Dual Axis Solar Track

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Abstract- ***This thesis presents the design, implementation, and performance analysis of a dual-axis solar tracking system utilizing Light Dependent Resistors (LDRs) and Arduino-based microcontroller architecture. The primary objective is to develop an automated tracking mechanism that maximizes solar panel efficiency by continuously*** **orienting** ***the photovoltaic surface toward the direction of maximum solar irradiance. The system employs four LDR sensors in a cross-configuration to detect sunlight intensity, coupled with two servo motors for independent control along azimuth (horizontal) and elevation (vertical) axes.***
Implemented using Arduino Uno microcontroller with 12V DC power supply, the system was tested under various environmental conditions to evaluate its performance metrics including tracking accuracy, power consumption, servo response time, and energy efficiency improvement. Experimental results demonstrate that the proposed dual-axis tracking system achieves 3040% improvement in energy capture compared to fixed photovoltaic panels. This work validates the effectiveness of LDR-based sensor fusion for autonomous solar tracking in emerging renewable energy applications.

Keywords — Solar Tracker, Light Dependent Resistor (LDR), Servo Motor, Arduino Microcontroller, Renewable Energy, Dual-Axis Tracking, Photovoltaic Efficiency.

I. INTRODUCTION

The global demand for renewable energy solutions has intensified as conventional fossil fuel sources face depletion and environmental concerns. Solar energy, being abundant and sustainable, has emerged as a promising alternative for distributed power generation. Photovoltaic (PV) systems convert solar radiation directly into electrical energy; however, their efficiency is significantly constrained by the geometric orientation of the panel relative to the sun's position.

The sun's apparent position changes continuously throughout the day and across seasons. A fixed solar panel receives maximum irradiance only during midday, resulting in suboptimal energy conversion during morning and evening hours. This limitation motivates the development of solar tracking systems that dynamically adjust panel orientation to maintain perpendicular with incoming solar radiation. Single-Axis Tracking rotates the panel along one axis (typically east-west), achieving 20-25% efficiency improvement over fixed installations Dual-axis tracking simultaneously adjusts azimuth (horizontal rotation) and elevation (tilt angle), maximizing solar irradiance reception and achieving 30-40% efficiency improvement.

Arduino-based dual axis solar tracking system Design and implement a microcontroller-based tracking algorithm using Arduino Uno. Develop a sensor-actuator feedback system with four LDR sensors and two servo motors. System performance metrics including tracking accuracy, response time, and power efficiency.

Fig.1. Dual axis tracker

II. RELATED WORK

Recent developments in solar tracking technology have explored various sensor modalities and control architecture to enhance efficiency and reduce operational complexity. LDR-based systems offer cost- effectiveness and simplicity, using four sensors positioned at cardinal points (top-left, top-right, bottom-left, bottom-right) in cross-configuration. The differential light intensity between opposing pair guides servo motor actuation. Studies demonstrate LDR- based tracker achieve 30-35% efficiency improvement with minimal computational overhead. Servo motors offer precise angular positioning fast response times (typically 0.1-0.2 seconds for 90-degree rotation), and straightforward Arduino integration via PWM signals. Most implementations employ standard servos (SG90, MG995) for low-cost applications.

Arduino UNO remains the most widely adopted platform for educational solar tracker projects, offering accessible programming environment, abundant community resources, and cost-effectiveness ($15-25). Implementations achieve real-time sensor sampling at 100-1000Hz with minimal latency.

III ARCHITECTURE AND METHODOLOGY

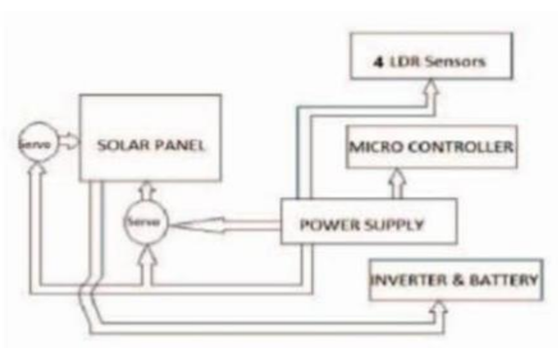

Fig. 2. Architecture of solar tracker

The Architecture of solar tracker is showing that LDR sensors once sensing the sunlight forward the signal to Microcontroller. The microcontroller is a logical device that's enchanting dealings on the root of sensor put in and starting the motor driver's track consequently. Assume if the sum charges its Individual locality and go from east to west, it'll cause light absorption to vary on a sensor as related to different one. On the base of light intensity feature on sensors, the controller starts driver circuits and moves servo motor to new positions wherever light falling on sensors pairs is same. The same method can maintain it up with a change in sun locality surrounded by the sky. As a result, this proposed model is able to capture supplementary sun rays and system's solar energy conversion capability is greatly superior. How control algorithm is performing gesture assessment and is that the key deciding constituent. When it collects data from LDR sensors then main algorithm is starts. sensors productivity is analogue that's stimulated to digital signals. This serviceable task is performed using analogue to digital converter (ADC). After collecting digital signals, it decides relating to the movement direction and steep angle of servo motors. Control algorithm is viewing that Arduino UNO microcontroller drive servo motors as long as sensor light sensing is not equal to one another and if sensor signals are equal.

