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Research Paper

Development of Pre-paid Energy Meter using Internet of Things

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ABSTRACT
This paper presents an implementation of IoT to develop a pre-paid energy meter system using an IoT prototype for monitoring and controlling energy and power consumption. This system is used for the remote or on-site management of energy and power consumption. The system provides a user interface using Global System for Mobile Communications (GSM) so the user can pay the required price for the desired unit. The system provides a web user interface to monitor energy and power consumption, including the number of units and price. The ultimate goal is to promote a sense of optimization of power usage by letting the user pay before they have access to electricity. The system consists of an energy meter box that is connected to individual load connections. This energy meter box consists of a microcontroller on Arduino, a GSM module, a voltage sensor, and current sensor, and an LCD. The LCDs are the energy and power consumed, the price remaining, and the number of units consumed.
Index terms: Energy and power consumption, GSM, Arduino, LCD, remote monitoring

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I. INTRODUCTION

Energy consumption is the total amount of energy required for a given process and is measured in Kilowatt hours (KWh). This includes the use of electricity. The concept of energy consumption is directly related to energy efficiency since higher consumption results in lower energy efficiency. [1]Power consumption is determined by dividing the energy consumption by time. To calculate a household's average consumption, the kilowatts of power consumed by each electronic appliance in the home must be added up. Homeowners get concerned about how energy-efficient their electrical appliances are becoming as a result. Energy meters play a crucial role in the control and management of energy, offering key information for improving energy efficiency. The key attribute of the meter is its ability to furnish billing data that reflects accurate energy consumption.[2] In this project, The energy meter is connected to the source grid as well as to the assumed load of light bulbs. The goal of this project is to create a prepaid energy meter system that will solely use the prepaid amount to manage the energy supply. The project's premise is "First Pay First Serve," Prepaid energy meter systems must therefore be designed and put into place to regulate the amount of energy supplied. The energy supply was used by the user by their available credit, which can be increased, and this capability can be used in shared spaces. Only after payment or reloading fists before use will electricity be provided. The credit is triggered upon a reload, at which point all of the electricity will be spent. The energy will be turned off right away when the credit runs out. The user's electricity use can be effectively managed via an energy metering system.

The system consists of a database system that holds their power, energy, balance, and consumed units with their contact number as the primary key. The system provides a web interface for the user to monitor their power consumption in real-time. A user can sign up on the website by entering their details. The user then can sign in on the website with their contact details as their unique identity and a password. The personal details are also stored in the database. If the primary key i.e. the contact number matches, then the values of each element are displayed in the personal dashboard of the user such as their details along with the parameters of the energy meter system.

Users have the option to purchase a certain quantity of energy to consume only as needed. As a result, every customer will use less electricity, be more cautious, and monitor their usage of energy.

Figure 1 layout of the prepaid energy meter system

We use the Arduino Uno board microcontroller to operate the LCD, voltage sensor, and current sensor. Arduino UNO is a microcontroller board based on the ATmega328P for easy interfacing. The latest value is stored in the Arduino. It is interfaced with ESP32 to display the data in the dashboard of the user on the website. Prepaid energy systems are designed with extremely quick accommodations due to the rapid advancement of technology.

The remainder of the paper is organized as follows. In section II, we discuss some related works. Section III describes the methodology used in this project. Sections IV and V describe the testing environment and the results respectively. We conclude the paper and discuss some future extensions of our current prototype.

II. RELATED WORKS

There are several research and hardware-implemented projects focused on the pre-paid energy meter using the Internet of Things, and another system. For our project, we have designed a prototype focusing on the remote monitoring of the exact energy and power consumption from the load of residential and commercial buildings. In paper [1], proposed the power monitoring of the consumed energy is one of the main concepts. Once the power is monitored, sent to the consumer through SMS and a feedback control is taken from the SMS to the microcontroller for the relay control.

The paper [2] they purpose introduces a pre-paid electricity system to overcome the problem of overbilling, and meter tempering and to ensure a cost-effective operation. The user purchased the unit by sending the messages to the service provider by GSM technology. The project [3] aims to propose a system that will reduce the loss of power and revenue due to power thefts and other illegal activities.

III. METHODOLOGY

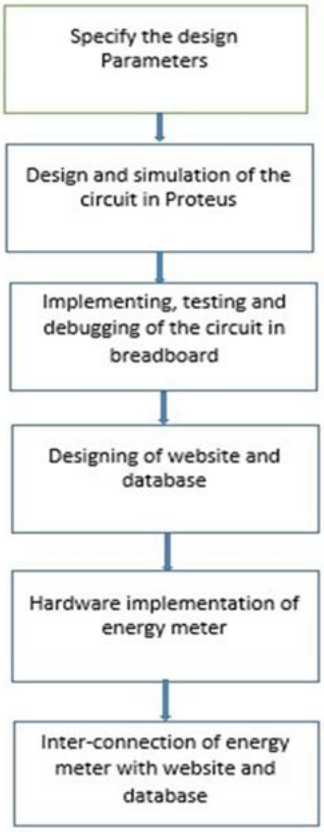

Figure 2 Overview of the energy meter system

A. ***Overview***

The system consists of an energy meter, database system, and website for remote real-time monitoring of the energy & power consumption, unit, and price from the personal dashboard of the user. The loads are connected; the parameters are displayed in the LCD of the energy meter and also displayed in the personal dashboard of the user on the website. The data from the Arduino is transferred to the database using ESP32.

