International Journal of Creative and Open Research in Engineering and Management
ISSN: **3108-1754 (Online)**
Volume 02 Issue 04 April-2026 | Impact Factor: 3.5

IoT-Enabled Home Appliances Protection and Control System Using ESP32

Nirmal Kumar V, Pachaiyappan C, V Kalist,

Department of Electronics and Communication,
Sathyabama Institute of Science and Technology, Chennai, India.
nikumar663@gmail.com, aravind2017007@gmail.com, Kalist.enc@sathyabama.ac.in

Abstract—In recent years, household appliances have become highly sensitive to electrical variations such as voltage fluctuations, current surges, and overheating. Conventional protection devices like fuses and circuit breakers provide only limited safety and do not support real-time monitoring or remote control. In this paper, an IoT-based home appliance protection and control system using the ESP32 microcontroller is presented. The system continuously monitors voltage, current, and temperature using appropriate sensors and automatically disconnects the load when abnormal conditions are detected. A web-based dashboard is used for remote monitoring and control, while Google Sheets is utilized for cloud data logging. The experimental results show that the system is capable of providing reliable protection along with real-time monitoring and data storage. The proposed system is low-cost, scalable, and suitable for applications such as homes, laboratories, and small offices.

Index Terms—Internet of Things (IoT), ESP32, Appliance Protection, Energy Monitoring, Relay Control, Cloud Logging, Smart Home Systems

I. INTRODUCTION

In recent years, the use of Internet of Things (IoT) technology has increased rapidly, especially in home automation and monitoring applications. IoT enables devices to be connected, monitored, and controlled remotely, improving convenience and efficiency in everyday life. In this paper, we focus on improving the safety and monitoring of household electrical systems using IoT technology.

In practical scenarios, electrical appliances used in homes such as refrigerators, computers, motors, and entertainment systems require stable voltage and current conditions for safe operation. Any variation in these parameters, such as over-voltage, under-voltage, or excessive current, can damage the appliances or reduce their lifespan. In many regions, power supply fluctuations are common, which increases the risk of failure in electrical devices.

Traditional protection devices such as fuses, stabilizers, and miniature circuit breakers (MCBs) provide only basic protection. These devices can disconnect the power during severe faults, but they do not provide real-time monitoring, remote access, or detailed information about the system. This highlights that there is still a gap in providing complete and intelligent protection for household electrical systems.

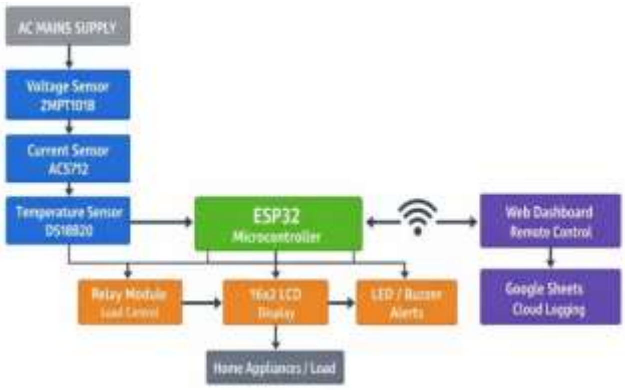

Fig. 1. System architecture showing sensors, ESP32, relay module, dashboard, and cloud storage.

To address these challenges, this paper proposes an IoT-based intelligent appliance monitoring and protection system. The system continuously monitors electrical parameters such as voltage, current, and temperature, and automatically disconnects the load when abnormal conditions are detected. The main idea of this work is to ensure both protection and real-time monitoring of appliances using a single integrated system.

In this work, the system is designed using low-cost components in a modular manner, making it easy to implement and suitable for different applications. The system also supports remote monitoring through a web dashboard and cloud-based data logging, which improves usability and provides better insight into system performance.

II. LITERATURE SURVEY

IoT-based monitoring and control systems have been widely used in smart home applications in recent years. These systems mainly focus on providing remote access, real-time monitoring, and automation of electrical devices. However, most of these systems concentrate more on control and visualization rather than providing immediate protection during electrical faults.

Hossain et al. [1] proposed an IoT-based energy management system that focuses on monitoring energy usage using cloud dashboards. But the system mainly emphasizes monitoring and does not provide fast protection during electrical fault conditions. This makes it clear that real-time protection mechanisms are necessary in addition to monitoring.

Palanisamy et al. [2] designed an IoT-based home automation system that allows remote control of appliances. However, the system does not include protection features such as over-voltage or over-current detection. This indicates that safety aspects are not fully addressed in their work.

