

IOT BASED ENERGY MONITORING SYSTEM WITH AUTOMATIC BILLING USING RASPBERRY PI

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Abstract: This project presents the design and implementation of an IoT-based Smart Energy Meter system utilizing the Raspberry Pi Pico and Node MCU ESP8266 to automate utility monitoring and load management. Traditional manual meter reading is a labor-intensive, time-consuming process prone to human error. By leveraging the Internet of Things (IoT), this system provides a seamless solution for remote data collection, real-time monitoring, and enhanced consumer control. The system architecture interfaces a digital energy meter with a microcontroller to capture consumption pulses. The Node MCU ESP8266 facilitates wireless connectivity, enabling users to monitor live consumption data through the Blynk IoT application. Beyond monitoring, the system integrates a GSM module to provide a dual-layered communication approach: the electricity department and the user receive periodic billing updates via SMS alerts, and the user can execute remote load shedding or appliance control through either the Blynk interface or SMS commands. A dedicated LCD module provides local visualization of real-time readings. By automating the billing cycle and offering instantaneous load control, this project minimizes operational costs for utility providers while empowering consumers to manage their electricity usage and costs efficiently.

Keywords: Residential energy monitoring, Smart billing systems, SMS alert systems, Load management, Smart Energy Meter, Raspberry Pi Pico, Node MCU ESP8266, GSM

1. INTRODUCTION

The rapid advancement of technology and the increasing demand for electricity have made efficient energy management a critical necessity. Traditional energy monitoring systems rely on manual meter reading, which is time-consuming, labour-intensive, and prone to human errors. These limitations often lead to inaccurate billing and delayed information for consumers. To overcome these challenges, an IoT-Based Energy Monitoring System with Automatic Billing using Raspberry Pi is proposed as a modern and efficient solution.

The Internet of Things (IoT) enables devices to communicate and exchange data over the internet, making it possible to monitor and control systems remotely. In this project, the Raspberry Pi acts as the central controller that collects data from sensors measuring voltage and current. This data is processed to calculate power consumption and energy usage. The system continuously monitors energy consumption in real time and transmits the data to cloud platforms for remote access.

One of the key features of this system is automatic billing. Based on the measured energy consumption, the system calculates the electricity bill using predefined tariff rates. This eliminates the need for manual meter reading and reduces errors in billing. Additionally, the system can send notifications or alerts to users regarding their energy usage and billing status, improving transparency and efficiency.

The proposed system also supports remote monitoring through web or mobile applications. Users can access their energy consumption data anytime and from anywhere, helping them to manage their electricity usage more effectively. This feature encourages energy conservation and promotes awareness among consumers.

In conclusion, the IoT-based energy monitoring system using Raspberry Pi provides a smart, reliable, and automated approach to energy management. It enhances accuracy, reduces human effort, and offers real-time monitoring and billing, making it highly suitable for modern smart homes, industries, and smart grid applications.

2. LITERATURE SURVEY

2.1 IoT-Based Smart Energy Monitoring Systems

The integration of the Internet of Things (IoT) into energy metering systems has significantly improved the efficiency of electricity monitoring and management. Traditional meter reading methods involve manual data collection, which is time-consuming and prone to human error. IoT-enabled smart meters automate this process by enabling real-time data acquisition and remote monitoring [1]. These systems use sensors and microcontrollers to measure parameters such as voltage, current, and power consumption, transmitting the data over the internet.

Researchers have proposed various IoT-based solutions to improve energy efficiency and reduce operational costs. For example, GSM-based automatic meter reading systems allow remote data transmission and billing without human intervention [2][3]. These systems enhance accuracy and transparency while minimizing delays in billing. Additionally, IoT systems support cloud integration, allowing users and utility providers to access data anytime and anywhere.

Another major advantage of IoT-based smart meters is their ability to detect abnormal energy usage and power theft. Continuous monitoring enables early detection of irregular patterns, helping reduce energy losses [4]. Furthermore, IoT-based systems support smart grid integration, improving overall energy distribution and management.

