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Energy Meter Billing and Monitoring System using IoT

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Abstract: *With the increasing demand for energy and the growing concern for sustainable development, energy conservation has become a necessity. It is essential to ensure that electricity is being consumed efficiently and not wasted, which can lead to a significant increase in energy bills. Moreover, the traditional energy billing methods are prone to errors and are not user-friendly, resulting in inaccurate bills and customer dissatisfaction. In light of these issues, a system that is based on the Internet of Things (IoT) has been proposed and analyzed for energy meter billing and monitoring. The proposed system employs cutting-edge technology to automate the energy billing process and provides real-time monitoring of energy consumption, which helps customers to keep track of their energy usage and reduce their electricity bills. One of the most significant advantages of the IoT-based energy meter billing and monitoring system is that it is highly scalable and can be easily customized to meet the specific needs of each customer. It provides a secure and reliable platform for data communication between the energy meter and the web server, which ensures accurate billing and eliminates the need for manual meter reading. Furthermore, the proposed system is also environmentally friendly as it promotes energy conservation and reduces the carbon footprint. With the help of real-time monitoring, customers can identify areas where energy is being wasted and take corrective actions, such as turning off appliances when not in use, which helps in reducing energy consumption and conserving resources.*

Keywords: IOT, Smart Energy Meter Billing, Relay, GSM, electricity, Energy, etc

I. INTRODUCTION

Household energy meter reading systems are essential for managing power consumption and billing. However, these systems have several issues that need to be addressed, such as complex construction, limited bandwidth, slow communication, and poor real-time monitoring. These issues can lead to inaccurate billing, power outages, and other problems. In order to overcome these issues, researchers have proposed an automatic meter reading system that uses wireless technology to transmit customer electricity usage and bill information in real-time. This system is designed to improve the efficiency of power systems and assist in analyzing power loss in various regions. The data is transmitted via an Internet of Things (IoT) connection between the electricity board and the consumer section. The voltage device and current sensor data are collected and transmitted to the microcontroller, which alerts the electricity board of any power fluctuations. Additionally, the system automatically manages home appliances based on power generation. The electricity board section can provide detailed information about the system's operation. Power Line Communication (PLC) and IoT-based meters have garnered the attention of numerous researchers. According to a thorough evaluation of related work and published literature, these systems can increase the efficiency of power systems and assist in analyzing power loss in various regions. The use of these technologies can improve the accuracy of billing and reduce power outages. The proposed system has several advantages over traditional energy meter reading systems. The use of wireless technology eliminates the need for complex construction and allows for faster and more accurate communication between the electricity board and the consumer section. The real-time monitoring of electricity usage and bill information enables consumers to make informed decisions about their power consumption and reduce their electricity bills.

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Furthermore, the automatic management of home appliances based on power generation can improve the efficiency of power systems and reduce power loss.

The proposed automatic meter reading system that uses wireless technology has the potential to overcome the issues of traditional energy meter reading systems. The use of IoT and PLC technologies can improve the efficiency of power systems and reduce power loss. Real-time monitoring of electricity usage and bill information can enable consumers to make informed decisions about their power consumption, reducing their electricity bills. The automatic management of home appliances based on power generation can improve the efficiency of power systems and reduce power loss.

II. RELATED WORK

There is related work currently present in the field of IoT-based energy meter billing and monitoring. Many researchers have proposed various methods and techniques to automate the energy billing process and provide real-time monitoring of energy consumption. One such research paper is "Smart Energy Metering and Billing System Based on IoT Technology" by S. K. Singh and K. Singh. The paper proposes a smart energy metering and billing system based on IoT technology that can monitor and control the electricity usage of a household or a commercial building. The system uses a microcontroller unit, Wi-Fi module, and cloud platform to collect energy consumption data, perform real-time analysis, and generate accurate bills. The system is also designed to alert the users in case of power fluctuations or abnormal energy usage patterns.

Another research paper titled "IoT-based Smart Energy Meter for Billing and Monitoring" by S. B. Hanchinal and S. C. Kumbar proposes a smart energy meter that uses IoT technology for real-time energy monitoring and billing. The system employs sensors and microcontrollers to collect energy consumption data and transmit it to a cloud server for analysis and billing. The system also allows users to monitor their energy consumption and receive alerts in case of abnormal usage patterns.

In the research paper "Smart Energy Metering and Billing System Using GSM and IoT Technologies" by S. M. Sunil and S. P. Shenoy, a smart energy metering and billing system is proposed that uses GSM and IoT technologies for real-time energy monitoring and billing. The system uses a GSM module to send energy consumption data to a cloud server for analysis and billing. The system also allows users to monitor their energy consumption and receive SMS alerts in case of abnormal usage patterns.

