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# Detecting Defects in Photovoltaic Cells and Panels and Evaluating the Impact on Output Performances

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*Abstract :* With the increasing demand for renewable energy and efficient energy management, solar power systems require intelligent monitoring and optimization techniques to ensure maximum performance. This paper presents the design and implementation of an IoT-enabled intelligent solar panel monitoring and analysis system for real-time performance tracking and control.The proposed system employs a 3-watt solar panel integrated with an ESP32 microcontroller to continuously monitor key electrical parameters such as voltage and current. Using a voltage sensor and ACS712 current sensor, the system accurately computes power output based on the relation P=V×IP = V \times IP=V×I. In addition, the system supports automated solar alignment and predictive health assessment to improve efficiency and reliability.To enhance energy harvesting efficiency, the system incorporates an automatic single-axis solar tracking mechanism using two Light Dependent Resistors (LDRs) placed on the east and west sides of the panel. Based on differential light intensity, a servo motor dynamically adjusts the panel orientation to face the sun optimally. Additionally, a second servo motor is employed for manual panel cleaning, activated through a mechanical pushbutton, addressing performance degradation due to dust accumulation.

*IndexTerms* - **Photovoltaic (PV) cells, Solar panels, Defect detection, Fault diagnosis, Output performance analysis, Power efficiency, I–V characteristics, Degradation analysis, Energy loss, Machine learning, IoT-based monitoring, Predictive maintenance, Solar energy systems**

## I. INTRODUCTION

The increasing demand for clean and sustainable energy has led to the widespread adoption of solar photovoltaic (PV) systems across residential, industrial, and institutional sectors. Solar energy is abundant, environmentally friendly, and renewable; however, the actual power output of solar panels is highly dependent on environmental and
operational conditions such as sunlight intensity, panel orientation, dust accumulation, and long-term degradation. Without continuous supervision and optimization, solar panels often operate below their maximum efficiency.
Conventional solar installations typically lack real-time monitoring, automated performance optimization, and predictive maintenance capabilities. As a result, faults, efficiency losses, and degradation often go unnoticed until significant power loss occurs.

Recent advancements in embedded systems, Internet of Things (IoT), cloud computing, and machine learning provide an opportunity to design intelligent systems capable of monitoring solar panel performance, optimizing energy generation, and predicting health conditions proactively.
This project proposes an IoT-based intelligent solar panel monitoring, tracking, and health analysis system using an ESP32 microcontroller. The system continuously measures voltage and current from a 3W solar panel, performs power calculations, uploads data to a cloud platform, and provides advanced analytical insights through a web-based interface. Conventional solar installations typically lack real-time monitoring, automated performance optimization, and predictive maintenance capabilities. As a result, faults, efficiency losses, and degradation often go unnoticed until significant power loss occurs. Recent advancements in embedded systems, Internet of Things (IoT), cloud computing, and machine learning provide an opportunity to design intelligent systems capable of monitoring solar panel performance, optimizing energy generation, and predicting health conditions proactively.

## II. LITERATURE SURVEY

This chapter presents a comprehensive review of existing IEEE-published research works related to solar panel monitoring, IoT-based data acquisition, solar tracking systems, automated cleaning mechanisms, and machine learning–based photovoltaic health analysis. The objective of this literature survey is to analyze the methodologies, strengths, and limitations of these approaches and to identify the research gaps that motivate the proposed system. By understanding the limitations of current solutions, the proposed project aims to deliver an integrated, intelligent, and scalable solar panel monitoring framework that combines real-time IoT monitoring, automated performance optimization, predictive health analysis, and AI-driven data interpretation.

**Existing System**

Existing solar systems mainly focus on basic monitoring of voltage, current, and power output. Most systems operate independently, handling only one function such as tracking or data logging, without proper integration. Data is often displayed locally or stored without real-time cloud access or advanced analysis. Fault detection is usually manual and requires expert knowledge, making it difficult to identify issues early. Many systems do not include automatic cleaning, which leads to reduced efficiency due to dust accumulation. Advanced monitoring systems like SCADA are expensive and not suitable for small-scale applications. Additionally, user interfaces are limited, with minimal visualization and no intelligent support for easy understanding or decision-making.

**Proposed System**

Our project is not just a single feature—it is a complete smart solar system. It combines multiple functions like solar tracking, performance monitoring, automatic cleaning, cloud data storage, dashboard visualization, machine learning prediction, and AI-based user interaction into one system.The system is designed for small solar panels (3W), making it low-cost and easy to use for labs, students, and small-scale applications. It continuously measures voltage and current, calculates power, and sends data to the cloud every 10 seconds for real-time monitoring.

