

SMART ENERGY METER AND MONITORING SYSTEM USING IOT

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ABSTRACT

The increasing demand for electrical energy requires efficient monitoring and management systems to reduce power wastage and improve energy efficiency. Conventional energy meters lack real-time monitoring and remote accessibility, resulting in limited control over energy consumption. This paper presents the design and implementation of a Smart Energy Meter and Monitoring System using Internet of Things (IoT) technology. The proposed system is developed using an ESP32 microcontroller, which collects electrical parameters such as voltage and energy consumption from sensing modules. The measured data is displayed locally on a 16×2 LCD and transmitted to the cloud through the Blynk IoT platform using Wi-Fi connectivity. A relay module is integrated to enable remote switching of electrical loads, allowing users to control appliances and minimize unnecessary energy usage. The system eliminates dependence on GSM and SMS-based communication, thereby reducing operational cost and improving reliability. Experimental results demonstrate accurate real-time monitoring, efficient remote control, and continuous cloud-based data storage, making the proposed system suitable for smart home and future smart grid applications.

Keywords: Smart Energy Meter, IoT, ESP32, Blynk, Energy Monitoring, Relay Control

INTRODUCTION

Electrical energy plays a vital role in modern society, supporting residential, commercial, and industrial activities. With rapid urbanization and technological advancement, electricity consumption has increased significantly. Efficient

monitoring and management of energy usage have therefore become essential to reduce power wastage and ensure sustainable energy utilization.

Traditional energy meters require manual reading and do not provide real-time monitoring or remote accessibility. This often leads to delayed billing, lack of transparency, and inefficient energy usage. In addition, conventional systems do not allow users to track their consumption patterns or control electrical loads remotely.

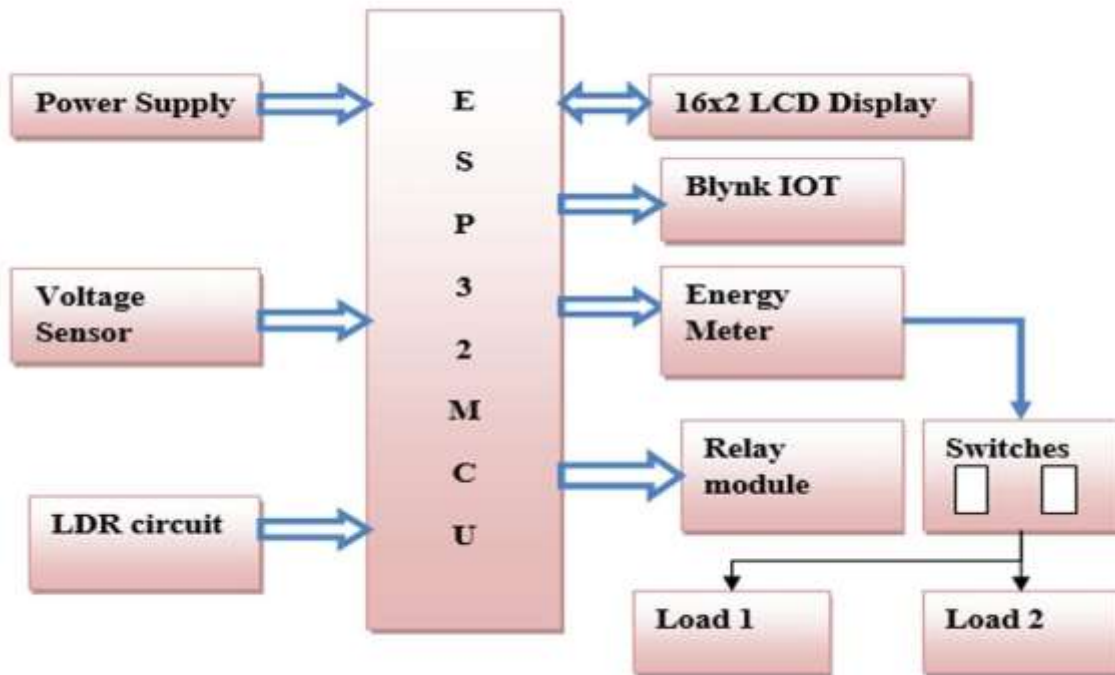
The advancement of Internet of Things (IoT) technology has enabled the development of intelligent energy monitoring systems. IoT-based smart energy meters provide real-time data acquisition, cloud storage, and remote access through mobile applications. These systems allow users to monitor electricity consumption instantly and make informed decisions to optimize energy usage.

