Solar Measurement using Arduino

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Abstract- *This paper presents the design and development of a low-power, cost-effective dual-axis solar tracker (DAST) to enhance photovoltaic (PV) energy generation. The system utilizes LDR sensors to detect solar irradiance and a microcontroller-based control unit to orient the PV panel toward maximum sunlight throughout the day. At night, the panel automatically returns to a horizontal position to protect the mechanical structure. A 12V battery charging system is integrated to power the tracker and associated electronics. Experimental analysis shows that the proposed DAST improves energy capture efficiency and reduces the payback period of a PV plant by approximately 8% compared to fixed systems.*

Keywords – *Aurdino UNO, Servo Motor, LED Display, Solar panel, LDR Sensor.*

INTRODUCTION

Over the past few years, there has been a significant global increase in interest in power. In Brazil, the production of electric vitality increased by 38.7% and power utilisation increased by 34% between 2006 and 2015 [1].It is critical to look for sustainable power sources that can meet global power demand given the growing need for energy and the threat of a hazardous atmospheric devastation. According to an analysis conducted by the European Renewable Energy Council (EREC) in collaboration with the non-governmental organization Greenpeace, sustainable energy sources, when paired with sensible and efficient energy use, will be able to supply some of the world's energy needs by 2050. Sun-oriented photovoltaic vitality (PV) has been growing recently among sustainable power sources, especially in Brazil due to sunlight-based radiation and direction impetuses, such as imposing exceptions related to power diIn 2016, Brazil saw a surge of over 7,000 new network associations, with a significant portion coming from private and business clients. This is just the beginning; the investment in solar-powered photovoltaic energy on the Brazilian vitality framework is expected to increase overall in the years to come [1]. However, Brazil is currently far behind the major countries in the photovoltaic vitality creation division, despite the enormous potential and driving force arrangements. The country's introduced limit of 21MW [1] corresponds to only 0.02% of Brazil's vitality framework, while China, the global leader in this regard, has more than 50.8GW. Photovoltaic offices accounted for 242 GW of installed control globally prior to the end of 2015.spersion accounts in a few states.

PV can be a good way to generate energy in areas with difficult access or without power, in addition to being a fantastic alternative option to broaden the Brazilian energy framework.

Therefore, it is interesting to think about ways to increase the photovoltaic modules' vitality generation. The efficiency of photovoltaic frameworks is not fully utilised when they are installed over established constructions. Using a sun-oriented following framework is the greatest way to improve this generation since it ensures the highest possible rate of sunlight-based radiation on the modules, which in turn increases the framework's capacity to create vitality. Recreations through SAM (System Advisor Model) programming, to the city of Santa Maria in South Brazil, demonstrate that is conceivable to increment in around 30% the measure of vitality created amid a year utilizing a business polycrystalline sun powered board, when it is mounted over a DAST. There are a few conceivable

outcomes to the introduction of DAST frameworks exhibited in the writing. Some depend on input signals, as the compelling sunlight based rate estimated by light depended resistors (LDR), or open circle control in light of sun powered maps or heuristic situating calculations [4-6]. This work exhibits the plan and viable execution of a minimal effort DAST framework that works in view of the sun oriented occurrence estimated by an arrangement of LDR

LITERATURE REVIEW

Earlier research shows that fixed solar panels have lower efficiency due to their inability to follow the sun's movement. Solar tracking systems improve energy capture by continuously adjusting the panel orientation toward maximum sunlight. Studies indicate that dual-axis trackers provide higher efficiency than single-axis systems by tracking both horizontal and vertical sun movement. Microcontrollers such as Arduino or NodeMCU with LDR sensors are commonly used for accurate and automatic sun tracking. Literature reports that dual-axis tracking systems can increase power output by about 20–40% compared to fixed solar panels.[1] Earlier research shows that fixed solar panels have low efficiency due to constant sun movement. Dual-axis solar tracking systems significantly improve energy capture, with reported efficiency gains of 35–43%. Most systems use LDR sensors and servo/DC motors for accurate horizontal and vertical tracking. Recent studies also integrate IoT modules like ESP8266 for real-time monitoring and data analysis. These advancements make dual-axis trackers more efficient, reliable, and suitable for smart solar applications.[6]Studies show that fixed solar panels have low efficiency due to constant sun movement. Dual-axis solar tracking systems improve energy output by about 25–35%. Most designs use LDR sensors, servo motors, and microcontrollers like NodeMCU for accurate tracking. Environmental sensors help monitor temperature and humidity effects. Energy storage and automation increase system reliability, while IoT and AI are suggested for future improvements[8]

