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IoT Applications for Meter Security and Energy Efficiency in Smart Grids

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Abstract

This research aims to address the drawbacks of conventional energy billing systems by introducing an affordable Prepaid Energy Meter that uses an ATmega328 microprocessor. The discreteness, inaccuracy, high cost, and sluggish processing of the current systems result in inefficiencies in both labor and time. The susceptibility of traditional invoicing techniques to energy and power theft is a serious problem. By operating under the tenet of "Pay first and then use it," the proposed prepaid energy meter reduces the possibility of theft. Furthermore, it completely eliminates the necessity for manual readings by drastically reducing the human error rate connected with them. Prepaid energy meters come with a GSM module that can be used to recharge them in different denominations (like Rs. 50, Rs. 100, Rs. 200, etc.). Based on power consumption, the system dynamically modifies the remaining electrical units. An LDR (light dependent resistor) sensor and DHT11 are integrated to prioritize load management while accounting for environmental variables. The remaining electrical units are shown on the LCD. When the recharge amount is exhausted, a relay mechanism is put in place to cut off the energy meter and related load from the mains supply, prohibiting illegal consumption. To improve the physical security of the metering system, an infrared sensor is used.

Keywords: Meter security, Internet of Things(IoT), smart grids, energy efficiency, microcontroller.

INTRODUCTION

One of the most important challenges facing electricity businesses today is the connecting of devices in electrical networks to facilitate data sharing. First, because it will improve the infrastructure's self-awareness through ongoing data monitoring. Conversely,on the other hand, due to the fact that European and national rules have greatly pushed businesses to modernize their systems in order to increase the efficiency of their energy use. The new infrastructure, commonly referred to as the "Smart Grid," integrates the latest developments in information and communication technologies with electric engineering. A more unified and straightforward system for managing and controlling the electrical grid—which includes generation, transmission, distribution, storage, and trade—will be achieved through the use of smart grid technology [13].

This new way of thinking considers a crucial component of energy production. The quantity and diversity of energy producers has expanded due to the growing popularity of solar facilities and other energy systems; customers are now regarded to be producers as well as consumers. This would mean delivering energy more cheaply and with fewer damaging pollutants.

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Furthermore, real-time energy data have benefits for both energy companies and consumers. On the one hand, customers may implement new consumption techniques since they would be conscious of how much energy they were using. Conversely, energy providers would deduce patterns of use and forecast requirements and possible activity peaks in order to establish suitable energy plans and the most competitive rates. Since they can measure energy consumption in much more detail than a conventional meter (fine-grained accurate readings) and because they can communicate this information back to the provider as well as to other devices or applications in the so-called smart home, smart meters can be viewed as one of the key components of the Smart Grid in this context. [1] offers a comprehensive overview of the development of smart meters, including information on their features, uses, and associated technologies in addition to the various ways in which these devices, which link the Home Area Network (HAN) and the Neighbourhood Area Network (NAN), can be solved. Generally speaking, the Meter Data Management System (MDMS), concentrators or collectors, and smart meters make up this Advance Metering Infrastructure (AMI). In addition, pertinent data like permission levels and the keys and passwords needed for safe communication are stored by smart meters. In essence, the MDMS is a database that holds all of the massive amounts of event and data associated with smart meters and concentrators, ready for analysis. In order for the smart meters to respond to remote commands as a result of the energy readings, AMI also facilitates communication between the smart meters and the energy provider. AMI has led to an increase in privacy concerns because of the flow of sensitive information [2]. According to certain research, for example, power consumption patterns may provide specific details about householders, such as the number of family members living there, their eating and sleeping schedules, and other habits [3, 4]. In an attempt to lessen these issues, other methods have surfaced, such as reviewing the many applications of metering data and the associated privacy laws [5] and suggesting solutions such data anonymization [6] or lowering the quantity of data needed for certain applications [7]. The development of energy meter technology has advanced significantly with the introduction of prepaid power meters. The current energy meters have not lived up to the expectations set for them, even after multiple attempts in the past to enhance billing techniques. Meeting the demand for energy has grown more difficult due to a rising number of energy customers. Time-consuming and labor-intensive, traditional manual meter reading and billing procedures are especially problematic when customers are not home. When customers fail to pay their bills on time, service staff are forced to make follow-up visits, which exacerbates the inefficiency. Furthermore, manual operators frequently have trouble spotting instances of tampering with the power supply or meter readings, as well as unauthorized connections [9].

