DESIGN AND CONSTRCTION OF GSM BASED PREPAID ENERGY METER USING ARDUINO

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ABSTRACT

In this part of the world, commercialization of electricity has been a problem, both for the users and the providers. Therefore, attempts are being made to automate the billing systems. Even though more accurate and faster meter readings have seen the light of day, bill payment is still based on an old procedure. They require the costumer to come to sales points of the electricity utility and buy electricity, where there are provided with vouchers (or tokens) that are then inserted back at home into the meter through a keypad. But the demand for computing power at all levels of electronic systems is driving advancements in semiconductor chip technology. The proposed system will be able to design a power supply unit, Voltage sensing device that automatically adjusts the power factor of the electricity supply through its calibration. To program a device using the arduino development board that will measure current, voltage, and effectively calculate the power consumed from the load. To Program and configure the Global System for Mobile communication (GSM) module to effectively send, receive message which is compatible with all mobile network operators. To design a circuit that disconnects the load when the unit is exhausted. To evaluate result based on the energy consumption of the measured values. A system that has the ability to automatically send some updates as alert to the user's mobile phone like low balance alert, cut of alert, resume alert and recharge alert.

Keywords: Prepaid energy meter(PEM), arduino development board (ADB), voltage sensing device (VSD), Global System for Mobile communication (GSM) module

INTRODUCTION

The conventional method of electricity billing involves a person from the distribution unit reading the number of units of electricity consumed in the energy meter, conveying this information to the distribution unit and then preparing the bill according to the units consumed for a fixed amount of time. This can prove quite tedious as it involves various tasks like reading, then preparing the bill. Still accuracy cannot be guaranteed as there can be errors in human reading. Even though digital meters are being replacing conventional electromechanical meters and provide much accurate readings, still the problem of deliberately making a false reading can exist (political reasons). Despite this, the task of billing for every consumer is a time consuming job for the distribution grid. Also the consumer can deliberately consume more amount of power than required and still refrain from paying the bill and nothing can be done to severe the electric power supply. To eliminate all these problems, the most convenient method is making the whole system prepaid similar to a mobile phone recharge or a DTH recharge. Electric energy meters, the direct billing interface between utilities and consumers for long, have undergone several advancements in the last decade. The AMR and power quality monitoring systems

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manufacturers are taking advantage of these advances and integrating them into new meters and instruments. The networking technologies are driven by the demand for interconnection of computer users' worldwide (Jackson, 1996). The AMR and power monitoring systems are using these advances to expand the monitoring systems. The idea of prepaid metering will be very important for the new research fields of Micro-grid and Smart Grid and is an inevitable step in making any grid smarter than it is now. The system designed in this paper can be used to develop more complex system where a smart card can be used for several applications including prepayment (Koay, 2003).

STATEMENT OF PROBLEMS

At the end of every month in the street of Nigeria, we always see group of persons standing or carrying ladder in front of our houses from Electricity board whose duties are:

i. to read the manual energy meter,
ii. handover the bills (electric) to the owner of that house,
iii. To check whether there are by-passes in the cases where the prepaid energy meters are in use.
iv. Cut our lights in the cases where the house holders defaulted in paying bills or cby passed the prepaid energy meters
v. In some cases where houses have no manual energy meter or the prepaid energy meter, estimated bills are given which the house holders must pay.
vi. In the manual meter cases wrong reading are always giving to the consumers and they must pay.
vii. For this prepaid energy meter, whenever a customer wants to recharge their energy meter, they would have to go all the way to the utility company to buy electricity and receive a voucher that is then must be taken back to the location of the meter and is entered through a keypad or slot the card into the prepaid meter. This is a very tiresome process for electricity recharge, especially if the location of the meter is far from the utility company.
viii. Lastly, in case the electricity runs out, the period of time the building where the meter is installed stays offline until it is once more recharged may be critical depending on the facility itself.