Overall, IoT-enabled energy meters provide an efficient, reliable, and scalable solution for modern energy management systems. Their ability to automate monitoring, enhance transparency, and support remote access makes them a key component of future smart grids.

2.2 Raspberry Pi-Based Smart Energy Monitoring

Raspberry Pi has emerged as a popular platform for developing smart energy meter systems due to its low cost, flexibility, and processing capabilities. It acts as a central controller that collects and processes data from sensors and communicates with cloud platforms [5]. In such systems, energy parameters are measured using sensors, and the data is converted into digital form using Analog-to-Digital Converters (ADC).

The Raspberry Pi processes this data using programming languages such as Python and calculates energy consumption in real time. It can store data locally or transmit it to cloud servers for further analysis. This enables users to monitor their energy usage patterns and optimize consumption [6].

One of the key features of Raspberry Pi-based systems is their connectivity. With built-in Wi-Fi and Ethernet support, these systems can easily integrate with IoT platforms. Data can be transmitted using communication protocols such as MQTT and HTTP, ensuring reliable and efficient data transfer.

Additionally, Raspberry Pi-based systems support automation features such as remote load control and alert generation. For instance, when energy consumption exceeds a predefined threshold, the system can automatically disconnect appliances or send notifications to users. This enhances energy efficiency and reduces wastage.

However, these systems also face challenges such as dependency on internet connectivity and security concerns. Proper encryption and authentication mechanisms are required to ensure safe data transmission. Despite these challenges, Raspberry Pi remains a powerful tool for developing smart energy monitoring systems.

2.3 Automatic Billing System in Smart Energy Monitoring

Automatic billing systems play a crucial role in modern energy meter solutions by eliminating the need for manual meter reading. Traditional billing systems are labour-intensive and prone to errors, leading to inaccurate billing and delays. Automated systems overcome these limitations by continuously monitoring energy consumption and generating bills in real time [7]

In IoT-based systems, energy consumption data is collected and processed by a central controller such as Raspberry Pi. The system calculates the total energy consumed in kilowatt-hours (kWh) and generates the bill based on predefined tariff rates. This ensures accuracy and transparency in billing [8].

The generated bill can be sent to users via SMS, email, or mobile applications. GSM-based communication systems are widely used for sending billing information directly to consumers, improving convenience and accessibility [9]. Additionally, users can monitor their energy usage in real time, helping them manage their consumption and reduce electricity costs.

Automatic billing systems also support remote monitoring by utility providers. This reduces operational costs and enables efficient management of large-scale energy distribution systems. Furthermore, these systems enhance data security by minimizing manual handling of meter readings.

In conclusion, automatic billing systems provide a smart and efficient solution for electricity billing. They reduce human effort, improve accuracy, and support real-time monitoring, making them an essential component of IoT-based energy meter systems.

3.EXISTING SYSTEM

In the current electricity distribution system, energy monitoring and billing are mostly handled using traditional **manual or semi-automatic methods**. Electricity consumption is measured using conventional electromechanical or digital energy meters installed at consumer premises. These meters record the total energy consumed over a billing period, and the data is usually collected manually by electricity board employees for generating bills. This process is time-consuming and prone to human errors.

In many regions, the existing system relies on **manual meter reading**, where a technician physically visits each consumer location, notes the reading, and submits it to the electricity office. After that, the billing is calculated and sent to consumers. This method creates delays in bill generation and sometimes leads to incorrect readings due to human mistakes or data entry errors.

Some modern systems have introduced **digital energy meters**, but they still lack real-time monitoring and automation. These meters only display consumption locally and do not provide remote access to users or electricity providers. As a result, consumers are not able to track their real-time energy usage, which leads to inefficient energy management and higher electricity bills.

Another major limitation of the existing system is the **lack of automation in billing and monitoring**. There is no direct communication between the energy meter and the electricity provider's central system. Because of this, consumers do not receive instant updates about their usage, and utilities cannot detect abnormal consumption patterns or power theft effectively in real time.

In addition, the traditional system does not support automatic billing or real-time alerts. There is no mechanism to notify users about excessive energy consumption or unusual usage patterns. This can lead to power wastage and increased costs, especially in residential and industrial sectors.

