Design and Implementation of a Global System for Mobile Communication (GSM)-based Smart Energy Meter

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Abstract

A smart meter is an electronic device that quantifies energy use at various periods, ranging from minutes to months. The suggested device gathers data from the meter and transmits it to a central database for storage, analysis, and monitoring of safety-related concerns. Additionally, it incorporates a module that allows for loading on-demand units from the energy supplier firm simply by submitting a short message service (SMS) request. The idea was initially implemented in software and subsequently, a prototype model was produced. The prototype model communicates with the energy service provider to obtain data on the consumed energy using the GSM network. This work presents the theory and implementation of remote monitoring and controlling of the energy meter using GSM architecture. This system, based on GSM technology, allows the electrical department to get regular meter readings without the need for manual readings. The work also enables prepaid billing, electricity management, and energy conservation.

Keywords:

Smart Energy Meter, Global System for Mobile Communication (GSM), Arduino.

Highlights:

- We present a comprehensive study on the development and implementation of a Smart Energy Meter with cloud connectivity.
- The system is built to measure current and voltage, calculate energy consumption, and seamlessly send the data to the cloud-based web server, ThingSpeak.
- The Smart Energy Meter presented in this paper represents a significant advancement in the field of energy monitoring. By harnessing the power of cloud connectivity, it offers a convenient and efficient solution for real-time energy consumption monitoring.

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1. Introduction

In this era of accelerated technological advancement, the need for efficient and precise energy management systems has become crucial [1]. Implementing Smart Energy Meters utilizing a Global System for GSM technology is one such solution that has garnered considerable attention. This emerging technology offers numerous advantages, including improved energy monitoring efficacy and precision, enhanced security measures, and long-term cost savings [2, 3].

The efficiency and accuracy of digital energy meters will be the first subtopic examined. The inaccuracies of conventional energy meters are frequently the result of manual reading errors or technical flaws. With the addition of GSM technology, however, smart meters can provide real-time data on energy consumption, eliminating human error and ensuring accurate readings. In addition, these advanced devices enable better load management by enabling consumers to monitor their electricity consumption patterns and make educated decisions about their consumption habits [4, 5].

The second subtopic emphasizes security and data privacy concerns related to smart meter GSM technology. As with any wireless communication system, unauthorized access or hacking attempts pose inherent hazards. It is essential to address these concerns by instituting robust security protocols that protect sensitive consumer data from potential breaches or mistreatment [6, 7].

GSM-based smart meters provide utilities with precise information regarding periods of peak demand, allowing them to optimize power generation and distribution accordingly [8]. By managing energy resources efficiently, utility companies can reduce operational expenses over time and promote sustainability [9, 10].

Smart Energy Meters utilizing GSM technology provide a promising solution for improving energy management systems globally. In addition to addressing security concerns with stringent protocols for data privacy protection, their efficacy and precision enable more precise measurements. In addition, their implementation results in long-term cost reductions for both consumers and utility companies, as resource allocation is optimized based on real-time data provided by these innovative devices [11].

Smart energy meters utilizing the Global System for GSM have revolutionized the measurement and management of energy consumption. These meters provide a multitude of advantages, efficiency, and precision being the most prominent. These digital meters offer instantaneous data on energy usage, enabling consumers to observe and modify their consumption patterns accordingly. This meter's precision is unparalleled, as it eliminates human error in traditional meter readings and provides precise measurements. This increased level of precision ensures that consumers are accurately billed for their energy consumption, thereby eliminating any discrepancies or disputes [12].

Moreover, the effectiveness of digital energy meters extends beyond the accuracy of their readings. These devices facilitate communication between consumers and utility providers [13]. Using GSM technology, the meter transmits data wirelessly to the utility company's database in real-time. This eliminates the need for manual meter reading visits by utility staff, sparing both parties time and resources. In addition, it expedites the identification of any prospective problems or faults in the energy distribution system [14].

One could argue that these smart meters cause a paradigm shift in how we perceive our energy consumption behaviors in terms of abruptness and complexity. By supplying real-time data on our usage patterns, they raise consumers' awareness of their daily energy consumption habits - a fact that was previously often overlooked. This sudden awareness can result in immediate behavioral changes as individuals endeavor to reduce their carbon footprint and conserve electricity [15, 16].

Moreover, these digital meters facilitate demand response programs, which contribute to a more sustainable future [13]. Utilizing the real-time data provided by these devices, utility companies can implement dynamic pricing schemes during prime hours and periods of high demand. This volatility enables consumers to make informed judgments regarding their electricity consumption based on fluctuating prices throughout the day [8, 17].

Smart energy meters that use GSM technology are incredibly accurate and efficient when it comes to measuring and managing energy consumption. Their ability to provide real-time data, eliminate human error, streamline communication, and facilitate demand response programs renders them indispensable in the current energy environment. Smart meters are essential in teaching customers about their energy consumption habits and enabling them to make informed decisions regarding their usage, as we strive for a more sustainable future [18, 19].