Another research paper titled "Smart Energy Metering and Billing System Using Raspberry Pi and IoT Technology" by N. N. Joshi and S. S. Naik proposes a smart energy metering and billing system that uses Raspberry Pi and IoT technology for real-time energy monitoring and billing. The system employs sensors and microcontrollers to collect energy consumption data and transmit it to a cloud server for analysis and billing. The system is also designed to alert the users in case of power fluctuations or abnormal energy usage patterns.

In the research paper "Design and Implementation of a Smart Energy Meter Based on IoT" by F. R. P. Cavalcanti and J. P. C. L. da Silva, a smart energy meter based on IoT technology is proposed that can monitor and control the energy usage of a household or a commercial building. The system uses a microcontroller unit, Wi-Fi module, and cloud platform to collect energy consumption data, perform real-time analysis, and generate accurate bills. The system is also designed to alert the users in case of power fluctuations or abnormal energy usage patterns.

Overall, these research papers demonstrate the potential of IoT-based energy metering and billing systems to revolutionize the energy industry. They offer efficient and accurate methods of energy billing and monitoring, promote energy conservation, and reduce the carbon footprint, making them highly desirable technologies in the field of energy.

III. METHODOLOGY

The system can be modeled into several units, each having a unique function. The following are the various units of the system:

3.1 IoT and Its Working

The Internet of Things (IoT) is an innovative concept that has gained significant momentum in recent years. It refers to a network of physical devices, vehicles, home appliances, and other items that are embedded with electronics, software, sensors, and network connectivity. These elements enable objects to connect and exchange data, allowing them to work

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together in ways that were previously impossible. One of the many potential applications of IoT is in the area of energy management. In a proposed system, IoT will play a crucial role in the communication between the energy meter and the web server. The energy meter will be embedded with sensors and network connectivity, allowing it to send data on energy usage to the web server in real-time. This information can be used to monitor energy consumption and identify areas where energy savings can be made. IoT-based energy management systems can help reduce energy consumption and costs, as well as improve overall energy efficiency. They can also help to reduce the environmental impact of energy use by providing insights into energy usage patterns and identifying opportunities for more sustainable practices. IoT technology has the potential to revolutionize energy management systems by enabling real-time communication between energy meters and web servers.

This will allow for better monitoring and control of energy consumption, leading to cost savings and improved sustainability. As IoT continues to evolve and become more accessible, it is likely that we will see many more applications in a wide range of industries and sectors.

3.2 Arduino UNO (Processor)

The Arduino UNO is a widely used board in various projects that serves as a standard board for Arduino. The name "UNO" is derived from the Italian word for "one," which represents the initial release of the Arduino software. The board features an ATmega328P microcontroller, which makes it easier to operate compared to other boards such as the Arduino Mega board. The board comes equipped with digital and analogInput/Output pins, shields, and supplementary circuits, making it an ideal choice for various applications.

Fig 1. Arduino UNO Processor

The Arduino UNO board is composed of six analog pin inputs, fourteen digital pins, a USB connector, a power jack, and an ICSP header. It can be programmed through the Integrated Development Environment (IDE), which can be used both online and offline. It is also compatible with an array of other features, including digital and analog I/O pins, shields, and supplementary circuits. Technical specifications of the Arduino UNO board include twenty Input/Output pins, including six Pulse Width Modulation (PWM) pins, six analog pins, and eight digital I/O pins. The board also features a crystal oscillator with a frequency of 16MHz and an integrated WiFi module based on the ESP8266 module and ATmega328P microcontroller. Its input voltage ranges from 7V to 20V, and it can obtain power from either an external power supply or a USB connection. Programming the Arduino UNO board can be achieved through the Arduino IDE or the Arduino Web Editor, which enables users to upload sketches and write code directly from their web browser. Establishing a USB connection between the board and the computer is essential, and once the connection is established, the PWR pins will emit a green light, indicating the board's power status. The green LED light serves as a power indicator. The Arduino UNO board is a potent board utilized in various projects, equipped with an array of features that make it easier to operate. Its compatibility with the Integrated Development Environment (IDE) and the Arduino Web Editor enables users to upload sketches and write code with ease, making it an ideal choice for both novice and advanced programmers.