Srivastava and Singh [3] developed a low-cost home automation system using ESP32, demonstrating the flexibility of IoT devices. Gupta et al. [6] also presented dashboard-based control systems for smart homes. However, both works mainly focus on usability and remote control, while protection mechanisms are not given significant importance. This shows the need for integrating monitoring and protection in a single system. Ahmed and Rehmani [5] discussed energy-efficient smart home systems using IoT-enabled appliances. However, their work mainly focuses on energy efficiency and does not include automatic fault isolation or protection features. This suggests that additional safety mechanisms are required in such systems.

Protection-oriented IoT systems have also been examined. John and George [7] introduced an IoT-based appliance fault detection system using threshold-based logic. A limitation is that their design lacks multi-load support and cloud connectivity. This shows that scalability and remote monitoring features are limited in their system.

Prakash and Venkatesh [10] proposed an IoT-based voltage protection system. However, their system is limited to monitoring a single parameter and does not consider multiple factors such as current and temperature. This indicates the need for a multi-parameter protection system.

Bhuiyan et al. [9] discussed the importance of security in IoT-based smart home systems. However, many practical implementations still lack proper encryption and authentication mechanisms. This highlights that security must be considered as an important factor in system design.

From the above studies, it is clear that most existing systems focus mainly on monitoring and remote control, while real-time protection is often not given sufficient importance. Many systems also lack multi-parameter sensing, cloud logging, and scalability. Therefore, there is a need for a system that combines monitoring, protection, and remote accessibility in a single platform. In this paper, we propose a system that addresses these limitations.

To address these limitations, the proposed system integrates real-time sensing, automatic relay-based protection, remote web control, and cloud data logging, offering a more comprehensive and scalable solution compared to existing works.

III. SYSTEM DESIGN METHODOLOGY

In this project, a systematic methodology is followed to ensure proper development and testing of the proposed system. The design process includes requirement analysis, system design, hardware integration, software development, and final testing.

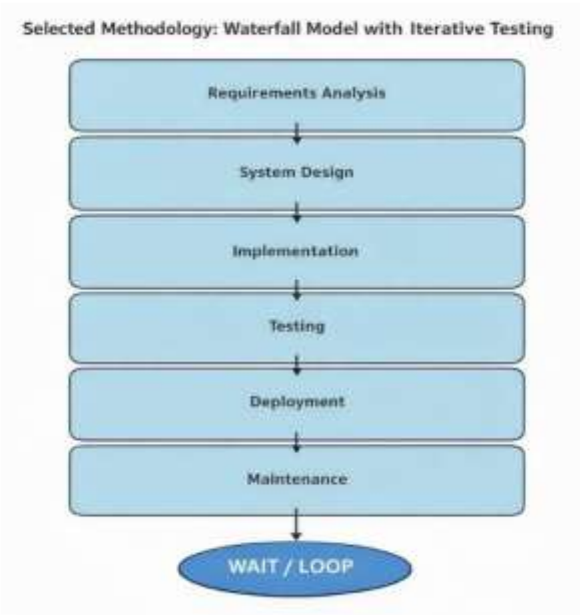

Fig. 2. Methodology workflow for development of the proposed system.

A. Requirement Analysis

The proposed system is designed to satisfy both functional and non-functional requirements.

Functional Requirements:

- Acquire real-time voltage, current, and temperature readings.
- Detect anomalies such as:
- Over-voltage
- Under-voltage
- Over-current
- Temperature rise
- Disconnect appliance instantaneously via relay.
- Display sensor values locally using LCD.
- Provide secure web dashboard access.
- Upload data to Google Sheets for long-term storage.

Non-functional Requirements:

- High reliability in fault detection.
- Low cost and low power consumption.
- Scalable design for multi-appliance monitoring.
- Minimal latency between detection and cutoff.
- Secure cloud communication.

B. System Architecture

The overall architecture of the proposed system integrates sensing, processing, control, display, and cloud communication modules.

The main components used in the proposed system are listed below:

- ESP32 microcontroller: A dual-core processor with Wi-Fi capability, suitable for IoT applications.
- ZMPT101B voltage sensor: In this system, AC voltage is measured and fluctuations are detected using this sensor.
- ACS712 current sensor: In this system, load current is measured and abnormal surges are identified.
- DS18B20 temperature sensor: In our design, temperature is monitored to ensure safe operating conditions.
- Relay module: The proposed system controls the relay to perform automatic ON/OFF switching during fault conditions.
- LCD display (I2C): Displays real-time sensor values and system status.
- Google Sheets cloud logging: In this system, data is stored for future analysis and monitoring.
- Web dashboard: Provides remote monitoring and control of the system.