Studies show that Arduino-based systems are widely used for measuring solar panel parameters. Commonly measured values include temperature, light intensity, voltage, and current. LDR and temperature sensors are used to analyze environmental effects on solar output. Voltage divider and current sensor modules ensure safe and accurate electrical measurements. LCD displays provide real-time monitoring, and portable designs are preferred for field applications.[18]

RESEARCH METHODOLOGY

The procedure of developing a dual axis solar tracker is explained in the first section. The progress of hardware and software will then be thoroughly discussed

2.1. Process of dual axis solar tracker

Through the use of the internet of things, this project has tracked the solar tracker system's performance. This project is split into two sections as well: the first is software development, and the second is hardware development. The system's block diagram is displayed in Figure 1. The sensors first determine the location of the sun and transmit the information to an Arduino. The 180-degree servo motor that holds the photovoltaic to move toward the sun is then controlled by the Arduino after processing the data from the sensor. After that, the photovoltaic system collects solar energy, charges the battery, and transmits the data to the Arduino. Finally, as illustrated in Figure 1, the Arduino will transmit the data collected by the PV to the WIFI module [19] and to the IOT monitoring system for documentation. Data will be updated by the IOT monitoring system every three seconds.
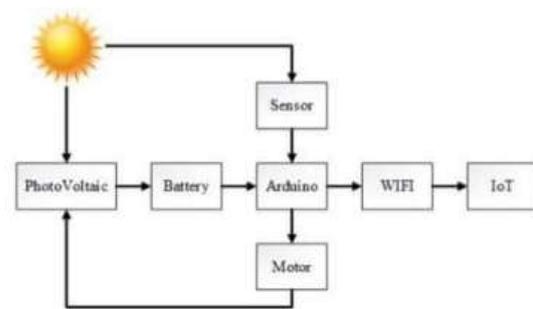

Figure 1. Process of solar tracker system

2.2. Software development

Proteus software has been used for simulation testing of the dual axis solar tracker [21–23]. The project's movement mechanism was tested using simulation circuit design software. The solar tracker's rotation and movement will be tested in this section to determine the system's correct order. The solar tracker's movement flowchart is displayed in Figure 2. beginning with four sensors that determine the sun's location. In order to make a comparison and orient the solar panel directly toward the sun ray, the data received from the sensor will be converted from analogue to digital and read by an Arduino UNO. The system will analyse the data to calculate the sun's direction and move the horizontal and vertical servo motors in accordance with the commands given in the Arduino IDE. Table 1 lists the definitions of the terms used in the flow chart

The circuit for moving the solar tracker is shown in Figure 3. The Arduino UNO and servo motor will switch on when the circuit receives power. The servo motor serves as the hardware component that rotates the solar tracker, while the Arduino serves as the primary CPU. Two 180-degree servo motors are used in this project for both horizontal and vertical motion. The servo motor [24] will be run in accordance with the sun-ray-detecting LDR sensor [25]. There are five requirements for the sensor to cause the servo motor to rotate. First, when sensor LT and RT detected sun radiation more than LD and RD the vertical servo motor will be turn from 0-degree to 120-degree angle. Secondly, when LT and RT less than LD and RD the vertical servo motor will rotates from 0-degree to 15-degree angle. Third, when sensor LT and LD more than sensor RT and RD the horizontal servo motor will be rotate to 65-degree angle. Forth, when sensor LT and LD lest than sensor RT and

RD the horizontal servo motor will be turn 180-degree angle and lastly when all the sensor in equal which mean all the sensor detected sun ray the motor will be stop All this conditions are depending on position of the sun and weather the sensor can detect the sun or not. The system will be loop to get the best position of sun..

