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IOT BASED SOLAR PANNEL EFFICIENCY MONITORING SYSTEM

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Abstract *-The growing demand for clean and sustainable energy has accelerated the adoption of solar power systems across residential, commercial, and industrial sectors. However, the performance of solar panels varies depending on environmental and operational factors such as temperature, irradiance, shading, and load conditions. To overcome these challenges, an IoT-based monitoring system is designed to observe and analyze key performance parameters of a solar panel in real time.*
The proposed system continuously measures voltage, current, power output, panel temperature, and light intensity, enabling proactive maintenance and efficient utilization of generated energy. The hardware setup consists of an ESP32 microcontroller, along with dedicated sensors for current, voltage, temperature, and irradiance, and an LCD display for local data visualization. The system ensures prompt detection of performance deviations, thereby improving reliability, enhancing efficiency, and supporting better energy management.

Keywords: *IoT-based Solar Monitoring, Solar Panel Efficiency, ESP32 Monitoring System, Renewable Energy.*

I. INTRODUCTION

With the rapid increase in global electricity demand and the need to reduce carbon emissions, solar power has emerged as one of the most promising renewable energy resources. Solar photovoltaic (PV) systems convert sunlight into electrical energy, serving as a sustainable alternative for various applications. However, the actual efficiency of solar panels is influenced by factors such as temperature rise, dust accumulation, shading, light intensity variations, and environmental conditions.

These variations can significantly reduce the output of the system if not monitored properly. Therefore, real-time monitoring plays a crucial role in diagnosing issues, optimizing performance, and ensuring the reliability of solar installations.

Recent advancements in the Internet of Things (IoT) have enabled remote monitoring, data logging, and intelligent decision-making in renewable energy systems. By integrating IoT technology with sensors and microcontrollers, solar panel parameters can be continuously tracked and analyzed, helping users identify faults, understand energy usage patterns, and plan maintenance more effectively.

II. METHODOLOGY

An The methodology adopted for the development of the IoT-based solar monitoring system includes the selection, integration, and programming of hardware and software components. The major steps are:

1. Component Selection

Appropriate sensors such as voltage sensors, current sensors, temperature sensors, and light intensity sensors are chosen to measure respective parameters accurately. An ESP32 microcontroller is selected for its built-in Wi-Fi and Bluetooth features, enabling seamless IoT connectivity.

2. System Integration

The sensors are interfaced with the ESP32, and an LCD display is connected to provide real-time local readings. The collected sensor data is transmitted wirelessly to the cloud using IoT

3. Software Development

Firmware is developed to read sensor values, calculate power, and transmit data securely. The Blynk or web dashboard is programmed to visualize the parameters in graphs and gauges.

4. Real-Time Monitoring & Alerts

The system continuously monitors solar panel parameters and triggers alerts in case of abnormal readings such as overheating, low irradiance, or sudden drops in power output.

5. Testing & Validation

The complete setup is tested under different environmental conditions to verify accuracy, reliability, and responsiveness. The results are compared with theoretical values to ensure proper functioning.

This methodology ensures a robust monitoring solution capable of improving system efficiency and minimizing maintenance downtime.

III. HARDWARE DESCRIPTION

ESP32 Microcontroller

The ESP32 is a powerful low-power microcontroller designed for IoT applications. It supports Wi-Fi and Bluetooth connectivity, making it suitable for remote monitoring applications. With features like dynamic power scaling, multiple sleep modes, and high processing capability, it efficiently handles data acquisition, processing, and wireless communication.

Voltage Regulator (7805)

To provide a stable and regulated 5V output, a 7805 linear voltage regulator is used. It protects the components from voltage fluctuations and ensures consistent power supply.

Load (Sensor/Transducer)

The load cell converts force into an electrical signal, allowing measurement and standardization of load variations. The system can use strain-gauge-based load sensors for accurate measurement.

Temperature Sensor

The temperature sensor monitors the surface temperature of the solar panel. Since panel efficiency decreases with temperature rise, this measurement helps evaluate thermal loss and performance degradation.

Voltage Sensor

The voltage sensor records the output voltage from the solar panel, battery, and load. This information helps calculate power generation and detect abnormalities.

Light Sensor

The light sensor (e.g., LDR or photodiode) measures solar irradiance falling on the panel. This helps identify shading issues and variations in sunlight intensity.

Solar Panel

The solar panel converts sunlight into electricity using semiconductor PV cells. It serves as the primary energy source for the system.

LCD Display

The LCD is used to display real-time values of voltage, current, power, temperature, and light intensity. It allows users to monitor the system locally without requiring a mobile device.

IV. OUTPUT

The implemented system successfully monitored solar panel parameters in real time using the ESP32 module and connected sensors. The data was visualized on the Blynk mobile application and web portal, enabling users to track performance remotely.

The hardware output confirmed that measured values including voltage, current, temperature, and irradiance were accurately displayed on the LCD. The graphical interface on the mobile app provided a clear representation of system behavior during different times of the day.