Older energy meters used smart card technology, which had drawbacks such as requiring computer interfaces and internet connectivity to function. In response, we provide a solution that gets beyond these limitations by utilizing GSM network technology. The energy meter and the service provider can communicate easily and without the need for internet access when a Prepaid Energy Meter system is integrated with GSM. The system consists of an Energy Meter and a GSM modem that notifies users to low balances and provides recharge information.

The solution makes database updates and account administration more efficient for the energy supplier. Customers are given more power by prepaid electricity meters, which let them use energy up to a preset threshold. Users receive a set number of energy units upon recharging, and the supply is automatically cut off when the balance drops below a predetermined threshold[11].

The system also includes environmental sensors, like the DHT11 and LDR, to modify energy use according to the current circumstances. The system optimizes energy use in response to environmental conditions through the integration of these sensors.

In conclusion, prepaid electricity meters give customers more flexibility and control over how much energy they use. They are a modern take on electric bills.

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Prepaid Energy Meter

Prepaid energy meters are an affordable way to handle billing problems and remove the need for human meter readings, which saves manpower deployment. The following are only a few benefits that this method has to provide, for both customers and suppliers:

Why Prepayment – Supplier's Perspective:

- Advance payment ensures usage is prepaid
- Maintains continuous service for customers
- Reduces operational costs and overhead
- Eliminates bill production and distribution
- Minimizes the need to pursue payments
- Places responsibility for disconnection on the customer
- Facilitates load and demand-side management
- Allows for load-based and time-based considerations

Why Prepayment – Customer's Perspective:

- Offers a flexible payment solution
- Allows payment alignment with income status
- Supports daily, weekly, and monthly budgeting
- Provides a clear view of consumption costs and remaining funds
- Encourages energy conservation to reduce waste
- Eliminates bills and potential billing errors

Block Diagram

Figure 1. displays the block diagram of a prepaid energy meter. The ATmega328 microcontroller, GSM, relay, single-phase energy meter, LDR, DHT11, and IR sensors are all part of it.

