

A Comprehensive Review on IoT-Based Smart Energy Meter with Real-Time Monitoring and Automated Billing System

Shubham Tathe¹, Abhishek Savalgi², Amit Thombare³, Ganesh Sarak⁴,
Ms. V. B. Utpat⁵, Dr. S. V. Pingale⁶

^{1,2,3,4}UG Students, Department of Electronics and Telecommunication Engineering

⁵Assistant Professor, Department of Electronics and Telecommunication Engineering

⁶Head of Department, Department of Computer Science and Engineering

SKN Sinhgad College of Engineering, Pandharpur

shubhamtathe2005@gmail.com, abhisheksavalgi601@gmail.com,

amitthombare1301@gmail.com, sarakganesh4924@gmail.com, vaishnavi.utpat@gamil.com

Abstract: *Traditional electricity meters depend on manual readings, which are prone to errors and lack real-time monitoring features. To address these challenges, this project proposes an IoT-based Smart Energy Meter designed to measure and monitor electricity consumption in real time. The system employs voltage and current sensors interfaced with a microcontroller to process the acquired data. The processed information is transmitted wirelessly to a cloud platform for secure storage and remote accessibility. Users can monitor detailed consumption reports and receive automated billing through a web or mobile application. Furthermore, the system provides features such as usage alerts and load management to ensure efficient energy utilization. The project demonstrates the application of core concepts from Electronics and Telecommunication Engineering, particularly in embedded systems, IoT communication, and smart grid technologies, to develop an intelligent and cost-effective energy monitoring solution.*

Keywords: IoT-based Smart Energy Meter, Real-time Monitoring, Automated Billing, Cloud-based Data Storage, Embedded Systems, Load Management

I. INTRODUCTION

Electricity has become the backbone of modern life, powering industries, businesses, households, and critical infrastructure. With the rapid growth in population, urbanization, and technological advancements, the demand for electricity is increasing at an unprecedented rate. This rise in demand makes it essential to ensure accurate monitoring, efficient distribution, and effective management of energy consumption. Traditional electricity meters, which are still widely used in many parts of the world, have significant limitations. They rely on manual readings by utility staff, which are not only time-consuming but also prone to errors. Moreover, these meters fail to provide real-time data, preventing consumers and providers from identifying consumption patterns, energy wastage, or unexpected load variations.

In the current digital era, where automation and connectivity are revolutionizing multiple sectors, there is a strong need to upgrade conventional metering systems. Consumers demand transparency in billing, better control over their energy usage, and convenient access to data. At the same time, utility companies require efficient systems to reduce losses, prevent theft, and optimize grid management. To address these challenges, the integration of modern communication technologies into energy metering has emerged as a promising solution.

The Internet of Things (IoT) is one such transformative technology that enables physical devices to communicate and share data over the internet. IoT allows sensors, actuators, and embedded devices to be connected into a network, creating intelligent systems that can operate with minimal human intervention. When applied to the domain of energy



management, IoT can provide continuous monitoring, automated billing, remote accessibility, and intelligent decision-making. For example, IoT-enabled meters can instantly transmit consumption data to the cloud, where it is securely stored and analyzed. Consumers can then access this data in real-time through mobile or web applications, receiving detailed reports, usage alerts, and recommendations for efficient consumption.

This project introduces an IoT-based Smart Energy Meter that directly addresses the drawbacks of conventional meters. The system employs voltage and current sensors to measure consumption accurately, while a microcontroller processes the data and transmits it wirelessly to a cloud platform. Through this setup, both consumers and utility providers gain access to accurate, real-time information that improves decision-making and energy efficiency. Unlike traditional methods, this system minimizes human error, reduces manual labor, and ensures faster and more reliable billing. Additionally, it promotes energy conservation by enabling users to monitor their consumption patterns and adjust their usage accordingly.

Beyond monitoring and billing, the proposed system also lays the foundation for smart grid implementation, where real-time data can be leveraged for predictive analytics, load forecasting, and dynamic tariff models. For Electronics and Telecommunication Engineering (ENTC) students, this project demonstrates the practical application of embedded systems, IoT communication protocols, and wireless data transmission in solving real-world energy challenges.

