GSM-Blockchain Based Energy Billing and Load Management system

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***Abstract*— This report presents the design and implementation of a GSM-Blockchain Based Smart Energy Billing and Load Management System, developed to enhance transparency, security, and automation in energy monitoring and control. Traditional energy meters often lack real-time monitoring, secure data handling, and remote accessibility, which can lead to billing errors and inefficiencies. This project addresses these challenges by integrating GSM communication with blockchain technology, ensuring reliable, tamper-proof, and remotely accessible energy management. At the core of the system is microcontroller, which facilitates data collection from current and voltage sensors to calculate power consumption accurately. The recorded energy data is securely stored on a blockchain ledger, ensuring data immutability and transparency between consumers and utility providers. The GSM module enables real-time communication, allowing users to receive energy usage and billing information via SMS. Additionally, users can remotely control connected loads (turn ON/OFF) through simple SMS commands, improving user convenience and energy efficiency**

Key components include the Arduino UNO, GSM SIM800L module, current sensor (ACS712), voltage sensor, relay module, and a blockchain-based cloud platform for secure record storage. The system ensures accurate, tamper-proof billing, provides real-time consumption alerts, and supports both manual and automatic load management. This dual integration of GSM and blockchain enhances both accessibility and data integrity, addressing major limitations of conventional energy meters. Testing demonstrates the system's ability to provide transparent and automated billing, reduce manual intervention, and prevent unauthorized data modification. It also promotes efficient energy utilization by allowing users to monitor and manage loads remotely. Applicable in industrial, commercial, and residential sectors, this Smart Energy System represents major step toward modernizing the power sector with secure, automated, and user-centric technology.

Keywords- Arduino UNO, GSM, Blockchain, Energy Billing, Load Management, Current Sensor, Relay, Remote Control, Secure Data Storage, Energy Efficiency.

I. INTRODUCTION

The purpose of this project is to show how smart energy monitoring can be automated and secured using modern communication and blockchain technology. Our project is to demonstrate how electrical energy consumption can be continuously measured and recorded in a transparent and tamper-proof manner for billing and load control applications. In the area of digital data security, blockchain networks are vital because of the decentralized and immutable properties that they can possess. In accordance with our project, the energy meter readings will be transmitted through a GSM module and simultaneously stored on the blockchain ledger to ensure accuracy and prevent manipulation [1]. The standard household energy supply generally operates at 230 volts AC, and this system will monitor the consumed units and generate corresponding billing automatically. Also, we will be using a microcontroller as the central processing unit which will act as the control and communication system for our project.

In an era where manual processes are being replaced by automation, it is imperative to discover new methods for secure and reliable data handling [2]. As a result, this same logic can be applied for electrical energy billing and remote load management as well. Our project will also show future electrical engineers an alternate way to manage energy usage, automate billing, and remotely control loads in real-time. The integration of blockchain ensures that energy consumption and billing data are transparent and tamper-proof, improving trust between users and providers [11]. Applications that we foresee include but are not limited to smart homes, industrial energy monitoring, utility provider billing automation [3], micro-grid energy sharing, and so on. Finally, this project is to show how engineering in general incorporates the dedication of group planning, research, design, and critical thinking skills before putting these characteristics to use in the professional world.

II. RELATED WORK

Blockchain has gained traction in smart grid research due to its ability to provide decentralized, tamper-proof audit trails, smart contracts for automated processes, and transparent billing mechanisms:

Blockchain-Based Smart Grids: Recent studies demonstrate how blockchain can support electrical billing automation and peer-to-peer energy trading through smart contracts. Distributed ledger systems can securely record energy consumption and billing records, enabling accurate, immutable logs and eliminating intermediaries in energy transactions.

Smart Energy Measurement Systems: Research prototypes such as BSEMS leverage blockchain frameworks (e.g., Hyperledger Fabric) to store smart meter readings securely and provide user interfaces for monitoring and management.

Energy Consumption Integrity: In related studies, energy measurement and anomaly detection are integrated with blockchain to improve transparency and trustworthiness of data collected from smart meters, enabling fault/attack detection and fair billing computation.

Smart Contracts for Billing Logic: Emerging work investigates energy billing automation via smart contracts—where billing logic is encoded on the blockchain, and transactions (consumption, payment, settlement) are executed transparently without centralized intermediaries.

