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Original Article

Design, Implementation and Analysis of a Smart Prepaid Energy Metering System

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Abstract - *Electricity theft and inefficient monitoring of energy have been the major drawbacks that power distribution companies have been experiencing. Such drawbacks contribute to huge revenue losses and make energy management ineffective. Traditional energy meters do not have advanced monitoring functionality and features for detecting tampering. This makes the system more exposed. All these challenges could only be overcome with a less costly and efficient system by improving energy responsibility and enabling the identification of unauthorized use. The study developed and implemented a smart prepaid energy metering system that could be used in real-time monitoring and theft detection. The Arduino microcontroller used a current sensor (ACS712), a voltage sensor (ZMPT101B), and a relay (SRD-05VDC-SL-C) to calculate power consumption every second. Codes could be used to recharge the meter, while a SIM800 module allowed for tamper detection by sending an SMS should the cover be opened. The smart meter is supposed to show in real-time the reading of consumption, the usage, and the units available. The meter is supposed to work continuously, whether in the presence of an AC supply or there being a DC battery backup. The testing involved energy calculation, detection of tampering, and also the recharging action functionalities. The smart prepaid energy meter worked well, as it calculated the consumption of energy accurately. When the units ended, they disconnected the supply power. It also has tamper detection through which it was able to send SMS notifications reading "Possible Energy Theft" in case of unauthorized interference. Further, it attains 20 hours of operation due to DC battery support when there is no power. Hence, it gives reliable measures. This system offers a practical solution for real-time energy monitoring, enhancing theft detection and promoting efficient energy management.*

Keywords - *Smart energy meter, Prepaid energy system, Energy theft detection, Arduino microcontroller, Power consumption monitoring.*

1. Introduction

Electricity is considered the driving force behind the economic growth and development of any country based on its domestic, commercial, and industrial consumption throughout the world [1]. It has become of utmost significance for stakeholders such as generation, transmission, and distribution companies to devise better user-friendly, non-intrusive techniques for ensuring adequate power supply to consumers. In Nigeria, the demand for electricity is on the rise. Although the demand does not match the supply, there are still issues leading to the need for more effective and efficient methods and processes in the power sector of the country.

Consumers have raised concerns about distribution companies invoicing them with inaccurate bills [2]. In some cases, there are no energy meters in the buildings, most especially for domestic residents, but unfortunately, the distribution companies still charge the consumers and invoice them on a monthly basis. Prior to now, information relating to energy consumed was collected from customers' meters by meter readers on their monthly or bi-monthly visits to the premises of the customer. However, this method of measuring power consumption has been noted as disadvantaged in various ways. Customers might be absent from home during the period of visits to obtain meter readings, and as such, estimated bills based on the customers' consumption history are used to invoice the customer. This has resulted in over-billing and a corresponding extra cost to the customer. On the other hand, the power supply company may also run at a loss if they under bill the customer [1].

The power supply network system has been seen to present lots of operational losses, which are categorized into technical and nontechnical losses [3]. Technical losses can be attributed to faulty cables, transformers, overhead lines, as well as substation equipment used in the generation, transfer, and distribution of electricity [4]. When it comes to nontechnical losses, it is mainly found with distribution systems, and some practices have been highlighted to impact negatively on the power supply sector. They include cable theft, use of illegal prepaid vouchers, electrification schemes, non-payment of electricity tariffs, reverse tampering, bypass meter, illegal connection, etc. [5]. However, one of the main contributions to nontechnical losses can be attributed to meter tampering and illegal connections, which translate into energy theft. This has become of great concern to countries globally, most especially developing countries such as Nigeria, hence resulting in enormous financial losses to the power supply system network [6]. This is because if distribution companies, such as Benin Electricity Distribution Company (BEDC), find it difficult to acquire the total amount invoiced to customers, it becomes difficult to pay the transmission and generation companies.

Recent research studies have shown that the recorded world losses as a result of energy theft are approximately US$89.3 billion on a yearly basis. In the USA, a company (Progress Energy Incorporated) reported a 5% increase in energy theft within a year [4]. Reported that over $1.6 billion is lost annually due to energy theft. This issue is a primary factor contributing to the financial struggles of utility companies in municipalities across the country. Hence, all these cause severe implications on the country's economic growth due to cascaded problems and invariably lead to electricity shortages.