II. LITERATURE SURVEY

Several studies have explored the automation and monitoring of poultry farms using embedded systems and Arduino platforms. Bhagat et al. [1] developed an Arduino and sensor-based system to automatically control poultry shed parameters, ensuring optimal environmental conditions. More et al. [2] presented a low-cost real-time embedded monitoring system focusing on affordability and efficient data acquisition in poultry sheds. Raut et al. [3] proposed a smart poultry environment monitoring system using embedded technology, targeting real-time analysis and response to changing conditions. Kale et al. [4] designed a system using Arduino for monitoring temperature and humidity in poultry sheds, emphasizing ease of implementation. Sharma et al. [5] focused on controlling temperature and humidity in real-time, leveraging embedded technologies to maintain healthy conditions in poultry farms. Shah et al. [6] offered an embedded system using Arduino to monitor and automate poultry house operations effectively. Chaukidar et al. [7] contributed an early system for automation and monitoring, which has continued to influence newer studies. Patil et al. [8] developed an Arduino-based monitoring system using environmental sensors for better control over poultry environments. Pawar et al. [10] proposed a wireless sensor network to enhance poultry environment monitoring, offering a scalable and remote solution. Yadav et al. [11] introduced automation techniques using Arduino, aiming to reduce manual labor and improve system efficiency. Although not directly focused on poultry farming, Natraj et al. [9] and Packiaslaser et al. [13] provided useful insights into IoT security and automation systems that can be adapted for agricultural and livestock environments. Bhat et al. [12] implemented a real-time livestock monitoring system based on Arduino and various sensors to ensure optimal living conditions. Sagar Dadhe et al. [14] IoT based smart energy meter improves monitoring, billing accuracy, energy efficiency, and enable real-time consumption control.

Proposed Methodology

The design and implementation of the IoT-based Smart Energy Meter follow a systematic methodology that integrates embedded hardware, sensor modules, and IoT communication technologies to achieve accurate and real-time energy monitoring and billing. The system begins by measuring electrical parameters such as voltage and current using dedicated sensors, which are interfaced with a microcontroller. The microcontroller processes this data to calculate instantaneous power, total energy consumed (units), and the corresponding bill amount.

The calculated information is displayed locally on an **I2C LCD**, providing immediate on-site feedback. Simultaneously, the data is transmitted wirelessly via Wi-Fi to the **Blynk dashboard**, allowing consumers to remotely monitor voltage, current, power, units consumed, and billing information in real time through a smartphone or tablet.

The system is powered by a regulated DC supply to ensure stable operation and protect sensitive electronics. Its modular design ensures scalability and allows for future integration of additional features, such as alerts or load



management. This methodology effectively combines **embedded electronics, sensor technology, and IoT-based cloud communication** to deliver a reliable, cost-effective, and transparent solution for energy management.

Figure 1 shows block diagram of proposed methodology as follows:

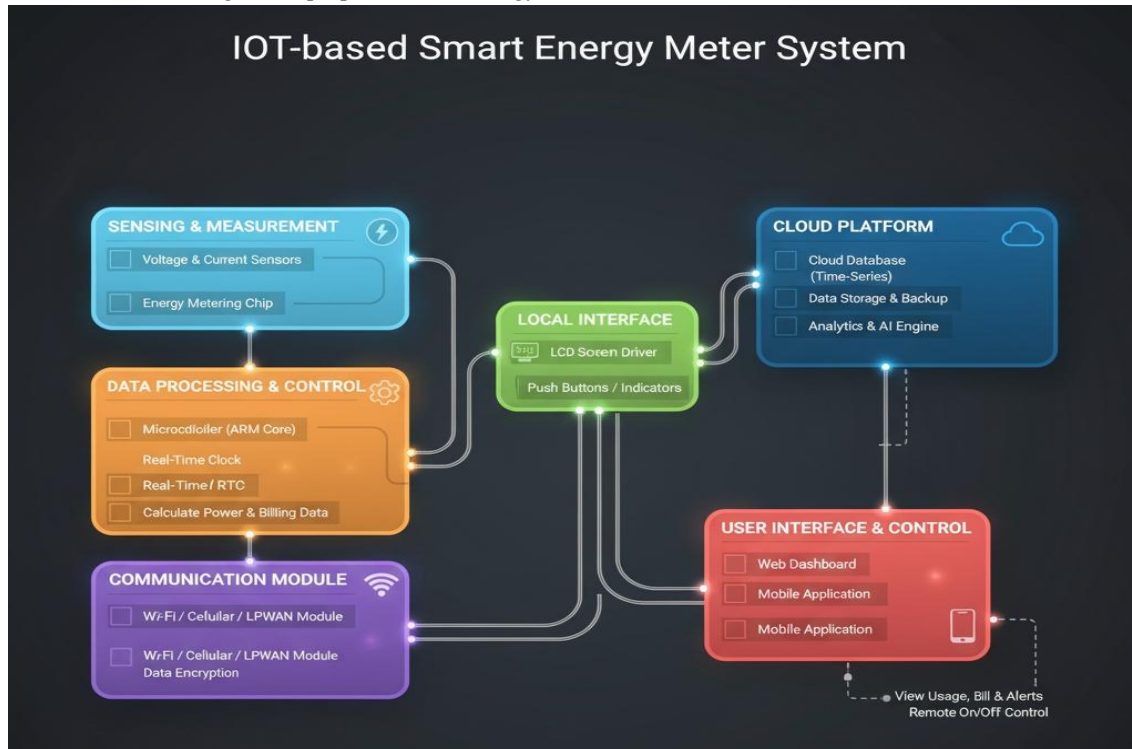


Figure1: Block Diagram of Proposed System

The proposed Smart Energy Meter is a compact and efficient IoT-based solution designed to monitor electricity consumption and provide automated billing. It integrates voltage and current sensors with a microcontroller to measure key electrical parameters, including voltage, current, instantaneous power, energy consumed (units), and the corresponding bill amount.

A ZMPT101B voltage sensor continuously monitors the supply voltage, while an ACS712 current sensor measures the current drawn by the connected load. These readings are processed by a microcontroller (ESP32), which calculates real-time power and cumulative energy consumption. Based on the units consumed, the system also computes the bill using predefined tariff rates.

The processed data is displayed locally on an I2C LCD for immediate on-site monitoring. In addition, the system leverages IoT connectivity to transmit data to the Blynk dashboard, enabling consumers to remotely view voltage, current, power, units, and billing information in real time via a smartphone or tablet. This dual display approach ensures transparency and easy access for users at all times.

The hardware is powered by a regulated 5V DC supply, safeguarding sensitive components from voltage fluctuations. The microcontroller handles all decision-making and data calculations, ensuring accurate measurement and reliable operation. The modular design allows easy integration with additional features in the future, such as alerts or load control, without modifying the core system.

In summary, this IoT-based Smart Energy Meter provides accurate, real-time monitoring of electricity usage, clear visibility of power parameters, and automated billing. By combining embedded electronics with IoT technology, it offers a cost-effective, user-friendly, and transparent solution for both residential and small commercial energy management.



III. CONCLUSION

The IoT-based Smart Energy Meter enables real-time monitoring of electricity consumption with high accuracy, reducing manual effort and eliminating errors commonly associated with traditional billing systems. Consumers can conveniently track their energy usage, calculate bills, and manage costs through mobile or web applications, making the system both user-friendly and accessible.

By integrating embedded sensors, microcontrollers, and IoT communication protocols, the system ensures reliable data acquisition, processing, and transmission. Features such as prepaid billing, automated calculation of units and bills, and remote monitoring through the Blynk dashboard provide enhanced transparency and control. This empowers users to optimize energy usage, avoid wastage, and make informed decisions regarding their electricity consumption. Furthermore, the modular and scalable design allows future integration with smart grid technologies, demand-side management, or renewable energy monitoring. Overall, the project demonstrates the practical application of Electronics and Telecommunication Engineering concepts in developing a cost-effective, efficient, and intelligent energy management system, supporting both operational efficiency and long-term sustainability goals.

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