iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** II **Month of publication:** February 2026

DOI: https://doi.org/10.22214/ijraset.2026.77654

IoT-Based Load Management System - An Effective Measure to Save Energy

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Abstract: With the increasing demand for electrical power, preventing overload conditions is critical to ensuring safety and efficiency. This paper presents an IoT-based mains power cut system that monitors power consumption using an ACS712-30A current sensor and automatically disconnects loads when a predefined threshold (135W) is exceeded. The system employs an ESP32 microcontroller, a 4-channel relay, and a WebSocket server for real-time control and monitoring. Users can manually or automatically manage loads through a web-based user interface, integrated with ThingSpeak for data visualization. Experimental results demonstrate the effectiveness of the system in preventing overload situations.rms: IoT, Power Monitoring, Overload Protection, ACS712, ESP32, WebSocket, ThingSpeak.

I. INTRODUCTION

Power consumption monitoring and control play a cru- cial role in energy management. Overloading can lead to equipment failure, safety hazards, and inefficiencies in power systems. Traditional circuit breakers lack real-time monitoring and remote control features. This paper introduces an IoT- based solution that provides real-time monitoring and automa- tion for preventing overloads.

II. LITERATURE REVIEW

Several studies have explored different methods for power monitoring, emphasizing IoT integration for enhanced control and automation. Smart meters, IoT-based monitoring systems, and automated cutoff mechanisms have been extensively re- searched.

Khandel et al. [1] introduced an IoT-based power monitoring system with remote access capabilities but lacked an automatic load disconnection feature. Saleem et al. [2] designed a smart energy management system leveraging IoT and cloud comput- ing for improved energy efficiency. Uzma et al. [3] developed an automatic electricity cutoff system to mitigate excessive power consumption. Kaur et al. [4] provided a comprehensive review of IoT-based smart grid applications, focusing on real- time data acquisition and intelligent control mechanisms.

Other research, such as that by Ke et al. [5] and Arun et al. [6], explored GSM-based automatic meter reading sys- tems, enabling remote power consumption tracking. Widen et al. [7] analyzed household energy consumption patterns, while Tan et al. [8] implemented an automated power meter reading approach for more accurate usage assessment. While these studies highlight the role of IoT in power management, they often lack real-time automation features necessary for proactive overload prevention.

III. SYSTEM DESIGN

The proposed system consists of the following key compo- nents:

1) ACS712-30A Current Sensor: Measures real-time cur- rent flow.
2) ESP32 Microcontroller: Processes data and controls relays.
3) 4-Channel Relay Module: Switches loads based on power calculations.
4) WebSocket Server: Facilitates real-time communication.
5) ThingSpeak API: Logs and visualizes power data.
6) Electrical Loads: The system is designed to control multiple loads, including a 9W LED bulb, a 33W fan, and a 100W incandescent bulb. These loads are indepen- dently monitored, and their combined power consumption determines whether the threshold is exceeded.

The system operates in two modes: manual and automatic. In manual mode, users receive alerts and take necessary actions. In automatic mode, the system proactively disconnects loads exceeding the threshold.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue II Feb 2026- Available at www.ijraset.com

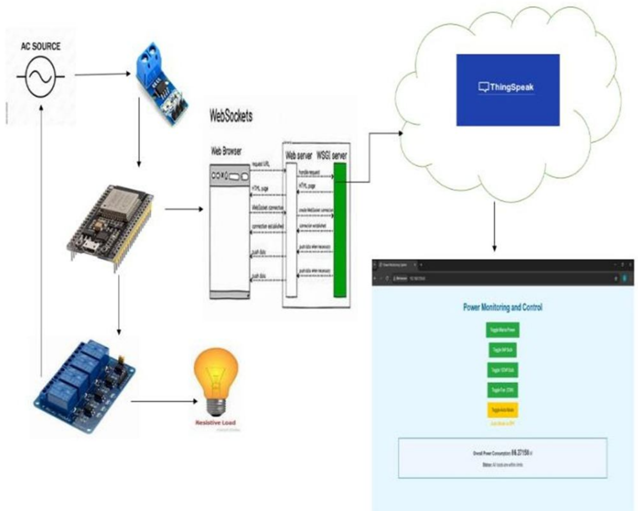

Fig. 1. Block Diagram of the System

IV. METHODOLOGY

The system workflow consists of the following steps:

1) Current Measurement: The ACS712 sensor continu- ously monitors the current flowing through the loads.