Unlike basic systems, this project also analyzes the condition of the solar panel using machine learning (LSTM) to identify whether the panel is working normally, degrading, or faulty. In addition, an AI-based interface helps users understand the data easily by answering questions and detecting problems.The system not only monitors performance but also improves it. Solar tracking helps capture more sunlight, and automatic cleaning reduces dust losses, increasing overall efficiency.A user-friendly dashboard is provided to view live data, filter results (daily/monthly), and download reports. This makes the system easy to use, understand, and present during demonstrations.

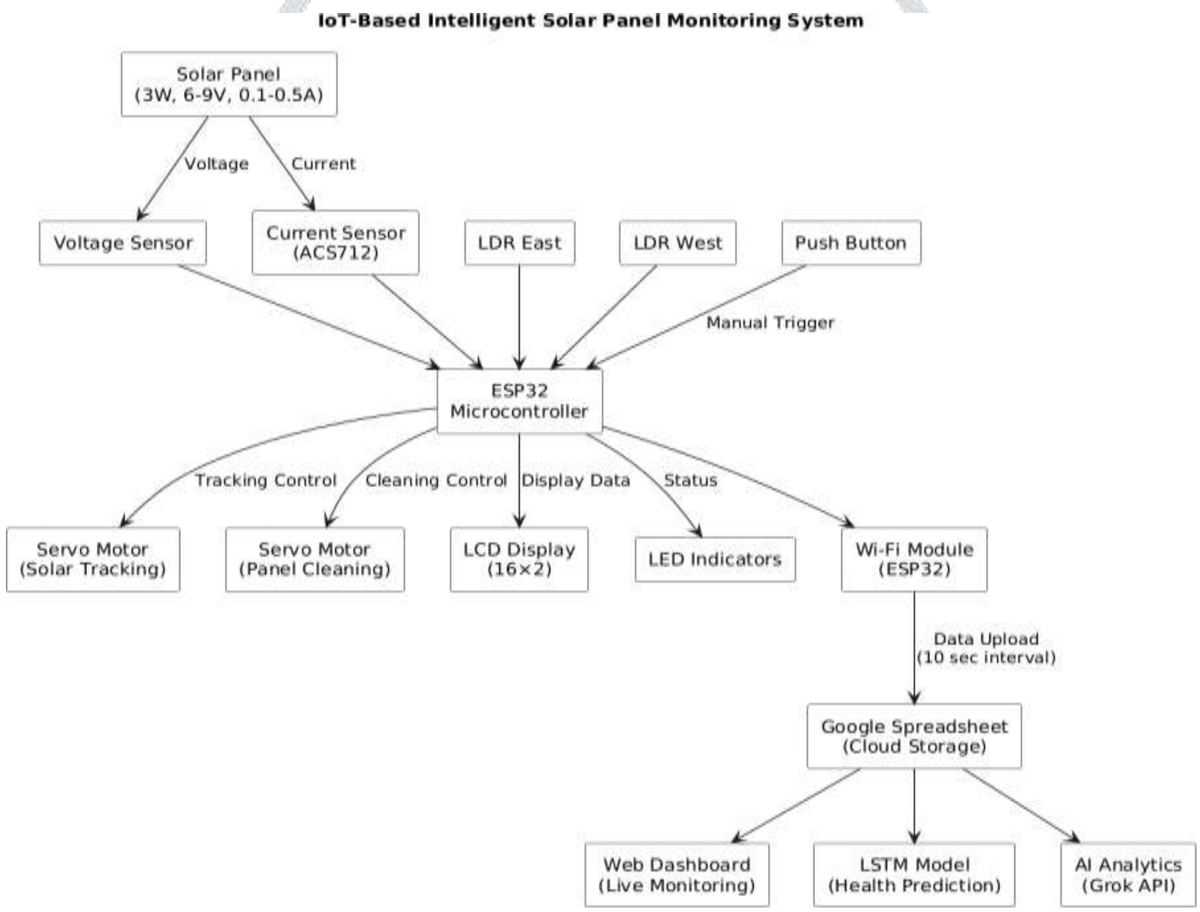



**Fig-1 Block Diagram**

## III. METHODOLOGY AND COMPONENTS

### 3.1 Solar Panel (3W Photovoltaic Module)

A solar panel is a photovoltaic device that converts sunlight directly into electrical energy using the photovoltaic effect. When sunlight strikes the semiconductor material inside the panel, electrons are excited and generate a flow of electric current.

In this project, a **3-watt solar panel** is used as the primary energy source for monitoring and analysis. The panel is designed for small-scale applications and provides stable output under varying sunlight conditions.

