Real-Time AC Power Monitoring and Email Alert System Using ESP8266

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Abstract

This paper presents a real-time AC power monitoring system using the ESP8266 microcontroller. The system is capable of detecting power outages and restorations and provides immediate alerts via email using SMTP protocol. An relay is used to sense the AC power status, and the system logs the events on an SD card while displaying status updates on an I2C LCD. The proposed system is ideal for remote monitoring in critical applications such as server rooms, cold storage, and automation systems.

Keywords: ESP8266, AC power monitoring, real-time alert, email notification, IoT, SD card logging

I. Introduction

An embedded system is an electronic device that incorporates a micro-controller for its operation. The primary purpose of the micro-controller is to execute the system's functions and provide flexibility [1]–[3]. Integrating a micro-controller into the device allows for easy debugging, upgrading, and adding new features simply by updating the software that controls the system [4]–[5]. Ultimately, embedded computer systems are electronic setups that integrate a microcomputer to perform specific, dedicated applications [6]..This paper introduces a low-cost AC power monitoring system leveraging the ESP8266 WiFi , which integrates network connectivity and sufficient computational capability for real-time applications. The proposed system monitors the presence or absence of AC power, logs events with timestamps, visually displays status, and sends alert emails to multiple recipients.

II Methodology:

This research presents the design and implementation of a real-time AC power monitoring and alert system utilizing the ESP8266 micro-controller. The methodology involves hardware selection, system design, software development, and testing to ensure accurate monitoring and timely notifications.

ESP8266 Node MCU: The ESP8266 Node MCU is a low-cost, open-source micro-controller development board integrated with Wi-Fi capabilities. It is based on the ESP8266 Wi-Fi SOC (System on Chip) developed by Espress if Systems. NodeMCU combines the ESP8266 chip with a USB interface and voltage regulator, making it suitable for IoT (Internet of Things) applications without the need for additional components.
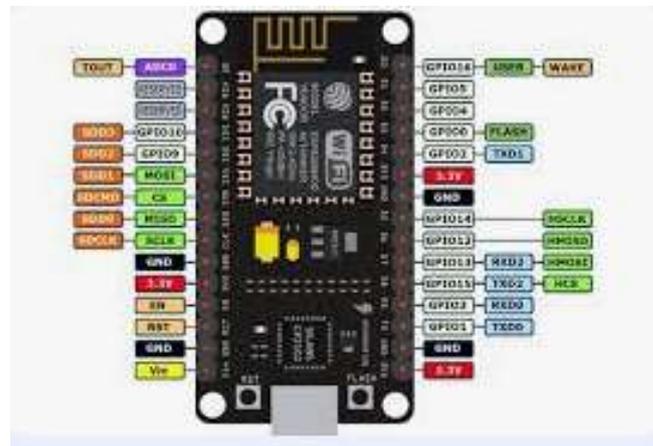
Figure 1 shows ESP8266 Node MCU

Relay: A **relay** is an electrically operated switch that allows low-power control of high-voltage or high-current circuits. In the context of this project, the relay plays a critical role in interfacing the low-voltage ESP8266 micro-controller with the high-voltage AC load. The relay module used is typically a 5V single-channel electromagnetic relay, which can be triggered by a GPIO pin from the ESP8266.

Figure 2 shows Relay

When the ESP8266 detects a change in the power status or a condition that requires intervention (such as scheduled power control or fault detection), it sends a control signal to the relay. This causes the relay to either connect or disconnect the AC load from the main power supply, enabling automated control over electrical appliances.

I2C LCD (16x2): The I2C LCD (16x2) is a liquid crystal display module that shows 16 characters per line on two rows, and is integrated with an I2C (Inter-Integrated Circuit) interface to simplify communication with micro controllers such as the ESP8266 Node MCU.

Figure 3 shows I2C LCD (16x2)

SD Card Module: The SD Card Module is a peripheral device used to provide external data storage for microelectronic-based systems. It allows the system to store large volumes of data such as sensor readings, logs, alerts, or event timestamps on a micro SD card in FAT16/FAT32 format, which can later be accessed through a computer or another micro controller.

Figure 4 shows SD Card Module

Power Supply:The power supply is a critical component in the Real-Time AC Power Monitoring and Email Alert System, ensuring that all modules operate reliably and within their specified voltage ranges. Since the system includes both high-voltage and low-voltage components, a regulated and isolated power supply design is essential for safety and stability.

