DESIGN AND TESTING OF A SMART ENERGY METERING SYSTEM BASED ON GSM MODEM

OYUBU A. O.
Department of Electrical/Electronic Engineering
Delta State University Abraka, Oleh Campus
NIGERIA

NWABUEZE C. A.
Department of Electrical/Electronic Engineering
Anambra State University, Uli
NIGERIA

ABSTRACT

Over the years, the traditional metering system has proven to be very time consuming, expensive, error prone, highly person dependent and generally ineffective due to topology and human factors among other things. The work in this paper, Smart Energy Metering System based on GSM Modem, overcomes the difficulties of the traditional system. It is a state- of- the-art technology for obtaining electrical energy meter readings from anywhere automatically without human intervention. It is a system for remotely monitoring and controlling domestic energy meter. 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. Two GSM modems each containing a SIM (subscriber identification module) card with unique numbers are used; one is integrated with the system and the user's energy meter while the other is interfaced with a PC (Personal Computer) containing the database of customers at the office of the energy company thus engendering a two-way communication process between the energy provider and the consumer's energy meter. The communication process employed here is achieved by installing sets of AT (Attention) command strings in both GSM modems. With the aid of the installed AT command strings, instructions and data are sent and received by both 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 database which was developed using Microsoft excel software, a spread sheet application contains such information as the customer's meter ID (Identity), SIM ID, Email address, mobile phone number, unit recharged etc. The database is updated each time a customer pays his/her bills via SMS recharge by simply sending a secret pin obtained from a purchased prepaid voucher provided by the power providing company together with the meter ID to an SMS code provided by the power company. Other information such as total energy consumed, total amount paid on consumption, and date(s) of recharge are also contained in the customer's database. 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, and the huge revenue loss which was inherent in the traditional metring system is completely avoided.

Keywords: Microcontroller, Metering System, LCD display, Embedded C language.

INTRODUCTION

Electricity no doubt is the driving force behind the development of any nation; therefore with the astronomical growth in residential, commercial, and industrial consumption of electric

power throughout the world, it has become absolutely imperative for utility companies like the Power holding company of Nigeria (PHCN) to devise better, non-intrusive, and user friendly techniques of measuring energy consumption as well as invoicing bills accurately. Traditionally, information of energy consumed is collected from customers' meter by meter readers on their monthly or bi-monthly visits to customers' premises. This method of measuring power consumption is disadvantaged in several ways: Customers might be absent from home during visits from meter readers; therefore, estimated bills based on the customers' consumption history is invoiced. This could result in over-billing thereby placing an extra cost on the customer; also, the power supply company could be running at a loss as a result of under-billing the customer. Various sharp practices such as current reversal, reverse tamper, partial earth fault condition, by-Pass meter etc. are adopted in the traditional system to manipulate meter readings. This results in the loss of colossal amount of revenue by the supply company. Meter readers may make mistakes in taking readings or may be bribed to record inaccurate readings such that the actual consumption is reduced thereby resulting in a loss to the supply company.

In all the cases outlined, there is power pilfering from the customers' end, and surcharge from the power supply company's end among other anomalies.

LITERATURE REVIEW

Over the years, many authors have worked on automatic meter reading system. Some of such works include technologies like the touch based AMR system, a handheld automatic meter reading system among others. Shwehdi et al [1] presented the Digital Tele-wattmeter system as an example of a microcontroller based meter. This meter was implemented to transmit data on a monthly basis to a remote central office through dedicated telephone line and a pair of modems. It is only a stand-alone metering system. Kaoy et al [2] designed and implemented a Bluetooth energy meter where several meters which are in close proximity, communicated wirelessly with a master PC. Distance coverage is a major setback for this kind of system because Bluetooth technology only works effectively at close range. Stanescu et al [3] presented 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 to for status reporting such as power failure. Issues on billing system for electricity board usage were not considered. Sharma et al [4] suggested a method where we utilize telecommunication system for automated transmission of data to facilitate bill generation at the server end and also to the customer via SMS or Email.

While both the design by Sharma et al and the proposed design, Smart Energy Metering System, utilize telecommunication for the automated transmission of data to facilitate bill generation, the proposed design is solely based on a prepaid system whereas the design by Sharma et al is not. In the proposed design, the data transmitted are not necessarily for bill generation as in Sharma et al where only the generated bills are sent to the customers via SMS alert on their mobile phones, but for other purposes like alert on the success of bill paid, amount of bill paid, unit recharged, unit balance, low unit alert, and to check for possible tampering by unscrupulous customers among other purposes. The transmitted data, especially the unit recharged, amount recharged, and unit balance are used to update the customer's data base at the office of the power providing company. This information are used for future planning/energy management by the power providing authority and also sent to customers annually or on request via email or by post.

