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Smart Energy Meter

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ABSTRACT: The primary objective of this project is to develop a cost-effective and reliable solution that enables users to prepay for electricity consumption and receive real-time feedback about their usage. The smart energy meter is designed to record the amount of energy consumed by the load, in this case, a bulb, and compare it against the user's prepaid balance. The energy consumption data is acquired through the 220V AC meter, which measures the load's power usage. The data is isolated using a 4N35 optocoupler for safety and signal integrity, and then processed by the Arduino Nano. This project is aimed at providing a practical solution for rural and urban users who wish to control their electricity consumption while avoiding unexpected billing and overconsumption. It also has potential applications in smart homes, small industries, and institutions where automated energy monitoring is required.

The results from this implementation demonstrate the feasibility of developing an intelligent prepaid energy meter system that is both economical and easy to operate, ensuring better energy management, improved user experience, and enhanced safety.

KEYWORDS: Arduino Nano, 16x2 LCD Display, 4N35 Optocoupler, GSM Module.

I. INTRODUCTION

The demand for efficient energy management systems is growing rapidly as the consumption of electricity increases in households, commercial buildings, and industries. With rising energy costs, power theft, and lack of consumer awareness, managing electricity consumption has become a significant concern. Traditional energy meters, which merely record the consumed electricity for billing at the end of the month, often lead to billing disputes, delays, and misuse. To address these challenges, **Smart energy meters** offer a modern and effective solution that allows users to control their energy consumption by paying in advance and receiving continuous updates on their usage. The **Smart Energy Meter** developed in this project is a cost-effective system designed using an **Arduino Nano** as the core controller. The system measures electricity consumption through a **220V AC meter**, processes the data using a **4N35 optocoupler** for safe signal isolation, and communicates the information to the user via a **16x2 LCD display with I2C interface**. The **GSM 800L module** is integrated to provide remote notifications and alerts, while a **5V single-channel relay** is used to control the electrical load depending on the available prepaid balance. A **5V buzzer** is incorporated to alert users when the balance reaches a critical point. Additional components such as a **1k resistor**, **AC bulb with holder**, and other interfacing circuits ensure stable and safe operation. The system's software is developed using the **Arduino IDE**, and the code is written in **C language**, providing modular, easy-to-read, and scalable architecture. The implementation focuses on real-time monitoring, quick communication, and load management, ensuring that electricity usage is tracked effectively, and users are informed of their energy consumption and remaining balance. This project is aimed at empowering users with better control over their energy consumption, preventing overuse, and reducing disputes related to billing. It also helps create awareness about electricity conservation and efficient usage.

II. FEATURES OF SMART ENERGY METER

The smart energy meter offers several features, which make it a practical solution for both urban and rural users:

Cost Control:

Users can only consume electricity based on their prepaid balance, preventing overspending and helping manage monthly expenses more effectively.

Real-time Consumption Tracking:

The **16×2 LCD with I2C interface** displays live data such as energy consumed, remaining balance, and status alerts, providing users with complete visibility.

Remote Communication:

With the integration of the **GSM 800L module**, users receive SMS alerts about their balance status and consumption patterns, allowing for timely recharge and usage control.

Safety:

The use of a **4N35 optocoupler** ensures signal isolation between the high-voltage AC load and the low voltage control circuitry, protecting users from electrical hazards.

Automatic Load Control:

The **5V single-channel relay** disconnects the load when the balance is exhausted, reducing wastage and preventing unauthorized consumption.

Alerts and Notifications:

The **5V buzzer** provides audible warnings when the balance is low, ensuring users are informed before supply disruption occurs.

Scalability and Adaptability:

The system's modular architecture allows for easy integration with other appliances and expansion to multi load systems.

Environmentally Friendly:

By promoting controlled usage, the system helps reduce unnecessary energy consumption, contributing to environmental sustainability.

III. CONCEPT

The primary Concept of this project are:

Design a Cost-effective Energy Meter:

Utilize affordable components such as Arduino Nano and standard communication modules to create a smart prepaid energy meter.

