IJRTSM

INTERNATIONAL JOURNAL OF RECENT TECHNOLOGY SCIENCE & MANAGEMENT

"IOT BASED SOLAR POWER MONITORING SYSTEM"

Durgesh Lodhi [1], Rupesh Chidar [2], Navin Jhade [3], Harbhajan Marko [4], Samrat Ghosh [5]

[1-5] *Department of Electronics & Communication Engineering Sagar Institute of Science, Technology and Research, Bhopal. M.P. (India)*

durgeshlodhi7974@gmail.com, deepeshchidar0a@gmail.com, sjhadenavin@gmail.com,markoharbhajan@gmail.com

ABSTRACT

Presently, we are entering a new period of modernism, namely the Internet of Things (IoT). By using IoT, supervising solar energy can greatly enhance the performance and monitoring of power plants. This system serves as a technique to keep track of parameters such as dust accumulation on solar panels to ensure maximum power induction for active utilization. The system monitors panel load using IoT technologies and transmits data to the cloud via the internet for future use, facilitating fault detection and preventive maintenance. The primary purpose of this paper is to enable solar panels to capture maximum radiation and maintain the system reliably and efficiently.

Key Words: Internet of Things (IoT), ESP32 Microcontroller, Solar Power Monitoring, Renewable Energy, Sensors, Cloud Computing.

I. INTRODUCTION

The Internet of Things (IoT) is a critical technology that enables connections between machines and the cloud to exchange data over a network. In this project, we monitor voltage, current, temperature, and sunlight intensity using various sensors connected to an ESP32 microcontroller. Real-time statistics are displayed on a 16X2 LCD and uploaded to an Arduino cloud server. As solar radiation varies by location, time, and climate, constant monitoring is necessary to optimize performance. This project provides an automated, efficient approach to replace manual monitoring, allowing for global data access and control.

II. LITERATURE REVIEW

Current research in IoT-based solar monitoring focuses on several critical areas:

- **Remote Monitoring and Management:** IoT enables remote tracking of parameters like voltage, current, and temperature, which is essential for plants in remote locations.
- **Performance Optimization:** Monitoring solar radiation and dust accumulation helps optimize systems to capture maximum energy and reduce generation losses.
- **Efficiency and Reliability:** Real-time statistics allow users to identify faults early and perform preventive maintenance.
- **Cost Reduction:** Automated monitoring decreases the overall cost of renewable energy generation by improving reliability and reducing manual intervention.

III. PROBLEM IDENTIFICATION

The existing systems often rely on human intervention for operation and data collection. This manual approach is inefficient for tracking real-time parameters like current, voltage, and temperature.

Solar panel efficiency is highly dependent on environmental factors, such as radiation levels which vary by location, time, and climate. Additionally, dust accumulation on panels can significantly reduce power induction. Without constant monitoring, these losses go undetected.

Solar plants are frequently located in remote areas that are difficult to reach on a daily basis. This geographical barrier makes traditional on-site maintenance and monitoring logistically challenging.

Without real-time data, identifying system faults or malfunctioning panels is slow. This delay leads to increased downtime, higher repair costs, and significant energy generation losses.

Conventional maintenance is often reactive rather than preventive. The lack of historical and real-time data makes it difficult to implement predictive maintenance, leading to overall higher operational costs for renewable energy generation.

IV. SOLUTION

To solve the identified problems, the system integrates an ESP32 microcontroller with a suite of sensors to automate data acquisition and enable remote management. A voltage divider and ACS712 sensor accurately monitor electrical output, while LM35 and LDR sensors track environmental factors like temperature and light intensity that affect efficiency. This data is transmitted via integrated Wi-Fi to a cloud platform (ThingSpeak or Arduino Cloud), allowing users to virtually monitor and control remote solar plants from any location. By providing real-time analytics and historical logging, the solution enables early fault detection, reduces manual maintenance costs, and ensures the solar panels operate at maximum induction capacity.

V. PROPOSED METHODOLOGY

There are several reasons to monitor the performance of your solar panels such as: to optimize energyproduction, to detect problems early, to reduce energy costs, to ensure safety and more. Solar energy is becoming increasingly popular around the world as a way to reduce reliance on fossil fuels and combat climate change. Many countries are investing in solar energy infrastructure and implementing policies to promote the adoption of solar energy.**Solar Power Generation system** with our **ESP32 IoT basedsolar power monitoring system**. ESP32 can be programmed to collect data from sensors which we connect to the solar panel, such as **voltage, current, temperature, and sunlight intensity** and transmit this data over the internet to a cloud server or a local server. This data can then be accessed andanalysedusing a web interface or a mobile app, allowing you to monitor the performance of your solar panel in real-time.