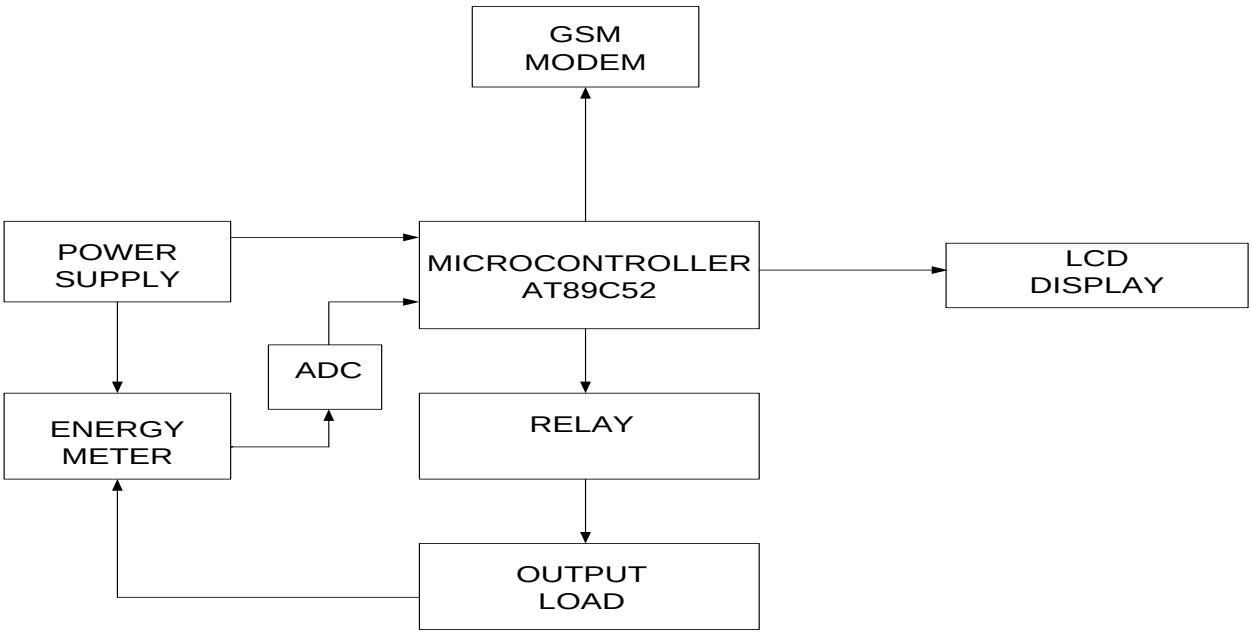
SYSTEM DESIGN/METHODOLGY

The design is made up of two sections-the hard ware section, and the software section. The approach used in the hard ware section of this work is the modular approach where the overall design was first broken down into functional block diagrams, with each block in the diagram representing a section of the circuit that carries out a specific function. The functional block diagram also shows interconnection between each block. The power supply unit functions to produce a constant regulated 12volts supply to power the entire circuit. The microcontroller unit is an Atmel (AT89C52) type which receives input from the GSM unit; the microcontroller sends signal to trigger ON or OFF the relay.

The relay unit consists of one 10A, 12V relays. The relay receives signal from the microcontroller and either switches ON or OFF the power supply to the house. The recharging of the meter is done from the phone; the microcontroller receives signals from the phone and triggers the relay accordingly. The ADC (analog to digital converter), which is used for A/D conversion is the interface between the Energy meter and the microcontroller, it continuously receives analog signals from the meter, converts to their digital equivalent and continuously sends the converted digital signals to the microcontroller for processing. Signals sent contain such information as unit consumed, unit left, and unit recharged among others; these information are displayed on the LCD.

The software section contains the embedded 'C' Language program consisting of a string of 'AT' command set and other instruction set to make the whole system workable. The 'C' source code was transferred to a Keil compiler software for conversion to 'Hex file', and then to the microcontroller. This section also contains the simulation of the whole system which was done with Proteus ISIS professional version 7.8 SP2.

FIGURE 1: GENERAL BLOCK DIAGRAM OF THE SYSTEM



Microcontroller unit

In this work, the power consumption circuit and GSM module are interfaced through the ports of standard microcontroller (AT89C52). The AT89C52 is a low-power, high-performance CMOS 8-bit microcomputer with 8K bytes of Flash programmable and erasable read only memory (PEROM). The device is manufactured using Atmel's high-density non-volatile memory technology and is compatible with the industry-standard 80C51 and 80C52 instruction set and pinout. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional non-volatile memory programmer. By combining a versatile 8-bit CPU with Flash on a monolithic chip, the Atmel AT89C52 is a powerful microcomputer which provides a highly-flexible and cost-effective solution to many embedded control applications.