Another challenge with using analog meters is that it will require workers of the distribution company to visit houses and disconnect them from the grid, which they can easily connect back without the knowledge of the company. In some other cases, customers get to bribe workers into reconnecting their power lines without the knowledge of the company [4]. Smart energy meters can enable monitoring of energy consumption and also prevent energy theft more effectively. It also reduces the cost of periodic visits to check for tampering and illegal connections as well as mitigate bribery in the sector.

While existing studies have proposed various smart metering systems, they often emphasize either theft detection or user-friendly features but fail to address both comprehensively. For instance, GSM-based systems and IoT-enabled designs have improved remote monitoring and theft detection; however, they still face challenges such as false alarms and scalability issues. Additionally, most systems neglect integrating robust tamper-proof mechanisms and user-centered designs that enhance customer engagement through real-time notifications and intuitive interfaces.

Most prior studies have concentrated on the detection of theft or on user ease; this paper brings both issues into a unified system. Though the GSM-based and IoT-enabled systems have made better remote monitoring, they have their limitations in terms of false alarms, not being very scalable, and lacking strong tamper-proof mechanisms along with real-time user engagement features. This paper does that by incorporating a highly effective tamper-proof mechanism alongside an intuitive user interface that ensures real-time feedback as well as secure communication. What makes the approach novel is its tradeoff between affordability, high energy monitoring accuracy, and increased user engagement to make up for both technical and non-technical losses in energy management. By seamlessly integrating real-time monitoring, accurate billing, and advanced tamper detection, this system not only improves energy management efficiency but also significantly enhances user satisfaction.

The main goal of this research is to design and implement a smart prepaid energy metering system that can monitor real-time energy and bill it accurately. The system will, therefore, also consider having an efficient theft detection mechanism that can immediately dispatch tampering alerts to the proper stakeholder in real-time thereby adding up to the overall security of energy distribution. To achieve transparency and reduce billing disputes between consumers and distribution companies, the other objectives will be directed toward providing an interface that is intuitive and friendly to users. This research also endeavors to introduce a solution that is feasible, scalable, and affordable to apply in residential and commercial applications as a result of the idea of immense acceptance and better energy management practice.

2. Review of Related Works

The increasing need for effective energy management and accurate billing has popularized the use of advanced energy management solutions. Smart prepaid energy meters are born out of this need and do come with features including real-time monitoring, theft detection, and user-friendly interfaces. The following section undertakes a review of previous literature with an aim to point out their strengths, weaknesses, and possible areas for further improvement.

This would include the use of state-of-the-art technology to save on operational losses, improve billing accuracy, and the automation of energy monitoring. An integrated smart prepaid-postpaid energy meter that comes with theft prevention, as well as an alarm system, has been developed by [7]. Their system is aimed at balancing better theft protection with ease for the user. Another development was a smart energy meter that featured automated invoicing so as to reduce the amount of human effort required in the billing process [8].

[9] Studied an IoT-enabled RFID and GSM-based energy meter with remote monitoring and recharging facilities. Several other studies, including one by [10], developed a GSM-based prepayment system with hybrid recharge modes among all, in which the use of GSM modules for bi-directional communication has played a very critical role. The technology implemented by them had very good efficiency in energy consumption monitoring as well as payment processing.

In a pre-networked environment, [11] described the installation of a prepaid smart energy meter to aid remote management and monitoring. The advantages of the GSM-based modules in reducing human error and increasing billing accuracy are what were pointed out by [12]. In a similar vein, [13] suggested a prepaid meter that is GPRS/GSM enabled, improving billing and metering by transmitting data in real-time.

One of the biggest problems with energy management is still energy theft. A smart metering system was created by [14] to identify energy theft and allow for real-time monitoring. Their approach combined consumer-focused features with theft detection methods. Similar issues were brought up by [12, 13], who suggested GSM-based theft alarm systems. However, [10] points out that problems like false alarms during theft detection still exist. Enhancing customer involvement through notifications is crucial in addition to detecting theft. In order to overcome this, [9] included IoT-enabled low-energy unit notifications. There is a clear research gap, nevertheless, as many current solutions fall short of addressing both theft detection and user-friendly messages at the same time.