IV. IMPLEMENTATION

A. Hardware Implementation

In this system, the sensors are connected to the ESP32 ADC pins for analog data acquisition. Proper voltage isolation is implemented to protect low-voltage components from high-voltage variations. The relay channels are controlled through GPIO pins, and flyback diodes along with optocouplers are used to ensure electrical noise immunity.

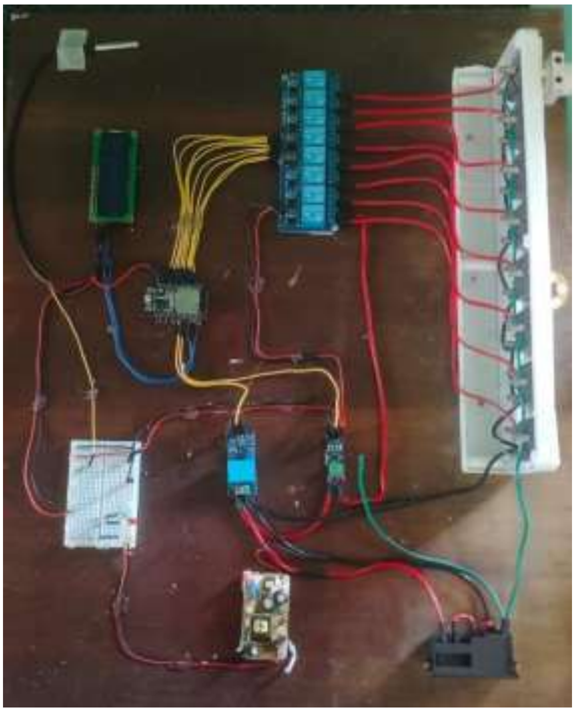

Fig. 3. Hardware prototype of the proposed system The LCD display operates using the I2C protocol, which reduces wiring complexity. The power supply is designed to provide stable 5V and 3.3V regulated outputs for reliable system operation.

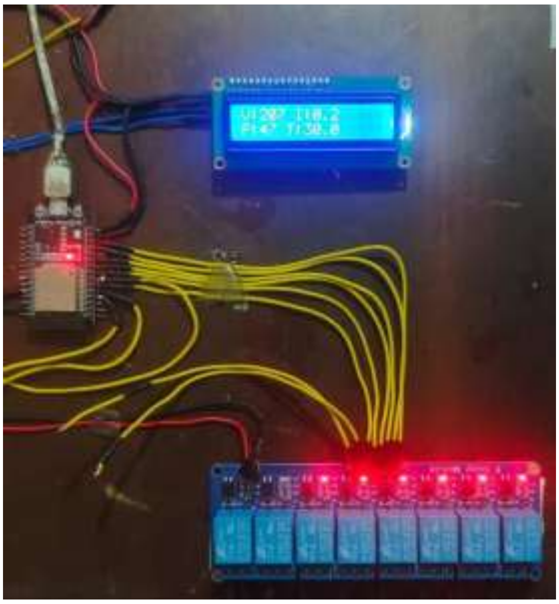

Fig. 4. LCD displaying real-time system parameters

B. Software Implementation

The firmware for the proposed system is developed using Arduino IDE. The main software modules used in the system include:

- Wi-Fi Initialization Module: Connects the ESP32 to a Wi-Fi network.
- Sensor Acquisition Module: Acquires voltage, current, and temperature data from sensors.
- Computation Module: Performs RMS calculations and compares values with predefined thresholds.
- Protection Logic Module: Controls the relay operation based on unsafe conditions.
- Dashboard Handler: Hosts an HTTP server on the ESP32 for real-time monitoring.
- Cloud Handler: Sends JSON data to the Google Apps Script endpoint for cloud storage.

