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Design and Implementation of an Efficient Smart Digital Energy Meter

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Abstract*: This research discusses the development of digital prepaid energy meters for homes and businesses that utilise GSM technology. The reduction of billing cost and electricity wastage is the primary goal of prototype development. The GSM module is used to receive short messaging service (SMS) messages from the user's mobile phone, which automatically enables the controller to take any further action, such as helping the consumer save money by using prepaid energy meter systems offered by power generation and distribution companies. Embedded C is used to integrate the system's microcontroller and GSM network interface. The integration was carried out using Easy EDA software. When the balance on the energy meter falls too low, the system sends the consumer an SMS. Consumer research is then lacking, leaving power to. After receiving the SMS command, the Consumer then balances their investigation. Therefore, each item facilitates the usage of electrical power in homes and businesses. The prepaid energy meter is then turned ON or OFF by the microcontroller unit, which subsequently automatically controls the electrical power to homes and businesses. In other words, it responds to the message it receives by reading it from the cell phone and maintaining the equipment accordingly.

Keywords*: EDA software, Embedded C, GSM MODULE, Smart meter, SMS.

I. INTRODUCTION

The conventional method of electricity billing involves human intervention, which can often lead to inaccuracies and a time-consuming process for the distribution grid. Digital meters have been introduced to address this issue, but they are not foolproof, as false readings can still occur. To combat these issues, a new approach to electricity billing has A digital prepaid energy meter has been proposed. This system functions similarly to a mobile phone recharge card, where the consumer purchases a balance of energy units that decrease as energy is consumed. Once the balance reaches zero, the power supply is automatically cut off. The distribution unit can also control the amount deducted for every unit of energy consumed, allowing for more efficient energy management during peak hours. This research paper aims to investigate the implementation and effectiveness of digital prepaid energy meters within the context of contemporary energy management practices. The paper will examine the technical aspects of the technology and its social and economic implications for widespread adoption. Ultimately, the research seeks to shed light on the benefits and limitations of digital prepaid energy meters and their potential to revolutionize the way we consume and pay for electricity [1].

In the 21st century, there is little tolerance for errors or faults in any technical system or general application. To address this, the prepaid energy meter has emerged as a valuable concept. This technology simplifies the process of paying for electricity consumption by allowing users to pay in advance for their usage. Electricity coupons can be easily purchased at nearby shops and used to prepay for the ongoing electricity supply to homes, industries, and other establishments. The term "prepaid" means "pay before use," which is a key advantage of this system. By eliminating the need for post-payment, the prepaid energy meter provides a convenient and efficient way for consumers to manage their energy consumption and budget. This technology has the potential to revolutionize the energy sector and promote sustainable energy practices for the future [2].

A smart prepaid energy meter can provide real-time data on energy usage, allowing consumers to make more informed decisions about their energy consumption habits. This data can be accessed through a mobile app or web portal, making it easy for consumers to track their usage and costs. By encouraging customers to use energy at off-peak times when demand is lower, utilities may more effectively manage energy demand with a smart prepaid energy meter. This can reduce the demand for new power plants and alleviate system pressure during peak times. This can permit remote power disconnection and reconnection in the event of non-payment. By eliminating the need for human power disconnects and reconnects, this can increase safety and free up utility staff. A smart prepaid energy meter can enable time-of-use pricing, which charges different rates for electricity usage based on the time of day.

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This can incentivize consumers to shift their usage to off-peak hours and reduce strain on the grid during peak hours [3].

Overall, a smart prepaid energy meter has the potential to improve energy efficiency, reduce costs, and promote sustainability in the energy sector. As technology continues to advance, we can expect to see even more innovative applications and benefits of this technology in the future.

The digital prepaid energy meter is a device that detects and monitors current and voltage, automatically disconnecting the load if necessary. In this project, a microcontroller, such as an Arduino, with a UART circuit is connected to a GSM module that can send SMS messages to a mobile device, allowing the user to remotely control the electrical device. The microcontroller can decode incoming messages and switch the relays attached to its port to turn the appliance on or off. Once the operation is complete, the controller sends an acknowledgement to the user's mobile device via SMS. If the mobile number is unauthorized, the SMS will be ignored. Overall, this device provides a simple and efficient way to manage prepaid energy usage through remote control and monitoring. The system consists of four main parts: the microcontroller circuit (Arduino Nano), the GSM-based module, the Current Transformer circuit, and a mobile phone. This project utilised an Arduino Nano, a Sim800L GSM Module, and library software for programming. The purpose of this project is to prevent the express bus driver from driving over the permitted speed limit as well as to educate the driver to obey the regulation; therefore, the accident can be prevented [4].

