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Research Article

Development of Solar Tracking Technique to Maximize PV system output with the sensor

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ABSTRACT:
All forms of energy can be traced back to the sun's energy. The sun's rays can be utilized in a variety of ways, of which the generation of electricity and thermal energy are the major ones. Photovoltaic (PV) cells have become the industry standard in the solar power sector. Elements such as solar radiation, ambient temperature, and wind speed have a great impact on solar cell performance. The panel loses most of the energy it receives by converting it into heat, which is always dissipated. The reason for carrying out the research is to analyze the PV system performance upon tracking the sun. An Arduino Nano microcontroller, a servo motor, a light-dependent resistor (LDR) sensor, etc., were all part of the system. The amount of radiation detected by the LDR sensor was used to determine the servo motor's output speed. The proposed system was tested experimentally, and the results exhibited a 32.5% increase in power gain over the fixed solar panel, which is 7.3% more than the existing model. Additionally, this study provides a graphical comparison of the output voltage and efficiency with the existing system.

Keywords: Photovoltaic technology, solar energy, tracking, LDR, efficiency.

Introduction

Solar energy is an unconventional form of energy that can be utilized to generate electricity. In light of this, someone came up with the idea of using solar panels to turn sunlight into power. The quantity of sunlight that falls directly on the solar panel is converted into the amount of power that is generated (Zhu *et al*., 2020). In most cases, solar panels are installed in fixed locations. Because of the rotation of the planet, the position of the sun changes over time. As a consequence, solar panels no longer face directly toward the sun, which results in a reduction in the amount of power they generate. This issue may be remedied with the installation of a device known as a solar tracker. A solar tracker is a device that automatically adjusts the orientation of a solar panel so that it faces in the direction of the sun and maximizes the amount of electricity generated. The cosine angle of incidence, or the angle at which a sunbeam strikes a horizontal surface, is the primary determinant of output. Maximum power is generated at the smallest possible incidence angle. In the case of a stationary panel, the sun's angle of movement is greatest at midday. An effective sun tracker is the solution to this issue. As the sun's rays get weaker, it will shift positions automatically. The angular separation between the solar panel and the sky is tracked by the solar tracker to stay close to 90 degrees (Hafez *et al*., 2018; Sallaberry *et al*., 2015).

The use of solar trackers may boost power generation compared to using stationary modules. Major components of the tracking system are the tracking algorithm, tracker mount, drives, sensors, sensor controller motor, and motor controller (Gutiérrez-Castro *et al*., 2014).

Types of Solar Trackers

Passive solar tracker

Without employing any motors or other moving elements, passive solar trackers can aim their detectors directly towards the sun. Actuators are replaced with shape-memory alloys or compressed gas fluids with a low boiling point. Irregularly dispersed light may be corrected by the panel's thermal expansion. Two examples of materials that exhibit unique properties are expandable gases and shape-memory alloys. The gaseous state of the liquid substance undergoes expansion and exhibits a directional flow towards the region of the tracker that has seen the highest absorption of thermal energy. Since the gravitational pull on the panel is not uniform, it will tilt until all sides are receiving the same amount of light. It's easier to use and does its job effectively, although it loses effectiveness in cold weather (Lazaroiu *et al*., 2015; Poulek *et al*., 1998; Brito *et al*., 2019).

Active Solar Tracker:

It utilizes a combination of sensors, motors, and microprocessors for tracking. Yet, they are energy hogs due to their dependence on external power sources. The sensors get a different quantity of light and hence transmit a different signal when the trackers are not facing the sun. These signals are used by a comparator or microcontroller to determine the correct next step (Chin *et al*., 2011; Kasburg *et al*., 2019). Thereafter, the correct signal is sent to the motors. When the PV module is positioned appropriately to receive sunlight and all sensors get identical illumination, the procedure is complete. The tracker-based system was able to store 40% more thermal energy than the fixed system in an experiment designed to increase thermal efficiency (Rana, 2013).

Active solar tracker with single-axis system

The sole degree of freedom in a single-axis tracking system is the rotation axis, as in the case of an active solar tracker I using a single-axis system. Using a stepper motor and a light-dependent sensor, a single-axis tracking solar system kept the panel tilted at the optimal angle to the sun's beams. As compared to a stationary horizontal array, the power gain was 30 percent higher (Ponniran *et al*., 2011; Pelaez *et al*., 2019; Sallaberry *et al*., 2015). Experiment with a microcontroller-based tracking system for solar panels, concluded that a single axis tracker improves efficiency by 30% compared to a fixed module. Findings indicated that following the sun along a path that was more southerly or westerly was the most effective way to increase energy production. Compared to the south-north axis, which saw a 16% improvement in efficiency, the east-west axis had an increase of just 8%. (Pelaez *et al*., 2019).

