

Solar Powered Robot with Solar Tracker

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Abstract

This research project focuses on assessing the impact of dual-axis solar tracking on battery capacity in three distinct geographical locations. Employing a dual-axis solar tracker to investigate the variations in the amount and duration of energy generated by solar panels, subsequently stored in batteries. The study spans diverse locations to capture the influence of environmental factors on solar energy absorption. Preliminary findings will shed light on the optimal conditions for maximizing solar energy harvesting efficiency. The second phase of the project involves utilizing the stored energy to power a Bluetooth car. By measuring the battery capacity before and after the car's movement over a standardized 6-meter distance, it aims to understand the efficiency of energy transfer from the solar panels to the battery and its application in real-world scenarios. Furthermore, it explores the impact of load on battery performance by introducing a load to the Bluetooth car. The study involves measuring the time taken for the car to cover the same 6-meter distance with the added load and monitoring the corresponding battery capacity changes. This comprehensive investigation allows us to establish a nuanced understanding of the relationship between load and electrical usage in the context of a solar-powered system. The outcomes of this research will contribute valuable insights for the advancement of solar energy applications in various settings, providing a foundation for future innovations in sustainable energy solutions.

1. Introduction

Solar energy stands out as the most promising solution to global energy challenges, with its renewable and clean attributes. However, the effective harnessing of this abundant resource poses a significant challenge [1]. Solar power's popularity, driven by its environmental friendliness and widespread accessibility, has recently extended to the realm of robotics, where solar-powered robots have garnered attention for their ability to operate independently in remote areas without reliance on traditional power sources.

In optimizing solar panel efficiency, solar trackers find applications in solar-powered robotics, lighting systems, and water pumps. The solar-powered path follower robot, a key focus of this endeavour, relies on strategically positioned solar panels equipped with photovoltaic cells to convert solar energy into electrical power. By incorporating sensors and control algorithms, the robot navigates along a predefined path, adjusting its movements based on detected markers. This solar-powered robot offers advantages such as reliance on renewable energy, reduced environmental impact, and minimized need for frequent battery replacements. In response to the limitations of conventional energy sources in outdoor robotic systems, the project aims to develop a solar-powered robot with a solar tracker to enhance energy production by 30%. The prototype will undergo

design, construction, and testing phases to evaluate its performance and contribute to the advancement of dependable, affordable, and durable power solutions for outdoor robotic systems. The project's objectives encompass the development of a solar-dependent robot with a solar tracker, designing and constructing the robot chassis and components, and thoroughly evaluating the robot's overall performance.

1.1 Type of Solar Tracker

Solar tracking systems are mainly designed to keep the surface of the PV panel perpendicular to the direction of the solar radiation beam. The solar tracking should be positioned so that it can achieve the optimum angle of incidence; thereby, the electrical energy produced by the PV panel can be maximized. Solar irradiance, solar azimuth angle, elevation angle, inclination angle, declination angle and zenith angle are the important parameters that identify the best position of a solar tracking system. The most important angles in determining the position of the sun are altitude (elevation) and azimuth angle. Moving solar tracking systems can be manually or automatically motioned. Solar tracking systems usually include several considerations, such as one or two motors, different types of optical sensors and independent or auxiliary power supply [2]. The classification of these aspects depends on various parameters including the force driving their moving fixtures and mode operation. Solar trackers can be classified, according to tracking mechanisms, into two main types single-axis and dual-axis.

1.2 Single-Axis Solar Tracker

A single-axis tracker changes its position relative to only one axis. Single axis solar trackers (Fig. 1) are a more cost-effective option than dual axis solar trackers, which track the sun's movement in two axes. However, they are not as efficient as dual axis trackers. The Arduino based variable and compactable system with a single axis solar tracking system. The Arduino gets the data from the two LDR sensors to rotate the solar panel to the lighting place by using servo motor. The battery is used to store the energy from the solar panel and applied to the Arduino.

