Energy Meter Monitoring Using IoT

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Abstract— Energy consumption monitoring has become essential in modern households and industries to promote efficient energy usage and cost reduction. To address this need, we have developed an IoT-based energy meter monitoring system that allows users to track real-time power consumption through an online platform or mobile application. The system uses sensors and a microcontroller to measure voltage, current, and power usage, transmitting the data to a cloud server via Wi-Fi. This enables users and utility providers to remotely monitor energy consumption patterns, detect overloads, and take timely actions to prevent wastage. The proposed system also includes alert notifications for abnormal energy usage and supports data logging for analytical purposes. By integrating Internet of Things (IoT) technology, the system enhances transparency, automation, and energy management efficiency.

Keywords: Internet of Things, Energy Meter, Power Monitoring, Smart System, Automation.

I. Introduction

An energy meter is a crucial device used to measure the electrical energy consumption of residential, commercial, or industrial users. Traditionally, electricity consumption is recorded manually by utility personnel, which is time-consuming, prone to human error, and often results in delayed billing. To address these challenges, modern technology offers an automated and efficient alternative through the use of the Internet of Things (IoT). By integrating IoT with energy meters, it becomes possible to remotely monitor and manage power usage in real time, ensuring greater accuracy and efficiency in the energy management process.

In the energy domain, smart monitoring systems maintain the stability and efficiency of energy distribution. IoT-enabled energy meters allow real-time communication between the consumer and the service provider. They continuously record energy usage data and transmit it through wireless communication networks such as Wi-Fi, GSM, or LoRa to centralized cloud servers. This data can then be analyzed for billing, load management, and fault detection. Consumers can monitor their electricity usage remotely through web or mobile applications, helping them make informed decisions about energy conservation and cost reduction.

We are currently living in an era of smart technologies, often referred to as “ubiquitous computing” or “Web 3.0,” where the Internet of Things (IoT) plays a vital role alongside cloud computing and big data. The concept of IoT, introduced by Kevin Ashton in 1999 and officially recognized in 2005, envisions a world where interconnected devices can sense, collect, and share data to automate various tasks intelligently. IoT-enabled devices, including smart meters, exemplify this vision by autonomously gathering and transmitting energy usage information, facilitating decision-making, and enhancing the reliability of power systems.

Unlike conventional meters that require manual readings, IoT-based energy meters provide continuous and remote monitoring, enabling both consumers and electricity providers to track energy consumption in real time. They offer additional features such as automated billing, power theft detection, and system alerts for abnormal usage or faults. This not only improves transparency and efficiency but also reduces operational costs for energy distribution companies. In summary, our IoT-based energy meter monitoring system ensures accurate, automated, and intelligent management of energy resources, making it a vital innovation for modern smart grids and sustainable energy management.

The rest of the article is structured as follows: Section II reviews related works; Section III presents the proposed model; Section IV focuses on the analysis of results; and Section V concludes the paper.

II Related works

Energy management and monitoring have become crucial aspects of modern smart systems due to the increasing demand for electricity and the need for efficient energy utilization. The work in [1] focuses on developing an IoT-based smart energy meter that can measure and monitor power consumption in real time. The system employs a current sensor and voltage sensor interfaced with an Arduino microcontroller to calculate power usage. The measured data is transmitted to a cloud server via Wi-Fi, allowing users to view live consumption details through a web or mobile application. The primary aim of this work is to enable real-time energy tracking and promote energy conservation by making users more aware of their consumption patterns.

The authors in [2] present a design for an automated energy monitoring and billing system using the Internet of Things. The system eliminates manual meter reading by transmitting energy data automatically to the power distribution company using a GSM or Wi-Fi module. It enables users to view their monthly consumption and bill information on their mobile devices. The proposed model improves billing transparency, reduces human error, and supports prepaid billing functionality to encourage responsible energy use.

In [3], the researchers propose a low-cost IoT-based smart energy meter that continuously measures the power consumption and uploads it to a cloud platform for analysis. The system employs an ESP8266 microcontroller and sensors such as the PZEM-004T module to collect data on voltage, current, and power factor. Users can monitor energy data remotely and receive alerts via SMS or email if consumption exceeds a predefined threshold. This system supports efficient energy management and helps in identifying wastage or abnormal usage patterns.

The study in [4] introduces a real-time energy monitoring system integrated with a home automation network. The system enables automatic control of household appliances based on consumption data collected by the energy meter. Using IoT protocols such as MQTT, data from the sensors is transmitted to a central server where it is analyzed for optimization. The implementation demonstrates how IoT-based systems can contribute to both energy efficiency and smart home management.

In [5], an intelligent energy meter system is presented that utilizes cloud computing and machine learning algorithms for predictive analysis. The system gathers consumption data through smart sensors and uploads it to a cloud database for processing. Machine learning models are used to predict future consumption trends and provide energy-saving recommendations to users. The authors highlight that integrating IoT with data analytics can significantly enhance energy forecasting and load management.

