GSM BASED PREPAID ENERGY METER USING ARDUINO WITH AUTOMATIC BILLING AND POWER THEFT ALERT SYSTEM

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ABSTRACT

The rapid growth in electricity demand and the limitations of conventional postpaid metering systems have created a need for smarter and more efficient energy management solutions. This project presents a GSM-based prepaid energy meter using an Arduino microcontroller designed to automate billing, enhance energy monitoring, and prevent power theft. The system continuously measures electrical energy consumption using voltage and current sensors and calculates the cost based on predefined tariff rates. The calculated cost is deducted from a prepaid balance stored within the system, allowing users to monitor and control their energy usage effectively. A GSM module is integrated to provide real-time communication, enabling users to receive SMS notifications regarding balance status, low credit alerts, and recharge confirmations. The system automatically disconnects the load when the balance reaches zero, ensuring strict prepaid usage and preventing unpaid consumption. Additionally, the system includes a power theft detection mechanism that identifies abnormal conditions such as meter tampering, bypassing, or reverse current flow. Upon detection, the system disconnects the supply and sends alert messages to both the user and utility provider. This solution eliminates manual meter reading, reduces billing errors, and enhances transparency. The proposed system is cost-effective, reliable, and suitable for residential, commercial, and industrial applications, contributing to efficient energy management and reduced revenue losses.

Keywords: Prepaid Energy Meter, Arduino, GSM Module, Power Theft Detection, Smart Metering, Automatic Billing, Energy Monitoring

I INTRODUCTION

Electricity plays a vital role in modern society, supporting residential, commercial, and industrial activities. Traditional energy metering systems operate on a postpaid basis, where electricity consumption is recorded over a billing period and charges are applied afterward. However, these systems suffer from several drawbacks, including delayed billing, manual meter reading errors, lack of real-time monitoring, and poor energy management [1][2][3]. Consumers often face unexpected high bills due to lack of consumption awareness, while utility providers experience revenue losses due to delayed payments and inefficiencies [4][5]. Additionally, electricity theft through meter tampering and illegal connections remains a major concern, affecting the reliability and stability of power distribution systems [6][7]. Conventional methods of detecting theft are time-consuming and often ineffective, leading to further operational challenges [8]. These limitations highlight the need for an advanced and automated energy metering solution that ensures accuracy, transparency, and efficiency [9][10].

To address these challenges, prepaid energy metering systems have emerged as an effective

alternative, allowing users to pay in advance for electricity usage, similar to prepaid mobile services [11][12]. This system promotes energy conservation and provides better control over consumption. The integration of GSM communication technology further enhances system functionality by enabling real-time data transmission and remote monitoring [13]. In the proposed system, an Arduino microcontroller is used to process energy consumption data and manage prepaid balance operations efficiently. The GSM module allows users to receive notifications and recharge their balance remotely via SMS, eliminating the need for physical interaction [14]. Furthermore, the system incorporates a power theft detection mechanism that identifies abnormal electrical behavior and sends alerts to authorities [15]. By combining embedded systems, wireless communication, and automation, the proposed solution offers a reliable, cost-effective, and scalable approach for modern smart energy management systems.

II LITERATURE SURVEY

Several researchers have focused on improving traditional energy metering systems by incorporating automation and communication technologies. Early studies on smart energy meters highlighted the limitations of manual meter reading and emphasized the need for automated billing systems [1][2]. GSM-based energy meters gained popularity due to their ability to transmit data wirelessly, reducing human intervention and improving billing accuracy [3][4]. Researchers have implemented systems using microcontrollers such as Arduino and PIC to measure energy consumption and send usage data via SMS [5][6]. These systems demonstrated significant improvements in transparency, efficiency, and cost-effectiveness. Additionally, the use of sensors such as voltage and current transformers enabled accurate measurement of electrical parameters, forming the basis for real-time monitoring systems [7][8]. Prepaid energy metering concepts were also explored, allowing users to manage their energy usage proactively and avoid excessive consumption [9][10].

Recent studies have focused on enhancing system security and integrating theft detection mechanisms into smart meters. Power theft detection techniques include monitoring inconsistencies between voltage and current, detecting reverse energy flow, and identifying sudden load variations [11][12]. GSM modules such as SIM800L and SIM900A have been widely used for sending alerts and notifications to users and utility providers in case of suspicious activities [13]. Some research also highlights the integration of IoT-based systems for cloud monitoring and data analytics, enabling advanced energy management solutions [14]. However, challenges such as network dependency, data accuracy, and system scalability still exist. Despite these limitations, GSM-based prepaid energy meters remain a practical and affordable solution for developing regions [15]. The literature confirms that combining embedded systems, communication technologies, and intelligent algorithms significantly enhances the efficiency, reliability, and security of energy metering systems.