Despite its many advantages in the domain of smart energy meters, GSM technology presents several security and data privacy concerns. As we delve deeper into the complexities of this technology, it becomes clear that its framework contains vulnerabilities that can compromise the integrity and confidentiality of user data [20]. The abruptness and complexity of these issues are sufficient to give even the most technologically savvy individuals pause. The potential for unauthorized access to sensitive information transmitted over GSM networks is one such concern. Given that these networks are wireless, they are inherently vulnerable to interception by malicious actors equipped with the knowledge and tools to exploit their vulnerabilities. This raises significant concerns regarding the security and confidentiality of consumer data transmitted by smart energy meters [21].

In addition, GSM technology relies on SIM cards for user authentication and identification [22]. While at first inspection this may appear to be a secure method, recent events have demonstrated that SIM cards are vulnerable to hacking attempts. This revelation adds to the complexity of security concerns regarding GSM technology in smart energy meters. If an attacker acquires unauthorized access to a SIM card or successfully clones it, they could potentially impersonate an authorized user, compromising not only their personal information but also their smart energy meter [23, 24]. The possibility of denial-of-service (DoS) assaults on smart energy meters employing this communication protocol is a further source of security concerns with GSM technology [25, 26]. By flooding a meter's GSM network with excessive traffic or exploiting software vulnerabilities, attackers can effectively disrupt communication between consumer devices and utility company servers. This disruption can result in inaccurate invoicing, delayed response times during emergencies or power outages, and a reduction in the overall efficiency of the system [27].

Smart energy meters are crucial for transitioning to a sustainable and cost-effective energy system. They provide real-time data on energy consumption, raising awareness and encouraging energy-efficient behaviors, resulting in lower electricity costs. They also enable utility companies to implement demand-response programs, promoting grid stability and reducing infrastructure costs. Remote meter reading and invoicing processes reduce administrative costs, and smart meters speed up power outages and system fault detection, resulting in faster response times and reduced downtime [28, 29].

Recent research has suggested the use of energy meter systems (EMS) to communicate data, such as the amount of energy spent in kilowatt-hours (kWh) and generate a bill via a GSM mobile network. Additional benefits of the system are its precise measurement of household power usage, its safe operation, and its fast update rate [30]. A methodology for energy meter reading, which involves human workers visiting individual homes and businesses to record electricity usage and generate bills, has been proposed. The objective of this project is to create a Smart Electricity meter with GSM technology. This technology can minimize human errors and facilitate the retrieval of real-time meter values using GSM. These values can then be sent to clients' mobile phones via GSM. This feature enables the power board to adjust the variable package pricing within a specified time frame. The administrator has the capability to analyze the power usage data of clients and generate a report from the data online [31]. A GSM-based autonomous remote meter-reading system was recently proposed. Obtaining meter readings when needed eliminates the requirement for meter readers to visit each customer for energy consumption data collecting and bill distribution. A microcontroller can be utilized for monitoring and logging meter readings. If a customer fails to pay, there is no requirement to dispatch a utility worker to disconnect the customer's connection. The utility can terminate and restore the customer's connection using SMS.

In addition, the customer can remotely monitor the electrical load status from any location. The energy meter values in this system are transmitted using GSM technology [32]. Furthermore, a theoretical proposition was presented to encompass any management system that aims to achieve automation, portability, and remote control [33]. A theoretical proposition was formulated for smart metering, as it represents a significant advancement in utility sectors, particularly in the electricity sector. Nevertheless, the potential advantages of smart metering have not been thoroughly investigated due to the restricted capabilities of the majority of prepaid meters currently in use in many developing nations. Given the increasing prevalence of internet usage and web-based applications, it is important to consider how prepaid meters might be supported to maintain online connectivity via Mobile Communication Systems [34].

Based on the literature analysis, it can be inferred that the metered safety system is highly effective for future use. A thorough investigation has been conducted to choose various materials, methods, and designs for different safety systems that provide attributes such as efficiency, environmental friendliness, cost-effectiveness in mass production, and advantages for users. In this work, an effective smart energy meter has been designed and implemented based on a global system for GSM. It provides a reliable solution to the drawbacks of conventional meter reading methods, including the requirement for employees, concerns with accuracy, and the inconvenience of client absence during meter readings. Fig. 1 shows the final designed prototype of the smart energy meter based on GSM.

