

# IOT-Based Smart Microgrid Monitoring System for Real-Time Energy Management

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## Abstract

The rapid expansion of renewable energy resources and distributed generation systems has increased the need for efficient monitoring solutions in microgrids. Conventional monitoring systems often lack real-time data acquisition, remote accessibility, and intelligent fault detection. This paper presents an **IoT-based Smart Microgrid Monitoring System** that integrates embedded sensors, renewable energy sources, and cloud-enabled communication technologies.

The proposed system uses an Arduino Uno microcontroller to collect electrical and environmental data from sensors such as voltage sensors, DHT11 temperature–humidity sensors, and LDR light sensors. A NodeMCU ESP8266 module transmits real-time data to an IoT platform for remote monitoring and analysis. A solar panel and battery provide renewable energy and backup power to ensure sustainable system operation. The system also includes an LCD display for local visualization and a buzzer for abnormal condition alerts. MATLAB/Simulink simulations were performed to analyze microgrid voltage stability and power flow characteristics. Experimental results demonstrate reliable monitoring performance and accurate real-time data transmission. The proposed system improves microgrid efficiency, automation, and energy management, supporting the development of smart grid infrastructure.

**Keywords:** IoT, Microgrid, Renewable Energy, Smart Grid, Monitoring System, Arduino.

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## 1.Introduction

Microgrids are localized energy systems that integrate renewable energy sources, energy storage systems, and distributed loads. These systems improve energy reliability and support sustainable electricity generation. However, traditional microgrid monitoring methods rely on manual observation and limited measuring devices, which cannot provide real-time insights into system performance.

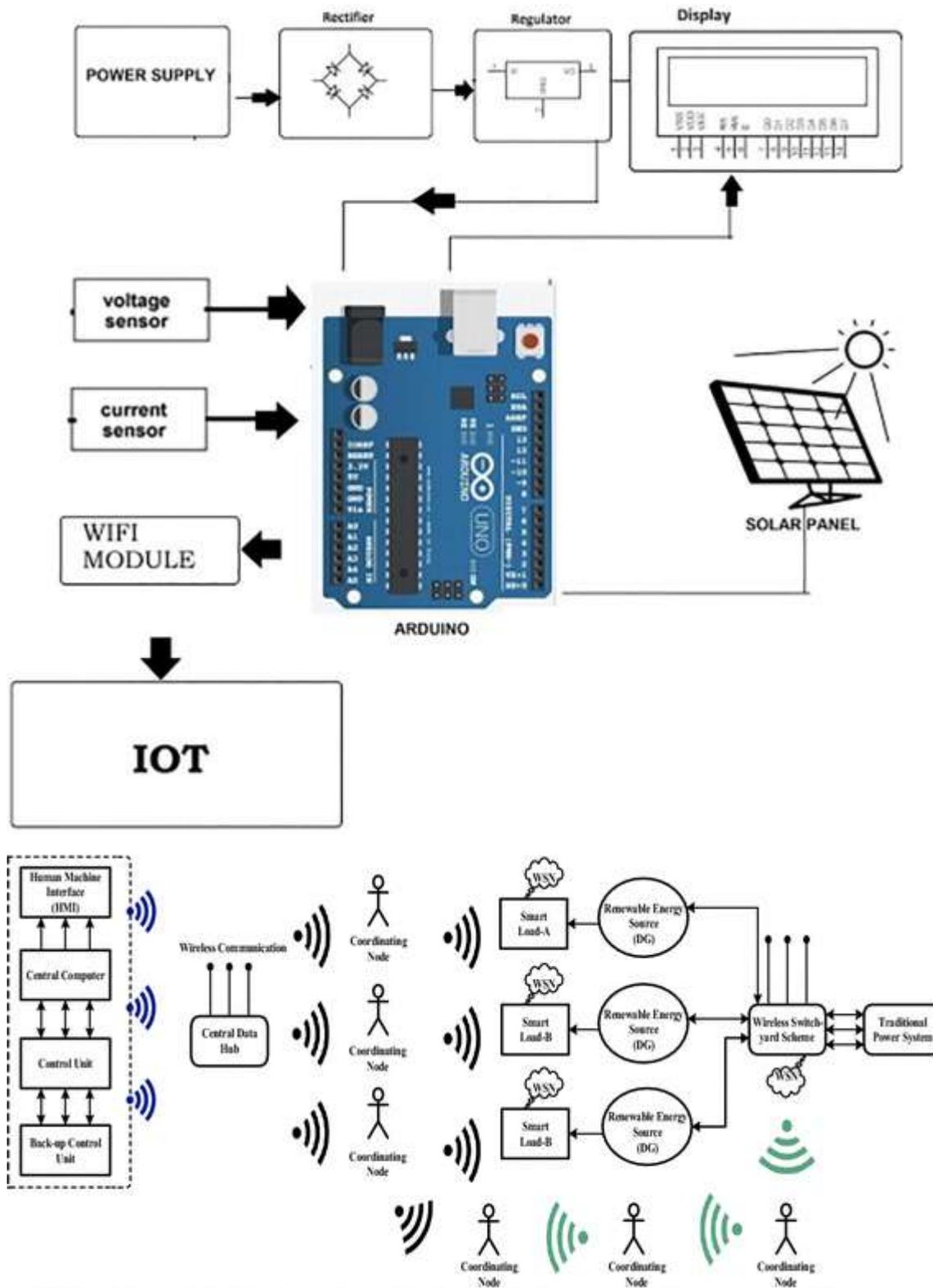
The **Internet of Things (IoT)** has emerged as a promising technology that enables intelligent monitoring and control of energy systems. IoT allows sensors, controllers, and communication modules to exchange data through internet connectivity, enabling real-time monitoring and remote management.

