PORTABLE SOLAR CHARGER: OPTIMIZING MOBILE CHARGING WITH DYNAMIC SOLAR TRACKING TECHNOLOGY

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Abstract: As the world's dependence on portable electronic devices continues to grow, the demand for effective and sustainable charging solutions is increasing. However, conventional stationary solar panels are limited in flexibility and energy production due to shifting sun angles. This paper proposes a unique solution for a mobile charger based on a single-axis solar tracker. The goal is to create a dynamic alignment system that adjusts the position of the solar panel in response to the sun's movement. We present a comprehensive approach to achieve this objective. We developed a prototype along with a software program for the microcontroller unit (ATmega328P) of the solar tracker. The microcontroller manages the servo motor that rotates the solar panel based on inputs from two LDR sensors positioned next to the panel. By incorporating this cutting-edge technology, we aim to improve the efficiency and availability of renewable energy for charging mobile devices. This study leverages the advantages of a dynamic solar tracker while addressing the limitations of conventional stationary solar panels. The proposed solution not only offers a viable path to addressing the energy crisis but also contributes to the advancement of environmentally friendly charging options. Future research avenues include exploring additional functionalities and enhancements to increase system efficiency, as well as investigating potential applications in various fields.

Keywords: solar tracking, solar phone charger, single axis, photovoltaic, Arduino

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INTRODUCTION

The increasing demand for mobile devices and their ubiquitous use has brought about a corresponding rise in the need for reliable and sustainable mobile charging solutions (Jena and Mohanty, 2015). Traditional mobile charging methods relying on grid electricity or disposable batteries often fall short regarding environmental impact, cost-effectiveness, and accessibility, especially in remote or off-grid areas. Consequently, harnessing renewable energy sources such as solar power has emerged as a promising alternative. Solar energy, abundant and freely available, presents an ideal solution for mobile charging (Anusha and Reddy, 2013). However, conventional stationary solar panels face several limitations (Kumar and Mehta, 2021). They are fixed in one position and cannot adapt to the sun's changing position throughout the day. This results in suboptimal energy generation and reduced charging efficiency (Stamatescu et al, 2018). Additionally, stationary panels are often bulky, making them less portable and limiting their deployment in various contexts (Lashkari et al, 2020). To address these challenges, we propose the utilisation of a single-axis solar tracker-based mobile charger. This innovative technology aims to maximise solar energy capture by dynamically aligning the solar panel with the sun's position throughout the day (Yadav et al, 2021). By incorporating a mechanism that enables the solar panel to follow the sun's movement along a single axis, we can significantly enhance energy generation and improve charging efficiency.

This research paper aims to comprehensively analyse a single-axis solar tracker-based mobile charger's design, performance, and potential impact. We investigate the technical aspects of the system, including the tracking mechanism, control algorithms, and power management. Furthermore, we explore the economic feasibility, environmental benefits, and practical implications of adopting this technology in real-world scenarios. By evaluating the effectiveness of a single-axis solar tracker-based mobile charger, we hope to encourage the broader adoption of sustainable practices and facilitate the transition towards a cleaner and more efficient energy future.

METHODOLOGY

Initially, we studied the existing solar systems and mobile charging mechanisms in the literature. After that, we explored different techniques to develop the design in literature. Further, we conducted face-to-face structured interviews with selected ten SMEs in the industry. After analysing the data from the literature review and the SMEs' suggestions, we decided on the design technique. As illustrated in Figure 1, the dynamic solar charger design consists of three parts: inputs, outputs, and the system. The Solar Tracker Charging System (ref. Figure 2) consists of two sections, i.e., Section A: high-quality solar tracker and Section B: charger circuit. Further, it consists of the hardware section and software section.

The Section A:

A high-quality solar tracker comprises two Light Dependent Resistors (LDRs), a solar panel, a servo motor, and an ATmega328P microcontroller (Ghosh and Sengupta, 2016). Two light-dependent resistors are positioned on the solar panel's edges, as shown in Figure 2. When light falls on light-dependent resistors, they

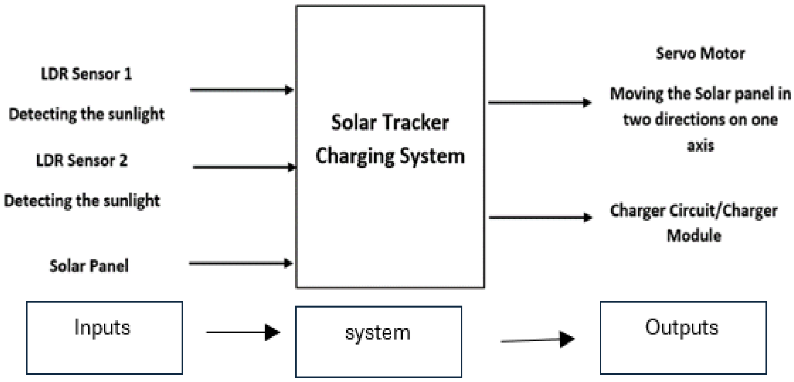

Fig. 1. The design for the dynamic solar charger consists of three parts. i.e., inputs, outputs, and system.

