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ABBREVIATIONS

Abbreviation	Full Form
SEEMS	Smart Electric Energy Management System
ACS712	Allegro Current Sensor 712
ESP32	Espressif Systems Programmable 32-bit Microcontroller
GSM	Global System for Mobile Communications
SMS	Short Message Service
ZMPT101B	Zero-phase Voltage Transformer 101B
IoT	Internet of Things
Wi-Fi	Wireless Fidelity
MQTT	Message Queuing Telemetry Transport
IDE	Integrated Development Environment
AI	Artificial Intelligence
API	Application Programming Interface
GPIO	General Purpose Input/Output

ABSTRACT

SEEMS is an IoT-based solution designed to optimize energy usage and reduce electricity costs in both residential and commercial settings. It combines real-time energy monitoring with GSM-based remote control, allowing users to efficiently manage power consumption and minimize wastage.

The system uses current sensors like the ACS712 to monitor energy usage, with data processed by a microcontroller (e.g., ESP32) and displayed via a custom mobile app. This app enables users to view energy statistics, set consumption goals, and make informed decisions about appliance usage—resulting in better energy savings.

A key feature of SEEMS is its GSM module, which allows users to control appliances remotely via SMS, making it ideal for areas with limited internet connectivity. This remote access improves convenience and extends usability to rural or remote locations.

To further support energy efficiency, SEEMS sends SMS alerts for abnormal energy consumption, helping users detect faults, prevent excessive usage, and avoid electrical hazards. This real-time feedback promotes quick action and better appliance management.Built with cost-effective and modular components like relays and ESP32, SEEMS is affordable, scalable, and suitable for various applications—from small homes to large buildings.

CHAPTER-1

INTRODUCTION

CHAPTER-1
INTRODUCTION

Smart Electric Energy Management System (SEEMS)

With rapid urbanization, industrial growth, and increasing reliance on electrical appliances, energy consumption has surged, leading to higher electricity costs and inefficient power management. Most residential and commercial setups lack real-time monitoring, resulting in energy wastage and inflated bills.

The Smart Electric Energy Management System (SEEMS) offers an IoT-based solution to these challenges by enabling real-time monitoring, remote control, and optimized energy usage. It uses sensors like the ACS712 current sensor and a ZMPT101B voltage sensor, connected to an ESP32 microcontroller, to measure and process energy consumption data. This information is displayed through a custom-designed mobile application, providing users with a clear interface to track power usage, control appliances, and analyze consumption trends—without relying on third-party platforms like Blynk or Thingspeak.

A standout feature of SEEMS is its GSM-based remote control and alert system, allowing users to manage appliances via SMS commands, making it effective even in areas with limited or no internet connectivity.

It also sends alerts for abnormal energy usage, helping identify inefficiencies early.

In summary, SEEMS is a smart, practical, and affordable solution for efficient energy management, reducing electricity costs while promoting energy conservation.

1.1 OVERVIEW

With the increasing demand for electricity, efficient energy management has become a necessity in both residential and commercial environments. High electricity consumption, rising costs, and energy wastage are common issues that require a smart and automated solution. The smart electric energy management system (SEEMS) is an innovative approach that utilizes IoT and GSM technology to monitor, analyze, and control power usage efficiently.

SEEMS is designed to provide real-time energy monitoring and remote appliance control, enabling users to track their energy consumption and optimize power usage. The system uses current sensors like ACS712 to measure voltage and current, with data processed by an ESP32 microcontroller. Unlike traditional energy monitoring systems that rely on cloud platforms like Blynk or ThingSpeak,

SEEMS features a custom-designed mobile application that allows users to access real-time energy consumption data, analyze usage trends, and control appliances remotely.

A key feature of SEEMS is its GSM-based remote control, which enables users to turn appliances on or off via SMS commands. This makes the system particularly useful in areas with limited or no internet connectivity, allowing seamless energy management from any location. Additionally, SEEMS sends SMS alerts for abnormal energy consumption, helping users detect inefficiencies and take corrective actions to prevent excessive power usage and high electricity bills.

The system is built using cost-effective components such as ESP32 microcontrollers, relays, and sensors, making it affordable and scalable for different applications. It can be deployed in homes, offices, and industries where energy efficiency and cost savings are essential. The modular design of SEEMS allows for future enhancements, including integration with renewable energy sources such as solar panels, further promoting sustainable energy management.

SEEMS provides a user-friendly interface for monitoring energy usage, optimizing appliance operation, and reducing electricity costs. The system's automated approach ensures better energy utilization, reduces wastage, and enhances convenience for users.

1.2 HISTORY

Energy management is increasingly crucial due to rising power demand, costs, and environmental impact. Traditional manual meter readings lacked efficiency and real-time monitoring. As technology evolved, automated and intelligent solutions became necessary. Microcontrollers and sensors in the late 20th century initiated the shift to smart energy systems.

The IoT boom in the 2010s enabled real-time data collection and remote monitoring. Platforms like Blynk and ThingSpeak helped visualize usage but lacked customization. To overcome these limitations, custom systems using ESP32, ACS712, PZEM, and CT sensors were developed. GSM modules allowed remote access in offline or rural areas.

SEEMS (Smart Electric Energy Management System) was created as a cost-effective, scalable, and user-focused solution. It features a dedicated mobile app for real-time monitoring and appliance control. Unlike cloud-based systems, SEEMS uses GSM for SMS-based commands and alerts. It ensures efficient usage, identifies abnormal consumption, and operates without internet.

SEEMS is ideal for homes, offices, and industries, promoting energy savings and sustainability. Future expansions include AI-based analytics and solar integration. Combining IoT, automation, and GSM,

SEEMS offers complete, real-time control, making it a modern milestone in smart energy management.

