Construction of a Dual Axis Solar Tracking with Solar Output Monitoring

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APPROVAL

This is to certify that the project on **"Duel Axils Solar Tracking with Solar Output Monitoring."** By Md. Farhan Islam (ME2101023428), Md. Asiful islam (ID: ME2101023518), Md Fazlul Karim (ID: ME2101023470) and Abdul Hoque Khokan (ID: ME2101023468) has been carried out under our supervision. The project has been carried out in partial fulfillment of the requirements of the degree of Bachelor of Science (B.Sc.) in Mechanical Engineering of years of 2024 and has been approved as to its style and contents.

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DECLERATION

We, hereby, declare that the work presented in this project is the outcome of the investigation and research work performed by us under the supervision of Md. Mahfujul Islam, Lecturer, Department of Mechanical Engineering, Sonargaon University (SU). We also declare that no part of this project and thesis has been or is being submitted elsewhere for the award of any degree.

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ABSTRACT

The biggest crisis we are heading into is the climate change due to excessive use of fossil fuels and to overcome these issues, we have only one solution that is utilizing Renewable Energy. Renewable energy is a type of energy that is harnessed from the nature without causing ill effects to the environment. One of the most prominent kinds of renewable energy is solar energy. The output electrical energy depends on the amount of sunlight falling on the solar panel. Traditionally, solar panels are fixed and the movement of sun over the horizon means that the solar panel does not harness maximum energy most of the time. In order to maximize the power from the solar panel, the panel should face the sun all time. In Arduino based solar tracker arm with the help of LDR and servo motor is used to generate maximum power.

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Chapter 1 Introduction

1.1 General

The goal of this thesis was to develop a laboratory prototype of a solar tracking system, which is able to enhance the performance of the photovoltaic modules in a solar energy system. The operating principle of the device is to keep the photovoltaic modules constantly aligned with the sunbeams, which maximises the exposure of solar panel to the Sun's radiation. As a result, more output power can be produced by the solar panel. The work of the project included hardware design and implementation, together with software programming for the microcontroller unit of the solar tracker. The system utilised an Node MCU microcontroller to control motion of two servo motors, which rotate solar panel in two axes. The amount of rotation was determined by the microcontroller, based on inputs retrieved from four photo sensors located next to solar panel. At the end of the project, a functional solar tracking system was designed and implemented. It was able to keep the solar panel aligned with the sun, or any light source repetitively. Design of the solar tracker from this project is also a reference and a starting point for the development of more advanced systems in the future.



Fig-1.1: Tracking System

1.2 Objective of the Project

The objective of the Dual Axis Solar Tracking System Project is to maximize the efficiency and energy output of solar panels by ensuring they are constantly aligned with the sun throughout the day. This is achieved by allowing the solar panels to move along two axes—horizontal (azimuth) and vertical (elevation). Here are the key goals of the project:

- Increased Energy Efficiency: By tracking the sun's movement, the system optimizes the angle of incidence of sunlight on the solar panels, maximizing power generation compared to stationary panels.
- Maximize Sunlight Exposure: The system ensures that solar panels receive maximum sunlight from sunrise to sunset, improving overall power generation throughout the day and across different seasons.

- Automation: The dual-axis tracker is designed to automatically follow the sun without manual intervention, using sensors or algorithms that detect sunlight direction and adjust the position of the panels accordingly.
- Cost-effectiveness: Despite the higher upfront cost compared to fixed systems, the project aims to demonstrate how the improved efficiency can lead to better return on investment (ROI) over time, particularly in high-sunlight regions.
- Sustainability: The project aligns with sustainability goals by enhancing the use of renewable energy and reducing reliance on non-renewable energy sources.
- Technological Innovation: The system involves advanced mechanical and electronic design, including motors, control systems, and sensors, providing an opportunity for technological advancement in solar energy systems.
- This project would typically focus on designing, developing, and testing the system to ensure it operates reliably in real-world conditions.

1.3 Background of the Project

When it comes to the development of any nation, energy is the main driving factor. An enormous amount of energy is extracted, distributed and consumed in global society daily. The world population is increasing day by day and the demand for energy is increasing accordingly. Oil and coal are the main source of energy nowadays but there is a fact that the fossil fuels are limited and hand strong pollution. Even the price of petroleum has been increasing year by year and the previsions on the medium term there are not quite encouraging. The use of these resources result in global warming due to emission of greenhouse gases. In order to provide a sustainable power production and a non-polluted world in future, there is a growing demand for energy from renewable sources like solar, wind, hydrothermal, and tidal waves. Solar energy is simply the energy produced directly by the sun. The history of solar energy is as old as the humankind. In total potential of the renewable energy solar power has the maximum percentage as solar energy is a very large, inexhaustible source of energy. Despite solar energy being a good source of energy, there is a need to improve the methods to harness this energy. This can be achieved by using a solar tracking system instead of a fixed system. A solar tracker is an automated solar panel that follows the sun to increase power. The two types of tracking system are Single axis solar tracker and dual-axis solar tracker. Single-axis can either have a horizontal or a vertical axis while the dual-axis has both horizontal and vertical axis, thus making them able to track the sun’s apparent motion almost anywhere in the world. Our project is that we will generate electricity by solar panel. In addition we will monitor the voltage from the LCD display. We will also be able to control the power supply from the solay system. We will store the received power in the battery and drive the load. We are used lamps as load.

1.4 Earlier Research

The research on Dual Axis Solar Tracking Systems has evolved significantly as interest in renewable energy, particularly solar energy, has grown over the years. Here's a brief overview of earlier research in this area: [1]

1. Early Solar Tracking Concepts (1970s–1990s)

Initial Interest: As solar panels became more widely used in the 1970s during the energy crisis, researchers began exploring methods to enhance energy output.

Basic Solar Tracking: Early studies focused on single-axis tracking systems, which adjusted the solar panels along one axis (usually horizontal) to follow the sun's path during the day.

Efficiency Gains: Researchers in the late 1980s and early 1990s established that solar tracking could increase energy output by 20-30% for single-axis systems. However, they also noted the potential for even higher gains with dual-axis systems.

2. Development of Dual Axis Systems (1990s–2000s)

Dual Axis Introduction: Research shifted towards dual-axis tracking systems, which allow panels to follow the sun in both the horizontal (azimuth) and vertical (elevation) directions. This enables optimal solar capture throughout the day and across different seasons.

Initial Prototypes: Early dual-axis tracking systems were mechanically complex and costly. These systems often used basic control mechanisms such as timers or rudimentary light sensors.

Research Focus: Studies during this period explored the theoretical efficiency gains of dual-axis tracking, showing potential improvements of 30-40% compared to fixed systems.

3. Technological Advances (2000s–2010s)

Advanced Sensors and Control: With advancements in electronics, researchers incorporated more sophisticated components like light-dependent resistors (LDRs), microcontrollers, and GPS systems for more precise sun tracking.

Improved Energy Harvesting: Studies demonstrated that dual-axis systems could increase energy harvesting by up to 40-50% in certain locations. These gains were especially significant in regions with long daylight hours or highly variable sun positions.

Mechanical and Control Innovations: Researchers began experimenting with various tracking mechanisms, such as hydraulic and gear-driven systems, to improve accuracy, reliability, and reduce power consumption of the tracker itself.

4. Recent Research (2010s–Present)

Optimization and Cost Reduction: More recent research has focused on reducing the cost of dual-axis systems, making them more accessible for large-scale and residential applications. Key innovations include:

Algorithm-Based Tracking: Using algorithms like fuzzy logic, neural networks, and predictive models to control the solar panel's movement more efficiently.

Photovoltaic Performance Studies: Studies comparing the performance of dual-axis systems in different geographical locations, showing the systems to be most effective in areas with high solar insolation and varying sun angles.

Materials and Durability: Researchers have also focused on improving the durability of these systems, especially in extreme weather conditions, to ensure long-term functionality and reduced maintenance costs.

5. Efficiency and ROI Studies

Long-Term Studies: Early research indicated the efficiency advantages of dual-axis systems. However, more detailed studies over longer periods (5–10 years) have provided deeper insights into the financial viability and overall ROI of dual-axis systems versus fixed and single-axis systems.

Comparative Research: Many studies compared dual-axis tracking to fixed panels and single-axis tracking. They consistently found energy gains of around 25-50%, though the specific performance varied depending on latitude, weather conditions, and system design.

6. Sustainability and Environmental Impact

Researchers in recent years have focused on the sustainability benefits of dual-axis systems, showing how increased energy output contributes to faster payback times for solar investments, making them a key technology in the fight against climate change.

Studies also explored how dual-axis systems can complement other renewable energy technologies, like battery storage, to create more reliable and efficient energy systems.