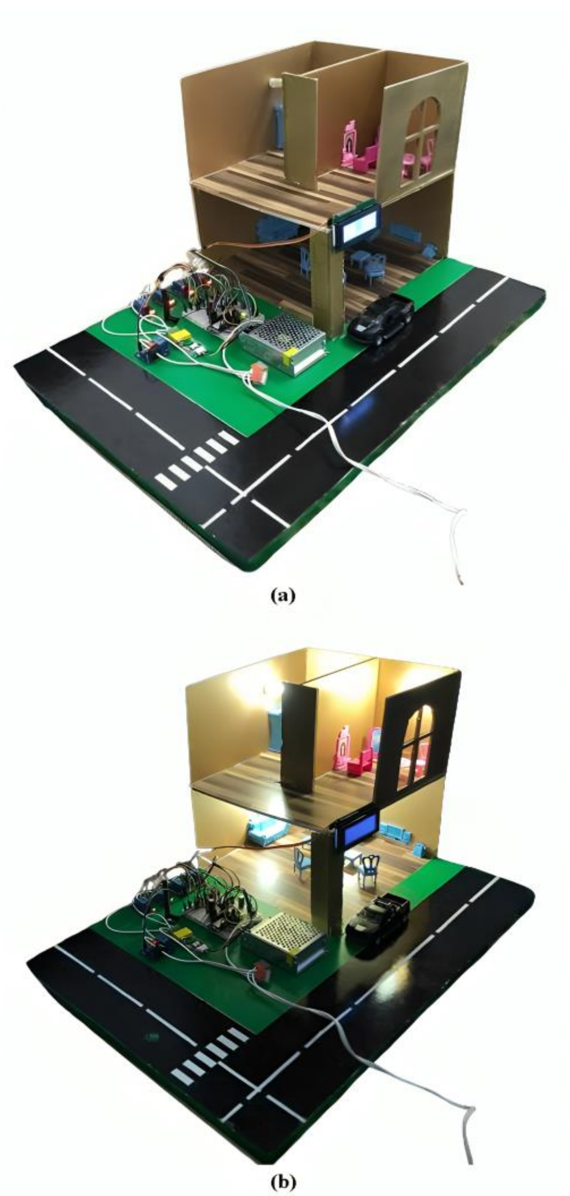

Fig. 1. (a) Side view of the prototype after placing the circuit with load turned OFF, and (b) side view of the prototype after placing the circuit with load turned ON

2. Methodology

The goal of this project is to create an inexpensive, user-friendly, and efficient tool for hardware programming. This product is incredibly potent for use in this project because of its inexpensive cost and straightforward, effective design. Not unexpectedly, a sizable user base actively supports Arduino and has supplied a plethora of materials for any potential users. This community offers the user an intuitive software-integrated development environment, comprehensive documentation, and tutorials. Given the abundance of information available and the affordable price of the product, it is not surprising that Arduino is gaining popularity so quickly. Someone with little experience with electronics and programming may be able to realize their ideas with the help of user community resources. The Arduino IDE greatly streamlines the process of working on the development phase of an Arduino project. The IDE is a work of simplicity; even for nonprogrammers, it is simple to understand and adaptable for seasoned developers. An uncluttered and uncomplicated development environment facilitates problem-free project progress.

The designed smart energy meter mainly depends on an Arduino MKR GSM 1400 board. The Arduino MKR GSM 1400 is a robust development board that integrates the capabilities of an Arduino with a GSM module for establishing cellular communication. This feature makes it well-suited for projects that necessitate remote monitoring or control, such as Internet of Things (IoT) applications or smart home devices.

An important distinction between the Arduino MKR GSM 1400 and other Arduino boards lie in its integrated GSM module. The board is capable of establishing connections with cellular networks, enabling a dependable and protected means of communication with distant devices. Conversely, conventional Arduino boards usually depend on Wi-Fi or Bluetooth for connectivity, which might not be accessible in every area. Another distinction lies in the form aspect of the Arduino MKR GSM 1400. The Arduino Nano is characterized by its smaller size and compact design, which facilitates its integration into projects that have limited space. Moreover, it is equipped with an integrated Li-Po battery charger, enabling its use in portable applications without reliance on external power sources.

Although there are variations, the Arduino MKR GSM 1400 exhibits numerous resemblances to other Arduino boards. It is compatible with the Arduino IDE and libraries, facilitating programming and usage for both novices and experts. Additionally, it possesses a diverse array of input/output ports and sensors, enabling a broad spectrum of project options.

2.1 Design of Smart Energy Meter

The development of smart energy meters utilizing Global System for GSM technology has been a subject of discussion in recent years. While there are proponents who assert that this technology represents the future of energy management and efficiency, there are also those who contend that it presents inherent risks and issues that must be acknowledged and resolved.

Advocates of GSM-based smart energy meters contend that these devices provide several advantages, such as the capacity to monitor energy consumption in real-time, remotely access data, and change usage patterns according to demand. This can result in substantial cost reductions for both consumers and utility companies, as well as decreased environmental impact due to enhanced energy efficiency.

Moreover, there are apprehensions regarding the dependability and durability of GSM networks in some locales, especially in rural areas or developing nations where the extent of coverage can be restricted. Loss or disruption of the network connection may lead to imprecise measurements or delayed reactions from utility companies.

Fig. 2 depicts the ultimate configuration of the intelligent meter. The yellow lines represent the active wire, the blue lines represent the neutral wires, the red lines represent the DC 5V wire, the black lines represent the ground wire, and the green line represents the signal wires. The load is connected to the normally closed pins of the relays, ensuring that they always start in the ON state. When the relay is triggered, the load will turn OFF. The relay cuts off the live wire, while the neutral wire remains connected to the load. Each relay is connected to a control circuit, which includes an NPN transistor and a current-limiting resistor. This setup allows the 5V relay to be triggered by a 3.3V signal. The 5V DC power supply provides electrical power to all the DC modules through the positive (+) and ground (GND) connections. The over-current protection relay operates independently of the Arduino as it has its control circuit. When the current in the live wire is above 5A, the relay will disconnect the load. The antenna is linked to the Arduino through the IPX connector of the Arduino. The PZEM004T module is linked to the UART pins of the Arduino, namely the TX and RX pins.

