

Smart Energy Meter for Load Control using Mobile Communication Technology

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Abstract- Smart metering is a major development in utility industries today especially the electricity industries. However, many benefits of smart metering have not been fully explored due to the limited functions of many prepaid meters that have been implemented so far in most developing countries. With the spread of internet use and web based application [1], there is the need to focus on how prepaid meters can be aided to stay online through Mobile Communication Systems [2] available in most developing countries. In this paper, design of Smart Energy Meter was achieved with Atmel microcontroller as the main part for evaluating consumed electric power and Power Factor (PF). ADE7756 metering IC is used as input unit as it contains voltage and current transformer. The root mean square (rms) value of voltage and current, consumed electric power, and PF will be monitored through LCD at customers premise and these parameters also are sent through a GSM wireless network to the base station in order to articulate consumed electrical power fees and also evaluate and monitor electric power consumption and demand.

Keyword: smart meter, load control, GSM module, Automatic Meter Reading (AMR)

1.0 Introduction

As commercial use of electric energy spread in the 1880s, it became increasingly important that an electric energy meter, similar to the then existing gas meters, was required to properly bill customers for the cost of energy, instead of billing for a fixed number of lamps per month [3]. Many experimental types of meter were developed. Accurate metering, detection of illegal activities and implementation of proper tariff became some of the challenges of the billing system that would manage the consumption of electrical energy. Collecting meter reading remains one of the most difficult procedures in billing. The traditional electrical energy meter data collection is such that a person from the utility provider visits the consumer sites periodically to note the meter reading. This procedure has lot of drawbacks including that it is time consuming, tiresome, requires more human resource; even human errors and corruption is a high probability [4]. The process may be interrupted due to bad weather conditions, also if the consumer is not available, the billing will be pending and billing officer needs to revisit. In recent years however,

shifts are being made towards prepaid meters and automatic meter reading (AMR).

Energy is an increasingly important societal resource, in that it directly correlates with the economic welfare of a populace [5]. Many countries across the globe like United States of America, South Africa, Botswana [6] etc., are already involved in projects with smart metering on a demonstration scale or full implementation. The last couple of decades have seen electric power being managed using different technologies [7]. The era in which we are now, is very much characterized by fast growing technologies [8]. These have found their way also in power management. The essence of using Smart Energy meters in the management of power is to help improve on service delivery, cash flow, reduce credit and arrears collection costs, avoid deposits and monthly bills as well as reconnect charges, reduce inconvenience to users and utility companies and many more. This system will also be used to effectively monitor energy usage, and disconnect the power supply to the house in case of non-payment of electricity bills or suspicion of fraud.

2.0 Review of Related Works

[9], in their work, 'GSM Based Automatic Energy Meter System with Instant Billing', proposed a system which measures the current consumption unit through IR sensor unit. The IR transmitter is placed in the rotating unit of the Electronic Billing (EB) meter. The receiver photo diode is placed with the IR receiver and is used to find number of rotation. By getting the number of rotation the current consumption was gotten. After getting the current consumption the ARM processor reduce the unit given for specific user. The unit here is taken as numeric value. If the unit is reduced to minimum value it will intimate the user through alarm and LCD unit. If the user wants to add more units, he has to send a message to EB section. From the EB section the required value will be sent to the ARM controller through GSM modem. From the obtained value the ARM increments the unit in the memory. Thus recharge process is done quickly with less manual interactions.

Also, [10] in their work, 'Gsm Based Power Meter Reading And Control System' presented a GPMC (GSM based power meter and control system) which consist of the integration of a single phase Class 1, IEC61036, standard compliance digital kWh power meter. It keep track of the meter reading of each day and the reading with the user identification number sent to the user as well as to the electricity department and Electricity e-Billing system associated with electricity department keeping the track of each SMS meter reading and the appropriate bill get generated at the last day of the month and the bill is forwarded to user from the server. So there are no chances of confusion to the user for paying the bill. The GPMC also feature distribution control system which controls the power of the appliances remotely.