Although these blockchain systems contribute significantly to security and transparency, they often do not incorporate cellular communication (such as GSM) for low-cost data transmission from remote meters—an important requirement for many rural or developing settings.

III. PROPOSED SYSTEM

A. *Overview*

The proposed GSM-Blockchain based Smart Energy Billing and Load Management System aims to modernize traditional electricity billing by introducing automated metering, secure data storage, and real-time monitoring. In this system, a smart energy meter continuously measures power consumption and sends the data to the utility provider using a GSM module, enabling accurate and instant updates without manual meter reading. Blockchain technology ensures that all consumption data and billing records are stored in a tamper-proof, transparent, and secure ledger, preventing fraud and manipulation. The system also includes an intelligent load management feature that monitors peak loads and automatically disconnects or controls the load in case of overload conditions, ensuring safety and stability. Users receive SMS alerts about their energy usage, billing details, and low balance notifications, while a mobile dashboard allows them to track real-time consumption and historical data. Overall, the proposed system provides a reliable, efficient, and secure solution for energy billing and load management, enhancing transparency for both consumers and electricity providers. AC Supply Monitoring

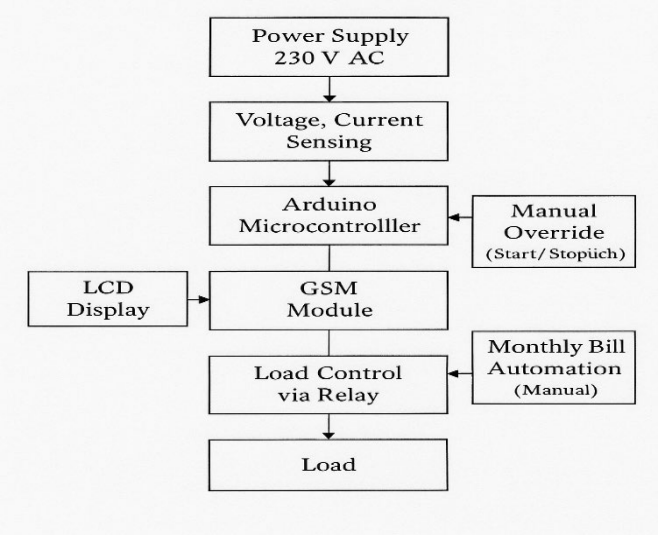

Fig. 1. Proposed System Block Diagram

The AC supply provides electrical power to both the load and the monitoring circuit. It also supplies voltage and current signals to the microcontroller for real-time sensing. These electrical parameters help the system detect overload, abnormal usage, or sudden changes in consumption. The AC supply acts as the operational backbone, allowing all connected devices to function properly while enabling accurate monitoring through sensors.

1) *Energy Meter Integration*

The energy meter is used to measure the real-time power consumption of the connected load. It continuously monitors units consumed and sends this information to the microcontroller for processing. The meter provides accurate readings of voltage, current, and energy usage, which form the basis of the entire monitoring system. This data is essential for generating alerts, calculating energy usage, and enabling remote monitoring through GSM. The energy meter ensures reliable measurement for smart billing and energy management.

2) *Microcontroller as Central Unit*

The microcontroller acts as the brain of the system. It receives input from the energy meter and AC sensors, processes the consumption data, and performs all logic-based decisions. It controls the relay module for load switching and communicates with the GSM module to send alerts. The microcontroller continuously monitors system status and ensures safety by detecting overload or abnormal conditions. All calculations, communication, and control functions depend on the microcontroller's programmed logic, making it the core of smart energy management.

3) *GSM Module Communication*

The GSM module enables wireless communication between the system and the user. It receives data from the microcontroller and sends SMS updates that include energy usage, load status, or warning alerts. The user can monitor energy consumption remotely, even from long distances. In some configurations, the GSM module also accepts SMS commands from the user to turn the load ON or OFF. This communication feature makes the system truly IoT-enabled, offering convenience, transparency, and real-time access to electricity usage.