### 3.2 ESP32 Microcontroller

The ESP32 is a powerful, low-cost, low-power microcontroller developed by Espressif Systems. It integrates **Wi-Fi, Bluetooth, multiple ADC channels, PWM outputs, and high-speed processing capabilities**, making it ideal for IoT and real- time embedded applications.Unlike traditional controllers, ESP32 supports **simultaneous sensor interfacing and cloud communication**, which is essential for this project.

### 3.3 Voltage Sensor

The voltage sensor module is used to measure the DC voltage output of the solar panel. It typically operates using a **voltage divider principle**, which scales down high voltage levels to a safe range suitable for microcontroller ADC inputs.

### 3.4 Current Sensor

The ACS712 is a current sensor that uses the Hall effect to measure both alternating current and direct current. It creates an analog voltage that changes based on the current passing through it, and it keeps the sensor and the load electrically separate.

### 3.5 Light Dependent Resistors(LDR)

An LDR is a passive light-sensitive resistor whose resistance decreases with increasing light intensity. Two LDRs are placed on opposite sides of the solar panel to detect sunlight direction.

### 3.6 LCD Display(16*2)

A 16×2 LCD is used for local visualization of system parameters.

## IV. CONTROLLER DESIGN AND IMPLEMENTATION

**1. Solar Energy Generation**

A 3W solar panel generates electrical energy when exposed to sunlight, producing an output voltage in the range of 6–9 V and current between 0.1–
0.5 A, depending on sunlight intensity.

**2. Sensing of Electrical Parameters**

A voltage sensor measures the panel output voltage.These sensors provide analog signals proportional to the actual electrical values.

**3. Data Acquisition by ESP32**

The ESP32 microcontroller reads analog values from the voltage and current sensors using its built-in ADC channels. The ESP32 converts these signals into digital values and calculates the instantaneous power using the formula:
P=V×IP = V \times IP=V×I

**4. Solar Tracking Mechanism**

Two Light Dependent Resistors (LDRs) are positioned on the east and west sides of the solar panel.When sunlight intensity differs between the two LDRs, the ESP32 detects the difference.Based on this difference, a servo motor rotates the solar panel along a single axis until both LDRs receive nearly equal light, ensuring maximum solar exposure.

**5. Panel Cleaning Mechanism**

When the pushbutton is pressed, the ESP32 activates the cleaning servo.This helps remove dust and debris from the panel surface, reducing efficiency loss due to soiling.

**6. Local Display and Indication**

A 16×2 LCD displays real-time voltage, current, and power values.LEDs are used as status indicators to show system activity and operational states.

**7. Cloud Data Upload**

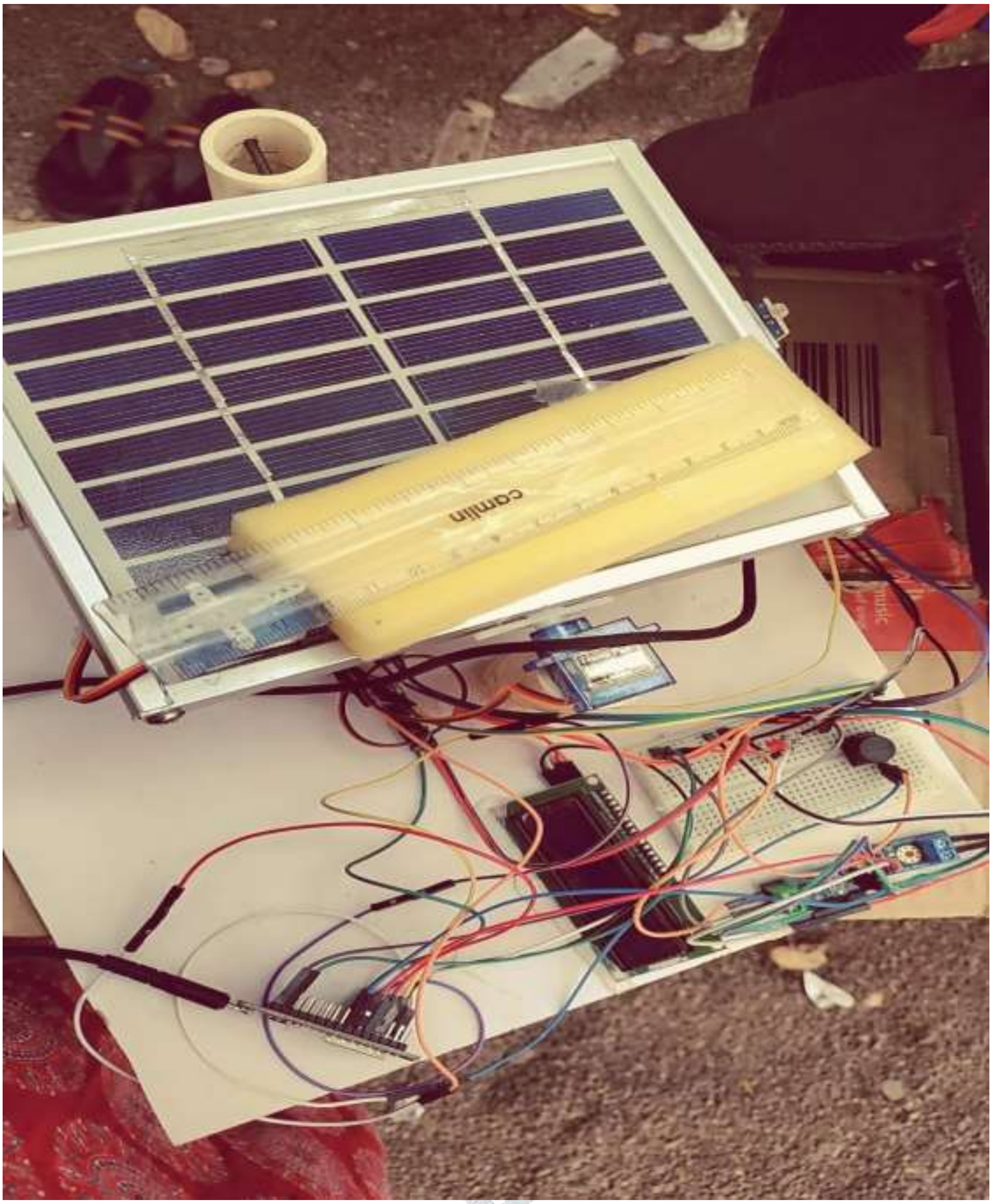
Using its built-in Wi-Fi module, the ESP32 sends voltage, current, and power data to a Google Spreadsheet via HTTP API requests.Data is uploaded every 10 seconds along with a timestamp.This enables continuous data logging and remote access.

