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Smart Solar Monitoring Using IoT and Wireless Data Transmission

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Abstract - Traditional solar panel monitoring systems rely heavily on manual inspections and offline data collection, leading to delayed fault detection and increased maintenance costs. This project proposes a Smart Solar Panel Monitoring System based on IoT and wireless data transmission, enabling real-time tracking of solar parameters like temperature, humidity, irradiance, voltage, and current. Using Arduino Nano and NodeMCU (ESP8266), sensor data is collected and transmitted to AdaFruit IO cloud platform for remote monitoring. This approach enhances early fault detection, optimizes energy management, and reduces manual intervention, thus promoting sustainable energy solutions.

Keywords: IoT, Solar Panel Monitoring, Energy Management, Wireless Communication, ESP8266, Arduino Nano, AdaFruit IO.

I. INTRODUCTION

A. Background

The growing adoption of solar energy highlights the importance of efficient monitoring systems for solar panels. Solar panels are vulnerable to environmental factors, and without efficient monitoring, their performance can degrade unnoticed. With the Internet of Things (IoT) revolutionizing real-time monitoring capabilities, it is now possible to remotely monitor critical parameters, enabling predictive maintenance and optimized energy utilization. Integrating sensors, microcontrollers, and wireless communication modules within solar systems ensures effective management of renewable energy resources.

B. Problem Statement

Manual inspections for solar panel maintenance are prone to delays, inefficiencies, and increased operational costs. Traditional monitoring methods often fail to detect faults at an early stage, leading to substantial energy loss and system downtime. This project aims to address these issues by developing a Smart Solar Panel Monitoring System that enables real-time tracking of solar parameters, fault detection, wireless data transmission, and remote accessibility, ensuring enhanced energy efficiency and reduced maintenance efforts.

II. LITERATURE REVIEW

(i) Marco Giordano proposed an energy-aware adaptive sampling rate algorithm for IoT devices, enhancing energy harvesting and self-sustainability using a finite state machine inspired by TCP Reno. Their model focused on maximizing efficiency while maintaining minimal energy consumption.

(ii) Saswat K. Ram developed "Eternal-Thing 2.0," a ripple-less solar energy harvesting system resilient to analog trojan attacks, ensuring reliability and security for IoT end nodes. Their work emphasized maintaining uninterrupted energy supply through MPPT and aging-tolerant circuits.

(iii) Gaikar Vilas Bhau demonstrated an IoT-based solar energy monitoring system utilizing Raspberry Pi and the Flask framework. They emphasized the importance of real-time energy consumption monitoring for solar systems in smart villages and solar cities.

(iv) Manh Duong Phung presented a dependable control system using IoT for managing solar energy in microgrids. Their system incorporated fault tolerance and resilience across distributed control units, ensuring continuous operation despite failures.

(v) Kazi Zehad Mostofa and Mohammad Aminul Islam proposed a live IoT system for monitoring remote solar photovoltaic installations. Their setup employed NodeMCU with Adafruit IO, ensuring real-time data transmission and fault detection, crucial for improving the efficiency of remote solar facilities.

III. METHODOLOGY

The smart solar monitoring system is built using a combination of sensors, microcontrollers, and IoT connectivity.