2) Power Calculation: The system computes power con- sumption using the formula:

$$P = V \times I \times PF \quad (1)$$

where V is the voltage, I is the measured current, and PF is the power factor (assumed to be 1 for purely resistive loads).

3) Threshold Comparison: The calculated power is com- pared with a predefined threshold of 135W.

4) Relay Control: If the power exceeds 135W, the ESP32 microcontroller sends a signal to the relay module to disconnect the highest consuming load.

5) Data Transmission: The ESP32 transmits power con- sumption data to the WebSocket server for real-time monitoring.

6) User Interface Update: The web-based user interface displays real-time power data, allowing users to monitor and control loads remotely.

7) Automation Logic: In automatic mode, the system dynamically adjusts load connections to maintain power within the permissible limit.

8) ThingSpeak Data Logging: Power consumption data is logged on ThingSpeak for historical analysis and visualization.

V. RESULTS AND DISCUSSION

The system successfully detects and manages power consumption. The web interface provides real-time status updates, as shown in Fig. 3.

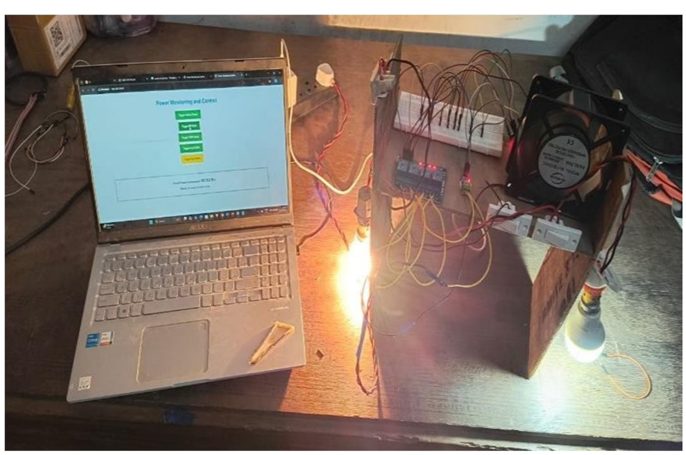

Fig. 2. System Architecture

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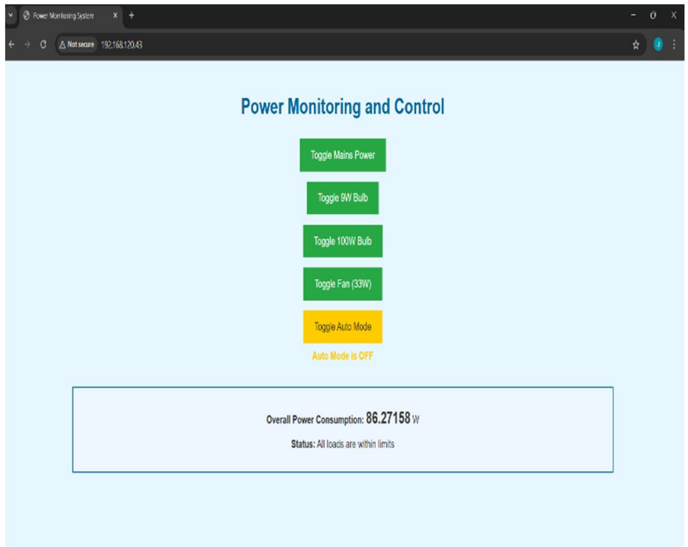

Fig. 3. User Interface of the Power Management System

When the threshold of 135W is exceeded, the system noti- fies the user and automatically turns off the last activated load in Auto Mode. The system logs power data and user actions on ThingSpeak. The system was tested with various load combinations. Table I presents the power readings obtained during testing.

TABLE I
POWER READINGS FOR DIFFERENT LOAD CONDITIONS

Load Combination	Measured Power (W)
9W Bulb	9W
33W Fan	33W
100W Bulb	100W
9W + 33W	42W
33W + 100W	133W
9W + 33W + 100W	142W

Experimental results confirm that the system successfully identifies and disconnects excess loads when power con- sumption exceeds 135W. The automation feature effectively prevents overload situations.

