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Smart Electricity Billing System Using IOT

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ABSTRACT—

This paper presents the development of a prepaid energy meter system tailored for digital meters, leveraging an Arduino microcontroller and a GSM module. The system innovatively adapts the concept of prepaid mobile phone services to electricity management. Users can conveniently recharge the meter balance, with the system seamlessly monitoring energy usage and issuing SMS alerts for low balance, disconnection due to depleted balance, reconnection upon recharge, and reminders for potential recharges. Central to the system is the integration of a standard digital electricity meter with the Arduino platform. An optocoupler serves to isolate the Arduino's digital input from the meter's pulse output, typically indicated by an LED. This pulse signal acts as a basis for accurate energy consumption computations. Furthermore, the inclusion of a GSM module enables bidirectional communication between the system and the user's mobile device for balance updates and remote control functionalities. The paper elaborates on the selection of components, encompassing hardware choices, circuit diagrams, and Arduino details. With its emphasis on affordability and user-friendliness, this design offers a practical solution for managing electricity consumption, fostering responsible energy usage, and potentially streamlining billing procedures. Along with detecting fire and object for the safety of energy meter.

Keywords—Energy meter, Arduino UNO, GSM module, Relay module, Electricity billing.

I. INTRODUCTION

With the increasing need for better ways to manage electricity, there's been a push for smarter energy meters. The old way of paying for electricity after using it doesn't always give us real-time information or control. This paper suggests a new type of digital energy meter that works like prepaid mobile phones, using Arduino microcontrollers and GSM modules.

This prepaid system lets users control their electricity usage by adding money to their meter in advance. As long as there's money in the meter, they can use electricity. The system keeps track of usage and sends text messages to users to keep them updated. These messages warn about low balance, power being cut off when the balance hits zero, power coming back on after a recharge, and reminders to top up.

The main part of this system involves connecting a electricity meter to the Arduino using an optocoupler. This ensures safe communication between the digital parts of the system and the meter. The meter sends pulses that help calculate energy use. Plus, a GSM module lets the system talk to the user's phone, sending updates about balance and allowing remote control.

The rest of this paper goes into more detail about how the system works. We talk about the different parts needed and why we chose them. We also show how everything is connected electrically and explain the software that makes the meter run. Overall, this prepaid energy meter offers an easy and affordable way for people to manage their electricity, promoting responsible usage and making billing simpler for everyone involved.

II. LITERATURE REVIEW

Several research projects have explored the design of prepaid energy meter systems using microcontrollers and GSM modules. One such project, outlines a system built with an Arduino Uno, a SIM800C GSM module, and an optocoupler to interface with a commercial electricity meter's pulse output. This system credits users with a pre-defined amount and decrements the credit based on energy consumption measured by the pulse output. When the credit falls below a threshold, the system sends an SMS notification and can potentially disconnect power. This project demonstrates the feasibility of using affordable and accessible components to create a basic prepaid energy meter system[2].

Studies have shown successful deployments of prepaid metering systems across various regions globally, emphasizing their role in enhancing energy management, improving revenue collection, and reducing energy theft. These meters offer advantages for both consumers and utility providers, including

real-time consumption feedback, energy conservation, cost savings, and operational efficiencies[1]. However, challenges such as technical reliability, regulatory compliance, affordability, and social equity need to be addressed to ensure the widespread acceptance and equitable access to prepaid metering systems. Additionally, research has examined the socio-economic impacts of prepaid metering on vulnerable populations and emphasized the importance of transparent pricing mechanisms and regulatory safeguards to protect consumers. In conclusion, while prepaid energy meters hold promise as a transformative technology in the electricity sector, further research is needed to address existing challenges and understand their long-term implications on energy access, affordability, and sustainability.

