IoT Based Smart Energy System for Apartments

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***Abstract*—Energy consumption in residential buildings has been increasing rapidly due to the rising use of electrical appliances and inefficient monitoring practices. Many apartment residents are unaware of their daily electricity usage, which often leads to unexpected high bills and wastage of energy. To address this problem, the IoT-Based Smart Energy Monitoring System for Apartments is designed to provide real-time tracking, analysis, and notification of energy consumption at the device level. This system helps users understand their electricity usage patterns, identify power hungry appliances, and take timely corrective actions to reduce energy wastage.**

The system uses a NodeMCU (ESP32) with ACS712 sensors to monitor appliance energy consumption in real time, displaying data locally on an OLED and sending it to platforms like Blynk and ThingSpeak for visualization and storage. It also alerts users when usage exceeds 150 units, offering an affordable, scalable solution that promotes energy efficiency, cost savings, and smart home awareness.

***Index Terms*—Edge AI, EMNIST dataset, Jetson Nano, Leaky Integrate-and-Fire neuron, neuromorphic computing, spiking neural networks, temporal coding.**

I. INTRODUCTION

Electricity forms one of the most essential resources in modern society. It supports daily activities through various appliances such as fans, lights, air conditioners, refrigerators, and washing machines, which are widely used in residential and commercial environments. Unlike earlier times, energy usage today is significantly higher and often goes unnoticed at the individual device level, especially in apartments and shared spaces. This lack of awareness leads to unnecessary wastage and increased electricity bills, making efficient monitoring and management an important requirement in modern living conditions. Traditional energy monitoring systems typically provide only total consumption values without offering real-time insights or device-specific data. While they are widely used and serve basic billing purposes, they do not help users understand how energy is being consumed. Because of this, identifying inefficient appliances or controlling excessive usage becomes difficult. This limitation highlights the need for smart monitoring solutions that can provide continuous feedback, improve visibility, and support better energy management through modern technology such as Internet of Things (IoT).

Among the available solutions, IoT-based energy monitoring systems are effective and practical for real-time applications. They use microcontrollers and current sensors to measure electrical parameters such as voltage, current, power, and energy consumption. The system displays these values locally on an OLED screen and transmits the data to platforms like Blynk and ThingSpeak. It also includes an alert mechanism that notifies users when energy usage exceeds a predefined limit, helping them take corrective actions. Even though the system is simple, it provides reliable monitoring and supports energy-efficient practices. In this work, the following tasks are carried out: Studying real-time energy consumption using sensors and a microcontroller

II. BACKGROUND AND RELATED WORK

Spiking neural networks represent an important approach in computational neuroscience and artificial intelligence. They process information using discrete spikes, which makes them different from traditional artificial neural networks that rely on continuous values. Among various neuron models, the Leaky Integrate-and-Fire model is widely used due to its simplicity and ability to capture essential neuronal behaviour such as integration, leakage, and spike generation when a threshold is reached. Earlier work by Chouhan [1] demonstrated that MATLAB-based implementations of the LIF model can reproduce realistic spiking behaviour while maintaining computational efficiency. In another study, Chaturvedi et al. [2] compared the LIF model with the Izhikevich model and observed that, despite its simplicity, LIF can achieve satisfactory performance in character recognition tasks when parameters are properly tuned. Some previous research, including the work by Gupta and Long [3], explored spike-based approaches for pattern and character recognition without relying heavily on conventional training techniques. Later, Bawane [4] introduced adaptive threshold mechanisms, which improved the performance of LIF-based systems to some extent. Lu [5] proposed a method to relate LIF-based models with deep neural networks, enabling a combination of efficient training and neuromorphic computation.

From a hardware perspective, Banik and Basu [6] demonstrated that spiking neural networks can be deployed on embedded platforms such as Jetson Nano for digit recognition tasks. Their work indicates that such systems can operate efficiently on low-power hardware without requiring very high computational resources.

In this work, an attempt is made to integrate simulation, recognition, and deployment into a single framework rather than treating them as separate components. under different load conditions to verify accuracy and performance, and the results are observed and analyzed to evaluate the overall effectiveness of the monitoring system.

In addition to the core functionality, calibration of sensors is performed to ensure accurate measurement of electrical parameters under varying load conditions. Proper error handling mechanisms are also implemented in the system software to maintain stable operation during network interruptions or hardware inconsistencies. Data logging is carried out on the cloud platform to enable long-term analysis of energy consumption patterns.

III. SIGNIFICANCE

The significance of this project lies in its ability to improve awareness of electricity consumption in apartment environments through real-time monitoring. By continuously tracking energy usage and displaying accurate consumption data, users gain a better understanding of how electrical power is utilized in their daily activities. The alert mechanism further supports users by notifying them when energy consumption exceeds a predefined limit, helping to reduce unnecessary power wastage and control electricity expenses. The integration of IoT technology enables remote access to energy data, supporting the concept of smart and connected living. Since the system is designed using low-cost and easily available components, it offers a practical and affordable solution for residential energy monitoring. Additionally, the project contributes to efficient energy management by allowing users to observe usage patterns and take timely corrective actions. The system also serves as a strong foundation for future improvements such as appliance automation, detailed analytics, and smart home integration.