1.5 Statements of Problems

The main goal is to keep solar PV panel perpendicular to the sun throughout the day in order to increase the energy generation. Dual axis solar tracking system can be an effective way to increase the efficiency of solar cells. The devastating problem on both biotic and abiotic components of our home can be reduced by using solar energy as the major source for power generation. The natural gift like fossil fuels, woods, etc. which are limited in amount can be saved from crisis and extinction. For people, due to its more efficiency and less harmful impacts dual axis solar tracking system might be good decision for the intermediate future. So, this project can practically demonstrate effect of this variation to people.

1.7 Motivation for Project

The motivation for developing a Dual Axis Solar Tracking System stems from the need to maximize solar energy harnessing and overcome the limitations of fixed solar panels. Below are key motivating factors for pursuing this project:

1. Maximizing Solar Energy Output

Improved Efficiency: Solar panels generate more electricity when they receive sunlight at an optimal angle. Fixed panels are limited because they remain in one position, and the angle of sunlight changes throughout the day and across seasons. Dual-axis tracking systems constantly adjust the panel's position, capturing sunlight more effectively and increasing energy output by 30-50%.

Optimal Sunlight Capture: Unlike fixed or single-axis systems, dual-axis tracking allows solar panels to capture sunlight throughout the entire day, from sunrise to sunset, maximizing energy generation even in varying weather conditions.

2. Addressing Global Energy Needs

Growing Demand for Clean Energy: With increasing global energy demands and the shift toward renewable energy to combat climate change, efficient solar power systems like dual-axis trackers are essential for meeting energy needs sustainably.

Reducing Dependence on Fossil Fuels: By increasing the efficiency of solar panels, dual-axis systems reduce the reliance on non-renewable energy sources, helping transition to cleaner and greener energy solutions.

3. Economic Benefits and Return on Investment (ROI)

Higher Energy Output = Better ROI: While dual-axis systems have a higher initial cost compared to fixed or single-axis systems, the increased energy output leads to better long-term financial returns. Higher energy generation means faster payback periods and greater overall savings for solar power installations.

Viability in Large-Scale Solar Farms: In utility-scale solar farms, where maximizing energy output is critical, dual-axis systems help operators extract more value from each solar panel installation, making them financially attractive in the long run.

4. Technological Innovation and Automation

Advancing Solar Technology: The development of dual-axis tracking systems is driven by a desire for technological innovation. These systems involve advanced control algorithms, sensors, and mechanical components, offering an opportunity to push the boundaries of solar energy technology.

Automation and Precision: The project provides a platform to experiment with sophisticated automation techniques, such as GPS tracking, light sensors, and predictive algorithms, which ensure that panels adjust to the sun's position with high precision and minimal human intervention.

5. Sustainability and Environmental Concerns

Reducing Carbon Footprint: By making solar energy more efficient, dual-axis tracking systems contribute directly to reducing greenhouse gas emissions, which is critical for mitigating climate change.

Efficient Land Use: In areas where land availability is a concern, dual-axis trackers allow solar panels to generate more power from a smaller footprint. This is especially important in regions with limited space for large solar farms.

6. Applicability Across Various Locations

Versatility in Different Climates: Dual-axis systems are motivated by the need to make solar power generation viable in diverse geographical locations. In areas with high solar variability (e.g., regions with both sunny and cloudy seasons or high latitudes), dual-axis tracking systems offer significant benefits by adjusting to seasonal sun patterns.

Global Expansion of Solar Power: The increasing global adoption of solar energy in countries with varying climates creates a demand for systems that can perform optimally regardless of location, further motivating the development of dual-axis systems.

7. Enhancing Energy Independence

Off-Grid Applications: For remote areas or off-grid applications where energy reliability is critical, dual-axis solar trackers help maximize energy production, reducing reliance on grid electricity or backup power sources.

Supporting Energy Resilience: In areas prone to power outages or energy supply challenges, dual-axis tracking systems can provide a reliable, efficient source of renewable energy, enhancing overall energy resilience.

8. Contribution to Research and Development

Educational and Research Opportunities: The project offers a valuable opportunity for researchers and engineers to test new ideas, innovate in solar tracking technologies, and contribute to the body of knowledge in renewable energy systems.

Driving Renewable Energy Solutions: By developing and refining dual-axis systems, the project contributes to global efforts to find scalable, efficient solutions for clean energy production.

1.8 Project Management

The Project Management of a Dual Axis Solar Tracking System involves careful planning, execution, monitoring, and control to ensure the successful completion of the project within scope, time, and budget constraints. The following outlines the typical phases and key components of project management for such a project:

1. Project Initiation

Project Objectives: Define the main goals, such as maximizing solar energy efficiency, designing a cost-effective system, and improving automation. Establish clear metrics for success (e.g., efficiency gains, system reliability).

Feasibility Study: Conduct a feasibility study to assess the technical, financial, and environmental viability of the dual-axis tracking system. Analyze potential return on investment (ROI), payback period, and overall project sustainability.

Stakeholder Identification: Identify key stakeholders, including project sponsors (e.g., investors, government agencies), project managers, engineers, suppliers, and end-users.

Project Charter: Develop a project charter that formalizes the project's scope, objectives, and stakeholders. Secure necessary approvals and align expectations.

2. Project Planning

Scope Definition: Clearly define the scope of the project, including system design, development, installation, and testing phases. Break the project into smaller tasks and deliverables.

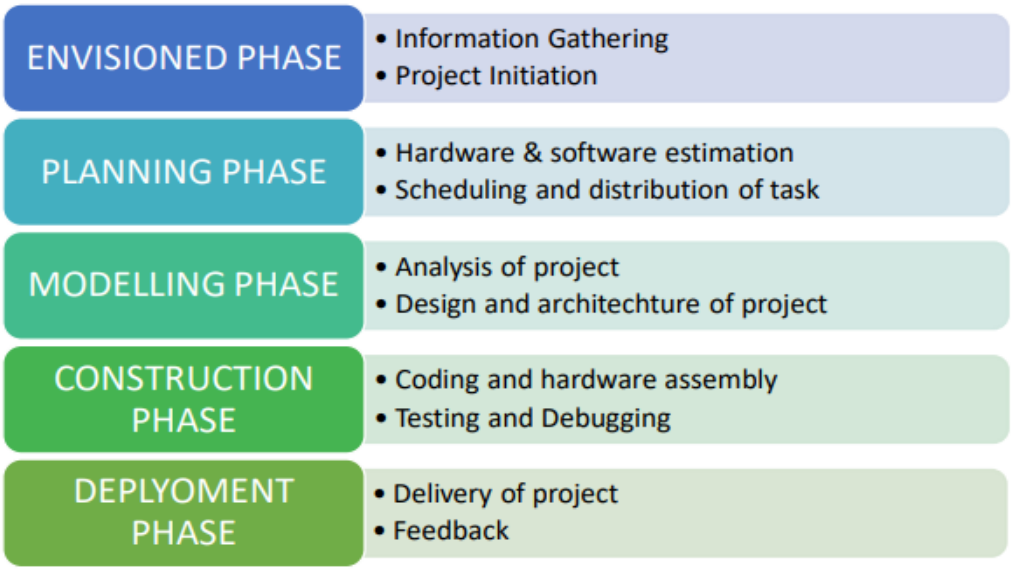


Fig-1.2: Project Management

Work Breakdown Structure (WBS): Develop a WBS to organize tasks and allocate resources effectively. Each phase of the project should be outlined in detail, including design, prototyping, installation, testing, and handover.

Time Management (Schedule Development): Create a detailed project timeline with milestones for each phase:

Design and Prototyping

Component Sourcing and Procurement

System Assembly

Software Development (Control Systems, Sensors)
Testing and Optimization
Final Installation and Commissioning
Cost Management: Develop a project budget covering costs for materials, labor, equipment, and any software needed. Include contingency reserves for unforeseen issues.
Risk Management: Identify potential risks (technical failures, delays in material delivery, budget overruns) and develop a risk mitigation plan. Create contingency plans for critical risks.
Resource Management: Allocate resources such as engineering teams, technical staff, suppliers, and contractors. Assign responsibilities for each task in the WBS.
3. Project Execution
Team Formation: Assemble the project team, including project managers, engineers (mechanical, electrical, software), technicians, and installation crews. Define clear roles and responsibilities.
Procurement and Sourcing: Purchase or fabricate components, including:
Solar panels
Motors and actuators for tracking movement
Sensors (e.g., light-dependent resistors or GPS systems)
Control systems (e.g., microcontrollers, software, and electronics)
System Design: Finalize the design of the dual-axis solar tracker, ensuring all components integrate properly. Prepare detailed engineering drawings and technical specifications.
Prototyping and Testing: Develop a prototype of the dual-axis system. Conduct initial testing to ensure that the solar tracker moves correctly and that sensors and control systems work as intended.
Software Development: Write and test the software code for automated sun tracking. Implement algorithms for positioning the solar panels based on real-time data from sensors or predictive models.
Quality Control: Conduct quality checks during assembly to ensure that the system meets design specifications. Use quality assurance processes to ensure components are reliable and the tracking mechanism functions correctly.
4. Monitoring and Control
Progress Monitoring: Track the progress of the project against the established schedule. Use project management software (e.g., Microsoft Project, Trello, or Primavera) to monitor tasks and team performance.
Cost Control: Monitor actual costs against the project budget. Regularly review financial reports to avoid overruns and take corrective actions if needed.
Risk Management Review: Continuously assess risks throughout the project lifecycle. Revisit risk management plans and update mitigation strategies if new risks arise or existing ones become more critical.
Performance Testing: Continuously test the system's performance at various stages (e.g., after the system is assembled, after software integration) to ensure that the tracker accurately follows the sun and the panels are generating optimal energy output.