The existing system also faces issues related to electricity theft and tampering. Since

monitoring is not continuous and real-time, unauthorized usage often goes unnoticed. This results in revenue losses for electricity providers and affects the overall efficiency of the power distribution system.

Furthermore, maintenance and operational costs are high in the existing system. The need for manual labour, physical visits, and paper-based billing increases expenses. It also lacks scalability and adaptability to modern smart grid technologies, making it less efficient in today's digital and connected world.

Overall, the existing system is **less efficient, less transparent, and not user-friendly**. It suffers from issues like delayed billing, human errors, lack of real-time monitoring, and poor energy management. These limitations highlight the need for an advanced solution such as an **IoT-based energy monitoring system with automatic billing**, which can provide real-time data, improve accuracy, and reduce manual intervention.

4.PROPOSED SYSTEM

The proposed system introduces an IoT-based smart energy monitoring and automatic billing solution using Raspberry Pi. This system is designed to overcome the limitations of traditional electricity monitoring by providing real-time data collection, analysis, and user interaction. It integrates sensors, a processing unit, and cloud connectivity to create a more efficient and intelligent energy management system.

In this system, current and voltage sensors are used to continuously measure electricity consumption. These sensors are connected to the Raspberry Pi, which acts as the central controller. It processes the collected data and calculates power consumption in real time. This enables accurate and continuous monitoring of energy usage without any manual intervention.

The proposed system uses IoT technology to send data to a cloud platform or mobile application. Users can monitor their electricity consumption from anywhere using a smartphone or computer. This remote accessibility allows consumers to track their usage patterns and take necessary actions to reduce energy wastage.

An important feature of the proposed system is automatic billing. The system calculates the electricity bill based on real-time consumption data and predefined tariff rates. The generated bill can be sent directly to the user via a mobile app, email, or web dashboard. This eliminates the need for manual meter reading and reduces billing errors.

The system also includes alert and notification features. Users receive notifications when their energy consumption exceeds a certain limit or when unusual activity is detected. This helps in preventing excessive electricity usage and promotes energy conservation. It also increases user awareness about their consumption behavior.

Additionally, the proposed system enhances security by detecting electricity theft or tampering. Since the data is continuously monitored and recorded, any abnormal changes in consumption can be easily identified. This helps electricity providers reduce losses and improve the reliability of the distribution system.

Overall, the proposed system is cost-effective, scalable, and suitable for modern smart grid applications. It reduces manual effort, improves billing accuracy, and provides real-time insights into energy consumption. By combining IoT technology with automation, the system offers a smart and efficient solution for energy monitoring and management.

5.BLOCK DIAGRAM

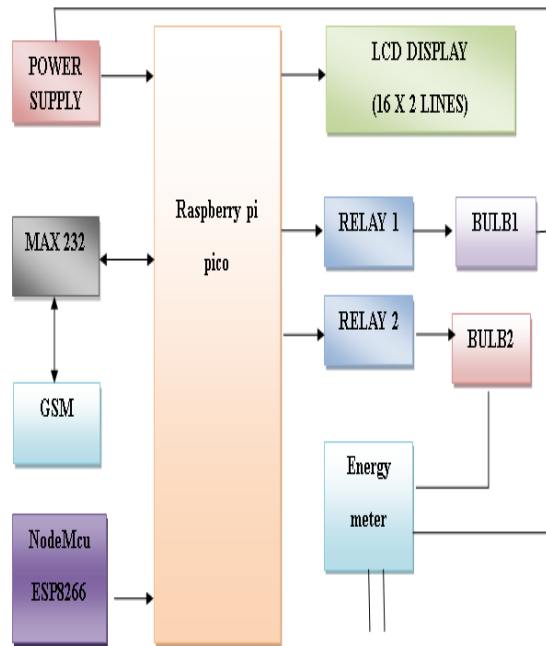
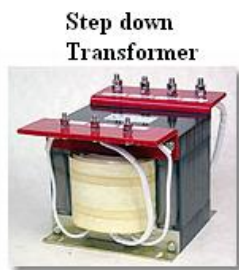