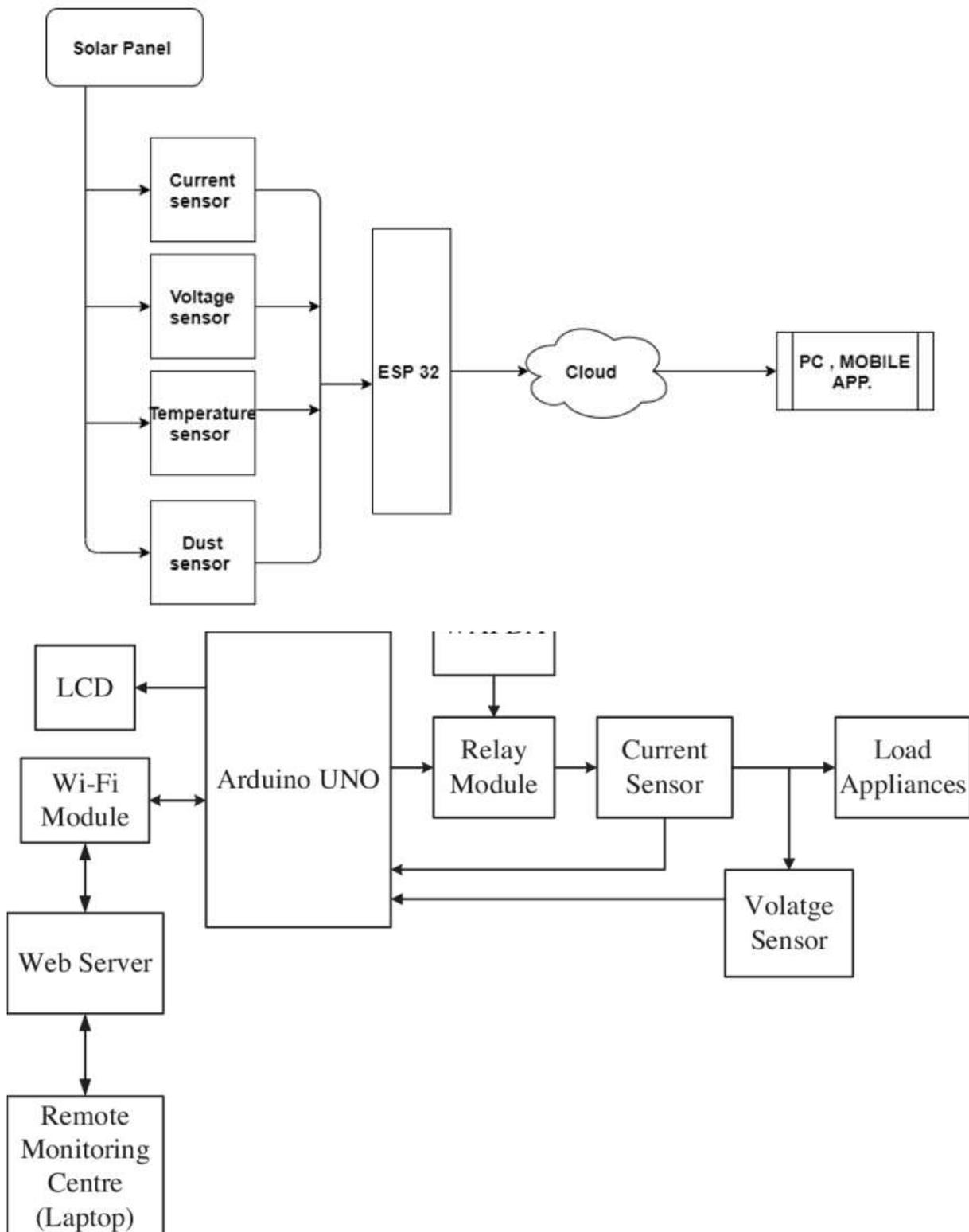
The proposed IoT-based monitoring system integrates multiple sensors and wireless communication modules to monitor microgrid parameters continuously. The system collects data related to voltage levels, temperature, humidity, and solar radiation intensity, and transmits this information to a cloud platform for remote monitoring and analysis.

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## 2. System Architecture

### Block Diagram of Proposed System





The proposed architecture consists of the following modules:

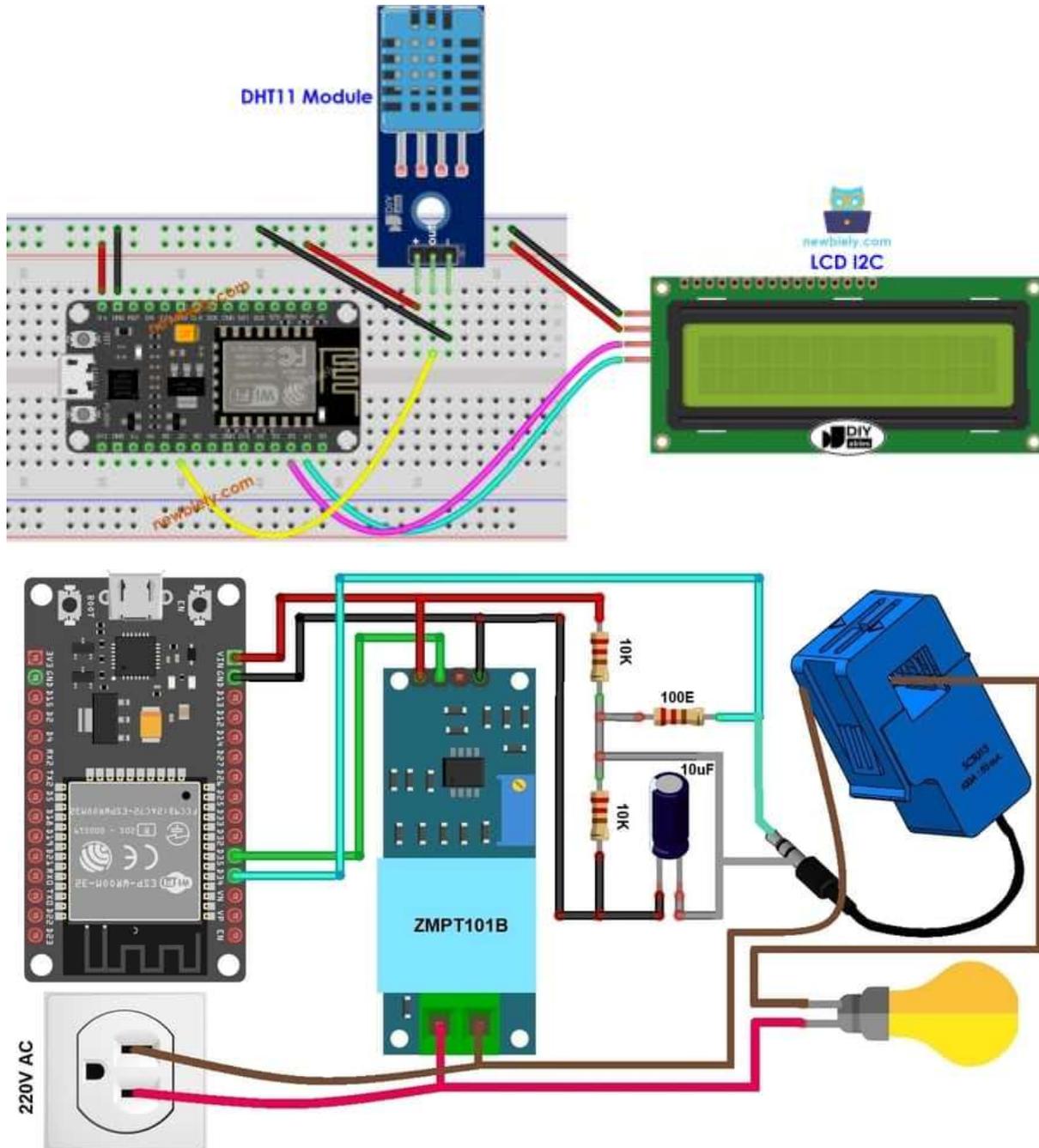
1. **Renewable Energy Module** – Solar panel generates electrical power.
2. **Energy Storage Module** – Battery stores energy and provides backup supply.
3. **Sensor Monitoring Module** – Sensors measure electrical and environmental parameters.
4. **Processing Module** – Arduino Uno processes sensor data.
5. **Communication Module** – NodeMCU transmits data to the IoT cloud platform.