1.3 USE CASE SURVEY

A use case survey helps analyze the real-world applications of a system, identifying its potential benefits, target users, and areas of implementation. The Smart Electric Energy Management System (SEEMS) is designed to optimize energy consumption, reduce electricity costs, and provide remote control of appliances. By integrating IoT, GSM communication, and a mobile application, SEEMS ensures efficient energy management for residential, commercial, and industrial applications. This survey explores various use cases where SEEMS can be effectively implemented.

1.3.1. Residential Energy Management

Homeowners often struggle with high electricity bills due to inefficient power usage. SEEMS provides a solution by enabling users to monitor real-time energy consumption, identify high-energy appliances, and remotely control devices via a mobile app or SMS.

Benefits

1. Reduces electricity wastage by switching off unused appliances remotely
2. Helps homeowners track power consumption and adjust usage habits

1.3.2. Commercial Buildings and Offices

Offices and commercial buildings consume large amounts of energy due to continuous operation of lights, air conditioning, and electronic devices. SEEMS allows facility managers to monitor energy consumption, schedule appliance usage, and prevent unnecessary energy wastage.

Benefits

1. Enables automatic scheduling of lights, ACs, and other equipment during working hours
2. Prevents energy wastage by remotely switching off appliances after office hours
3. Reduces operational costs and increases energy efficiency

1.3.3. Industrial Load Management

Industries require efficient load distribution to prevent overloading and high electricity bills. SEEMS helps industrial users track energy usage, optimize power consumption, and control heavy machinery remotely.

Benefits

1. Helps industries manage power loads efficiently to avoid peak-hour tariffs
2. Prevents machinery from running unnecessarily, reducing maintenance costs

3. Sends SMS alerts for high power consumption to avoid system failures
4. Can be expanded with renewable energy sources like solar panels for cost savings

1.3.4. Educational Institutions

Educational institutions often waste electricity due to improperly managed lighting, fans, and projectors left running unnecessarily. SEEMS allows school administrators to monitor power usage and automatically control electrical appliances.

Benefits

1. Reduces electricity wastage by automatically turning off devices after school hours
2. Helps educational institutions cut down on electricity costs
3. Provides real-time monitoring of classrooms, labs, and campus-wide energy usage
4. Can be integrated into smart campus initiatives for better resource management

1.3.5. Remote and Rural Areas

Many rural areas have limited internet connectivity but still require effective energy management solutions. SEEMS, with its GSM-based remote control, enables users to monitor and control energy consumption without requiring a constant internet connection.

Benefits

1. Provides energy monitoring and appliance control using SMS-based commands
2. Ideal for locations where Wi-Fi-based IoT systems are not practical
3. Helps optimize power usage for solar-powered homes or microgrids
4. Reduces reliance on manual monitoring of power usage in remote villages

1.3.6. Hospitals and Healthcare Centers

Hospitals require uninterrupted power supply and efficient energy usage to ensure the smooth operation of medical equipment. SEEMS allows hospital administrators to monitor energy consumption and optimize power distribution.

Benefits

1. Ensures critical medical equipment remains operational by monitoring power usage
2. Reduces electricity costs by optimizing power distribution in non-essential areas
3. Sends SMS alerts for power fluctuations to prevent equipment failures

1.4 FEATURES OF SMART ENERGY MANAGEMENT SYSTEM

1.4.1. Real-Time Energy Monitoring

1. Continuously tracks voltage, current, and power consumption of connected appliances.
2. Uses current sensors like ACS712 to provide accurate energy readings.
3. Displays real-time energy data on a custom-designed mobile application.

1.4.2. GSM-Based Remote Control

1. Enables users to turn appliances on or off using SMS commands.
2. Works efficiently even in areas with limited or no internet connectivity.
3. Provides a flexible solution for remote energy management in rural and urban areas.

1.4.3. SMS Alerts for Abnormal Energy Consumption

1. Sends instant notifications if power consumption exceeds a predefined limit.
2. Alerts users about unexpected energy usage or potential electrical faults.
3. Helps in preventing unnecessary electricity wastage and high electricity bills.

1.4.4. Custom Mobile Application for Monitoring and Control

1. Provides a user-friendly interface for real-time energy tracking.
2. Allows users to monitor and control appliances from anywhere.
3. Eliminates the need for third-party IoT platforms like Blynk or Thingspeak.

1.4.5. Cost-Effective and Scalable System

1. Uses affordable and readily available components like ESP32, relays, and sensors.
2. Suitable for small homes, offices, commercial buildings, and industries.
3. Can be expanded and upgraded for future energy management needs.

1.5 Literature Survey

Energy management has become an essential field of research due to the increasing demand for electricity and rising energy costs. The integration of smart technologies such as the Internet of Things (IoT), wireless communication, and automation has significantly improved energy consumption monitoring and control. This literature survey explores existing research, technologies, and systems related to smart energy management, highlighting advancements, limitations, and the need for the Smart Electric Energy Management System (SEEMS).

1.5.1 Review of Existing Energy Management Systems

Traditional Energy Monitoring Systems

Earlier energy monitoring relied on manual meter readings and basic digital meters, which only displayed power consumption without real-time tracking. Traditional systems lacked remote monitoring, appliance control, and data analytics, leading to inefficient energy usage.

Limitations:

1. No real-time data visualization or tracking.
2. Inability to detect energy wastage or abnormal consumption.
3. Lack of remote control for appliances.

1.6 Need for the Smart Electric Energy Management System

Based on the limitations of existing solutions, SEEMS is designed to address the following gaps:

1. **Custom Mobile Application:** Unlike cloud-based platforms like Blynk and ThingSpeak, SEEMS features a dedicated mobile app for real-time energy tracking and control.
2. **GSM-Based Remote Control:** Unlike internet-dependent IoT solutions, SEEMS allows users to turn appliances on/off via SMS, making it ideal for areas with limited internet access.