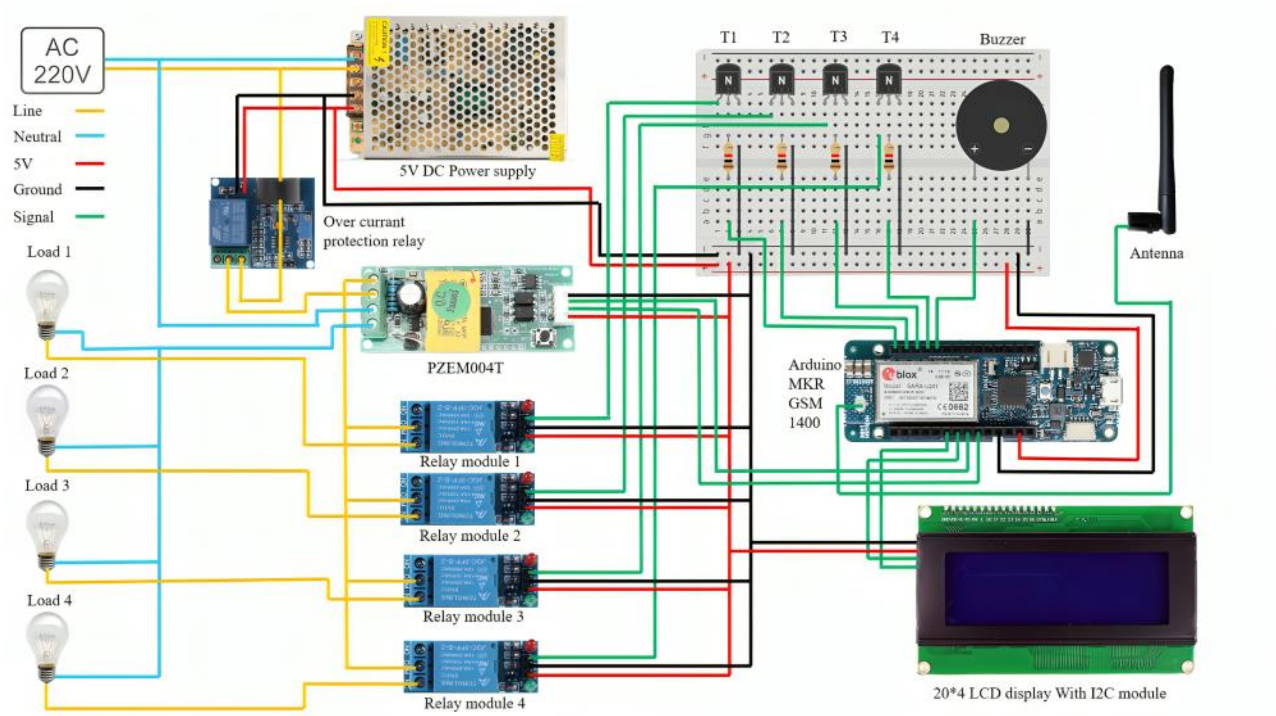

Fig. 2. Circuit diagram of the designed smart energy meter.

The LCD is linked to the Arduino's SCL and SDA pins using the I2C protocol. The wiring pins are shown in Table 1.

Table 1: Wiring pins of the designed smart energy meter.

Module	Module Pins	Arduino Pins
PZEM004T	RX	14
	TX	13
LCD	SLC	12
	SDA	11
Buzzer	Positive (+)	D5
Relay Module1	IN	D1
Relay Module1	IN	D2
Relay Module1	IN	D3
Relay Module1	IN	D4

As shown in Fig. 3 upon activation of the smart meter, the microcontroller will commence the initialization process for several modules including PZEM004T, LCD, and the integrated GSM module. Subsequently, it will retrieve data from the PZEM004T module to calculate load parameters such as voltage, current, power, energy, power factor, and frequency. The subsequent action is computing the balance, and if the balance equates to zero, it will deactivate the load. Subsequently, the calculated data, encompassing voltage, current, power, energy, power factor, frequency, and balance, will be exhibited on the LCD. Subsequently, the program will verify the presence of incoming SMS messages. If an SMS message is detected, it will verify if the sender's number is approved. If authorized, the program will execute the command and respond with the results. If not authorized, the program will proceed with the loop, beginning with the calculation of parameters.

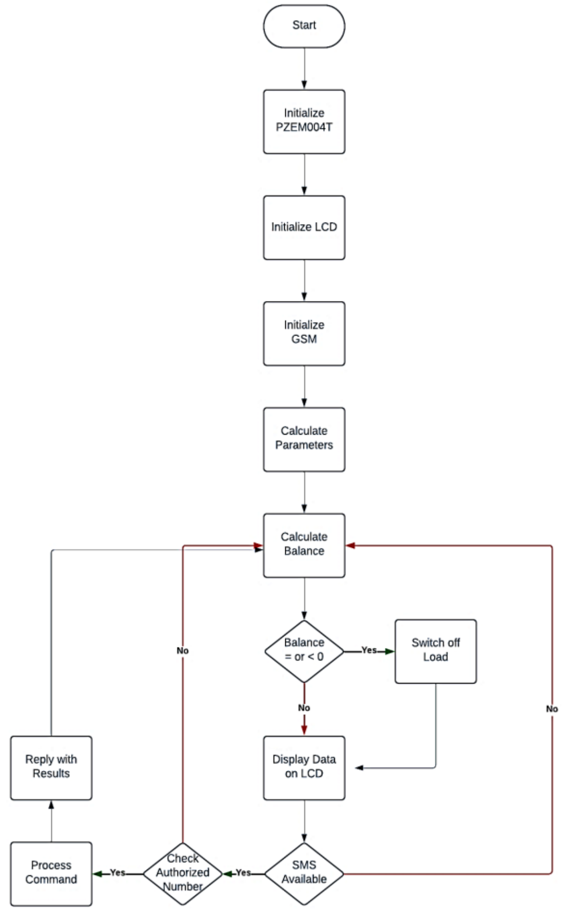

Fig. 3. Flow chart of the system.