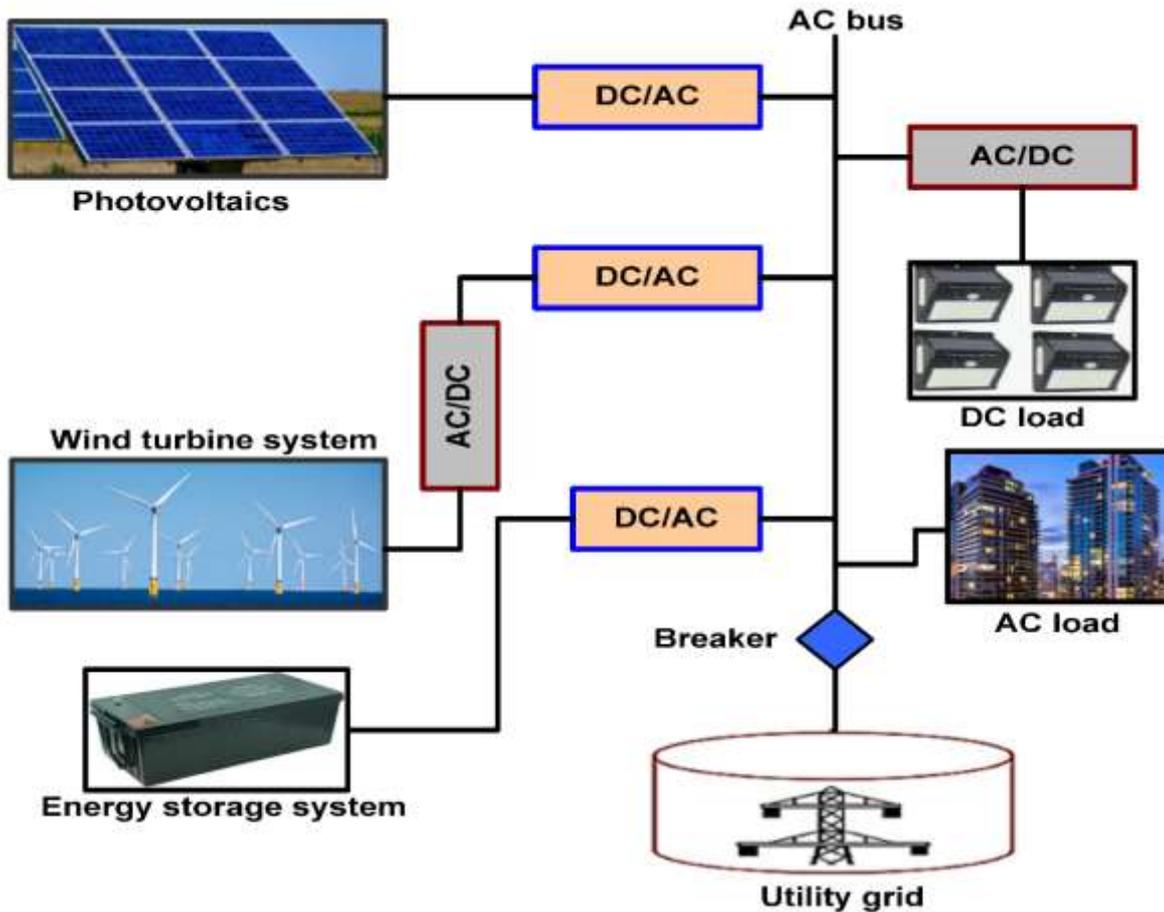
6. **User Interface Module** – LCD display shows real-time readings and buzzer alerts users.

The system continuously monitors microgrid conditions and transmits data to remote users through internet connectivity.