CHAPTER – 2

PROBLEM IDENTIFICATION

Chapter-2
PROBLEM IDENTIFICATION

INTRODUCTION

With the increasing use of electrical appliances in homes, offices, and industries, energy consumption has significantly increased, leading to high electricity bills and unnecessary power wastage. Many users lack awareness of their real-time energy consumption and do not have control over their appliances when they are away from their location. Additionally, existing energy monitoring systems have limitations, such as internet dependency, high costs, MQTT client connection problems, Arduino IDE code run issues, port detection errors, and a lack of real-time alerts for excessive energy consumption.

1. Traditional energy meters only provide monthly consumption details, making it difficult to track daily or hourly energy usage.
2. Users are unable to identify which appliances consume the most energy, leading to inefficient usage.

2.1 Problems in Existing Energy Management Systems

2.1.1 Lack of Real-Time Monitoring

1. Traditional energy meters only provide monthly consumption details, making it difficult to track daily or hourly energy usage.
2. Users are unable to identify which appliances consume the most energy, leading to inefficient usage.

2.1.2 No Remote Control Over Appliances

1. Many users forget to turn off appliances, leading to unnecessary power consumption.
2. There is no mechanism to remotely turn ON/OFF appliances in most traditional systems.

2.1.3 Dependency on Internet-Based IoT Platforms

1. Many modern IoT-based energy monitoring systems require a constant internet connection to function.
2. In rural and remote areas, where internet connectivity is unstable or unavailable, these systems become ineffective.

2.1.4 MQTT Client Connection Problems

1. MQTT (Message Queuing Telemetry Transport) is widely used for IoT-based communication, but it requires a stable internet connection.
2. Users often face connection failures, delays, and unreliable data transmission when the internet is weak or unstable.
3. MQTT-based systems may struggle with packet loss, reconnection issues, and high latency, leading to inaccurate energy monitoring and delayed remote control responses.

2.1.5 Arduino IDE Code Run Problems & Port Detection Errors

1. Users often face compilation errors and upload failures when running Arduino IDE code for microcontrollers like ESP32.

2. The Arduino IDE may fail to detect the correct COM port, preventing successful code uploads.
3. Issues such as library mismatches, driver incompatibility, or incorrect board selection can cause code execution failures, making it difficult to develop and test the system efficiently.

2.1.6 No Automated Alerts for High Energy Consumption

1. Users are not notified when their energy usage crosses a certain threshold.
2. Abnormal power consumption goes unnoticed, leading to higher electricity bills and potential electrical hazards.

2.1.7 High Cost of Smart Energy Management Solutions

1. Many existing smart energy systems require expensive components and high-end AI-based cloud platforms.
2. Small households, offices, and industries cannot afford complex, high-cost solutions.

2.1.8 UI/UX Challenges for Energy Visualization

1. Designing an intuitive, responsive, and user-friendly interface for displaying energy consumption trends, appliance status, and alerts.
2. Implementing charts and graphs to visually represent energy data using Flutter libraries like Fl chart or syncfusion_flutter_charts.

2.1.9 Handling Calls and Data Processing

1. The app must be able to process energy data from sensors via an ESP32 microcontroller and format it for display.
2. Efficient handling of API calls, error management, and retries in case of network issues.
3. Deciding between Firebase, REST APIs, or local storage for managing user preferences and appliance settings.

2.1.10 Cross-Platform Compatibility Issues

1. Ensuring the app works seamlessly on both Android and iOS without compatibility issues.
2. Handling device-specific permissions (e.g., SMS permissions in iOS vs. Android).
3. Managing Flutter dependencies and updates to avoid build failures during deployment.

CHAPTER-3

COMPONENTS REQUIRED

CHAPTER-3

COMPONENTS REQUIRED

3.1 ESP32 Microcontroller

The ESP32 is a low-power, high-performance microcontroller developed by Espressif Systems. It is widely used in IoT applications, embedded systems, and smart automation due to its Wi-Fi and Bluetooth connectivity, multiple GPIO pins, and energy-efficient design. For the Smart Electric Energy Management System (SEEMS), the ESP32 serves as the core processing unit, responsible for collecting sensor data, processing energy consumption details, sending commands to appliances, and communicating with the mobile application or GSM module.

I. Role of ESP32 in SEEMS

In the Smart Electric Energy Management System (SEEMS), ESP32 performs the following critical functions:

1. Sensor Data Collection

a. Reads current and voltage data from ACS712 current sensor and PZEM-004T voltage sensor.

b. Converts analog sensor signals into digital values using its 12-bit ADC.

c. Processes real-time energy consumption calculations.

2. **Appliance Control via Relay Module**
    a. Sends ON/OFF signals to relay modules, controlling connected electrical appliances.
    b. Uses GPIO pins to switch appliances remotely via the mobile app or SMS commands.
3. **GSM-Based Remote Control and Alert System**
    a. Interfaces with the SIM800/SIM900 GSM module via UART to send/receive SMS commands.
    b. Processes user commands received via SMS for remote appliance control.
    c. Sends alerts for abnormal power consumption to users via SMS notifications.
4. **Mobile App Communication**
    a. Transmits real-time energy data to a Flutter-based mobile application for user monitoring and control.
    b. Updates power usage trends, appliance status, and user settings in the app.
5. **Power Optimization and Energy Management**
    a. Controls appliance usage based on predefined schedules or user preferences.
    b. Optimizes power usage by switching appliances ON/OFF automatically when required.

II. ESP32 Pinout and Key Connections in SEEMS

ESP32 Pin	Connected Component	Purpose
3.3V	Power to sensors and modules	Supplies voltage to connected components
GND	Ground	Common ground for all components
GPIO 36(VP), GPIO 39 (VN)	ACS712 Current Sensor	Reads real-time current consumption
GPIO 32, GPIO 33	PZEM-004T Voltage Sensor	Measures voltage levels
GPIO 26, GPIO 27	Relay Module	Controls appliances (ON/OFF switching)

Table-3.1.1

III. Advantages of Using ESP32 in SEEMS

1. **High Processing Speed** – Dual-core CPU for multitasking (e.g., data collection, appliance control, GSM communication).
2. **Energy Efficient** – Supports deep sleep mode for low power consumption when idle.
3. **Multiple Communication Interfaces** – Works with GSM, Bluetooth, UART, SPI, and I2C.
4. **Scalability** – Supports additional sensors, AI-based optimization, and future enhancements.