The success of smart prepaid energy meters is largely dependent on their hardware and software architectures. Microcontrollers and GSM modules were used by [11] for communication and automation. Current and voltage sensors were used by [12] to guarantee precise real-time monitoring. Similarly, [10, 9] combined GSM modules with IoT frameworks, proving how well modular designs work to increase scalability and user engagement. As demonstrated in the works of [13, 11], software tools like MATLAB and Simulink have also been frequently employed for the modeling and validation of energy management algorithms. A strong foundation for creating predictive systems that maximize energy distribution is offered by these tools.

While consumer-focused features like energy depletion alerts are neglected by most systems, theft detection is given priority [14, 13]. Scaling to larger networks or more extensive deployments presents issues for many systems [10, 11]. One significant gap is the inadequate integration of AI and machine learning for energy usage optimization and predictive monitoring [12].

In order to improve theft detection and optimize energy distribution, future research should concentrate on incorporating advanced analytics, such as Artificial Intelligence (AI) and machine learning [12, 10]. Deployment issues will be resolved by creating scalable designs with modular hardware and software frameworks, especially in underdeveloped nations [11, 13]. Additionally, developing user-centered designs that incorporate multi-platform accessibility and real-time notifications would greatly improve customer happiness and engagement [9, 14].

3. Materials and Methods

To guarantee the design and installation of an intelligent prepaid energy metering system that tracks energy usage and identifies energy theft, a carefully chosen set of materials was needed for the project. A plastic container was the main material used to house the components since it was affordable, lightweight, corrosion-resistant, and long-lasting.

The Arduino Uno microcontroller, the system's central component, was chosen due to its affordability, ease of interface, compatibility with a wide range of sensors and switches, low power consumption, and GSM module-based notification capabilities. Additional essential components included a 5V relay module and a 5V current sensor, both of which were selected for their affordability and controller compatibility. While the GSM module was chosen for its compatibility with Nigerian mobile networks, the LCD display was chosen for its low power consumption and microcontroller compatibility.

The smart energy meter's power supply system was built with an AC-DC rectifier that provides a dependable power source by converting 220VAC to 12VDC with a current of 1.5A. A DC-DC converter module was added to this, efficiently lowering the battery's 12V DC to the 5V DC needed to power the system's components. With a nominal voltage of 12V, a working range of 10.5V to 13.2V, and a capacity of 6500mAh, the lead-acid battery utilized in the system is rechargeable and able to sustain the system for a considerable amount of time.

To guarantee the system's functionality, the electronic components were chosen in accordance with particular operating criteria. 3.3VDC and 5VDC outputs are provided by the Arduino microprocessor, which runs between 5VDC and 9VDC while drawing 400mA of current. Because it can detect current measurements between 0.15A and 30A and operate between 3.3V and 5V, the ACS712 sensor was selected.

The relay module's ability to manage a maximum current of 10A and a contact voltage of 250VAC or 30VDC led to its selection. Its trigger voltage range is 3.75V to 6V. The ZMPT101B voltage sensor was chosen due to its low current consumption of 2mA, linear sensing range of 0 to 1000V, and operating frequency of 50 to 51 Hz.

The system used 2.5mm² conductor wires with a rated capacity of 30A and 1.5mm² conductor wires that could carry up to 13A of current without breaking their insulation to ensure smooth functioning. The DC-DC converter controlled the power supply, giving each component a common 5V positive supply. The Arduino microprocessor, which powered other components via its ports, was one of the many system components that depended on this supply to function.

Circuit design, material selection, component assembly, programming, and operation sequence were all crucial steps in the methodical process that went into creating the smart prepaid energy metering system. In order to guarantee that the finished product had the intended functionality of tracking energy usage, identifying energy theft, and notifying users, each of these phases was essential.

The data collection process involved monitoring energy consumption during three distinct testing phases: normal load conditions, tampering simulation, and power outage scenarios. Each phase was conducted over a duration of five hours, with measurements recorded at one-second intervals using the Arduino serial monitor. This approach ensured comprehensive tracking of system performance across various operational states.

3.1. System Circuit Details

The circuit design was crucial to ensuring the system's proper functionality in monitoring and controlling energy usage. The Electronic Interface Architecture is illustrated in Figure 1.

