

IoT and GSM Based Smart Energy Monitoring & Load Scheduling

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Abstract: The rapid rise in electrical energy consumption and the need for efficient power use have made real-time energy monitoring and smart load management necessary. This paper explains the design and implementation of a smart energy monitoring and load scheduling system that uses IoT and GSM technology. The goal is to improve energy efficiency and cut down on power waste. The system continuously measures electrical parameters like voltage, current, power, and energy using digital energy sensors connected to a microcontroller. It sends the collected data to a cloud platform via IoT for real-time viewing and analysis. A GSM module is also included to provide remote access and alerts in areas with limited internet.

Load scheduling is managed by controlling connected appliances through relay modules based on set time schedules and priority levels. This allows for automatic load management during busy and quiet hours, ensuring the best use of electrical energy. Users can monitor their consumption patterns from afar and take actions to reduce unnecessary use. Experimental results show that this system provides reliable monitoring, effective communication, and efficient load control with low cost and low power needs. This solution can be used in homes, businesses, and small industrial settings to encourage energy conservation.

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I. INTRODUCTION

In today's world, using electrical energy efficiently has become very important because the demand for electricity is increasing, costs are rising, and there are growing environmental concerns. Most traditional electrical systems do not have proper monitoring or control, which often leads to energy wastage and higher electricity bills. To solve these problems, smart energy management systems are being developed.

This project presents a smart energy monitoring and scheduling system that uses IoT and GSM technology. The system continuously tracks important electrical parameters such as voltage, current, power, and energy consumption using sensors. This data is displayed on an LCD and can

also be accessed remotely through a web platform or mobile messages, allowing users to easily monitor their energy usage from anywhere.

The main focus of this project is energy scheduling, which allows electrical appliances to operate automatically at specific times. With the help of an ESP32 microcontroller and a Real-Time Clock (RTC), devices can be turned ON and OFF based on predefined timings without any manual effort. This helps in avoiding unnecessary power usage and improves overall efficiency.

Overall, this project provides a smart, simple, and cost-effective way to manage energy in homes and industries. It not only helps in reducing electricity bills but also supports better and more sustainable use of energy.

II. LITERATURE REVIEW

Table 1 Literature Review

Author(s)	Title	Interface / Approach	Gap Addressed	Relevance
Bajracharya et al.	IoT-Based Energy Monitoring and Remote-Control System	Cloud dashboard; basic monitoring and app-based remote control	Our system adds automatic scheduling and GSM fallback for areas with no internet	Both target smart energy management and IoT-based load automation
Rao, Sahoo & Yanine (2025a)	Real-Time Optimal Load Scheduling for IoT Smart Energy Management	ZigBee wireless; algorithm-driven controller with real-time display	We offer RTC-based real-time scheduling and a more accessible user interface	Both include IoT-based real-time energy control and monitoring
Rao, Sahoo & Yanine (2025b)	Review of IoT-Enabled Smart Energy Management for PV Systems	IoT + cloud monitoring integrated with photovoltaic generation	We add web-based load scheduling and GSM-based load control	Reinforces the value of IoT smart energy management and real-time monitoring
Kumar, Kumar & Kumar (2023)	Multi-Objective Home Energy Management with Smart Meter	Smart meter + IoT-based appliance monitoring and load scheduling	We extend monitoring with GSM-based control and alerts	Real-time load monitoring and automatic load scheduling
Mir et al. (2019)	Smart Electric Metering System Based on GSM/IoT	GSM + LCD + cloud; prepaid billing; web and Android interface	We focus on real-time energy monitoring and scheduling via web and SMS	Uses both GSM and IoT for smart energy monitoring
Albraheem et al. (2023)	IoT-Based Smart Plug Energy Monitoring System	Smart plug monitoring via IoT and mobile app	We add real-time scheduling and GSM remote communication	IoT-based load monitoring with wireless communication
Sarikaya & Partal (2022)	Load Scheduling for Home Energy Management with Renewable Energy	MATLAB/Simulink; monitors consumption and renewable generation	We use GSM alerts and IoT scheduling, making the system more field-deployable	Smart monitoring and load scheduling focus
Sayed, Said & Ibrahim (2024)	Smart Utilities IoT-Based Data Collection Scheduling	IoT metering with scheduling algorithm and communication stack	We incorporate GSM alerts and IoT-based remote load control	IoT monitoring and scheduling algorithm

From the above table, it is clear that most existing systems focus mainly on monitoring or manual control and lack proper automation and reliability. The proposed system addresses these gaps by integrating real-time monitoring, automated scheduling, and dual communication technology. This makes it a more efficient, reliable, and user-friendly solution for modern energy management systems.