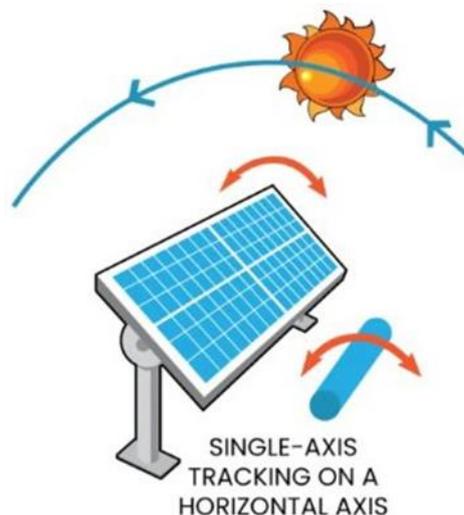


Fig.1 Single-Axis Solar Tracker

1.3 Dual-Axis Solar Tracker

This project focused on the development of a dual-axis solar tracker, which uses Light Dependent Resistor (LDR) sensors as a tracking mechanism to follow the sun's position, called the closed-loop system [3]. This dual-axis solar tracker is more efficient than a single-axis tracker in terms of collecting solar irradiation. This system uses a combination of Arduino, resistors, capacitors, diodes and transistors to form a complete circuit. The output voltage from the circuit will supply power to the circuit that controls the motor movements and direction change based on which sensor receives a higher amount of solar irradiance and align the solar panel perpendicularly to the sunrays. In this work, the Arduino UNO programming will control the rotation of servo motor using a closed-loop tracking system that depends on the voltage differences between the LDR sensor based on the intensity of the solar irradiance.

1.4 Combination of solar-powered robots with a solar tracker system

Solar panel power production may be increased with the use of sun trackers, which have shown to be an extremely effective method. These gadgets can adjust the panel's angle for optimal daylight exposure by detecting the sun's position throughout the day. In recent years, solar trackers have become more and more popular since they provide a workable alternative for reducing power costs and enhancing sustainability. Solar trackers are likely to become even more environmentally friendly and economically effective in the future because to continued technological developments and design improvements. Overall, using solar trackers marks a significant advancement in pursuing renewable energy and a more environmentally friendly future.

1.5 Solar Tracker Scenario in Malaysia

In Malaysia, solar trackers are becoming more and more popular due to its ability to generate more energy than conventional solar panels. Solar trackers are devices that monitor the movement of the sun throughout the day, making the solar panels vertical to maximize the sunlight. Solar trackers are particularly effective in producing solar electricity in Malaysia, where the sun's light is abundant. The Malaysian government's push towards renewable energy sources, including solar power, has provided incentives for the adoption of solar trackers. The existing literature on Zulkafli et al. (2018) is extensive and focuses particularly on the solar trackers that have two axes of rotation, which enable them to rotate along the west-east and north-south axes. Meanwhile, the fixed solar tracker panel was located at the optimum tilt angle for the location of Perlis, which is 6.840° . The testing is to observe the differential power output for both fixed and dual-axis solar tracking systems in real field conditions. The results indicate the efficiency and performance of the trackers during a sunny day.

2. Methodology

Fig. 2 shows the flow of the project. The solar tracking system outlined in this project represents an innovative approach to optimizing solar energy capture and utilization. The solar tracking system LDR detects sunlight, initiating a sequence of steps for optimized energy capture. LDR assess sunlight intensity and direction, enabling the calculation of the ideal position for the solar panel.