Environmental Monitoring: Implement a comprehensive environmental monitoring program to track emissions, effluents, waste byproducts, and other potential impacts on air, water, and soil quality. Ensure compliance with environmental standards and reporting requirements.

Community Engagement: Maintain ongoing communication and engagement with local communities and stakeholders. Address any concerns, provide updates on project performance, and promote awareness of the benefits of the WtE project.

Waste Management and Byproduct Utilization: Manage waste byproducts (like ash, char, digestate, etc.) in an environmentally responsible manner. Explore opportunities for recycling and reuse of byproducts to minimize environmental impact.

Project Evaluation and Improvement

Post-Implementation Review: Conduct a post-implementation review to evaluate project performance against objectives, including energy output, waste processing efficiency, cost control, and environmental impact. Identify lessons learned and areas for improvement.

Continuous Improvement: Implement continuous improvement processes to enhance plant performance, optimize operations, reduce costs, and minimize environmental impacts over time.

Financial and Risk Management

Financial Monitoring: Monitor project costs and revenues to ensure financial sustainability. Adjust budgets and financial strategies as needed to manage any deviations or unforeseen expenses.

Risk Management: Continuously assess risks throughout the project lifecycle and implement mitigation strategies to address new or evolving risks.

Chapter 2 Theoretical Review

2.1 Introduction

Nowadays the depletion of conventional energy resources forced many researchers to search for various renewable energy sources. Among the nonconventional resources available, solar energy has the greatest potential to be converted into electrical energy. Converting solar energy into electrical energy signifies one of the favorable technologies, providing dirt-free, dependable with negligible environmental impact. Solar energy is well known as an unrestricted, endless source, and involves no pollution filtrates or greenhouse gases emission. The solar photovoltaic industry has been improving very well recently. Most of the currently installed PV systems are of the fixed-tilt mounting design, of which the PV modules are tilted at an optimal angle. For this type, these PV modules are reduced to severe cosine losses during harnessing of solar energy, especially early in the morning, and in the late evening. This project employs a sun-tracking solar panel to track the maximum rays using LDR's. This is more acceptable when compared to the light-sensing method that may not be accurate. The main aim of this work is to design a system that could track the sun with solar panel in a more efficient way compared to the existing system. This is obtained by coupling the LDR sensors with a DC servo motor to the solar panel such that the panel maintains its face always perpendicular to the sun to generate maximum energy. This is achieved by employing a programmed ARDUINO IC.

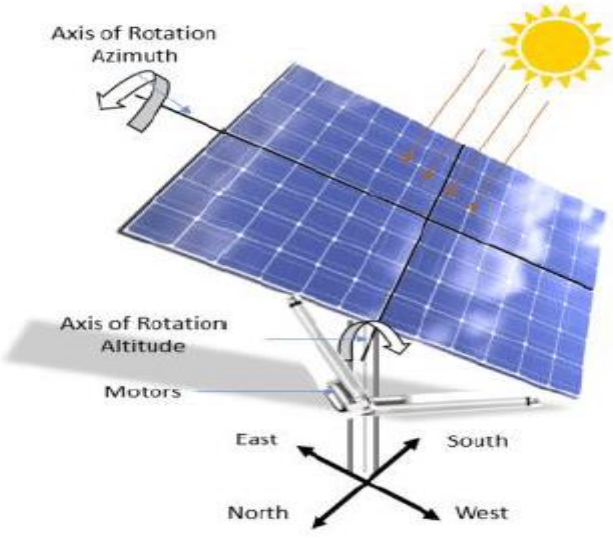


Fig-2.1: Solar and Sun Axis

2.2 Duel Axils Solar Tracking

A Dual Axis Solar Tracking System is a technology designed to enhance the efficiency of solar panels by enabling them to follow the sun's movement across the sky throughout the day and the year. Unlike fixed or single-axis systems, which can only move along one direction (either vertically or horizontally), dual-axis systems adjust in both azimuth (horizontal

movement) and elevation (vertical movement), ensuring that the solar panels maintain an optimal angle toward the sun at all times.
Key Features of Dual Axis Solar Tracking Systems:
Two Degrees of Movement:
Azimuthal Tracking (Horizontal): This axis tracks the sun's movement from east to west throughout the day.
Elevational Tracking (Vertical): This axis adjusts the angle of the panels to follow the sun's changing height in the sky as the seasons change.
Components:
Solar Panels: Photovoltaic cells that convert sunlight into electricity.
Tracking Mechanism: Motors and actuators that adjust the solar panel's position.
Control System: Sensors (like light-dependent resistors, or LDRs), microcontrollers, or GPS systems that detect the sun's position and automatically adjust the panels.
Structure and Mount: A sturdy frame to support the solar panels and allow for smooth movement along both axes.

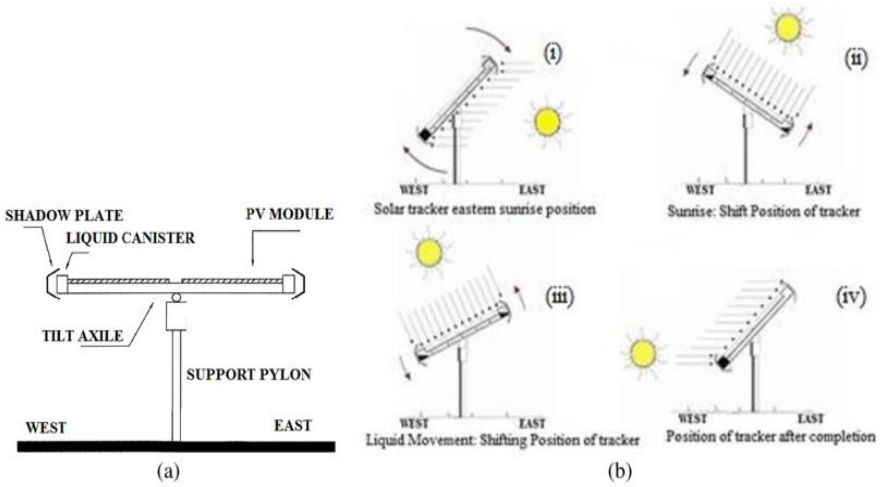


Fig-2.2: Dual Axis Solar Tracking

2.3 Software Tools

The software that is used to program the microcontroller is open-source-software and can be downloaded for free on www.arduino.cc. With this "Arduino software" we can write little programs with the microcontroller. These programs are called "Sketch".In the end the sketches are transferred to the microcontroller by USB cable. More on that later on the subject "programming". [2]

- **Installation** Now one after another the Arduino software and the USB driver for the board have to be installed.

- **Installation and setup of the Arduino software**

1. We have downloaded the Arduino software from www.arduino.cc and installed it on the computer (This was NOT connected to the PC). After that we opened the software file and installed the program named arduino.exe.

Two set ups on the program are important and should be considered.

a) The board that we want to connect has to be selected on the arduino software. The “Arduino Uno” is here known as “Arduino / Genuino Uno”.

b) We have to choose the right “Serial-Port”, to let the Computer know to which port the board has been connected. That is only possible if the USB driver has been installed correctly. It can be checked this way:

At the moment the Arduino wasn’t connected to the PC. If we now choose “Port”, under the field “Tool”, we will already see one or more ports here (COM1/ COM2/ COM3…). The quantity of the shown ports doesn't depend on the quantity of the USB ports on the computer. When the board gets connected to the computer, we will find one more port.