This validates the effectiveness of IoT-enabled monitoring in optimizing solar panel efficiency and identifying issues promptly

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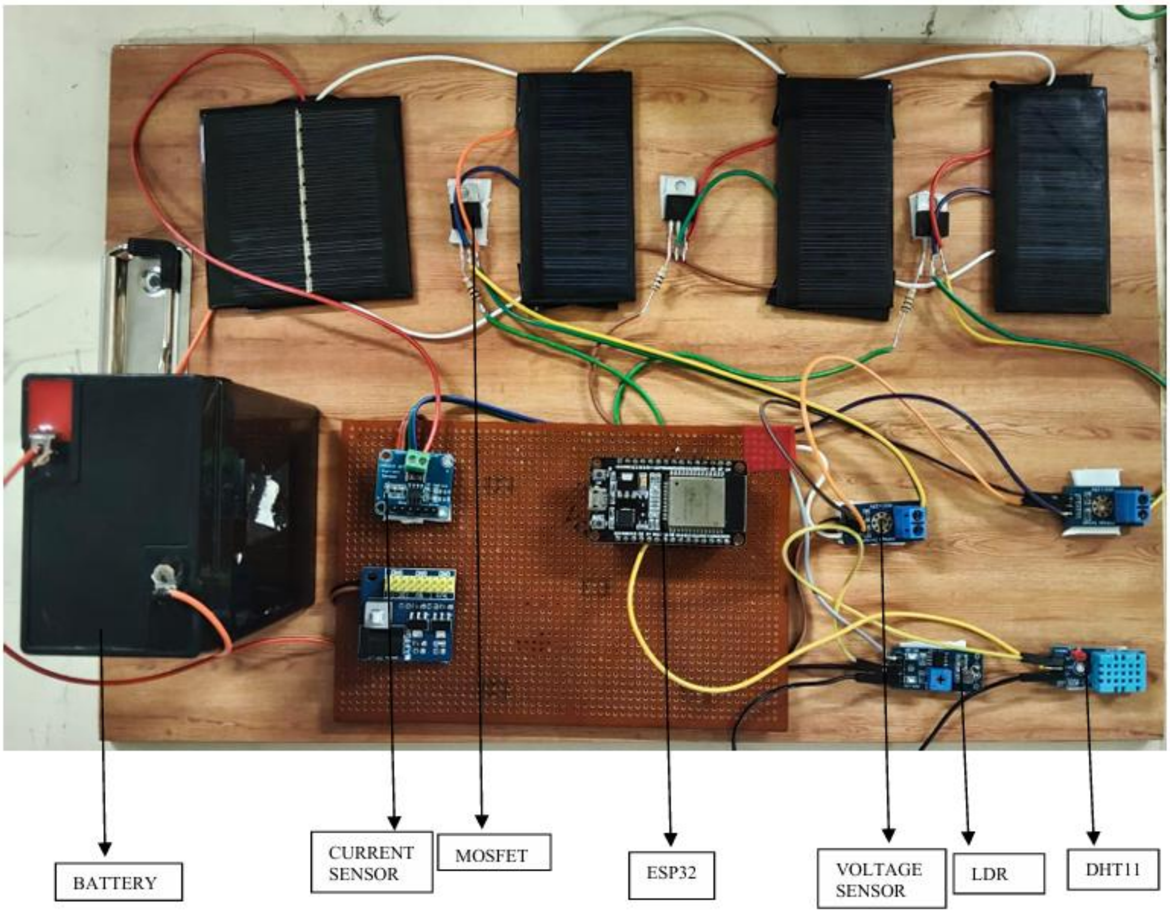

Fig.1 : Hardware output of Solar Pannel Monitoring System

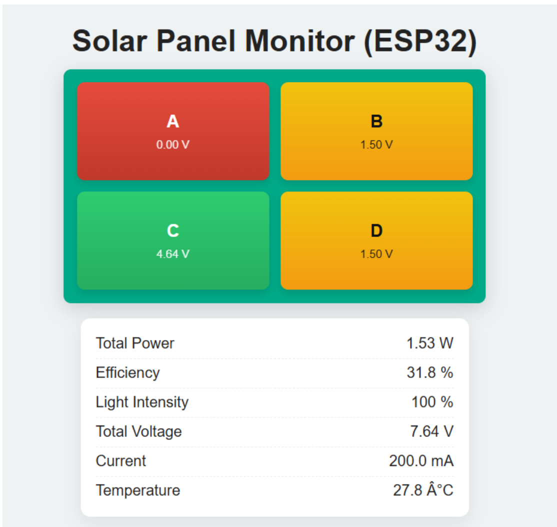

Fig.2 : Web-Application output of Solar Pannel Monitoring System

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V. CONCLUSION

The IoT-based solar panel monitoring system provides an efficient, cost-effective, and reliable solution for tracking the performance of solar installations. By continuously measuring key parameters, the system helps users understand energy generation trends, detect faults early, and plan maintenance effectively.

The integration of ESP32 with various sensors and cloud platforms enables remote access and real-time analysis, improving overall system efficiency and extending the lifespan of solar panels. Additionally, the system supports sustainable energy management by enabling data-driven decision-making and reducing energy wastage.

Going forward, the system can be enhanced by integrating features such as predictive analytics, machine learning-based fault detection, automatic cleaning systems, and solar tracking mechanisms for further performance improvement.

VI. ACKNOWLEDGEMENT

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