RESEARCH ARTICLE OPEN ACCESS

Design and Implementation of A Gsm-Based Prepaid Meter with Tamper Proof and Anti-Meter Theft Feature

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ABSTRACT
Utility companies have not been achieving maximum profit due to electricity and meter thefts. Prepaid energy metering system with GSM interface being proposed in this work will help to improve the profit margin of the utility companies. Detection of electricity and meter thefts by the utility companies will enhance efficiency in transaction and communication with their customers. This is achieved through the use of tamper and meter theft detection units (TDU & MTDU) with GSM Module/Modem. The detection switches are connected at the back and the cover of the meter to prevent meter theft and tampering. When the cover of the meter is tampered with, the microcontroller sends appropriate signal to the server via GSM interface and the server in turn sends a signal that disconnects the meter and an alert to the customer's phone notifying the customer of the incident. Power is restored automatically, when the anomaly is cleared. A back-up battery is incorporated to keep the circuit active, when there is power failure so that the utility company will be notified, if there is an attempt to tamper or by-pass the supply cable.
Keywords - ATMega8, Digital Meter, GSM Module, Meter Tampering, Meter theft

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I. INTRODUCTION

The growth of an economy is directly linked to several societal resources, one of which is energy [1]. Smart metering is the next big thing in utility industries today, especially the electricity distribution. Countries like the USA, Australia, South Africa, etc. are actively researching on the implementation of smart metering. Different technologies are currently being used in the management of electric power. These technologies are characterized by their fast-changing nature [2]. These technologies have found their way into power management. Prepaid meters have become an important tool in power management, because when used properly, they help in the reduction of cash leakages/theft, while improving the inflow of cash and credit reduction. With the use of prepaid meters, the recurrent cost of printing and distribution of monthly bills is eliminated. With the use of the mobile communication systems available in Nigeria, prepaid meters can be recharged online using the internet and web-based applications. This will provide additional functionality to the system, because users can be remotely disconnected from power supply in the case of non-payment of electricity bills or suspicion of fraud. A dedicated Global System for Mobile Communication (GSM) with Subscriber Identification Module (SIM) or Reusable Identification Module (RUIM) card for Code Division Multiple Access (CDMA) cellular system will be required for each meter [2], while providing consumers with mobility, accessibility and comfort.

II. RELATED WORKS

This section reviews some of the works related to Prepaid Energy Meter with GSM interface.

The design and implementation of a ZigBee based smart power meter was presented [3], which was based on a Microchip dsPIC30F microcontroller whose firmware is designed to process and store power consumption, interruption and outage event. A ZigBee system is designed and integrated into the proposed power meter and is used to transmit the detailed power consumption data, interruption and outage event data to rear-end processing system. This work is focused on the design of a smart meter with no attention given to tampering.

Energy efficiency with regard to smart metering was researched [4] and concluded that great improved can be achieved when the right policies are in place to support smart metering. The paper contained a detailed review of the advantages of smart metering in power network such as the improvement of energy efficiency and decrease in the emission of greenhouse gases. A number of case studies were discussed. International engineering

practices and policy were also discussed but no recommendation was made on any smart metering method.

Jubi and John proposed a prepaid energy meter with GSM technology aimed at minimizing queues at the utility company billing counters and automatically denying the use of electricity, once electricity bills are not paid. It was noted that the system would decrease power losses as well as revenue due to power thefts and other illegal practices. The work adopts a totally new concept of "prepaid electricity". Furthermore, with the use of GSM technology, consumers receive SMS containing information about their consumption of power (in Watts) and a recharge alert when their available amount drops to a minimum. This technology could be useful in electricity distribution companies, private communities, IT parks and self-containing housing projects.

GSM based smart energy meter with microcontroller (Arduino) for advanced metering and billing system was proposed [6]. The energy consumption is calculated using the energy meter IC (BL6503) and Arduino. The Arduino shield is used for interfacing GSM modem with Arduino. Based on the design, if the metering unit is tampered with, the Arduino turns OFF the relay and turns ON the buzzer that alerts the service provider.

Kesav and Rahim [7] presented an automated wireless meter reading system for monitoring and controlling power consumption. The work focused mainly on accurate billing and the reduction of revenue losses by automatically disconnecting nonpaying customers.