RESEARCH OBJECTIVES

The objectives include:

i) To design a power supply unit, Voltage sensing device that automatically adjusts the power factor of the electricity supply through its calibration.
ii) To design a voltage sensing device that automatically adjusts the power factor of the electricity supply through its calibration and current sensing device to measure the accurate current consumed by the load.
iii) To program a device using the arduino development board that will measure current, voltage, and effectively calculate the power consumed from the load.
iv) To Program and configure the Global System for Mobile communication (GSM) module to effectively send, receive message which is compatible with all mobile network operators.
v) To design a circuit that disconnects the load when the unit is exhausted.
vi) To evaluate result based on the energy consumption of the measured values.
vii) A system that has the ability to automatically send some updates as alert to the user's mobile phone like low balance alert, cut of alert, resume alert and recharge alert.

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REVIEW OF RELATED LITERATURE

Evolution of Prepaid Energy Meters

Evolution of Prepaid Energy Meters The use of electronic token prepayment metering has been widely used in UK for customers with poor record of payment. Ning et al (2004) in their paper presented the Digital Tele-wattmeter System as an example of a microcontroller-based meter. The meter was implemented to transmit data on a monthly basis to a remote central office through dedicated telephone line and a pair of modems. Maheswari et al (2009) utilized a DSP-based meter to measure the electricity consumption of multiple users in a residential area. A Personal Computer (PC) at the control center was used to send commands to a remote meter, which in turn transmitted data back, using the power Line Communication (PLC) technique. The major problem with this system is that it cannot detect tampering by consumers. A paper suggests a design of a system which can be used for data transmission between the personal computer and smart card. The device will transmit the data in half duplex mode (Kwan, 2002). In this paper, an Intelligent Prepaid Energy Meter has been designed, modeled and simulated using Matlab/Simulink tools. Koay et al (2003) in their work (Koay .B.S, 2003), designed and implemented a Bluetooth energy meter where several meters are in close proximity, communicated wirelessly with a Master PC. Distance coverage is a major set-back for this kind of system because the Bluetooth technology works effectively at close range. In their paper,(Scaradozzi, 2003) Scaradozzi and Conte (2003) viewed home- automation systems as Multiple Agent Systems (MAS). Hong and Ning (2004) in their paper (Ning.L, 2004), proposed the use of Automatic Meter Reading (AMR) using wireless networks. Some commercial AMR products use the internet for data transmission. Stanescu et al (2006) present a design and implementation of SMS based control for monitoring systems (Stanescu, 2006). Prepayment poly-phase electricity metering systems have also been developed consisting of local prepayment and a card reader based energy meter (Ling Zou, 2010).

Related Works

Energy Meter is a device that measures the amount of electrical energy consumed by a residence, business, or an electrically powered device. They are typically calibrated in billing units and the most common one is the kilowatt hour, which is equal to the amount of energy used by a load of one kilowatt over a period of one hour, or 3,600,000 joules. Electricity meters operate by continuously measuring the instantaneous voltage (volts) and current (amperes) The product of which gives the instantaneous electrical power (watts) which is then integrated against time to give energy used. A Prepaid Energy Meter enables power utilities to collect electricity bills from the consumers prior to its consumption. The prepaid meter is also attributed with prepaid recharging ability and information exchange with the utilities pertaining to customer's consumption details. Literature has witnessed quite an amount of work in this area (Nwaoko, 2006; Omijeh, 2012).

Simple Prepaid Energy Meter Kit: A simplest type of prepaid energy meter consists of 2 EEPROMs interfaced to a microcontroller. One EEPROM contains the recharged balance amount. The microcontroller reads this balance and stores it in the other EEPROM along with the tariff. The energy meter supplies pulses to the microcontroller for every unit of energy consumed. The microcontroller increases the spent energy unit by one and decreases the balance amount in the EEPROM by the fixed tariff. As soon as the balance amount in the EEPROM comes down to zero, the microcontroller sends a signal to the relay driver which in turn switches off the relay, such that the main supply to the load is switched off. An LCD is also interfaced to the microcontroller which displays the amount of energy consumed.