Table 2 Abbreviations and Acronyms

Abbreviation	Full Form
GSM	Global System for Mobile Communication
ESP32	Espressif Systems 32-bit Microcontroller
LCD	Liquid Crystal Display
Wi-Fi	Wireless Fidelity
RTC	Real-Time Clock
IoT	Internet of Things
PZEM	Peacefair Electric Energy Meter
HTTP	Hyper Text Transfer Protocol

III. METHODOLOGY

This project demonstrates the smart energy management and load scheduling using IoT and GSM technology. It is carefully designed, developed and tested as a part of the study methodology.

➤ Approach to System Design

We started this project after noticing how much electrical energy is being wasted in daily life, which ultimately increases electricity bills. Also, with the growing demand for electricity and people having busy schedules, it becomes difficult to manage energy usages efficiently. To solve this, we have added the scheduling features that helps in better utilization of electrical energy in simple and smart way.

➤ Strategy for Monitoring of a System

This system continuously monitors electrical parameters like voltage, current and load (displayed in LCD) using sensors. And further it is processed by the ESP32 microcontroller to calculate power and energy consumption. Further this data is transmitted to users through Wi-Fi and mobile networks for real time monitor.

➤ Strategy for Load Scheduling

For a real-time load scheduling we have integrated system with Real Time Clock (RTC) module, which enables automatic control of appliances based on predefined time schedules in the websites.

➤ Real-Time Monitoring and Scheduling

In order to monitor the electrical parameters, sensor is used. The LCD displays real-time voltage and current in LCD, sends data to the microcontroller, microcontroller sends data via Wi-Fi and mobile networks to user. For scheduling, the time is set on the website and system can be monitored and scheduled remotely.

IV. FABRICATION

➤ Component Selection and Circuit Design

All the required components such as microcontroller (ESP32), RTC module, GSM module (A76070C), 2-channel relay module, 16x2 LCD display, PZEM004T current-voltage sensor and power supply were selected according to the needs of a system. After selecting the components, the circuit was designed using 'circuit designer' website to show how each part is connected and work together.

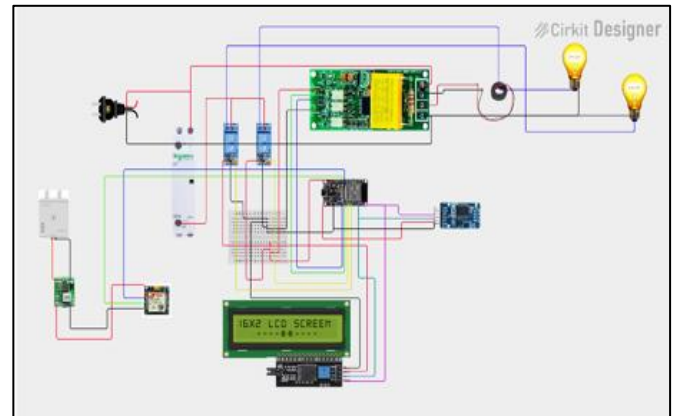


Fig 1: Circuit Diagram Made by Using Cirkuit Designer

This circuit helps in understand the flow of signal and power between the modules, ensuring reliable and smooth operation of a system.

➤ Hardware Assembly

All the hardware components are physically assembled according to circuit diagram. All the components and power supply are also connected using proper wiring method. Once the assembly of components were completed, the entire hardware setup was checked and tested.

➤ Microcontroller and Sensing Circuit Integration

The microcontroller is connected with voltage-current sensor (PZEM004T) and control circuit of the system. All the components were interfaced carefully to ensure proper communication between all the parts of the system. Microcontroller is programmed to receive signals from the sensor and control the electrical load via mobile networks and WiFi based on the scheduled timings.

➤ Display and Control Access

The 16x2 LCD display is connected with the microcontroller to display important electrical parameters such as voltage, current and power. And all this data will also display in the website. The proper connection was made between the display, control circuit, GSM module and also over the WiFi for smooth communication without any disturbance.



Fig 2-LCD display

➤ *Load Scheduling Implementation*

Real time load scheduling is done using RTC module and ESP32 microcontroller. The system was programmed to automatically switch electrical load ON and OFF according to the pre-set time given by the user in the website.

➤ *Testing and Verification*

After completing all the system setup, the entire system is tested under different operating conditions to ensure proper functioning. Its components, includes sensing circuit,

relay module, GSM module, RTC module and LCD display were checked individually along with all the section of a system (include sensing, monitoring and scheduling).

➤ *Final Prototype and Development*

After completion of all the testing and verification process, the entire system is arranged and organized into a compact prototype model. All the components were connected and placed properly to ensure safe and smooth operation of a system.