The authors in [6] developed an IoT-based energy monitoring and theft detection system. Unauthorized tapping of power lines or tampering with meters often causes revenue loss to electricity boards. The proposed system uses current sensors at various points of the distribution line and sends real-time data to a central control unit via IoT communication modules. Any mismatch between the transmitted and received readings triggers an alert, enabling immediate detection of electricity theft.

The work in [7] focuses on industrial energy management using IoT. In this approach, multiple energy meters are networked across industrial sections to monitor power usage per unit of production. The system uses Raspberry Pi and wireless modules for centralized data collection. The recorded data is visualized through a web dashboard, providing insights into equipment performance and helping management optimize power allocation and minimize wastage.

A similar study in [8] presents a smart prepaid energy meter that allows users to recharge energy credit through a mobile application. The IoT-enabled system uses RFID and GSM modules to handle payments and disconnections remotely. Once the balance is depleted, the power supply is automatically cut off, and users receive alerts to recharge. This model is particularly suitable for residential and rural regions where billing infrastructure is limited.

The research in [9] implements a hybrid IoT and blockchain-based smart energy meter for secure data transactions. Blockchain technology ensures that the energy usage records are tamper-proof and verifiable, addressing the challenge of data integrity. The system records each unit of power consumed as a transaction on the blockchain, allowing transparent billing and audit trails.

Lastly, the work in [10] presents a comprehensive smart grid energy management system integrating IoT-enabled meters, cloud analytics, and renewable energy sources. The system not only monitors electricity consumption but also tracks energy generation from solar panels. It balances energy distribution dynamically using cloud-based analytics to reduce dependency on the main grid and promote sustainable energy practices

III PROPOSED MODEL FOR ENERGY METER

The controller, which serves as the main electrical component in the energy meter monitoring system, is responsible for receiving electrical signals from the energy meter and processing them to obtain the corresponding readings. In this project, the ATmega8 microcontroller is used as the central controller. The ATmega8 is an 8-bit AVR microcontroller that is widely used for embedded system applications due to its reliability, low power consumption, and ease of programming. It features built-in ADC channels, UART interface, and sufficient I/O pins, making it ideal for IoT-based monitoring applications.

The energy meter used in this system provides pulse outputs proportional to the amount of energy consumed. Each pulse generated by the energy meter represents a fixed unit of energy, typically in kilowatt-hours (kWh). These pulses are detected through the input pins of the ATmega8 microcontroller. The microcontroller counts the number of pulses over time and calculates the total power consumption based on the energy meter's calibration constant.

The processed data is then transmitted to an IoT module, such as the ESP8266 Wi-Fi module, which enables wireless communication between the energy meter and a cloud server or web application. This allows users or electricity providers to remotely monitor energy usage in real time through a smartphone or computer.

To ensure accurate data transmission, the system uses both hardware and software filtering methods to eliminate disturbances or false pulse counts caused by electrical noise. The microcontroller continuously monitors the pulse inputs, updates the energy readings, and sends the updated data to the cloud at regular intervals.

An LCD display is also interfaced with the ATmega8 to show real-time parameters such as the number of pulses, energy consumption, and units used. Additionally, the system can generate alerts if abnormal power usage is detected, ensuring better management of electrical energy and timely detection of faults or overconsumption.

Through this integration of the ATmega8 microcontroller, energy meter, and IoT connectivity, the proposed model provides an efficient, low-cost, and reliable method for monitoring household or industrial power consumption. It helps users analyze usage patterns, reduce wastage, and contribute to effective energy management.

A. Block Diagram

Here in this section, the block diagram for the proposed model is discussed. Figure.1 shows the detailed block diagram for the same.

The IoT-based Energy Meter Monitoring System is designed to measure and transmit real-time energy consumption data through the Internet. The system enables remote monitoring, eliminating the need for manual meter readings.

The block diagram represents the overall implementation using a microcontroller and Wi-Fi module for real-time IoT-based monitoring.