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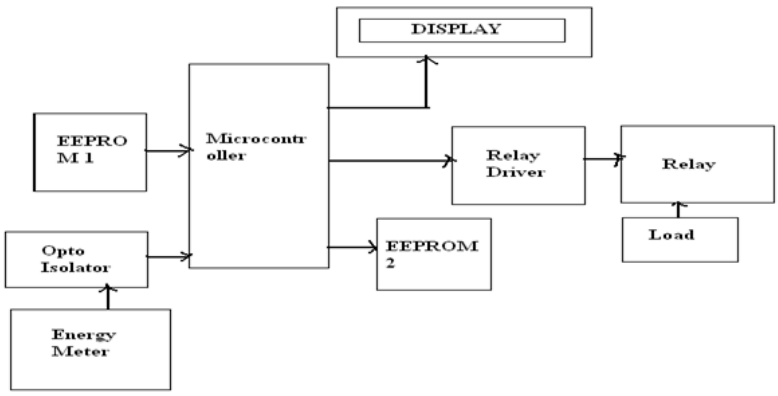

Figure 1: Simple Prepaid Energy Meter block diagram [liberty online]

Figure 2: Prepaid Energy Meter [liberty online]

Zhang et al (1998) utilized a DSP-based meter to measure the electricity consumption of multiple users in a residential area. A Personal Computer (PC) at the control centre was used to send commands to a remote meter, which in turn transmitted data back, using the power Line Communication (PLC) technique. The major problem with this system is that it cannot detect tampering by consumers.

A paper suggests a design of a system which can be used for data transmission between the personal computer and smart card. The device will transmit the data in half duplex mode (Kwan *et al*, 2002). In this paper, an Intelligent Prepaid Energy Meter has been designed, modeled and simulated using matlab/simulink tools. Koay et al (2003) in their work, designed and implemented a Bluetooth energy meter where several meters are in close proximity, communicated wirelessly with a Master PC. Distance coverage is a major set-back for this kind of system because the Bluetooth technology works effectively at close range.

In their paper, Scaradozzi and Conte (2003) viewed home- automation systems as Multiple Agent Systems (MAS). Home automation system was proposed where by home appliances and devices are controlled and maintained for home management. It is only a home management system and does not measure the amount of energy consumed by users. Hong and Ning (2005) in their paper**,** proposed the use **of** Automatic Meter Reading (AMR) using wireless networks. Some commercial AMR products use the internet for data transmission.

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Stanescu et al(2006) present a design and implementation of SMS -based control for monitoring systems. The paper has three modules involving sensing unit for monitoring the complex applications. The SMS is used for status reporting such as power failure. Issues on billing system for electricity board usage were not considered.Prepaid meters can also make use of state of art technologies like WiMAX owing to the idea of centralized accounting, monitoring and charging. It brings telecommunication to the core of its activities to support more Smart Grid applications such as Demand Response and Plug-in electric vehicles (Khan *et al*, 2007). Prepayment polyphase electricity metering systems have also been developed consisting of local prepayment and a card reader based energy meter (Ling *et al*, 2010).

Malik et al (2009) in their paper, mainly focused on the controlling of home appliances remotely and providing security when the user is away from the place using an SMS- based wireless Home Appliance Control. In their lighting system using Global System for Mobile communication [GSM] and General Packet Radio Service [GPRS]. The whole set-up provides the remote operator to turn off the lights when not required, regulate the voltage supplied to the streetlights and prepare daily reports on glowing hours

Sharma and Shoeb (2011), in their paper suggested a method where we utilize telecommunication systems for automated transmission of data to facilitate bill generation at the server end and also to the customer via SMS, Email. Amit. and Mohnish (2011). Suggested in their paper, a prepaid energy meter behaving like a prepaid mobile phone. The meter contains a prepaid card analogous to mobile SIM card. The prepaid card communicates with the power utility using mobile communication infrastructure. Once the prepaid card is out of balance, the consumer load is disconnected from the utility supply by the contactor. The power utility can recharge the prepaid card remotely through mobile communication based on customer requests.