3.3 GSM System

The Global System for Mobile Communication (GSM) is a widely adopted standard for cellular communication that enables mobile devices to connect to the internet and communicate with each other. In the proposed system, the GSM module will be utilized to send SMS alerts to customers regarding their energy consumption and billing. By using the

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GSM module, the proposed system will allow the energy company to send automated SMS alerts to customers when they have reached a certain level of energy consumption or when their bill is due. This will provide the customers with timely and useful information, helping them manage their energy consumption and avoid any surprises in their billing. The GSM module works by sending and receiving data over the cellular network. It is a reliable and secure method for transmitting data, making it an ideal solution for sending important information such as energy consumption and billing alerts. The module will be integrated with the energy monitoring system, allowing it to automatically send alerts when certain thresholds are met. The proposed system will benefit both the customers and the energy company. Customers will receive timely information about their energy consumption, helping them to reduce their energy usage and save money. The energy company, on the other hand, will be able to improve customer satisfaction by providing them with valuable information and reducing the number of customer complaints related to billing and energy consumption. The GSM module is an important component of the proposed system that enables the energy company to send SMS alerts to customers regarding their energy consumption and billing. By leveraging the power of the cellular network, the proposed system provides a reliable and secure method for transmitting important information to customers, helping them manage their energy consumption and avoid surprises in their billing.

3.4 Relay

A relay is an electrical switch that is operated by an electromagnet. It is a device that is commonly used to control electrical circuits by opening and closing them using a low power signal. In the proposed system, a relay will be used to turn off the power connectivity in case the customer fails to pay their bill on time.

Fig 2. Relay Switch

The relay in the proposed system will be integrated with the billing system of the energy company. It will be programmed to receive a signal from the billing system when a customer's bill is overdue. Once the signal is received, the relay will be triggered, and it will turn off the power connectivity to the customer's premises. The use of a relay in this manner is a common practice among energy companies to ensure that customers pay their bills on time. By disconnecting the power, the energy company can motivate the customer to pay their bills promptly. Once the bill is paid, the relay can be triggered again to reconnect the power connectivity. The proposed system can benefit both the energy company and the customers. The energy company can ensure timely payments and reduce losses due to non-payment. The customers, on the other hand, can benefit from better electricity supply and avoid any inconvenience caused by power disconnection.

The relay is a useful device that can be used to control electrical circuits. In the proposed system, it will play a critical role in turning off the power connectivity in case the customer fails to pay their bill on time. By using this mechanism, the energy company can ensure timely payments, and the customers can enjoy uninterrupted electricity supply.

3.5 LCD and Its Interfacing with Microcontroller

The Liquid Crystal Display (LCD) is a widely used type of display that uses liquid crystals to produce images. It is a low-power, high-contrast display that is commonly used in electronic devices such as calculators, digital watches, and smartphones. In the proposed system, the LCD will be used to display energy consumption and billing information to the customer. The LCD in the proposed system will be integrated with the energy monitoring system of the customer's premises. It will be programmed to display the energy consumption and billing information in a user-friendly manner, allowing the customer to easily understand their usage and billing information.

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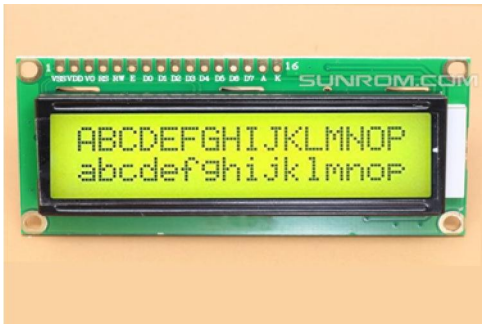

Fig 3. LCD Display

The LCD will display information such as the current energy consumption, the monthly bill, and any alerts related to the energy usage. By using an LCD display, the proposed system will provide the customers with real-time information about their energy usage and billing information. This will enable the customers to make informed decisions about their energy usage and reduce their consumption accordingly. Additionally, it will provide transparency to the customers, reducing the number of customer complaints related to billing and energy consumption.

The LCD is a cost-effective and reliable display technology that is widely used in the industry. It has a low-power consumption, making it an ideal solution for energy monitoring systems. The LCD display in the proposed system will be easy to read, and it will provide accurate and up-to-date information to the customers. The LCD is a useful display technology that can be used to display energy consumption and billing information to the customers. By using this technology, the proposed system can provide real-time information to the customers, enabling them to make informed decisions about their energy usage. Additionally, it will reduce customer complaints related to billing and energy consumption, improving customer satisfaction.

3.6 Working of the System

The proposed system for energy meter billing and monitoring is a fully Internet of Things (IoT) based system that utilizes the Arduino UNO board as its foundation. The system consists of an Arduino-based smart energy meter that displays different parameters, such as voltage, current, power, energy, and power factor, on its LCD screen. Additionally, the system provides load management and protection against tampering, alerting the user via the LCD screen and SMS notifications to their mobile device. The system allows users to interact with the energy meter through a web-based user interface that provides various options, such as adding customers, generating bills, adding administrators, and logging out. The web-based user interface is accessible through a range of devices, including smartphones and tablets. The system also includes a GSM module that sends energy and billing information to the user's mobile phone at fixed intervals, typically set at three minutes.