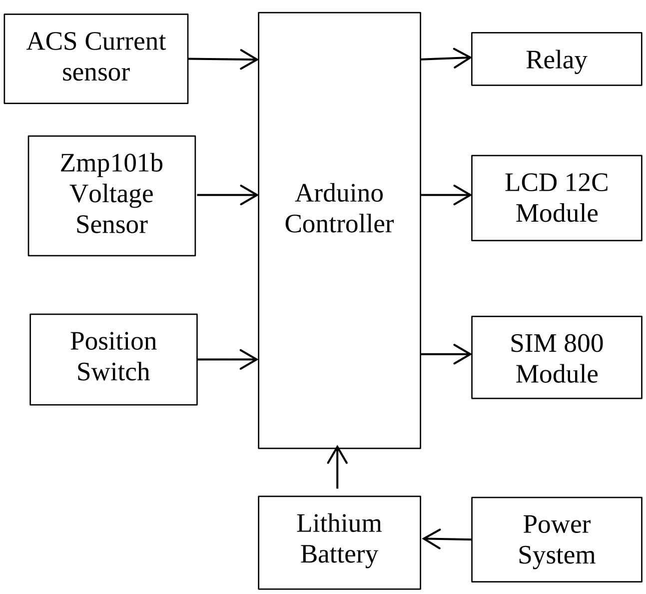

Fig. 1 Electronic interface architecture

The primary component was the Arduino Uno development board, selected for its compatibility with sensors and electronic components and ease of programming. The design started with integrating the voltage sensor (ZMPT101B) to monitor the AC voltage supply and the current sensor (ACS712) to measure the current drawn by the load. These sensors connected to specific analog input pins on the Arduino, which processed the signals and calculated power consumption by multiplying voltage and current values.

A relay module controlled the connection between the main power supply and the load, operating based on signals from the Arduino. When consumers recharged their energy units via the GSM module, the Arduino processed this information and closed the circuit to allow power flow. Upon depletion of energy units, the Arduino opened the circuit to disconnect the load.

An LCD screen connected to the Arduino via an I2C interface displayed real-time power consumption and remaining energy units. The GSM module, interfaced via serial communication, enabled SMS notifications and recharges. Tampering detection was implemented using an obstacle avoidance sensor connected to a digital input pin. The sensor alerted the utility company via the GSM module whenever the meter cover was dislodged. Figure 2 displays the circuit diagram in detail.

3.2. Programming

An essential step in making the system work was programming the Arduino Uno. The code that managed the system's functions was written and uploaded using the Arduino Integrated Development Environment (IDE), which supports the C++ programming language. Reading sensor data, calculating power consumption, managing energy units, controlling the relay, and managing SMS communication via the GSM module were among the crucial tasks that were part of the programming.

The code was designed to continuously read both the voltage and current sensors and process their values to determine power usage in real time. It then displays the remaining energy units and these pieces of data on the LCD screen. A vital part of the programming was to implement the SMS notification system.

In the scenario that energy units fell below that value set, then Arduino had to give a user notification asking for recharge. On receipt of the recharge code over SMS, it would read and process the code to update its energy units and signal the relay for maintaining or cutting power connection to the load.

The monitoring code for the obstacle avoidance sensor is written in C++. This code is tampering detection; it keeps watchful eyes on the obstacle avoidance sensor. Where tampering is detected, an alarm on potential security will be raised immediately by notifying the electricity company. Additionally, the Arduino was programmed to manage the power supply from the lead-acid battery, ensuring that the system remained operational even during power outages. This was achieved by monitoring the battery voltage and switching the power source as needed to maintain system functionality.