Chetan and Anish [8] used of the microcontroller AT89S52 microcontroller for prepaid meter with theft detection. The paper reported an electricity billing which is cost efficient. The work identified the major flaws in the traditional billing system to be power and energy theft. To combat these flaws, the use of a prepaid energy meter based on the concept of "Pay first and then use it" was employed. The prepaid energy meter used a recharge card. Customers are able to input the secret code printed on the recharge card by using a keypad. It is equipped with a magnetic switch, which triggers the microcontroller to disconnect the load and send an SMS to the utility company when the meter is either bypassed or tampered.

The design and modelling of a GSM-based energy recharge system for prepaid metering was presented by JayChand et al [9]. This was because the system of energy billing in India was error prone as well as time and labours consuming. The aim of the project was to minimize the errors by introducing a new system of prepaid energy metering, whereby the customer and utility provider communicate via a GSM module. This mode of communication allows the user to recharge his/her electricity account from wherever there is a GSM network. The methodology adopted could easily incorporate add-ons, which include energy demand prediction, real time dynamic tariff as a function of demand, supply and so on. A major drawback in this research is, it does not include the protection against energy theft.

Power Line Communication (PLC) technology, which enables sending data over existing power cables was utilized [10]. The output of the total cost of the meter reading is displayed using serial communication. It is claimed that using Abinayam et al [11[also applied PLC for the transmission of data between the consumer and the utility via existing AC power lines. Payment of bill take place at the home using a smart card. An RFID reader detect the smart card and decodes the amount paid through it. Based on the status of the bill payment, the controller sends ON/OFF signal to the user. The payment method can be replaced with the scratch card method whereby the consumer sends the scratch card number to the utility company and the credit is automatically recharged on the meter.

Zhang et al [12] provided an understanding of electricity theft as it relates to advanced energy applications such as energy harvesting and smart grid. Further discussions on ethical and education issues relating to energy theft was also included. The authors identified various electricity theft such as fraud, billing issues, tampering, etc. They explored digital meters for electricity theft and the impact of digital meter tampering.

the existing power lines, the project is very economical and can be easily adapted, when compared with other methodologies.

III. BLOCK DIAGRAM OF THE AUTOMATIC PREPAID METER

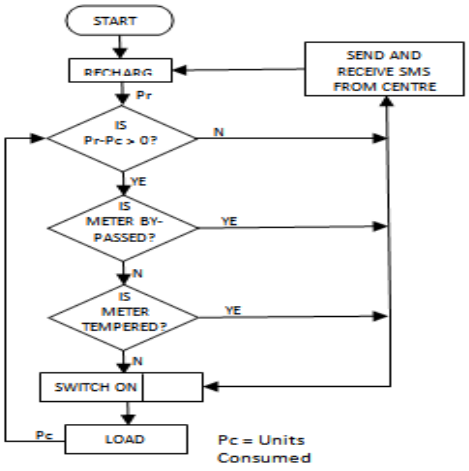

Figure 1. Block diagram of the Automatic Prepaid

The block diagram of the automatic prepaid meter is shown in Fig. 1. It comprises seven blocks, two feedbacks and three feedforwards. The feedback

on the left is to enable comparison of the recharged and consumed energy units. The feedback on the right informs the Energy Centre and the Customer the status of the energy units, so that the meter can be recharged, either when the Consumer desires or when the energy units are used up. The feedforwards accomplish the task of monitoring the security of the meter, i.e. by alerting the Energy Centre and Customer and also switching off the supply when there are no energy units or the meter is either tampered with or bypassed.

The recharged units from the handset is denoted Pr, while that consumed by the load is denoted Pc. When the meter is powered, it checks whether:

There are energy units Pr available for the load, the meter is not by-passed and the meter is not tampered with.

If these three conditions are fulfilled, the switch (a relay) is turned on, powering the load and energy units Pc, in form of watt-hours, are consumed. The feedback from the load to the first comparator provides a continuous check on the balance of the energy units (Pr – Pc). Once the remaining energy units are not greater than zero, a signal is sent to the switch to turn off the load.