Table 1. Table of sensor

Code Name	Function
LT	Left Top
LD	Left Down
RT	Right Top
RD	Right Down

2.3. Hardware development

Sketch Up software has been used to draw the prototype's design [26]. The solar panel is intended to be held and moved in the direction of the sun. Using a motor bracket to support the motor and photovoltaic is the fundamental component of this design. Aside from that, every component is kept in a black project   box.
Figures 4, 5, and 6 show the project design in front, isometric, and top views using Sketch Up. The real prototype developed for this project is shown in Figures 7 and 8.
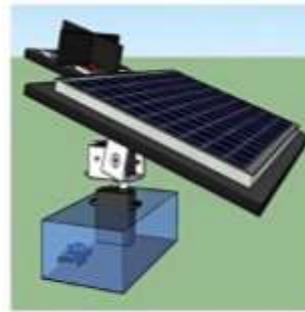

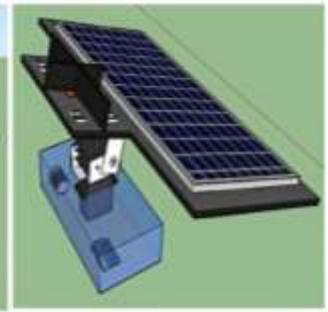Figure 3. Simulation of circuit

Figure 4. Front view   Figure 5. Isometric view

3. Results and Discussion

The results of the experiments that were carried out are covered in this section. The purpose of the studies was to compare the performance of solar panels that were stationary and those that had tracking mechanisms in the direction of the sun. Universiti Malaysia Perlis maincampus, situated at latitude 6.46, longitude 100.35, is the site of the experiments. The trials were conducted on May 29 and May 30, 2021. All information and findings are obtained between 0900 and 1800 hours, when the weather is favourable.

3.1. Comparison results

The comparison findings from the outdoor trials are covered in this section. The time graph shows the total efficiency of the static solar panel and the solar with tracking mechanism, as well as the voltages, currents, power outputs, and solar irradiance. Table 2 provides the recorded and computed data.
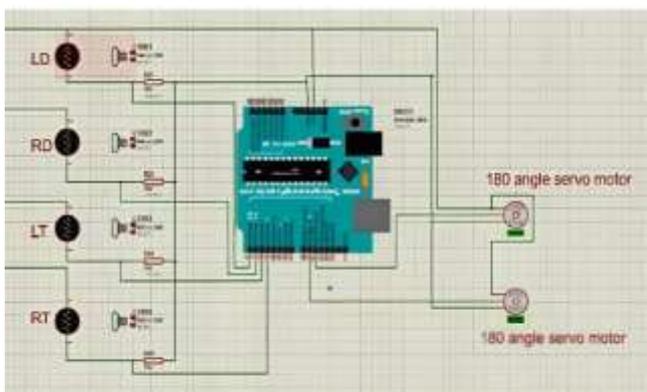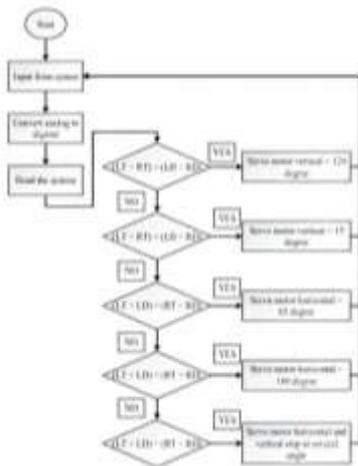
Table 2. Comparison of output values between the static solar panel and solar panel with a tracking mechanism