### 3.Circuit Design

#### Hardware Circuit Diagram





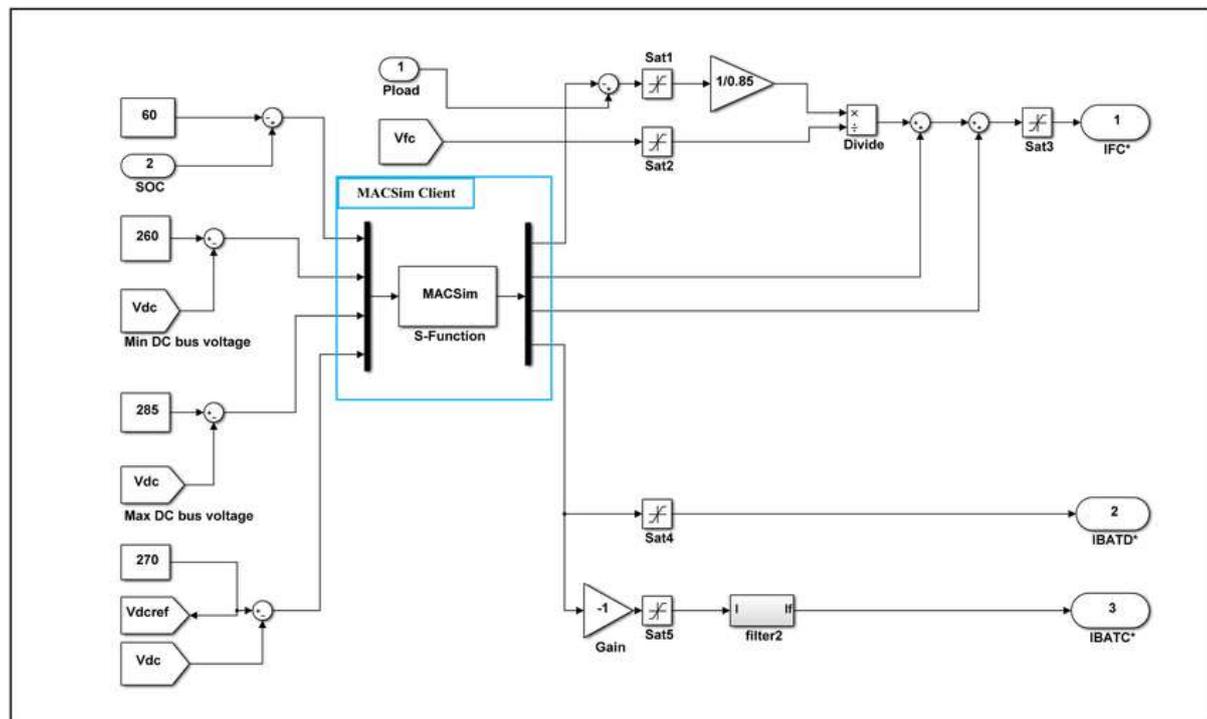
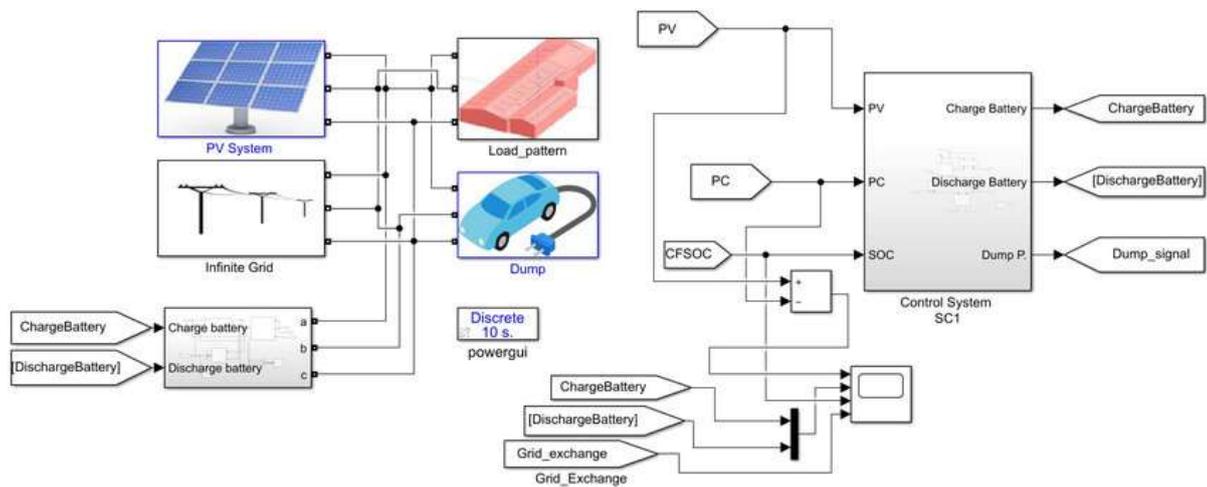
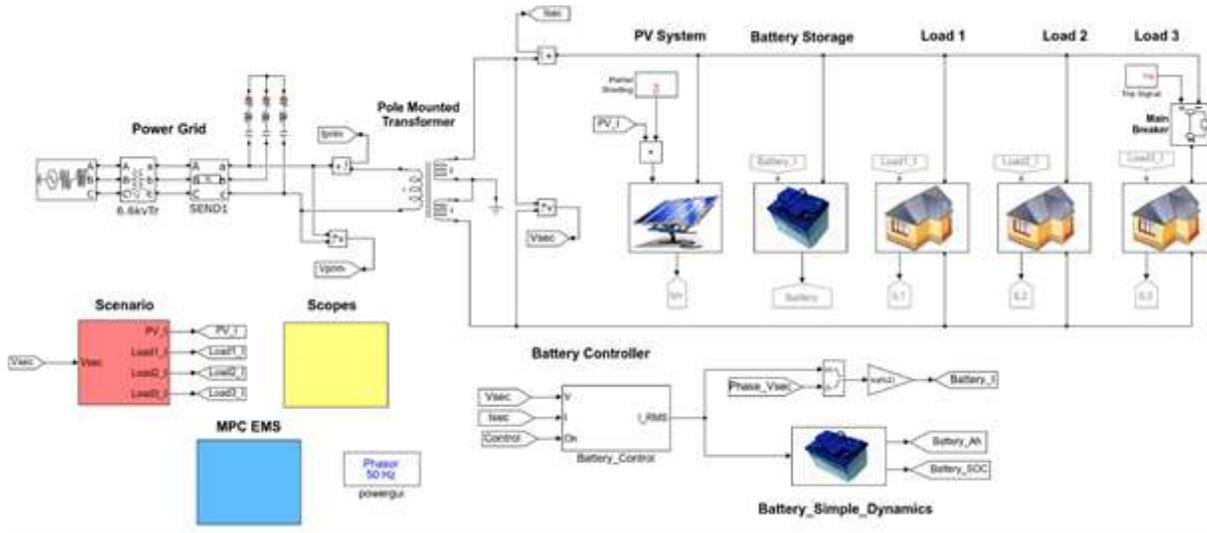
The hardware circuit integrates several sensors with the Arduino controller. The voltage sensor measures the supply voltage of the microgrid system, while the DHT11 sensor monitors environmental temperature and humidity. The LDR sensor detects solar radiation intensity, which affects the output of the solar panel.