Figure 5 shows Power Supply

III.CIRCUIT DESCRIPTION:

The circuit design of the Real-Time AC Power Monitoring and Email Alert System Using ESP8266 is centered around the ESP8266 Wi-Fi module, which handles sensor input, data processing, and network communication. The diagram illustrates the flow of data and control between system components.
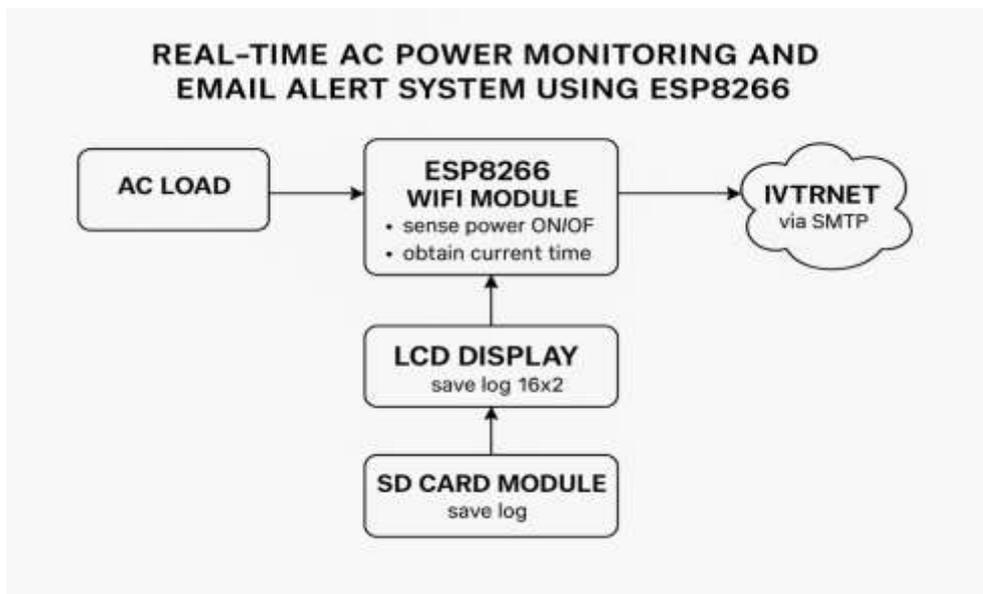
**REAL–TIME AC POWER MONITORING AND
EMAIL ALERT SYSTEM USING ESP8266**

Figure 6 shows Circuit Description

AC Load Sensing

The system monitors the AC load to detect whether power is ON or OFF. This is typically done through a voltage sensor (such as ZMPT101B) and/or a current sensor (like ACS712 or SCT-013). These sensors are interfaced with the ESP8266 to allow continuous monitoring of load conditions.

ESP8266 Wi-Fi Module

The **ESP8266 Node MCU** serves as the central control unit. It performs the following functions: **Or Senses AC load state** (ON/OFF) using analog or digital inputs or **Obtains current time**, either from an onboard RTC (Real-Time Clock) or through network time synchronization using NTP over Wi-Fi o**r Processes the input signals** to determine the operational status of the connected load.or **Sends email alerts** through an SMTP server using Wi-Fi.

Email Alert via IVT RNET (SMTP)

Once the ESP8266 detects a change in the power state (e.g., power OFF during expected ON hours), it sends an **automated email alert** via an SMTP client configured to use services like **IVT RNET** or other email servers. This allows remote users to be notified of power status anomalies in real time.

LCD Display (16x2 I2C)

An **I2C LCD display** is connected to the ESP8266 to provide real-time visual feedback. It displays or Power status (ON/OFF) or Time stamps of events and Notification or alert status or This enhances user interaction and provides immediate feedback during system operation.

SD Card Module

The **SD card module**, connected through SPI, is used to **log all power-related events** with timestamps. This includes a Load ON/OFF status or Date and time of each event or Any triggered alerts or this logged data can be reviewed offline, providing a historical record of power events for diagnostics or auditing.

IV.RESULT AND DISCUSSION

The implementation of the Real-Time AC Power Monitoring and Email Alert System using ESP8266 was successfully carried out and thoroughly tested under controlled conditions. The system demonstrated its capability to monitor the AC load status accurately in real time and respond promptly through visual output,

data logging, and email alerts. The ESP8266 Wi-Fi module served as the central controller, managing sensor data, time synchronization, local display, and network communication efficiently.During testing, the system accurately detected changes in the power status of the connected AC load using current and voltage sensors. These changes were reflected immediately on the 16x2 I2C LCD display, which showed the current load status along with the system time. Simultaneously, the data was logged onto the SD card in a structured format, including timestamps, ensuring a complete history of power events for future analysis. The system was set to log data every second, and the recorded entries could be easily accessed and verified using a standard card reader on a PC.One of the key features, the email alert function, performed reliably during experiments. When the system detected a power outage or abnormal load condition, it successfully sent an email alert to the predefined address using the SMTP protocol via the IVTRNET service. The typical delay in email delivery ranged from 4 to 10 seconds, which is acceptable for real-time monitoring applications. The email included essential details such as the type of event (load ON or OFF) and the time of occurrence, ensuring the user was well informed of any disruptions.