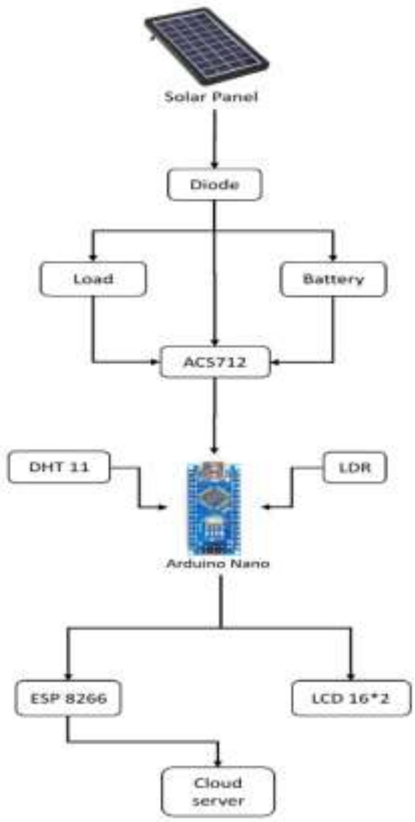
- The **solar panel** generates electricity, which is monitored for voltage and current through sensors (Voltage Divider and ACS712 respectively).
- Environmental parameters such as temperature and humidity are measured using a **DHT11 sensor**, and sunlight intensity is captured through an **LDR sensor**.
- An **Arduino Nano** acts as the primary microcontroller, collecting all sensor data, processing it, and displaying immediate results on a **16x2 LCD display** for local monitoring.
- For remote access, a **NodeMCU ESP8266** module is used to wirelessly transmit the processed data over Wi-Fi to Adafruit IO, enabling real-time monitoring from anywhere.
- The system is powered using a 3W solar panel, maintaining energy efficiency and promoting sustainable operation.

This methodology ensures continuous, real-time tracking of solar panel performance with minimal manual intervention, enhancing the overall reliability and maintainability of the system.

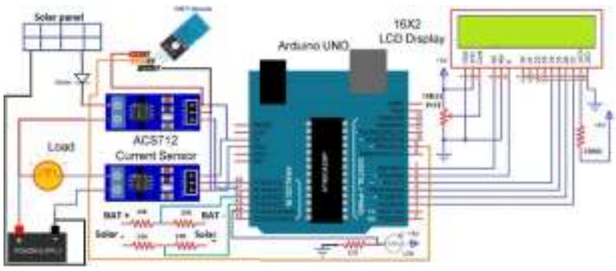
IV. SYSTEM DESIGN

- Power Generation: Solar panels generate DC electricity, ensuring eco-friendly and self-sustainable operation.
- Sensing and Monitoring: Real-time monitoring of voltage, current, temperature, humidity, and light intensity using appropriate sensors.
- Data Processing: Arduino Nano processes sensor data and formats it for transmission.
- Wireless Communication: NodeMCU ESP8266 module transmits data over Wi-Fi to the AdaFruit IO cloud platform.
- User Interface: The system provides immediate visual feedback using an LCD and remote access via

Adafruit IO dashboards.



V. CIRCUIT DIAGRAM



VI. WORKING

The working principle revolves around continuous monitoring of solar energy system parameters and ensuring their transmission to a cloud platform for remote supervision. The solar panel generates electrical power, simultaneously supplying energy to the system and recharging storage components. Sensor data is gathered, processed, and displayed locally by the Arduino Nano. This information is also relayed to the NodeMCU, which uploads the data to the Adafruit IO server. The system thus enables real-time visibility of solar energy performance, environmental conditions, and system health, allowing proactive maintenance and optimized energy usage.

VII. RESULT

Without Load:

- The system showed nominal voltage and current levels when the panel operated without external loads. Verified proper sensor and communication functionality through consistent real-time updates to Adafruit IO.

With Load:

- Increased current readings validated effective power output under load conditions.
- Voltage fluctuations matched expected behavior, confirming sensor accuracy.
- Successful real-time data transmission demonstrated system robustness.
- Early fault detection and performance anomalies were visible through remote monitoring, highlighting the practical utility of IoT integration.

VIII. CONCLUSION

This research successfully implements a smart IoT-based solar panel monitoring system that enables real-time, remote surveillance of key solar parameters. The integration of Arduino Nano and NodeMCU ensures seamless data acquisition, processing, and wireless transmission. The system enhances solar panel efficiency, reduces maintenance costs, enables predictive maintenance, and supports proactive energy management. By combining renewable energy with IoT technology, this project showcases an innovative, scalable solution that contributes to the future of sustainable energy systems and smart cities.

IX. REFERENCE

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