II. EARLY RESEARCH

An Energy Meter is a device that measures the amount of electrical energy consumed by a home, business, or electrically powered device, typically measured in kilowatt-hours. This device measures the instantaneous voltage and current to calculate the instantaneous electrical power, which is then integrated over time to give the energy used. With a Prepaid Energy Meter, power utilities can collect electricity bills from consumers before they consume the electricity, as well as allowing for prepaid recharging and information exchange with the utilities. Metering plays a crucial role in modern life, typically involving four steps. Initially, a meter measures the amount of electricity that the consumer consumes.

Then, an individual captures an image of the meter for each user, and the computer system calculates the charges and distributes bills accordingly. However, meter reading collection, which involves visiting each house regularly, is a challenging task. This outdated method demands additional workers to revisit the homes frequently and takes longer to complete, especially when the collection is not finished during the workers' first visit. Additionally, human errors can affect the accuracy of this process. Therefore, there is a need for improvement to address these challenges. The current system involves installing an electronic or electromechanical meter on the premises to measure energy usage, but these meters can only record kWh units. To determine the amount owed, the recorded usage data must be linked to the account holder and processed by a meter reading company. This is typically done by having representatives of the electricity board manually read the meter every month at residential and commercial locations, recording the data on paper along with a snapshot of the meter. The data is then submitted to the local electricity board office, where officials read the snapshot and meter readings and input the information into software for bill calculations. The bills are then sent to consumers for payment. This process is time-consuming, requires many workers for frequent visits, and may lead to errors in data collection and processing. A real-time implementation of a GSM-based prepaid energy meter and control system using the "dribble home Mythology" approach could provide the benefits of maintaining uniformity. For mobile devices, a software operating system is used that includes a working framework, middleware, and crucial functions. We proposed a framework for improving the nation's nursery generation. The advancement of an integrated framework to automate the trickle treatment watering system in greenhouses is part of the proposed arrangement.

Electricity is one energy source that the populace is recklessly consuming in the twenty-first century. Energy, and if action is not taken early on, this supply of energy will be depleted quickly. While some people use it intentionally, others are unaware that someone else is using some of the electricity they are paying for. A new technique that will significantly cut down on the quantity of electricity used is being developed to stop this excessive use of electricity [5].

Energy meter for prepayment Control of Reading and Distribution primarily focused on measuring the power from the consumer side that they have utilized via GSM networks. A built-in system is designed to connect to an existing digital meter on the customer's end and set up GSM communication between the customer and the service provider. The proposed design is an improvement over the traditional energy reading system, enabling consumers to have control over their electricity usage. It is embedded with Arduino and GSM technologies. To prevent electricity theft, a prepaid energy meter was suggested in [3]. In this setup, a server is maintained at the service provider's end, while a smart energy meter equipped with a GSM module is deployed at the consumer's end. Discusses several prepaid energies in innovative metering methods.

With the help of this technology, users will be able to prepay for electricity and set the amount of electric energy they want to use in advance. Once the predetermined number of units of electricity has been consumed, the power will be turned off. This technology will not only relieve the burden on the populace to pay high amounts, but it will also lessen the load on the power grid [6]. Electric energy consumed by any appliance is measured by a device known as an electric energy meter. For a long time, the journey of the energy meter has begun. An electric meter, also known as an energy meter, is a device that measures the amount of electrical energy consumed in units of measurement. The most common unit of measurement for electricity is the kilowatt-hour [kWh], which is the quantity of energy consumed by a load of 1 kilowatt-hour over one hour. Energy meter systems are designed to ease or meet your specific requirements.

The use of an energy meter is not only beneficial for power supply companies but also for the ordinary person, who can accurately track the amount of units consumed and pay the corresponding amount. The use of electric meters started in the late 19th century, and it became increasingly important that an electric energy meter, similar to the then-existing gas meters, was required to keep users up to date with ongoing technologies and to establish an accurate billing system for customers, rather than charging the same amount from users every month.

Due to the wide range of technological development, the electronic world has played an increasingly important role. There is always a chance for technology to be high-speed, accurate, and user-friendly in various fields that require specialised expertise. Among the growing technologies is the pre-paid energy meter-based technology, which Thomas Edison invented. PRE-PAID ENERGY METER refers to the ease of human life. This feature allows users to select the amount of electricity they want to consume and then pay the corresponding amount in advance. They can then consume electricity accordingly. This technology can surpass current methods and processes for electricity bill payment. It can be implemented on a small scale, i.e., in the home, and on a large scale, i.e., in big industries as well. The pre-paid energy meter can stand on measures like safety, accuracy, environmental friendliness, etc. [7].