The Arduino UNO board, which is the backbone of the system, features a total of twenty Input/Output pins, six of which are Pulse Width Modulation (PWM) pins, six analog pins, and eight digital I/O pins. The board operates at a frequency of 16MHz and includes an integrated WiFi module that is based on the ESP8266 module and ATmega328P microcontroller. The input voltage of the board ranges from 7V to 20V, and it can be powered through an external power supply or a USB connection. To program the Arduino UNO board, users can utilize the Arduino IDE, an Integrated Development Environment that is shared among all boards. Alternatively, users can opt to use the Arduino Web Editor, an online platform that enables users to upload sketches and write code directly from their web browser.

Establishing a USB connection between the computer and the board is essential for programming. Upon establishing the connection, the PWR pins will emit a green light, indicating the board's power status. The proposed system for energy meter billing and monitoring is a comprehensive and efficient system that utilizes the Arduino UNO board, GSM module, and web-based user interface to provide users with real-time information about energy consumption, load management, and billing. The system offers various features that make it highly desirable in the field of energy management, such as real-time monitoring of energy consumption, automatic load shedding, and tamper-proof mechanisms. Additionally, the system provides users with a user-friendly web-based interface that enables them to interact with the energy meter and manage their energy consumption efficiently.

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IV. RESULT

The results of the Arduino based Smart energy meter have been found to be satisfactory. The LCD displays all the relevant parameters such as Voltage, Current, Power, Energy, and Power Factor on its screen, providing the user with a clear view of their energy consumption. Additionally, the meter provides load management and protection against tampering. When the load is turned on, the LCD displays all the relevant parameters, including Voltage, Current, Power Factor, Power, and Energy. This information is crucial in helping users manage their energy usage more efficiently. The smart energy meter is also equipped with load management capabilities. If the consumer's load exceeds the maximum demand, the meter automatically sheds the load and sends an alert message to the LCD display.

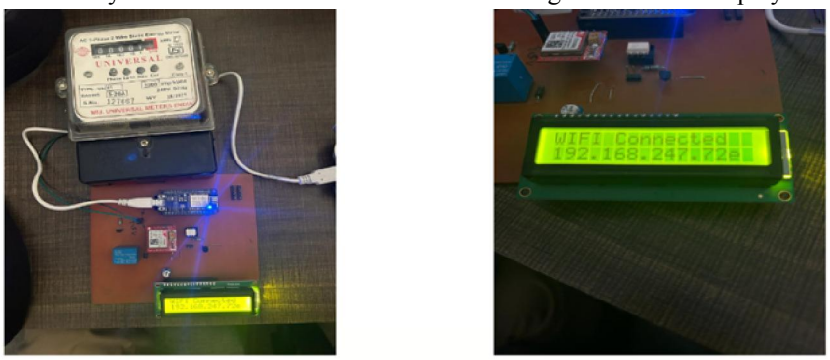

Fig 3. Energy Meter and LCD Display

This helps consumers limit their load and prevent wasteful energy consumption. The GSM module of the Arduino Smart Energy Meter sends energy and billing information at fixed intervals. In this study, the time interval was set to three minutes. During normal operating conditions, information about total energy consumption and billing is sent to the user's mobile phone via SMS. This helps consumers keep track of their energy usage and billing in real-time. If the consumer's load exceeds the maximum demand, an alert message is sent to their mobile phone, reminding them to limit their load. Additionally, if someone attempts to tamper with the meter by pulling off its casing, the meter automatically turns off the load and sends an alert message to the user's mobile phone.

The results of the study indicate that the Arduino based Smart Energy Meter is an effective solution for energy monitoring and billing. The system provides real-time data on energy consumption and billing, load management, and protection against tampering. The system can help consumers manage their energy usage more efficiently, reduce energy waste, and ultimately lower their electricity bills.