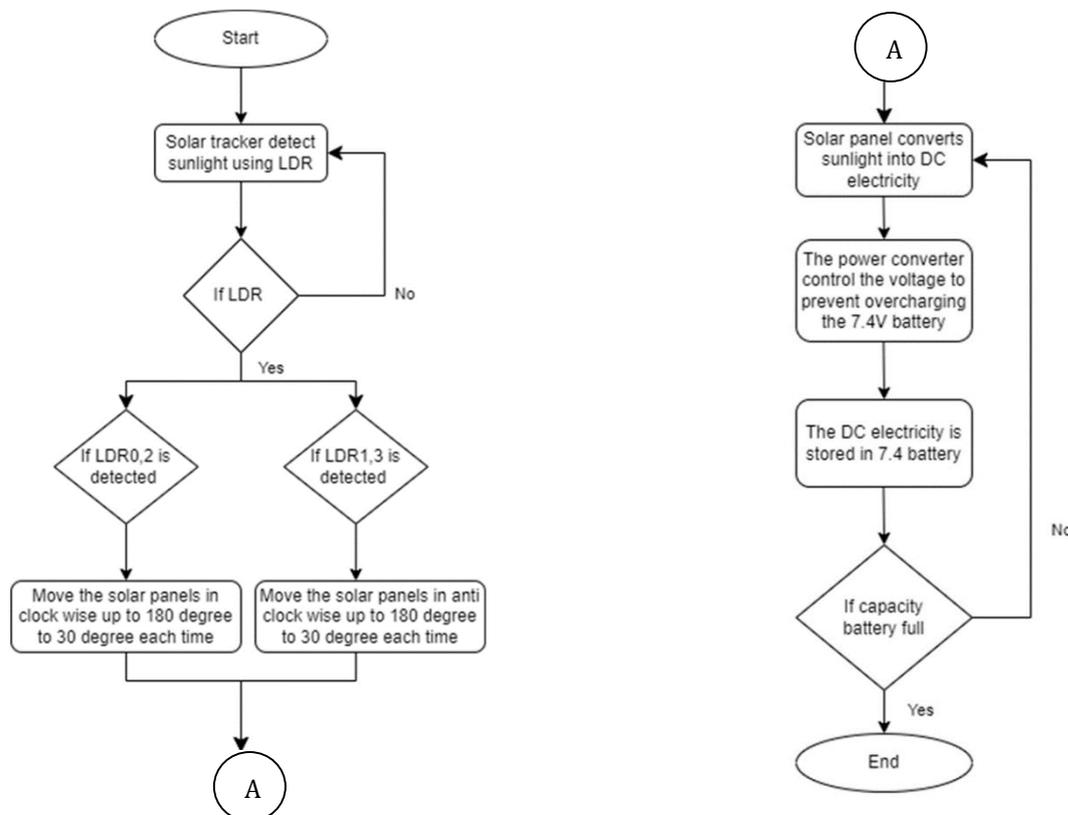


Fig. 2 Solar panel control architecture

A servo motor adjusts the panel's orientation accordingly to directly face the sun, maximizing energy generation. The solar panel then converts sunlight into DC electricity, which undergoes voltage regulation through a power

converter to prevent overcharging. The regulated electricity is stored in a mini generator until reaching full capacity.

2.1 Mini Generator

In the mini generator setup (shown in Fig. 3a), a crucial factor is the DC step-up converter, liable for efficiently growing the voltage from the lithium-ion battery to meet the desired output necessities. This converter ensures that the energy generated by the lithium-ion battery, typically employed for its excessive strength density and rechargeable characteristics, is optimized for the application. Alongside the step-up converter, the 1S Battery Management System (BMS) for lithium-ion batteries is incorporated into the system.

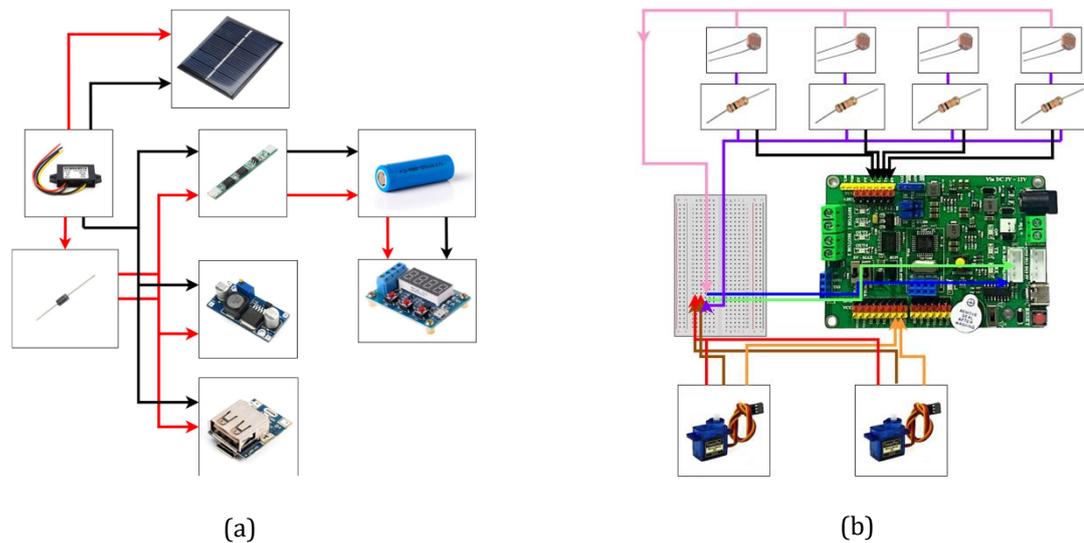


Fig. 3 (a) Mini generator schematic diagram and (b) Dual axis solar tracker schematic diagram

2.2 Dual-axis Solar Tracker

Fig. 3b shows the setup for the dual-axis solar tracker. In this setup, LDRs strategically stationed around the solar panel, acting as the eyes of our solar tracker. As sunlight brightens, these LDRs smartly increase resistance, providing valuable data to the conductor of our solar symphony, the Arduino Uno V2. This compact yet powerful microcontroller processes the LDR signals, calculates the optimal tilt angles for the solar panel, and orchestrates the movements. The servo motors, our muscles for movement, tirelessly adjust the solar panel's tilt in both horizontal and vertical axes. Guided by the instructions from the Arduino Uno V2, these motors ensure the panel is constantly aligned with the sun's path, performing a synchronized dance across the sky.

