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Design and Fabrication of Floating Sun Tracker Hydraulic Solar Panel System

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ABSTRACT

The increasing demand for renewable energy has encouraged the development of efficient solar power systems. This project presents the design and fabrication of an automated sun tracking solar panel that continuously aligns itself with the sun to maximize energy generation. The system uses Light Dependent Resistor (LDR) sensors to detect sunlight intensity and direction. An Arduino-based controller processes the sensor signals and operates a motorized mechanism to adjust the panel position. Unlike fixed solar panels, the tracking system maintains optimal exposure to sunlight throughout the day. The proposed system is simple, reliable, and cost-effective. Experimental results show that the sun tracking panel generates significantly more energy than a fixed panel. The efficiency improvement is found to be approximately 20–35%. The system can be used for both domestic and commercial applications. Thus, it promotes better utilization of solar energy and supports sustainable power generation.

1. INTRODUCTION

Solar energy is one of the most important renewable energy sources due to its availability, eco-friendliness, and low operating cost. The growing demand for clean energy has increased the use of solar photovoltaic (PV) systems in domestic, industrial, and agricultural applications. However, conventional fixed solar panels receive maximum sunlight only for a limited period of the day, reducing their overall efficiency. To overcome this limitation, solar tracking systems are used to continuously align the solar panel with the position of the sun. By maintaining the panel perpendicular to sunlight, the amount of solar radiation received is increased, resulting in higher energy generation. This project focuses on the design and development of a Sun Tracking Solar System. The system automatically adjusts the position of the solar panel according to the movement of the sun throughout the day. Light Dependent Resistors (LDRs) are used to detect sunlight intensity and direction. An Arduino-based controller processes the sensor signals and controls a motorized mechanism to rotate the panel toward the maximum sunlight. Solar tracking systems can be classified as single-axis and dual-axis trackers. Single-axis trackers rotate along one axis and are simple, economical, and widely used. Dual-axis trackers provide more accurate tracking by adjusting both tilt and azimuth angles but require a more complex mechanism. The proposed system is designed to improve the efficiency of solar energy utilization. Experimental studies show that sun tracking systems can increase energy output by approximately 20–35% compared to fixed solar panels. The system is reliable, cost-effective, and suitable for domestic, industrial, and agricultural applications. It contributes to sustainable energy generation and reduces dependence on conventional fossil fuels.

2. Prospective Application

The Sun Tracking Solar Panel System has a wide range of applications due to its ability to maximize solar energy absorption and improve power generation efficiency. Some of the major applications are:

A. *Residential Power Generation*
Used in homes to increase electricity generation from rooftop solar panels and reduce electricity bills.

B. *Agricultural Applications*
Provides power for irrigation pumps, crop drying systems, greenhouse operations, and other farm equipment.

C. *Industrial Solar Power Systems*
Enhances the efficiency of industrial solar installations by increasing energy output throughout the day.

D. *Solar Power Plants*
Widely used in large-scale solar farms to maximize energy production and improve plant performance.

E. *Street Lighting Systems*
Can be integrated with solar street lights to ensure efficient battery charging and longer operating hours.

F. *Remote and Rural Electrification*
Supplies reliable electricity to remote villages and off-grid areas where conventional power sources are unavailable.

G. *Water Pumping Systems*
Used in solar-powered water pumping applications for drinking water supply and agricultural irrigation.

H. *Research and Educational Projects*
Serves as an effective platform for studying renewable energy technologies, automation, and control systems.

I. *Telecommunication Systems*
Provides uninterrupted power to remote communication towers and monitoring stations.

Smart Renewable Energy Systems
Integrated with IoT and smart grid technologies for advanced energy management and monitoring.

Thus, the Sun Tracking Solar Panel System offers an efficient, sustainable, and environmentally friendly solution for various domestic, commercial, industrial, and agricultural energy applications.

3. Parameterization

A. *Geometric based parameterization*

Parameter Selection: The parameter selection is essential for efficient tracking and accurate performance of the solar panel system. Electrical Parameters: Solar panel rating: 10W–20W, 12V; operating voltage: 12V DC; output current varies with sunlight; LDR sensors are used for light detection.

Mechanical Parameters: Single-axis or dual-axis tracking; servo motor (SG90/MG995); rotation range 0°–180°; torque depends on panel weight.