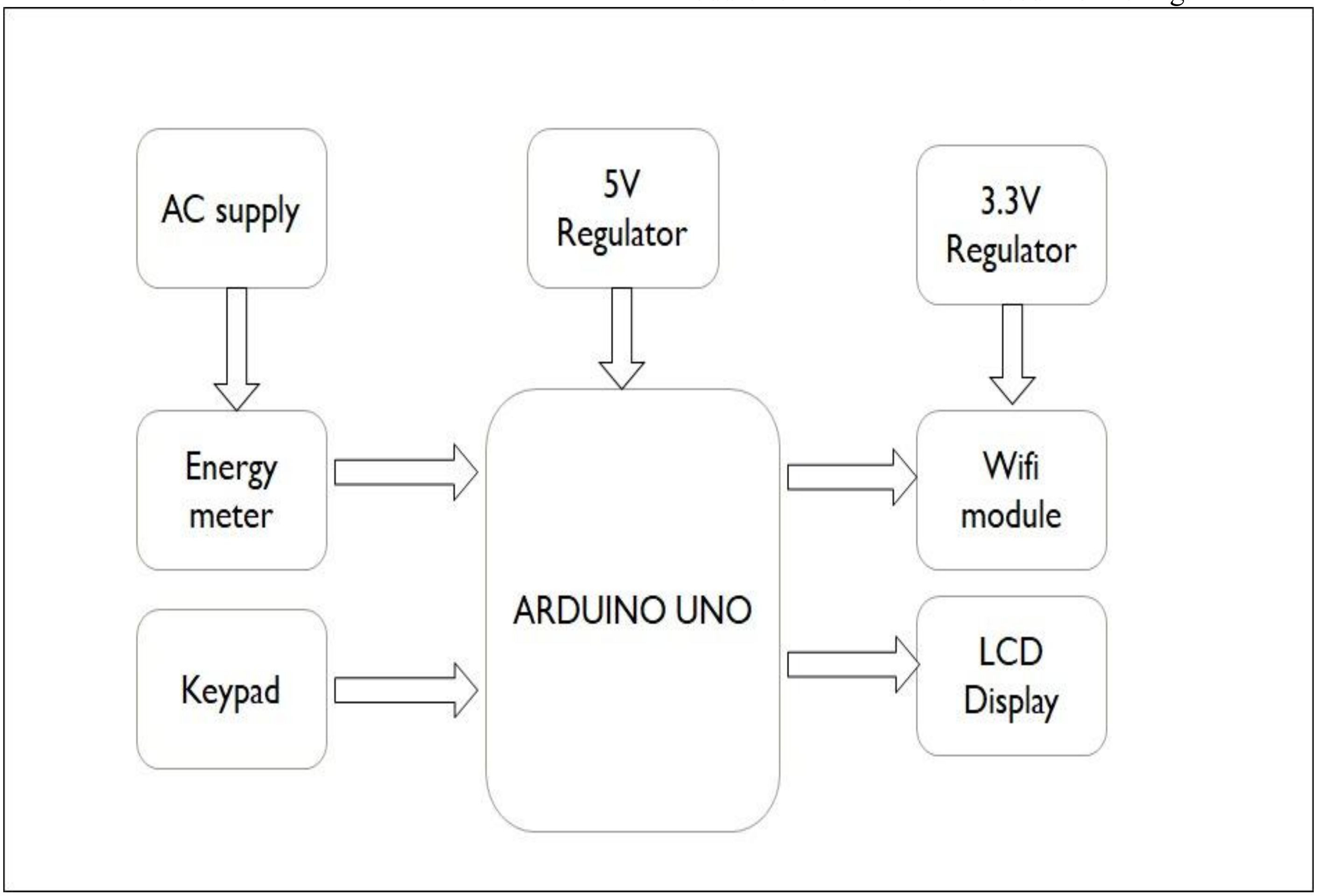

Figure 1. Block Diagram

It consists of an energy meter, microcontroller, Wi-Fi module, LCD display, keypad, and power supply unit. The power supply section, which includes a transformer, rectifier, and voltage regulators, provides stable DC voltage to the components. The energy meter records power usage and sends pulse signals to the microcontroller (Arduino UNO), which processes the data and sends it to the Wi-Fi module for cloud storage and online monitoring.

The LCD display shows local readings such as voltage and energy consumed, while the keypad allows basic user input. This system provides an efficient and smart solution for monitoring power consumption, detecting abnormal usage, and promoting energy savings.

B. Experimental Setup

"Energy Meter Monitoring Using IoT" consists of a energy meter, as shown in Figure 2. The meter is connected to the supply, and an Arduino controller is placed beside it to collect and send the readings to the cloud. A small display shows real-time energy data, while LEDs indicate power and network status. All wiring is organized neatly with proper separation of high- and low-voltage sections for safety.