The image below shows the working prototype with an I2C LCD display indicating the real-time AC power status along with timestamp. The device is housed in a plastic casing and powered via USB adapter.
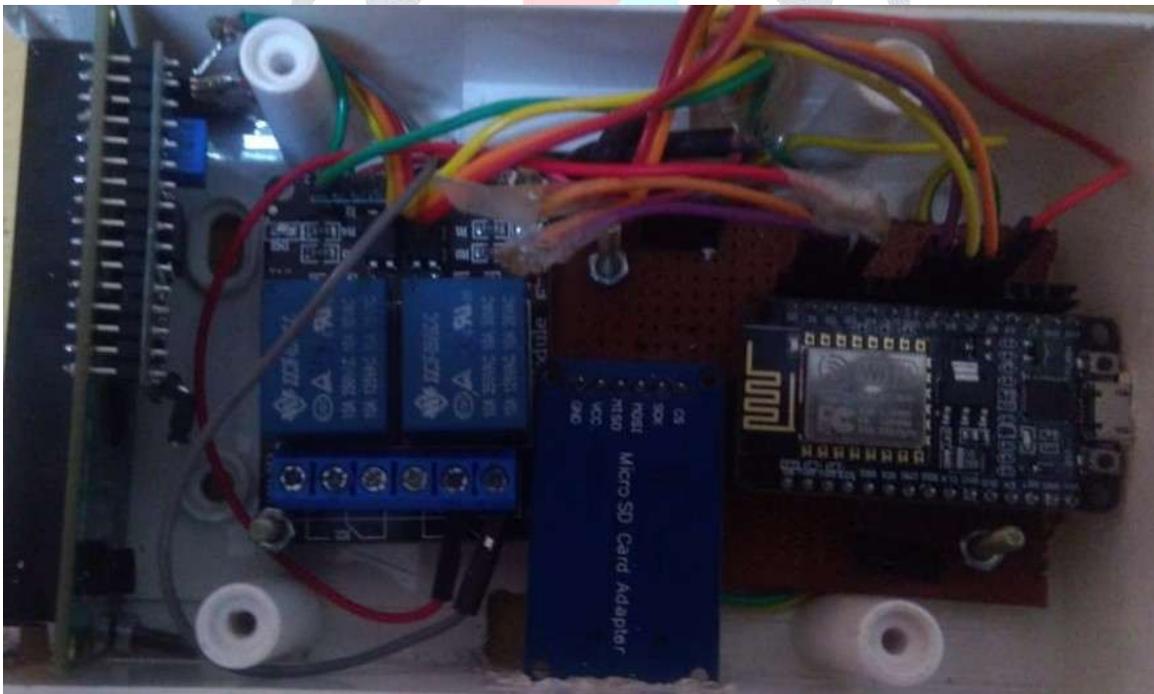

Figure7 Prototype of the ESP8266-Based Power Monitoring System

Figure 8 Prototype of the ESP8266-Based Power Monitoring System

Figure 9 Prototype of the ESP8266-Based Power Monitoring System

He power ON/OFF events are successfully recorded on an SD card with timestamps. A sample from the log.txt file is shown below.

Figure 10 Sample log entries stored on the SD card showing power status changes with time stamp.