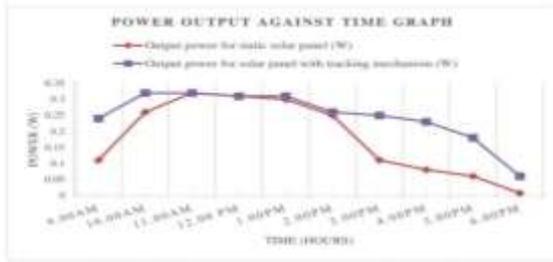| Time (Hours)	Static Solar Panel				Solar Panel with a tracking mechanism			
	Voltage (V)	Current (A)	Power (W)	Solar Irradiance (W/m²)	Voltage (V)	Current (A)	Power (W)	Solar Irradiance (W/m²)
9.00am	4.30	0.025	0.11	29.86	4.80	0.050	0.24	66.67
10.00am	4.90	0.053	0.26	72.14	5.30	0.060	0.32	88.33
11.00am	5.57	0.057	0.32	88.19	5.56	0.058	0.32	89.58
12.00pm	6.17	0.050	0.31	85.69	6.17	0.050	0.31	85.69
1.00pm	6.03	0.049	0.30	82.08	6.03	0.051	0.31	85.43
2.00pm	5.98	0.042	0.25	69.77	5.98	0.043	0.26	71.43
3.00pm	5.29	0.021	0.11	30.86	5.91	0.042	0.25	68.95
4.00pm	4.21	0.019	0.08	22.22	5.36	0.043	0.23	64.02
5.00pm	4.03	0.015	0.06	16.79	4.63	0.039	0.18	50.16
6.00pm	2.14	0.003	0.007	1.78	3.66	0.016	0.06	16.27
	Total Power		1.82		Total Power		2.47	
	Average Power		0.18		Average Power		0.25	

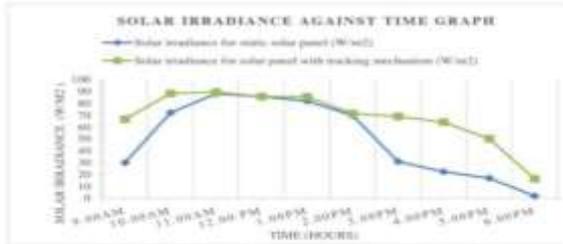**Figure 2.** Power output versus time comparison graph

Figure 3. Solar irradiance versus time comparison graph

3.2. Discussion

Because both solar panels are positioned horizontally, facing vertically upward, and receive the same amount of sunlight, the comparison graphs show that a solar panel with a solar tracking mechanism performs better than a static solar panel while the values from 11:00 am to 2:00 pm are similar.

Weather conditions during data collection are one of the factors that can cause disruptions to the solar panel's performance during an outside experiment. Malaysia experiences a variety of weather conditions, including sunny, overcast, and rainy days. On cloudy days, the solar panel's performance would be impacted since clouds would obscure the sun's beam radiation, making it impossible for the panel to directly receive the Sun's dispersed radiation.

An Arduino-controlled solar tracking prototype was constructed in order to evaluate the performance of solar panels with a tracking mechanism versus static solar panels. The building of the solar tracking structure covered by Sujatha et al. [2] is cited in the hardware modelling of the solar tracking mechanism. The solar parameters were measured in an outside experiment, and the results are verified by contrasting them with the earlier model. Even though the values being compared are different, the comparison graph showed a comparable trend, indicating that the measured value was obtained correctly.

4. Conclusion

This paper describes the construction of an actual solar tracking system prototype utilising an Arduino-based controller. The mechanical construction of the solar tracking structure covered in earlier research is cited in the design modelling. The Arduino board's control system, the light sensor's light detection, the servo motor's rotating mechanism, and the solar panel's primary component make up the prototype. In order to accomplish the goal, an outdoor experiment is carried out to test the solar panels' parameters and compare their performance with that of a tracking mechanism and a static solar panel.

According to the results, using a solar tracking mechanism for energy improved the performance of solar panels by 38.89%.

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