III. SYSTEM COMPONENTS

•Arduino Uno Microcontroller:

Arduino is an open-source electronics platform based on easy-to-use hardware and software[3]. The Arduino Uno serves as the brain of this prepaid energy meter system. It reads the pulse output from a commercial electricity meter using an optocoupler for electrical isolation. The Arduino program interprets these pulses to calculate energy consumption and manages the user's credit balance. Additionally, the Arduino can interface with a GSM/GPRS module for SMS notifications and potential remote control functionalities. This versatile microcontroller provides a user-friendly and cost-effective platform for implementing the prepaid energy meter's core logic and communication..

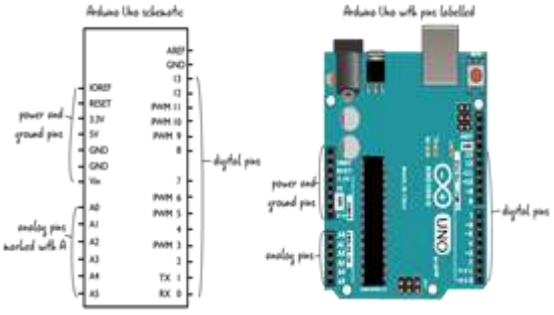

Fig 1: Pin diagram of Arduino uno

• LCD:

Integrating a 16x2 Liquid Crystal Display (LCD) enhances the user experience and functionality of the prepaid energy meter system. This readily available and cost-effective display provides a clear visual interface for users to interact with the system. The Arduino can be programmed to transmit relevant information to the LCD, such as current credit balance, remaining energy units, and potential warning messages for low credit. Users can easily monitor their energy consumption and receive timely notifications without relying solely on SMS alerts. The 16x2 LCD offers two rows of 16 characters, enabling the display of essential data in a compact and readable format. Furthermore, the low power consumption of most 16x2 LCDs makes them suitable for battery-powered applications or integration with the microcontroller's power supply. By incorporating a 16x2 LCD, the prepaid energy meter becomes more user-friendly, promoting transparency and informed energy management for consumers.

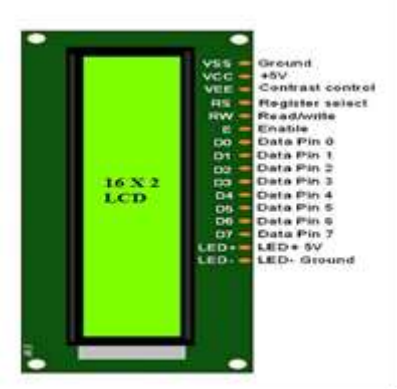

Fig 2: Liquid Crystal Display

• GSM Module:

The GSM/GPRS module serves as the communication backbone of the prepaid energy meter system, enabling remote interaction and user notifications. In this project, a SIM800C module or its functional equivalent is a suitable choice. This module provides cellular network connectivity, allowing the system to send SMS messages to a designated phone number. SMS notifications can be critical for alerting users about low credit balances before power shutoff or for providing meter readings upon request. Additionally, GSM modules with GPRS capabilities could potentially be explored for future upgrades, enabling remote monitoring of the energy meter's data (consumption history, credit status) through a web-based interface or mobile application.

The GSM module, therefore, plays a vital role in enhancing the user experience and functionality of the prepaid energy meter system by providing remote communication capabilities.

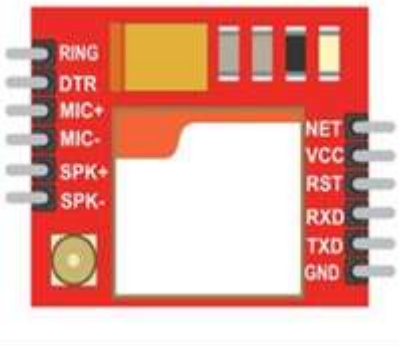

Fig 3: GSM Module

- **IR Sensor for object detection:**

Infrared (IR) sensors detect objects by measuring the reflection or interruption of emitted infrared radiation. Passive Infrared (PIR) sensors sense changes in emitted IR radiation, ideal for motion detection in security systems. Active IR sensors emit IR radiation and detect its reflection, used in proximity sensing and object detection. Infrared distance sensors measure the time taken for IR beams to reflect off objects, determining distances. These sensors find applications in security, automation, robotics, and industrial processes.