Control Parameters: Arduino Uno controller; threshold difference between LDR values for movement; delay time 0.5–2 seconds for stability.

Environmental Parameters: Solar irradiance variation, ambient temperature, and weather conditions affect system performance.. Parameterization of the Floating Sun Tracker Hydraulic Solar Panel System involves defining and analyzing the key design, electrical, mechanical, and hydraulic parameters that govern the performance and efficiency of the system. The primary parameter is the solar panel rating, which determines the maximum power output under standard test conditions.

The panel size and area directly affect the amount of solar radiation captured. The tilt angle and tracking range are important geometric parameters that ensure maximum exposure to sunlight throughout the day. The system uses a hydraulic actuator, and parameters involve microcontroller processing speed, control algorithm accuracy, and motor/valve actuation timing. These parameters ensure proper coordination between sunlight detection and hydraulic movement. Environmental parameters such as wind speed, wave disturbance, temperature variation, and solar irradiance also significantly affect system behavior and must be considered during design. The optimization of all these parameters ensures that the floating sun tracker hydraulic solar system operates efficiently, maintains stability, and achieves maximum solar energy harvesting under varying environmental condition its performance depends on parameters such as fluid pressure, flow rate, cylinder bore diameter, stroke length, and response time. These factors control the speed and accuracy of panel movement. The floating structure parameters include buoyancy force, water level variation tolerance, stability factor, and material strength. These ensure that the system remains stable and balanced on water surfaces such as ponds, lakes, or reservoirs. Electrical parameters include voltage, current, power output, and efficiency of the solar panel system. The energy conversion efficiency is a key factor in evaluating system performance. Sensor parameters such as LDR sensitivity and response time are also considered for accurate sun tracking.

4. Challenges And Future Scope

The Design and Fabrication of a Floating Sun Tracker Hydraulic Solar Panel System involves several technical and environmental challenges. One of the major challenges is maintaining structural stability on water surfaces, as waves, wind load, and water level variations can affect system balance and tracking accuracy. Another challenge is the proper sealing and waterproofing of electrical and hydraulic component**s** to prevent damage due to water exposure.

The hydraulic control system complexity also presents difficulties, as precise control of fluid pressure and actuator movement is required for accurate solar tracking. Any leakage or delay in hydraulic response can reduce system efficiency. Energy consumption of control units and actuators is another concern, as the system must ensure that the energy used for tracking does not exceed the gain in solar output. Additionally, sensor accuracy and calibration issues can affect the performance of sun tracking under cloudy or diffused light conditions. Maintenance in a floating environment is also challenging due to algae formation, corrosion, and accessibility issues. Overall system cost and durability of floating structures are further limitations for large-scale implementation. The future scope of the Floating Sun Tracker Hydraulic Solar Panel System is highly promising due to increasing demand for renewable energy and efficient solar utilization. The system can be enhanced using IoT-based monitoring and control, allowing real-time performance tracking and remote operation. Integration of AI-based predictive tracking algorithms can further improve accuracy and energy efficiency. Advanced lightweight and corrosion-resistant floating materials can be developed to improve durability and reduce maintenance costs. Hybrid systems combining solar tracking with energy storage solutions (batteries) can ensure continuous power supply. In future developments, fully automated smart solar farms on water bodies can be established to optimize land use and increase power generation efficiency. The system can also be scaled for industrial applications and integrated into smart grid networks. Thus, with technological improvements, this system has strong potential to become a highly efficient and sustainable solution for large-scale solar energy production.

Conclusion

The sun tracking solar panel system demonstrates a significant improvement in energy efficiency compared to fixed solar panels. By continuously aligning the panel perpendicular to the sun's rays, the system maximizes solar energy absorption throughout the day. The use of light-dependent resistors (LDRs), a microcontroller, and a motorized mechanism enables automatic and real-time tracking of sunlight. Experimental results indicate that the tracking system produces higher voltage and power output than a stationary panel, especially during morning and evening hours when the angle of sunlight changes rapidly. This confirms that implementing a tracking mechanism enhance overall system performance and energy yield. Although the system involves additional components and cost, the increase in energy generation can justify the investment in the long run. Therefore, sun tracking solar panels are a practical and efficient solution for improving renewable energy utilization. Recent studies indicate a shift toward intelligent and hybrid solar tracking systems incorporating IoT and AI for improved performance and reliability

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