The AT89C52 provides the following standard features: 8K bytes of flash, 256 bytes of RAM, 32 I/O lines, three 16 – bit timer / counter, a six vector two level interrupt architecture, full duplex serial port, on chip oscillator and clock circuitry. The extension ports can be done by using 8255 standard PPI. Here a programmed AT89C52 microcontroller with embedded C language is used. This AT89C52 is interfaced with a GSM modem, LCD module, Energy measuring module/ Energy meter, Load, etc.

Relay unit

A latching Relay is the connecting link between the consumer load and utility supply. The opening and closing of this relay depends on the balance present in the prepaid card at that moment. While the prepaid card has some amount more than zero it stays closed and keeps the utility supply uninterrupted to the consumer load. When the card runs out of balance, it opens and disconnects the load from the supply. Hence, even when the energy meter receives voltage supply, it does not reach the load while the latching relay is open because the balance in the prepaid card is not available. Since the latching relay too will consume some amount of electrical energy, it is inclusive in the calculations made for meter and prepaid card.

GSM Modem

The GSM modem is a Nokia 1600 GSM dual band phone (operating at 900/1800MHz GSM frequency Band)This phone was used for this work because it easily supports the 'AT' command and its software and the 'AT' commands are readily available; it can easily be interfaced as well. The three signals of the serial port interface of both the phone (modem) and the microcontroller are interfaced, i.e. TXD, RXD, and GND. This is followed by sending a string of 'AT' command to the system to initialize its operation. The baud rate here is 9600 bps.

Liquid crystal display

The LCD used in this work is HD 44780 (Hitachi controller) with 2 rows and 16 characters (2×16); meaning it has 2 lines of 16 characters each. The 44870 standard requires 3 control lines as well as either 4 or 8 I/O lines for the data bus. The 8-bit mode was used in this work. Thus, 11 data lines (3 control lines plus the 8 lines for data bus) are used because it is simpler for programming. In this system, we can find power usage instantaneously through the readings of this LCD; also, since the system is a prepaid type, the LCD display becomes very useful in knowing when to recharge and how many units are still left for usage.

Analog to Digital converter

ADC (Analog to digital converter) forms a very essential part in many embedded projects. In this work, ADC 0804LNC is interfaced with AT89C52 to convert analog inputs from the energy meter to the corresponding digital data which are accepted by the microcontroller for processing.

Digital Energy Meter

It contains a metering IC which measures the current and voltage signals and generates instantaneous active power. The instantaneous active power values are continuously integrated to an active energy register, the value of which is periodically accessed by the microcontroller via SPI (serial peripheral interface). The microcontroller uses the rate active register value to calculate the active power consumed.

GSM Based Recharge System

The power supply company sets the amount in the prepaid card to a measure that the consumer recharges the card to, called Recharge Amount (R_A). The tariff rates are already programmed and fed into the card. As the energy is consumed by the load, the meter sends units consumed to the prepaid card which continuously converts these units into expenditure (E) at each instance and then subtracts it from the Recharged Amount to obtain a balance (B)

Mathematical Model

$$R_A - E = B \quad (1.0)$$

In Nigeria billing structure [5], Expenditure is given by the expressions below:

$$E = N_A + VAT + C_c \quad (2.0)$$

$$C_c = Ec \times E_N \times M_F \quad (3.0)$$

$$E_C = L_R - P_R \quad (4.0)$$

Where
N_A = Net Arrears
VAT = Value Added Tax
C_c = Current Charge;
E_c = Energy consumed
L_R = Last Reading,
P_R = Present Reading
E_N = Energy charge per KWh,
M_F = Multiplier Factor

From equation (1.0), when the expenditure (E) = the recharged Amount (R_A), the Balance (B) becomes zero, the microcontroller pin in charge becomes high and triggers the relay to open and the consumer is disconnected. This action is reversed when the consumer recharges again.

Simulation/Test Results

The results obtained from the simulation/experiment are here presented:

FIGURE 2: LCD DISPLAY AT NO LOAD AND ZERO UNIT BALANCE.