2.2 Main Code

When delving into the world of Arduino coding, it is essential to grasp the fundamentals before embarking on more complex projects such as creating a GSM-based smart energy meter. The first step in writing Arduino's code for this device is understanding the syntax and structure of the language. Arduino uses a simplified version of C++, making it accessible to beginners while still powerful enough for advanced users. This means that variables must be declared before they are used, functions must be defined before they are called, and statements must end with semicolons. Additionally, curly braces are used to group blocks of code, allowing for easier organization and readability.

Another crucial aspect of Arduino coding is understanding how to work with libraries. Libraries contain pre-written code that can be easily incorporated into your projects, saving time and effort. For a GSM-based smart energy meter, you may need to use libraries that interface with the GSM module and handle communication protocols such as SMS or GPRS. By including these libraries in your code, you can focus on implementing the specific functionality you need without having to reinvent the wheel.

Furthermore, error handling is an important consideration when writing Arduino code for a complex device like a smart energy meter. Errors can occur at any stage of the development process, from syntax errors in your code to hardware malfunctions in your circuitry. It is crucial to include error-checking mechanisms in your code to detect and respond to these issues appropriately. This may involve using conditional statements or try-catch blocks to handle exceptions gracefully. Mastering the basics of Arduino coding is essential for successfully developing a GSM-based smart energy meter. By familiarizing yourself with the syntax and structure of the language, working with libraries effectively, and implementing robust error-handling mechanisms, you can create a reliable and efficient device that meets your needs. The main functions in the MKRGSM library and PZEM-004T-v30 library are illustrated in Appendices A and B, respectively. The primary function of Arduino code can be summarized in the following points:

- Energy Monitoring and Billing: The algorithm enables the continuous monitoring of energy usage; computes expenses based on consumption and oversees credit balances. Efficient energy usage and correct billing depend on this.
- Remote Control via SMS: Users could operate power-consuming gadgets or appliances that are connected to the smart meter by sending commands through SMS. This function improves convenience and optimizes energy management.
- User-Friendly Interaction: The programming processes SMS commands from users and provides appropriate information or executes corresponding actions. The software offers an intuitive interface for retrieving energy data and overseeing meter operations.
- Error Handling and Reliability: Implementing robust error handling mechanisms enhances the stability of the system by effectively dealing with potential issues that may arise during data reading and SMS processing, hence improving the overall usefulness.

Arduino programming relies on numerous essential functions that have significant roles in your code. These functions establish the framework of your program and dictate its execution process. The primary purposes of an Arduino sketch are:

- setup() Function: The setup() function runs once during the initialization of your Arduino board, either when it starts up or is reset. It is utilized for initialization operations such as configuring pins, establishing serial connectivity, and initializing.
- libraries. This function is executed before the loop() function.
- loop() Function: The loop() function serves as the fundamental component of your Arduino program. It continuously executes in a loop once the setup() method finishes. The basic logic of your program is implemented in this section, where you can do tasks like reading sensors, manipulating actuators, and making decisions based on sensor data.

3. Measurements and Results

For one hour, readings of a 25W load were obtained every five minutes, as illustrated in Fig. 4. Throughout the hour, the voltage stays between about 222V and 217V, while the current stays constant at 0.11A. The voltage fluctuation is caused by the possibility that the voltage provided by the power utility will fluctuate based on the supply and demand of electricity inside the power grid. The power supply frequency is a critical factor in determining the energy efficiency of electrical systems. An alteration in frequency can cause inefficiencies in the transmission and utilization of power, leading to elevated energy consumption and greater operational expenses. Deviation from the standard frequency might result in inferior equipment performance, leading to energy inefficiency and reduced overall effectiveness. In addition, variations in frequency can significantly affect the efficiency of power factor correction devices, worsening energy wastage.

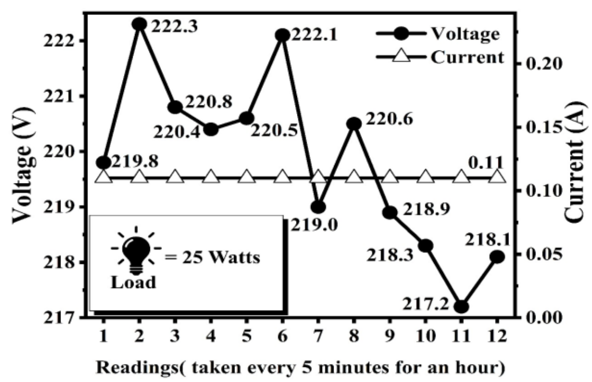

Fig. 4. Voltage and current readings of the smart energy meter.

