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# Smart Energy Monitoring System

**T.S. Nagananthini , S.M. Aswin, S. Dharun, D. Kaviarasan, A. Mukeshwaran**

Assistant Professor, Dept. of Information Technology, K L N College of Engineering, Madurai,  
Tamil Nadu, India

B. Tech Student, Dept. of Information Technology, K L N College of Engineering, Madurai, Tamil Nadu, India

B. Tech Student, Dept. of Information Technology, K L N College of Engineering, Madurai, Tamil Nadu, India

B. Tech Student, Dept. of Information Technology, K L N College of Engineering, Madurai, Tamil Nadu, India

B. Tech Student, Dept. of Information Technology, K L N College of Engineering, Madurai, Tamil Nadu, India

**ABSTRACT:** This project introduces a Smart Energy Monitoring System (SEMS), an IoT-based solution designed to monitor and control electrical energy consumption in real time. The system utilizes ESP32 microcontrollers integrated with current sensors to measure energy usage and transmit data using the MQTT protocol to a cloud backend. Firebase services are used for data storage, processing, and notification management, while a Flutter-based mobile application provides a user-friendly interface for monitoring and control.

The increasing demand for electricity and the lack of real-time monitoring systems have led to inefficient energy usage in residential and commercial environments. Traditional energy meters only provide total consumption data and do not offer detailed insights into individual appliance usage, making it difficult to detect energy wastage and ensure safety. The system enables real-time energy tracking, remote device control, alert generation, and scheduling features.

## I. INTRODUCTION

The rapid growth in energy consumption due to increased usage of electrical appliances has created a need for efficient energy management systems. Traditional energy meters provide only overall consumption readings, which do not help users understand how energy is distributed across individual devices. This lack of detailed information leads to energy wastage, higher electricity bills, and inefficient usage patterns.

With advancements in Internet of Things (IoT) technology, it is now possible to monitor and control energy usage in real time. Smart energy monitoring systems integrate sensors, microcontrollers, cloud platforms, and mobile applications to provide detailed insights and remote control capabilities. These systems enable users to make informed decisions about their energy consumption and improve overall efficiency. It provides real-time monitoring, safety alerts, remote control, and intelligent energy management features, making it suitable for modern smart homes and future energy systems

## II. LITERATURE SURVEY

[1] IoT-Based Smart Energy Monitoring System (2021)

This study uses ESP32 and sensors for real-time monitoring and demonstrates the importance of remote access and energy awareness. Limitation: Limited scalability and analytics.

[2] MQTT-Based Energy Monitoring (2020)

Focuses on lightweight communication using MQTT protocol for real-time data transfer. Limitation: Lacks integration with advanced cloud analytics.

[3] Cloud-Based Energy Systems using Firebase (2022)

Explores real-time data storage and synchronization using Firebase. Limitation: Limited hardware integration and device control.

[4] Smart Meter with Protection System (2019)

Introduces relay-based control and safety features such as overload protection. Limitation: Does not provide mobile-based interaction.

### III. METHODOLOGY

#### 3.1 Requirement Analysis

The system requirements are identified based on both user expectations and technical feasibility to ensure a reliable and efficient solution.

The system must be scalable to support multiple devices and users without performance degradation. Reliability is essential to ensure continuous monitoring even during network interruptions, with mechanisms for reconnection and data recovery. Security requirements include safe data transmission, user authentication, and protection against unauthorized access. The system should also maintain low latency to provide real-time updates and a smooth user experience. Overall, the requirement analysis ensures that the system meets user needs while maintaining efficiency, safety, and flexibility.

#### 3.2 System Design

The system is designed using a multi-layered architecture to ensure modularity, scalability, and efficient data handling. The hardware layer consists of ESP32 microcontrollers connected to current sensors and relay modules, responsible for data acquisition and device control.

For this project, The design focuses on seamless data flow from sensors to the user interface while ensuring modular integration of components. Each module is independent yet interconnected, allowing easy upgrades and maintenance. This layered approach improves system performance, reduces complexity, and enables future enhancements such as AI analytics and solar energy integration. The cloud backend layer is implemented using Firebase services, which handle data storage, processing, authentication, and push notifications.

#### 3.3 Development Tools and Technologies

The Smart Energy Monitoring System is developed using Flutter for the frontend, providing a user-friendly mobile interface. The backend and data storage are handled using Firebase, enabling real-time data updates and cloud storage. The hardware setup includes an ESP8266 with an ACS712 to measure energy consumption. Data is transmitted using the MQTT broker for efficient communication between the device and the mobile application. The ESP module is programmed in C++ using the Arduino IDE, while the mobile app is developed using Dart in Flutter.