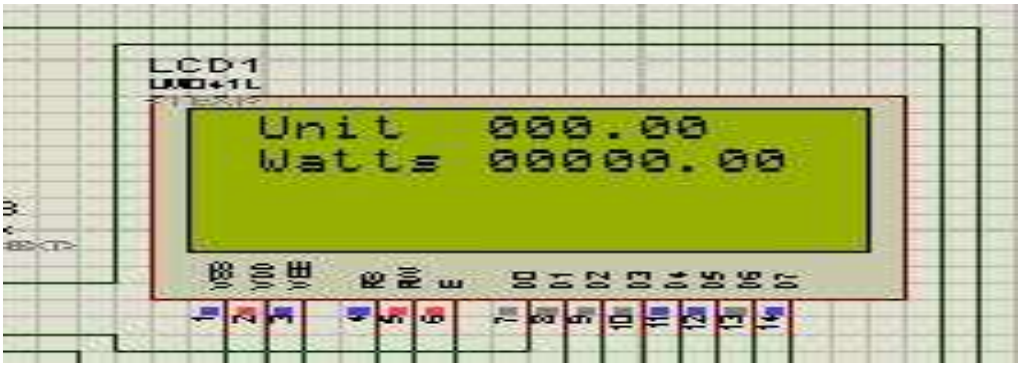
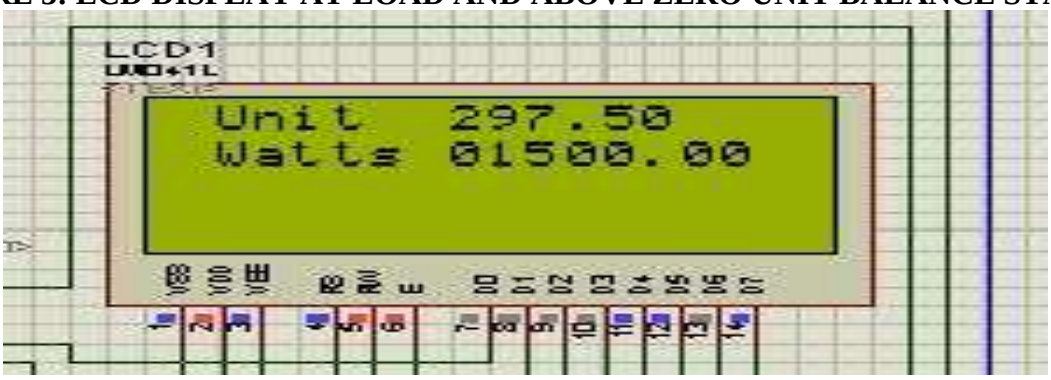


FIGURE 3: LCD DISPLAY AT LOAD AND ABOVE ZERO UNIT BALANCE STATE



Samples of SMS sent to user's mobile phone

- Your meter was successfully recharged with 300 units
- Your unit balance is critically low; recharge as soon as possible to avoid loss of power supply.
- Unit exhausted; recharge to continue to receive power supply.
- You have been disconnected by the power supply company.
- You have been reconnected by the power supply company.

TABLE 1: COMPARISON BETWEEN THE TRADITIONAL AND THE PROPOSED SMART ENERGY METERING SYSTEMS

S/N	FEATURES	SMART ENERGY METERING SYSTEM	TRADITIONAL METERING
1.	Remote monitoring	Possible(Electricity company reads meter without visitation)	Not possible
2.	Control of domestic energy meter.	Done from anywhere.	Done only at respective customers' houses
3.	Auto disconnect feature	Present here; customers are also alerted when their unit is exhausted	Not possible
4.	Bill payment as you go.	Bill is settled the moment the system is recharged	Not possible
5.	Power cut information	This system provides power cut information.	Not possible
6.	Data security	SIMS eliminates meter reading errors and manipulations thereby securing data.	Meter reading error and manipulation are inherent; no data security.
7.	Recharge Alert	The system alerts the user of any recharge done on it	Not possible.
8.	Critically Low unit alert.	Present; user is alerted when unit balance becomes critically low to recharge system.	Not possible
9.	Man power	No man power required	Huge man power required

CONCLUSION

The design and Testing of a Smart and Metering System (SEMS) demonstrate the concept and implementation of a new power metering system. GSM Based (SEMS) has low infrastructure cost, low operating costs, more data security and less man power requirement. It does not only solve the problem of manual meter reading but also provides additional feature such as power disconnect, power reconnect, and SMS alert on a number of operations in the system. Customers can also pay bill via SMS on authenticated number(s). Data Base server can store the current month data and also all previous month data for future use and planning by the power supply company.

REFERENCES

[1] Shwedi M.H and Jackson. C (1996).A microprocessor based digital wattmeter System design. Proceedings of the31st inter society conference on Energy conservation Engineering. Vol 31, pp1840-1845

[2] Kaoy B.S et al (2003).Design and implementation of Bluetooth energy meter Proceedings of the joint 4th international conference on Information, communication and signal processing and the 4th Pacific Rim conference on multimedia vol 3, pp.1474-1477

[3] Stanescu.D et al (2006).Wireless solutions for telemetry in civil equipment and Infrastructure monitoring 3rd Romanian-Hungarian Joint Symposium on applied computational intelligence (SACI) http://www.bmf.hu/conferences/Saci 2006/ ciubotaru.pdf

[4] Sharma.S and Shoeb.S (2011).Design and implementation of wireless automatic Meter reading system.International Journal of

Engineering,Science and Technology(IJEST),vol 3,No 3,pp 2329-2334

[5] Nwaoko Kosi Joy (2006).Electrical energy accounting methods .Impressed Publishers Lagos Nigeria, pp 1-8