2.3 Bluetooth Car

The DC motors function the dynamic force driving the task, supplying mechanical movement or propulsion. With the Durian Uno (an Arduino Uno variant), the challenge gains an effective brain to govern and orchestrate the actions of the DC automobiles. The Durian Uno, ready with a microcontroller, helps with seamless programming and communication among the special additives, supplying a consumer-friendly interface for personalisation. Adding the HC-05 Bluetooth Module to the mix introduces a layer of wi-fi control and connectivity to the venture. This module acts as the bridge between the project and outside gadgets, allowing wireless command and monitoring of the DC motors and the usage of a telephone or other Bluetooth-enabled gadgets. Fig. 4 shows the Bluetooth car schematic diagram.

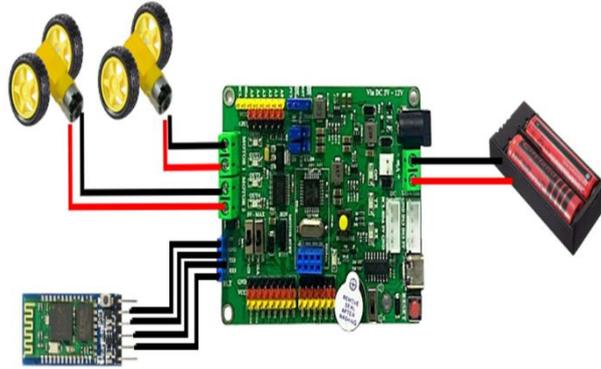


Fig. 4 Bluetooth car schematic diagram

2.4 Dual Solar Trackers Powering Mini Generators for Remote Car

The idea of Dual Solar Trackers Powering Mini Generators for Remote Cars (as in Fig. 5) embodies a sustainable and innovative method of harnessing solar power for powering remote-managed vehicles. In this system, dual-axis solar trackers are strategically employed to maximise sunlight absorption with the aid of adjusting the orientation of solar panels. These trackers continuously follow the sun's course, making sure ideal energy is captured throughout the day. The harvested solar electricity is then directed to power mini turbines, compact devices designed to successfully convert sunlight into electric power. This synergy among twin sun trackers and mini-mills creates a dynamic, self-sustaining strength ecosystem, imparting a renewable energy supply for far-off-managed automobiles.



Fig. 5 Dual Solar Trackers Powering Mini Generators for Remote Car

3. Results and Discussion

The idea of Dual Solar Trackers Powering Mini Generators for Remote Car embodies a sustainable and innovative method to harnessing solar power for powering remote-managed vehicles. In this system, dual-axis solar trackers are strategically employed to maximize sunlight absorption with the aid of adjusting the orientation of solar panels. These trackers continuously follow the sun's course, making sure ideal energy is captured throughout the day. The harvested solar electricity is then directed to power mini turbines, compact devices designed to successfully convert sunlight into electric power. This synergy among twin sun trackers and mini mills creates a dynamic, self-sustaining strength ecosystem, imparting a renewable energy supply for far off-managed automobiles.

Choosing the optimal location for your solar tracker in an open area is crucial for maximizing its energy production and ensuring its long-term stability. The ideal location for a solar tracker hinges on several factors, including its proximity to the equator, climate, terrain, shading, and wind conditions. To optimize efficiency, choose a site with clear skies, minimal cloud cover, flat and unobstructed ground, full sun exposure throughout the day, and wind protection. Consider utilizing solar mapping tools and consulting a solar installer for further

guidance. Options for placement include rooftops, ground mounts, poles, and even water bodies through floating installations. Weighing your individual needs and circumstances will lead you to the most suitable location for your solar tracker.

Table 1 Data for location 1,2 and 3

Location	Date	Capacity Battery (V)		Amount of Electrical Power (V)	Time		Total Time (Hours)	Weather
		Before	After		Start	End		
Location 1	12/11/2023	0.2	0.42	0.22	10:15	15:15	05:00	Hot
	13/11/2023	0.42	0.57	0.15	12:15	16:00	03:45	Hot
	14/11/2023	0.57	0.63	0.06	10:36	16:15	05:39	Cloudy
	15/11/2023	0.63	0.71	0.08	11:11	15:03	03:52	Cloudy
	16/11/2023	0.71	0.8	0.09	12:02	14:45	02:43	Cloudy
Location 2	17/11/2023	0.8	0.94	0.14	10:25	14:41	04:16	Cloudy
	18/11/2023	0.94	1.2	0.26	10:51	16:01	05:10	Hot
	19/11/2023	1.2	1.3	0.1	10:42	16:23	05:41	Cloudy
	20/11/2023	1.3	1.6	0.3	10:13	15:43	05:30	Hot
	21/11/2023	1.6	1.8	0.2	11:41	16:33	04:52	Cloudy
Location 3	22/11/2023	1.8	2	0.2	10:07	14:13	04:06	Cloudy
	23/11/2023	2	2.3	0.3	10:56	14:56	04:00	Cloudy
	24/11/2023	2.3	2.6	0.3	10:39	15:17	04:38	Cloudy
	25/11/2023	2.6	2.9	0.3	10:51	14:32	03:41	Cloudy
	26/11/2023	2.9	3.3	0.4	10:24	15:43	05:19	Cloudy

