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SOLAR POWER MONITORING AND MANAGEMENT USING IOT

Srimanya.S[1], Adhiselvam.A[2]

Department. of Information Technology, Dr N.G.P Arts and Science College, Coimbatore, Tamil Nadu, India.[1]

Professor & Head, Department of Information Technology, Dr N.G.P Arts and Science College, Coimbatore, Tamil Nadu, India.[2]

Abstract: The goal of this project is to improve efficiency and dependability by managing and monitoring solar energy characteristics in real time. The system monitors important solar metrics including light intensity, voltage, and current using the ESP32 microcontroller, which has integrated WiFi and energy efficiency. To ensure accurate data gathering, a voltage sensor keeps an eye on the solar panels' output voltage while the ACS712 current sensor measures the current produced by the panels. Through the processing and wireless transmission of this data by the ESP32, customers can utilize a mobile application to track solar performance in real time. One noteworthy aspect is the automated light control system, which maintains constant illumination by turning on an artificial light source when the solar voltage drops below a predetermined threshold. Even in a variety of environmental circumstances, its feature guarantees dependable operation. Applications such as real-time solar power monitoring, renewable energy management, and smart lighting systems are ideal for the suggested system. This project optimizes energy consumption and supports consistent illumination by providing a cost-effective, efficient, and sustainable method of controlling solar power. This helps to improve the use of renewable resources and make smarter energy consumption decisions.

Keyword: Green energy, IOT, Remote storage, Solar panels, Real-time monitoring, solar panel

I. INTRODUCTION

This project presents a cutting-edge system for real-time solar energy monitoring and management within the framework of developing renewable energy technologies. The system precisely measures vital solar factors including light intensity, voltage, and current by utilizing the ESP32 microcontroller, which has integrated WiFi and energy-saving features. The gathered data is wirelessly sent to an intuitive mobile application by integrating sensors such as the ACS712 for current measurement and a voltage sensor for output monitoring. The system's automated lighting control, which turns on artificial light when solar voltage falls below a predetermined threshold, is one of its best features. It guarantees continuous illumination. Reliability is improved by this process in a variety of environmental circumstances. With uses including real-time solar monitoring, smart lighting, and renewable energy management, this affordable solution encourages efficient energy use and aids with sustainability initiatives. It offers increased efficiency and more intelligent usage, demonstrating a progressive approach to the use of renewable energy.

II. FIELD OF THE PROJECT

By enabling smooth connectivity and data sharing between devices, as well as remote monitoring and control, the Internet of Things (IoT) has completely changed daily life. In order to ensure effective performance, well-informed decision-making, and operational reliability, IoT devices use sensors to gather data on physical objects and environments in real-time.

Direct beam sunlight accounts for 90% of solar energy, whereas diffuse sunlight makes up the remaining 10%. Given that the direct beam's contribution diminishes with the cosine of the angle to the panel surface, it is imperative to arrange solar panels optimally to optimize energy absorption. By offering real-time data for better management, IoT solutions improve solar energy systems, allowing for increased sustainability and efficiency.

III. LITERATURE SURVEY

The increasing global demand for renewable energy sources has led to extensive research on solar energy monitoring and management systems. Several studies have explored the integration of IoT, automation, and sensor-based technologies to enhance solar energy utilization. This literature survey highlights relevant research and advancements in the field of solar parameter monitoring and intelligent lighting control.

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1. Solar Energy Monitoring Systems
Several research studies have focused on real-time monitoring of solar energy parameters such as voltage, current, and light intensity. In a study by **A. Gupta et al. (2020)**, an IoT-based solar power monitoring system was developed using sensors and cloud-based platforms for data visualization. The study emphasized the importance of real-time monitoring for improving solar panel efficiency and energy management. Similarly, **R. Sharma et al. (2021)** proposed a system using ESP8266 for remote solar data transmission, demonstrating the benefits of wireless monitoring.

2. Bluetooth-Based Monitoring and IoT Applications
Wireless communication technologies, such as Bluetooth and Wi-Fi, have been widely used for real-time data transmission in energy monitoring systems. **K. Patel et al. (2019)** presented a Bluetooth-based solar tracking system where an ESP32 microcontroller transmitted real-time data to a mobile application. Their findings showed that Bluetooth-based monitoring provides a low-power and cost-effective solution for local data transmission without requiring an internet connection.

3. Automatic Light Control Using Renewable Energy
Automated lighting control based on solar energy availability has been explored in smart lighting systems. **M. Singh et al. (2020)** designed an intelligent street lighting system that activated artificial lights when solar power generation dropped. The study concluded that automation in lighting control reduces energy wastage and enhances sustainability. Another study by **L. Wang et al. (2022)** introduced an AI-based lighting system that dynamically adjusted brightness based on ambient light levels, further improving energy efficiency.