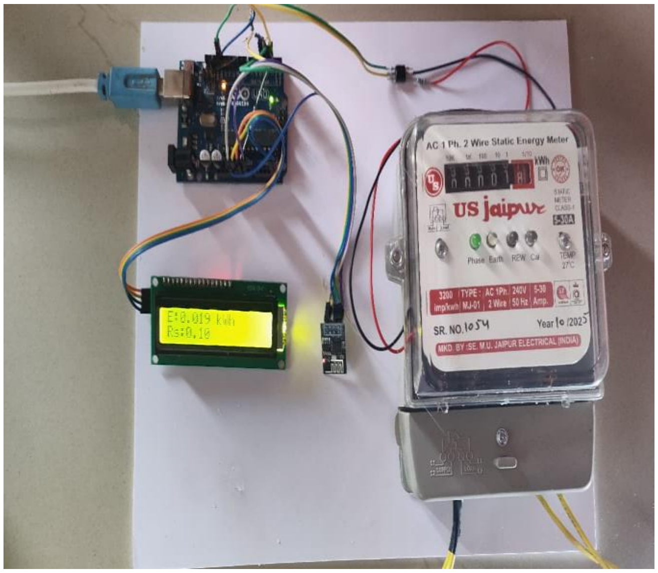

Figure 2. Experimental Setup

Figure 3. Measuring consumed energy

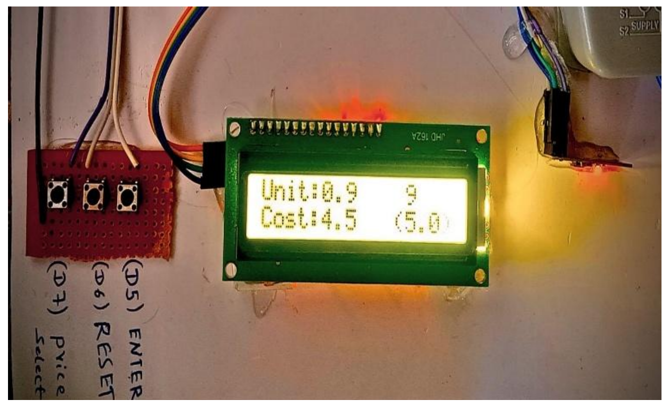

Figure 4. Display of energy and cost

C. Working

The Arduino UNO, which serves as the main controller, manages the overall operation of the Energy Meter Monitoring system. The energy meter is interfaced with a sensor that measures real-time voltage, current, and unit consumption. Once the system is powered ON, these values are sensed and sent to the Arduino for processing. The Arduino then uploads the processed data to the IoT platform for remote monitoring. The block diagram below represents the basic working of the system. Based on the set limits, the Arduino compares the measured consumption with the threshold and sends alerts when the usage exceeds the limit. The system features include controllable parameters like real-time unit calculation and observable parameters like load status and live monitoring through the mobile application.

IV. RESLUTS AND DISCUSSION

The experimental and simulated results of the proposed work are discussed in this section. Figure 3 and 4 shows the measuring of the energy consumed and display of the consumed energy and cost respectively.

Figure 5 depicts the results of the proposed work in which consumed energy and cost are displayed.

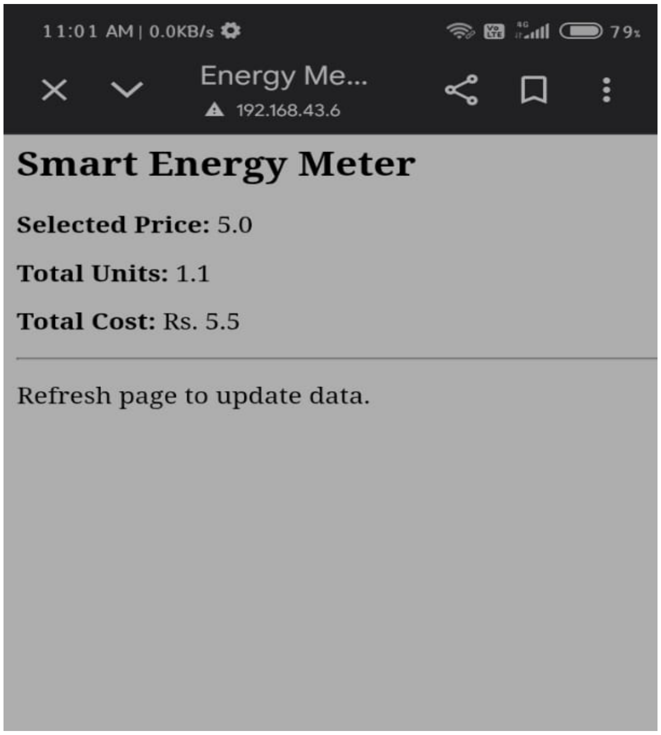

Figure 5. Simulation results

V. CONCLUSION

The development of an IoT-enabled energy meter monitoring system marks an important step toward achieving smarter and more efficient power management. By integrating real-time data acquisition, remote monitoring, and automated alerts, the system ensures accurate tracking of energy consumption while reducing the possibility of manual errors. Advanced technologies, such as IoT connectivity and cloud-based dashboards, enable users and utility providers to access live meter readings, analyze usage patterns, and make informed decisions to optimize energy usage. Furthermore, continuous monitoring helps in early detection of abnormalities, preventing potential electrical faults and ensuring safety. Overall, this intelligent solution not only enhances energy transparency and reliability but also supports sustainable energy practices, offering improved control and convenience to consumers and service providers alike.

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