In distant locations where technological innovation is occurring at a rapid rate, the existing method of preparing electricity bill payments is laborious and time-consuming, with a slower tempo. Even the electricity provider faces several challenges in the current electricity distribution system, including meter tampering, late customer payments, electricity theft issues, and discrepancies between the amount of electricity generated and consumed. Many problems, including mechanical errors, human errors, incorrect meter photos, and obscured meter readings owing to dust and filth on energy meters, can be attributed to the flawed system. Prepaid energy bills are the solution to this problem. The real-time usage and consumption can be monitored through the automatic prepaid billing system. The automated prepaid billing system is capable of monitoring the actual consumption of time. The consumer has the option to recharge the system as needed. The goal of the project is to reduce customer wait times at the billing counters. The project also aims to provide a solution that will minimise revenue loss from power thefts and other unlawful activities, as well as losses incurred by the power transmission agency. With the use of GSM technology, customers can receive SMS updates on their power usage (measured in kW/hr), and when their balance drops below a certain point, an automatic reminder to recharge is sent. The outcomes offer constructive criticism and a clear picture of the project's potential future because the current billing system's shortcomings will be eliminated [8].

III. METHODOLOGY

The Electronic Prepaid Energy Meter can be fed as input to the Microcontroller ATMEGA328 after it has been recharged for a specific amount. The ATMEGA328 is configured so that when the recharge amount is depleted, the power supply will be shut off via a relay. A message regarding the units of power spent and their balance is sent to the customer via the GSM communication module. The LCD display is also used to show the balance amount.

A. Block Diagram of Smart Prepaid Energy Meter

The system was powered and run utilizing a variety of options, such as ensuring that the prepaid energy meter only starts when the prepaid meter has fallen below the threshold. The seven-segment display was also subjected to rigorous testing to ensure that the power unit's screen displayed the correct program, as shown in Fig. 1. Additionally, the sensors were evaluated. All of the findings, calculations, and pertinent comments will be presented in this chapter.

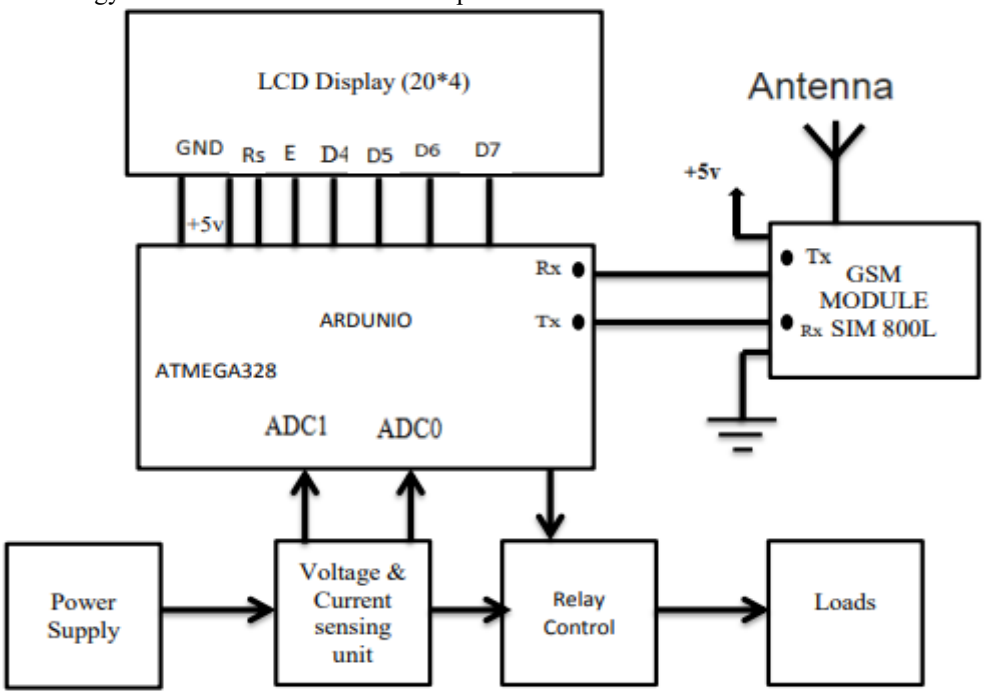

Fig. 1. Block Diagram GSM Based Prepaid Energy meter

B. Circuit Diagram of Smart Prepaid Energy Meter

The applications of GSM-based digital prepaid energy meters are pretty diverse. There are many real-life uses for the home and industry. In such cases, a wireless connection is a better option. Home and industrial appliance theft has been a major issue, as crime rates are decreasing, and everyone wants to take proper measures to address intrusion. Additionally, it is necessary to automate research on mobile phones. So that the user can take advantage of technological support. This project presents a model in Fig. 2 that will provide control to their company [9].