Active solar tracker with dual-axis system

Dual-axis trackers include two axes of rotation that are perpendicular to one another, providing four total degrees of freedom. One fundamental axis is the one that does not move with regard to the ground. A subsidiary axis is one that serves as a reference for the main one (Hammoumi *et al*., 2018; Ferdaus *et al*., 2014). Using solar trackers results in a 40% increase in the overall amount of thermal energy stored. A correctly tracked system may increase power production by up to 30.98% compared to a stationary system (Muhammad *et al*., 2019).

Chronological solar tracker

Based on the research, it is known that a chronological solar tracker is one that follows the sun at the same rate and at the same angle every day and month (Last *et al*., 2002). This necessitates setting the motor or actuator to rotate at 15 degrees per hour, or once each day on average. Based on mathematical estimates of the sun's course, this tracking system can determine the sun's location at any given moment (Tharamuttam *et al*., 2017).

Solar photovoltaics (PV) or concentrated solar power, or both, make up the solar-powered energy-producing system. Research has demonstrated that dual-axis solar systems exhibit higher efficiency levels compared to their single-axis counterparts because they absorb a greater amount of solar energy throughout the day, but for constraint space, reliability, and technical and financial feasibility, those dual-axis trackers are justified for large investments. For the general-purpose and medium-size project, single-axis trackers are best suited.

Materials and Method

Follows is a list shown in Table 1, with technical specifications, of the many parts that were used to make up a solar tracking solar panel.

Table 1: List of the component for the experimental setup

Sl No.	Name of the Component	Specification	Qty
01.	Solar Panel	Solar cell type: Polysilicon, Dimension: 350 × 290 × 17 mm	01
02.	Arduino Nano	Microcontroller: Atmel ATmega328, Operating	01
03.	Servo motor	Model: MG995, Weight: 55 gm, Operating V: 4.8V~ 7.2V	01
04.	Light dependent	Spectral peak: 560nm, Maximum voltage: 250 VDC	02
05.	Latch switch	Power/Voltage: 250V	01
06.	Electrolytic Capacitor	Capacitance: 68uF, Tolerance: ±20%	04
07.	7805 voltage regulators	Fixed output voltage is 5V	01
08.	7806 voltage regulators	Fixed output voltage is 6V	01
09.	Connecting wire	-	05
10.	Dot Board	Dimension: 14.5×6 cm	01
11.	Pin Connector	Power: 300V 10A	02

The present study focuses on the experimental construction of a solar tracker device shown in Figure 1

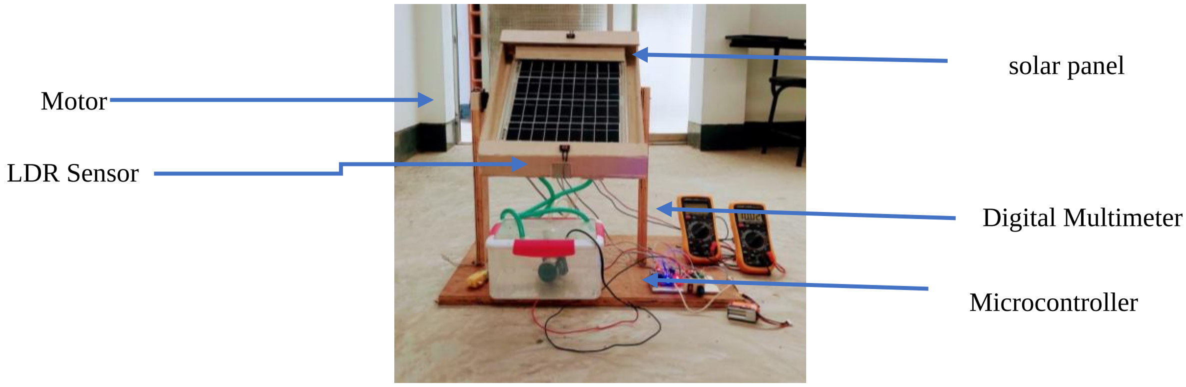

Figure 1: Experimental layout of solar tracker device

The initial algorithm employed may be succinctly expressed as follows in figure 2.