V. FLOWCHART FOR REAL TIME MONITORING AND LOAD SCHEDULING

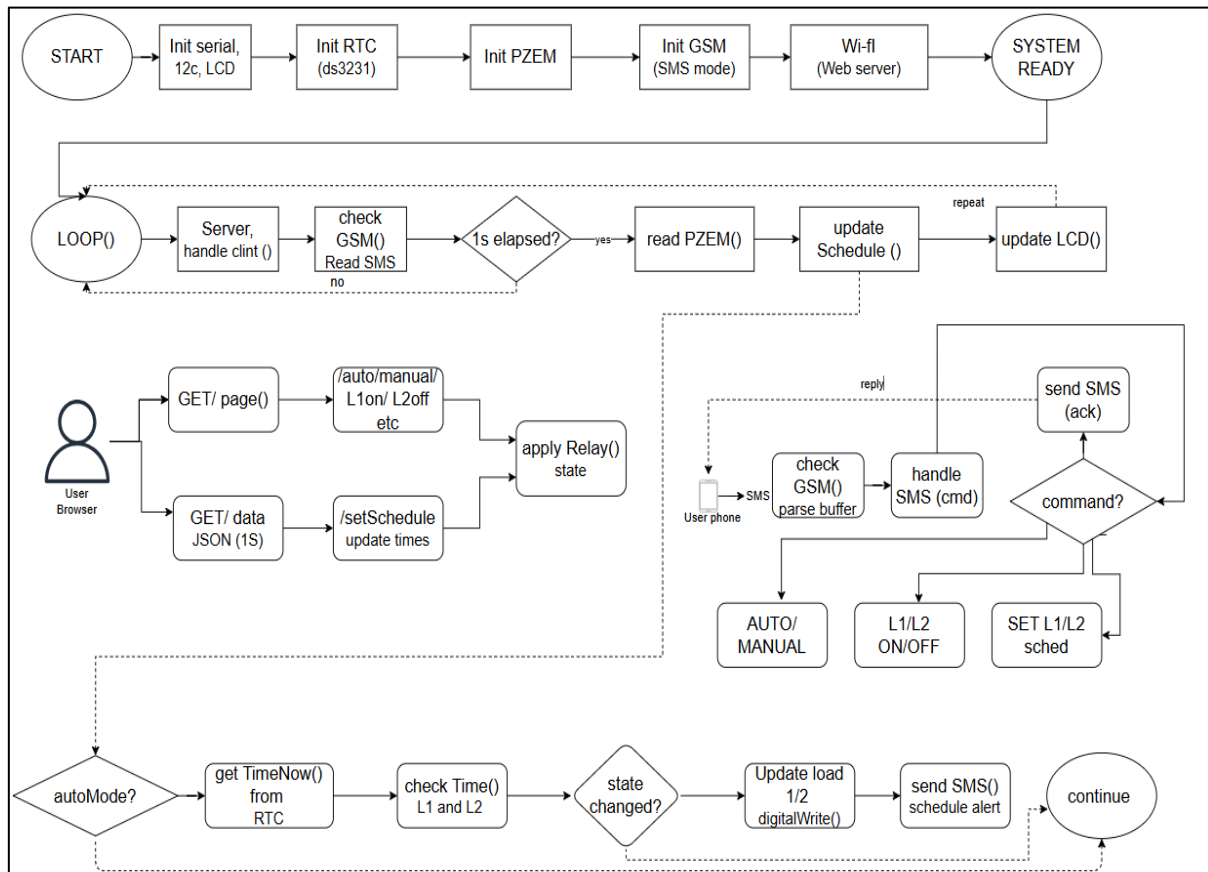


Fig 3: Flowchart

This flowchart describes the step-by-step logic developed on the ESP32 microcontroller using IoT and GSM based load monitoring and scheduling. Whenever the system is ON, the function starts and initializes all the required modules and communication. After initialization, the program continuously run inside the loop and web server handles HTTP requests for controlling loads via manual or automatic modes. Next, GSM module checks the incoming commands, PZEM modules continuously checks the parameters like voltage, current and power and RTC modules manages real-time based automatic load scheduling. The states of relay updated according to the user commands or preset scheduling and the LCD will continuously display the system parameters and information.

VI. RESULTS AND DISCUSSION

The final prototype of IoT and GSM based smart monitoring and load scheduling system was thoroughly tasted under different conditions to verify accuracy, stability and responsiveness. The results were obtained through both quantitatively (measurable outputs such as voltage, current, response time and scheduling accuracy) and qualitatively (system performance, reliability and user convenience) evaluation methods.