B. ***Design and Development***

The system includes hardware, software and an interface between them. This this system is divided into three components as follows:

1) Energy meter:

A 12-0-12 transformer is used and this voltage is reduced to 4 Volts using voltage divider resistors. This data is provided to Arduino. The ACS712 current sensor is used to sense the current of the load and its data is also provided to the Arduino. Both data are converted in terms of Kilowatts per hour and eventually in terms of the unit inside the code. In this way, real-time energy consumption is shown on the 20x4 LCD screen. The 20x4 LCD Display connects to the I2C Pins of the Arduino UNO Board. SIM900A GSM Module is used for GMS SMS functions, which is the most important part of this project. Using GSM, this system will read the energy meter readings and automatically send some updates to the user's mobile phone such as low balance alert, cut off alert, resume alert, and recharge alert. The whole device is directly connected to the 220V AC power supply to test the system. When you power on the device, the LCD will display the unit, pulse, and price as zero. This meter needs to be recharged, as there is no money to operate this device. The power generated by the load is converted into energy.

$$\textbf{Power}=V_{rms} * I_{rms} \textbf{ in KW}$$

This energy is converted into Energy per hour (Watt per hour)

$$\textbf{Energy=Power* Time in KWh}$$

and this data is converted into UNIT consumed by the user. Ideally, 1Kilo-watt per hour=1 unit=NPR 10.

2) Database system:

For the database system, we have created two different tables. One table is to store the personal information of the users including the first name, last name, contact number, address, number of amounts deposited, and many more. The other table was created to store the parameters of the energy meter such as energy consumed, power consumed, number of units remaining, and the price remaining. The values are displayed on the website for real-time monitoring.

3) Website and IoT:

The website is created using HTML/CSS. The website consists of an introduction page, login page, signup page, about us page, and a recharge page. All the values entered are stored in a database. Each user is differentiated by their contact number. The database is connected using the PHP language. A web host is created to be able to access the internet on any device of the registered user.

IV. TESTING

A) Sensor Testing

Every sensor is calibrated and tested using a single load and connected to the Arduino. We have used a current sensor and voltage sensor to calculate the energy and power consumption.

B) Energy meter testing

After the connection between the loads, Arduino UNO, GSM module, LCD, and others are completed; the energy meter is tested for its accuracy. For certain power loads, the power calculated from the data of voltage and current sensor was 92% accurate. The parameters are displayed in the LCD with a delay of about1sec.

C) Database and Website

The website was tested for the individual users and their accounts. Later, the website was tested for the real-time values of the parameters of the energy meter. When the database is connected to the hardware implementation of the energy meter, we tested to see if the real-time data displayed in the LCD is also displayed in the personal dashboard of the user on the website.

V. RESULT AND DISCUSSION

When the energy meter is opened, the user receives a message "Your pre-paid energy meter has been breached". It means the energy meter has been opened without the user's consent. As the price decreases with use, the user receives a warning when their balance is less than 20 as a reminder to pay their desired amount. When the user pays for the desired unit, they receive a message after it has been updated.

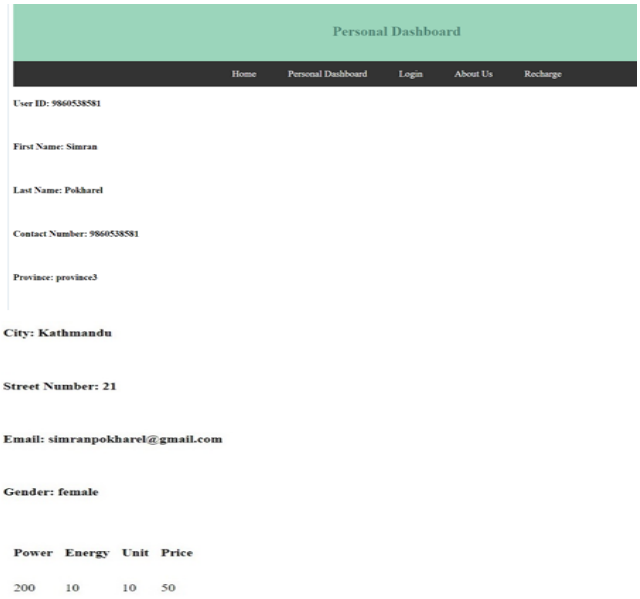

Figure 3 Personal dashboard on the website

VI. CONCLUSION

As a user pays the amount for the desired number of units through the GSM and text message, they can expect the number of units in their household. With time, the number of units decreases with the price. In the energy meter, the power and the energy consumed are displayed through the LCD along with the price and the units. The user can also monitor the power, energy, price, and units by registering on the website. The user receives a message when the number of units is almost finished. We have completed the project as our objective and implemented it with multiple loads.

The conventional method of paying electric bills and electricity theft is still prevalent in most parts of our country. In such context, the Pre-paid Energy Meter System shall provide a solution to those problems. Due to the pre-payment usage monitoring module, users are likely to pay more attention to their electricity usage habits. The energy meters can be installed in multiple locations. Multiple energy meters can be used in a single building for different tenants. It is a reliable, accurate, and safe device to monitor the usage of energy for everyone. The usage of IoT will make it even more user-friendly and accessible to a large range of people.

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