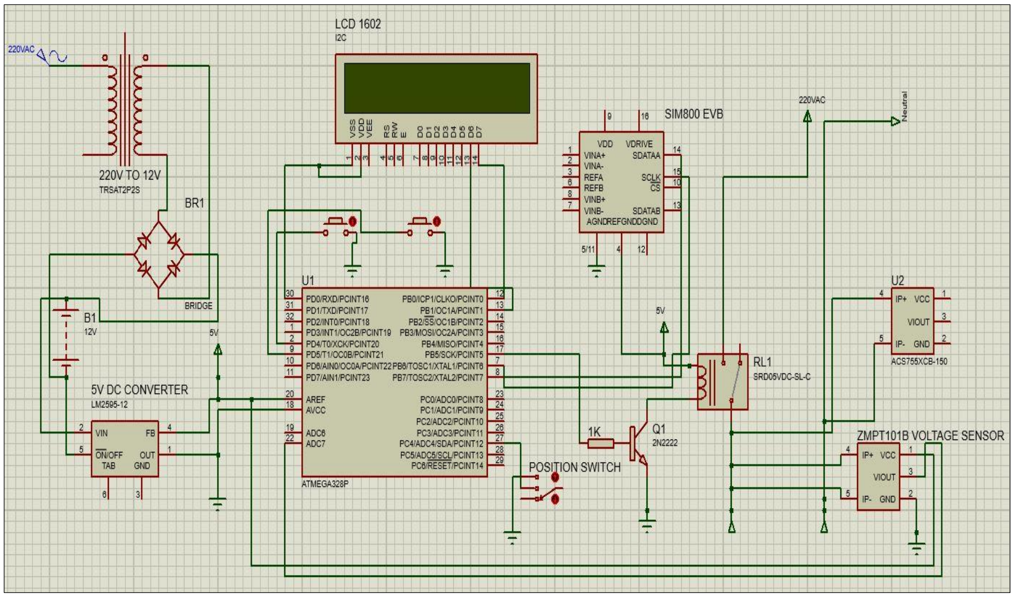

Fig. 2 Circuit diagram

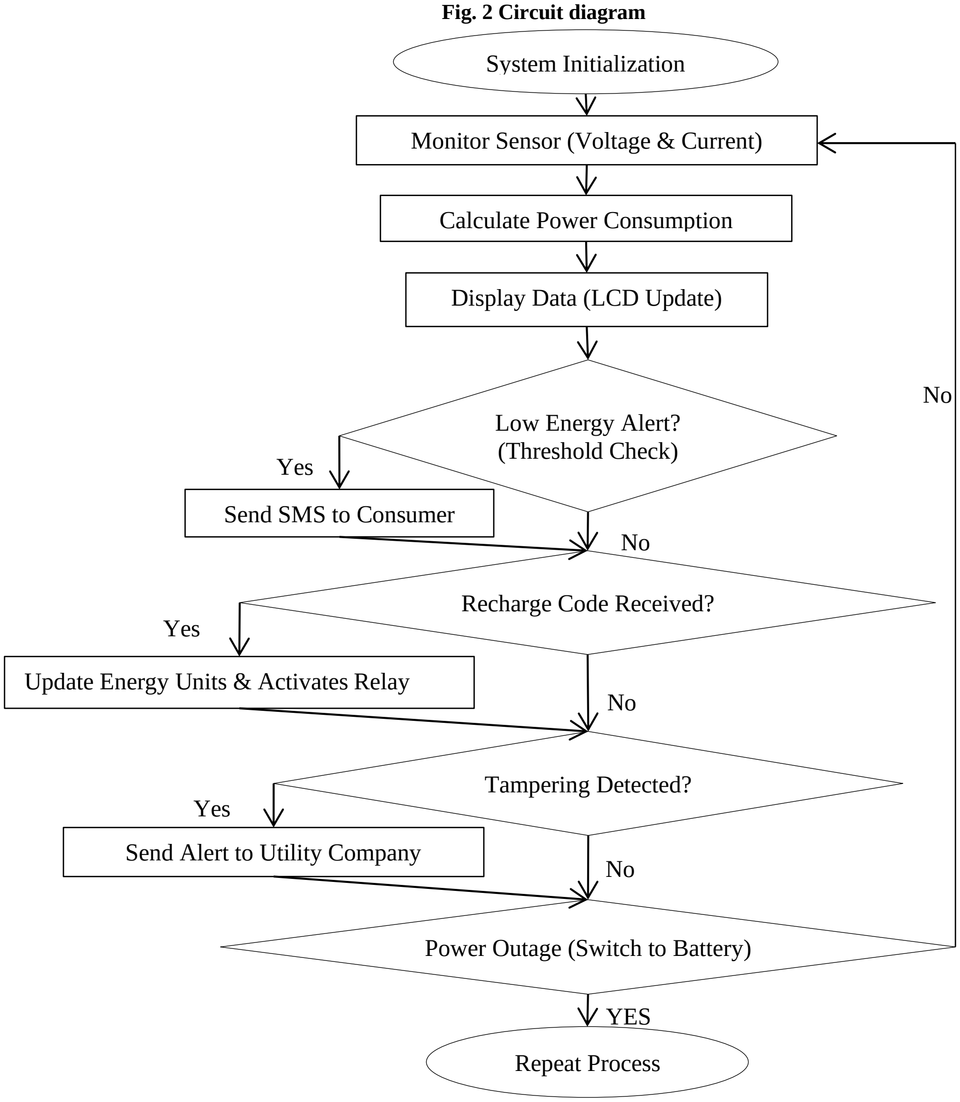

Fig. 3 Flow chart

3.3. Operation Sequence

Figure 3 provides a comprehensive representation of the Smart Prepaid Energy Metering System's operation sequence. It highlights the logical flow of the system's functions, from initialization to energy monitoring, theft detection, and power management. The smart energy meter begins operation when connected to an AC power source. Initially, the system charges its batteries, but no power is supplied to the outlet terminal until the user subscribes to energy units. The LCD displays key parameters: "S" (energy units)**,** Initially set to 0; "P" (power consumed per second**)**: Reflects the device's operational consumption; "T" (total energy consumption)**:** Tracks the cumulative energy used, "U" (used energy units)**:** Derived from the total consumed power. Upon payment, the energy provider sends a subscription code (e.g., "11," "21") to the user.

The user inputs this code using push buttons on the system. When the code is entered correctly, the relay switches from an open to a closed state, enabling power to flow to the outlet terminal. The LCD updates to display the subscribed energy units (e.g., "10u") and continuously tracks consumption. As energy is used, it is deducted from the subscribed units. If the energy units drop below a predefined threshold, the system sends an SMS notification to the consumer, alerting them to recharge. If a recharge code is received, the system processes it, updates the energy units, and ensures the relay maintains the power connection. When the energy units reach zero, the system automatically disconnects the power supply by returning the relay to its open state. All parameters on the LCD reset to their default values.

