AUTOMATED SOLAR PANEL POSITIONING AND MAINTENANCE SYSTEM USING LABVIEW

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Introduction:

The project focuses on the design and implementation of an advanced solar panel system with integrated smart features to address these challenges. The system employs a 9V solar panel mounted on a 3D-printed dual-axis support structure, which enables precise tracking of the sun throughout the day. Using Light Dependent Resistors (LDRs) for light intensity detection and servo motors for movement, the system ensures optimal sunlight exposure, thereby enhancing energy capture. To further improve efficiency, a motorized wiper system is incorporated to automatically clean the solar panel, minimizing energy loss due to dirt accumulation. Additionally, the system includes a Li-ion battery storage setup with a quick-charge (QC) circuit, allowing for efficient energy storage and utilization. The Battery Management System (BMS) monitors and optimizes energy flow to ensure reliable operation. Real-time monitoring and control are provided through a LabVIEW-based interface, enabling users to track key metrics such as voltage, current output, battery status, and panel cleanliness. The interface also facilitates manual or automated operation of the wiper system, ensuring ease of maintenance.

Moreover, the project incorporates a LabVIEW simulation interface to visualize real-time data such as solar panel voltage, current output, and battery status, facilitating comprehensive performance monitoring. This aspect of the project not only enhances user interaction but also aids in the analysis and optimization of the tracking system's performance. Through this project, main aim to demonstrate the effectiveness of advanced solar tracking technologies in improving the efficiency of solar energy systems. By combining electronics, programming, and renewable energy principles, the dual-axis solar tracking system serves as both a viable solution for enhancing solar energy capture and a valuable educational tool for understanding modern energy technologies. Solar Energy is a clean energy source available in abundance throughout the world. This energy can be converted to electrical form by means of Solar panels. The conversion efficiency of solar panels is about 20%. The use of dual axis solar trackers raises the efficiency to around 35%-40%, thereby providing more output power.

Objectives:

The objectives of this work are described below:

- To interface LDR sensor to Arduino microcontroller to detect and measure light intensity.
- To provide precise control of angular position, speed, and acceleration in a system using servomotor.
- To develop a LabVIEW interface that monitors real-time performance metrics such as solar panel voltage, current output, and battery status, enhancing user interaction and enabling data analysis.
- LabVIEW will analyse the data and raise alerts for potential faults, enabling timely repairs or cleaning to maintain optimal performance.

Methodology:

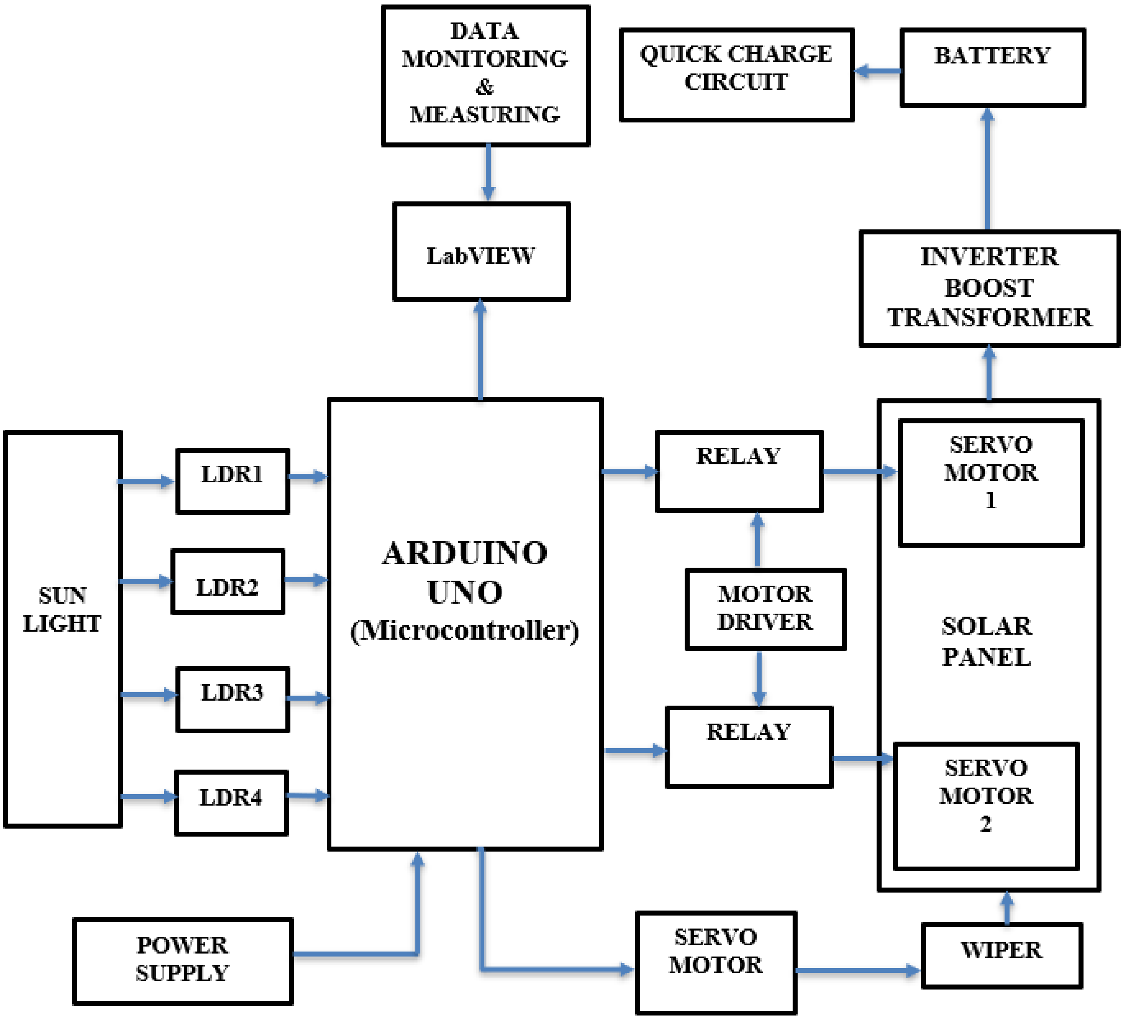

Figure 1: Block diagram of Automated Solar Panel Positioning and Maintenance System

Fig 1 shows the block diagram of the Dual-axis solar tracking system that tracks the maximum sun rays in both axes using LDR sensors. The system includes a power supply, Arduino, two servo motors, four LDR sensors, battery, charge controller, and solar panel. The power supply is given to Arduino. Construction is being built out of the 3D model base installed at the ground of it, affixed with the iron rods on both the sides in a cross shaped manner connected with a hollow cylindrical rod from both the sides. The analog information is transferred from LDRs to Arduino. The Arduino is programmed to provide instructions to the servo motors and these motors eventually provide movement to the solar panel. Light-dependent resistors (LDRs) or photodiodes placed on each side of the panel to detect the sun's position. The sensors provide input signals representing the intensity of light on the panel. LabVIEW interfaces with the sensors through a DAQ device (such as NI-DAQmx) that converts the analog sensor signals into digital values. These values are then used to determine where the sun is relative to the panel. The servo motors are used to adjust the solar panel’s axes and elevation by rotating the panel to the correct position. Each servo motor controls different axis of solar panel. To further improve efficiency, a motorized wiper system is incorporated to automatically clean the solar panel, minimizing energy loss due to dirt accumulation. The system includes a Li-ion battery storage setup with a quick-charge (QC) circuit, allowing for efficient energy storage and utilization. Further, the system is incorporated for Real-time monitoring through a LabVIEW-based interface, enabling users to track key metrics such as voltage, current output, battery status, and panel cleanliness.

The description about the different components used for the proposed system are as follows:

- **SOLAR PANEL**
  - A 9V solar panel is selected based on the project’s energy requirements. The 9V panel offers a suitable balance of power output and size for this application, allowing for sufficient energy collection while being compatible with the overall design of the system.
- **DUAL-AXIS TRACKING SUPPORT**
  - Design of Dual-Axis Tracking Support: A 3D model is created for the dual-axis movement support structure. This support is designed to allow the solar panel to rotate both horizontally and vertically ensuring the panel stays aligned with the sun throughout the day.
- **LIGHT DEPENDENT RESISTORS (LDRs)**
  - Four Light Dependent Resistors (LDRs) are strategically placed around the solar panel to detect the intensity of light from different angles. This sensor array allows the system to determine the optimal position of the panel for maximum sunlight exposure.
  - The LDRs are connected to an Arduino microcontroller, which processes their inputs and calculates the necessary adjustments for the servo motors controlling the panel’s movement.

- By continuously adjusting the position of the solar panel based on the sun's position throughout the day, the tracking system ensures that the panel always faces the sun directly, optimizing the amount of solar energy it can collect and convert into electricity.

➢ **SERVO MOTORS**

  - Two servo motors are chosen to enable the dual-axis movement of the solar panel. One motor control the horizontal movement, while the other controls the vertical (elevation) movement.
  - The servo motors are connected to the Arduino microcontroller, which uses a feedback loop based on the LDR inputs to move the solar panel accordingly.

➢ **BATTERY STORAGE AND QUICK-CHARGE CIRCUIT**

- A Li-ion battery storage system is used to store the excess solar energy generated during the day. The battery is connected to a charge controller to regulate the charging process.
- A quick-charge (QC) circuit is incorporated into the system to enable efficient charging of mobile devices or small appliances. The circuit ensures that the charging process is fast, without overloading the battery.

➢ **MOTORIZED WIPER SYSTEM**

- A motorized wiper system is designed to keep the solar panel clean from dust and debris. The wiper mechanism is mounted on top of the panel and moves horizontally across its surface.
- The wiper is operated either manually or automatically, based on a timer or sensor input, via an Arduino-based control system.
  - ✓ Automatically at predefined intervals.
  - ✓ Manually via a user interface.

➢ **ARDUINO FIRMWARE DEVELOPMENT**

- The core control logic for the solar tracking system was developed in Arduino. The firmware is designed to:
- ✓ Read inputs from the LDR sensors.