DESIGN METHODOLOGY

The design methodology we are going to use for the research work is Embedded system development methodology. Our lives are surrounded by an overwhelming number and variety of information equipment. Many of them provide their required functionalities by means of the so-called embedded system. In the core of this embedded system is the embedded software. In order to develop the embedded software efficiently and ensure that the developed software is of high quality, there is a need to execute the appropriate tasks in the appropriate sequence in the course of development. This trend has led the development of embedded software to expand in scale in order to meet the ever-growing functional needs. In earlier days, the developers of embedded software did not have to be that conscious about development process to build the software required to be embedded in the final product, since their scope of development was relatively limited. But due to the recent expansion in scale of software development, numerous problems attributable to embedded software or embedded system have come to surface. As a result, more and more attention is given now to improve the development process to address these emerging problems.

This Research is useful for billing purposes in Electricity board. Instead of going to every house and taking the readings or using a token, by just sending an SMS the readings of the house can be received and the electric bill can be recharged. The microcontroller and the GSM unit are interfaced with the energy meter of each house. Every house has a separate number, which is given by the corresponding authority. The GSM unit is fixed in the energy meter. The amount of consumption is stored in the microcontroller's memory and available to the authority as SMS. Using this software, SMS can be sent through the GSM Modem to that

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particular number which is assigned by these authorities and wait for the response. On other end, the modem will receive the data in the form of a command and informs the controller to do the readings. After the readings the controller will send data to the modem. The modem, in turn sends data to the other end. In the office the GSM unit will receive the data and the total consumption information. The number assigned by the authorities is unique. Using GSM, the response can be obtained very fast, due to which time is saved. After consumption of the entire balance on the meter, the power will be cut-off, and the consumer must send an SMS to recharge. This will reduce illegal power using without paying money, and also able to solve by - pass of voltage.

The system gives the information of meter reading, power cut, total unit used, unit left, power disconnect, and tampering on request or regularly at a particular interval through SMS. Information is sent and received by the energy providing company such as PHCN (Power Holding Company of Nigeria) using the Global System for Mobile Communication (GSM) Network. A quad band GSM modems with a registered SIM (subscriber identification module) card with unique numbers is used. The communication process employed here is achieved by installing sets of AT (Attention) command strings in the GSM modems through HyperTerminal software which comes with Microsoft operating system. With the aid of the installed AT command strings, instructions and data are sent and received by the GSM modems respectively. Data received from the consumer unit are used to update the customer's database at the office of the power providing company. The EEPROM of the microcontroller is updated each time a customer pays his/her bills via SMS recharge by simply sending a secret pin from his mobile number to the developed system. Other information such as total energy consumed, total amount paid on consumption, User's interface consist of LCD (Liquid Crystal Display) which displays energy consumed, the (unit recharged) amount of bill paid and the amount left to be used. Information such as unit recharged, success of recharge, power disconnect/reconnect by the supply company, and when the unit left is critically low to avoid loss of power supply is communicated through the customer's mobile phone to the customer via SMS. With this new system, customers are confident that they are not being exploited, power pilfering is eliminated, rogue customers are shut off, prevention of bypass and the huge revenue loss which was inherent in the traditional metering system is completely avoided. For the programming and development of the controller part of the project at the energy meter end was made possible by the use of arduino development board. It is inexpensive, simple, cross platform and has other extensible properties. The microcontroller on the board has a flash memory of 32kB, making the processing speed fast enough for the single IC to cater to not just one but multiple microcontrollers in a residential building. The software section will contain the arduino C variant and java for serial communication and the interface. The components that will be used to achieve the system are:

i. Arduino development board
ii. GSM module
iii. 16 X 2 LCD
iv. Analogue electricity energy meter
v. Optocoupler 4n35
vi. Resistors
vii. Connecting wires
viii. Bulb and holder
ix. SIM card
x. Power supply