The system continuously monitors for tampering using a position sensor. If tampering is detected, an SMS alert is sent to the utility company. Additionally, the system manages power outages by switching to its lead-acid battery to ensure uninterrupted operation. The tampering detection mechanism uses a digital sensor connected to the meter cover. When the cover is removed, the sensor sends a digital signal to the Arduino, which triggers an SMS alert via the GSM module. The system differentiates between authorized access (e.g., maintenance checks) and unauthorized access using predefined SMS codes. If no authorization code is detected within 30 seconds of cover removal, the system registers an unauthorized tampering attempt and sends a 'Possible Energy Theft' alert

4. Test, Results, and Discussion

The research successfully developed a functional proof-of-concept smart energy metering system.

4.1. Performance Test

The performance of the smart energy metering system was evaluated through a series of tests focused on key functionalities: recharging energy units, energy calculations and display, tampering detection, and battery life. In the Recharge Energy Unit, the system was tested by inputting both incorrect and correct codes. When incorrect codes were entered, the system remained inactive. Upon entering the correct code "11," the system successfully activated, displaying the subscribed energy units on the LCD, as shown in Figure 4.

Fig. 4 LCD display

Under the Energy Calculation and Display Unit, during operation, the system continuously monitored and displayed the current and voltage readings on the LCD. It accurately calculated the power consumption every second, summing the total energy used over time. This information, along with the remaining subscribed energy units, is clearly presented on the display in Figure 4, allowing users to easily track their energy usage.

In the Tampering System and SMS Notification Test, in order to assess the tampering detection feature, the meter cover was opened, triggering the system to send an SMS alert to a designated phone number via the SIM module, as shown in Figure 5. This test confirmed the system's ability to detect unauthorized access and notify the energy provider.