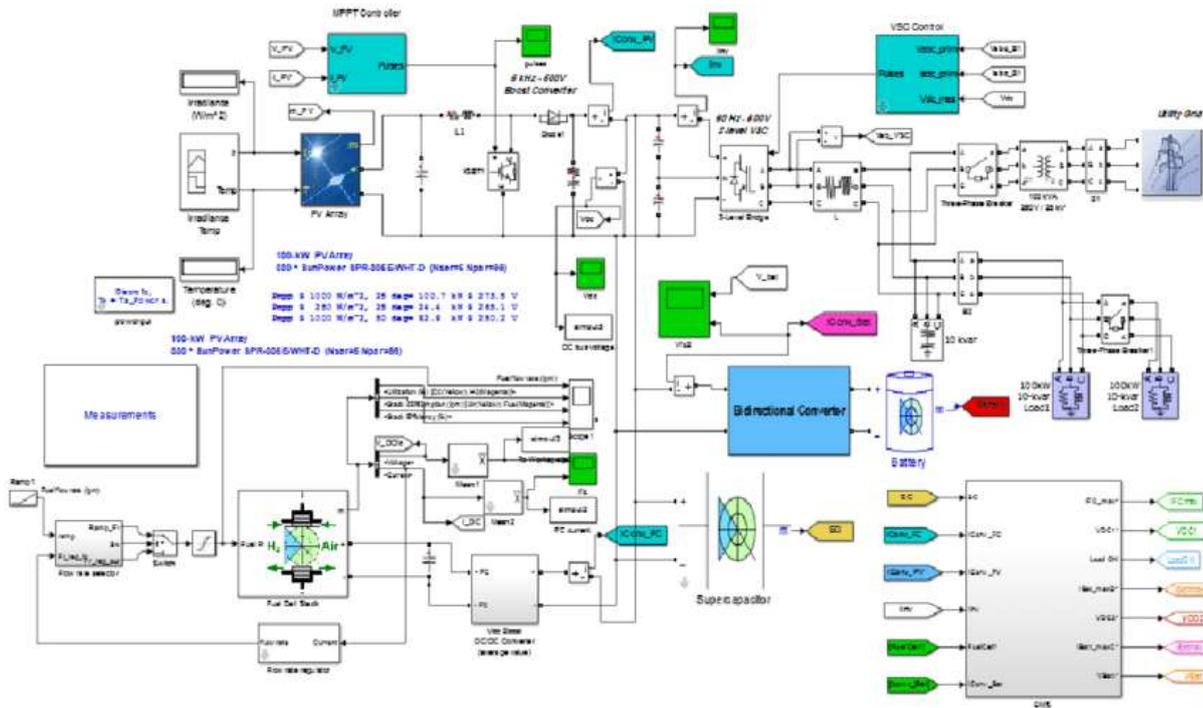
Sensor data is processed by the Arduino microcontroller and transmitted to the NodeMCU module through serial communication. The NodeMCU connects to a Wi-Fi network and uploads the data to the IoT platform.

#### 4.MATLAB Simulation Model

To analyze system performance, the proposed microgrid was simulated using MATLAB/Simulink. The simulation model includes renewable energy generation, battery storage, load demand, and monitoring modules.

### MATLAB/Simulink Microgrid Model





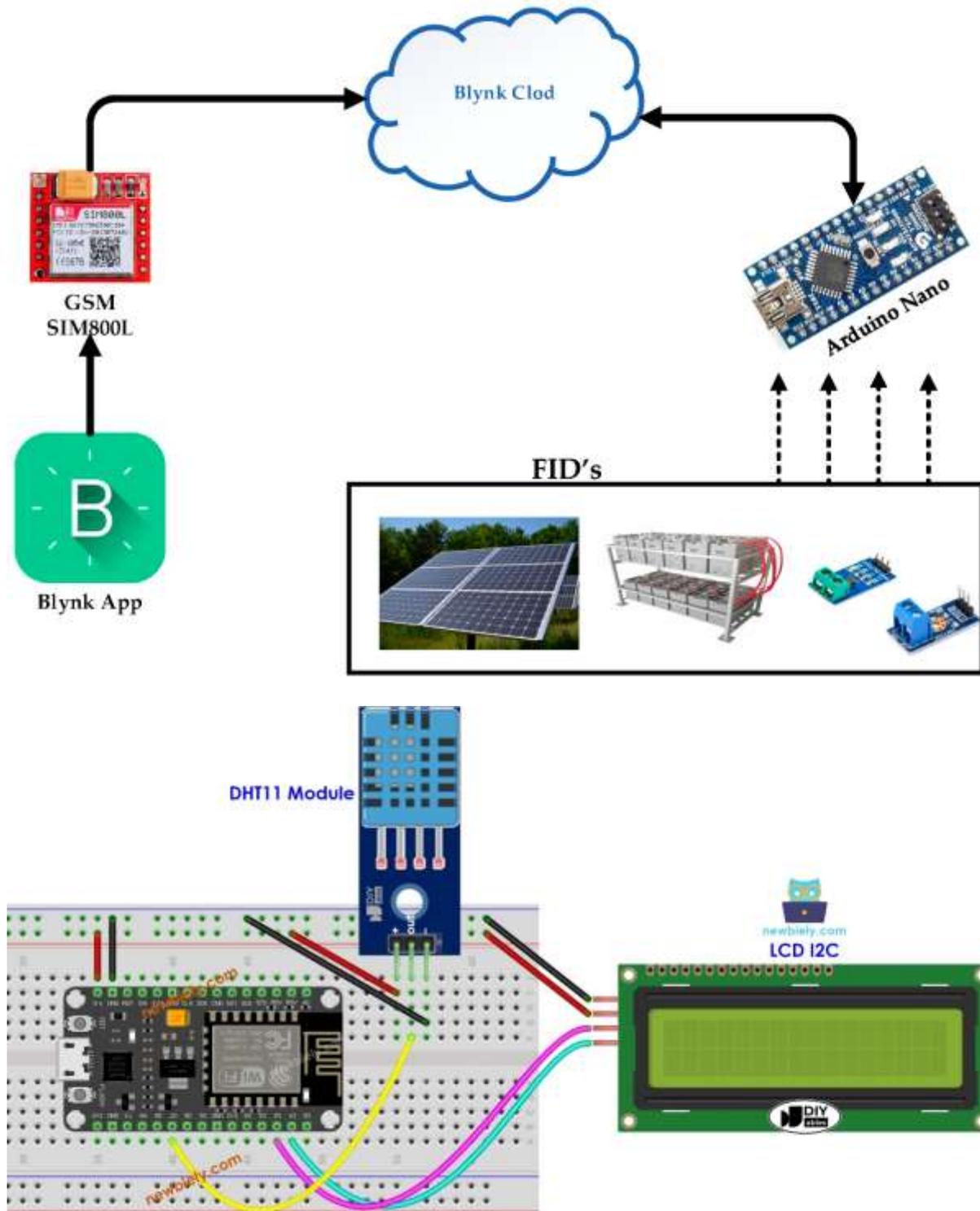
The simulation evaluates the following parameters:

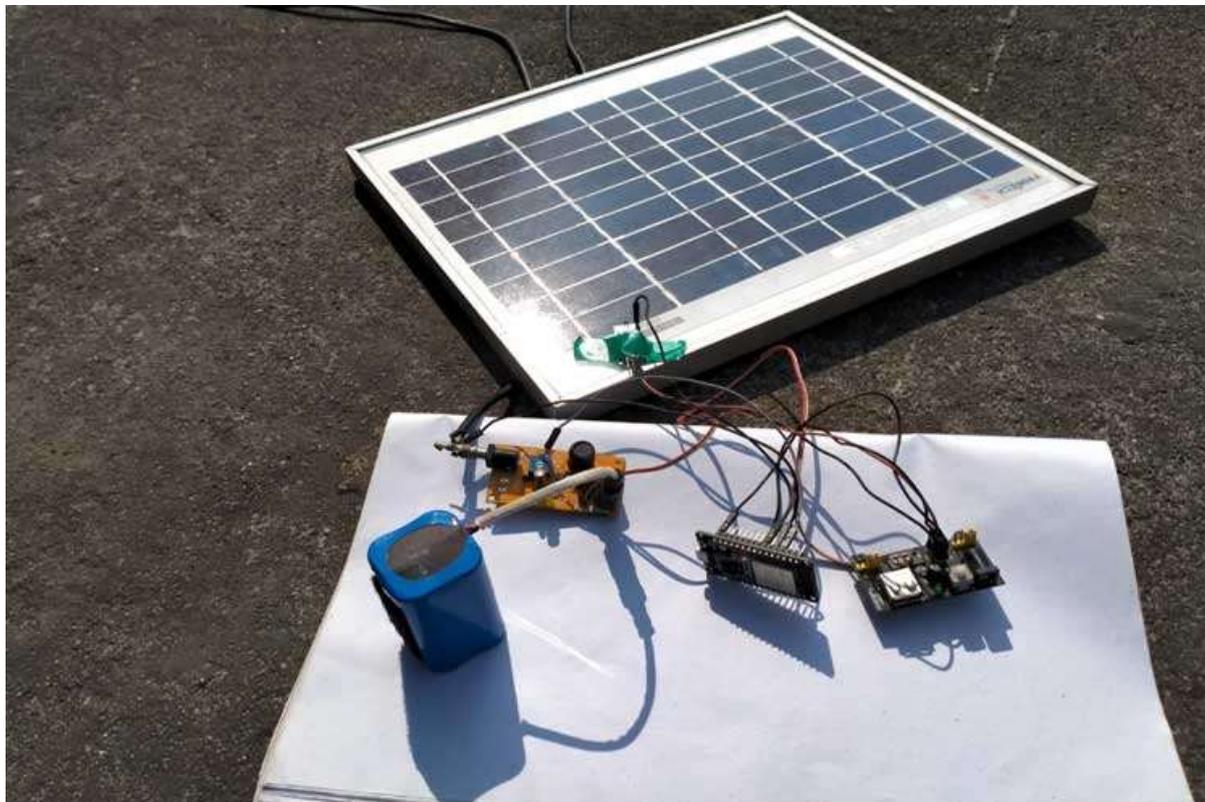
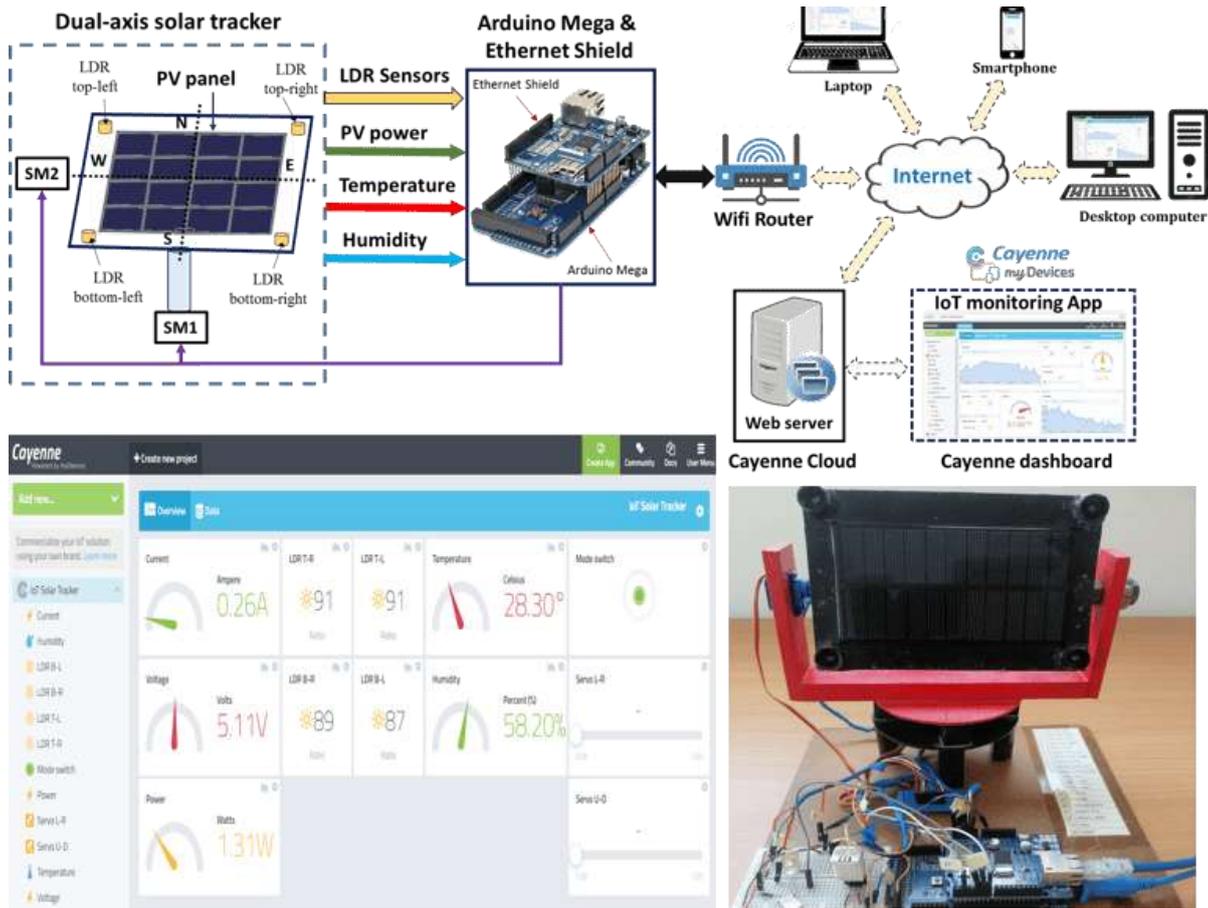
- Voltage stability
- Renewable energy output
- Load demand behavior
- Battery charging and discharging characteristics