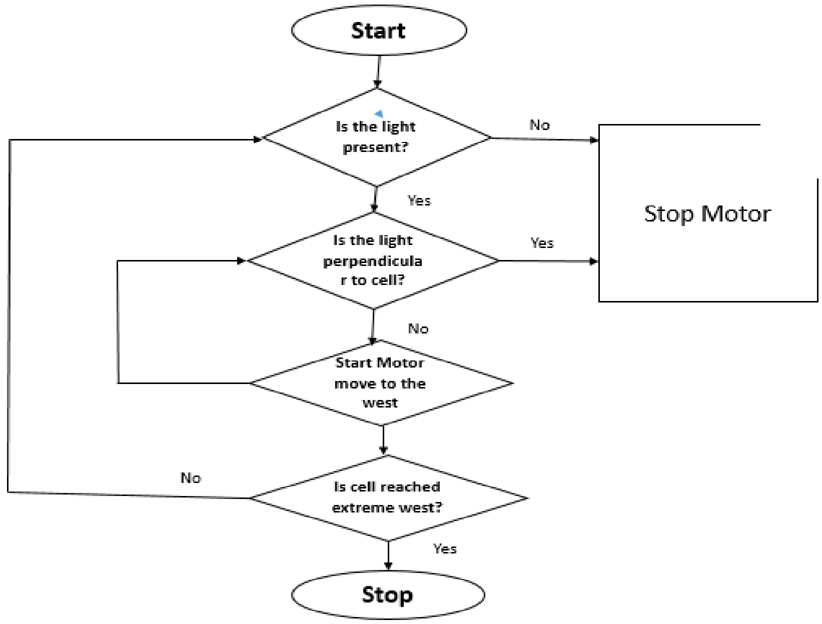

Figure 2: Logic Diagram of tracking the sun.

Results and Discussion:

Table 2 shows the average radiation, current and voltage data for one month when solar panel is fixed as well as panel with tracker system respectively. Power output and panel efficiency is calculated with the help of the subsequent equations respectively.

Power = (Voltage x Current) watts

The power efficiency formula is,
While the efficiency of the solar panel is calculated using,

= (Output Power of Solar Cell / Solar Radiation*Area of Solar Panel) *100%

Table 2: Radiation, current and voltage data when solar panel is fixed

Time	Radiation (W/m2)	Fixed Panel			Panel with Tracker		
		Voltage (V)	Current (A)	Power (watt)	Voltage (V)	Current (A)	Power (watt)
09:00 AM	557	5.4	0.11	0.594	7.2	0.14	1.008
09:30 AM	588	7.2	0.14	1.008	8.8	0.17	1.496
10:00 AM	633	9	0.15	1.35	10.1	0.2	2.02
10:30 AM	703	10	0.2	2	11.6	0.23	2.668
11:00 AM	721	10.6	0.21	2.226	12.4	0.28	3.472
11:30 AM	754	11.4	0.24	2.736	13.1	0.3	3.93
12:00 PM	824.7	12	0.28	3.36	13.3	0.31	4.123
12:30 PM	836	12.8	0.3	3.84	13.4	0.31	4.154
01:00 PM	850.4	13.2	0.31	4.092	13.9	0.31	4.309
01:30 PM	856	13.2	0.3	3.96	13.8	0.31	4.278
02:00 PM	800	13	0.3	3.9	13.7	0.3	4.11
02:30 PM	754	11.2	0.23	2.576	13.3	0.3	3.99
03:00 Pm	763	11	0.23	2.53	13	0.28	3.64

03:30 PM	757	9.7	0.18	1.746	11.5	0.25	2.875
04:00 PM	634.9	8	0.16	1.28	10.1	0.24	2.424
04:30 PM	421	7.2	0.13	0.936	8	0.18	1.44
05:00 PM	312.1	6	0.12	0.72	7	0.14	0.98
05:30 PM	209	4.1	0.1	0.41	6.5	0.13	0.845
06:00 PM	167	2.6	0.05	0.13	4.3	0.1	0.43
			Average	2.07		Average	2.74
			Efficiency	2.86		Efficiency	3.80

Panel output power:

The evaluation and monitoring of the sun-tracker's performance were conducted through the different times of the day from 9 am to 6 pm. Figure 3 shows the graphical representation of the power difference between fixed and tracking system.