#### 3.4 Implementation

The implementation phase involves the development and integration of both hardware and software components. The ESP32 microcontroller is programmed using embedded C/C++ to read sensor data, process it, and publish it to the MQTT broker. The ACS712 current sensor is calibrated to ensure accurate measurement of current values, which are then used to calculate power and energy consumption. The Flutter mobile application is developed to provide an interactive user interface with features such as real-time dashboards, graphs, device control, and notifications. The implementation follows a modular approach, allowing each component to function independently while maintaining seamless integration.

#### 3.5 Testing and Deployment

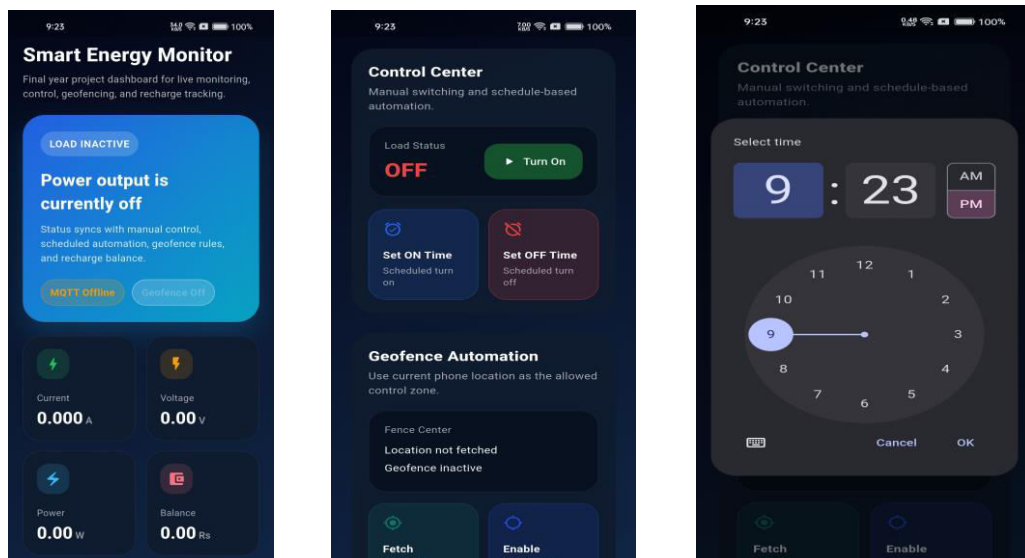
Software Testing is a critical phase to ensure that the system operates accurately and reliably under different conditions. Sensor calibration is performed to verify the accuracy of current measurements by comparing readings with known loads. Communication testing is conducted to ensure that data is transmitted correctly between the ESP32, MQTT broker, and cloud backend without delays or data loss. Functional testing is carried out to validate all system features, including real-time monitoring, device control, alert generation, and scheduling.

The deployment phase involves installing and configuring the system in a real-time environment for practical use. The ESP32 device, sensors, and relay modules are assembled and connected to electrical loads. The system is powered using a regulated power supply and connected to a Wi-Fi network for communication.

### IV. SYSTEM ARCHITECTURE

The system architecture defines the overall structure and workflow of the Smart Energy Monitoring System (SEMS), illustrating how different components interact to monitor, process, and control energy consumption in real time. The

architecture ensures a seamless flow of data from the hardware layer to the user interface while maintaining modularity, scalability, and efficiency. The system begins with the data acquisition layer, where the ESP32 microcontroller collects electrical parameters such as current using sensors like ACS712. These raw sensor values are processed to calculate power and energy consumption. The processed data is then transmitted through the communication layer using the MQTT protocol, which ensures lightweight, reliable, and real-time data exchange between the device and the cloud backend.



**Figure -1:** Overall System Architecture of Smart Energy Monitoring System

The core of the system is the IoT Processing Engine, which follows a structured workflow consisting of data acquisition, signal processing, communication, cloud storage, and user interaction. The ESP32 continuously reads sensor data, processes it into meaningful electrical parameters, and transmits it to the cloud. The system evaluates energy usage patterns and ensures accurate data representation. Supporting components such as the alert module provide notifications for abnormal conditions, while the control module enables remote switching of appliances through relay circuits. The system also maintains synchronization between device states and the mobile application. Finally, the processed data is displayed through an interactive dashboard, enabling users to monitor energy consumption and make informed decisions for efficient energy management.

