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Development of Solar Tracking on Floating Surface

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***Abstract*—** The increasing global demand for electricity, coupled with the rapid depletion of fossil fuels and growing environmental concerns, has prompted the widespread deployment of solar photovoltaic (PV) plants. However, traditional land-based installations face challenges due to limited land availability, making it essential to explore alternative locations. Installing solar PV systems on water bodies such as oceans, lakes, reservoirs, and canals presents an attractive solution to conserve valuable land and water resources. Floating solar photovoltaic panels offer several advantages over land-based installations. They experience fewer obstructions to sunlight, resulting in higher energy efficiency and power generation. Additionally, the cooler temperature beneath the panels contributes to increased power generation efficiency. Moreover, these installations benefit the aquatic environment by reducing water evaporation, controlling algae growth, and potentially enhancing water quality.

Keywords— Sun Tracking, LDR Sensor, Arduino, Water Floater, Battery, DC Motor, Land conservation, Renewable energy etc.

I. Introduction

Over the years, solar energy has proven to be beneficial for humanity. It is widely acknowledged that solar energy is the most abundant source of energy on Earth, although it alone may not solve the current energy crisis. The radiant light and heat from the sun have been harnessed by humans since ancient times, utilizing various evolving technologies. The decreasing cost of solar panels has encouraged their use across various sectors, making solar power the future of renewable energy generation.

However, traditional rooftop or ground-mounted solar panels require significant space and can be challenging to install, maintain, and clean regularly. To address these limitations, we propose a new type of solar panel that can be mounted on water bodies such as lakes or ponds, thereby conserving land space. Additionally, we introduce an innovative solar tracker and panel movement system utilizing an Arduino UNO microcontroller and LDR sensor to adjust the position of the solar panels according to the sun's position, thereby maximizing power generation.

Some of the benefits of a floating solar panel system include:

- Minimizing land usage as panels float on water.
- Continuous operation as they can float on water 24/7.
- Automatic sun tracking throughout the day using an Arduino UNO microcontroller.
- Reducing water evaporation by covering water bodies and keeping them cool
- Utilizing water to prevent solar panels from overheating.
- Simplified cleaning of solar panels using water from the lake or pond.

II. Problem Identification

The objective is to design a functional solar tracking system capable of tracking the sun's movement using a light-dependent resistor (LDR) as a sensor to detect sunlight intensity. The solar tracking system utilizes a platform as its base, which is controlled by a DC motor to adjust its position towards the sunlight for optimal exposure. Programming for the solar tracking system is implemented using a microcontroller, with Arduino UNO serving as the primary controller. Upon completion of hardware setup and programming, the solar tracking system is operational to track the sun's movement based on the direction of sunlight.

In this setup, the movement of the tracking system depends on the reading obtained from the LDR. Ultimately, the solar tracking system aims to enhance the efficiency of solar panels by ensuring they remain perpendicular to the sun's position. This system will operate on a floating platform to minimize land usage.

Fig.1 Floating Solar panel.

III. Objectives

The main objectives of the study are outlined below:

- Designing a system capable of automatically adjusting the position of solar panels based on the sun's position.
- Developing a cost-effective solar tracker alternative to commercially available options.
- Utilizing the generated electric energy for AC loads using Maximum Power Point Tracking (MPPT) and an inverter module.
- Maximizing solar energy utilization through the implementation of an MPPT Controller.
- Implementing automatic solar panel tracking from East to West and North to South to optimize light intensity.
- Designing the system to float easily on the surface of water for enhanced flexibility and applicability.

IV. Literature Survey

The growing demand for energy has propelled the popularity of renewable energy sources and their associated technologies for electricity generation. Among these sources, solar energy stands out as the most favored due to its cleanliness and abundance compared to others.

D Venkatakrishna, E Siva Sai, K Sree Hari, The utilization of solar energy for generating electricity became achievable following the discovery of the photoelectric effect and the subsequent advancement of solar cell technology. Solar cells, composed of semiconductor materials, convert visible light into direct current by dislodging electrons from their atoms upon exposure to sunlight, facilitating their movement through the material. Solar arrays, comprising interconnected solar cells, generate direct current voltage suitable for powering various loads, and their usage is on the rise due to improving efficiencies. Particularly popular in remote regions lacking grid connectivity, solar arrays offer a viable solution for electricity generation. Moreover, the declining cost of solar cells over time renders solar energy conversion increasingly economically viable. Therefore, there is a growing preference for energy conversion units that are uncomplicated, dependable, cost-effective, and efficient in harvesting solar energy.