Moreover, variations in frequency can cause an asymmetry in the power factor, which in turn can lead to higher consumption of reactive power. This can put extra pressure on the electrical grid and compromise the stability of the system. This not only raises the expenses of utility providers but also adds to environmental deterioration by increasing the release of greenhouse gases.

To minimize these adverse impacts on energy efficiency, electrical systems must uphold a consistent frequency within permissible parameters. Effective oversight and regulation are necessary to rapidly rectify any aberrations and maintain optimal operational efficiency of the equipment. By considering the influence of frequency on energy efficiency, we may strive to develop electrical systems that are more sustainable and economical, thereby benefiting both customers and the environment.

The PZEM004T device is capable of measuring both Frequency and Power Factor. These measurements can be viewed on the LCD, as depicted in Fig. 5 (a). Alternatively, by sending the command “status” from the permitted phone number, the readings can be received as an SMS message, as shown in Fig. 5 (b). By measuring a 40W resistive load and comparing the measured value between the smart energy meter and a reference multimeter, I obtained the values displayed in Table 2. The Mean Average Error (MAE) is significantly modest for all parameters, namely voltage, current, and power. This demonstrates the efficacy of the designed smart meter. The smart meter demonstrates accuracy by displaying readings that closely align with the reference multimeter readings.

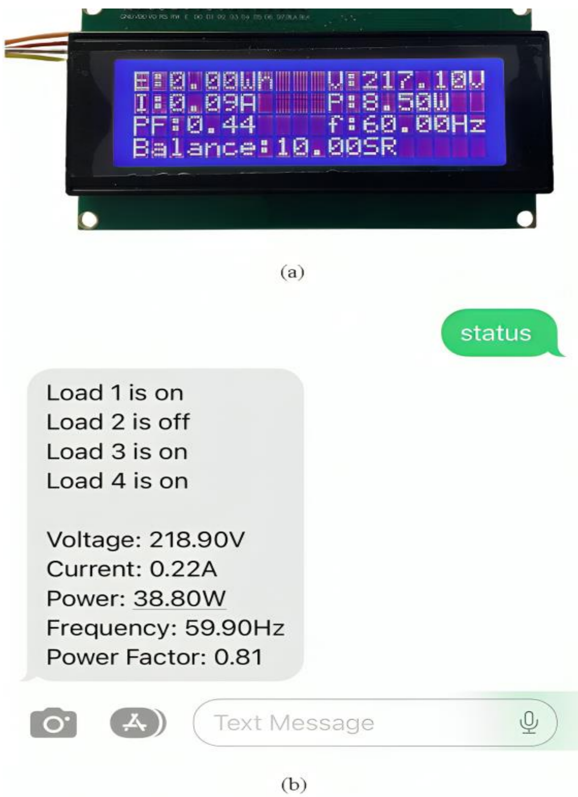

Fig. 5. (a) Power factor and frequency readings on the LCD, and (b) power factor and frequency readings as an SMS message.

Table 2: Percent error calculations of the smart meter readings.

Parameters	Smart Meter	Multimeter	Error (%)	MAE
Voltage (V)	224.90	225.10	0.09	0.2
Current (A)	0.183	0.184	0.54	0.001
Power (W)	41.15	41.41	0.62	0.26

As presented in Fig. 6, Multiple SMS instructions can be used to monitor and manage the system. One of these commands is “on” followed by a load number ranging from 1 to 4, which is used to activate a specific load.

Activation and deactivation of the smart meter can be achieved as follows:

- Use the command “off” followed by a load number ranging from 1 to 4 to deactivate a specific load.
- Use the command “onAll” to activate all linked loads.
- Use the command “offAll” to deactivate all associated loads.

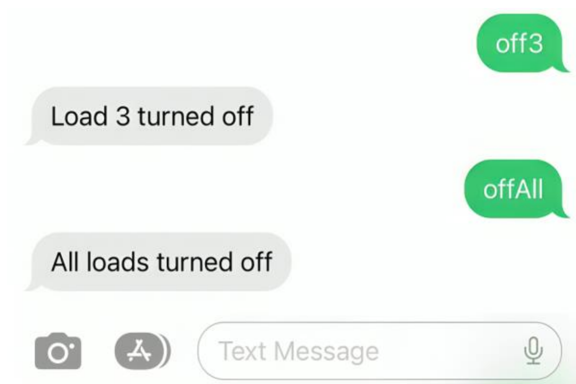

Fig. 6. Smart energy meter response to the SMS commands.

As shown in Fig. 7 The Smart energy meter will also respond to acknowledge the execution of the command. Before executing the command, the device will produce a beeping sound from the buzzer. The commands for monitoring the smart energy meter are as follows:

- Use the command “status” to monitor load metrics such as Voltage, Current, Power, Energy, Frequency, and Power Factor. Additionally, it checks the operational condition of the load that is connected to the smart energy meter, determining whether it is in an active (ON) or inactive (OFF) state.
- By entering the term “adscript” along with the desired amount, you can add credit to your balance. The system will then provide you with the updated balance, including the added credit.
- The term “balance” is utilized to get the present balance.