In this project, a Smart Energy Meter and Monitoring System using IoT is designed and implemented using an ESP32 microcontroller. The system measures electrical parameters such as voltage and energy consumption using appropriate sensors. The collected data is displayed locally on an LCD and transmitted to a cloud platform via Wi-Fi for real-time monitoring. A relay module is incorporated to enable remote load control, thereby reducing unnecessary power consumption.

The proposed system aims to provide a cost-effective, reliable, and scalable solution for smart home energy management and future smart grid integration.

SYSTEM ARCHITECTURE AND DESIGN

The overall architecture consists of four main layers: sensing layer, processing layer, communication layer, and application layer.



1. Sensing Layer

The sensing layer is responsible for acquiring electrical parameters from the load. It consists of a voltage sensor and an energy meter module that continuously measure voltage, current, power, and energy consumption. These sensors convert physical electrical quantities into electrical signals suitable for digital processing.

2. Processing Layer

The processing layer is built around the ESP32 microcontroller, which acts as the central control unit of the system. The ESP32 receives sensor data, processes the signals, and calculates power and energy values using embedded algorithms. It also controls peripheral devices such as the LCD display and relay module. The ESP32 is selected due to its low power consumption, high processing capability, and integrated Wi-Fi module.

3. Communication Layer

The communication layer enables wireless data transfer between the processing unit and the cloud platform. Using Wi-Fi connectivity, the ESP32 transmits real-time energy data to the IoT cloud server. This layer eliminates

the dependency on GSM and SMS-based communication, ensuring faster and more reliable data transmission.

4. Application and Control Layer

The application layer provides a user interface through a mobile application connected to the IoT cloud platform. Users can monitor real-time energy consumption, view historical data, and receive system status updates. This layer also allows users to remotely control electrical loads through commands sent to the relay module, enabling efficient energy utilization.

IMPLEMENTATION METHODOLOGY

The implementation methodology of the Smart Energy Meter and Monitoring System using IoT describes the systematic steps followed to design, develop, and test the proposed system. The methodology ensures accurate energy measurement, reliable data transmission, and efficient remote control of electrical loads.

Step 1: Hardware Setup

The hardware components are assembled according to the system architecture. The voltage sensor and energy meter module are connected to the input terminals of the electrical load to measure voltage and energy consumption. These sensors are interfaced with the ESP32 microcontroller. A 16×2 LCD is connected to display real-time parameters locally. The relay module is connected between the ESP32 and the load to enable remote ON/OFF control. A regulated power supply is provided to all components.

Step 2: Sensor Data Acquisition

The voltage sensor and energy meter module continuously sense electrical parameters from the load. The analog and digital outputs from the sensors are fed to the ESP32. The microcontroller reads the sensor values at regular intervals to ensure continuous monitoring.

Step 3: Data Processing and Computation

The ESP32 processes the acquired sensor data using embedded algorithms. Voltage, current, power, and energy consumption values are calculated based on the sensed inputs. The processed data is formatted for display and cloud transmission.

Step 4: Local Display

The calculated electrical parameters are displayed on the 16×2 LCD in real time. This allows users to view energy consumption directly at the meter location without relying on internet connectivity.

Step 5: Cloud Communication

Using its built-in Wi-Fi capability, the ESP32 connects to the IoT cloud platform. The processed energy data is transmitted to the cloud at regular intervals. This enables real-time monitoring and data storage without GSM or SMS dependency.

Step 6: Remote Monitoring and Control

A mobile application is used to access the cloud-stored data. Users can monitor real-time energy consumption and view system status remotely. Control commands sent from the application are received by the ESP32, which activates or deactivates the relay module to switch the connected load ON or OFF.

Step 7: Testing and Validation

The complete system is tested under different load conditions to verify accurate energy measurement, reliable data transmission, and proper relay operation. The results confirm the effectiveness and reliability of the proposed implementation.