Md. Tanvir Arafat Khan, S.M. Shahrear Tanzil, Rifat Rahman, S M Shafiul Alam, Solar panels are commonly employed to harness solar radiation for electricity generation. Comprising solar cells grouped into modules typically containing around 40 cells each, solar panels are integral to solar energy systems. The most efficient solar panels are often crafted from materials like amorphous silicon or non-silicon alternatives such as cadmium telluride. In larger installations, solar panels are arranged in arrays or arrays of mirrors, often positioned at specific tilt angles to optimize power generation. However, such setups may not always be maximally efficient and can incur substantial costs, prompting the exploration of solar tracking devices. A solar tracker is a mechanism designed to align a payload with the direction of the sun, ensuring continuous exposure to sunlight regardless of the time of day or the panel's location.

K.H. Hussein, I Muta, T Hoshino, M Osakada, Sun-synchronous navigation involves maneuvering the solar-powered rover (robot) to continuously orient its solar panel towards the sun, ensuring optimal battery charging for extended operational hours. This unique solar tracking system utilizes the sun as its reference point instead of Earth. Equipped with active sensors, the system dynamically adjusts the panel's position to maximize sunlight exposure. Light-dependent resistors detect changes in the sun's position, providing input to the control circuit, which commands the motor to adjust the panel accordingly. This system can generate an additional 25% to 30% energy with minimal power consumption. The paper details the design and implementation of a fuzzy logic computer-controlled sun tracking system aimed at boosting the power output of photovoltaic solar panels. The tracking system employs two permanent magnet DC motors to enable motion in two axes for precise alignment.

K P J Pradeep, K Sai Prasad Reddy, C Chandra Mouli, K Nagabhushan Raju, the project presents a microcontroller-based approach for an automatic solar tracker design, utilizing light-dependent resistors as sensors. This solar tracking system optimizes solar cell efficiency by aligning a solar panel with the highest light intensity. Various types of motors, including DC motors, stepper motors, and servo motors, along with real-time actuators, are explored for controlling the moving components of the solar tracker. The system is devised to ensure that the solar cell array remains parallel to the sun's rays throughout the day. The objective of this endeavor is to develop and deploy a prototype of a two-axis solar tracking system driven by a microcontroller. Additionally, a parabolic reflector or dish, constructed around a dual-feed diameter, is employed to concentrate solar energy onto a small area, achieving extremely high temperatures.

Naveen Kumar Sharma, Prashant Kumar Tiwari, Yog Raj Sood, Temperature probes are utilized to measure the temperature at the focal point of the parabolic reflector. This automated tracking system is driven by two 12V, 6W DC gear box motors. Five light sensors (LDR) are employed for sun tracking and to initiate operation based on day/night conditions. The paper adopts PWM DC motor controllers, known for their ability to achieve precise, reliable, and stable motor speed control, a feat challenging to achieve with traditional analog controllers. The project focuses on designing and controlling a dual-axis orientation system for photovoltaic solar panels. The orientation system's calculations rely on astronomical data and are assumed to be applicable to any region with minor adjustments. It is engineered to manage the Altitude angle in the vertical plane and the Azimuth angle in the horizontal plane of the photovoltaic panel workspace. This system is anticipated to enhance energy savings by over 40% by maintaining the panel's orientation perpendicular to the sun's rays.

David Barlev, Ruxandra Vidu,
In the prior solutions, the tracking direction for each axis is managed through a Sun sensor employing a pair of phototransistors. A single matrix Sun sensor (MSS) governs both axes of the tracking system, drawing inspiration from antique solar clocks. The MSS consists of 8 photo resistors arranged within a cylinder. An electronic circuit distinguishes between shaded and illuminated photo resistor cells, generating corresponding output voltage signals. These signals are then transmitted to the DC motors, which adjust the array's position towards the sun. To enhance solar tracking precision, the author proposes a fusion of program control and sensor control.
Hossein Mousazadeh, Alireza Keyhani , Program control involves utilizing calendar-check tracking along with local longitude, latitude, and time information to compute the solar altitude and azimuth using a single-chip microcomputer (SCM). A servo motor is then employed to adjust the orientation of the solar panel based on these calculations. On the other hand, sensor control entails detecting sunlight using a photoelectric detector, followed by transmitting the modified signal to control a stepper motor to adjust the solar panel's orientation. The paper explores various technological options, their current status, and the opportunities and challenges associated with developing solar thermal power plants in India. The National Solar Mission, a significant initiative of the Government of India and State Governments, aims to promote environmentally sustainable growth while addressing the nation's energy security concerns. Additionally, it represents India's substantial contribution to the global endeavor to tackle the challenges posed by climate change.