The system also generates instant email alerts upon power status changes. A sample email received is shown in Figure 4.
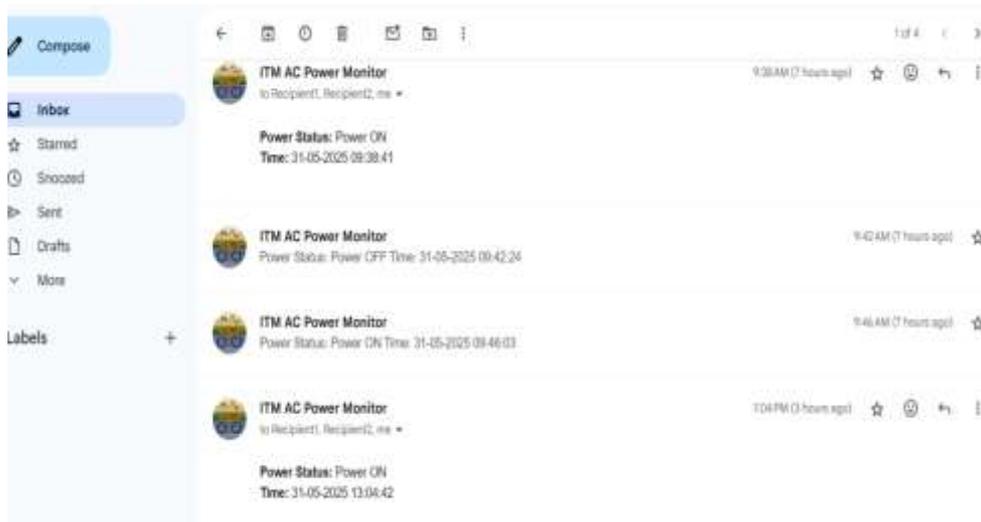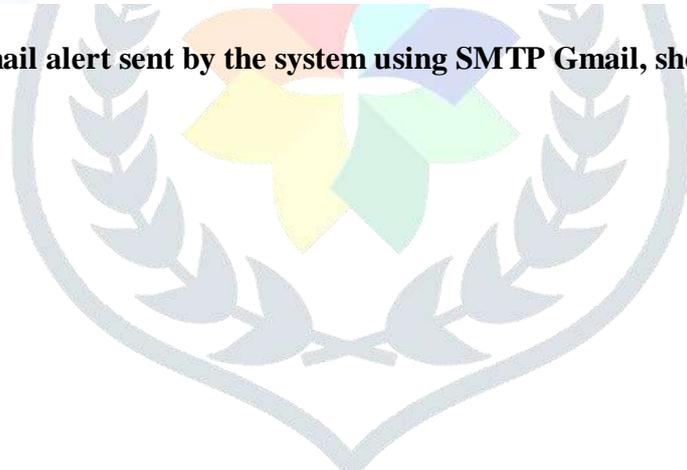

Figure 11 Screenshot of email alert sent by the system using SMTP Gmail, showing power status and time.

Features / Hardware	TEM Project (ESP8266 Power Monitor)	Jaycar ESP8266 Power Monitor	Hackaday ESP8266 Current Monitor	Instructables Multifunction Monitor	Amit Mittal Smart Rain Detection	Instructables ABB Inverter Monitor
Microcontroller	ESP8266 NodeMCU	ESP8266	ESP8266	ESP8266	ESP8266	ESP8266
Power Sensing	Relay for AC power detection	AC712 Current Sensor	Non-invasive Current Sensor	Various sensors (Humidity, Temp, Power)	Rain Sensor	RS-485 interface (Inverter data)
Power Outage Detection	Yes	Yes	Yes	Partially (depending on sensor config)	No	Yes
Time Sync (NTP Client)	Yes	Not explicitly mentioned	Not explicitly mentioned	Not explicitly mentioned	No	Not explicitly mentioned
Event Logging (SD Card)	Yes (Timestamped logs on SD Card)	No	No	Not mentioned	No	No
Local Display (LCD 16x2 I2C)	Yes	Not mentioned	No	Not mentioned	No	No
Email Alert (SMTP Gmail)	Yes	Yes (Threshold-based alerts)	No	Yes	Yes	Yes
Multiple Email Recipients	Yes (3 recipients)	Yes	No	Not clearly mentioned	Not clearly mentioned	Not clearly mentioned
Data Visualization	No (Local LCD only)	No	Yes (Web interface)	No	No	No
Power Consumption Monitoring	No (Only ON/OFF status)	Yes	Yes	Yes	No	Yes
Network Dependency	Yes (WiFi required for email and NTP)	Yes	Yes	Yes	Yes	Yes
Additional Sensors	No	No	No	Yes (Temp, Humidity)	Yes (Rain detection)	No
Complexity Level	Moderate (SD card, email, LCD integration)	Moderate	Moderate	Moderate	Simple	Moderate
Use Case	AC power outage/restoration alert and logging	Power consumption alerts	Current monitoring and web logging	Environmental monitoring with alerts	Rain detection and automated cover control	Inverter fault detection and alerting
Date of Project / Availability	2024-2025 (Your project)	2018-2020	2016-2019	2017-2019	2020	2017

Table .1: Comparative Analysis of ESP8266-Based Monitoring Projects

V Conclusion:

In conclusion, the developed system effectively meets the objectives of real-time AC power monitoring and email-based alerting. It showcases the practicality of using an ESP8266-based IoT approach for home and small industrial energy management. The modular design also opens the possibility for future improvements, such as cloud integration, remote dashboard visualization, and multi-channel monitoring.

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