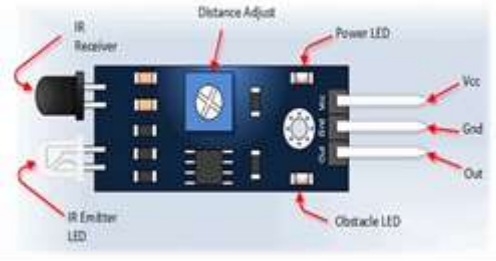

Fig 3: IR Sensor for object detection

• Flame Sensor:

A flame sensor is a device that detects the presence of a flame or fire by sensing the infrared radiation emitted by the flames. It typically consists of a sensor element that detects infrared light and a circuit that processes the signal. Flame sensors are commonly used in fire detection and suppression systems, as well as in gas appliances like furnaces and water heaters to ensure safe operation by shutting off the gas supply in the presence of a flame failure.

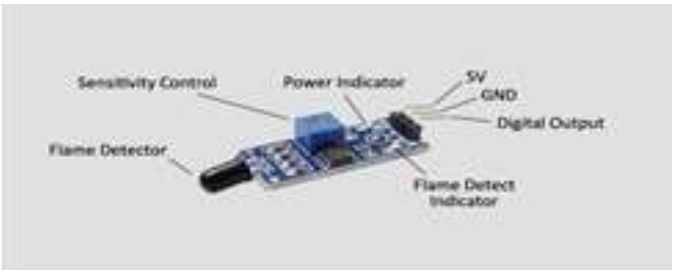

Fig 3: Flame Sensor

- **RFID-RC522:**

The RFID-RC522 is a popular RFID (Radio-Frequency Identification) module used for wireless communication. It operates at 13.56 MHz frequency and interfaces with microcontrollers via SPI (Serial Peripheral Interface). The module consists of an RFID reader, an antenna, and a control circuitry. It can read and write RFID tags/cards, facilitating contactless data exchange. Commonly employed in access control systems, inventory management, and electronic payment systems, it offers a cost-effective solution for various identification applications.

Fig 3: RFID-RC522

IV.SYSTEM CONSTRUCTION

The prepaid energy meter system construction follows a modular approach, integrating readily available components for ease of assembly and scalability. Here's a breakdown of the process:

Hardware Assembly:

- The core of the system is an Arduino Uno microcontroller, which serves as the processing unit.
- A SIM800C GSM/GPRS module (or compatible model) enables communication for SMS notifications and potential remote functionalities.
- An optocoupler provides crucial electrical isolation between the Arduino's low-voltage control circuit and the potentially high-voltage pulse output from the commercial electricity meter.
- During the initial development and testing phase, a breadboard facilitates easy component connection using jumper wires. For a more permanent setup, Dupont connectors offer reliable connections.
- The system requires a 5V DC power supply to operate the Arduino and GSM module.
- An activated SIM card with a data plan is necessary for SMS communication.

Interfacing with the Electricity Meter:

- Access to a commercial electricity meter with a readily accessible pulse output is essential. Consulting local regulations and obtaining necessary permissions might be required for meter access and data collection.

Software Development:

- The Arduino IDE software environment is used to program the Arduino Uno. The program logic should.
- Read the pulse output from the electricity meter using the optocoupler.
- Calculate energy consumption based on the number of pulses and pre-defined calibration factors.
- Manage the user's credit balance, decrementing it based on calculated consumption.
- Interface with the GSM module for SMS notifications upon low credit or other relevant events.

Testing and Deployment:

- Thorough testing on a breadboard is crucial to ensure proper functionality and communication between all components.
- Once verified, the system can be transferred to a more permanent enclosure for deployment.