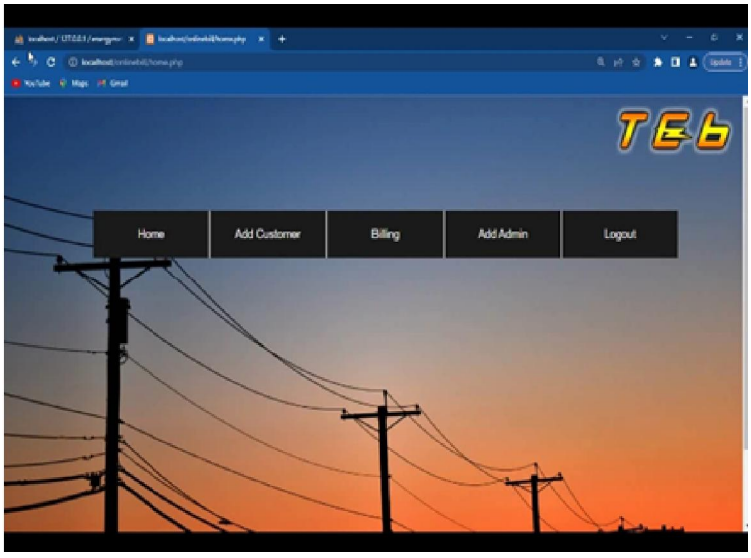

Fig 4. Webpage for user interaction

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The result of the Webpage for user interaction in Figure 4 is a user-friendly interface that provides various options to the user, including adding a new customer, managing billing information, adding an admin, and logging out of the system. The webpage is designed to facilitate the user's interaction with the system and ensure that they can access the necessary information quickly and easily.

The "Home" option on the webpage allows the user to return to the main page of the system, where they can view various system-related information such as energy consumption data and customer details.

The "Add Customer" option enables the user to add new customers to the system and input their details, including their name, address, and contact information. This feature ensures that the system can keep track of all customers and their associated billing information.

The "Billing" option on the webpage enables the user to manage the billing information for each customer. This feature allows the user to view billing statements, generate bills, and manage payments for each customer. The system automatically calculates the amount owed by each customer based on their energy consumption data, which is continuously monitored by the system.

The "Add Admin" option on the webpage is used to create a new system administrator, who will have access to all the features and functionalities of the system. This feature ensures that the system can be managed effectively by authorized personnel only.

Finally, the "Logout" option on the webpage allows the user to securely log out of the system. This feature ensures that the system remains secure and prevents unauthorized access to sensitive information.

Overall, the Webpage for user interaction provides a user-friendly interface that enables the user to interact with the system efficiently and effectively. The various options provided on the webpage ensure that the system can be managed and maintained easily, and that the user can access the necessary information quickly and securely.

V. DISCUSSION

The results of the study indicate that the proposed smart energy meter system has successfully achieved its objectives of providing accurate and real-time energy consumption and billing information to the consumers. The LCD display shows various parameters such as voltage, current, power, energy, and power factor, which are important indicators of energy consumption. Moreover, load management and protection against tampering are also provided by the smart energy meter. One of the key features of the smart energy meter is its load management capability, which is critical in ensuring that the energy distribution network is not overloaded. When the consumer load exceeds the maximum demand, the meter sheds the load and alerts the consumer through the LCD display and SMS notifications. This helps in preventing overloading and improving the efficiency of the energy distribution system. The GSM module is also an important component of the smart energy meter, as it enables the system to send energy and billing information to the consumers at regular intervals. The SMS notifications are sent to the consumer's mobile phone, providing them with real-time information about their energy consumption and billing status. Furthermore, the GSM module also sends alert messages to the consumer's mobile phone in case of load shedding and tampering, ensuring that the consumer is aware of any potential issues with their energy consumption.

Overall, the proposed smart energy meter system has several advantages over traditional energy meter systems, including increased accuracy, real-time information, load management capabilities, and protection against tampering. These features not only benefit the consumers but also the energy distribution network, as they help in reducing the likelihood of overloading and improving the overall efficiency of the energy distribution system. Future research could focus on further improving the system's accuracy and efficiency, as well as exploring additional features such as renewable energy integration and demand response management.

VI. CONCLUSION

In conclusion, the proposed system of an Arduino-based smart energy meter with IoT and GSM technology provides an efficient solution to the traditional energy billing and monitoring methods. The system is capable of displaying various parameters such as voltage, current, power, energy, and power factor on an LCD screen. Load management and protection against tampering are also provided by the system.

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The load shedding feature of the smart energy meter helps in reducing the overall energy consumption and preventing overload situations, which can lead to power outages. The GSM module sends energy and billing information to the consumer's mobile phone at a fixed interval, providing timely updates on their energy usage and billing. The use of IoT technology enables real-time communication between the energy meter and the web server, allowing for accurate monitoring and billing. The proposed system is highly efficient, reliable, and cost-effective compared to traditional energy metering methods. It can be easily implemented in households, industries, and other commercial areas.

Overall, the Arduino-based smart energy meter with IoT and GSM technology can provide a significant contribution to the energy conservation and billing practices, ensuring a sustainable and efficient energy usage in the future

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