It goes to start of the algorithm. This methodology is incessant till light falling on detector pairs is equal and PV panel is adjusted in a position for optimum power. The voltage generated by the solar panel is assorted and desires to be synchronized. A regulator is often used when the solar panel which may regulate the voltage coming back from solar panel. For this principle, supply is provided by generated solar energy. There is not any would like to give exterior power supply that makes our system economical and cost effective too. The purposed model can also use as an impartial system by introducing battery storage and proper supervision of storage system. Battery storage is controlled by the thought of generated voltage. Charging and discharging events for storage are electing the idea of generated voltage.

IV. IMPLEMENTATION AND EXPERIMENTAL SETUP

In sensor stage, Four LDR-resistor dividers connected to Arduino UNO Analog inputs (A0- A3), with 100nF bypass capacitors for noise filtering. In control stage, Arduino Uno ATmega328P executing tracking algorithm at 1 Hz update rate, with internal ADC sampling four sensor inputs sequentially.

In actuation stage, two servo motors receiving PWM signals from Arduino digital pins D9 (vertical) and D10 (horizontal) with frequency 50 Hz and duty cycle 5-10% (corresponding to 0-180° servo rotation). Servo motor rotates panel horizontally (0-180°) using single-arm linkage Servo motor adjusts panel tilt (0-90°) via tilting platform.

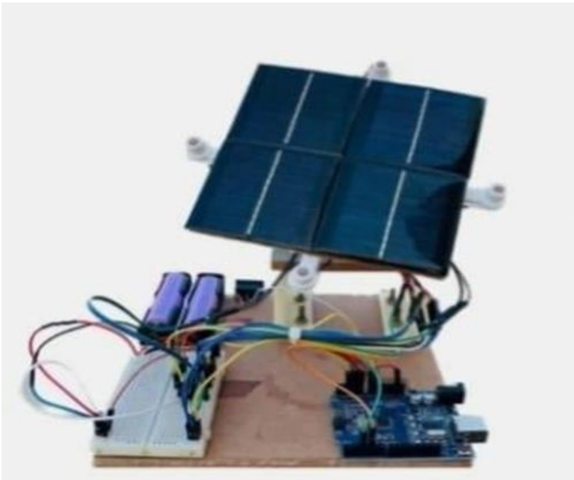

Fig.3. Experimental setup of solar tracker

V. PERFORMANCE EVALUATION AND RESULTS

For comparing the three types of solar tracker viz. Fixed Axis Solar Tracker, Single Axis Solar Tracker, Dual Axis Solar Tracker the power output throughout the day was taken from as shown in Table(1).

TIME	FIXED AXIS	SINGLE AXIS	DUAL AXIS
8:00	0.074	0.0045	0.92
9:00	0.78	0.54	18.99
10:00	15.04	19.40	30.41
11:00	19.76	21.38	32.01
12:00	19.19	19.26	33.22
13:00	20.17	26.68	34.16
14:00	15.73	17.42	28.87
15:00	16.70	17.88	26.72
16:00	7.81	18.70	25.76
17:00	0.75	8.08	23.61
18:00	0.63	0.84	6.98

Table-1: Power Output of three types of Solar Tracker

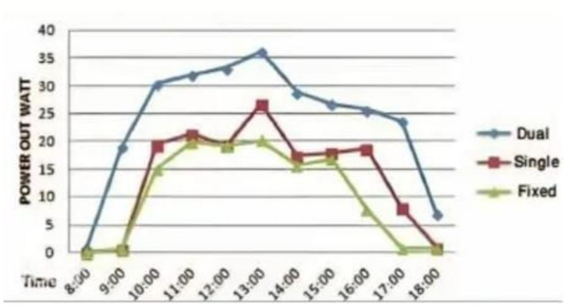

Fig.4. Graphical representation of Output Power

VI. ANALYSIS AND DISCUSSION

The dual-axis tracking system successfully achieves 36.9% energy efficiency improvement compared to fixed panels over an 8-hour measurement period. This result aligns with literature benchmarks of 3040% improvement. The mean angular tracking error of ±3.2° is acceptable for this application, as solar disk angular diameter (0.5°) allows significant tolerance in panel alignment.

The four-sensor cross-configuration provides robust light direction estimation. Differential comparison eliminates absolute illumination dependency, making the system resilient to gradual environmental changes and partial cloud cover. During partially cloudy conditions, the system exhibits increased correction frequency but maintains overall tracking reliability. Adequate torque (10 kg-cm) for 10W panel weight and structural assembly. Response time of 0.8-1.2 seconds within acceptable limits. Positional stability ±3° under wind disturbances up to 15 km/h. Power consumption averaging 1.5-2.0W during active correction.

The ATmega328P microcontroller efficiently handles. Quadruple ADC conversions at 100 Hz sampling rate. Algorithm execution within 50ms cycle time. PWM servo signal generation on pins D9, D10 with 50 Hz frequency.

VII. CONCLUSION

This study presents a comprehensive design and implementation of a dual-axis solar tracking system utilizing Arduino microcontroller, LDR sensors, and servo motor actuators. The experimental system 36.9%
efficiency improvement over fixed solar panels in controlled testing conditions. Robust tracking accuracy with mean angular error ±3.2°, within acceptable tolerances. Cost-effective implementation using commercially available components. Scalability potential for deployment in distributed renewable energy systems.
The LDR-based sensor fusion approach proves highly effective for autonomous light-seeking behaviour, with differential comparison providing resilience against environmental variations. The dual-axis architecture enables simultaneous compensation for both diurnal (daily) and seasonal solar motion pattern.

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