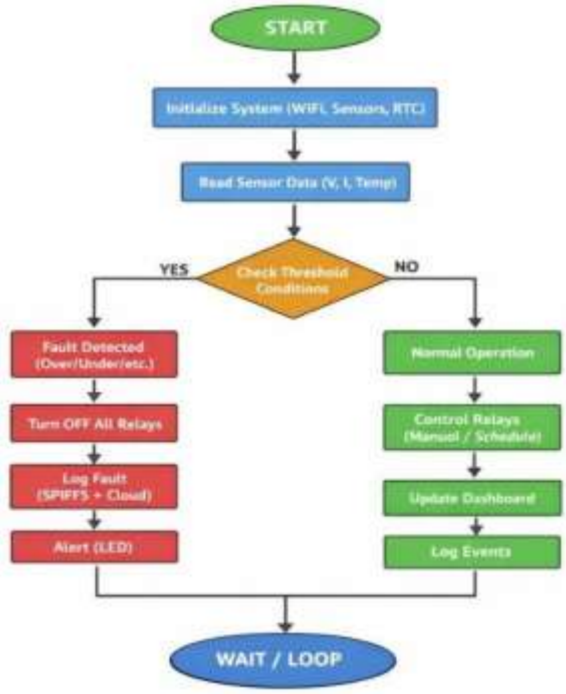

Fig. 5. Flowchart of system operation and fault detection

The protection algorithm ensures fast disconnection (within 50 ms) when a fault condition is detected. The threshold values can be configured based on system requirements.

C. *Cloud Logging*

Google Sheets is used as a lightweight and easily accessible cloud database in this system. Using Google Apps Script, a custom endpoint is created to accept HTTP POST requests. Each entry includes:

- Timestamp
- Voltage
- Current
- Temperature
- Relay status

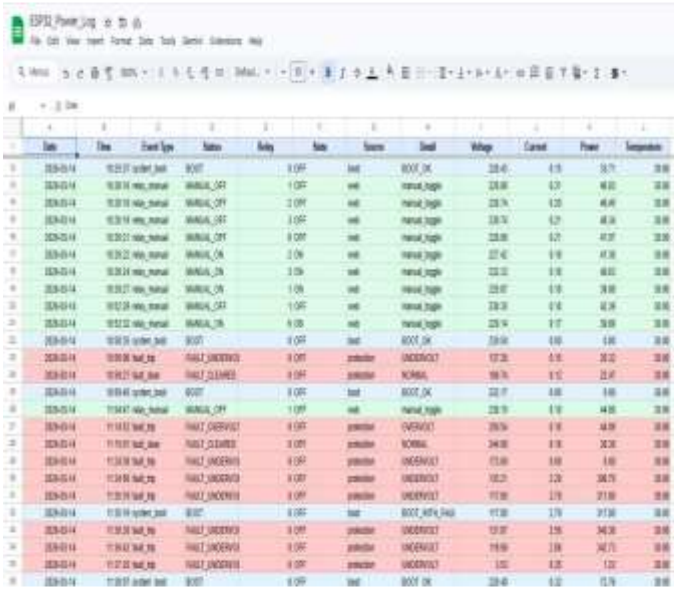

Fig. 6. Cloud-based logging of system parameters using Google Sheets

This enables analysis of fault trends and helps in predicting possible future failures.

V. RESULTS AND DISCUSSION

The system was subjected to various electrical test conditions:

- Over-voltage → successful automated cutoff
- Under-voltage → relay deactivated to prevent damage
- Over-current → ACS712 detected load surge
- Overheating →DS18B20 triggered temperature alert

The dashboard displayed accurate real-time values, and all logged entries appeared correctly in the cloud.

Fig. 7. Web dashboard showing normal operating condition

Fig. 8. Web dashboard displaying overvoltage fault detection

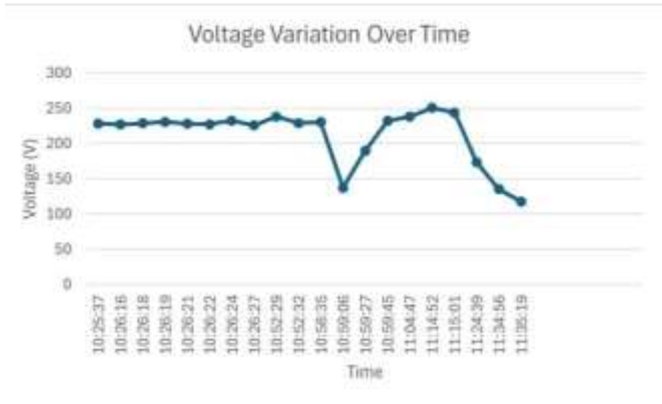

Fig. 9. Voltage variation over time showing normal operation and fault conditions

VI. CONCLUSION

In this work, an IoT-based home appliance protection and control system was successfully designed and implemented using the ESP32 microcontroller. The integration of voltage, current, and temperature sensing ensures comprehensive protection. Cloud logging and a responsive dashboard enhance user awareness and enable informed decisions. The low cost and modularity of the system make it suitable for real-world deployment, especially in regions with unstable power supply. The system was tested under different conditions, and it was observed that it performs reliably in protecting electrical appliances.