This modular approach allows for customization based on specific project needs. Additional components, such as a current sensor for more precise energy measurement or an LCD display for user interface, can be integrated for enhanced functionality.

V. WORKING

The prepaid energy meter system operates as a mechanism for pre-paying electricity consumption, providing users with control and transparency over their energy usage. Below is a detailed breakdown of its key functionalities:

Pulse Reading and Energy Calculation:

The system interfaces with a commercial electricity meter's pulse output through an optocoupler, ensuring electrical isolation for safety. Each pulse corresponds to a specific amount of energy consumed, typically measured in watt-hours. By programming the Arduino to read these pulses and maintain a count, the system accurately calculates the total energy consumption. This calculation relies on a pre-defined calibration factor, which accounts for the specific pulse-to-energy ratio of the meter.

Credit Management and User Interaction:

Initially, the system is loaded with a predetermined credit value, representing the user's prepaid electricity quota. As energy is consumed, reflected by the pulse count, the program automatically deducts the corresponding amount from the user's credit balance. Deductions can follow a fixed rate per pulse or a tiered pricing structure, depending on the project's design. For user convenience, an optional LCD display can be incorporated to showcase the remaining credit balance or provide energy consumption details.

Alerting and Communication:

Utilizing the GSM module, the system enables communication functionalities. Configurable SMS notifications can be sent to a designated phone number when the credit balance reaches low thresholds, prompting users to recharge before service interruption. Additional SMS alerts, such as notifications for power shutoff due to depleted credit, can be implemented depending on project requirements.

Power Control:

Certain project variations may include an automatic power shutoff feature. When the credit balance drops below a critical level, the Arduino program can activate a relay module to physically disconnect the power supply to the load. This ensures that users cannot consume electricity beyond their prepaid credit, promoting responsible usage.

Recharging and System Reset:

The method for recharging the prepaid balance may vary based on project specifications. Options include sending a top-up SMS with a specific code or utilizing a separate user interface if provided. Upon successful recharge, the system updates the user's credit balance, potentially resetting any power shutoff conditions.

In summary, this prepaid energy meter system offers users a manageable and self-regulated approach to electricity consumption, encouraging responsible usage habits and facilitating timely recharges.

Detecting and alerting fire:

An IR fire sensor, also known as an infrared flame detector, is a crucial component integrated into an energy meter to detect signs of fire or overheating. This sensor operates by detecting the infrared radiation emitted by flames or high temperatures associated with fire incidents. When installed within the energy meter, the IR fire sensor continuously monitors the surrounding environment for any abnormal increases in temperature beyond preset thresholds. Upon detecting such a temperature rise indicative of a potential fire event, the sensor promptly triggers an alarm signal within the energy meter's control system.

Detecting and alerting motion:

The IR object detection sensor serves as a crucial component for detecting any motion in the vicinity of the energy meter. Integrated into the system, the IR sensor continuously monitors the surrounding area for changes in infrared radiation, typically emitted by objects in motion. When the sensor detects movement, indicating potential unauthorized access or tampering with the energy meter, it triggers an alert mechanism programmed within the system. This alert mechanism is configured to send SMS notifications to the consumer's designated phone number, promptly informing them of the detected motion event. Through this real-time communication, consumers are immediately made aware of any suspicious activity involving their energy meter, empowering them to take necessary actions, such as contacting authorities or investigating the situation further. By incorporating the IR object detection sensor and SMS alerting feature, the prepaid energy meter system enhances security measures, providing consumers with peace of mind and control over the integrity of their energy usage infrastructure.

The complete work flow of the system is represented in the below figure.

