

IOT Based Smart Solar Cleaner and Monitoring System

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ABSTRACT

Increasing demand for clean and sustainable energy has made solar energy one of the most significant renewable energy sources. Nevertheless, the output of solar panels is highly influenced by the surrounding conditions, which include sunlight intensity, temperature, humidity, and changes in weather. Hence, monitoring these parameters continuously is very much needed for solar power systems to be at their best and also to be reliable.

The paper discusses an IoT based Solar Monitoring System design and implementation using the popular NodeMCU ESP8266, INA219 voltage, and current sensor, DHT11 temperature and humidity sensor, rain sensor, soil moisture sensor, light-dependent resistor (LDR), and a 16×2 LCD display. The setup constantly measures the voltage, current, power of a solar panel, and also ambient temperature, humidity, rainfall status, moisture level, and sunlight availability. The data is processed by the NodeMCU microcontroller and displayed on an LCD locally. Also, the system can be upgraded to send data wirelessly to cloud platforms for remote monitoring.

The system being proposed is low-cost, energy efficient, simple to set up, and appropriate for residential, educational, and small-scale solar installations. The experiments have shown that monitoring in real-time can assist in detecting faults early and thus the overall performance of the system becomes better.

Keywords:- Solar Energy, NodeMCU ESP8266, INA219, IoT, Solar Monitoring, Renewable Energy.

1. INTRODUCTION

With the rapid increase in global energy consumption and depletion of fossil fuel resources, renewable energy sources have gained significant attention. Among all renewable sources, solar energy is widely adopted due to its availability, scalability, and environmental friendliness. Solar photovoltaic (PV) systems convert sunlight into electrical energy, but their efficiency depends on several factors such as solar irradiance, temperature, dust accumulation, humidity, and weather conditions.

Traditional solar systems lack real-time monitoring capabilities, making it difficult to detect faults, performance degradation, or environmental impacts. Manual monitoring is time-consuming and inefficient, especially for remote installations. Therefore, an intelligent monitoring system is required to observe the electrical and environmental parameters continuously.

The advancement of Internet of Things (IoT) technology enables real-time data acquisition, processing, and remote monitoring. Microcontrollers like NodeMCU ESP8266 provide built-in Wi-Fi connectivity, making them ideal for IoT-based solar monitoring applications. Sensors such as INA219 allow accurate measurement of voltage and current, while environmental sensors like DHT11, rain sensor, moisture sensor, and LDR provide essential weather-related data.

2. SYSTEM ARCHITECTURE

The proposed solar monitoring system consists of sensing, processing, display, and communication units. The solar panel is connected to the INA219 sensor to measure voltage and current. Environmental sensors are placed near the panel to collect temperature, humidity, rainfall, moisture, and sunlight data. All sensors are interfaced with the NodeMCU ESP8266 microcontroller.

The microcontroller processes sensor data and calculates solar power using voltage and current values. A 16×2 LCD display is used to show real-time system parameters. The system can be powered using a regulated DC supply derived from the solar panel or an external adapter.

3. PROBLEM IDENTIFICATION

In numerous small and medium-sized solar power installations, monitoring is restricted to simple voltage checking or inverter signals. This method fails to deliver comprehensive data regarding the environmental conditions and the electrical performance. Problems like inadequate sunlight, high temperature, rain, moisture, or shading might remain unnoticed which eventually would result in lower efficiency and slower fault detection.

Moreover, manual monitoring process is very labor-intensive and is not a good choice for remote or unattended installations. The unavailability of real-time data makes the tasks of system optimization and preventive maintenance tricky. Hence, a demand arises for an automated, intelligent, and economical monitoring system that will be capable of constantly recording both electrical and environmental parameters of a solar PV system.

4. RESULTS

The suggested solar monitoring system was validated through trials conducted in a real-world setting. With great precision, the INA219 sensor was able to monitor both the voltage and current of the solar panel. The instantaneous power consumption was calculated based on the values obtained through the measurement. Weather-dependent, the temperature and humidity were measured by the DHT11 sensor, which gave varying but stable readings.

- The rain sensor was able to pinpoint rainfall accurately, whereas the moisture sensor was indicating wetness close to the solar panel. The LDR was able to discriminate very well between the presence and absence of sunlight. All the parameters that were measured were displayed clearly on the 16×2 LCD.
- The comprehensive system not only monitored the solar installation constantly but also determined the real-time voltage, current, power, temperature, humidity, rain status, moisture level, and sunlight availability.
- The INA219 sensor was very precise in its calculations of solar panel voltage, current, and power, thus making it possible to monitor the energy production during the daytime operation.
- NodeMCU ESP8266 was right on the mark in processing the whole data from the sensors and at the same time, the 16×2 LCD showed the monitored parameters for local observation.
- Sunlight detection through the LDR sensor was a reliable technique in distinguishing the day from the night time.
- The system was set to work in a monitoring mode only, at day time, thus, solar power measurement and environmental data collection were not disturbed.
- At night (when no sunlight was detected), the system shifted automatically from the monitoring mode to the cleaning mode.
- The solar panel cleaning mechanism was put into operation at night without any risk and without power generation being affected.
- The cleaning system performed its job very well and all solar panels were cleaned equally by victoriously removing dust, moisture residue, and dirt that had been building up during the day.
- The rain and moisture sensors were very helpful in determining the environmental conditions and thus avoided unnecessary cleaning during the rain or wet conditions.

5. CONCLUSION

A solar monitoring system based on IoT and NodeMCU ESP8266 has been successfully designed and implemented. The system can monitor in real time the solar panel's voltage, current, and power, as well as temperature, humidity, rainfall, and moisture, and sunlight conditions. The application of INA219 guarantees precise electrical measurements, while the environmental sensors deliver necessary information concerning the weather.

The proposed system is economical, it can easily be enlarged or reduced, and it is fit for educational, residential, and small-scale commercial solar applications. The connection of IoT technology makes it possible to have future remote monitoring and data logging, which help to improve system reliability and maintenance efficiency.

6. FUTURE SCOPE

- Implementation of automatic solar panel cleaning mechanisms
- Use of advanced sensors for irradiance and dust detection
- Development of mobile and web applications for real-time monitoring

7. REFERENCES

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