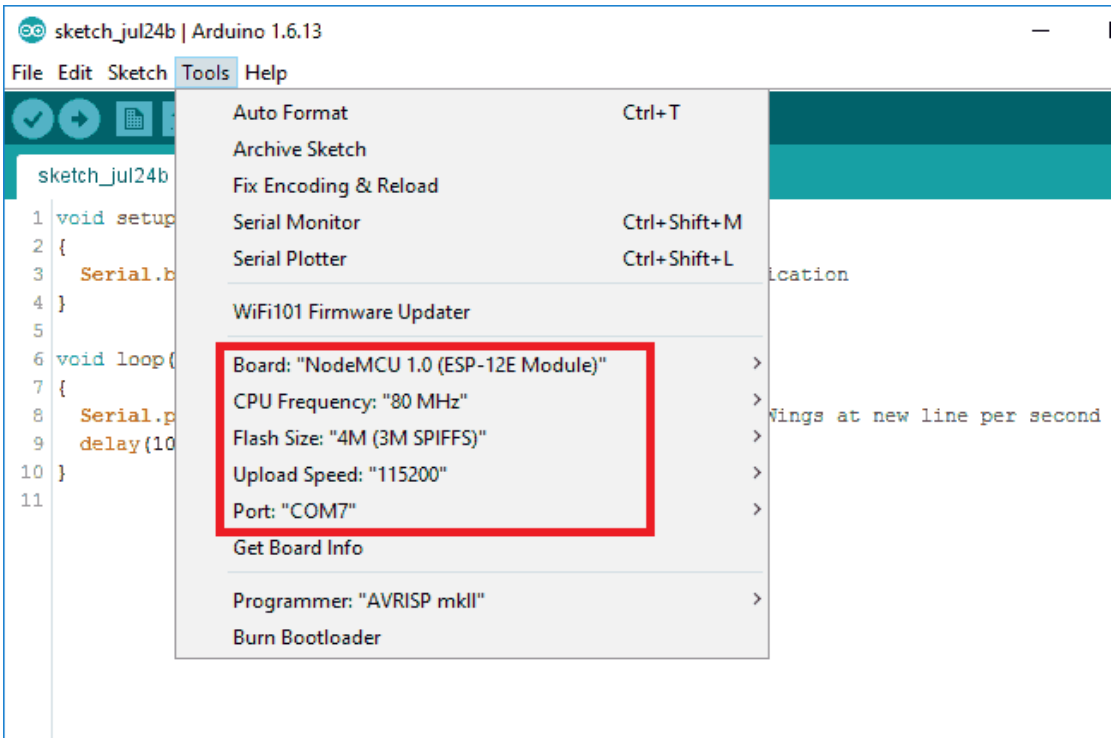


Fig- 2.5: Program Installation Process

2.4 Programming

The development cycle is divided into 4 phases:

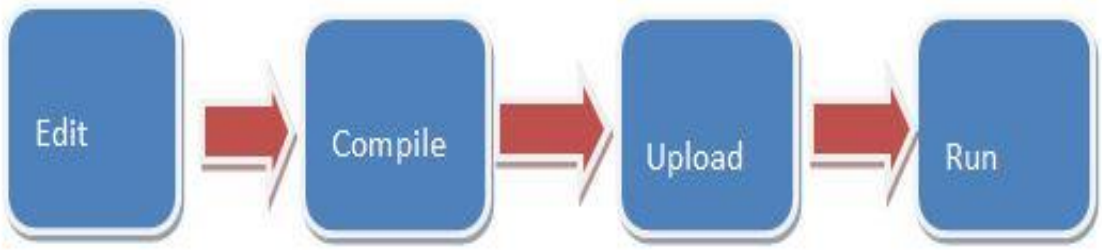


Fig-2.6: Flowchart of the Compiling Process

Compile: Compile means to translate the sketch into machine language, also known as object.
Code Run: Arduino sketch is executed as soon as terminates the step of uploading on the board.

2.5 Arduino Program Development

- Based on C++ without 80% of the instructions.
- A handful of new commands.
- Programs are called 'sketches'.
- Sketches need two functions:
- void setup ( )
- Void loop ( )
- Setup ( ) runs first and once.
- loop ( ) runs over and over, until power is lost or a new sketch is loaded.

2.6 Proposed Project in Proteus

Proteus 8 is best simulation software for various designs with microcontroller. It is mainly popular because of availability of almost all microcontrollers in it. So it is a handy tool to test programs and embedded designs for electronics hobbyist. You can simulate your programming of microcontroller in Proteus 8 Simulation Software. After simulating your circuit in Proteus 8 Software you can directly make PCB design with it so it could be a all in one package for students and hobbyists. So I think now you have a little bit idea about what is proteus software.

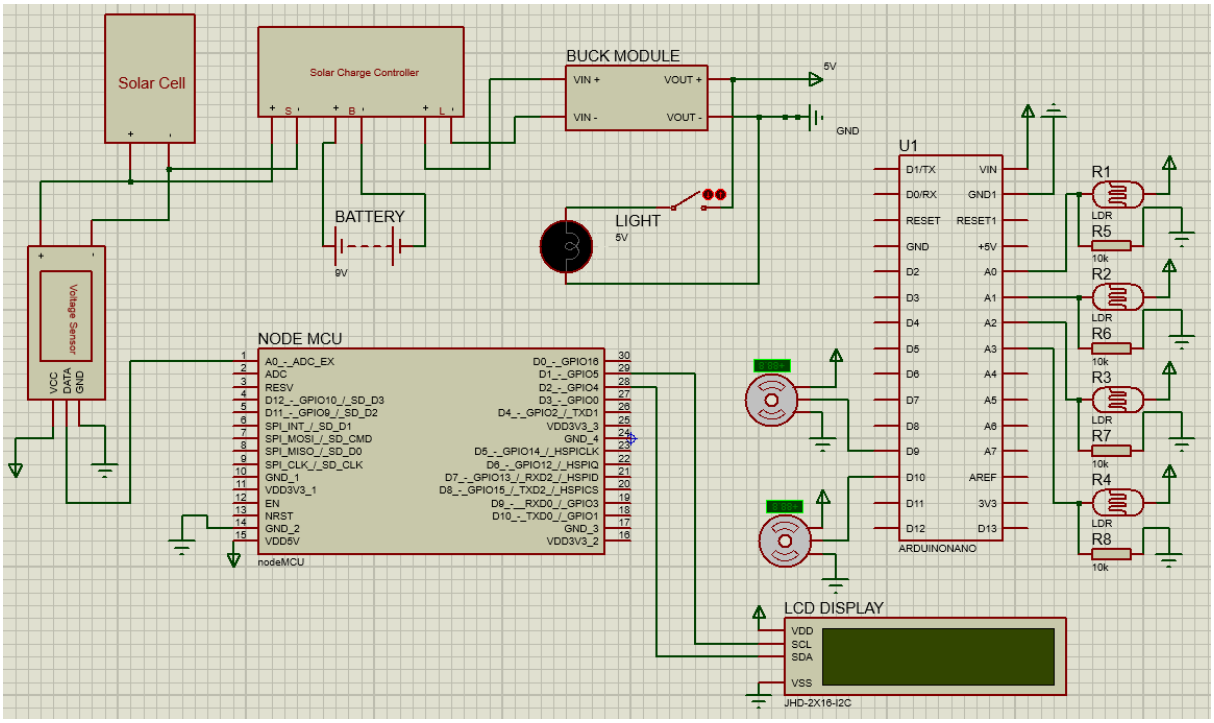


Fig-2.7: User Interface of Proteus

2.7 Literature Survey

Hossein Mousazadeh et Al.,[(2011), [3] Journal of Solar Energy Engineering,Vol.133] studied and investigated maximization of collected energy from an on-board PV array, on a solar assist plug-in hybrid electric tractor (SAPHT). Using four light dependent resistive sensors a suntracking system on a mobile structure was constructed and evaluated. The experimental tests using the sun-tracking system showed that 30% more energy was collected in comparison to that of the horizontally fixed mode.. Four LDR sensors were used to sense the direct beams of sun. Each pair of LDRs was separated by an obstruction as a shading device. A microcontroller based electronic drive board was used as an interface between the hardware and the software. For driving of each motor, a power MOSFET was used to control the actuators. The experimental results indicated that the designed system was very robust and effective.

K.S. Madhu et al., (2012) [4] International Journal of Scientific & Engineering Research vol. 3, 2229–5518, states that a single axis tracker tracks the sun east to west, and a two-axis tracker tracks the daily east to west movement of the sun and the seasonal declination movement of the sun. Concentrates solar power systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. PV converts light into electric current using the photoelectric effect. Solar power is the conversion of sunlight into electricity. Test results indicate that the increase in power efficiency of tracking solar plate in normal days is 26 to 38% compared to fixed plate. And during cloudy or rainy days it’s varies at any level.

Chapter 3 Methodology

3.1 Process of Project

The methodology for a Dual Axis Solar Tracking System Project involves a structured approach to design, develop, implement, and test a functional solar tracking system. This methodology ensures that the system is efficient, reliable, and cost-effective. Below is a step-by-step methodology that outlines the process:

1. Problem Definition and Objective Setting

Identify the Problem: Solar panels on fixed mounts cannot capture the maximum amount of sunlight because the angle of sunlight changes throughout the day and across seasons. This leads to reduced energy efficiency.

Set Objectives: The main goal of the project is to design and build a system that maximizes solar energy capture by automatically adjusting the position of the panels to track the sun's movement along both horizontal (azimuth) and vertical (elevation) axes.

2. Literature Review and Research

Review Previous Work: Analyze existing solar tracking systems, focusing on the benefits and challenges of single-axis and dual-axis trackers.

Identify Gaps: Identify gaps in efficiency, cost-effectiveness, control systems, and automation techniques from previous research. Use this knowledge to improve upon existing designs.