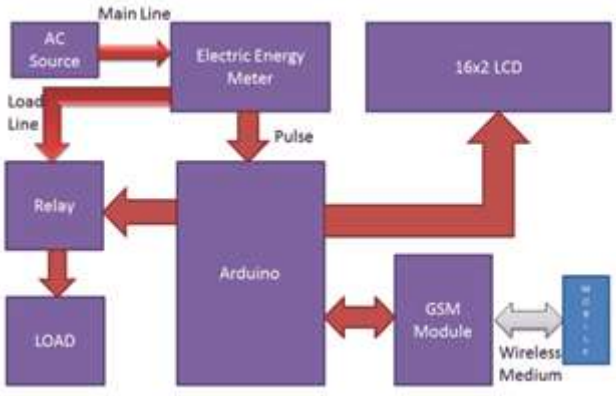

Fig 5: Block diagram of the system

VI. ADVANTAGES

A prepaid energy meter system constructed with Arduino and GSM technology offers several advantages over traditional postpaid billing methods for electricity consumption. Here's a breakdown of its key benefits:

- **Increased User Control and Budgeting:**

Users gain greater control over their electricity usage by pre-paying for their desired consumption. Real-time monitoring of the remaining credit balance allows for informed budgeting and adjustments in energy consumption habits. This empowers users to avoid unexpected high bills often associated with postpaid systems.

- **Improved Transparency and Reduced Disputes:**

Prepaid billing eliminates discrepancies and disputes that can arise with estimated billing practices. Users only pay for the electricity they consume, fostering transparency and trust in the billing system.

- **Potential for Reduced Energy Consumption:**

The system's real-time feedback on remaining credit can incentivize users to be more mindful of their energy consumption[5]. This awareness can lead to behavioral changes, such as switching off appliances when not in use, potentially resulting in reduced overall energy usage.

- **Enhanced Revenue Collection for Utility Providers:**

For utility providers implementing such systems, prepayment ensures upfront collection of revenue, potentially improving cash flow and reducing bad debt.

- **Scalability and Customization:**

The modular design of Arduino-based systems allows for easy customization and future expansion. Additional functionalities, such as remote meter reading or integration with smart grids (depending on project complexity), can be incorporated as needed.

- **User-Friendly Interface and Potential for Automation:**

The system can be designed with user-friendly interfaces (like LCD displays) for easy monitoring and interaction. SMS notifications for low credit and potential automation features (like automatic power shutoff) can further enhance user experience.

- **Affordable and Accessible Technology:**

The use of Arduino and GSM modules leverages readily available and relatively affordable technologies. This makes the system a potentially cost-effective solution for implementing prepaid energy metering in various contexts.

- **Fire Detection:**

This proactive approach to fire detection helps prevent potential damages, injuries, or even fatalities, safeguarding both property and lives.

- **Object Detection:**

This capability empowers users to respond swiftly to suspicious activities, preventing potential theft, vandalism, or unauthorized usage of electricity.

VII.CONCLUSION

In conclusion, the paper presented the design and development of a prepaid energy meter system utilizing Arduino and GSM technology. The system effectively interfaces with a commercial electricity meter's pulse output, enabling real-time energy consumption monitoring and credit management[4]. The core functionalities of pulse reading, energy calculation, credit deduction, and user communication ensure a robust pre-payment mechanism for electricity usage. The modular design leverages readily available and affordable components, making the system a potentially cost-effective solution for various applications.

The implementation of this prepaid energy meter system offers several advantages. Users benefit from increased control over their electricity consumption and budgeting, fostered by real-time credit balance monitoring and transparent billing practices. Furthermore, the system has the potential to encourage responsible energy use through user awareness. Additionally, for utility providers, the system can streamline revenue collection and potentially reduce bad debt.

Looking forward, future advancements could explore the integration of more sophisticated features, such as remote meter reading, integration with smart grids, and advanced user interfaces. By continuously refining and expanding functionalities, prepaid energy meter systems using Arduino and GSM technology hold promise for revolutionizing energy management practices, promoting responsible consumption, and fostering a more sustainable energy future.

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