Simulation results confirm that the system maintains stable voltage output during load variations and renewable energy fluctuations.

### 5. Hardware Implementation

#### Prototype Hardware Setup



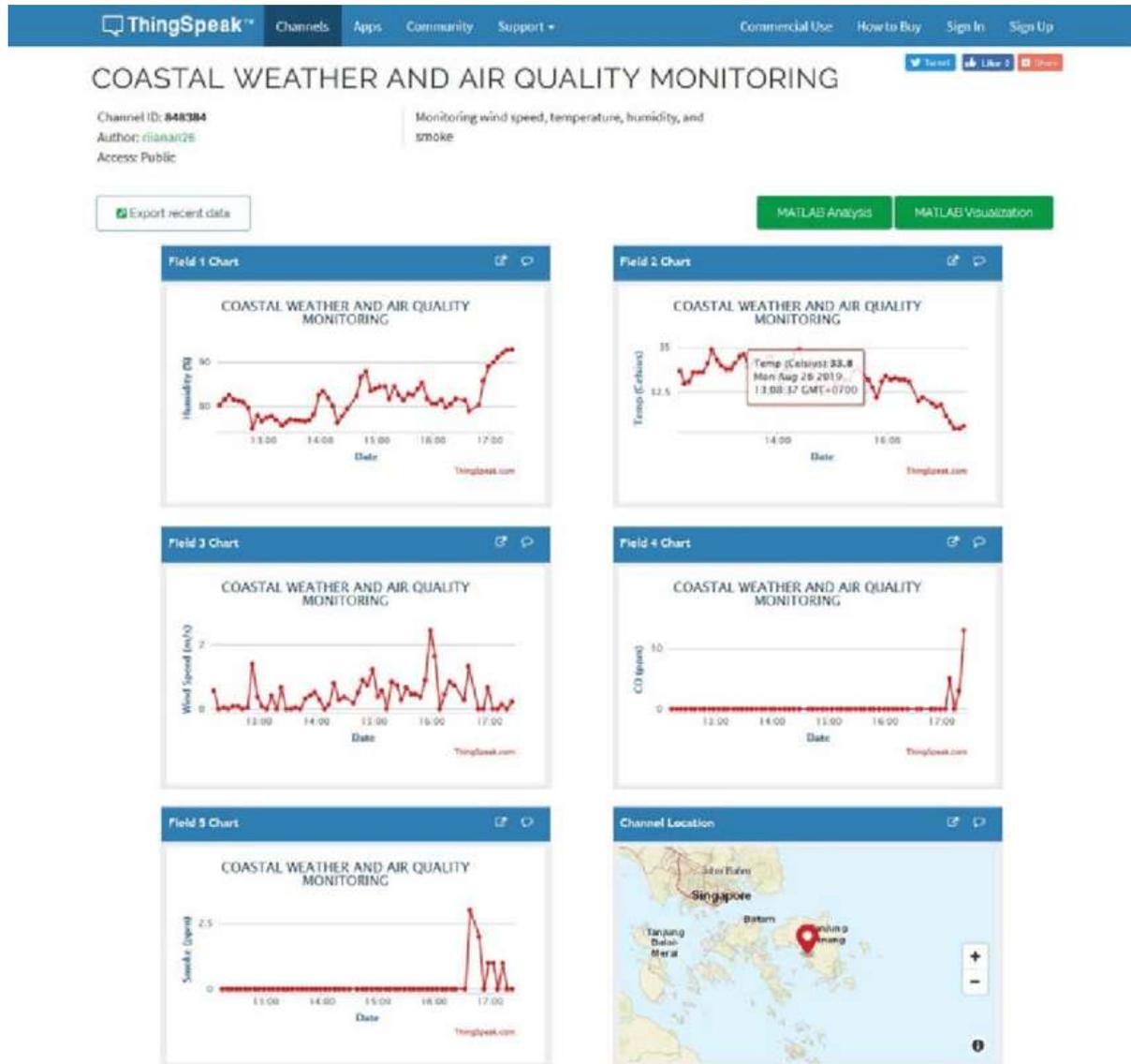


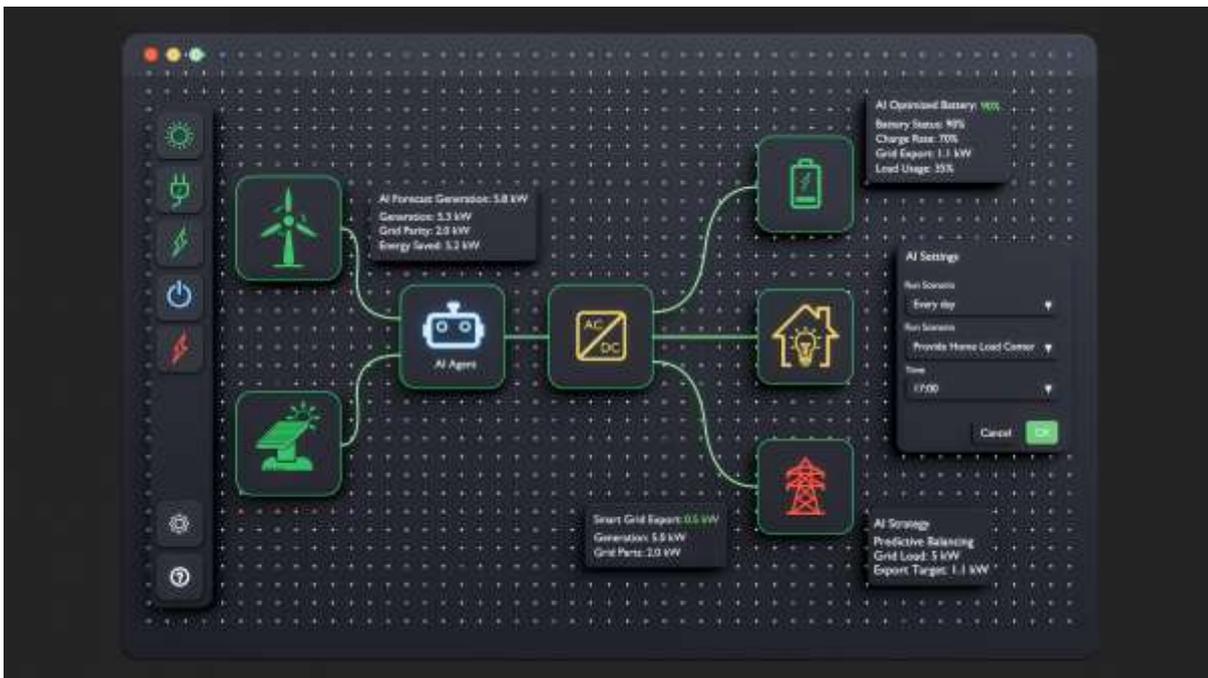
The hardware prototype was developed using Arduino Uno and NodeMCU ESP8266 modules. Sensors were connected to measure voltage, temperature, humidity, and light intensity.

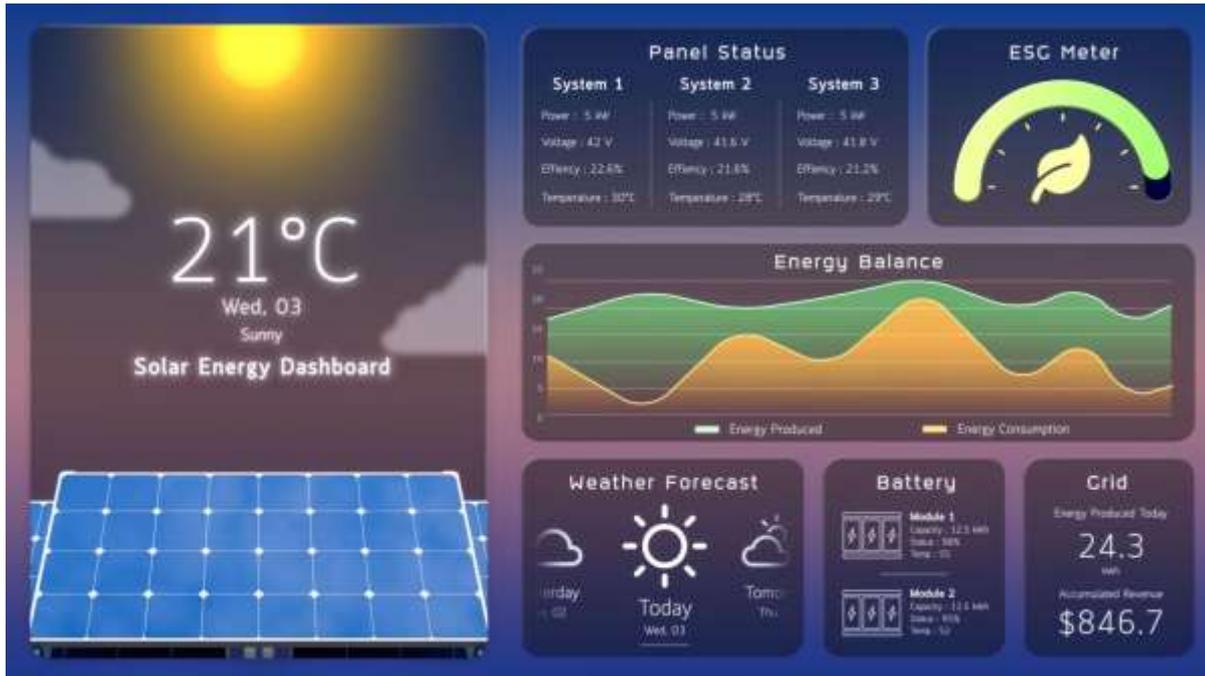
The NodeMCU module transmits sensor data to the IoT platform through Wi-Fi connectivity. The LCD display shows system parameters locally, while the buzzer provides alert signals during abnormal voltage conditions.

## 6.IoT Dashboard Monitoring

### Cloud Monitoring Interface







The IoT dashboard displays real-time system parameters and graphical analysis of microgrid performance. The cloud platform allows users to monitor energy conditions remotely using a web browser or mobile application.

## 7. Results and Discussion

Parameter	Measured Value
Voltage	12.3 V
Temperature	30°C
Humidity	62%
Light Intensity	High

The experimental results show that the system successfully monitors microgrid parameters and transmits real-time data to the IoT cloud platform.

Key observations include:

- Data transmission delay was less than **3 seconds**
- Sensor readings were accurate and stable
- Renewable energy integration improved system sustainability
- Buzzer alerts effectively indicated abnormal voltage conditions

## 8. Advantages

- Real-time monitoring of microgrid parameters
- Integration of renewable energy sources
- Remote monitoring through IoT platforms
- Early detection of abnormal conditions
- Low-cost and easy implementation

## 9. Applications

The proposed monitoring system can be used in several applications including:

- Smart microgrid systems
- Renewable energy monitoring
- Industrial energy management
- Smart campus energy systems
- Smart building automation

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## 10. Conclusion

This paper presented an **IoT-based Smart Microgrid Monitoring System** designed to monitor electrical and environmental parameters in microgrid environments. The system integrates embedded sensors, renewable energy sources, and cloud-based communication technologies to provide real-time monitoring capabilities.

Simulation and experimental results demonstrate that the system accurately measures voltage and environmental parameters while providing reliable remote monitoring through IoT platforms. The proposed solution improves microgrid efficiency, reliability, and automation, contributing to the advancement of smart grid technologies.

Future work may include integration of **machine learning algorithms for energy prediction and advanced cybersecurity techniques for IoT-based power systems**.

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