**8. Web-Based Analysis and Visualization**

The stored data is accessed through a web application consisting of three pages:

o Live Monitoring Page: Displays real-time values, historical trends, filtering options, and Excel download.

## V. RESULT




## VI. CONCLUSION

This project successfully designed and implemented an IoT-based intelligent solar panel monitoring, tracking, and health analysis system that addresses key limitations of conventional solar installations. By integrating real-timesensing, automated control, cloud connectivity, machine learning, and artificial intelligence, the system provides a comprehensive solution for efficient solar energy management.

The system continuously monitors voltage and current generated by a 3W solar panel and computes power output in real time. Using an ESP32 microcontroller, the collected data is displayed locally and uploaded to a Google Spreadsheet every 10 seconds, ensuring reliable cloud-based data storage. The implementation of automatic solar tracking using LDR sensors aservo

motor significantly improves energy harvesting efficiency, while the manual panel cleaning mechanism helps reduce performance degradation caused by dust accumulation.

Overall, the proposed system demonstrates that combining IoT, machine learning, and AI techniques can significantly improve the performance monitoring,maintenance efficiency, and usability of solar energy systems. The solution is cost-effective, scalable, and suitable for educational, research, and small-scale real-world applications

## VII. REFERENCES

[1] R. Ramaprabha and B. L. Mathur, “Intelligent monitoring of solar PV system,” *IEEE International Conference on Power Electronics, Drives and Energy Systems*, 2010.

[2] S. S. Reddy, “Optimization of renewable energy resources in hybrid energy systems,” *IEEE Transactions on Smart Grid*, vol. 5, no. 6, pp. 2693–2701, Nov. 2014.

[3]S. Jain and V. Agarwal, “Comparison of the performance of maximum power point tracking schemes applied to single-stage grid-connected photovoltaic systems,” *IET Electric Power Applications*, vol. 1, no. 5, pp. 753–762, 2007.

[3] S. Jain and V. Agarwal, “Comparison of the performance of maximum power point tracking schemes applied to single-stage grid-connected photovoltaic systems,” *IET Electric Power Applications*, vol. 1, no. 5, pp. 753–762, 2007.

[4] A. T. Al-Awami, M. A. Abido, and S. H. E. Abdel Aleem, “Optimal sizing and allocation of renewable energy-based distributed generation,” *IEEE Transactions on Sustainable Energy*, vol. 7, no. 3, pp. 1089–1099, 2016.

[5] M. A. S. Al-Saud, “Design and implementation of automatic solar tracking system,” *IEEE International Conference on Renewable Energy Research and Applications*, 2016.