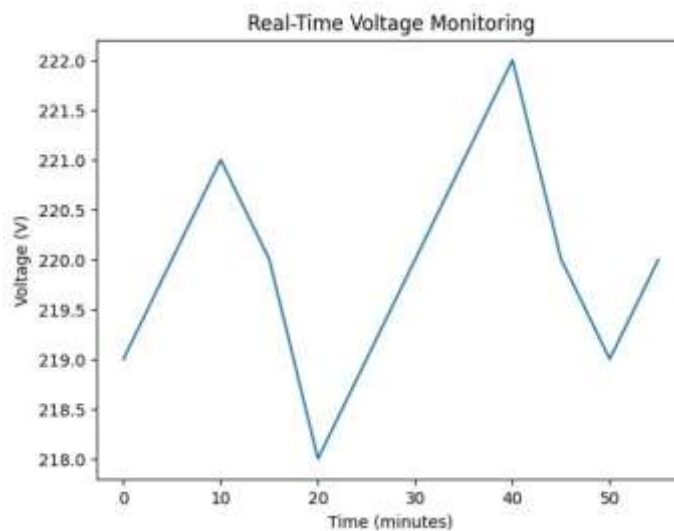
RESULTS AND DISCUSSION (CONCEPTUAL)

The Smart Energy Meter and Monitoring System using IoT was designed and implemented to evaluate its effectiveness in real-time energy monitoring and

remote load control. The system was tested under different operating conditions to verify functionality, reliability, and communication performance.

A. Energy Monitoring Performance

The system successfully monitored electrical parameters such as voltage, power, and energy consumption in real time. The sensed values were processed by the ESP32 microcontroller and displayed continuously on the LCD. This confirmed that the sensing and processing units worked accurately and reliably for continuous monitoring.



B. Cloud Data Transmission

The processed energy data was transmitted to the IoT cloud platform through Wi-Fi without noticeable delay. The data updates were observed in real time on the mobile application, demonstrating reliable wireless communication. Continuous data logging enabled users to track energy usage trends over time.

C. Remote Load Control

The relay control feature functioned effectively in response to commands sent from the mobile application. Electrical loads could be switched ON or OFF remotely, which helped in preventing unnecessary power consumption. The

response time of the relay operation was fast, indicating efficient communication between the cloud and the control unit.

D. System Reliability and Efficiency

The elimination of GSM and SMS-based communication reduced operational cost and dependency on mobile networks. The system operated stably during continuous operation, showing suitability for smart home energy management. The modular design also allows easy expansion for additional sensors or features.

E. Discussion

The obtained results demonstrate that the proposed IoT-based energy meter offers significant improvements over conventional and GSM-based systems. Real-time monitoring increases user awareness of energy consumption, while remote load control enhances energy efficiency. The cloud-based approach ensures scalability and future integration with smart grid technology.

APPLICATIONS

The Smart Energy Meter and Monitoring System using IoT has wide applications in residential, commercial, and industrial sectors. In smart homes, it enables real-time monitoring of electricity consumption and remote control of appliances, helping users reduce unnecessary power usage and improve energy efficiency. In commercial buildings such as offices and shopping complexes, the system supports centralized energy monitoring and cost optimization. Industries can utilize the system to track machine-level power consumption, detect abnormal energy usage, and enhance preventive maintenance. Furthermore, it can be integrated with smart grid infrastructure and renewable energy systems such as solar power plants for advanced energy analytics and efficient power management.

CONCLUSION

This paper presented the design and implementation of a Smart Energy Meter and Monitoring System using IoT technology. The proposed system enables real-time monitoring of electrical parameters and provides remote load control

through a cloud-based mobile application. By replacing conventional and GSM-based meters, the system reduces operational cost, eliminates manual meter reading, and improves energy awareness among users. Experimental results from real-time operation demonstrate reliable data acquisition, stable wireless communication, and effective load control. The modular and scalable design makes the system suitable for smart homes, commercial buildings, and future smart grid applications. Overall, the proposed solution offers an efficient, cost-effective, and practical approach to modern energy management.

AUTHORS AND CONTRIBUTION

S. Nazma provided overall guidance, supervision and provided technical suggestions, assisted in troubleshooting technical issues and refined the project documentation and presentation. N. Darshini responsible for overall project planning, system architecture design, implementation and document preparation. Y. Lakshmi handled circuit design, sensor connections and ESP32 interfacing. B. Sreenivasulu developed the code and ensured real time monitoring. S. Sher Hussain and Y. Nandini managed the wi-fi configuration, contributed to literature review.

CONFLICTS OF INTEREST

The authors declare that they have no known financial or personal relationships that could have appeared to influence the work reported in this paper.

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