Technology Assessment: Research the most suitable technologies, including sensors, motors, and control systems, to be used for dual-axis tracking. This includes exploring new sensor technologies, tracking algorithms, and energy-efficient motors.

3. System Design

Mechanical Design:

Tracking Structure: Design a robust structure to support the solar panels, allowing smooth movement on two axes (horizontal and vertical).

Actuators and Motors: Select appropriate actuators and motors that can handle the load of solar panels and provide precise movements. Ensure that the motors are energy efficient to minimize power consumption.

Electrical and Control System Design:

Sensors: Incorporate sensors like light-dependent resistors (LDRs), photoresistors, or GPS sensors to detect the sun’s position in real-time. Use these sensors to feed data into the control system.

Control Algorithms: Develop or select control algorithms that will process sensor data and adjust the motor positions accordingly. Algorithms can range from basic PID (Proportional-Integral-Derivative) control to more advanced techniques like fuzzy logic or neural networks.

Microcontroller or Programmable Logic Controller (PLC): Choose a microcontroller (e.g., Arduino, Raspberry Pi) or PLC to process sensor inputs and control the movement of the motors based on the tracking algorithm.

Power System: Design a power system to operate the motors, control system, and sensors. This could involve using a small portion of the solar energy generated to power the system.

4. Prototyping

Build a Scaled Prototype: Develop a small-scale prototype of the dual-axis tracker to validate the design. This involves constructing the mechanical structure, integrating motors, sensors, and the control system.

Initial Testing: Conduct initial tests to verify that the system tracks the sun correctly, that the motors are responding to sensor inputs, and that the control algorithms are functioning as intended.

Debugging: Identify and correct any mechanical, electrical, or software issues. Adjust the design if necessary, based on testing feedback.

5. Software Development

Tracking Algorithm: Develop or refine the sun-tracking algorithm to ensure it accurately tracks the sun's movement throughout the day and adjusts for seasonal changes.

Programming: Write the software for the microcontroller or PLC that will control the system. This software will handle input from sensors, process the data, and adjust the solar panel’s position.

Testing in Simulation: Before deployment, test the control system and tracking algorithm in a simulated environment to ensure correct behavior under various conditions.

6. Full System Assembly

Mechanical Assembly: Build the full-scale mechanical structure to support the solar panels. Ensure the structure is durable, weather-resistant, and capable of withstanding the environmental conditions at the installation site.

Integration of Motors and Actuators: Install the motors and actuators that will control the azimuth and elevation movements of the solar panels.

Electrical Wiring: Connect the sensors, control system, motors, and power supply to create a fully integrated system.

Software Upload: Install the control software onto the microcontroller or PLC, ensuring that all necessary inputs and outputs are correctly connected.

7. System Testing and Calibration

Initial Calibration: Calibrate the system to ensure it correctly tracks the sun's position. This involves adjusting sensor sensitivity, motor speed, and control parameters.

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Initial Calibration: Calibrate the system to ensure it correctly tracks the sun's position. This involves adjusting sensor sensitivity, motor speed, and control parameters.

Performance Testing:

Test the system under various environmental conditions (e.g., cloudy days, sunrise, and sunset) to ensure it tracks the sun effectively.

Measure energy output from the solar panels and compare it to energy output from a fixed solar panel system to quantify the efficiency gains.

Stress Testing: Ensure the system can handle extreme weather conditions (wind, rain, dust) and operate reliably over time.

Optimization: Based on test results, fine-tune the tracking algorithm, motor control, and other parameters to improve the system's performance.

8. Implementation

Site Preparation: Prepare the installation site, ensuring it is suitable for the dual-axis tracking system. This may include laying the foundation, securing the tracking system, and setting up safety measures.

System Installation: Install the dual-axis tracking system on-site, connect it to the grid (if applicable), and ensure the entire system is operational.
Monitoring and Adjustment: Monitor the system over several weeks or months to ensure that it operates as expected. Make adjustments based on environmental factors or system performance.
9. Data Collection and Analysis
Energy Output Data: Collect data on the energy output of the dual-axis system. Compare this data to a fixed-panel setup or a single-axis tracking system to evaluate efficiency improvements.
Performance Metrics: Track performance metrics such as energy generation, motor power consumption, accuracy of sun tracking, and system downtime (if any).
ROI Analysis: Analyze the return on investment (ROI) by comparing installation and maintenance costs with the energy output gains over time.
10. Documentation and Reporting
System Documentation: Prepare detailed documentation, including system design specifications, installation guides, maintenance procedures, and software code documentation.
Final Report: Compile a project report that summarizes the design, implementation, testing, and results of the dual-axis solar tracking system. Highlight the efficiency gains, challenges faced, and future improvements that can be made.
Presentation of Findings: Present the final results and findings to stakeholders, highlighting key performance improvements and sustainability benefits.

3.2 Block Diagram of This Project

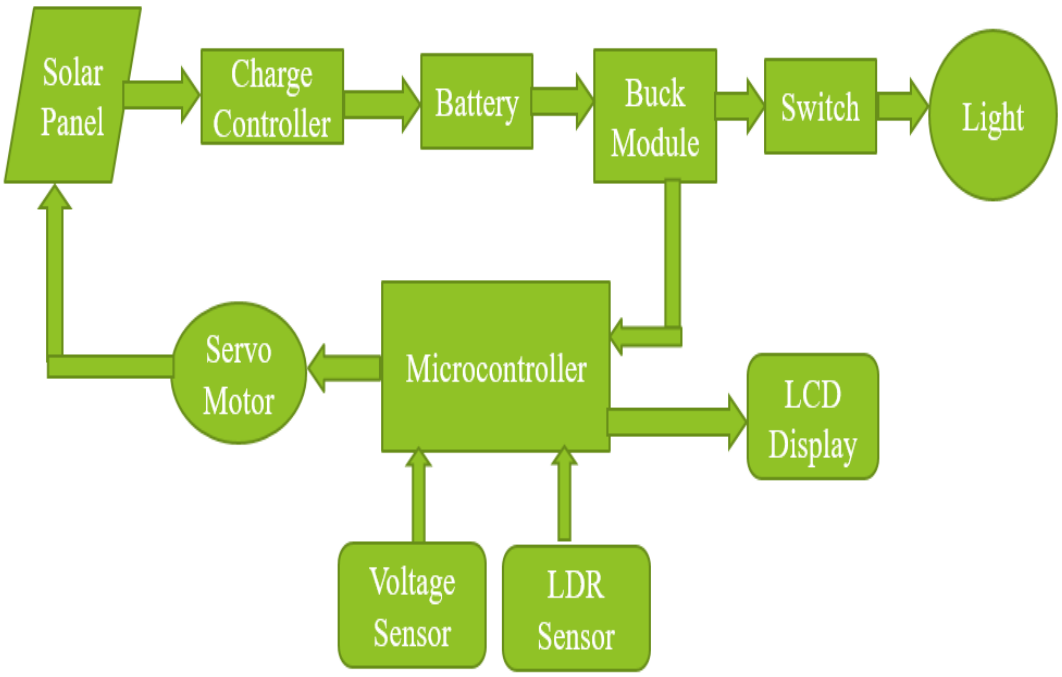


Fig-3.1: Block Diagram

3.3 Circuit Diagram of This Project

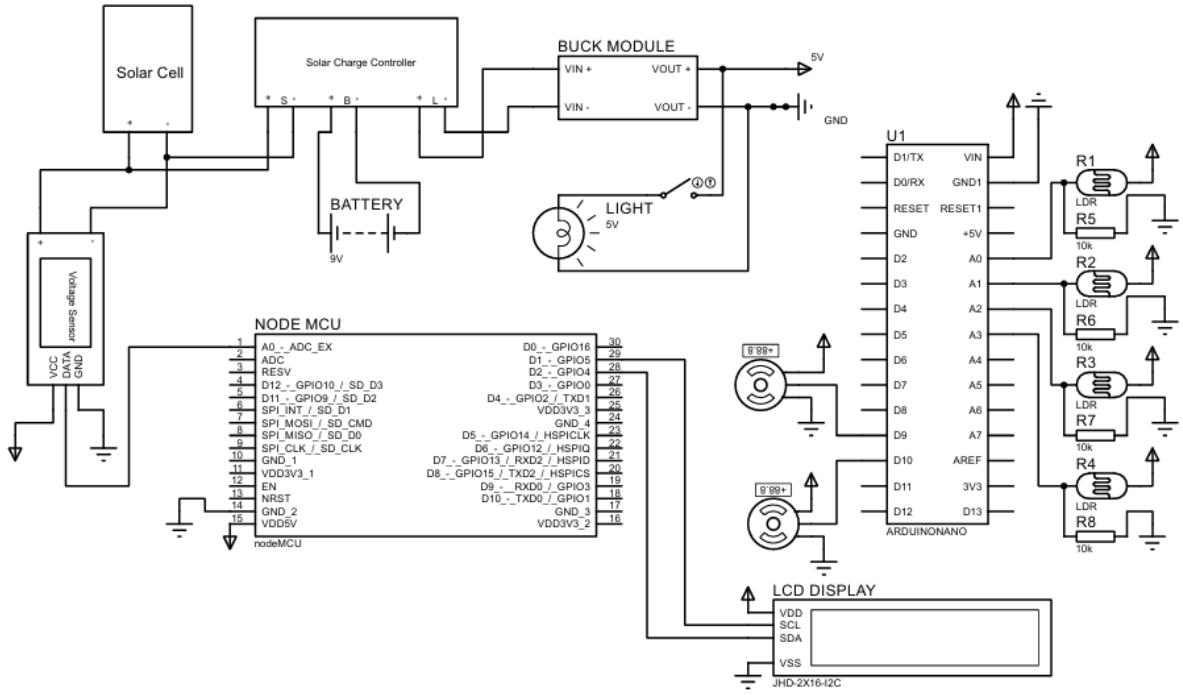


Fig-3.2: Circuit Diagram

3.5 The list of Devices used in the Project is Given Below

- Node MCU.
- Buck Module.
- Battery.
- LCD Display.
- Voltage Sensor.
- Arduino Nano.
- Solar Panel.