## V. EXISTING SYSTEM

The existing energy monitoring systems are primarily based on traditional electricity meters, which provide only cumulative energy consumption readings without any real-time monitoring or appliance-level insights. These systems do not offer detailed information about how energy is consumed across different devices.

However, Additionally, conventional systems lack remote control capabilities, automated alerts, and intelligent analytics. Users cannot monitor or control appliances from a remote location, and there are no mechanisms to detect abnormal conditions such as overload or excessive consumption. This manual approach is inefficient, lacks transparency, and does not support modern energy management needs. As a result, energy wastage increases, electricity costs rise, and the overall system becomes less efficient and less responsive to user requirements.

## VI. PROPOSED SYSTEM

The proposed Smart Energy Monitoring System (SEMS) introduces an IoT-based intelligent solution for real-time energy monitoring and control. Unlike traditional systems, this system provides continuous tracking of energy consumption at the device level and enables users to control appliances remotely through a mobile application.

The core of the system is built on an IoT architecture that includes ESP32 microcontrollers, current sensors, MQTT communication, Firebase cloud services, and a Flutter-based mobile application. The system follows a structured workflow consisting of data acquisition, processing, communication, storage, and visualization. Sensor data is collected and processed to calculate power consumption, which is then transmitted to the cloud for storage and analysis. Users can interact with the system through the mobile application, where they can view real-time energy data, control appliances, set schedules, and receive alerts.

### VII. RESULT

The implemented Smart Energy Monitoring System (SEMS) successfully demonstrates real-time monitoring and control of electrical energy usage. The system accurately measures current and calculates power consumption using sensor data, which is displayed in real time through the mobile application.

The Flutter-based interface allows users to monitor energy usage, control appliances, and receive instant alerts for abnormal conditions. Test results show that the system provides reliable data transmission through MQTT and efficient cloud storage using Firebase. The alert system effectively notifies users during overcurrent conditions, improving safety and preventing potential hazards. Overall, the system improves energy awareness, reduces wastage, and enhances user control over electrical devices.