In their work of [11], 'GSM based Automatic Energy Meter Reading' presented a project of which its purpose is the remote monitoring and control of the Domestic Energy meter. This system enables the Electricity Department to read the meter readings regularly without the person visiting each house. This can be achieved by the use of Microcontroller unit that continuously monitors and records the Energy Meter readings in its permanent (non-volatile) memory location. This system also makes use of a GSM modem for remote monitoring and control of Energy Meter.

Besides, [12] in his work titled, "GSM Based Automatic Meter Reading System Using ARM

Controller", proposed an energy meter which generates the pulses as well as count the energy consumed. In that kind of meter, an ARM processor based board is used. It uses a 32-bit processor with on-chip ADC, timer/counter module, PWM and UART module to interface a GSM modem and energy meter. The digital energy meter has an LED which blinks for a specific number of times to indicate the energy consumed (e.g. 1 Unit = 1600 pulses). These pulses are fed to ARM based system which is programmed to count these pulses. The system reads these pulses and after counting specific number of pulses it increments the internal counter by one which indicates the number of units consumed.

The work in this paper adopts the use of easily available yet viable components to achieve automatic metering hence driving the cost low while at the same time achieving high precision monitoring and control of used energy.

3.0 Methodology and System Designs

The methodology adopted in this work follows a structured design process that requires a systematic approach with intelligently guided computer simulations and testing.

Incremental prototyping approach is used in the implementation of hardware which entails the development of a particular hardware unit on a breadboard, testing and evaluating the performance of that unit to verify its workability before moving on to the development of other units. After the development of the various units, the units are then integrated and then further tested based on predetermined test criteria to ascertain the system's workability before the final packaging. This approach is however carried out after all the necessary circuit designs have been done and simulated on a computer.

3.1 System Architecture

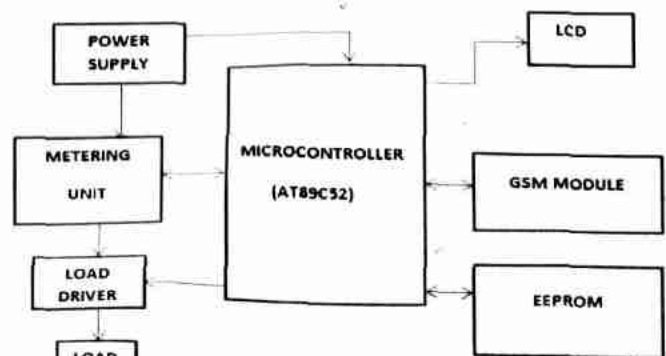


Figure 1: Smart energy metering system Architecture

The system is made of various units chiefly the metering unit, the controlling unit, the communication unit and the load unit (see Figure 1).

As shown in figure 1, the system comprises the communication, display, control, and metering units. The microcontroller is the control unit, assemble language was used in programming the AT89C52 microcontroller, the communication unit is the GSM module, GSM Modules are similar to modems, but A GSM/GPRS Modem is an external equipment, whereas the GSM Module is a module that can be integrated within an equipment. It is an embedded piece of hardware. The microcontroller uses AT commands to control the GSM Module. GSM Modules support an extended set of AT commands. These extended AT commands are defined in the GSM standards.

3.2 Hardware Design

(i) The metering Unit

The metering unit is responsible for measuring the amount of load connected to the meter and forwarding it to the processing system for the necessary computation to be done with it. The metering unit uses a Voltage and Current Sensor connected to an Energy Metering Unit (EMU) to measure average, active and real power. The core of the metering unit is a metering IC—ADE7756 (Figure 2); The ADE7756 is a high-accuracy electrical power measurement IC with a serial interface and a pulse output. The ADE7756 incorporates two second-order sigma-delta ADC's, reference circuitry, temperature sensor, and all the signal processing required to perform active power and energy measurement. It achieves the integration of the Active Power signal by continuously accumulating the Active Power signal in the 40-bit Active Energy register. This discrete time accumulation or summation is equivalent to integration in continuous time. Equation 1 expresses the relationship.

$$E = \int P(t)dt = \lim_{T \rightarrow 0} \left\{ \sum_{n=0}^{\infty} P(nT) \times T \right\} \quad (1)$$

Where n is the discrete time sample number and T is the sample period.

