary Graduate School of Engineering Sciences, Kyushu University, 2023, pp. pp.59-64.

[10] S. Racharla and K. Rajan, "Solar tracking system–a review," Int. J. Sustain. Eng., vol. 10, no. 2, pp. 72–81, 2017, doi: 10.1080/19397038.2016.1267816.

[11] M. K. Iqbal, T. Islam, M. Chowdhury, and A. Imteaj, "Construction of Single Axis Automatic Solar Tracking System," Int. J. u- e-Service, Sci. Technol., vol. 8, no. 1, pp. 389–400, 2015, doi: 10.14257/ijunesst.2015.8.1.34.

[12] S. Racharla and K. Rajan, "Solar tracking system," Int. J. Sustain. Eng., vol. 10, no. 2, pp. 72–81, 2017, doi: 10.1080/19397038.2016.1267816.