IV. Comparison of ESP32 with Other Microcontrollers

Feature	ESP32	Arduino Uno	Raspberry Pi
Processing Speed	240 MHz (Dual-Core)	16 MHz	1.5 GHz (Quad-Core)
Wi-Fi& Bluetooth	Yes	No	Yes
GPIO Pins	36	14	40

Table-3.1.2

V. Conclusion

The ESP32 microcontroller is the best choice for the Smart Electric Energy Management System (SEEMS) due to its power efficiency, real-time processing capabilities, built-in wireless connectivity, and support for multiple interfaces. It acts as the brain of the system, handling sensor data collection, appliance control, GSM-based SMS communication, and mobile app integration.

FIGURE 3.1. ESP32 NODEMCU

3.2 ACS712 Current Sensor

The ACS712 is a widely used current sensor module that provides accurate real-time current measurements in electronic and electrical applications. It is designed to measure both AC and DC currents and is commonly used in energy monitoring systems, motor control applications, and automation projects.

In the Smart Electric Energy Management System (SEEMS), the ACS712 current sensor is used to monitor real-time power consumption of connected electrical appliances. The sensor provides Analog output proportional to the current flowing through the circuit, which is then processed by the ESP32 microcontroller to calculate energy usage.

I. Types of ACS712 Modules

ACS712 comes in three different variants, depending on the maximum current range it can measure:

ACS712 Model	Current Range	Sensitivity
ACS712-05B	±5A	185 Mv/A
ACS712-20B	±20A	100 Mv/A
ACS712-30B	±30A	66 Mv/A

TABLE-3.2.1

For SEEMS, the choice of ACS712 variant depends on the power rating of the appliances being monitored.

II. Why ACS712 is Used in SEEMS?

The ACS712 current sensor is chosen for Smart Electric Energy Management System (SEEMS) due to the following advantages:

1. **Real-Time Current Measurement** – Provides an analog voltage output proportional to the current flowing through the circuit.
2. **Measures Both AC and DC Currents** – Useful for various types of loads, including home appliances, industrial motors, and office equipment.
3. **High Accuracy and Fast Response Time** – Ensures real-time monitoring of energy consumption.
4. **Galvanic Isolation** – Provides electrical isolation between the high-power circuit and the microcontroller, improving safety.

III. Working Principle of ACS712

The ACS712 sensor works on the Hall Effect Principle:

1. Current flows through the sensor's internal conductor.
2. This current generates a magnetic field, which is detected by the Hall effect sensor inside the module.
3. The Hall sensor converts this magnetic field into a proportional voltage signal.
4. This analog voltage output is read by the ESP32 microcontroller, which converts it into current and power values using the following formula: $I=(VOUT-VOFFSET)/Sensitivity$.

Where:

1. **I =** Measured current (Amperes)
2. **V_{OUT} =** Sensor output voltage (Volts)
3. **V_{OFFSET}=** Midpoint voltage (Typically 2.5V for a 5V system)
4. **Sensitivity =** As per the ACS712 variant used (185 mV/A, 100 mV/A, or 66 mV/A)

To calculate power consumption: $P=V\times I$

Where:

1. P = Power in Watts (W)
2. V= Voltage (Measured using a voltage sensor like PZEM-004T)
3. I = Current from ACS712

IV. Connection of ACS712 with ESP32 in SEEMS

ACS712 Pin	ESP32 Pin	Purpose
VCC	5V	Powers the sensor
GND	GND	Common ground
OUT	Analog Pin (A0/A2)	Outputs voltage proportional to current

TABLE-3.2.2

V. Role of ACS712 in SEEMS

In the Smart Electric Energy Management System (SEEMS), ACS712 is used:

1. **Real-Time Monitoring:** Continuously measuring current flow through appliances.
2. **Energy Consumption Calculation:** Used with voltage sensors to determine power usage in watts.
3. **Fault Detection & Alerts:** Detects overcurrent conditions and triggers alerts via GSM module.
4. **Appliance Control:** Helps identify high-power-consuming appliances for energy-saving automation.

VI. Advantages of Using ACS712 in SEEMS

1. Real-time current monitoring with high accuracy.
2. Compact and low-cost solution for IoT-based energy management.
3. Measures both AC and DC currents, unlike CT sensors, which measure only AC.
4. Provides electrical isolation, ensuring safety for microcontroller circuits.
5. Easy to interface with ESP32 and other microcontrollers for real-time data logging.

VII. CONCLUSION

The ACS712 current sensor is an integral component of SEEMS, enabling accurate real-time current measurement for energy management. Its ability to monitor both AC and DC currents, along with its high accuracy and safety features, makes it the ideal choice for tracking power consumption in smart energy applications.

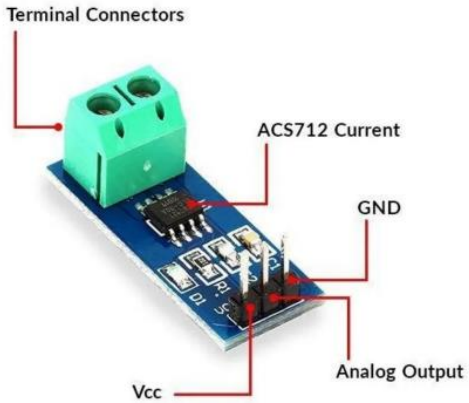


FIGURE 3.2. ACS712 CURRENT SENSOR

3.3 SIM900 GSM Module

I. Introduction to SIM900 GSM Module

The SIM900 GSM module is a quad-band GSM/GPRS module widely used in IoT applications for wireless communication. It allows SMS-based remote control, alert notifications, and data transmission over the 2G network.