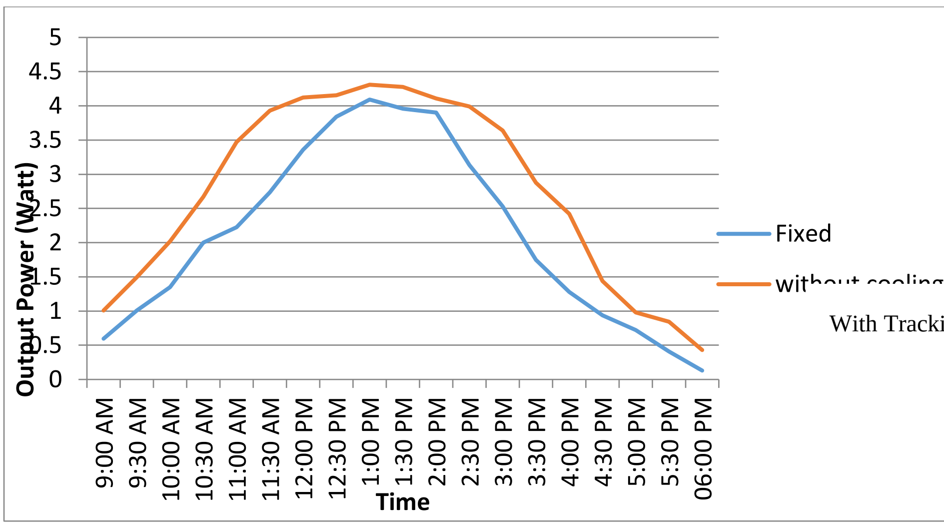

Figure 3: Comparison of the suggested model's power output for a fixed panel and a panel with a tracker

The observed power production exhibited a significant rise throughout the early and mid-morning periods. Indeed, the overall enhancement in the tracking mode showed a surpassing increase of over 40% within the time frame spanning from 12 pm to 1 pm. Nevertheless, the mean overall enhancement across the whole day exhibited superior results as compared to those of a static module. The results obtained from the evaluation of both fixed and tracking systems indicate that the average surface temperature of the modules remained within the specified operating conditions. Additionally, it was noticed that when the power output rose, there was a corresponding increase in the temperature of the panels. When comparing the performance between the tracking system in relation to the static system, the tracking system imparts 32.5% more power.

Figure 3 and Figure 4 depict the power output for a fixed panel and a panel with a tracker for the existing proposed and the existing model, respectively.

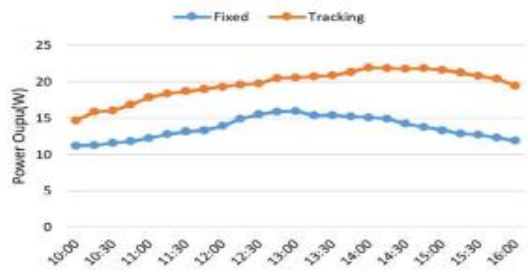

Figure 4: Power output for a fixed panel and panel with a tracker for the existing model (Munanga *et al*., 2020)

The ability to track was facilitated by the utilization of electronic components, and the significance of their influence was underscored by the contrasting power outputs observed between the fixed panel and the tracking panel, as seen in Figure 3 and Figure 4. The microcontroller computed the average hourly movement by ascertaining the quantity of daylight hours. Figures 3 and 4 depict the power production outcomes of the solar system, comparing the use of a tracker in both the present and suggested models. From the plots of figure 3, it is clearly stated that the proposed tracking system is efficient over the fixed panel and similar to the uniform curve of normal distribution. Power increases from the morning till noon. The peak power gain is accomplished at midday and then starts to decline. On the contrary, the power graph for the existing system is quite flat, and the tracking graph seems non-uniform.

Most of the previous research reveals an average efficiency of 15-20% is achieved from the panel with a tracking mechanism over the fixed one. The conducted experiment was to assess the impact of the proposed system on efficiency compared to a fixed 10W panel. The results indicated a significant increase in power output by 32.5%, which provides sufficient justification for implementing the suggested system. This is particularly noteworthy considering the present system's efficiency is only 25% (Munanga *et al*., 2020).

Conclusions

The analysis of this work's data revealed that the tracking system, module type, and weather condition are the most important elements in determining the power output. This study also proved that the single-axis tracking system significantly outperformed the fixed panel by positioning the PV modules perpendicular to the sun. The findings also showed that compared to a fixed panel at an angle of 30 degrees to the horizontal, the panel with a tracking system provides 32.5% more power. More testing is required to determine the precise parameters that reduce power output; however, they may be related to climatic conditions like temperature and cloud cover. The generation of energy by solar cells is constrained by the sun's extreme heat. Solar panels cannot function properly without proper cooling. Applying an active water-cooling system to reduce cell temperature.