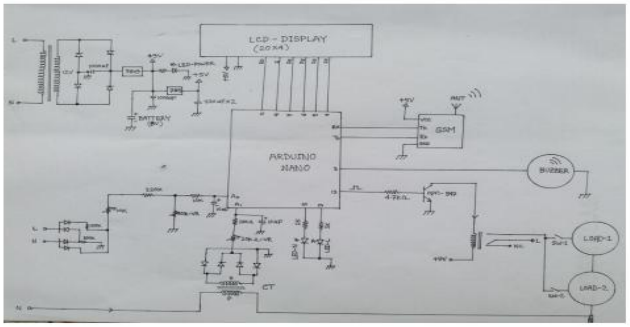

Fig. 2. Circuit Diagram of GSM-Based Prepaid Energy Meter

In this diagram, the prepaid energy meter and the utility company or service provider are connected via the GSM network. The microcontroller reads the SIM card, where the prepaid credit balance is stored. The primary control device that accepts input from the energy meter and transmits output signals to the relay or load is a microcontroller, such as an Arduino Uno. The microcontroller is programmed to perform several tasks, including managing the load, tracking the credit balance, and monitoring energy usage. The relay controls the load or real power supply to the home or company. It is linked to the energy meter and managed by the microcontroller, based on the remaining credit and the amount of energy used. The circuit's primary objective is to facilitate prepaid energy management by utilising a SIM card and GSM connectivity, thereby enabling remote monitoring, control, and invoicing of energy usage.

IV. RESULT ANALYSIS

There are numerous applications for GSM-based digital prepaid energy meters. The household and industries have a wide range of practical applications. A wireless connection is a superior choice in these circumstances. Appliances in homes and businesses have been a big problem. If there is a decline in crime, everyone wants to take appropriate action to prevent further incursion. Additionally, research on mobile phone automation is necessary. To enable users to benefit from technological assistance, this project provides a strategy that will give their business control.

A. Implemented Prototype and Output Result

The circuit schematic connected all of the parts. The hardware connection and the output are displayed in Fig. 3 below.

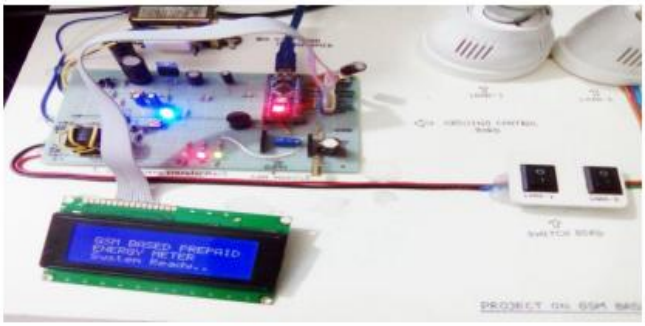

Fig. 3. GSM base prepaid energy meter system

The power supply is connected to the device, and the GSM base prepaid energy meter system is now ready.

The GSM-based prepaid energy meter system enables convenient and efficient management of electricity usage. With this system, users can easily monitor their energy consumption and purchase credits to keep their devices powered. The system also provides real-time data on energy usage, enabling users to make informed decisions about their energy consumption and adjust their usage habits as needed. This technology helps promote energy conservation and sustainability, while also providing a reliable and affordable energy source for users.

Fig. 4. No load shows the balance

Load balance is a critical aspect of many industries, particularly in manufacturing and construction, where heavy equipment and machinery can put excessive strain on workers. However, load balance is not always visible when taking a load, as it is often determined by a variety of factors that can be difficult to assess accurately, as shown in Fig. 4.

Fig. 5. Meter with active load

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When the balance is high load is active "when the user's account balance for the meter is high, the load (i.e. the amount of electricity consumed) is active as Fig. 5. In other words, when the user has sufficient credit on their account, the energy supply to their household or business will be turned on. This could be a feature of the smart meter's programming designed to ensure the user has sufficient credit to cover their electricity consumption and avoid the inconvenience of a power outage due to insufficient funds. When the balance on the prepaid account is low, the load may be automatically disconnected to prevent the user from using more electricity than they can afford. It's important to note that the exact workings of prepaid smart energy meters may vary depending on the specific device and service provider.