1. In the Smart Electric Energy Management System (SEEMS), the SIM900 module is used for sending SMS alerts about abnormal energy consumption.
2. Enabling remote appliance control via SMS commands.
3. Providing wireless connectivity for real-time monitoring and automation.

II. USAGE OF SIM900 IN SEEMS

The SIM900 GSM module is chosen for SEEMS due to the following advantages:

1. **SMS-based Remote Control** – Allows users to turn appliances ON/OFF via SMS.
2. **Alert Notifications** – Sends SMS alerts for high power consumption or faults.
3. **No Need for Internet** – Works in areas with limited or no Wi-Fi connectivity.
4. **Low Power Consumption** – Suitable for continuous operation.

III. Working Principle of SIM900

The SIM900 module connects to a GSM network using a SIM card and enables communication through AT commands.

How SIM900 Works in SEEMS:

1. ESP32 sends AT commands to SIM900 via UART.
2. SIM900 processes the command and communicates with the mobile network.
3. If a user sends an SMS command, SIM900 receives it and forwards it to ESP32.
4. If abnormal power consumption is detected, ESP32 sends an alert SMS via SIM900.

IV. SIM900 Pinout and ESP32 Connection

SIM900 Pin	ESP32 Pin	Function
VCC	5V	Power supply
GND	GND	Ground connection
TXD	RX (GPIO16)	Serial communication
RXD	TX (GPIO17)	Serial communication

TABLE-3.3.1

V. Role of SIM900 in SEEMS

1. **Remote Appliance Control:** Users can turn appliances ON/OFF via SMS.
2. **Energy Consumption Alerts:** Sends SMS notifications when abnormal power usage is detected.
3. **No Internet Required:** Works even in rural areas with no Wi-Fi.
4. **Automated Notifications:** Can be programmed to send periodic energy consumption updates.

VI. Common Issues with SIM900 and Troubleshooting

Issue	Possible Cause	Solution
SIM900 not responding	Incorrect baud rate	Set correct baud rate (9600 or 115200 bps)
No network registration	Weak signal	Use an external antenna
SMS not sent	SIM not inserted properly	Check SIM card and reinsert

TABLE-3.3.2

VII. Comparison of SIM900 with Other GSM Modules

Feature	SIM900	SIM800	A6 GSM
Network Support	2G (Quad-band)	2G (Quad-band)	2G
Power Supply	4V	3.7V – 4.2V	3.3V – 4.2V
Power Consumption	1.5A (Peak)	1A (Peak)	500mA (Peak)
Data Support	GPRS	GPRS	GPRS

TABLE-3.3.3

VIII. CONCLUSION

The SIM900 GSM module is an essential component of SEEMS, enabling SMS-based remote appliance control and energy alerts. It provides reliable wireless communication without requiring the internet, making it perfect for remote areas.

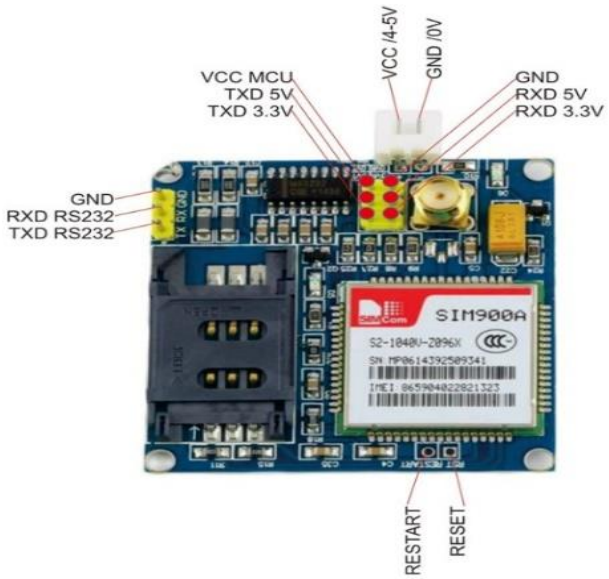


FIGURE .3.3. SIM900A GSM MODULE

3.4 RELAY MODULE

I. Introduction to Relay Module

A relay module is an electromechanical switch used to control high-power electrical devices using a low-voltage microcontroller signal. In the Smart Electric Energy Management System (SEEMS), a 12V relay module is used to turn appliances ON and OFF remotely based on user commands and energy consumption analysis.

II. Working Principle of a Relay Module

The relay module consists of a coil, contacts, and a switching mechanism. It operates as follows:

1. **Input Signal from Microcontroller (ESP32):**
   a. When the ESP32 sends a HIGH signal (3.3V – 5V), the relay coil gets energized.
   b. This activates the electromagnetic switch, closing the circuit and allowing power to flow to the appliance.
2. **Relay Switching Mechanism:**
   a. When energized, the relay switches from NC (Normally Closed) to NO (Normally Open).
   b. When de-energized, the relay returns to its default state.

3. **Controlling High-Power Appliances:**
    a. The relay acts as a bridge between low-voltage microcontroller signals and high-voltage devices (bulbs, fans, ACs, etc.).
    b. Appliances can be turned ON or OFF remotely based on commands from the mobile app.

Applications of Relay Module in SEEMS

1. **Home Automation:** Smart control of lights, fans, and other electrical appliances.
2. **Energy Management:** Switching off non-essential appliances to reduce power wastage.
3. **Industrial Applications:** Controlling machinery and optimizing power usage in factories.

FIGURE .3.4. 2-CHANNEL RELAY MODULE

3.5 POWER SUPPLY (5V/12V DC Adapter):

I. Introduction to Power Supply in SEEMS

A power supply unit (PSU) is essential in the Smart Electric Energy Management System (SEEMS) to provide the necessary voltage and current for different components. The system uses 5V and 12V DC adapters to power the ESP32 microcontroller, sensors, and relay modules. These adapters convert AC mains power (220V or 110V) into regulated DC voltage, ensuring stable operation of the system.