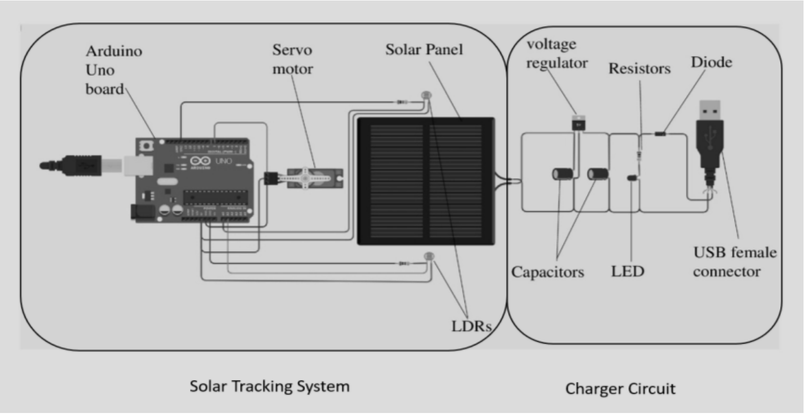

Fig. 2. Solar Tracker Charging System consists of two sections. Section A: Solar Tracking System. Section B: Charger Circuit.

produce low resistance. The panel is rotated in the sun's direction by a servo motor connected to it. The panel is set up to rotate toward the LDR with the highest intensity so that the light from two LDRs is compared, and the panel is redirected to the lowest resistance. The panel is rotated at a specific angle by the servo motor. The panel progressively slides to the right when the intensity of the light falls to the right. LDR is higher, and to the left, when the intensity of the light falling on the left LDR is higher. The sun is ahead at midday, and the light intensity on both panels is the same. In such circumstances, the panel remains stationary and does not rotate. Depending on the timing of the logic signals, the servo motor can rotate either clockwise or anticlockwise. The difference in light intensity of the LDR sensors determines how the logic signals are sequenced. The LDR controls the solar tracking system's essential operation. Two LDRs are attached to the Arduino analogue pins A0 to A1, which serve as the system's input. The LDR's analogue value will be converted into a digital value using the integrated analogue-to-digital converter. LDR analogue values serve as the inputs, Arduino as the controller, and the servo motor as the output. We consider LDR1 and LDR2 to be a pair. If one LDR receives more light than the other, a difference in node voltages is delivered to the appropriate Arduino channel, and the relevant action is taken. The servo motor will move the solar panel to the predetermined location of the high-intensity LDR.

The Section B:

Another essential part of the design is the charger circuit. That should be connected separately to the solar panel. The main components of that charger circuit are the voltage regulator and the female USB connector. The voltage regulator regulates the voltage supplied to the phone or power bank. Otherwise, the device would be damaged. Then, we can get our power output by connecting the mobile phone or power bank to the USB connector.

RESULTS AND DISCUSSION

A current supply of 1A to 2A is typically required to charge a mobile phone efficiently. In this setup, we utilised a solar panel with an output voltage of 6 volts and a power output of 10 watts.

According to the Electrical Power Formula,

$$P = VI \qquad (1)$$

$$I = P/V = 10/6$$

$$I = 1.66\ \text{A}$$

Thus, using a 6V, 10W solar panel, we successfully achieved the required electric current to charge the mobile phone. The solar irradiance at the location where the system was mounted influenced the charging time. We tested eleven scenarios using three mobile phones (i.e., Samsung Galaxy A70, Apple iPhone 8, and Oppo Reno 8 Pro). As illustrated in Tables I, II, and II, we considered the charge range from 0% to

30%, 30% to 70%, and 70% to 100%, respectively. Likewise, we tested eleven scenarios for three different mobile phones. For each test, we observed an increase in the charging percentage for each mobile phone. As illustrated in Table I, for the charge range 0% - 30%, we observed a 2% to 4% charge percentage change after 5 minutes of charging. Then, after 10 minutes, it increased to 3% - 4%. As illustrated in Table II, for the charge range of 30% - 70%, we observed a 1% - 2% charge percentage change after 5 minutes and a 2% - 4 % change after 10 minutes of charging. However, as illustrated in Table III, for the charge range 70% - 100%, only a 1% - 2% charge range was observed after 5 minutes and after 10 minutes. Therefore, at this stage, the percentage difference did not increase with time, as shown in Table I and Table II. Further, we conducted two more tests to identify the total charging time of the mobile time in Shiny Day and Cloudy Day. Such as Test A, When the charge range was 5%, and it was a sunny day, and Test B, When the charge range was 5%, and it was a cloudy day. As illustrated in TABLE IV, we can conclude that the charging speed on a Shiny day is higher than on a Cloudy day. Also, the charging speed increases during the peak hours of the day (12.00 pm to 3.00 am) for two different types of days.