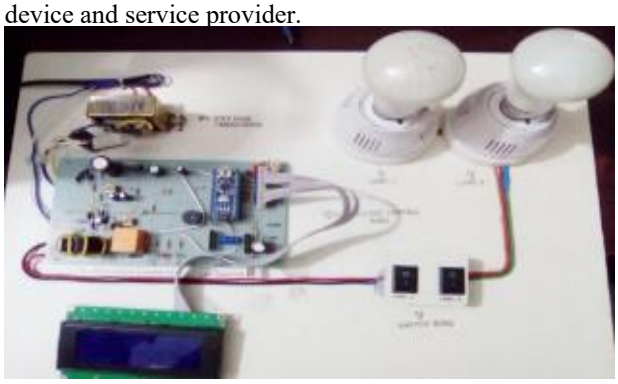

Fig. 6. Meter with empty balance

If the balance empty light is off in a smart prepaid energy meter, it means that there is sufficient balance in the meter to continue using electricity. The balance is usually an indicator that the prepaid balance has reached a certain low threshold. It serves as a warning to the customer to recharge the meter to avoid a power outage as showing in Fig. 6. However, if the balance empty light is off, it could mean that the meter has not reached the low threshold yet or that the customer has recently recharged the meter with enough credit to last for some time. It's essential to note that different smart prepaid energy meters may have slightly different indicators or lights. Therefore, it's always advisable to refer to the user manual or contact the energy provider for more information on how to interpret the meter's readings. The prepaid energy meter has received a recharge or credit top-up, which will be utilised to supply electricity to the home or business, according to the balance recharge light. When the recharge light is on, the

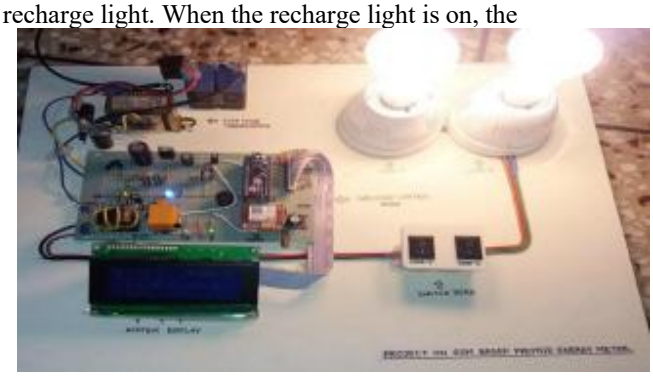

Fig. 7. When the Balances recharge, Light ON

The meter is now prepared to start resupplying electricity, as the fresh credit has been added to the account, as shown in Fig. 7. Typically, credit is added to the account by purchasing a recharge voucher or using an online payment method. The balance recharge light will turn on once the credit has been added, signalling that the meter has received the new credit and is prepared to start dispensing electricity. It's crucial to keep in mind that depending on the specific balance, the recharge light may potentially have different names or signs.

V. CONCLUSION

The monopolistic power distribution market in Asia is gradually transforming into a competitive marketplace. Differentiation in service will be the key competitive factor in improving market share in deregulated power markets. Prepaid meters, with their advantages over conventional ones, are likely to help power distributors differentiate and offer value–added services to consumers. Encouraging consumers to opt for prepaid meters voluntarily and offering tariff or non-tariff incentives to those who prepay their power would help utilities implement this system. In addition to providing an opportunity for power distributors to differentiate themselves in a competitive market, prepaid meters also offer benefits to consumers. By allowing consumers to pay for electricity in advance, prepaid meters provide greater control over electricity usage, enabling consumers to manage their energy consumption more effectively. Prepaid meters can also reduce the risk of bill shock, as consumers can monitor their energy usage in real-time and top up their accounts as needed. Furthermore, prepaid meters can reduce the administrative burden of billing and payment processing for both power distributors and consumers. As such, the adoption of prepaid meters is likely to increase as more consumers become aware of their benefits

DECLARATION

We thus certify that this research article, "Design and Implementation of an Efficient Smart Digital Energy Meter," is our original work and has not been previously published. All information sources utilised in this research have been appropriately acknowledged and cited in the reference list. We confirm that this study was conducted ethically and in compliance with all applicable laws and regulations. We obtained informed consent from all study participants, and all data gathered were handled discreetly and strictly for research purposes. Yet, we have worked hard to reduce these constraints by careful data collection, analysis, and interpretation. Lastly, we acknowledge that any errors or omissions in this work are entirely our responsibility, and we accept full responsibility for its content. References.

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Availability of Data and Material/ Data Access Statement	Not relevant
Authors Contributions	All authors have equal participation in this article.

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