II. Working Principle of Power Supply

1. **AC to DC Conversion:**
   a. The adapter takes in 110V or 220V AC power from the mains supply.
   b. It passes through a transformer, which steps down the voltage to a lower level.
2. **Rectification & Filtering:**
   a. A bridge rectifier converts AC to pulsating DC voltage.
   b. A capacitor filter smooths out the fluctuations, providing steady DC output.
3. **Voltage Regulation & Output:**
   a. A voltage regulator circuit ensures the output remains at a fixed 5V or 12V DC.
   b. The regulated power is then supplied to the respective microcontroller, sensors, and relays.

4. USE OF POWER SUPPLY IN SEEMS

5V Power Supply

a. Powers the ESP32 microcontroller and sensors like ACS712.

b. Ensures reliable operation of low-power components.

12V Power Supply

a. Powers the relay module, which requires higher voltage for switching high-power loads.

b. Provides stable current for safe operation of appliances.

III. Applications of Power Supply in SEEMS

1. Stable operation of ESP32 and sensors for real-time energy monitoring.
2. Reliable switching of appliances via relays without voltage fluctuations.
3. Prevention of circuit failures due to voltage spikes or overcurrent issues.

FIGURE.3.5 POWER SUPPLY (5V/12V DC Adapter)

3.6. VOLTAGE SENSOR(PZEM-004T)

I. Introduction to Voltage Sensor in SEEMS

A voltage sensor is used in the Smart Electric Energy Management System (SEEMS) to measure the voltage of an electrical system accurately. This helps in power calculation, energy monitoring, and ensuring appliance safety.

II. PZEM-004T Voltage Sensor Module

The PZEM-004T is a digital energy meter module designed for measuring voltage, current, power, and energy consumption. It is commonly used in smart energy monitoring projects like SEEMS.

1. High-accuracy voltage and current measurement.
2. Non-invasive measurement with minimal circuit interference.
3. Serial communication (UART) support for data logging and remote monitoring.

III. Working Principle

1. The PZEM-004T sensor connects directly to the AC mains supply to measure voltage and current.
2. It processes the data internally and sends it to the ESP32 microcontroller via UART (TX, RX pins).

IV. Applications of PZEM-004T in SEEMS

1. Accurate voltage and power measurements.
2. Helps in energy consumption analysis.
3. Detects overvoltage or undervoltage conditions for appliance safety.
4. Can be integrated with GSM module for SMS alerts in case of voltage fluctuations.

V. Conclusion

In SEEMS, the choice of voltage sensor depends on the application. The PZEM-004T module is ideal for accurate energy management, whereas a voltage divider is useful for simple voltage monitoring. By integrating these sensors, SEEMS ensures real-time voltage measurement, improving energy efficiency and safety.

FIGURE.3.6. PZEM-004T VOLTAGE SENSOR

CHAPTER-4

OBSERVATION & ANALYSIS

CHAPTER-4
OBSERVATION & ANALYSIS

4.1 OBSERVATION

The Smart Electric Energy Management System (SEEMS) is an IoT-based solution designed to optimize energy usage, reduce wastage, and enable remote control of appliances. Based on the development and implementation of SEEMS, the following key observations have been

1. **Real-Time Energy Monitoring** – The system effectively tracks voltage, current, and power consumption using the ACS712 current sensor and voltage sensors. The data is processed by the ESP32 microcontroller and displayed in a custom mobile application.
2. **Remote Control via GSM** – The SIM900 GSM module allows users to turn appliances ON or OFF using SMS commands.
3. **Efficient Power Management** – The relay module enables users to automate and control electrical appliances based on predefined schedules or energy consumption patterns.
4. **User-Friendly Application** – The mobile app provides an intuitive interface for monitoring and controlling appliances.
5. **MQTT Connection Issues** – During testing, MQTT client connection problems were observed due to network instability, improper broker configuration, or incorrect credentials.
6. **Arduino IDE Port and Code Execution Issues** – Users faced port recognition problems while uploading the code to ESP32 in the Arduino IDE, requiring proper driver installation and board selection.

7. **App Development Challenges** – The custom mobile app built using Flutter and Dart encountered UI responsiveness and backend integration issues, requiring optimization.

4.2 Analysis of SEEMS

Accuracy of Energy Measurement

1. The combination of ACS712 and voltage sensors allows for real-time energy tracking.
2. However, the accuracy depends on sensor calibration and environmental factors (e.g., temperature variations affecting sensor readings).

Remote Appliance Control Efficiency

1. GSM-based SMS control works well but has a time delay compared to Wi-Fi or MQTT-based systems.
2. The relay module switching speed was found to be reliable, making it suitable for home and industrial automation.

Cost-Effectiveness

1. SEEMS is built using affordable components such as ESP32, ACS712, relays, and GSM modules, making it budget-friendly.
2. It is cheaper than commercial smart energy meters while offering similar functionalities.

System Reliability and Connectivity

1. The GSM module provides robust connectivity, even in areas with weak Wi-Fi signals.
2. However, MQTT client connection problems need troubleshooting to ensure seamless real-time data updates.

Scalability and Future Integration

1. The system can be expanded by integrating renewable energy sources like solar power monitoring.
2. It has the potential to connect with cloud-based AI systems for predictive energy management in the future.

CHAPTER-5

CONCLUSION , RESULT & FUTURE SCOPE

CHAPTER-5

5.1 CONCLUSION

The smart electric energy management system (seems) provides a cost-effective and efficient solution for monitoring and controlling electrical appliances. by integrating iot-based technology with real-time energy tracking and remote control functionalities, the system enables users to optimize power consumption and reduce unnecessary electricity wastage. the use of an esp32 microcontroller, acs712 current sensor, voltage sensor, relay module, and gsm-based control ensures reliable operation in both residential and commercial environments.

while the system successfully achieves energy monitoring and appliance control, certain technical challenges need to be addressed for improved performance. MQTT client connection issues, gsm response delays, and Arduino IDE code execution errors were observed during implementation.