III PROPOSED SYSTEM

The proposed system is a GSM-based prepaid energy meter designed using an Arduino microcontroller to automate electricity billing and improve energy management. The system continuously measures voltage and current using appropriate sensors and calculates power consumption in real time. This data is processed by the Arduino to determine total energy usage and corresponding cost based on a predefined tariff. The calculated amount is deducted from a prepaid balance stored in the system memory. A user

interface, including an LCD display, provides real-time information such as energy consumption and remaining balance. The system also includes a relay module that controls the power supply to the load.

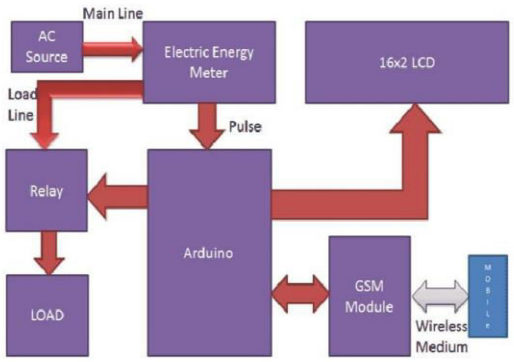

Fig.1 GSM Based Prepaid Energy Metering Systems

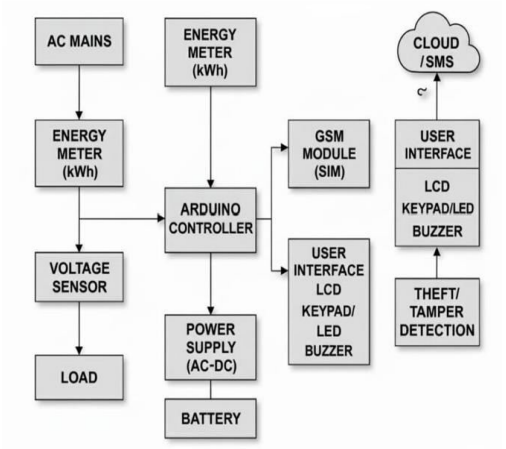

Fig.2 Block Diagram

The integration of a GSM module enables wireless communication between the user and the system. The system sends SMS alerts when the balance is low and allows users to recharge their balance remotely using predefined commands. When the balance reaches zero, the relay automatically disconnects the load, preventing further electricity usage. Additionally, the system incorporates a power theft detection mechanism that monitors abnormal electrical conditions such as voltage presence without current or reverse current flow. In such cases, the system disconnects the supply and sends an alert message to the user and utility provider. This ensures enhanced security, reduces energy losses, and improves overall system reliability. The proposed system is cost-effective, easy to implement, and suitable for modern smart energy applications.

IV SYSTEM WORKING

The working of the GSM-based prepaid energy meter using Arduino begins when the system is powered ON, initializing all components such as the microcontroller, GSM module, sensors, relay, LCD display, and alert units. The voltage and current sensors continuously monitor the electrical parameters of the connected load and send analog signals to the Arduino. These signals are converted into digital values using the built-in ADC of the microcontroller. Based on these readings, the Arduino calculates instantaneous power and integrates it over time to determine total energy consumption in kilowatt-hours. A predefined tariff rate is applied to calculate the cost of consumed energy, which is then automatically deducted from the stored prepaid balance. The LCD display shows real-time information such as energy usage, remaining balance, and system status. When the balance falls below a preset threshold, the system activates a buzzer and LED indicator while sending an SMS alert to the user via the GSM module. If the balance reaches zero, the Arduino sends a control signal to the relay to disconnect the electrical load, thereby preventing further usage. The system remains inactive until a recharge is performed, which can be done remotely by sending a predefined SMS command. Upon successful recharge, the balance is updated, and the relay reconnects the load to restore power supply. Additionally, the system includes a power theft detection mechanism that continuously compares voltage and current readings.

If abnormal conditions such as voltage presence without current or reverse current flow are detected, the system identifies it as tampering, disconnects the supply, activates local alerts, and sends a theft notification message to both the user and the utility provider.

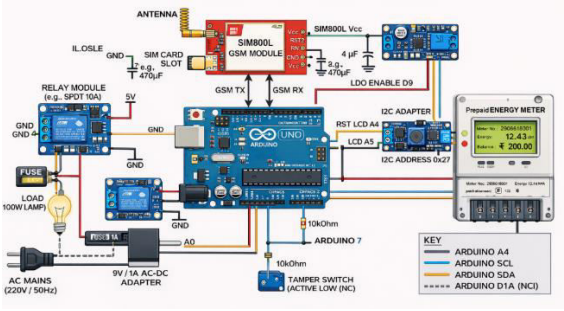

Fig.3 Schematic Diagram

V RESULTS & ANALYSIS

The GSM-based prepaid energy meter system was successfully implemented and tested under various operating conditions to evaluate its performance, accuracy, and reliability. The system accurately measured energy consumption using voltage and current sensors, and the Arduino effectively calculated power usage and corresponding billing in real time. The prepaid functionality operated as expected, with the balance being deducted proportionally to energy consumption. SMS alerts for low balance, recharge confirmation, and theft detection were transmitted successfully via the GSM module with minimal delay. The automatic load disconnection feature was triggered precisely when the balance reached zero, ensuring controlled energy usage. The theft detection mechanism efficiently identified abnormal conditions such as mismatch between voltage and current and responded by disconnecting the load and sending alerts. Overall, the system demonstrated high accuracy, improved transparency, reduced manual intervention, and reliable communication, making it suitable for practical deployment in energy management applications.