4. Challenges and Future Developments
Despite advancements, several challenges remain in solar energy monitoring and control. Sensor accuracy, environmental variations, and data transmission reliability are key factors affecting system performance. Researchers are exploring **machine learning algorithms** to predict solar power generation and optimize energy usage. Future developments may include **hybrid communication methods** combining Bluetooth, Wi-Fi, and cloud integration for enhanced monitoring capabilities.

IV. BLOCK DIAGRAM

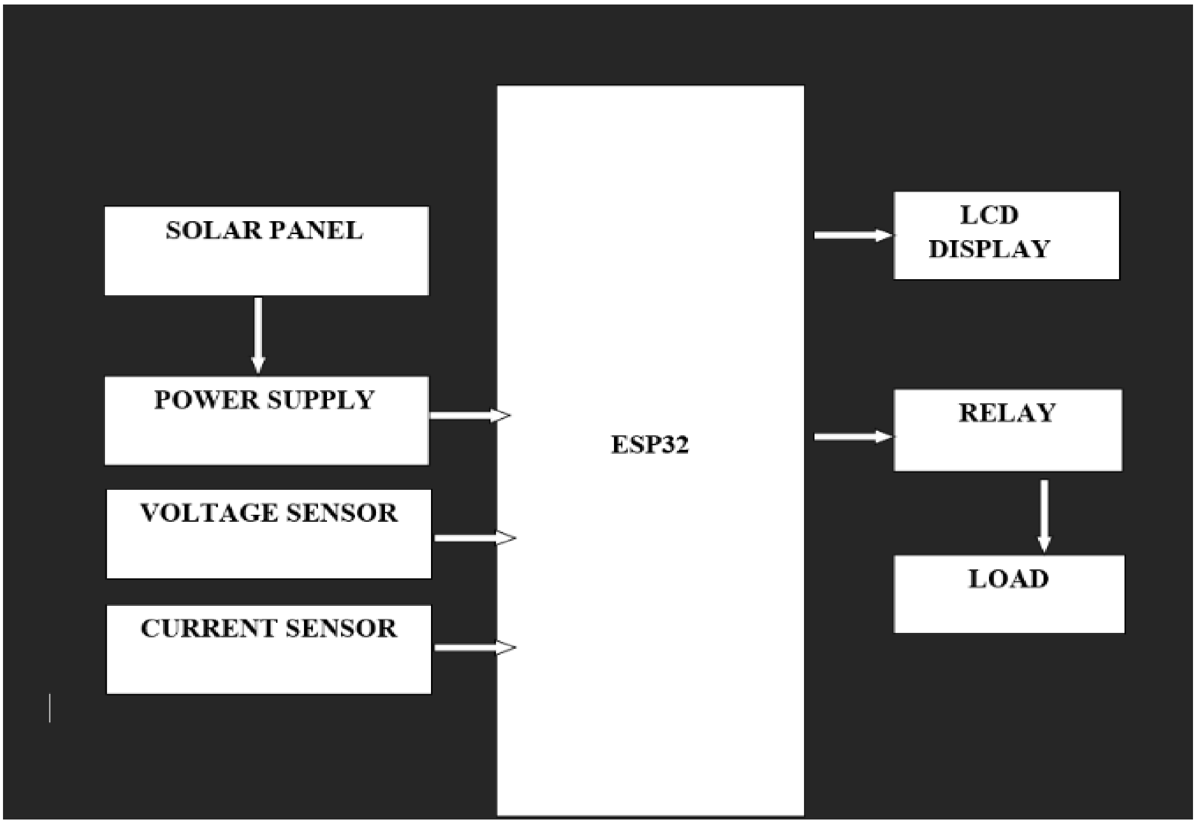

Fig 1: Block diagram

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V. CIRCUIT DIAGRAM

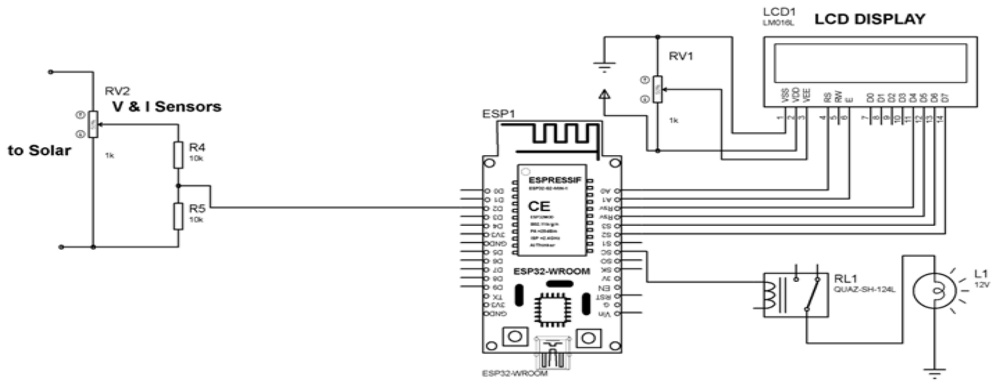

Fig 2: Circuit diagram

VI. WORKING PRINCIPLE

The solar parameter monitoring and light control system operates by continuously measuring solar energy parameters and making real-time decisions to optimize energy utilization. The system consists of sensors for light intensity, voltage, and current measurement, an ESP32 microcontroller for processing data, and a Bluetooth module for wireless communication.