VII. FUTURE WORK

Planned enhancements include:

- AI-based electrical fault prediction
- Dedicated Android/iOS application
- MQTT-based high-speed cloud messaging
- Hardware PCB miniaturization
- Offline buffer storage

REFERENCES

[1] M. A. Hossain, M. S. Kaiser, and M. Rahman, "Smart home energy management system using IoT," *IEEE Access*, vol. 8, pp. 175940–175951, 2020.

[2] S. Palanisamy, B. Thirumalai, and K. Duraiswamy, "IoT-based smart energy monitoring and control system," in *Proc. IEEE Int. Conf. Power, Control and Embedded Systems (ICPCES)*, 2019, pp. 1–6.

[3] A. Srivastava and P. Singh, "Low-cost IoT enabled home automation using ESP32," *Int. J. Recent Technology and Engineering (IJRTE)*, vol. 8, no. 4, pp. 1226–1230, 2019.

[4] R. Kumar and V. Singh, "IoT-based smart home security and monitoring system," in *Proc. IEEE Int. Conf. Computing, Communication and Automation (ICCCA)*, 2020, pp. 1–6.

[5] S. Ahmed and F. Rehmani, "Energy-efficient smart home systems with IoT enabled appliances," *IEEE Internet of Things Journal*, vol. 7, no. 6, pp. 5445–5457, 2020.

[6] P. Gupta, S. Agrawal, and R. Yadav, "Real-time IoT dashboard for home automation using ESP32 and Blynk," in *Proc. IEEE Int. Conf. Smart Technologies (ICST)*, 2021, pp. 58–63.

[7] J. P. John and A. George, "IoT-based fault detection and protection of home appliances," *Int. J. Engineering Research & Technology (IJERT)*, vol. 9, no. 7, pp. 1–5, 2020.

[8] H. Ghayvat, S. Mukhopadhyay, and X. Gui, "Smart home systems: A survey of self-health monitoring," *IEEE Sensors Journal*, vol. 19, no. 20, pp. 8402–8412, 2019.

[9] M. Z. A. Bhuiyan, G. Wang, and J. Wu, "Dependable and secure IoT systems for smart home applications," *Future Generation Computer Systems*, vol. 78, pp. 421–430, 2018.

[10] K. Prakash and T. Venkatesh, "IoT-based energy protection system for smart homes," in *Proc. IEEE Int. Conf. Intelligent Sustainable Systems (ICISS)*, 2021, pp. 132–138.

[11] Y. Lee and J. Kim, "A real-time monitoring and control framework for smart homes using MQTT protocol," *IEEE Consumer Electronics Magazine*, vol. 10, no. 4, pp. 52–60, 2021.

[12] C. Gomez, J. Oller, and J. Paradells, "Overview and evaluation of Bluetooth Low Energy: An emerging low-power wireless technology," *Sensors*, vol. 12, no. 9,
pp. 11734–11753, 2012.

[13] A. Al-Fuqaha *et al.*, "Internet of Things: A survey on enabling technologies, protocols, and applications," *IEEE Communications Surveys & Tutorials*, vol. 17, no. 4, pp. 2347–2376, 2015.

[14] A. Banerjee, S. Roy, and T. Chatterjee, "Smart energy monitoring system using ESP32 and IoT cloud," *Int. J. Scientific & Engineering Research (IJSER)*, vol. 11, no. 5, pp. 45–51, 2020.

[15] L. D. Xu, W. He, and S. Li, "Internet of Things in industries: A survey," *IEEE Trans. Industrial Informatics*, vol. 10, no. 4, pp. 2233–2243, 2014.

[16] V. Sharma and S. Kumar, "IoT-based load monitoring and control system for smart homes," in *Proc. IEEE Int. Conf. Power Electronics and IoT Applications (PEIOTA)*, 2020, pp. 1–5.

[17] B. Balamurugan and S. Vidhya, "IoT-based smart plug for home appliance protection," *Int. J. Engineering and Technology (IJET)*, vol. 7, no. 2, pp. 85–90, 2020.

[18] T. W. Kim and K. S. Lee, "Secure communication in smart home IoT devices," *IEEE Access*, vol. 9, pp. 123456–123468, 2021.

[19] N. Gupta and A. Verma, "Smart home appliance monitoring and protection system using ESP32 and Firebase," *Int. J. Advanced Research in Electrical, Electronics and Instrumentation Engineering (IJAREEIE)*, vol. 9, no. 11, pp. 914–920, 2020.