The principal idea of an IoT-based solar panel monitoring system is to leverage Internet of Things (IoT) technology to remotely monitor and manage solar panel installations efficiently. Here's an overview of the key components and functionalities:

Sensor Integration: The system includes sensors installed on each solar panel to measure relevant parameters such as voltage, current, temperature, and irradiance. These sensors collect real-time data on the performance and environmental conditions affecting the solar panels.

Data Acquisition: The sensor data is collected and transmitted to a central gateway device using wireless communication protocols such as Wi-Fi, Zigbee, or LoRa. The gateway aggregates the data from multiple sensors and forwards it to the cloud for further processing.

Cloud-based Monitoring and Analysis: The sensor data is stored and processed in the cloud using IoT platforms or custom-built applications. Cloud-based software analyzes the data to assess the performance of individual solar panels, detect anomalies, and identify potential issues such as shading, soiling, or malfunctioning panels.

Visualization and Reporting: The monitoring system provides users with access to real-time and historical data through web-based dashboards or mobile applications. Users can visualize key performance metrics, receive alerts for abnormal

conditions, and generate reports on energy generation, efficiency, and maintenance activities.

Fault Detection and Diagnostics: The system employs machine learning algorithms or rule-based logic to detect faults or abnormalities in solar panel performance. By analyzing patterns in the sensor data, the system can identify potential issues early, allowing for timely maintenance and troubleshooting.

Remote Control and Optimization: In addition to monitoring, the system may offer remote control capabilities to optimize the operation of solar panel installations. This could include adjusting panel orientation, tilt angle, or cleaning schedules based on real-time weather conditions and energy production forecasts.

Integration with Energy Management Systems: The monitoring system can be integrated with energy management systems to optimize energy usage and storage. By combining solar panel data with information from other sources such as weather forecasts and grid demand, the system can optimize energy production and consumption patterns.

BLOCK DIAGRAM-
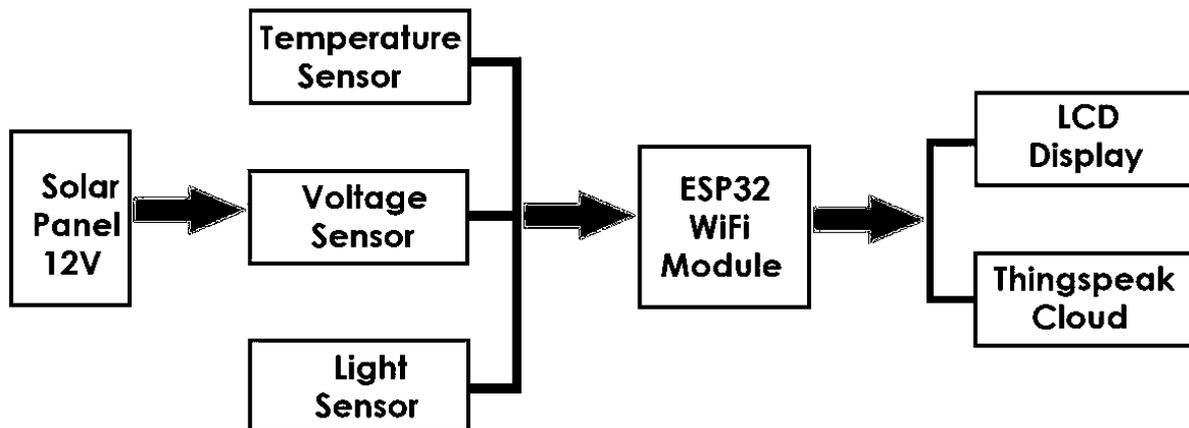
The **block diagram** of **IoT Based Solar Power MonitoringSystem** with ESP32. The ESP32 is interfaced with the voltage Sensor, LM-35 temperature sensor, and LDR sensor. These three sensors are used to monitor the **power** output, **temperature**, and incident **light intensity** respectively.

A **character LCD** is also interfaced with the board for real-time display of the measured parameters. The solar panels are assumed to be installed with **internet hotspots** at their installation site. The ESP32 not only displays the measured parameters on the LCD screen but also sends the measured values to the **things speak cloud server**.

The voltage, temperature & light parameters can be monitored in real-time and logged on things speak Server for analytics and performance evaluation.

The ESP32 is the main controller for the entire project. There are 3 sensors that directly connect to the GPIO pin of ESP32. The 3 sensors are Voltage Sensor (0-25V), LM35 Temperature Sensor & LDR Sensor.