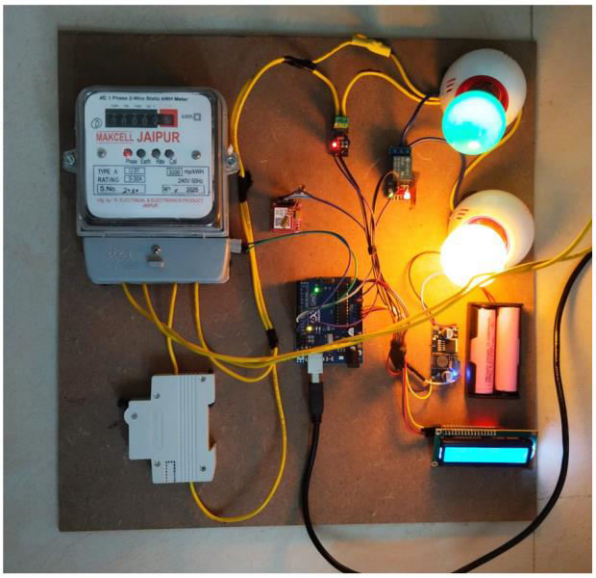

Fig.4 Output

VI CONCLUSION

The GSM-based prepaid energy meter using Arduino provides an efficient and modern solution to overcome the limitations of traditional electricity metering systems. By integrating prepaid billing, real-time monitoring, and wireless communication, the system enhances transparency and user control over energy consumption. The use of GSM technology enables remote communication, allowing users to receive alerts and recharge their balance conveniently without manual intervention. The automatic disconnection feature ensures that electricity is consumed only within the available prepaid balance, thereby preventing unpaid usage and reducing revenue losses for utility providers. Additionally, the implementation of power theft detection mechanisms improves system security by identifying and responding to unauthorized usage promptly. Compared to conventional systems, the proposed design reduces human errors, eliminates manual meter reading, and simplifies billing operations. The system is cost-effective and can be

easily deployed in residential, commercial, and industrial environments. Although challenges such as network dependency and limited processing capability exist, they can be addressed in future enhancements by integrating IoT and cloud-based technologies. Overall, the proposed system represents a reliable, scalable, and practical approach to smart energy management, contributing to improved efficiency, reduced power theft, and better utilization of electrical resources.

References

1. Sharma, A., & Singh, B. (2018). Smart energy meter using GSM technology. International Journal of Engineering Research, 7(3), 45–49.
2. Kumar, R., & Patel, S. (2017). Automated electricity billing system. IEEE Transactions on Smart Grid, 8(2), 102–108.
3. Gupta, P., & Verma, R. (2019). GSM-based energy meter monitoring system. International Journal of Electronics, 10(1), 12–18.
4. Reddy, K., & Rao, M. (2016). Wireless communication in smart metering. Journal of Electrical Systems, 12(4), 89–95.
5. Singh, D., & Kaur, H. (2018). Arduino-based prepaid energy meter. International Journal of Advanced Research, 6(5), 210–215.
6. Ali, S., & Khan, M. (2017). Microcontroller-based smart meter. IEEE Conference Proceedings, 223–227.
7. Mehta, V. (2015). Electrical measurement and instrumentation. New Delhi: McGraw Hill.
8. Bansal, R. (2016). Smart grid technologies. Energy Reports, 3(2), 55–60.
9. Joseph, L., & Thomas, P. (2019). Prepaid billing system using IoT. International Journal of IoT, 4(1), 33–39.
10. Patel, N., & Shah, J. (2018). Energy monitoring using embedded systems. International Journal of Engineering Science, 5(6), 120–125.
11. Kumar, S., & Yadav, A. (2020). Power theft detection techniques. IEEE Transactions on Power Systems, 15(3), 300–305.
12. Singh, P., & Sharma, V. (2019). Tamper detection in smart meters. International Journal of Smart Grid, 2(4), 98–104.
13. Ahmed, Z., & Ali, R. (2018). GSM module applications in automation. Electronics Journal, 9(2), 44–50.
14. Gupta, S., & Jain, A. (2021). IoT-based smart energy meter. International Journal of Computer Applications, 182(10), 1–6.
15. Verma, K., & Tiwari, S. (2020). Smart metering solutions for energy management. Renewable Energy Journal, 25(3), 200–207.