In the event of any by-pass or tampering with the meter, a signal is sent to the switch and the load is disconnected. SMS is sent to the Energy Centre and the Customer, alerting them on whether the energy units are exhausted or the meter is either by-passed or tampered with. If the alert is for the exhaustion of energy units, the Customer can recharge using his handset, but if the alert is for by-pass or tampering, then it is only the Energy Centre that can reset it after a thorough investigation**.**

IV. IMPLEMENTATION BLOCK DIAGRAM

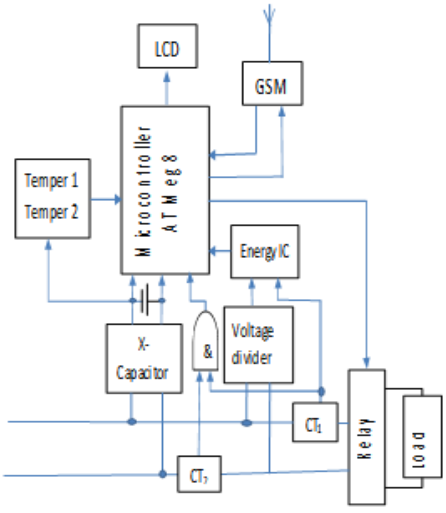

Figure 2. Implementation Block Diagram

Fig. 2 depicts the implementation block diagram. The heart of the prepaid meter is ATMega8 microcontroller, which is fed from a power circuit comprising an X-capacitor, diodes and a stand-by battery. It receives control signals from the electrical energy measuring IC (ADE7753), the GSM modem, the tamper and meter theft circuits and sends signals to the GSM, LCD and relay circuits. The energy measuring circuit, which computes the energy consumed, is made up of the energy IC. This IC derives its signals from the current transformers and a voltage divider circuit. The by-pass circuit has two current transformers, one on live wire and the other on the neutral. Their main function is to monitor the state of the power supply. The tamper proof circuit has two normally ON limit switches, one at the back and the other inside the panel. The switch at the back protects against the removal of the meter from the place, where it is installed, while the switch inside the panel protects against opening of the lid or cover of the panel. These switches are connected in series. The switching circuit consists of a transistor and a relay, which when de-energized, turns off the load. The LCD constantly displays the status of the meter.
A control program was written based on the flow chart on Figure 3 and burnt into the microcontroller. The prototype of the automatic prepaid energy meter was assembled on a bread board and tested.

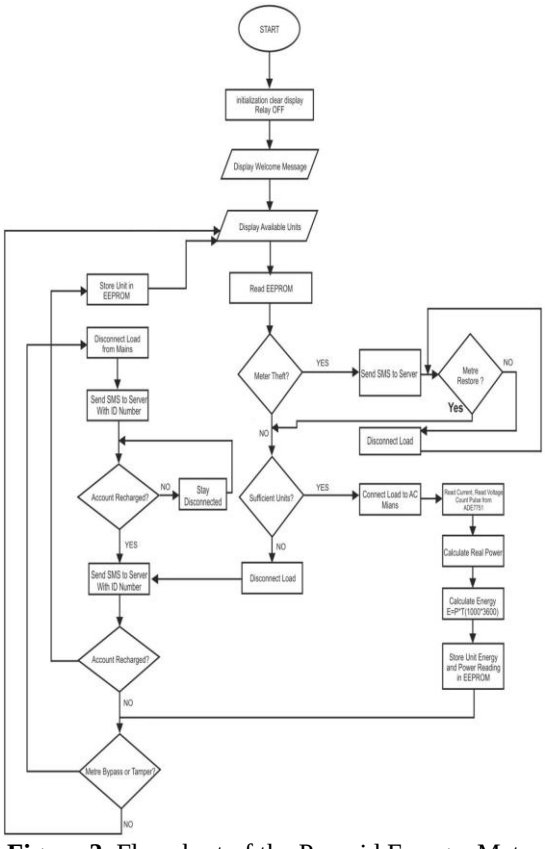

Figure 3. Flowchart of the Prepaid Energy Meter

V. TESTING AND RESULTS

At the end of the construction, the design was subjected to different tests to ensure that the meter meets the design specifications and that the aim of the project was achieved. For the purpose of the test, a 60-Watt incandescent bulb was used. The prototype was tested using existing telecom GSM infrastructure. Electricity theft control capabilities and others were tested in line with the objectives of the work. The report of energy theft is instantly sent to the Energy Provider Company. Therefore, energy provider Company can prosecute the case by taking legal action against the erring customer and likewise, a message is sent, if it is an attempt to remove the meter from the original place of installation, this helps the Electricity Company to also recover stolen meters.

The following figures depict the status of the prototype GSM based energy meter during operation, i.e after the consumer had recharged the meter. Fig. 4 shows the assembled prototype meter with no supply.

Figure 4: Prototype of GSM based Energy Meter.