Conflict of interest: No conflict of interest is associated with the research.

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Authors contributions

Research concept & design, materials purchasing, data collection and analysis, literature search, writing articles, and editing.

References:

1. Brito, M. C., Pó, J. M., Pereira, D., Simões, F., Rodriguez, R., & Amador, J. C. (2019). Passive solar tracker based in the differential thermal expansion of vertical strips. Journal of Renewable and Sustainable Energy, 11(4).
2. Chin, C. S., Babu, A., & McBride, W. (2011). Design, modeling and testing of a standalone single axis active solar tracker using MATLAB/Simulink. Renewable Energy, 36(11), 3075-3090.
3. Ferdaus, R. A., Mohammed, M. A., Rahman, S., Salehin, S., & Mannan, M. A. (2014). Energy efficient hybrid dual axis solar tracking system. Journal of Renewable Energy, 2014.
4. Gutiérrez-Castro, L. M., Quinto-Diez, P., Barbosa-Saldaña, J. G., Tovar-Galvez, L. R., & Reyes-Leon, A. (2014). Comparison between a fixed and a tracking solar heating system for a thermophilic anaerobic digester. Energy Procedia, 57, 2937-2945.
5. Hafez, A. Z., Yousef, A. M., & Harag, N. M. (2018). Solar tracking systems: Technologies and trackers drive types–A review. Renewable and Sustainable Energy Reviews, 91, 754-782.
6. Hammoumi, A. E., Motahhir, S., Ghzizal, A. E., Chalh, A., & Derouich, A. (2018). A simple and low-cost active dual-axis solar tracker. Energy science & engineering, 6(5), 607-620.
7. Kasburg, C., & Stefenon, S. F. (2019). Deep learning for photovoltaic generation forecast in active solar trackers. IEEE Latin America Transactions, 17(12), 2013-2019.
8. Last, W. M., & Smol, J. P. (Eds.). (2002). Tracking environmental change using lake sediments: volume 1: basin analysis, coring, and chronological techniques (Vol. 1). Springer Science & Business Media.
9. Lazaroiu, G. C., Longo, M., Roscia, M., & Pagano, M. (2015). Comparative analysis of fixed and sun tracking low power PV systems considering energy consumption. Energy Conversion and Management, 92, 143-148.
10. Muhammad, J. Y. U., Jimoh, M. T., Kyari, I. B., Gele, M. A., & Musa, I. (2019). A review on solar tracking system: A technique of solar power output enhancement. Engineering Science, 4(1), 1-11.
11. Munanga, P., Chinguwa, S., Nyemba, W. R., & Mbohwa, C. (2020). Design for manufacture and assembly of an intelligent single axis solar tracking system. Procedia CIRP, 91, 571-576.
12. Pelaez, S. A., Deline, C., Greenberg, P., Stein, J. S., & Kostuk, R. K. (2019). Model and validation of single-axis tracking with bifacial PV. IEEE Journal of Photovoltaics, 9(3), 715-721.
13. Ponniran, A., Hashim, A., & Joret, A. (2011). A design of low power single axis solar tracking system regardless of motor speed. International Journal of Integrated Engineering, 3(2).
14. Ponniran, A., Hashim, A., & Munir, H. A. (2011, June). A design of single axis sun tracking system. In 2011 5th International Power Engineering and Optimization Conference (pp. 107-110). IEEE.
15. Poulek, V., & Libra, M. (1998). New solar tracker. Solar energy materials and solar cells, 51(2), 113-120.
16. Rana, S. (2013). A study on automatic dual axis solar tracker system using 555 timer. International Journal of Scientific & Technology Research, 1(4), 77-85.
17. Sallaberry, F., Pujol-Nadal, R., Larcher, M., & Rittmann-Frank, M. H. (2015). Direct tracking error characterization on a single-axis solar tracker. Energy Conversion and Management, 105, 1281-1290.
18. Tharamuttam, J. K., & Ng, A. K. (2017). Design and development of an automatic solar tracker. Energy Procedia, 143, 629-634.
19. Zhu, Y., Liu, J., & Yang, X. (2020). Design and performance analysis of a solar tracking system with a novel single-axis tracking structure to maximize energy collection. Applied Energy, 264, 114647.

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