Connect the input of Voltage Sensor to GPIO14 of ESP32 Board. On the other side of the Voltage, the Sensor connects the Solar Panel with a voltage range between 3V-25V as the voltage sensor's maximum sensing capacity is 25V only. Similarly, connect the input of the LM35 temperature sensor to the GPIO34 of ESP32. The LDR requires a resistor of 2.2K in series to measure the Analogvoltage fed to the ESP32 Analog pin. The LDR input pins connect to the GPIO35 of ESP32.Connect the SDA & SCL pin of I2C LCD Display to GPIO21 & GPIO22 respectively. You can power the LCD Display, & LM35 via 5V pin of ESP32.

MEASURING TEMPERATURE

We have used an external DS18B20 probe for measuring the ambient temperature. It uses a one-wire protocol to communicate with the microcontroller. One-wire devices need apull-up resistor connected to their signal line to be properly read by our board. Here, we have used a 4.7k resistor as a pull-up resistor.

MEASURING VOLTAGE

ESP32's Analog inputs can be used to measure DC voltage between 0 and 3.3V. The solar panel that we have considered can generate up to 12V. To read this voltage we have to step down the voltage which can be done by using a voltage divider network. For a voltage divider circuit Vout = R2/ (R1+R2) * Vin

Vin = (R1+R2)/R2 *Vout. The Analog read () function reads the voltage and converts it to a number 0 to 4095. We are going to read the output value with one of the Analog inputs of Arduino and its Analog Read () function. That function

outputs a value between 0 to 4095 which is 3.3/4095 for each increment.

MEASURING CURRENT

For the current sensor, we have used ACS712. The ACS712 current sensor reads the current value and converts it into a relevant voltage value, the value that links the two measurements is sensitivity. The output sensitivity can be obtained from the datasheet. As for the datasheet, the sensitivity is 200mV/A. Current in amp = (ADC Voltage - Offset Voltage) / sensitivity.

INTERFACING LED DISPLAY

To display the solar panel parameter locally, we have used an OLED to display. It uses a 12C bus to communicate with the ESP32. Two pins SCL (GPIO22), and SDA (GPIO21) in ESP32 are used for communication.

MEASURING LIGHT INTENSITY

To measure the light intensity we will have to use LDR (Light Dependent Resistor) as the name states is a special type of resistor that works on the photoconductivity principle means that resistance changes according to the intensity of light. Its resistance decreases with an increase in the intensity of light.

It is often used as a light sensor, light meter, Automatic street light, and in areas where we need to have light sensitivity. LDR is also known as a Light Sensor. LDR are usually available in 5mm, 8mm, 12mm, and 25mm dimensions.

.

VI. RESULT

The system successfully monitored a **12V Solar Panel**. Voltage was calculated using the divider network formula:$Vin = \frac{R1+R2}{R2} * V2$

Current was derived by comparing the ADC voltage against an offset:$Current = \frac{ADC\ Volage - Offset\ Voltage}{Sensitivity}$

The integration of the ESP32's crypto-accelerator ensured that data transmission to the web server remained secure.

.

VII. CONCLUSION

The IoT-based solar power monitoring system is an innovative solution for real-time analysis of solar panel health. It offers significant advantages, including improved energy management, reduced maintenance costs, and increased system reliability. By leveraging the ESP32's parallel processing and cloud capabilities, the system ensures efficient renewable energy management globally.

REFERENCES

[1] Rao, S., et al. (2018). "Power optimization techniques for IoT-based monitoring systems." IEEE Sensors Journal, 18(15), 6342-6350.

[2] Ray, P. P. (2016). "A survey on Internet of Things architectures." Journal of King Saud University-Computer and Information Sciences, 30(3), 291-319.

[3] Sahoo, S., et al. (2019). "Temperature sensors for solar panel monitoring: A comparative study." Materials Today: Proceedings, 18, 3456-3463.

[4] Sharma, V., & Singh, R. (2019). "Parameter monitoring for solar PV performance optimization." Energy Procedia, 158, 1234-1241.

[5] Singh, A., & Jain, A. (2019). "Data visualization techniques for solar monitoring systems." International Journal of Human-Computer Interaction, 35(12), 1089-1101.

[6] Wang, L., et al. (2020). "ESP32-based monitoring system for commercial solar farms: A case study." Applied Energy, 265, 114789.

[7] Zhang, Y., et al. (2020). "Data reliability in IoT-based monitoring systems under network constraints." IEEE Transactions on Network and Service Management, 17(3), 1567-1579