The mobile application developed using flutter and dart provides a user-friendly interface, allowing users to control appliances and monitor energy usage seamlessly. however, further optimizations in ui responsiveness and backend integration can improve its overall functionality.

The project demonstrates significant potential for future scalability. integrating renewable energy sources such as solar power and leveraging ai-driven analytics can further enhance its capabilities.

overall, the smart electric energy management system is a step towards a more intelligent and sustainable approach to energy management. with continued improvements and technological advancements, it can be widely adopted to promote energy efficiency, cost savings, and environmental sustainability in both residential and industrial sectors.

5.2 RESULT

The Smart Electric Energy Management System (SEEMS) turned out to be a successful and practical solution for managing energy usage in a smart and user-friendly way. Throughout the project, we were able to design and implement a system that brings together both hardware and software to monitor and control energy consumption effectively.

We achieved real-time energy monitoring using the ACS712 current sensor and voltage sensors, with data processed by the ESP32 microcontroller. This data was displayed in a custom mobile app built using Flutter and Dart, allowing users to track their power usage live.

One of the highlights was the ability to control appliances remotely through SMS using the SIM900 GSM module. This worked well even in places where internet connectivity was poor, making the system more accessible and practical for real-life use.

The mobile app was easy to use and made it convenient for users to check their electricity usage and control appliances from

anywhere. The system also alerted users in case of unusual energy consumption, helping them stay aware and avoid unnecessary electricity waste.

All the components—including sensors, relays, and the power supply—worked well together, and we were able to successfully control electrical loads based on user inputs and real-time data. The project also helped us identify energy consumption patterns, giving users a chance to save on electricity bills by adjusting their usage habits.

During the process, we faced a few technical issues like MQTT connection problems and difficulties uploading code through the Arduino IDE. These challenges became learning opportunities, helping us improve our troubleshooting and problem-solving skills.

Overall, SEEMS proved to be a useful, low-cost solution for energy management, with the potential to make everyday electricity usage smarter and more efficient—both at home and in commercial settings.

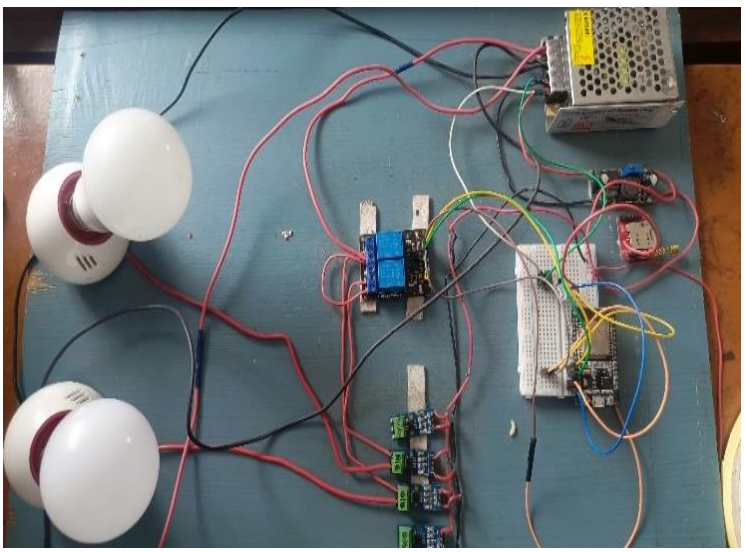
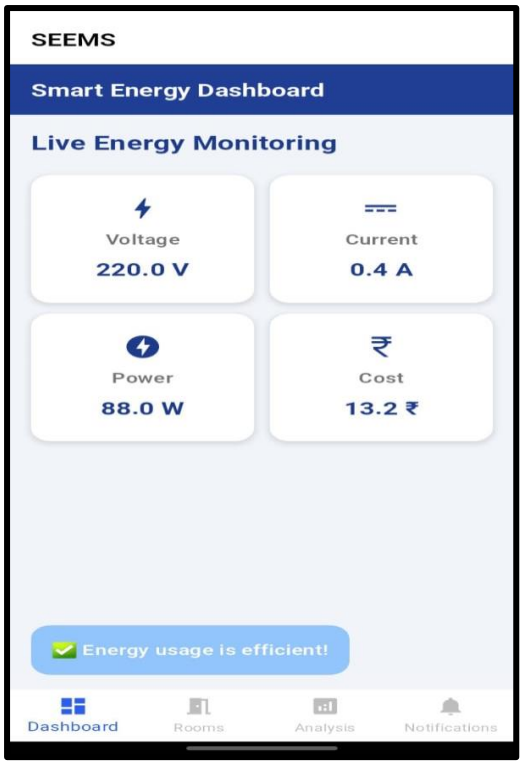
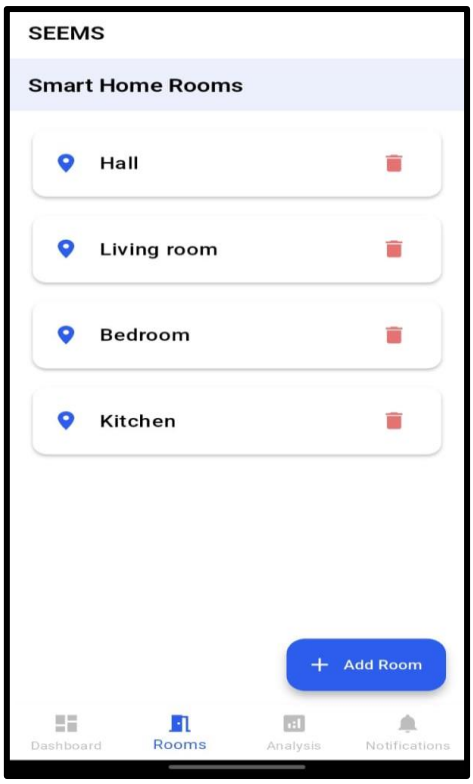