Implement Real-time Energy Monitoring:

Measure energy consumption using a **220V AC meter** and display it continuously on the **LCD screen**, ensuring users are aware of their usage.

Integrate Remote Alerts and Notifications:

Use the **GSM 800L module** to send SMS alerts regarding the user's consumption and prepaid balance status.

Enhance Safety and Isolation:

Incorporate a **4N35 optocoupler** to isolate the high-voltage AC system from the control circuitry, ensuring user safety and circuit reliability.

Provide Automated Load Control:

Use the **5V relay** to automatically disconnect the load once the prepaid balance is exhausted, preventing unnecessary power usage.

Create a Scalable and Modular System:

Design the system architecture in a way that allows easy upgrades and integration with additional appliances.

Encourage Responsible Energy Usage:

Help users reduce wastage and plan their consumption efficiently by providing alerts and visual feedback.

Develop a Practical Educational Tool:

Offer students and practitioners a hands-on experience in embedded systems, communication protocols, and power electronics.

IV. OVERALL WORKING OF THE SYSTEM**The operational process of the smart energy meter involves several key stages:**

1.Power Supply: A regulated 5V DC supply is used to power the Arduino Nano, LCD display, GSM module, relay, and buzzer. The AC section, including the energy meter and the load, operates at 220V AC, with proper insulation and isolation provided by the optocoupler.

2.Energy Meter Connection: The 220V AC meter is connected in series with the AC bulb to measure the energy consumption. The output pulse of the meter is fed through the **4N35 optocoupler** to ensure electrical isolation before reaching the Arduino Nano.

3.Arduino Nano: The input pin of the Arduino Nano receives pulse signals from the optocoupler circuit. Output pins are connected to the LCD display via I2C lines, the buzzer for alerts, the relay for load control, and the GSM module for communication.

4. 16×2 LCD Display with I2C: The display module is connected using the I2C protocol, requiring only two communication lines (SDA and SCL). It shows energy consumption, available balance, and warnings regarding recharge requirements.

5. 5V Buzzer: Connected to a digital output of the Arduino Nano, the buzzer provides audible warnings when the balance is low.

6. GSM 800L Module: Connected to the Arduino using Software Serial communication. It is powered with the correct voltage and sends SMS alerts when the balance reaches a critical threshold or is depleted.

7. 5V Relay Module: Controlled by the Arduino Nano, it switches the AC load (bulb) ON or OFF depending on the balance. The relay provides safe isolation between the low-voltage control circuit and the high-voltage AC supply.

8. AC Bulb and Holder: Acts as the load whose energy consumption is monitored. Connected to the relay output, allowing controlled power supply based on the prepaid balance.

V. FUTURE SCOPE OF SMART ENERGY METER**Adding Mobile App Integration**

– Users can monitor and recharge their balance through a smartphone app.

Adding Support for Multiple Loads

– The system can be extended to control and monitor several devices at once.

Including Solar Power Monitoring

– It can be integrated with solar panels to track renewable energy usage.

Improving Security Features

– Adding password protection and advanced encryption can make the system more secure.

Cloud Data Storage

– Storing energy usage data online will help in analyzing and optimizing consumption patterns. These improvements will make the system even more useful, efficient, and user-friendly.

VI. CONCLUSION

In this project, we successfully designed and implemented a **Smart Energy Meter** using **Arduino Nano**, **LCD display**, **GSM module**, **relay**, and other necessary components. The system accurately measured energy consumption, updated the balance in real time, and provided alerts using a buzzer and SMS when the balance was low. The load was safely disconnected when the balance became zero, preventing unauthorized electricity usage.

The project met all its objectives, and the testing results showed that it works reliably and safely. The use of isolation components like the **4N35 optocoupler** ensured user safety, and the system was easy to operate through the LCD and GSM communication.

This project can be used in homes and small businesses where controlling electricity usage and avoiding high bills is important.

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