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xi. Mobile phone etc

When the system is powered up, the previous values stored in the EEPROM displays and immediate action will be taken depending on the balance. If the available balance is greater than N500 then the arduino turns on the electricity of the home or office depending on the context. If the balance is less than N500 then the arduino sends a message to the user regarding the low balance and instruct him to recharge as soon as possible. If the balance is less than N100, arduino turn off the light from the home or office and send a light cut off message to the user and request for a recharge or complete cut off. The proposed system block diagram, circuit diagram and the assumed system are shown below in figure 4, figure 5 and figure 6.

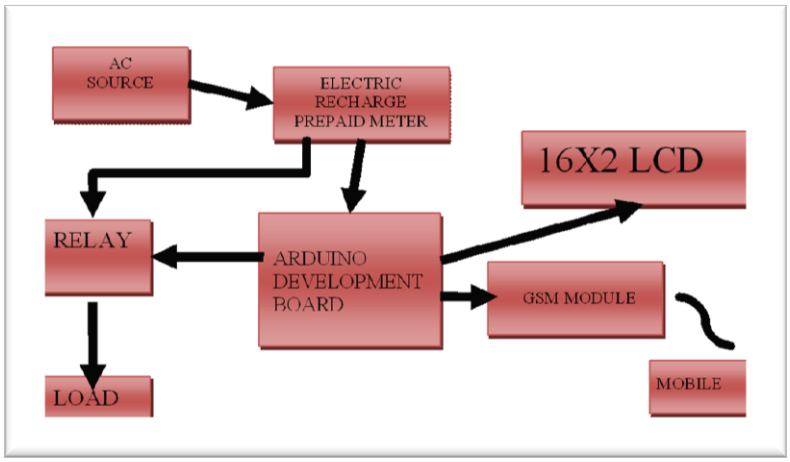