1. Sensor Data Acquisition
- The **ACS712 current sensor** monitors the current generated by the solar panel, providing insights into the power output.
- A **voltage sensor** measures the voltage generated by the solar panel, ensuring efficient monitoring of solar energy production.

2. Data Processing and Transmission
- The ESP32 microcontroller collects data from all sensors, processes it, and transmits it via WiFi.
- Users can access real-time solar energy parameters on a mobile application

3. Automatic Light Control
- If the **solar voltage** falls below a predefined threshold (indicating insufficient sunlight or power generation), the ESP32 activates an external light source.
- When the solar voltage is sufficient, the artificial light is automatically turned off to conserve energy.

4. Wireless Communication and Monitoring
- The ESP32 sends sensor data via WiFi, allowing users to remotely monitor solar energy performance

IoT-Driven Solar Energy Optimization and Management

This project integrates IoT with renewable energy systems to monitor and manage solar power effectively. It uses voltage and current sensors to measure the output of a solar panel. An ESP32 microcontroller, programmed using Arduino code, processes the sensor data and controls a relay that indicates the panel's performance. If the voltage falls below a predetermined level, the relay activates, turning on an indicator light; otherwise, the relay turns off. The system includes an LCD for displaying real-time data locally and uploads the data to ThinkSpeak for remote monitoring and analytics.

The design emphasizes smart energy management by combining hardware, software, and IoT platforms. The use of Arduino coding ensures flexibility and ease in programming. The system's ability to monitor energy levels and send data to the IoT platform demonstrates its suitability for remote applications, such as monitoring solar panels in rural areas or harsh environments. This project can serve as an educational tool for understanding renewable energy concepts, IoT integration, and real-time data analytics. Additionally, it promotes sustainable practices by showcasing the efficient utilization of solar power.

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HARDWARE REQUIREMENTS

Solar panel:
Solar energy refers to the power produced by harnessing sunlight, serving various residential and commercial needs. The sun acts as a natural nuclear reactor, emitting energy in the form of tiny particles known as photons. When these photons strike solar cells, they cause atoms to release electrons, enabling the generation of electricity. A solar panel comprises several interconnected panels, and the greater the number of panels, the higher the electricity output. Solar panels generate energy in the form of Direct Current (DC).

Fig 3: solar panel

Power supply:
A battery is a portable power source that converts stored chemical energy into electrical energy through reactions within its cells. It consists of an anode, cathode, and electrolyte, generating current when connected to a circuit. Batteries are versatile, reliable, and widely used for powering devices in various applications.

Voltage sensor:
A voltage sensor plays a crucial role in a solar power monitoring system by measuring the output voltage of solar panels. This data helps assess the performance of the panels and ensures optimal energy generation. By tracking voltage levels, the sensor can detect fluctuations or inefficiencies, enabling timely adjustments to improve system efficiency. Additionally, voltage sensors contribute to automated processes, such as activating external lighting when solar voltage drops below a predefined threshold, ensuring consistent operation in varying conditions.

Fig 4: Voltage sensor

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ACS712 Current sensor:
Electricity revolutionized human life, powering devices and simplifying tasks. The flow of charge, known as current, varies by device requirements, with sensitive devices at risk of damage from excessive current. Current measurement is essential for proper device functioning, requiring sensors like the ACS712 Current Sensor. ACS712, a Hall-effect-based linear sensor IC, measures current without impacting system performance. It features 2.1kV RMS voltage isolation and a low-resistance current conductor. While voltage measurement is passive and straightforward, current measurement is intrusive, necessitating sensors due to its indirect nature. The ACS712 helps prevent overload by accurately monitoring current flow, ensuring device safety and reliability.

Fig 5: ACS712 Current sensor

ESP32:
The ESP32-CAM is a low-cost IoT development board featuring the ESP32-S microcontroller with WiFi and Bluetooth support. It is popular for IoT and machine vision applications due to its onboard camera module (OV2640), MicroSD card slot (up to 4G), and external 4MB PSRAM. It requires additional hardware for programming (e.g., FTDI programmer or Arduino UNO) due to the absence of a conventional USB port.