V. Proposed System

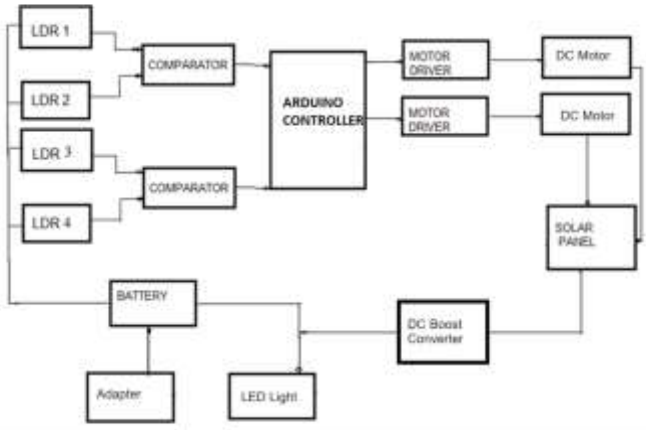

Fig.1. Block Diagram

To facilitate the implementation of this project on a larger scale, it is essential to position the Light Dependent Resistors (LDRs) on a surface with significant curvature. Additionally, the mechanism should ensure that any adjacent pair of LDRs remains active simultaneously. The stepper motor will then follow the bit pattern generated by these active LDR pairs, causing the solar panel, connected to the motor's shaft, to consistently face the sun directly. The combination of four LDRs plays a crucial role in this process. The signals produced by these combinations are transmitted to the Arduino Uno microcontroller, which controls the associated motor. As a result, the solar tracking function is executed, leading to an increase in the efficiency of the solar panel. The generated power from the solar panel is stored in a battery, which is subsequently utilized to operate AC loads with the assistance of an inverter and boost converter.

This type of solar tracking relies on the differential electrical output of the four LDRs, which is fed into the Arduino Uno controller to accurately track the sun's movement.

VI. Result and Discussion

The constructed prototype underwent testing using sunlight. Beginning from the east, where LDR1 was positioned, the comparator's differential output was observed to be positive and above the threshold value. Progressing towards the west, the comparator output gradually decreased until reaching a point where it equaled zero, indicating that the sunlight was perpendicular to the solar panel. Continuing further west, the comparator output began to increase in the negative direction.

In the prototype setup, an 8051 microcontroller was employed, an OPAMP served as the comparator, an L293D was utilized as the DC motor driver, and a 12V DC motor was integrated.

- *Experimental Result*

Table 2: Output Voltage and Current for a Fixed and a Tracking Solar Panel.

Time	Fixed Solar Panel		Tracking Solar Panel	
	Output Voltage (Volts)	Output Current (Ampere)	Output Voltage (Volts)	Output Current (Ampere)
8.00 hrs	10.8	0.21	11.9	0.37
9.00 hrs	10.9	0.45	11.8	0.47
10.00 hrs	11	0.48	12.2	0.51
11.00 hrs	11.4	0.50	12.3	0.53
12.00 hrs	11.8	0.52	12.8	0.56
13.00hrs	12.3	0.51	12.7	0.55
14.00hrs	12.8	0.50	12.6	0.53
15.00 hrs	11.5	0.43	11.9	0.49
16.00hrs	11.4	0.37	11.5	0.42

We know that Output Power of DC equipment is given as:

$$Pout = Voltage * Current$$

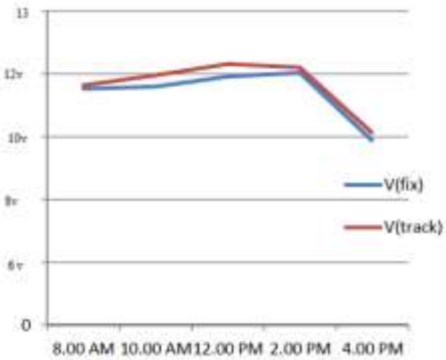

Fig.2. Comparison of Voltage O/P between fixed solar panel and tracking solar panel

The above line graph representation in Fig 2 shows comparison between output voltage of a fixed solar panel (Vfix) and a tracking solar panel (Vtrack), at every 2 hrs interval shown on X-axis and Vout in volts on the Y-Axis.