- The command "reset" is utilized to reset the energy reading. When this command is executed, the smart energy meter will respond.
- The "command" function is utilized to obtain a comprehensive list of the authorized commands.
- The command "price" is utilized to modify the price package in Saudi rials per watt hour (SR/Wh). The response will be demonstrated. This command can only be executed by the utility phone with a minor modification in the main code

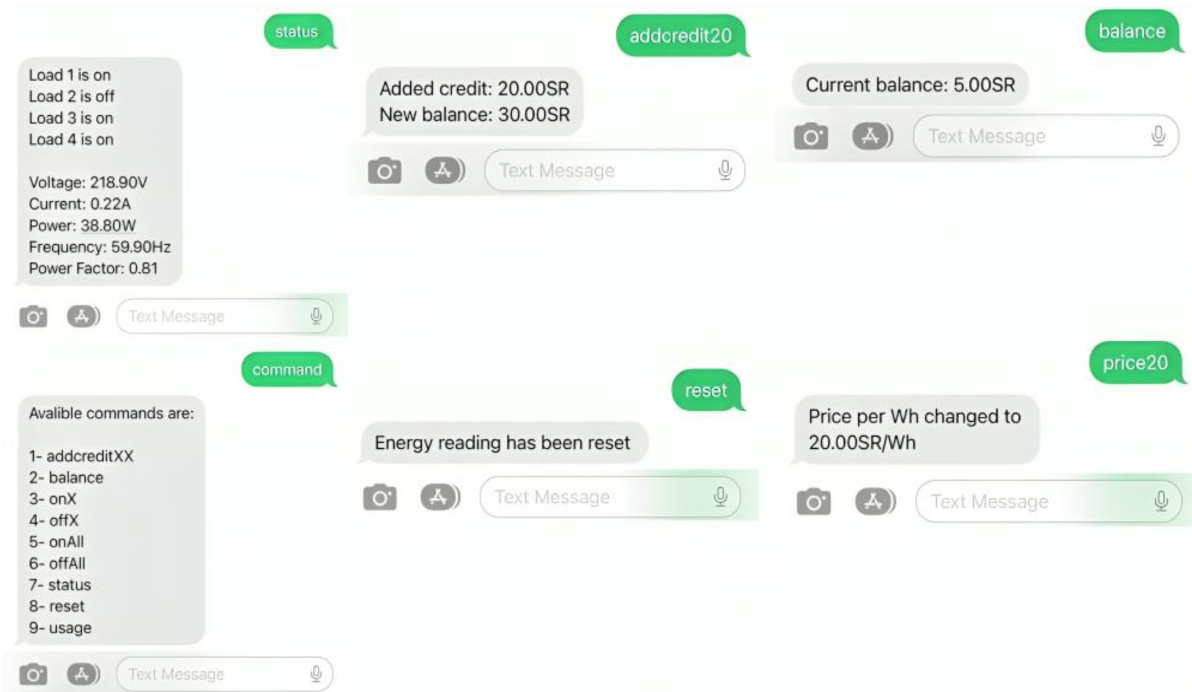

Fig. 7. Main SMS commands to monitor the smart energy meter.

If a random message (invalid command) is delivered to the smart energy meter, or if an attempt is made to turn on the load while the balance is zero, the smart energy meter will respond, as illustrated in Fig. 8.

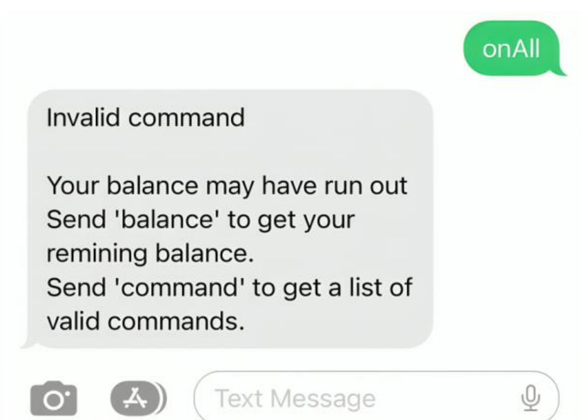

Fig. 8. Smart energy meter response to invalid commands.

4. Conclusion

The development and execution of a GSM-based intelligent energy meter system has proven to be effective in overseeing and controlling energy usage. Smart meters offer instantaneous data on energy consumption, enabling consumers to make well-informed choices on their usage patterns. This not only fosters energy efficiency but also aids in diminishing overall energy usage.

Moreover, the cost-effectiveness of deploying smart meters is apparent, since they can result in substantial reductions in operational expenses and maintenance expenditures. Although the initial investment may appear substantial, the long-term advantages significantly surpass the expenses. Ensuring security is of utmost importance when adopting GSM-based smart meters. It is crucial to implement adequate encryption and security protocols to safeguard sensitive data from cyber threats.

The influence on customer awareness and behavior should not be underestimated. By furnishing consumers with comprehensive data regarding their energy consumption, they are more inclined to embrace energy-conserving behaviors and diminish their ecological impact. It is crucial to integrate GSM-based smart meters with the current energy infrastructure to smoothly move towards a more sustainable future. The advantages of adopting this system greatly surpass any difficulties or disadvantages, making it a feasible alternative for effective energy management worldwide.