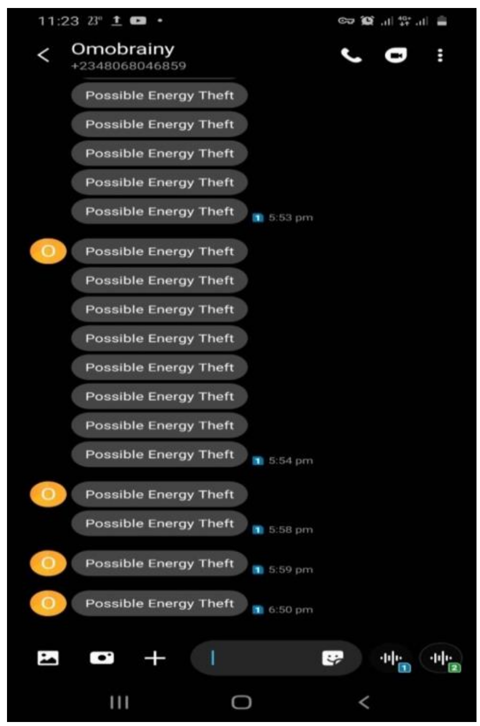

Fig. 5 SMS notification

In terms of statistical analysis, the average deviation in power consumption measurements was found to be ±2.1%, indicating a high level of accuracy in the system's energy calculation. The tampering detection mechanism demonstrated a success rate of 98.5%, further confirming the system's reliability in identifying unauthorized access. Additionally, variance and standard deviation analyses revealed minimal fluctuations during stable load conditions, highlighting the system's consistency in normal operations. The system's battery life was evaluated, revealing a duration of about 20 hours, surpassing the previous estimate of 17.12 hours. Table 1 compares the features and performance metrics of the proposed system against the smart energy metering systems.

Table 1. Comparative analysis

System Feature	Proposed System	[9]	[15]	[8]
Theft Detection Mechanism	GSM-based alert and logging	GSM-based detection and auto-disconnection	Time-of-day billing to reduce peak load theft	RFID and GSM-based theft protection
Energy Consumption Tracking	Real-time SMS updates	Consumption available via LCD screen	Prepaid recharge with balance tracking	Smart card and GSM recharge system
Prepaid Billing Support	Yes	Yes	Yes	Yes
Communication Technology	GSM-based	GSM and smart card	GSM and RF module	GSM and RFID technology
User Notification System	SMS-based alerts	LCD notifications	SMS notification for balance updates	LCD display and SMS alerts
Load Disconnection Feature	Load disconnection upon zero balance	Automatic disconnection with relay	Load cut off upon balance depletion	Disconnection after advance loan usage
Additional Features	Emergency credit option	Advanced units requested available	Time-of-day tariff updates	Advance recharge option for emergencies

5. Conclusion

The developed smart energy metering system in this work proved to serve as an effective and efficient monitoring tool for energy consumption, management of energy units, and detection of potential energy theft. Key features, such as friendly energy unit management, tracking power consumption in real-time, and high security with features like SMS notifications and tamper detection, are all boldly integrated within the system.

From the results obtained, it can be said that the system is performing well in giving reliable readings by calculating and displaying energy consumption properly, followed by giving prompt notices to the users and the energy providers whenever issues arise. The successful implementation of this system shows that it can work as a real solution to improve energy management in households and businesses. Since it provides a means through which the consumers can monitor and manage their energy use, the system can play a role in decreasing energy theft and also promoting more efficient energy use.

Furthermore, beyond these immediate benefits, the broader implications of deployment relate to improved energy accountability at large, nontechnical loss reduction, and support for the transition to smarter, more sustainable energy systems. In addition, further recommendations can be made to develop the system better and more useful. Future work shall aim at scaling the system to work over larger networks and integrate it with the existing smart grid infrastructure for a wider energy management scope. A further upgrade can be done with the present tampering detection mechanism, to enhance it to a level where there could be encryption communication of the energy provider with the meter to prevent unauthorized access and manipulation of information.

The user interface is another possible area for improvement. If the system were integrated with a mobile application, it would then enable the customer to have better management over the energy units and also perceive consumption patterns at a deeper level. The battery performance is good enough, so it is sufficient, but more optimization can be done in this way to increase the operating hours, especially in the regions where power cuts are a usual thing.

Apart from this, other energy sources like solar energy should also be considered for making the system more sustainable and reliable. At the broader level of policy recommendations, harmonized regulatory frameworks towards the incorporation of smart energy solutions in national energy strategies would be essential. Investments in innovation, such as hybrid energy storage systems and decentralized smart grids, would boost system resilience and pave the way for mainstream adoption.

Financial inclusion efforts, for example, targeted subsidies and micro financing options, may make the smart metering solutions affordable to low-income households and the communities that are less served, hence contributing to increased energy equity. Public acceptance and education programs would then enhance further with local benefits to be accrued by the user through deploying smart energy management systems at their premises. Finally, extensive field tests should be conducted in real-life situations to see the system in action and get the feedback of the end-users, which may help to identify new features or modifications that could improve the performance of the system as well as the user experience on the whole. In a nutshell, this intelligent energy metering system represents a breakthrough in technology for managing energy. With continued development, user-driven improvements, and broader adoption supported by effective policies, the system has the potential to make a substantial contribution to secure and efficient energy utilization across various applications, fostering a more sustainable and resilient energy future.