Fig 1

BLOCK DIAGRAM

POWER

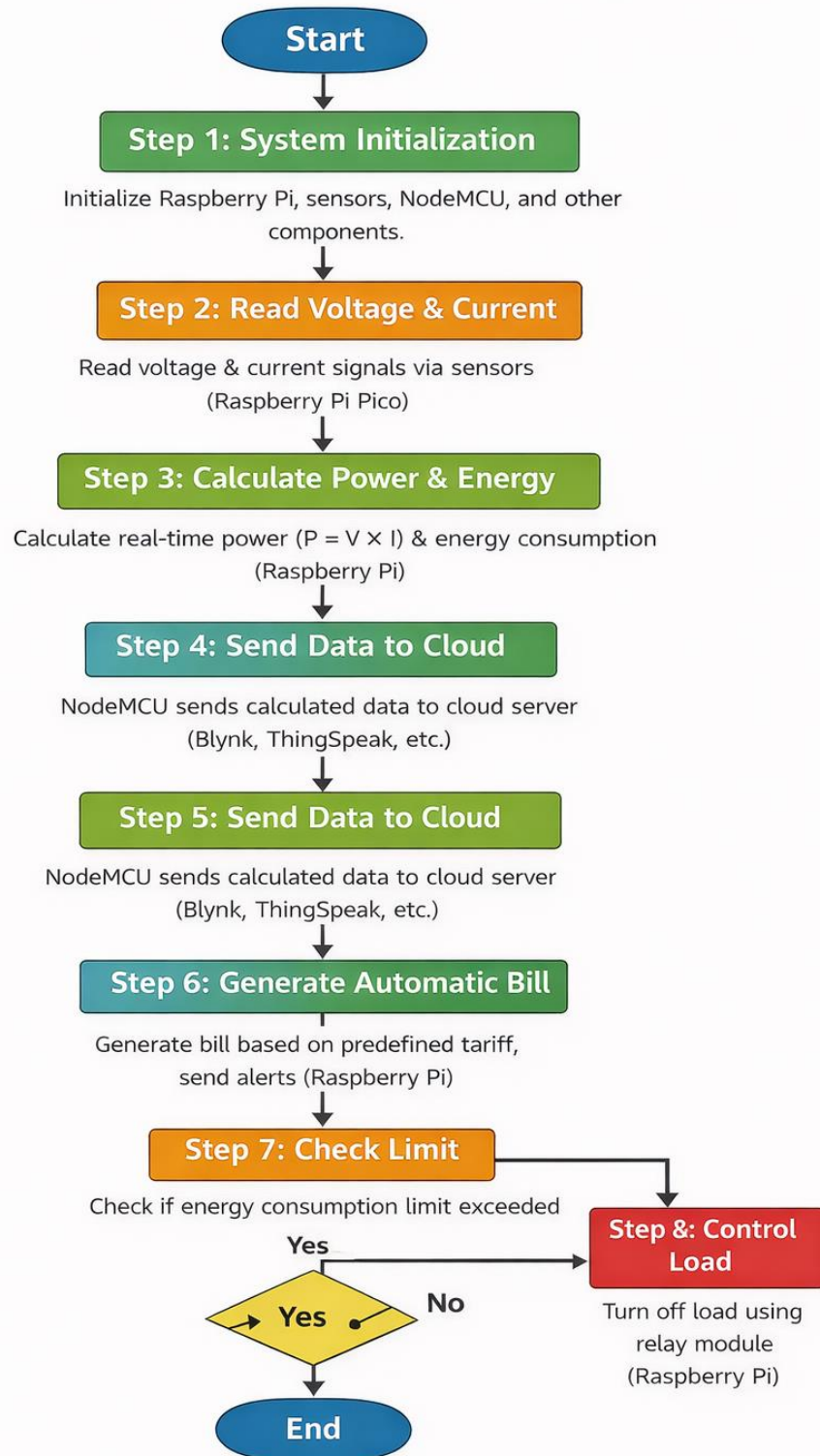


output

SUPPLY:

6.Methodology

Methodology of IoT-Based Energy Monitoring System



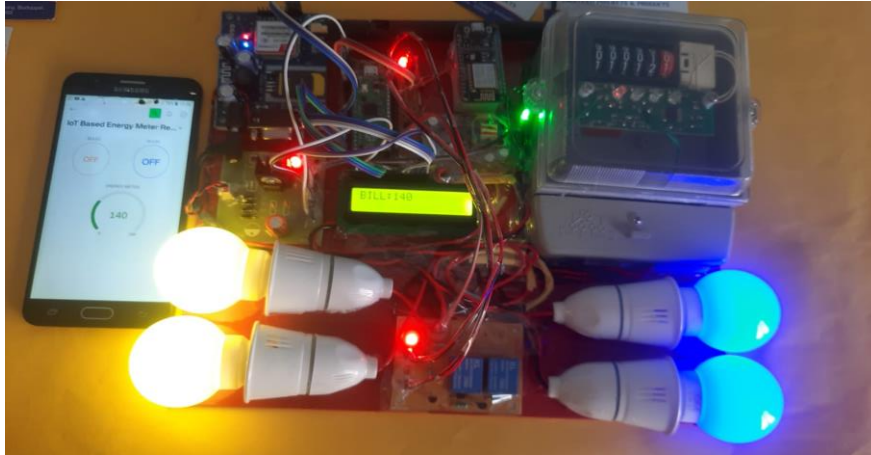


Fig 2. Hardware Design

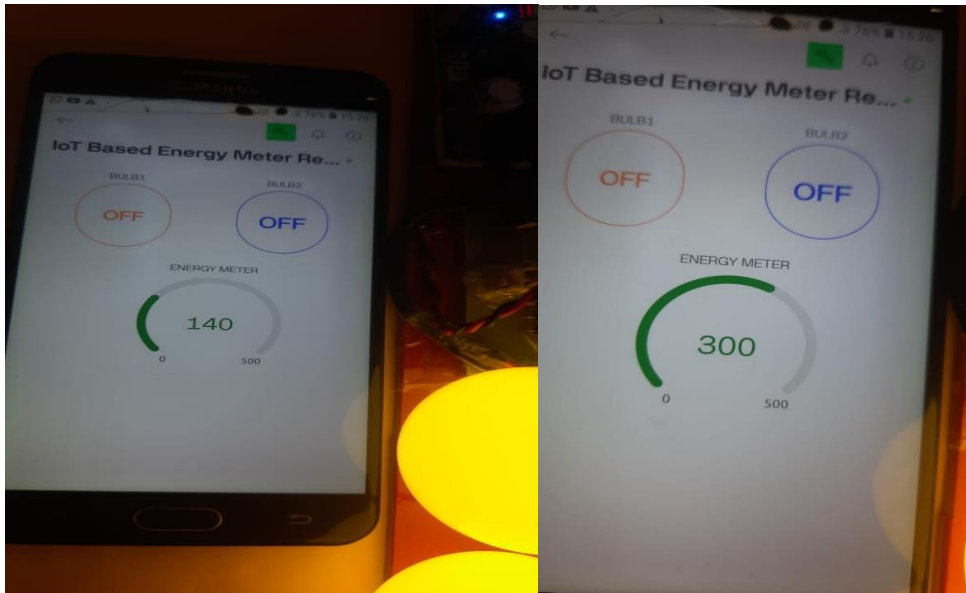


Fig 3. ENERGY OUTPUT

7.CONCLUSION

This paper presented an IoT-based energy meter reading and automatic billing system using Raspberry Pi Pico and Node MCU. The proposed system successfully automates electricity consumption monitoring, billing estimation, and remote load management. Experimental results demonstrate that the system provides accurate readings, timely billing alerts, and improved convenience for both consumers and utility providers. The solution reduces human intervention, minimizes billing errors, and supports efficient energy management. Future work may include integrating machine learning for energy usage prediction, implementing prepaid billing, and enhancing cybersecurity for secure data transmission.

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