VI. CONCLUSION

This paper presented an IoT-based mains power cut system that ensures overload protection through real-time monitoring and automation. The proposed system provides an efficient and user-friendly approach to managing power loads, reducing risks associated with excessive consumption. Future work will involve extending the system with machine learning for predictive analysis, improving energy efficiency through dy- namic load adjustments, and integrating adaptive thresholding mechanisms to enhance performance . In the future, the system can be enhanced with Implementing machine learning algorithms for predictive maintenance. Moreover, Integrating renewable energy sources for enhanced energy efficiency and lastly, developing a mobile application for better user interaction and remote access.

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ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
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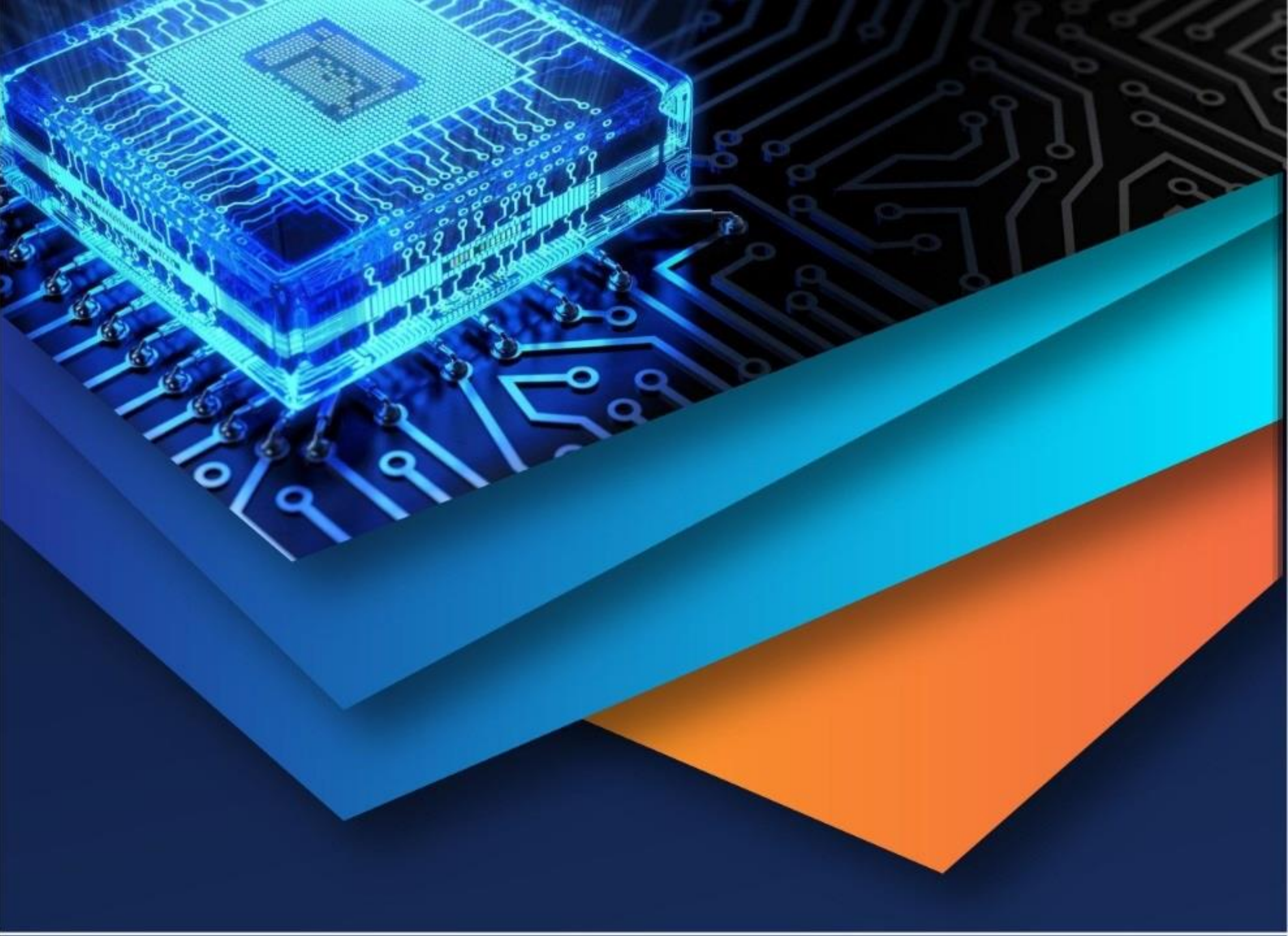

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