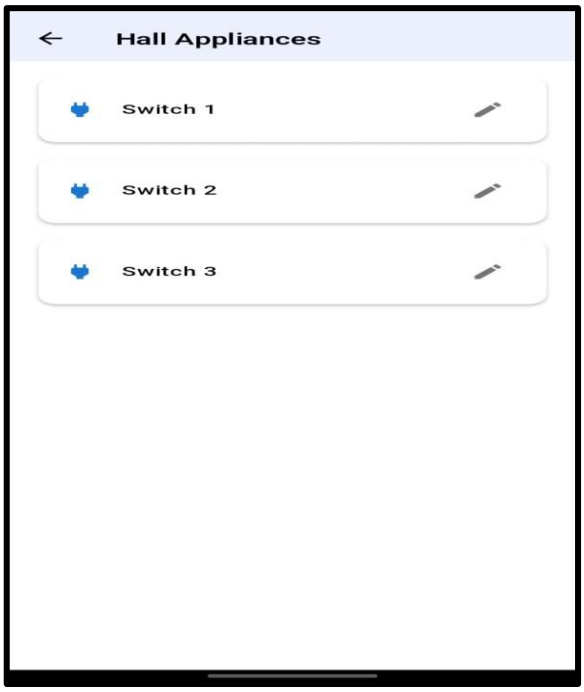
Figure No. 5.2 Hardware Module



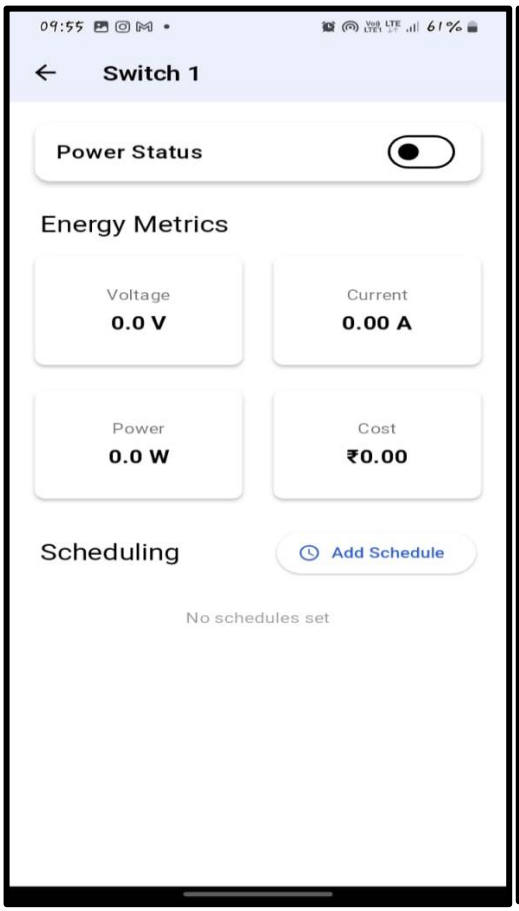
Dashboard Page



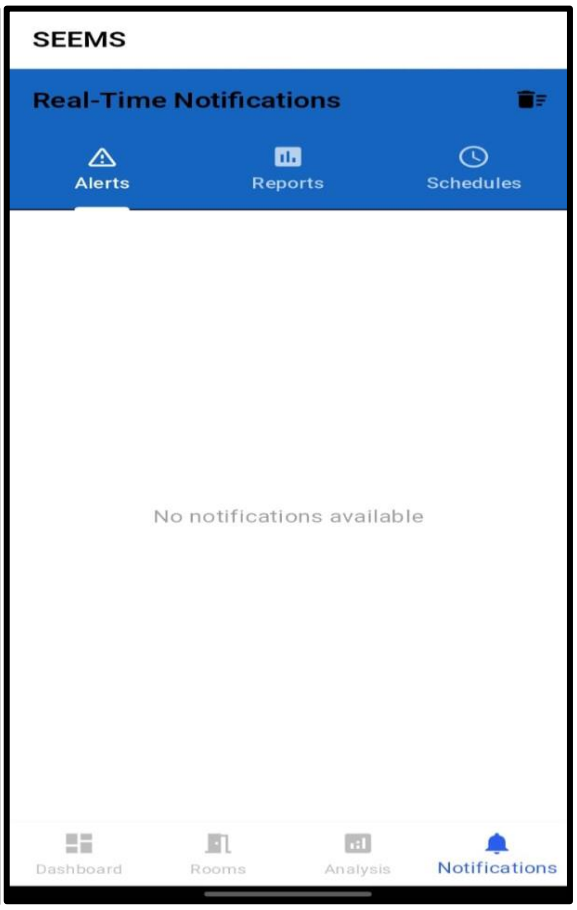
Rooms Page



Switches Page



Switch-1 Page



Notifications Page

5.3 FUTURE SCOPE

The smart electric energy management system (seems) has significant potential for future advancements and scalability. as technology continues to evolve, several enhancements can be made to improve the efficiency, reliability, and functionality of the system.

I. Artificial Intelligence & Machine Learning (AI&ML) Integration

AI-based predictive analytics can help forecast energy usage patterns and suggest optimizations. ML algorithms can analyze historical consumption data to recommend efficient appliance scheduling, reducing power wastage.

II. Cloud-Based Data Storage And Processing

Implementing cloud computing will allow seamless data storage, analysis, and accessibility from anywhere. users can retrieve historical energy usage trends and optimize consumption through advanced analytics.

III. Advanced Mobile Application Features

Enhancing the mobile application with voice control, smart assistant integration (such as google assistant or alexa), and custom automation settings will improve user experience and convenience.

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