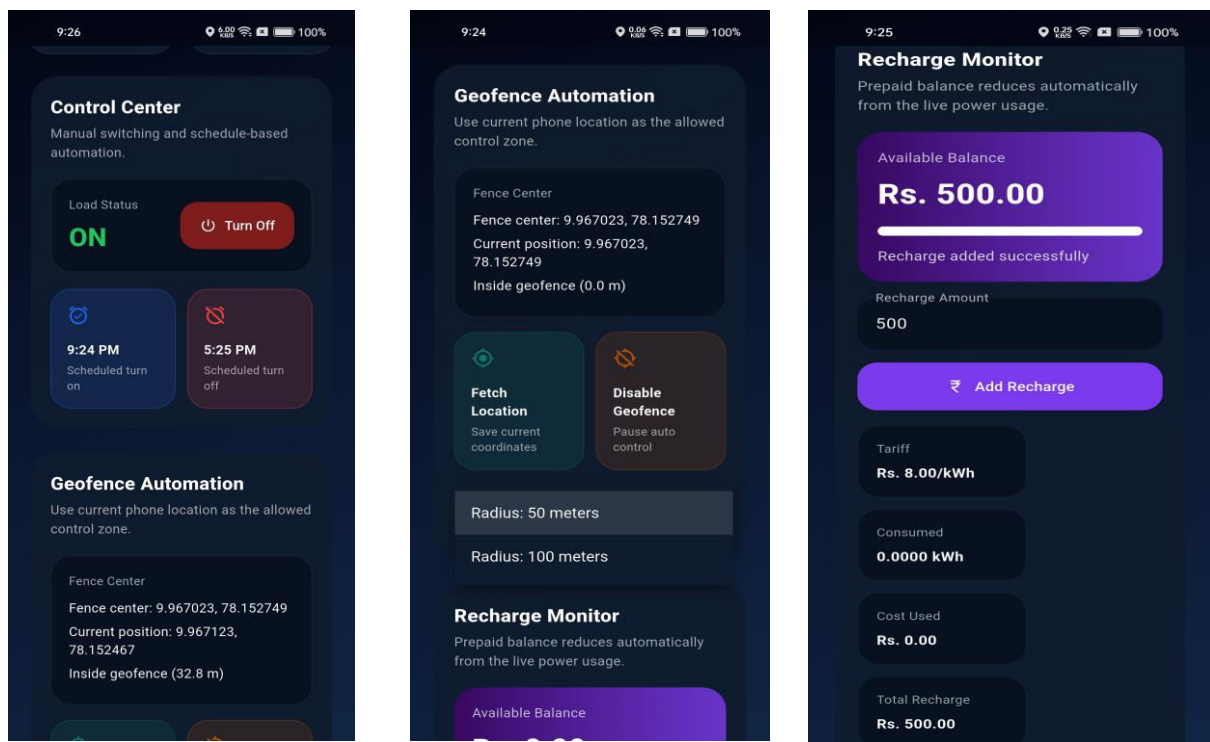


Figure -2: outputs

### VIII. FUTURE ENHANCEMENT

The current system provides efficient energy monitoring and control, but several enhancements can further improve its performance and capabilities. Future developments include the integration of solar energy monitoring to track energy generation, consumption, and grid interaction in real time. Advanced analytics and AI-based prediction models can be incorporated to forecast energy usage and provide intelligent recommendations for energy savings. The system can also be enhanced with smart home integration, allowing it to connect with voice assistants and other IoT devices for automated control. Developing a web dashboard and expanding mobile application features can improve user

accessibility and experience. Additionally, implementing Over-The-Air (OTA) updates will allow remote firmware upgrades for devices. Improving hardware accuracy by replacing ACS712 with high-precision CT sensors and ADC modules can enhance measurement reliability. Security features such as encrypted communication and advanced authentication mechanisms can also be implemented to ensure data privacy.

## IX. CONCLUSION

The Smart Energy Monitoring System (SEMS) was developed to address the limitations of traditional energy monitoring systems by providing a modern, intelligent, and automated solution. Conventional systems lack real-time monitoring, remote control, and detailed insights, making energy management inefficient and less effective.

The proposed system leverages IoT technologies, including ESP32, MQTT communication, cloud computing, and mobile applications, to provide real-time monitoring, control, and alert features. It enables users to track energy consumption, control appliances remotely, and make informed decisions to optimize energy usage. The integration of safety mechanisms further enhances system reliability and prevents electrical hazards. Overall, the system provides a cost-effective, scalable, and user-friendly solution for energy management. It not only improves efficiency and reduces costs but also contributes to energy conservation and sustainable development.

## REFERENCES

- [1]EspressifSystems, “*ESP32SeriesDatasheet*EspressifSystems,2023.This document provides detailed technical specifications of the ESP32 microcontroller, including its dual-core processor, Wi-Fi and Bluetooth capabilities, GPIO features, and power consumption characteristics, which are essential for IoT-based energy monitoring systems.
- [2] Allegro Microsystems, “*ACS712 Fully Integrated Hall-Effect-Based Linear Current Sensor IC Datasheet,*” 2022. This datasheet explains the working principle, sensitivity, and calibration methods of the ACS712 current sensor used for measuring AC and DC current in real-time energy monitoring applications.
- [3] OASIS Standard, “*MQTT Version 3.1.1 Protocol Specification,*” Organization for the Advancement of Structured InformationStandards,2014.This specification defines the MQTT messaging protocol, including publish-subscribe architecture, Quality of Service (QoS) levels, and lightweight communication mechanisms suitable for IoT applications.
- [4] Google, “*Firestore Documentation: Cloud Firestore, Cloud Functions, and Firebase Cloud Messaging,*” Google LLC,2023.This documentation provides comprehensive details on Firebase services used for real-time data storage, backend processing, authentication, and push notifications in cloud-connected applications.
- [5]Google, “*FlutterSDKDocumentation,*”GoogleDevelopers,2023.The Flutter documentation describes tools and frameworks for building cross-platform mobile applications with responsive user interfaces, used in developing the SEMS mobile application.
- [6] HiveMQ, “*MQTT Essentials – A Beginner’s Guide to IoT Messaging Protocol,*” HiveMQ GmbH, 2023. This guide explains MQTT concepts such as topics, brokers, retained messages, and message delivery mechanisms, which are essential for implementing reliable IoT communication systems.
- [7]TexasInstruments, “*ADS111516-bitAnalog-to-DigitalConverterDatasheet,*”2022.This document provides technical details about high-precision ADC modules that can be used to improve measurement accuracy in advanced energy monitoring systems.
- [8]YHDC Corporation, “*SCT-013 Non-Invasive Current Transformer Datasheet,*” 2021 .This datasheet describes the working and advantages of CT sensors, including electrical isolation and safety, making them suitable for household energy monitoring applications..
- [9] IEEE, “IoT-Based Energy Monitoring Systems,” 2022.
- [10] International Journal of Smart Grid, “Energy Management Using IoT,” 2021



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