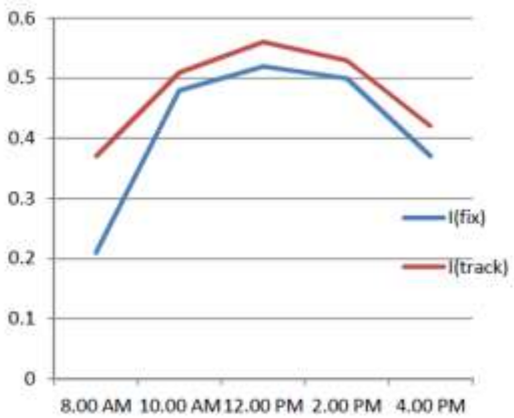

Fig.3. Comparison of Current O/P between fixed solar panel and tracking solar panel

The above line graph representation in Fig 3 shows comparison between output current of a fixed solar panel, I(fix), and a tracking solar panel, I(track), at every 2 hrs interval shown on X-axis and Iout in Amperes on the Y-Axis.

To calculate percentage increase in the power output due to the tracking solar panels with respect to fixed solar panels we have the following formula:

$$\left(\left(\frac{Power\ Output\ of\ Tracking\ Solar\ Panel}{Power\ Output\ of\ Fixed\ Solar\ Panel}\right) - 1\right) * 100$$

As indicated in the table, both single-axis and dual-axis tracking systems possess their own set of advantages and drawbacks. While the dual-axis system offers higher efficiency, the relatively lower cost of designing a single-axis tracker is appealing. Additionally, in regions of the country where there are consistently bright sunny days, the impact on the solar panel output is not significantly affected by having two trackers. Moreover, considering the seasonal variations, it is feasible to manually orient the solar panel due north during summer and south during winter every six months with minimal effort. Therefore, we opted to develop a single-axis tracking system.

Project Image:

Energy serves as the cornerstone of modern society, driving relentless productivity and progress. While the principle of energy conservation implies its ability to be stored, efforts are underway to unravel this concept and make it a tangible reality. Prolonged reliance on conventional energy sources often leads to depletion of Earth's finite resources. The sun, towering above all celestial bodies, has been the primal source of energy since the dawn of time, nurturing life itself. This endeavor seeks to harness such fundamental energy principles, primarily focusing on solar energy storage. However, aside from solar energy, humanity has resorted to burning various materials, resulting in widespread pollution and environmental degradation. Each passing day presents new challenges and endeavors, all propelled by the fundamental force of energy. Regrettably, rampant commercialization has led to a dangerous disregard for the planet's resources, plunging us into a state of global scarcity and environmental crisis.

VII. ADVANTAGES

1) Increases average voltage output of solar panel as compared to the fixed panel.
2) Helps in protecting the solar panel from dirt.
3) Greater amount of electrical output throughout the day.

VIII. Conclusion

As the proposed model represents a miniature version of larger-scale systems, it inherently possesses certain limitations that can be addressed through future developments. Currently, the system incorporates a small cardboard frame and utilizes a 12V solar panel for experimentation, yielding satisfactory results at this scale. However, to optimize performance and conduct a more comprehensive cost-benefit analysis, integration of larger solar panels into the system is warranted. Our research and statistical analysis have demonstrated that a solar tracking system with a single-axis configuration can potentially increase energy output by approximately 20%. To further enhance efficiency, mechanical enhancements could be implemented to enable dual-axis tracking. The designed Arduino solar tracker, utilizing Light Dependent Resistors (LDRs), has shown promise in maximizing power generation by ensuring optimal exposure to solar radiation. This enhancement can result in a significant increase in energy generation, ranging from 10% to 40% depending on the geographic location of the tracking system. Such highly efficient installations are suitable for various project sites, both large and small, provided they are situated in appropriate locations with favorable site conditions. Consequently, this technology is poised to play a pivotal role in the renewable energy industry. The primary objective of this paper is to present novel and advanced proposals aimed at advancing the cause of green energy and facilitating widespread adoption among individuals and communities.

IX. Future Scope

Over the past decade, solar energy has experienced remarkable growth. In 2010, the global market was relatively limited and heavily dependent on government subsidies, particularly in countries like Germany and Italy. Fast forward to the present day, and over 115 gigawatts (GW) of solar capacity will be installed worldwide, surpassing all other forms of electricity generation combined. Moreover, solar energy is becoming increasingly cost-effective, especially in regions with abundant sunlight, where it has emerged as the most economical option for new power generation. Looking ahead, ongoing technological advancements are expected to drive further cost reductions, potentially making solar energy the predominant source of electricity production across vast swathes of the globe by 2030. This shift towards solar energy will not only have positive implications for the environment but also contribute significantly to mitigating climate change.

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