References

[1] A.O. Oyubu, and C.A. Nwabueze, "Design And Testing of a Smart Energy Metering System Based on GSM MODEM," *European Journal of Engineering and Technology*, vol. 3, no. 4, pp. 35-42, 2015. [Google Scholar]

[2] Soma Shekara Sreenadh Reddy Depuru, Lingfeng Wang, and Vijay Devabhaktuni, "Electricity Theft: Overview, Issues, Prevention, and a Smart Meter-Based Approach to Control Theft," *Energy Policy*, vol. 39, no. 2, pp. 1007-1015, 2011. [CrossRef] [Google Scholar] [Publisher Link]

[3] C.L. Zulu, and O. Dzobo "Design of an Electric Meter with a Double-Connected Data Capture System for Energy Theft Monitoring," *2021 IEEE AFRICON*, Arusha, Tanzania, United Republic of, pp. 1-6, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[4] Celimpilo Lindani Zulu, and Oliver Dzobo, "Real-Time Power Theft Monitoring and Detection with a Double-Connected Data Capture System," *Electrical Engineering*, vol. 105, pp. 3065-3083, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[5] Malka Tarannu, Durga Sharma, and Dharmendra Singh, "A Survey on Monitoring and Controlling Power Theft Problems in Local Areas," *International Journal of Advance Research, Ideas and Innovations in Technology*, vol. 3, no. 5, pp. 401-405, 2017. [Google Scholar] [Publisher Link]

[6] Nicholas Nhede, "Analysis: of Electricity Theft in South Africa," 2017. [Google Scholar]

[7] Kumar Ask et al., "Design and Simulation of Smart Prepaid-Postpaid Energy Meter with Alarm and Theft Control," *2018 5th IEEE Uttar Pradesh Section International Conference on Electrical, Electronics and Computer Engineering*, Gorakhpur, India, pp. 1-6, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[8] V. Preethi, and G. Harish, "Design and Implementation of Smart Energy Meter," *2016 International Conference on Inventive Computation Technologies*, Coimbatore, India, vol. 1, pp. 1-5, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[9] Kanwal Naz Shaikh, and Imran Mustafa, "Design and Implementation of RFID and GSM based Smart Prepaid Energy Meter," *International Journal of Electrical Engineering & Emerging Technology*, vol. 4, no. SI 1, pp. 33-36, 2021. [Google Scholar] [Publisher Link]

[10] Henry Erialuode Amhenrior, and Fredrick Edeko, "Design and Implementation of a GSM-Based Single Phase Prepayment Energy Meter with Hybrid Recharge Mode," *American Journal of Embedded Systems and Applications*, vol. 6, no. 1, pp. 46-55, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[11] Sagar Rathee, Aayush Goyal, and Anup Shukla, "Designing Prepaid Smart Energy Meter and Deployment in a Network," *2020 IEEE 4th Information Technology, Networking, Electronic and Automation Control Conference*, Chongqing, China, pp. 1208-1211, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[12] Kumarsagar M. Dange, Sachin S. Patil, and Sanjay P. Patil, "Prepaid Energy Meter Using GSM Module," *International Journal of Engineering Science Invention*, vol. 6, no. 2, pp. 80-85, 2017. [Google Scholar] [Publisher Link]

[13] W.D.A.S. Rodrigo et al., "A Prepaid Energy Meter Using GPRS/GSM Technology for Improved Metering and Billing," *International Journal of Computer Science and Electronics Engineering*, vol. 4, no. 2, pp. 64-69, 2016. [Google Scholar]

[14] T.E. Somefun, C.O.A. Awosope, and A. Chiagoro, "Smart Prepaid Energy Metering System to Detect Energy Theft with Facility for Real Time Monitoring," *International Journal of Electrical and Computer Engineering*, vol. 9, no. 5, pp. 4184-4191, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[15] R. Bhavani, and S. Alagammal, "Design and Implementation of GSM Based Smart Energy Meter (SEM) for Home Applications," *International Journal of Latest Trends in Engineering and Technology*, vol. 8, no. 1, pp. 431-439, 2016. [CrossRef] [Google Scholar] [Publisher Link]