IV. METHODOLOGY

I. Methodology

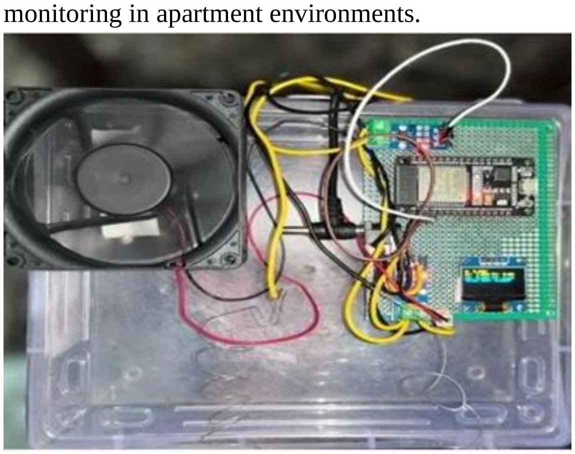
The methodology of the project begins with system requirement analysis, where key parameters, alert limits, and IoT connectivity needs are identified. Based on these requirements, suitable hardware components such as the microcontroller, current sensor, OLED display, power supply, and connecting modules are selected considering accuracy, cost, and compatibility. The current sensor is then interfaced with the electrical load to measure current, and its output is provided to the microcontroller for processing. The microcontroller processes the sensor data to calculate electrical parameters such as current, power, and total energy consumption, which are displayed in real time on the OLED screen for local monitoring. Simultaneously, the processed data is transmitted to an IoT cloud platform via Wi-Fi, enabling remote access through web or mobile applications. A predefined energy threshold is set in the system, and whenever the consumption exceeds this limit, an alert notification is generated. Finally, the system is tested

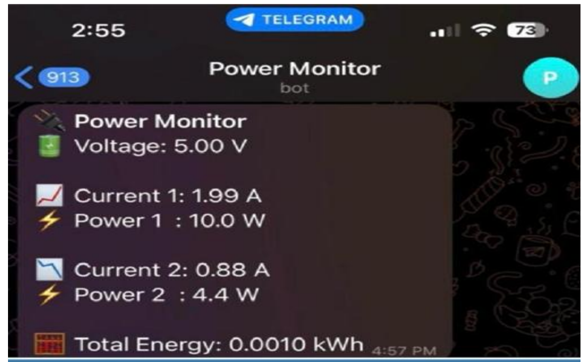
The system is designed with modular architecture, allowing easy expansion for additional sensors or features in future. Security considerations such as secure data transmission are taken into account while integrating IoT services. User-friendly interfaces are ensured for better understanding of usage. The overall implementation focuses on reliability and efficient performance for real-world applications.

V. RESULTS AND DISCUSSION

V. Results and Discussion

The IoT-Based Smart Energy Monitoring System was successfully implemented and tested under various load conditions. The ESP32 and ACS712 sensor accurately measured current, voltage, power, and energy, with real-time values displayed on the OLED screen. The readings changed correctly with different household loads, confirming reliable sensing and accurate energy calculation. Energy data was consistently uploaded to the ThingSpeak platform and visualized through real-time graphs, enabling remote monitoring. The Telegram alert system functioned as expected by sending notifications when energy usage exceeded 150 units. Overall, the system proved to be stable, efficient, and suitable for real-time energy monitoring in apartment environments.





C. Spike Pattern Analysis

The hardware setup of the IoT-Based Smart Energy Monitoring System consists of the following main components:

1. ESP32 Microcontroller:
1. Acts as the central controller of the system.
2. Reads sensor data, processes it, and sends it to the IoT platform (ThingSpeak).
3 Also communicates with the Telegram bot for alert notifications.

2. ACS712 Current Sensor:
1 Measures the current drawn by the connected load (e.g., bulb or fan).
2 Provides real-time current data to the ESP32 for energy calculations.
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3. OLED Display:
1. Displays real-time electrical parameters including current, voltage, power, and energy consumption.
2. Enables local monitoring without accessing the cloud.

4. Connected Loads:
1 Household appliances such as bulbs and fans are connected to test the system.
2 Helps demonstrate energy monitoring under different load conditions.

5. Power Supply:
1. Provides stable voltage to the ESP32 and sensors.
2. Ensures accurate measurement and proper functioning of the system.

6. Connections and Wiring:
1. ACS712 sensor is connected in series with the load to measure current.
2. ESP32 reads data from the sensor via its analog input pin.
3. OLED is connected via I2C pins (SDA and SCL) to the ESP32.
4. Load receives power through the ACS712 sensor.
Purpose of Hardware Setup:
This setup ensures that energy parameters can be monitored in real-time both locally (OLED) and remotely (ThingSpeak).

It forms the physical basis for testing the system's functionality, including power calculation, energy measurement, and alert notifications.

VI. CONCLUSION

The IoT-Based Smart Energy Monitoring System for Apartments successfully demonstrates an efficient and reliable approach to monitoring electrical energy consumption in real time. By integrating the ESP32 microcontroller with current and voltage sensors, the system accurately measures key electrical parameters such as current, power, and total energy usage. The real-time values are displayed locally on an OLED screen, allowing users to monitor consumption directly at the installation site. The integration of cloud platforms enables remote monitoring and data visualization, providing better insight into energy usage patterns.
The implementation of a Telegram based alert mechanism further enhances the system by notifying users when energy consumption exceeds the predefined limit of 150 units. This feature helps users take timely action to reduce power wastage and control electricity expenses.

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