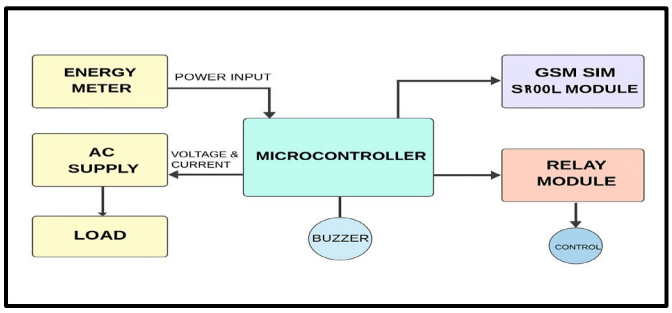

Fig. 2. Proposed System Block Diagram

4) *Relay Module Control*

The relay module functions as an electronically controlled switch that manages the ON/OFF state of the electrical load. It receives control signals from the microcontroller based on system logic or remote commands received via GSM. The relay ensures safe load switching during overloads or high consumption conditions. It enables full automation, allowing the load to be disconnected when consumption exceeds set limits. The module improves safety, prevents damage, and

supports remote load control, making the system intelligent and efficient.

5) Load Operation

The load refers to the electrical appliance being monitored and controlled, such as lights, motors, or household devices. The load's energy consumption is continuously measured by the system to ensure accurate monitoring. Through the relay module, the microcontroller can switch the load ON or OFF automatically or through user commands. Monitoring the load helps prevent excessive power usage, reduce energy wastage, and protect appliances from damage during faults. The entire smart energy management process revolves around effective load monitoring and control.

6) Buzzer Alert System

The buzzer provides audible alerts to notify users about abnormal system conditions, such as overload, high energy usage, or fault situations. It is activated by the microcontroller whenever critical thresholds are crossed. The buzzer ensures the user receives an immediate warning even if they are not monitoring SMS notifications. This enhances the safety and reliability of the system by offering timely alerts. It also helps in preventing electrical hazards by prompting quick action during emergencies or unsafe power conditions.

IV. TECHNICAL FRAMEWORK

Step A: Data Acquisition (Pulse Sensing)

Most digital meters have an LED that blinks for every unit of energy consumed (e.g., 3200 impulses per kWh). Your Arduino is likely connected to an Optocoupler circuit or directly to the meter's pulse output to count these blinks.

Step B: Data Processing

The Arduino calculates the total energy using the formula:

$$\text{Energy (kWh)} = \frac{\text{Total Pulses}}{\text{Meter Constant (e.g., 3200)}}$$

It then calculates the cost based on a predefined tariff rate.

Step C: Communication & IoT Interface

Monitoring: The GSM module sends periodic updates via SMS to the user's phone or via data to an IoT cloud platform.

Control: The user can send an SMS command (e.g., "OFF") to the GSM module. The Arduino interprets this and triggers the Relay to cut off the power supply to the load socketStep C: Communication & IoT Interface Monitoring: The GSM module sends periodic updates via SMS to the user's phone or via data to an IoT cloud platform (like Thing Speak or Blynk) Control: The user can send an SMS command (e.g., "OFF") to the GSM module. The Arduino interprets this and triggers the Relay to cut off the power supply to the load socket

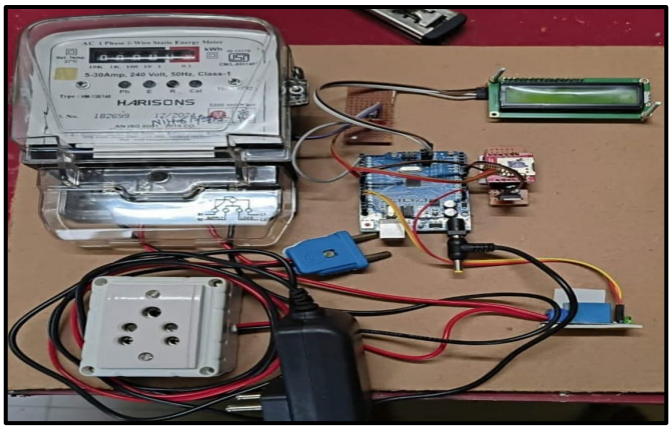

Fig. 1. GSM-Blockchain Based Energy Billing and Load Management system

Current/Voltage Sensors: Adding a sensor like the ACS712 would allow you to measure instantaneous power (Watts) and Power Factor, rather than just waiting for meter pulses.