Hardware implementation of the Dynamic Solar Charger

The model developed for the Dynamic Solar Charger is illustrated in Figure 3. This single-axis solar tracker-based mobile phone charger system consisted of two separate parts: a single-axis solar tracker and mobile phone charging circuit.

TABLE I. CHARGE RANGE OF THE MOBILE PHONES ARE FROM 0% - 30%.

Mobile Phone	**Charge Percentage**		
	Before Charging	***After 5 Minutes***	***After 10 Minutes***
Samsung Galaxy A70	25%	29%	33%
Apple iPhone 8	19%	21%	24%
Oppo Reno 8 Pro	22%	25%	28%

TABLE II. CHARGE RANGE OF THE MOBILE PHONES ARE FROM 30% - 70%.

Mobile Phone	**Charge Percentage**		
	Before Charging	***After 5 Minutes***	***After 10 Minutes***
Samsung Galaxy A70	35%	37%	41%
Apple iPhone 8	59%	60%	62%
Oppo Reno 8 Pro	41%	43%	45%

Single-axis solar tracker circuit:

The solar panel face always faces the sun, owing to the single-axis solar tracking mechanism, which rotates east to west. Two LDRs, a servo motor, and an Arduino interface are used. Both LDRs are positioned on the east and west sides of the panel, respectively. LDRs serve as input by measuring the sun's intensity. The servo motor will rotate the panel towards the west as the intensity falling on the west side LDR increases more than on the east side LDR. LDRs' outputs serve as the Arduino board's input. Through the prewritten Arduino program, the Arduino processes these inputs and produces an output for the servo motor. The Arduino board's signals direct the motor to move the panel in that direction, where solar radiation is maximum. Driver stages or subsystems were used to accomplish this. (i.e., the Input stage is considered as converting incident light to voltage, the Control stage is regarded as controlling actuation and decision-making, and the Driver stage (with the servo motor) is regarded as the actual movement of the panel.)

Mobile phone charging circuit:

Solar tracker circuit follows the sun throughout the day to maximise energy output. Therefore, this maximises the energy output used to charge a mobile phone or power bank. That process is done by this charging circuit part.

TABLE III. CHARGE RANGE OF THE MOBILE PHONES ARE FROM 70% - 100%.

Mobile Phone	**Charge Percentage**		
	Before Charging	***After 5 Minutes***	***After 10 Minutes***
Samsung Galaxy A70	85%	88%	90%
Apple iPhone 8	72%	74%	76%
Oppo Reno 8 Pro	92%	93%	94%

TABLE IV. FULLY CHARGING TIME OF A MOBILE

Day type	***Time duration***	
Shiny day (Test A)	6.00AM to 9.00AM	4 Hours
	9.00 AM to 12.00 PM	3 Hours 30 Minutes
	12.00 PM to 3.00 PM	3 Hours
	3.00 PM to 6.00 PM	3 Hours 45 Minutes
Cloudy day (Test B)	6.00AM to 9.00AM	6 Hours
	9.00 AM to 12.00 PM	5 Hours 15 Minutes
	12.00 PM to 3.00 PM	5 Hours
	3.00 PM to 6.00 PM	6 Hours 30 Minutes

A simple and hand-efficient solar tracker-based mobile charger is implemented, and it helps consumers charge their phones in public places when they are away from their homes and offices.

CONCLUSIONS/RECOMMENDATIONS

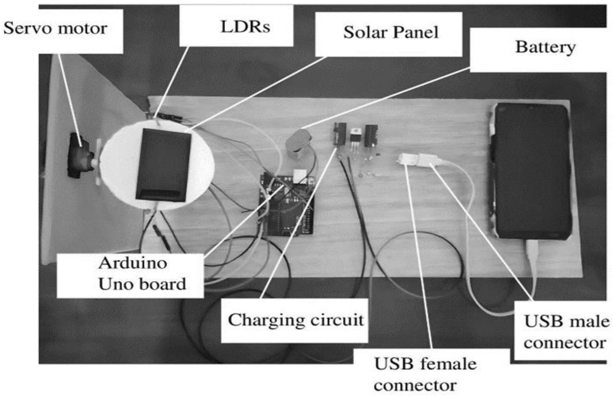

Figure 3: Hardware implementation of the Dynamic Solar Charge – The sample model

A single-axis solar tracker tracks solar radiation more than the fixed solar panel. An annual increase in electricity output using a solar tracker can typically reach 20%.

Because the solar panel will face the sun perpendicularly to absorb more solar energy, solar tracking systems produce more during the daytime, while fixed solar panel installations produce the least. The developed Dynamic Solar Charger is perfect for usage in rural areas and places where the sun shines due to its compactness, affordability, and reliability. Using different solar panels, more effective sensors, and charge controller architecture, this system can power the entire house. Energy production is increasing using single-axis tracker technology, promoting sustainable development using renewable energy. The idea of a single-axis solar tracker can be expanded into a fully functional dual-axis solar tracker.

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