Figure 4: System Block Diagram

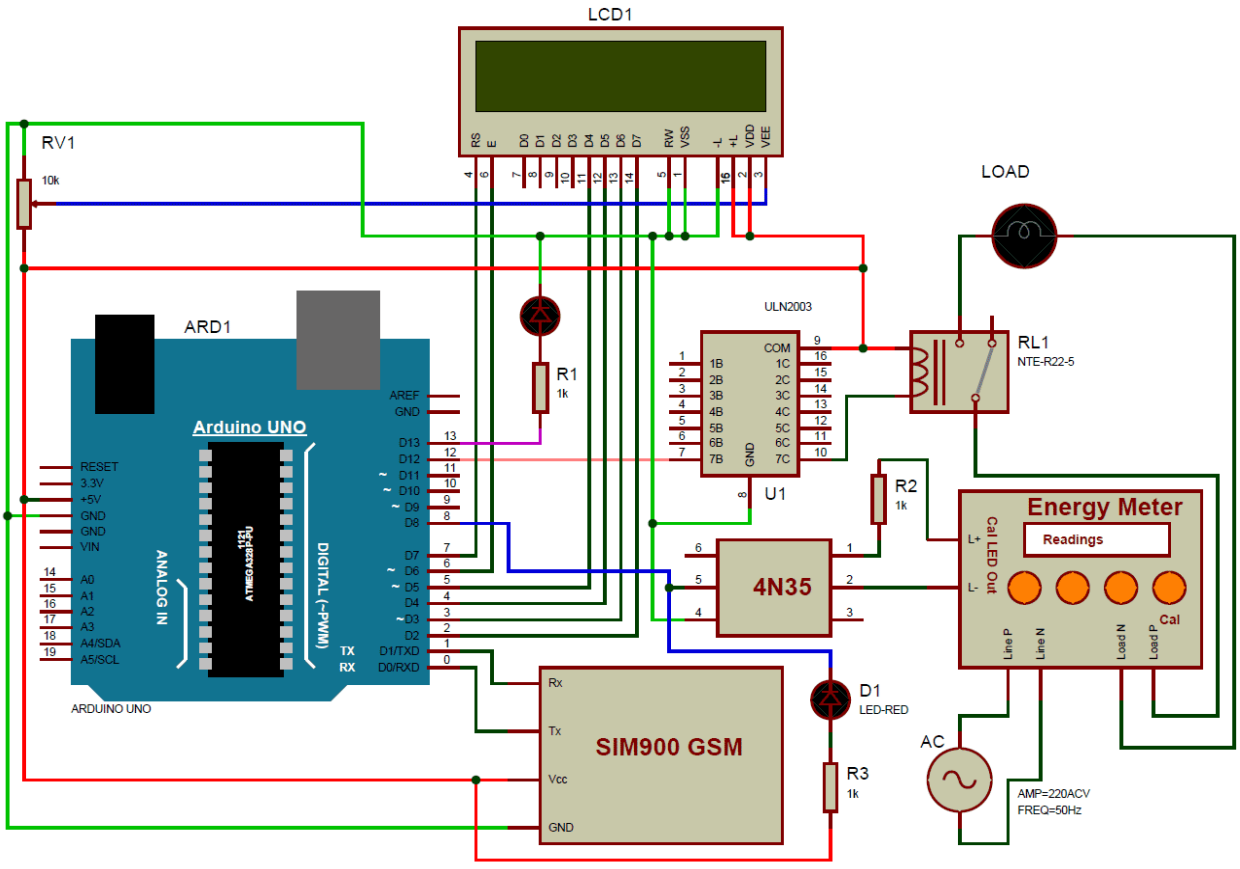

Figure 5: System Circuit

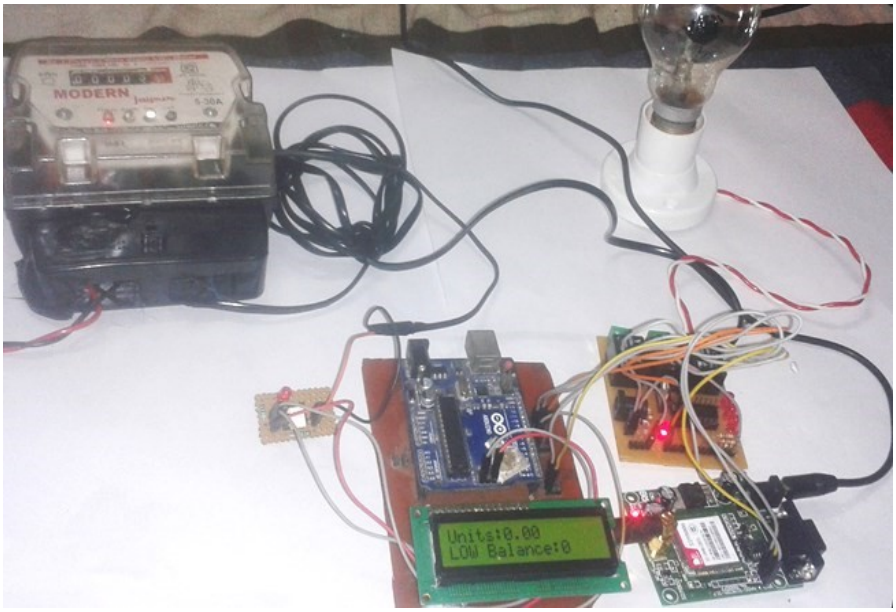

Figure 6: The Developed System

EXPECTED RESEARCH RESULTS

This proposed simple and economic digital prepaid energy meter controlled by GSM based communication can cover rural area as well as urban areas. At the end of the research will be able to achieve what we stated in the objectives. This is an effort about improving the present conventional electromechanical meters through the fusion of analog and digital circuits which have aim of collecting bills for consumption of power thus improved the revenue collection for scheduled supply. This is beneficial for Nigeria as a developing country which having huge population for improving the economic through power utility.

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