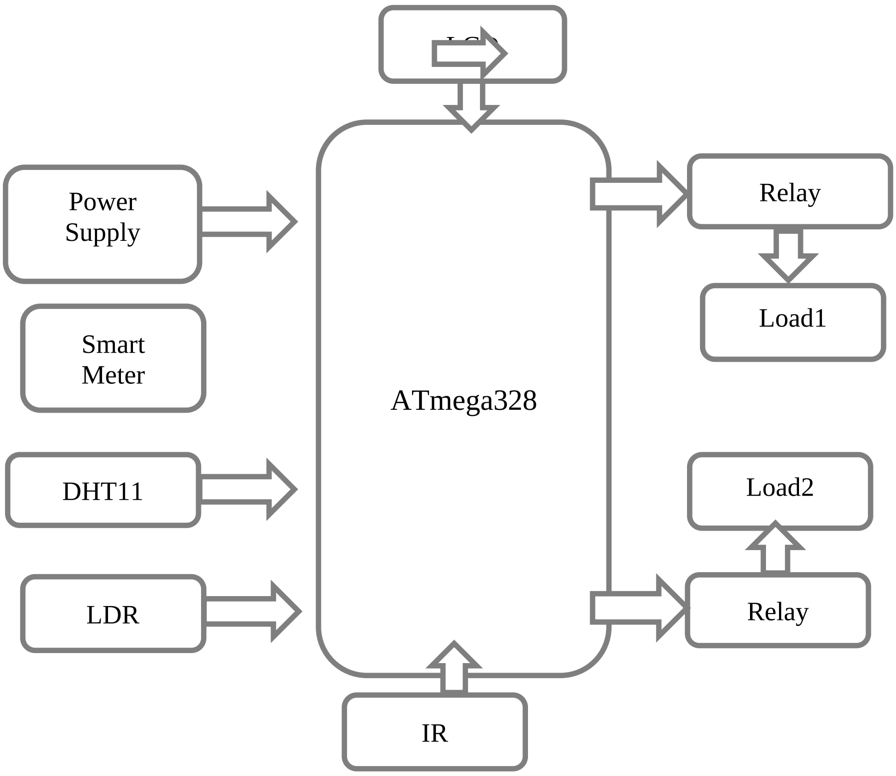

Figure 1. Block Diagram

Circuit Description

The required power source is obtained by using a step-down converter that converts 230V AC to 12V DC. The rectifier circuit transforms AC energy into DC, producing an output of +12V. This is controlled to +5V by a 3-pin IC 7805. In our design, the IC7805's output provides the +5V supply, and its input provides the +12V supply. The 40-pin microcontroller AT89S52 initiates the keypad input of the recharge number upon receiving input signals. This data is flashed on the LCD along with a message indicating that the "recharge successful" process was successful. It is saved in the IC AT24C02, an EEPROM with volatile memory. For load driving, the integrated circuit ULN2003, a high-voltage/high-current Darlington array with seven open collector Darlington pairs, is employed. ULN2003 is used to amplify the microcontroller's output current to 80mA, which activates the relay because it is only 10mA, insufficient to drive one. The LCD unit drops by Rs. 1 as power is consumed, yet the single-phase energy meter reading (connected across X2-1 and X2-2) grows. A buzzer alerts users to the need for a recharge when the balance drops to Rs. 10. When the balance is zero, the relay deactivates, stopping the flow of electricity.

Energy is the quantity of work done in a given length of time. In our example, we are using a lightbulb that has a 100 watt power rating, meaning that it needs to use 100 watts of active electricity in order to create light (and heat). First, the power consumed by the load is measured using a wattmeter and the following equation:

F= 0.5 Hz
And Po = 100*X/0.5
Po = 200*X
Where X is the frequency of pulses that is produced by the energy meter.
1 watt sec = 1 kW sec/1000
1 watt sec = 1 kWh/ (1000*3600)
Therefore Energy = Po * Sec/ (1000*3600)

Software Requirement

The C programming language is used to create the system software, and Win-AVR is used to edit, compile, and debug the code. There is also the option to program the system using MATLAB.

Load Prioritization:

The concept of load prioritizing in smart homes is based on the dynamic energy management theory, which incorporates sophisticated algorithms and real-time sensor data. The foundation of this idea is demand-side management, which intelligently modifies the distribution of electrical loads in response to changing circumstances. The system uses light and temperature sensors as vital inputs to guide its judgments.

Load prioritizing is a complex energy management technique that is dependent on temperature and light sensor inputs. It is exemplified with a fan (Load 1) and a lightbulb (Load 2). In order to keep the atmosphere comfortable, the technology automatically prioritizes the fan when it senses rising temperatures. Concurrently, the light sensor evaluates ambient light levels; should natural light be adequate, the system might reduce the bulb's energy-saving priority. On the other hand, when it gets darker, the bulb becomes more important. By reacting to environmental cues in real time, energy-hungry equipment are turned on sparingly thanks to this dynamic decision-making process [810].

RESULTS

A 230 V supply voltage and a 100-watt electric light bulb with a current draw of up to A were used to test the energy meter's performance. At first, a wattmeter was used to measure the load's power consumption. Then, 10-second intervals were used to measure the amount of energy consumed; the energy meter registered a total of 5 pulses each 10-second interval. The testing procedure took two minutes in total, during which time measurements were meticulously taken at intervals of ten seconds.

CONCLUSION

The purpose of this paper is to give an overview of prepaid energy meters, which help reduce power waste by controlling customer electricity usage. Prepaid energy meters are made to reduce power theft in an economical way.

- Users with prepaid energy meters only pay for the electricity they use, so they are not forced to make large payments.
- These meters can lessen the need for manual meter readings and help customers in remote places with billing-related problems.
- Prepaid energy meters are more dependable and easily programmable, making them available to a larger variety of users.
- These arguments suggest that the use of prepaid energy meters would have a positive impact.

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