- ✓ Calculate the optimal panel orientation based on light intensity.
- ✓ Control the servo motors to adjust the panel's position.
- ✓ Operate the motorized wiper system periodically or based on a user input.

➢ **LabVIEW INTERFACE**

- Data Collection: The system monitors key performance metrics, such as Voltage and current output from the solar panel, Battery charge level and status, Light intensity detected by the LDR sensors.

10.Result and Conclusion:

The system includes a power supply, Arduino, two servo motors, four LDR sensors, battery, charge controller, and solar panel. Light-dependent resistors (LDRs) or photodiodes placed on each side of the panel to detect the sun's position. The analog information is transferred from LDRs to Arduino. The sensors provide input signals representing the intensity of light on the panel. Each servo motor controls different axis of solar panel. The built-in Analog-to-Digital Converter will convert the analog value of LDR and convert it into digital. For real time monitoring, the block diagram for a dual-axis solar tracking system in LabVIEW is designed to handle the data acquisition of the solar panel's movement based on real-time inputs. The designed block diagram represents different LDRs sensor in accordance with to show the intensity measures in front panel. The process starts with data acquisition blocks (such as DAQmx functions) to read system key performance metrics, such as Voltage and current output from the solar panel, Battery charge level and status, Light intensity detected by the LDR sensors, which are used to determine the sun's position.

The project features a dual axis solar tracking system using LDRs. To allow the solar panel to adjust quickly to the point of maximum light intensity, two servo motors are used. This motor provides the movement in both horizontal axis and vertical axis. The system continuously monitors and display real time electrical parameter such as voltage, current and light intensity via a LabVIEW interface. This graphical representation simplifies the assessment of system performance.

11. Project Outcome & Industry Relevance (10-15 lines):

This dual-axis solar tracking system enhances energy efficiency by dynamically aligning panels with optimal sunlight, increasing power output compared to fixed installations. The low-cost design (Arduino, servos, LDRs) and LabVIEW-based control make it accessible for small-scale renewable energy projects. Its proportional control logic ensures rapid, stable tracking without overshoot, validated by first-order models. While tested with artificial light, scalability to real-world sunlight requires wider LDR spacing and wireless power. The system addresses a critical industry need—maximizing solar harvest while minimizing costs—making it relevant for residential solar arrays, agricultural IoT sensors, and off-grid applications. Future integration with AI-driven predictive algorithms or cloud monitoring could further boost its industrial appeal. By bridging affordability and precision, this project contributes to sustainable energy solutions, aligning with global decarbonization goals.

Working Model vs. Simulation/Study:

The project's working model approach provided critical advantages over pure simulation studies by revealing practical implementation challenges that theoretical models often overlook. Through physical prototyping with Arduino, servos, and LDRs, the team encountered and solved real-world issues like USB tethering limitations, ambient light interference, and mechanical constraints of servo operation - problems that might remain hidden in simulation. The hands-on implementation validated the system's sub-2-second response time and stable tracking performance under actual operating conditions, while exposing sensor placement sensitivities and power delivery challenges. While simulations offer valuable opportunities for initial parameter optimization and virtual testing of control algorithms under various environmental conditions, they cannot fully replicate the complexities of physical systems. The working model's empirical results provided concrete proof of concept and demonstrated cost-effectiveness for small-scale applications.

Project Outcomes and Learnings:

The project successfully developed a functional dual-axis solar tracking system that demonstrated significantly improved energy capture compared to stationary panels. Key outcomes included the validation of a proportional control system achieving sub-2-second response times and the development of effective noise-filtering algorithms for LDR sensors. The working model approach provided invaluable practical insights, revealing unexpected challenges like USB power limitations and servo torque requirements that simulations might have missed. We learned that careful sensor placement and ambient light normalization were critical for reliable operation, while the physical implementation highlighted the importance of mechanical durability in real-world conditions. The project confirmed the cost-effectiveness of Arduino-based control systems for small-scale renewable energy applications, though it also identified scalability challenges for larger installations. Most importantly, the hands-on development process underscored the complementary value of both theoretical modelling and physical prototyping in engineering design, with each approach contributing unique perspectives to the final solution. These findings provide a foundation for future improvements in solar tracking technology and its practical implementation.

Future Scope:

As the need of time is to increase the capacity generation of electricity, the renewable generation using solar PV is a potential option. It is crucial to find new ways to improve the collection of energy to compete with conventional energy resources such as coal. This solar tacking system will be very useful in rural areas where developer can use highly sensitive solar panels which can work in mild sun light also and by connecting number of solar tracker assemblies, users will be able to produce sufficiently large quantity of power. Dual axis solar tracking or tracking using internet of things and visual monitoring of solar panel are few of the future prospective of LabVIEW based dual axis Solar PV System.

The solar tracking system has significant potential for future development across multiple dimensions. By incorporating IoT and cloud connectivity, the system could enable real-time performance monitoring and predictive maintenance for commercial solar farms. Machine learning algorithms could enhance tracking accuracy by predicting sun paths and adapting to weather patterns, reducing reliance on physical sensors. The design could be scaled for residential rooftops using lightweight materials and wireless power solutions to overcome current tethering limitations.