The ADE7756 contains a sampled Waveform register and an Active Energy register capable of holding at least five seconds of accumulated power at full load. Data is read from the ADE7756 via the serial interface.

The error associated with the energy measurement made by the ADE7756 is defined by the following formula:

Percentage error =

$$\left(\frac{\text{Energy registered by ADE7756} - \text{True energy}}{\text{True energy}} \right) \times 100\% \quad (2)$$

The communication unit is achieved by the use of GSM Module coupled with a Microcontroller using MAX232 to send and receive information.

The MAX232 device is a dual driver/receiver that includes a capacitive voltage generator using four capacitors to supply TIA/EIA-232-F voltage levels from a single 5-V supply. Each receiver converts TIA/EIA-232-F inputs to 5-V TTL/CMOS levels. MAX232 is proposed for application in high-performance information processing systems and control devices of wide application.

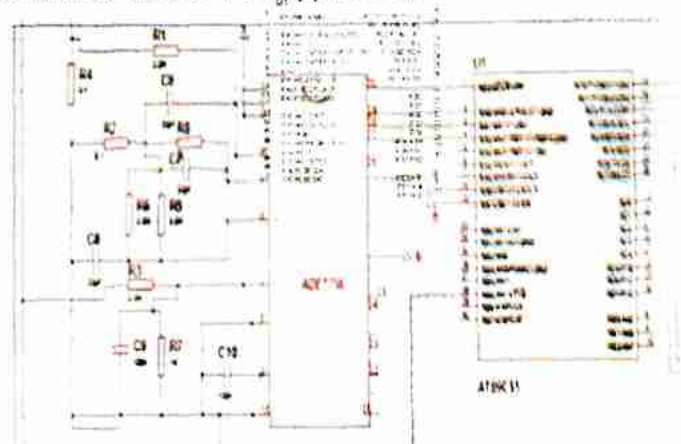


Figure 2: the metering Unit Design

(ii) Interfacing GSM module to the AT89C52 microcontroller

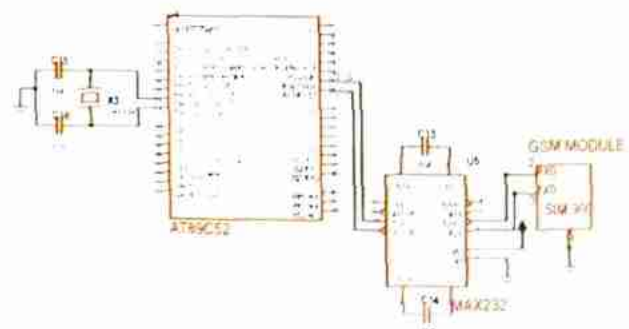


Figure 3: Interfacing GSM Module

To interface the GSM modem to the AT89C52 microcontroller, it is required that they transmit and receive pins be inversely connected to each other through the MAX232 IC which is also a voltage converter circuit. By inversely, it means that the RXD pin of the microcontroller connect with the TXD pin of the GSM module and the TXD pin of the microcontroller connect with the RXD pin of the GSM module. Only the RXD and TXD pins are needed to send message, to receive message, to make

call and to receive call on GSM module through the microcontroller. The microcontroller uses AT commands to control the GSM Module (see Figure 3).

(iii) Interfacing the display unit

The display unit used for the design is the Liquid Crystal Display (LCD) because of its ability to display numbers, character, and graphics, the ease of programming for characters and graphics and low power consumption. Figure 4 shows the LCD and its interface with the microcontroller.