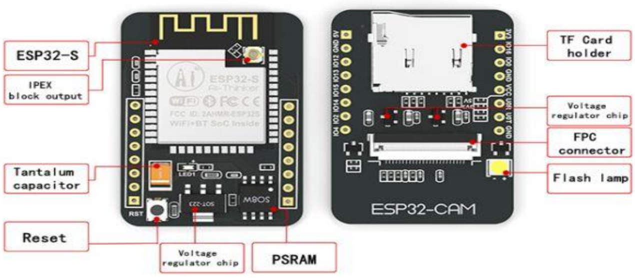

Fig 6: what's on board

Arduino UNO:
the Arduino UNO board, the most popular and beginner-friendly Arduino board, ideal for learning electronics and coding. While various Arduino boards differ in features like input/output capabilities, speed, and form factor, all are programmable using the Arduino IDE. Some boards require external programming hardware, and power requirements vary between boards.

Arduino Overview: Arduino is an open-source prototype platform combining programmable circuit boards (microcontrollers) with user-friendly software (Arduino IDE). Key features include:

- Reading analog/digital signals and producing outputs (e.g., motor control, LED operations).
- Programming via simplified C++ in the Arduino IDE, using a USB cable (no external programmer needed).
- A standardized form factor for easier integration.

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Fig 7: Arduino UNO board

LCD display:
There are many display devices used by the hobbyists. LCD displays are one of the most sophisticated display devices used by them. Once you learn how to interface it, it will be the easiest and very reliable output device used by you! More, for micro controller based project, not every time any debugger can be used. So LCD displays can be used to test the outputs.

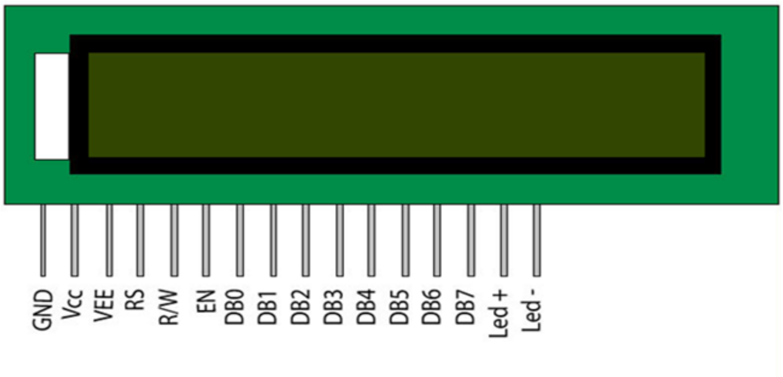

Fig 8: Pin diagram of LCD display

Relay:
A relay is an electrical switch that opens and closes under the control of another electrical circuit. In the original form, the switch is operated by an electromagnet to open or close one or many sets of contacts. It was invented by Joseph Henry in 1835. Because a relay is able to control an output circuit of higher power than the input circuit, it can be considered to be, in a broad sense, a form of an electrical amplifier

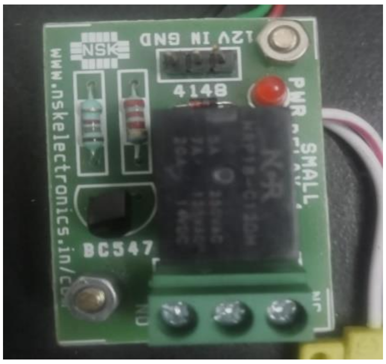

Fig 9: Relay

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SOFTWARE REQUIREMENTS

Arduino IDE:

Arduino IDE (Integrated Development Environment) is the software platform used to write, compile, and upload code to Arduino boards and compatible microcontrollers like ESP32. It's beginner-friendly and supports the C and C++ programming languages with additional Arduino-specific libraries. The IDE provides a simple interface for coding, debugging, and uploading sketches (programs) to your microcontroller. It also includes features like serial monitor support for real-time debugging and communication.

Thing speak IoT Server

- Thing Speak is an open data platform for the Internet of Things. Your device or application can communicate with Thing Speak using a RESTful API, and you can either keep your data private, or make it public. In addition, use Thing Speak to analyze and act on your data. Thing Speak provides an online text editor to perform data analysis and visualization using MATLAB®. You can also perform actions such as running regularly scheduled MATLAB code or sending a tweet when your data passes a defined threshold. Thing Speak is used for diverse applications ranging from weather data collection and analysis, to synchronizing the colour of lights across the world.

- At the heart of Thing Speak is a time-series database. Thing Speak provides users with free time-series data storage in channels. Each channel can include up to eight data fields. This tutorial provides an introduction to some of the applications of Thing Speak, a conceptual overview of how Thing Speak stores time-series data, and how MATLAB analysis is incorporated in Thing Speak.

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