3.5 Node MCU

NodeMCU is an open source IoT platform.It includes firmware which runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware which is based on the ESP-12 module. The term "NodeMCU" by default refers to the firmware rather than the development kits. The firmware uses the Lua scripting language. It is based on the eLua project, and built on the Espressif Non-OS SDK for ESP8266. It uses many open source projects, such as lua-cjson and SPIFFS. [5]

3.5.1 Technical Specifications

- Power input: 4.5V ~ 9V (10VMAX), USB-powered
- Transfer rate: 110-460800bps
- Support UART / GPIO data communication interface
- Support Smart Link Smart Networking
- Working temperature: -40°C ~ + 125°C
- Drive Type: Dual high-power H-bridge
- Don’t need to download resetting
- A great set of tools to develop ESP8266
- Flash size: 4Mbyte



Fig-3.3: Node MCU

3.6 Buck Module

The LM2596 series of regulators are monolithic integrated circuits that provide all the active functions for a step-down (buck) switching regulator, capable of driving a 3-A load with [5]



Fig-3.4: LM2596 Voltage Converter

excellent line and load regulation. These devices are available in fixed output voltages of 3.3 V, 5 V, 12 V, and an adjustable output version. Requiring a minimum number of external components, these regulators are simple to use and include internal frequency compensation, and a fixed frequency oscillator. The LM2596 series operates at a switching frequency of 150 kHz, thus allowing smaller sized filter components than what would be required with lower

frequency switching regulators. Available in a standard 7-pin TO-220 package with several different lead bend options, and a 7-pin TO-263 surface mount package.

3.7 Battery

The Li-ion 18650 rechargeable battery is a widely used cylindrical lithium-ion battery that is known for its high energy density, long cycle life, and versatility in various applications. The name "18650" refers to its dimensions: 18 mm in diameter and 65 mm in length, with the zero indicating it has a cylindrical shape.The Li-ion 18650 rechargeable battery is a versatile and powerful energy source used in a wide range of applications. Its high energy density, long cycle life, and availability make it a popular choice for both commercial and DIY projects. However, due to potential safety concerns, it is important to handle and charge these batteries carefully, especially when using unprotected cells. [5]

3.7.1 Specifications

- Cell: 18650 (High quality 18650)
- Capacity: 1000mAh
- Voltage: 3.7V
- Charging Voltage: 4.2V CC/CV
- Maximal continuous charging current: 2.5A (Current can be changed according to the demand.)
- Over charge detection voltage: 4.28V ± 0.025V
- Over charge release voltage: 4.08 ± 0.025V
- Over discharge detection voltage: 3.0V ± 0.05V
- Over discharge release voltage: 3.0V ± 0.05V



Fig-3.5: Battery

3.8 LCD Display

A Liquid crystal display (LCD) is a flat display that uses the light modulating properties of liquid display. They are common in consumer devices such as video players, gaming devices, clocks, telephones, computers, calculators etc. [5]
A (16×2) LCD panel consists of 16 coulums and 2 rows. It can show upto 16 characters in 2 lines.
You may want to have a look on these similar products:
1. LCD Display 16X2 with Header soldered
2. LCD display module 16X2

3. LCD display module advanced 16X2
4. 3 wire LCD module 16X2
5. I2C LCD Display 16X2
6. Arduino LCD keypad shield
7. LCD Display (16X2)

Pin	Function
VSS	connected to ground
VDD	connected to a +5V power supply
VO	to adjust the contrast
RS	A register select pin that controls where in the LCD's memory you are writing data to. You can select either the data register, which holds what goes on the screen, or an instruction register, which is where the LCD's controller looks for instructions on what to do next.
R/W	A Read/Write pin to select between reading and writing mode
E	An enabling pin that reads the information when High level (1) is received. The instructions are run when the signal changes from High level to Low level.
D0-D7	to read and write data
A	Pins that control the LCD backlight. Connect A to 3.3v.
K	Pins that control the LCD backlight. Connect K to GND.

Table 01: LCD Display Outline

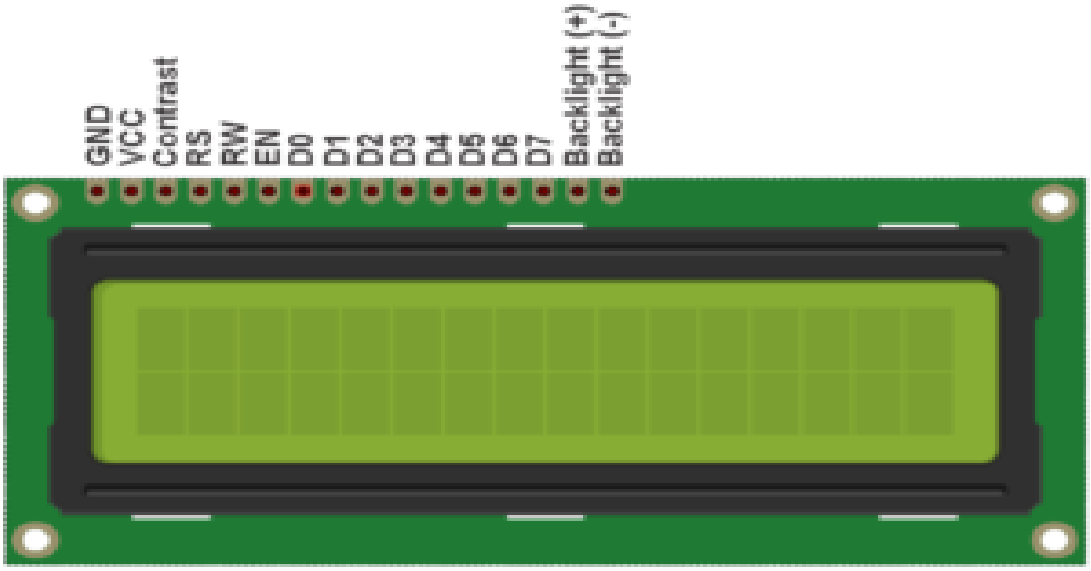


Fig-3.6: LCD Display

3.9 Voltage Sensor

The Voltage sensor can detect the supply voltage from 0.0245V to 25V. This module is based on resistor divider principle.This module allows the input voltage to reduce 5 times. As the Arduino or microcontroller analog input voltage is normally maximum 5V, the input voltage of this module can not exceed 5Vx5 which is 25V. If you give 25V DC to Vin, you will get 5V output in the 'Sig' pin. [5]

3.9.1 Feature

- Voltage input range: DC 0-25V
- Voltage detection range: DC 0.02445V-25V
- Voltage Analog Resolution: 0.00489V
- DC input connector: Terminal cathode connected to VCC, GND negative pole Output interface: "+" connect 5/3.3V, "-" connect GND, "s" connect the Arduino AD pins

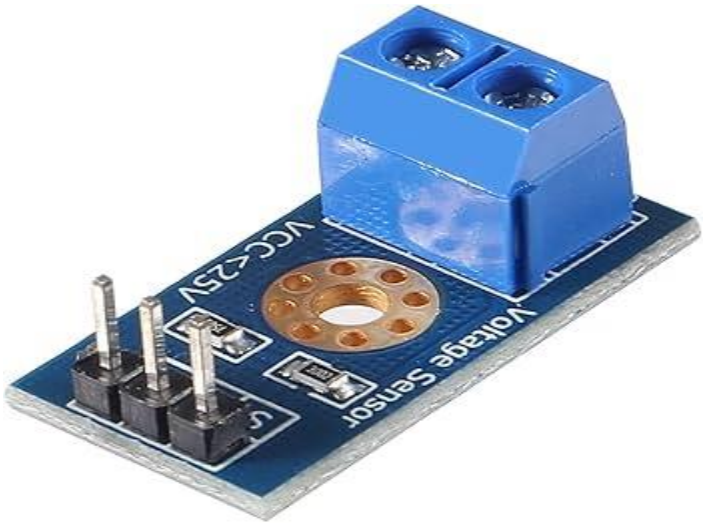


Fig-3.7: DC Voltage Sensor

3.10 Arduino NANO

The Arduino Nano is a compact, versatile, and easy-to-use microcontroller board, widely used in electronics projects and prototyping. It is built around the ATmega328 or ATmega168 microcontroller and is designed to be small, breadboard-friendly, and compatible with the Arduino programming environment. The Nano is similar in functionality to the Arduino Uno but comes in a smaller form factor, making it ideal for projects with limited space. [5]