3.1 Battery Usage

As the solar tracker charges the mini generator, the electric energy generated becomes a versatile resource. This sustainable power is utilized to control a remote car equipped with data-gathering capabilities. The car's movements and operations, powered by solar-derived electricity, allow for real-time data collection. Sensors on the remote car measure various parameters, such as speed, distance travelled, and environmental conditions.

Additionally, a sophisticated battery monitoring system onboard gathers insights into the battery capacity, providing valuable data on the efficiency and sustainability of the entire solar-powered system. This interconnected setup exemplifies green energy utilization and emphasizes the solar tracker's role as a pivotal component in a broader network of renewable energy applications. The distance will be in 6 meter and the amount of electrical power will be measured.

Table 2 *Battery Usage*

Date	Capacity Battery (V)		Amount of Electrical Power (V)	Time		Total Time (Minute)
	Before	After		Start	End	
7/12/2023	4.2	4.1	0.1	14:13	14:16	03:00
7/12/2023	4.1	3.9	0.2	14:16	14:20	04:00
7/12/2023	3.9	3.8	0.1	14:20	14:23	03:00
7/12/2023	3.8	3.6	0.2	14:23	14:26	03:00
7/12/2023	3.6	3.5	0.1	14:26	14:29	03:00
7/12/2023	3.5	3.3	0.2	14:29	14:32	03:00
7/12/2023	3.3	3.1	0.2	14:32	14:36	04:00
7/12/2023	3.1	2.9	0.2	14:36	14:39	03:00
7/12/2023	2.9	2.8	0.1	14:39	14:44	05:00
7/12/2023	2.8	2.6	0.2	14:44	14:49	05:00

3.2 Weight measuring

A comprehensive data collection process was initiated to understand the electric usage patterns of remote control, each weighing 0.1kg, 0.2kg, 0.3kg, 0.4kg, and 0.5kg. The objective is to measure the corresponding electric consumption from the device's battery across these different weight variations.

Table 3 *Data for usage battery*

Date	Weight (Kg)	Capacity Battery (V)		Amount of Electrical Power (V)	Time		Total Time (Minute)
		Before	After		Start	End	
30/12/2023	0.1	3.93	3.89	0.04	10:56	10:58	02:00
30/12/2023	0.2	3.89	3.85	0.04	11:14	11:16	02:00
30/12/2023	0.3	3.85	3.79	0.06	11:25	11:27	02:00
30/12/2023	0.4	3.79	3.62	0.17	11:34	11:37	03:00
30/12/2023	0.5	3.62	3.57	0.05	11:41	11:43	02:00

The weight-sensitive remote-control system was meticulously configured to record data at each weight increment. The electric use corresponding to each weight category was carefully documented through a series of controlled experiments. This dataset will serve as a valuable resource for analysing how the weight variations of the remote-control correlate with the amount of electric energy consumed. The findings from this study aim to

provide insights into optimizing battery efficiency and enhancing the overall performance of weight-sensitive remote-control devices.

4. Conclusion

In conclusion, this research project systematically examined the impact of dual-axis solar tracking on battery capacity across diverse geographical locations. Utilizing a dual-axis solar tracker, the study scrutinized variations in energy generation by solar panels and subsequent storage in batteries. Preliminary findings illuminated optimal conditions for maximizing solar energy harvesting efficiency, highlighting the project's crucial insights into sustainable energy utilization. The project's second phase seamlessly transitioned from theory to practical application by employing the stored energy to power a Bluetooth car. Measurements of battery capacity before and after the car's movement over a standardized 6-meter distance provided essential data, enabling a real-world assessment of the efficiency of energy transfer from solar panels to batteries. Additionally, the exploration of the impact of load on battery performance furnished nuanced insights into the intricate relationship between load and electrical usage within the solar-powered system. These findings collectively contribute valuable knowledge to the field of solar energy applications, paving the way for future innovations and sustainable energy solutions in diverse settings.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

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