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Appendices

Appendix A. Main Functions in MKRGSM Library

The communication capabilities of the Arduino MKR GSM 1400 can be managed by utilizing the MKRGSM library. The MKRGSM library facilitates the establishment of a GSM network connection using the Arduino MKR GSM 1400 board. This library enables users to establish voice conversations, both incoming and outgoing, as well as send and receive SMS messages using the u-blox SARA-U201 module. Additionally, it allows users to connect to the internet using GPRS networks.

To utilize this library, it is necessary to incorporate the header file into the Arduino project. The library is composed of distinct classes that manage different capabilities. The GSM class is responsible for managing commands to the radio modem and handling the connectivity features of the module. The GSMVoiceCall class is responsible for the management of voice call handling. The GSM_SMS class is tasked with the transmission and reception of SMS messages. The GPRSClass enables internet connectivity. The GSMClient and GSMServer classes offer distinct implementations for a client and server, correspondingly. For this project, we will exclusively require the functions of the GSM_SMS class.

The primary functions in the GSM_SMS class are:

- GSM gsmAccess: The code instantiates an object of the GSM class, which has functions for interacting with the GSM network and controlling the modem.
- GSM_SMS SMS: The code instantiates an object of the GSM_SMS class, which has functions for transmitting and receiving SMS messages.
- sms.beginSMS(); It initiates the procedure of transmitting an SMS message to a designated phone number. The function requires a character array as input, which should include the phone number in international format (e.g., "+966-212-555-1212").
- sms. ready(): This function verifies the readiness of the modem to transmit or receive SMS messages. The function returns a boolean value of true if it is ready, and false if it is not.
- sms.endSMS(): It completes the process of transmitting an SMS message. The function should be invoked after composing the message content using either sms.print() or sms.write().
- sms. available(): This function verifies the presence of any SMS message stored on the SIM card. The function returns a boolean value of true if there is at least one message, and false if there are no messages.
- sms.remoteNumber(): This function returns the telephone number of the individual who sent an SMS message. The function requires a character array as a parameter, which must have a size capable of storing the phone number, with a minimum of 20 characters. The function SMS.available() should be called to verify if there is a message available.
- sms. read(): This function retrieves a solitary character from an SMS message. The function returns the character as an integer, or -1 if there is

no additional data available to be read. The function should be invoked after verifying the presence of a message using the available() method in SMS.

- sms. write(): This function is responsible for appending a solitary character to an SMS message. The function requires an integer input that must represent a valid ASCII character. The name should be assigned upon initiating the SMS message sending procedure using SMS.Initialize the SMS function.
- sms. print(): This function outputs a sequence of characters to a Short Message Service (SMS) message. The method accepts either a character array or a String object as a parameter. The action of initiating the SMS message sending procedure should be named accordingly.Invoke the beginSMS() function.
- sms. peek(): This function retrieves the index number of the upcoming SMS message that will be read from the SIM card. It does not delete the message from the This function receives the index number of the next SMS message that will be accessed from the SIM card. The message is not erased from the SIM card. In the absence of a message, the function will yield a value of -1.
- sms. flush(): This function removes all SMS messages stored on the SIM card.

Appendix B. Main Functions in PZEM-004T-v30 library

The PZEM-004T-v30 library is an Arduino library specifically designed for the latest version, PZEM 004T v3.0, of the power and energy meter. The UART communication protocol enables the measurement of voltage, current, power, energy, power factor, and frequency. The primary functionalities provided by the PZEM-004T-v30 library include:

- PZEM004Tv30(): An instance of the PZEM004Tv30 class is created to represent a single PZEM-004T device. The function requires two parameters: a HardwareSerial or SoftwareSerial object for establishing communication with the device, and an optional slave address (with a default value of 0xF8).
- setAddress(): It modifies the slave address of the device. The function requires a byte argument that must be within the range of 0x01 and 0xF7. The function returns a boolean value of true if it is successful, and false if it is not.
- voltage(): This function retrieves the voltage measurement from the device. The function returns a floating-point value representing voltage in volts. If there is a problem, it returns NAN (Not a Number).
- current(): This function retrieves the electrical current flowing through the device. The function returns a floating-point value representing the current in amperes. If there is an error, it returns the value NAN.
- power(): This function retrieves the electrical power measurement from the device. The function returns a floating-point value representing the power in watts. If there is an error, it returns the value NAN.
- energy(): This function retrieves the energy data from the device. The function will output a decimal value representing the energy in watt-hours. If there is a mistake, it will return a value of NAN.
- frequency(): This function retrieves the frequency data from the device. The function returns a floating-point value representing the frequency in hertz. If there is an error, it returns the value NAN.
- pf(): This function retrieves the power factor value from the device. The function yields a floating-point value ranging from 0 to 1, or NAN if an error occurs.
- reset energy (): This function restores the energy counter on the device to its initial state. The function returns a boolean value of true if it is successful, and false if it is not.
- setPowerAlarm(): This function establishes the power alarm threshold on the device. The function requires an uint16_t parameter, which must have a value ranging from 0 to 25000 (watts). The function returns a Boolean value of true if it is successful, and false if it is not.