Fig. 4 depicts the complete assembly of the prototype of the designed GSM based energy meter that controls electricity theft and pilfering.

Fig 5 shows the energy meter status when the load is turned ON. The 60-Watt bulb glows and the LCD display the available energy unit balance of 245. This is when the consumer has a recharge balance of 245 energy units available.

Figure 5: GSM Based Energy Meter Showing Mains 'ON' and Unit Balance.

Fig. 6 shows energy meter status OFF and displays no unit. In this mode of operation, the consumer has been disconnected using the relay circuit when the recharge amount reaches zero. The consumer will be alerted with SMS through the registered mobile number of exhausted unit and purchase of recharge unit can be done through SMS request to enable the meter status to revert from OFF to ON.

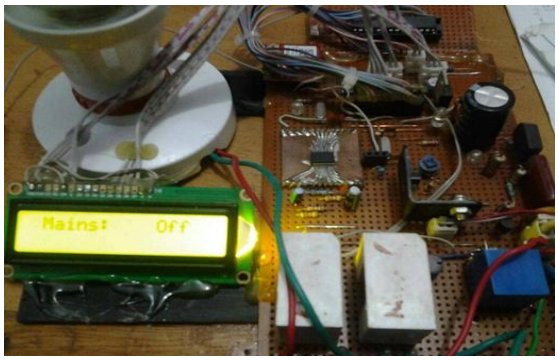

Figure 6: GSM based Energy Meter Showing Mains 'OFF'

Fig. 7 shows the GSM based energy meter when tampered by someone trying to bypass the energy meter. The proposed GSM based energy meter case cover and the backup rechargeable battery case cover both have lever switches that are used to prevent the whole energy meter from bypass. A terminal is connected to the microcontroller with the remaining terminal connected to 5V DC supply. In normal running condition of the energy meter, that is, when tampering attempt is not detected, the lever contacts are in closed position and the microcontroller detects 5V at its respective pin. But when someone attempts to have illegal access to the energy meter or the backup battery, the lever contacts are then opened, thereby making the microcontroller to detect 0V at its input pin. At this occurrence, the microcontroller alerts the server, which then notifies the electricity company through SMS of electricity theft and the consumer's meter terminal number as shown in Figure 8, eradicating the problems associated with estimated billings as observed in most developing countries like Nigeria.

Fig. 7 shows the GSM based energy meter displayed meter tampered when attempt by the user to bypass the meter is made. This results in automatic disconnection by the relay and turning on the red LED.

Figure 7: GSM based Energy Meter Showing 'Meter tampered' when tried to be bypass.

Fig. 8 shows the SMS sent to the consumer mobile phone by the meter indicating tampered attempt with meter terminal number and the corresponding LCD display of meter tampered with supply off, at the same time send the corresponding tampered attempt to the energy providing company including the user meter terminal number.

The important of the SMS notifying user of the tampered attempt on the meter is to raise alarm in case the act is not committed by the user.

Figure 8: shows a tampered meter terminal with SMS sent to user while supply turns off.

Fig. 9 shows energy providing company window displays recharging of the meter and tampered SMS with the meter terminal stated as AN1002.

Figure 9: Window Showing Recharging and Getting Tampered SMS

VI. CONCLUSION

GSM based energy metering is obviously the way forward in the pursuit of power efficiency on the part of the power companies as well as their consumers. The major issues that have been confronting the design and the implementation of smart meters have been the method of information exchange between the user's meter and the server as well as the cost of implementation.

In this thesis, an energy metering system with a GSM module for communication has been designed and a prototype implemented. This system includes a GSM based energy meter which communicates with a central database server in real time. Meter statuses such as available credit unit and power availability are all sent to the server. Updates and meter settings on the other hand are sent to the meter from the hyper terminal. Power companies and their customers can use the system but only after a successful authentication by the hyper terminal.

Prototype has been tested using existing telecom GSM infrastructure. Electricity theft control capabilities and others were tested in line with the objective of the work. The report of energy theft is instantly sent to the Energy Provider Company. Energy Providers can therefore institute an instant legal case against the defaulting consumer and thereby reducing energy theft drastically. It was observed that the prototype meter met all the set objectives of the thesis.

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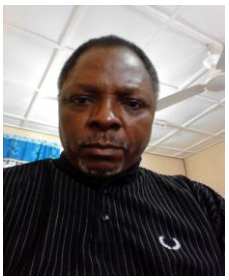

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