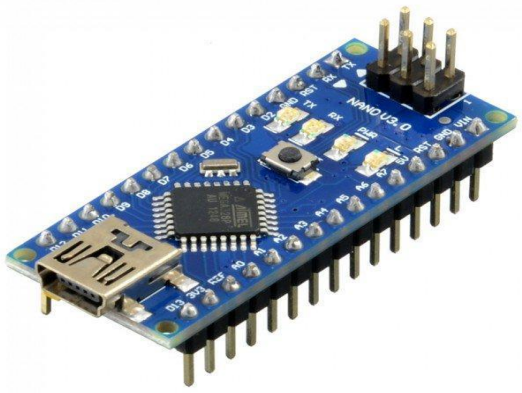


Fig-3.8: Arduino NANO

3.10.1 Specification

- Microcontroller: Atmel ATmega328
- Operating Voltage (logic level): 5V
- Input Voltage (recommended): 7-12V
- Input Voltage (limits): 6-20V
- Digital I/O Pins: 14 (of which 6 provide PWM output)
- Analog Input Pins: 8
- DC Current per I/O: Pin 40mA
- Flash Memory: 32KB (of which 2KB used by bootloader)
- SRAM: 2KB
- EEPROM: 1KB
- Clock Speed: 16MHz

3.10 Solar Panel

A mini solar panel is a small photovoltaic (PV) device that converts sunlight into electrical energy, just like larger solar panels, but on a smaller scale. Mini solar panels are typically used in low-power applications and for educational, DIY, and hobbyist projects. They are often portable, making them convenient for powering small devices or charging batteries in off-grid environments. [5]

Mini solar panels are an excellent solution for powering small, low-energy devices, charging batteries, or learning about renewable energy. Their portability and versatility make them useful in various hobbyist projects, educational settings, and portable electronics applications. Although they have limited power output, they offer a sustainable and cost-effective way to harness solar energy.



Fig-3.9: Solar Panel

3.10.1 Specification

- Size: 40x30mm
- Thickness: 2.5mm

- Max Power Rating: 0.15W
- Max Rated voltage: 3.7V
- Max Rated Current: 0-30mA
- Material: Polycrystalline
- Encapsulation: PCB + Epoxy
- Product life: 5 – 10 years
- Type: Epoxy solar panel / module

Chapter 4 Result and Discussion

4.1 Result

In this project, a dual-axis solar tracking system has been proposed. This project deals with dual-axis solar tracking to collect maximum rays using LDRs. It resolves the problem by providing an arrangement for a solar panel to track the movement of the sun on both axes. Here two DC Servo motors are used to give two types of movement i.e. horizontal axis and vertical axis directions. Motor Driver IC is arranged such that it can control both the servo motors simultaneously. Here the LDR sensors are used to sense the photovoltaic cells and analog signals are sent to the comparator where the voltage is compared and using Arduino the direction of movement is decided and it is displayed on the LCD display. The simulation conducted on a Grid-connected PV system with an electric vehicle, electric battery, and load resulted in concluding that Dual axis tracking is the best efficient method of tracking when compared to other existing sun-tracking methods thereby, increasing the output obtained. It is a low-cost system that provides better efficiency. Here the analog signals are analyzed and controlled by Arduino. This automatic system is completely programmed. The positions and amount of energy obtained at two LDRs on the same axis are compared and analyzed to decide the movement of the servo motors which moves the panel to the direction where more energy is available. It has to output visual information of the type of rotation needed an angle of rotation and inclination.

Our project is that we will generate electricity by solar panel. In addition we will monitor the voltage from the LCD display. We will also be able to control the power supply from the solay system. We will store the received power in the battery and drive the load. We are used lamps as load. [5]

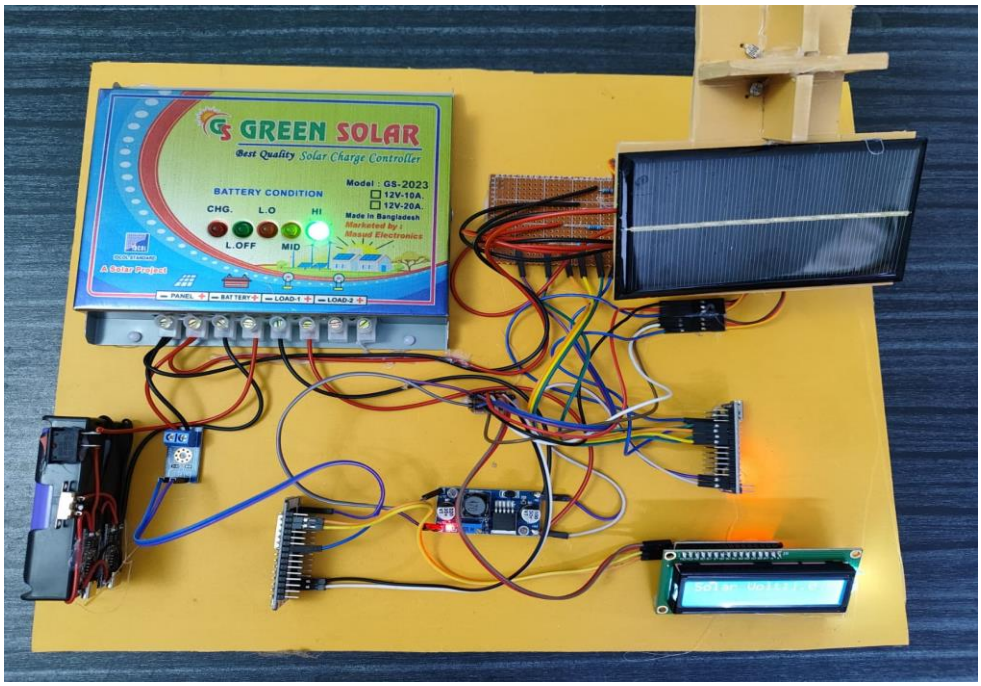


Fig-4.1: Project Picture

4.2 Discussion

This project deals with dual-axis solar tracking to collect maximum rays using LDRs. It resolves the problem by providing an arrangement for a solar panel to track the movement of the sun on both axes. With the increase of scarcity of nonrenewable resources, people are trying to identify alternate sources of energy. From all available renewable resources, solar energy is relatively easy to convert to electrical energy. The use of solar panels to convert the sun's energy to electrical energy is very popular. But due to the movement of the Sun from east to west the fixed solar panels may not be able to generate ideal energy. Hence single-axis solar tracking systems were introduced aiming to generate ideal energy. But even single-axis solar tracking has been analyzed and results show that it can track sun rays on only one axis (either north-south or east-west). Hence a prototype is constructed more efficiently to track maximum sun rays in both the axes (both north-south and east-west). It is a low-cost system that provides better efficiency. Here the analog signals are analyzed and controlled by Arduino. This automatic system is completely programmed. The energy obtained from the sun is collected using a solar panel by arranging four LDRs. The amount of energy obtained and positions at two LDRs on the same axis are compared and analyzed to decide the movement of the servo motors which moves the panel to the direction where more energy is available. It has an LCD to display the output visual information of the type of rotation needed and angle of rotation and inclination.

Our project is that we will generate electricity by solar panel. In addition we will monitor the voltage from the LCD display. We will also be able to control the power supply from the solar system. We will store the received power in the battery and drive the load. We are used lamps as load.

Chapter 5 Conclusion

5.1 Advantage

The Dual Axis Solar Tracking System offers several advantages over fixed solar panel systems. Here are the key benefits:

1. Increased Energy Efficiency

Optimal Sunlight Exposure: Dual axis trackers adjust the solar panels to follow the sun's path across the sky, maintaining an optimal angle of incidence throughout the day. This maximizes the amount of sunlight that the panels capture.

Higher Energy Output: By tracking the sun more accurately, dual-axis systems can increase energy production by 25-40% compared to fixed solar panels and 10-20% more than single-axis trackers.

2. Enhanced Performance Across Seasons

Seasonal Variations: Dual-axis trackers adjust for the sun’s changing position throughout the year, which is particularly important in regions with significant seasonal variations in the sun’s path.

Increased Winter Performance: They maintain better performance during winter months when the sun is lower in the sky.