Mobile App: Creating a dedicated interface to visualize daily consumption graphs

V. RESULT ANALYSIS

The GSM-Blockchain-based energy management system using a microcontroller offers a comprehensive and intelligent solution for monitoring, controlling, and recording energy consumption. By integrating IoT technology with GSM communication, the system allows users to access real-time data on energy usage remotely, enabling informed decisions and effective load management. The addition of blockchain ensures that all energy consumption records and billing data are secure, tamper-proof, and transparent, enhancing trust between consumers and energy providers. The combination of GSM and blockchain has been identified as a secure, scalable approach for smart grid applications [6],[9].

This system helps in reducing energy wastage by automatically controlling appliances based on user preferences or predefined thresholds, such as turning off idle devices or optimizing load distribution during peak hours. By integrating blockchain and GSM communication, the system aligns with global trends in secure, automated, and data-driven smart grid management [11],[14],[15]. The real-time monitoring capability allows users to identify high-energy-consuming devices and implement energy-saving strategies, resulting in significant cost savings. Furthermore, the integration of renewable energy sources, such as solar power, with this system ensures a sustainable approach to energy management.

Fig. 2.

The GSM-Blockchain energy management system is suitable for homes, offices, industries, and smart grids, making it a versatile solution. It promotes energy conservation, financial efficiency, and environmental sustainability while offering the convenience of remote control through mobile applications. Overall, this system demonstrates how modern technologies like IoT, GSM communication, and blockchain can be combined to create reliable, secure, and future-ready energy management solutions. This system aligns with sustainable smart energy management research [8],[10]

TABLE I.

Testing Aspects	Procedure	Result
MCU (Arduino Uno)	Power Arduino, check boot and GSM module.	Fast startup; GSM initialized in 15 sec.
GSM Communication	Send test SMS, upload data to Blynk.	Stable; data updated every 5 sec.
Mobile Application / Dashboard	Monitor usage and control loads.	Data accurate; control works properly.
Energy Meter / 4N35 Optocoupler	Check pulses and kWh calculation.	Accurate within ±2%.
Relay Module / Load Control	Turn loads ON/OFF via app.	Loads switched reliably.
LCD Display	Display energy and billing info.	Clear, real-time updates.
Blockchain Data Logging	Generate and verify hashes for readings.	Data integrity confirmed.

VI. TEST AND EVALUATION

The IoT-Based Smart Energy Monitoring and Control System Using GSM was thoroughly tested to ensure accurate measurement, reliable communication, and effective load control. The testing process was carried out in multiple stages, including hardware testing, software validation, GSM communication testing, and overall system performance evaluation .metrics and sterilization conditions, an area where traditional systems.

A. Hardware Testing

All hardware components such as the energy meter, current sensor, voltage sensor, relay module, and microcontroller were individually tested. The sensors were verified for accuracy by comparing their readings with standard measuring instruments. The relay module was tested to ensure proper ON/OFF switching of the connected load.

B. Software and Firmware Validation

The software and firmware of the IoT-based smart energy monitoring system were tested to ensure accurate data processing and reliable communication. The microcontroller program was validated using serial monitoring to check the correctness of sensor data acquisition, calculation of voltage, current, power, and formatting of SMS messages. Error-handling conditions such as sensor disconnection, invalid readings, or GSM failure were tested to verify system stability. The firmware was also evaluated for response time, execution speed, and proper triggering of load control actions based on incoming SMS commands.

Fig. 3. Result & Evolution Test

C. GSM Communication Testing

The GSM module was tested for SMS transmission and reception in different network conditions. Data sending delay, signal strength response, and error cases (e.g., message not delivered) were evaluated. SMS-based control commands (ON/OFF) were executed multiple times to check reliability.

FUTURE SCOPE

The project "GSM-Blockchain Based Smart Energy Billing and Load Management System" is based on recent studies and research developments in the fields of smart metering, wireless communication, and blockchain technology. Many research papers on GSM-based smart energy meters highlight the need for remote meter reading, accurate billing, and automatic consumption alerts using GSM communication. These systems help eliminate manual meter reading errors and allow real-time energy monitoring. On the other hand, various blockchain-based research works show how blockchain ensures secure, tamper-proof, and transparent energy data storage, making the billing process more reliable. Blockchain is also used to support smart contracts for automatic bill generation, load control, and even peer-to-peer energy trading. Combining GSM with blockchain creates a modern hybrid system that enables secure data transmission, prevents electricity theft, and provides an efficient load management solution. This research direction shows that integrating traditional GSM communication with advanced blockchain technology can significantly improve the accuracy, transparency, and automation of energy billing systems in the future.

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