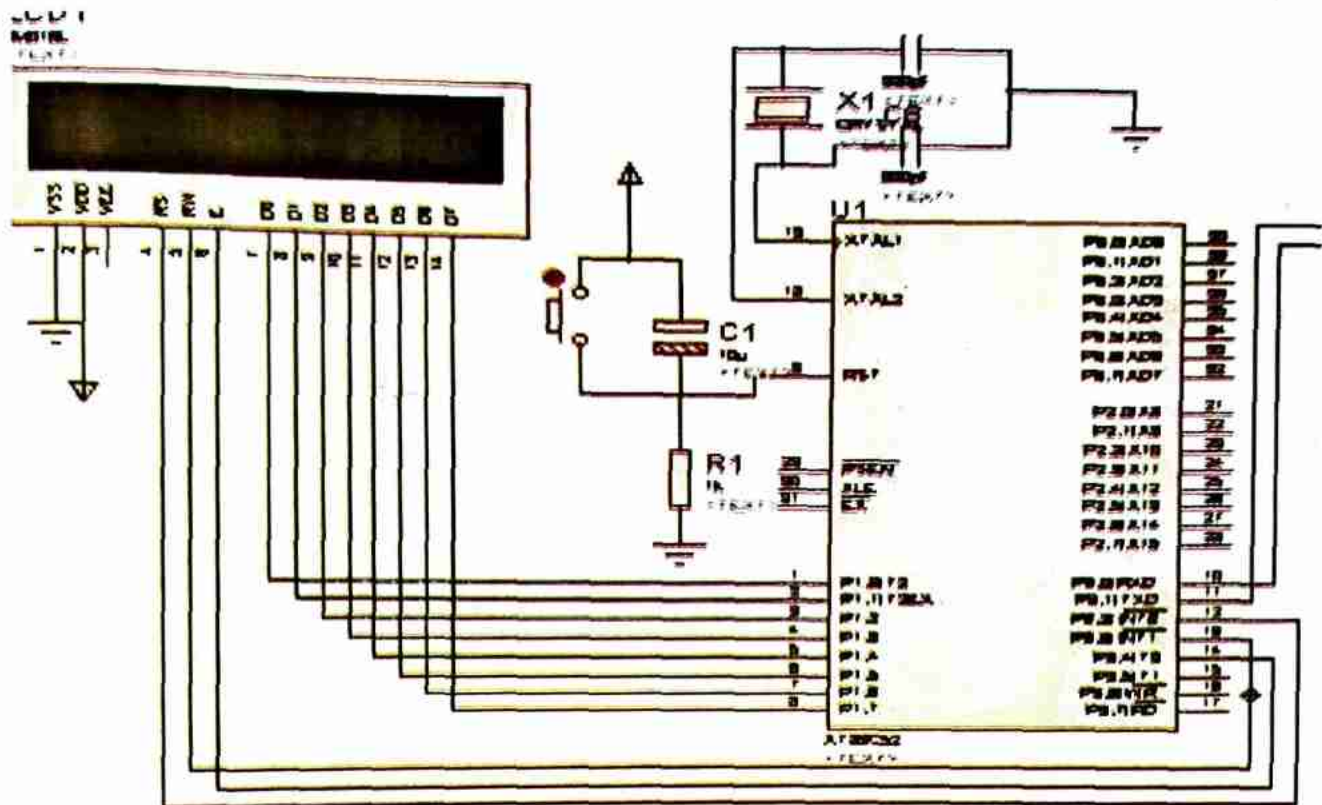


Figure 4: Interfacing Display Unit.

The hardware design involves all the components and tools used to design the smart energy metering System. There are five Units involved in the hardware design stage; power supply unit, Input unit (Metering Unit), Processing Unit, Communication Interface unit, and Output unit. The complete circuit for the project was obtained from the integration of these various units of the project together as shown in Figure 5.