Table 3: Load Scheduling Comparison Between Desired and Practical Time

Load	Desired ON	Actual ON	Desired OFF	Actual OFF	Status
Load 1	08:00 am	08:00 am	08:20 pm	08:20 pm	Accurate
Load 2	11:10 am	11:10 am	11:40 am	11:39 am	Minor delay
Load 1	02:00 pm	02:00 pm	02:30 pm	02:30 pm	Successful
Load 2	04:40 pm	04:40 pm	05:30 pm	05:31 pm	Acceptable

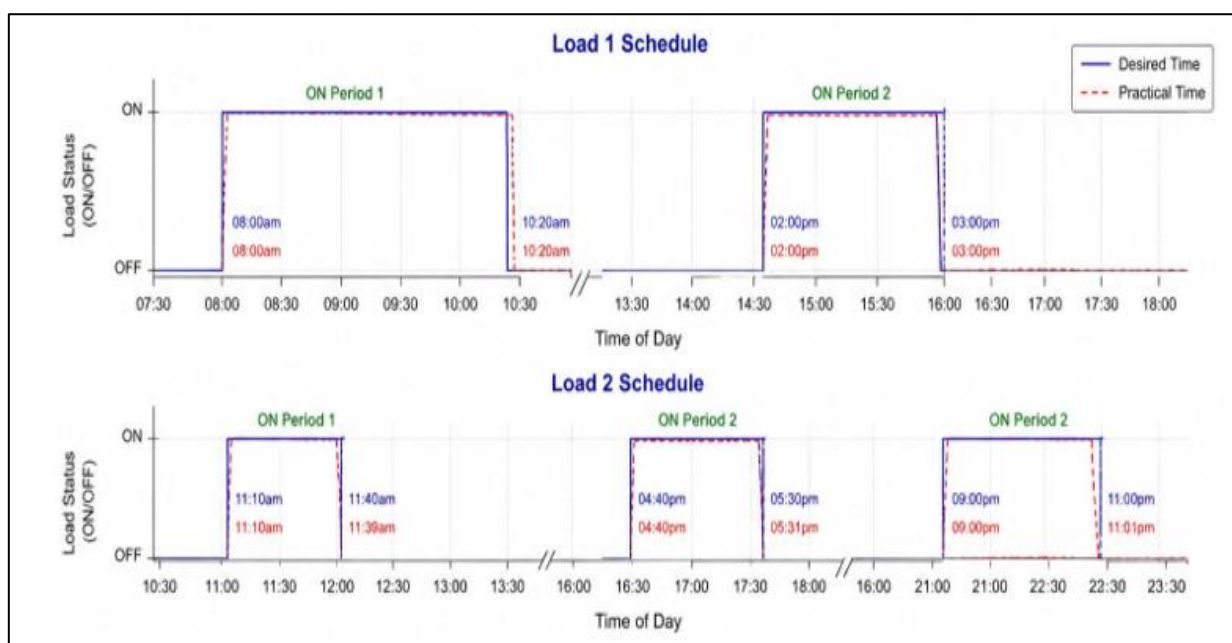


Fig 4: Comparison Between Desired and Practical Time While Doing Scheduling

➤ *Prototype Setup*

The IoT and GSM based smart monitoring and load scheduling prototype system was successfully developed to automatic load monitoring and real-time load scheduling using GSM and IoT based communication techniques. It is user friendly as well as good remote-control access.

➤ *Test Case*

The main test situation includes:

- Load monitoring through PZEM module.
- Continuously display through 16x2 LCD.
- Load monitoring via GSM module.
- Load monitoring and scheduling from website.

➤ *Accuracy Analysis*

The system performances and accuracy are analyzed by seeing the ability of the system to monitor operations and by comparing preset scheduled ON/OFF time with practical scheduled ON/OFF time. Monitoring is 100 percent accurate where as in scheduling there is some time delay like 1 to 2 minutes.

➤ *Problem Experienced During Testing.*

In accurate in real-time scheduling as compare to preset time for scheduling, it has a delay of some minutes. And problem while controlling through IoT platform due to short WiFi range.

➤ *Practical Use Case Discussion*

The IoT and GSM based smart monitoring and load scheduling system can be install in various place where the automatic load control, monitoring, scheduling and efficient energy management is required. It can be applicable in household’s appliances, industries, educational institute etc.

VII. CONCLUSION

The GSM and IoT-based smart monitoring and load scheduling system was successfully developed and tested as a functional prototype. This system effectively monitors electrical parameters in real time and automatically manages loads based on predefined schedules.

By integrating GSM communication, IoT monitoring, and automated load control, the project offers a straightforward and efficient solution for minimizing unnecessary power consumption while enhancing energy management. The system demonstrated dependable performance during testing and is suitable for use in homes, offices, and small industries.

In summary, the prototype showed that smart load scheduling can enhance convenience, conserve energy, and facilitate efficient power management. Future enhancements could include mobile app integration, cloud storage options, and more advanced automation features.

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