3. Improved Low-Light Performance

Better Angle of Incidence: By adjusting the panel’s angle to the sun’s position, dual-axis trackers capture more sunlight even during early morning and late afternoon hours, and in less-than-ideal weather conditions (e.g., cloudy days).

4. Enhanced System Longevity

Reduced Shading: Better alignment reduces the risk of shading from nearby objects or structures, which can lead to improved performance and less wear on the system.

Optimized Energy Production: Consistent optimization helps in maintaining the system's efficiency over a longer period, potentially extending its operational lifespan.

5. Higher Energy Yield

Maximized Solar Exposure: The ability to track the sun on both the horizontal and vertical axes means that the panels are almost always facing the optimal angle to the sun, maximizing the amount of solar energy captured throughout the day.

6. Faster Return on Investment (ROI)

Increased Energy Generation: With higher energy production, the return on investment can be realized more quickly. This is particularly advantageous in areas with high electricity costs or where maximizing energy output is crucial.

7. Flexibility and Adaptability

Adjustable to Various Locations: Dual-axis trackers can be adapted to different geographical locations and solar radiation patterns, making them suitable for a variety of environments and applications.

Customizable Settings: Many systems offer programmable settings to adjust the tracking algorithms based on specific project requirements or environmental conditions.

8. Enhanced Grid Integration

Consistent Energy Supply: Improved energy production can lead to a more consistent and reliable energy supply, which is beneficial for grid integration and reducing dependency on fossil fuels.

9. Educational and Demonstration Purposes

Learning Tool: Dual-axis solar tracking systems serve as excellent educational tools for demonstrating the principles of solar energy and tracking technology.

Public Demonstrations: They can be used in public installations to showcase advanced solar technologies and promote renewable energy awareness.

10. Reduced Maintenance and Operational Costs

Low Maintenance: Modern dual-axis systems are designed to be robust and require minimal maintenance. High-quality components and well-designed tracking mechanisms reduce the likelihood of frequent repairs.

A Dual Axis Solar Tracking System offers significant advantages in terms of energy efficiency, increased power output, and performance optimization throughout the day and across seasons. It enhances the overall energy yield, reduces shading effects, and can provide a faster return on investment. Its flexibility and adaptability make it suitable for various applications, while also serving as a valuable educational and demonstration tool.

5.2 Application

The Dual Axis Solar Tracking System has a wide range of applications across different fields due to its ability to significantly enhance solar energy capture and efficiency. Here are some of the key applications:

1. Residential Solar Power Systems

Home Energy Generation: Dual-axis trackers can be used in residential solar power systems to maximize energy production from rooftop or ground-mounted solar panels, reducing electricity bills and increasing energy independence.

2. Commercial Solar Installations

Business Facilities: Businesses and commercial properties can benefit from dual-axis solar trackers by increasing the efficiency of their solar installations, leading to greater energy savings and a faster return on investment.

Retail and Office Buildings: Enhanced energy production can help meet the energy needs of large buildings or contribute to sustainable building certifications.

3. Utility-Scale Solar Power Plants

Large-Scale Solar Farms: In utility-scale solar power plants, dual-axis trackers are used to maximize the energy output of large arrays of solar panels. This can significantly increase the overall power generation capacity and efficiency of solar farms.

Grid Support: Higher energy yields can help support the grid and provide a more consistent power supply.

4. Agricultural Applications

Agrivoltaics: In agricultural settings, dual-axis trackers can be integrated with farming operations to provide shade for crops while simultaneously generating solar energy. This can enhance land use efficiency and improve crop yields in some cases.

Remote Water Pumping: Solar-powered water pumping systems for irrigation can be more effective with dual-axis tracking, ensuring a consistent water supply by maximizing energy generation from the solar panels.

5. Remote and Off-Grid Locations

Remote Energy Needs: In remote areas where grid access is limited or unavailable, dual-axis solar trackers can be used to provide reliable and efficient solar power for homes, research stations, and other off-grid applications.

Emergency and Backup Power: They can also be employed in emergency power systems to provide backup energy during outages or in disaster-stricken areas.

6. Educational and Research Institutions

Demonstration Projects: Dual-axis solar trackers are valuable for educational institutions and research facilities for demonstrating solar tracking technology and renewable energy principles.

Research and Development: They can be used in R&D projects to study the performance of different solar tracking mechanisms and their impact on energy efficiency.

7. Public and Commercial Buildings

Solar-Powered Attractions: Public buildings, parks, and attractions can use dual-axis trackers to power lighting, interactive displays, and other features, contributing to sustainable public spaces.

Transport Infrastructure: Solar tracking systems can be used to power streetlights, signs, and other infrastructure in transport systems.

8. Solar-Powered Vehicles

Electric Vehicles (EVs): Dual-axis trackers can be used in solar-powered vehicles or charging stations to optimize the energy capture and improve the efficiency of solar-assisted EV systems.

Solar Boats and Drones: They can also be employed in solar-powered boats and drones to maximize energy capture and extend operational time.

9. Experimental and Prototype Systems

Technology Testing: Dual-axis tracking systems are often used in experimental setups and prototypes to test new technologies and innovations in solar tracking and energy capture.

The Dual Axis Solar Tracking System is versatile and can be applied in various domains, including residential and commercial solar power, utility-scale solar farms, agriculture, remote energy needs, education, public infrastructure, and solar-powered vehicles. Its ability to significantly enhance solar energy capture and efficiency makes it valuable in both practical applications and research environments.

5.3 Future Scope

The Future Scope of the Dual Axis Solar Tracking System project includes several potential advancements and applications that can enhance its performance, cost-effectiveness, and integration with emerging technologies. Here's a look at some promising areas for future development:

1. Integration with Smart Grids

Demand Response: Dual-axis solar tracking systems can be integrated with smart grids to optimize energy distribution based on real-time demand and supply conditions.

Energy Storage: Improved integration with energy storage solutions, such as batteries, to store excess energy generated during peak sunlight hours for use during low-light periods or peak demand times.

2. Advanced Tracking Algorithms

AI and Machine Learning: Implementing artificial intelligence (AI) and machine learning algorithms to enhance tracking precision and efficiency. These technologies can predict solar movement more accurately and adapt to changing weather conditions.

Predictive Maintenance: Using AI for predictive maintenance to forecast potential system failures and optimize maintenance schedules.

3. Improved Materials and Designs

Lightweight Materials: Development of lighter and more durable materials for trackers to reduce costs and improve ease of installation and maintenance.

Flexible and Thin-Film Panels: Integration with advanced flexible or thin-film solar panels that can adapt to various shapes and surfaces, improving the versatility of dual-axis systems.

4. Cost Reduction

Manufacturing Advances: Innovations in manufacturing techniques to reduce the cost of dual-axis tracking systems, making them more accessible for residential and small-scale commercial applications.

Economies of Scale: Larger-scale production and installation could lower costs and improve the economic feasibility of dual-axis trackers.

5. Enhanced Automation and Control

Autonomous Operation: Further automation of tracking mechanisms to reduce the need for human intervention and improve reliability.

Real-Time Monitoring: Development of advanced monitoring systems that provide real-time data on system performance, energy output, and maintenance needs.

6. Integration with Other Renewable Energy Sources

Hybrid Systems: Combining dual-axis solar tracking with other renewable energy sources, such as wind turbines or biomass, to create hybrid energy systems that optimize overall energy production.

Energy Management Systems: Integrating with comprehensive energy management systems to optimize energy production and usage across multiple renewable sources.

7. Application in Emerging Technologies

Vertical and Building-Integrated Photovoltaics: Applying dual-axis tracking technology to vertical solar panels or building-integrated photovoltaics (BIPV) to improve energy capture in urban environments.

Mobile and Transport Applications: Expanding the use of dual-axis trackers in mobile applications, such as solar-powered vehicles, drones, and other transport systems.

8. Environmental and Aesthetic Considerations

Sustainable Practices: Designing systems with environmentally friendly materials and processes to minimize their carbon footprint and environmental impact.

Architectural Integration: Developing aesthetically pleasing dual-axis trackers that blend seamlessly with building designs and urban landscapes.

9. Global Expansion

Developing Regions: Increasing deployment in developing regions with high solar potential but limited access to energy, providing reliable and sustainable power solutions.

Adaptation to Local Conditions: Customizing systems to suit specific geographic and climatic conditions, enhancing performance and reliability in diverse environments.

10. Educational and Outreach Initiatives

Awareness Programs: Expanding educational programs and outreach initiatives to promote the benefits of dual-axis solar tracking systems and renewable energy technologies.

Research Collaborations: Encouraging partnerships between research institutions, industry leaders, and policymakers to drive innovation and adoption of advanced solar tracking technologies.

5.4 Conclusion

In order to produce electricity, dual axis solar trackers constructed of monocrystalline are mounted to follow the sun's rays in all directions with the highest intensity. It is the cheapest method of energy conversion compared to other systems. Dual axis solar tracking systems are more efficient and produce more energy than fixed and single axis sun tracking systems, as shown by the comparison of the two types of solar tracking systems in this article.

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