3.3 Software Design

The software design of the work consists of developing computer program for the microcontroller to implement the desire software features and integrate the various hardware elements. This also includes the program codes to implement and interface the various sub-unit of the system with the microcontroller. Basically the programs are written in assemble language and implemented on the microcontroller.

The program development was carried out in modules using an algorithm. The first task was to initialize the registers and variables to be used in the program in the microcontroller. Next was to send metering configurations from the microcontroller to the metering chip and GSM module. In turn, the microcontroller fetches the energy reading from the metering chip, compute the power value which is then displayed on the LCD, compute the consumed power cost and deduct from the available credit. The next routine was designed to perform a check on the available credit, if available credit is less than or equal to 10, a credit low alert is sent through the GSM module. A request can then be sent to the microcontroller to turn ON or turn OFF load. All the routines were written using the assembly language and was ensured error free.

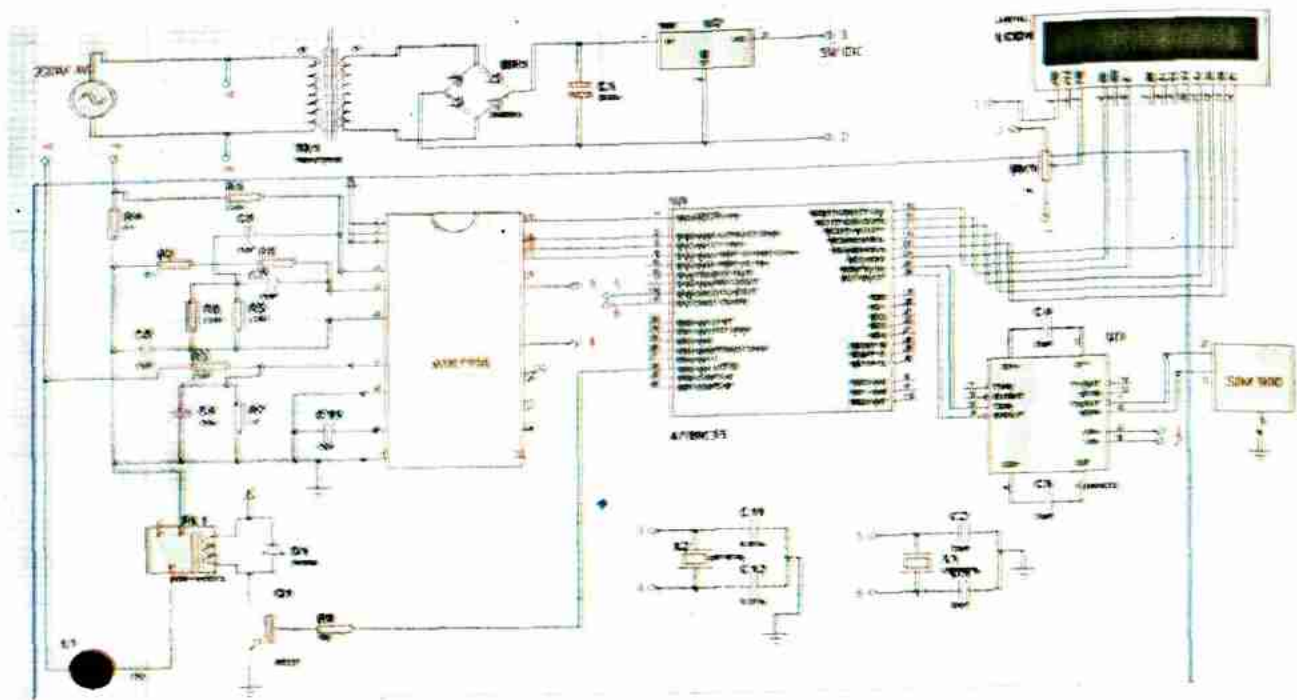


Figure 5 complete circuit diagram of fully integrated design

4.0 System Integration Testing and Evaluation

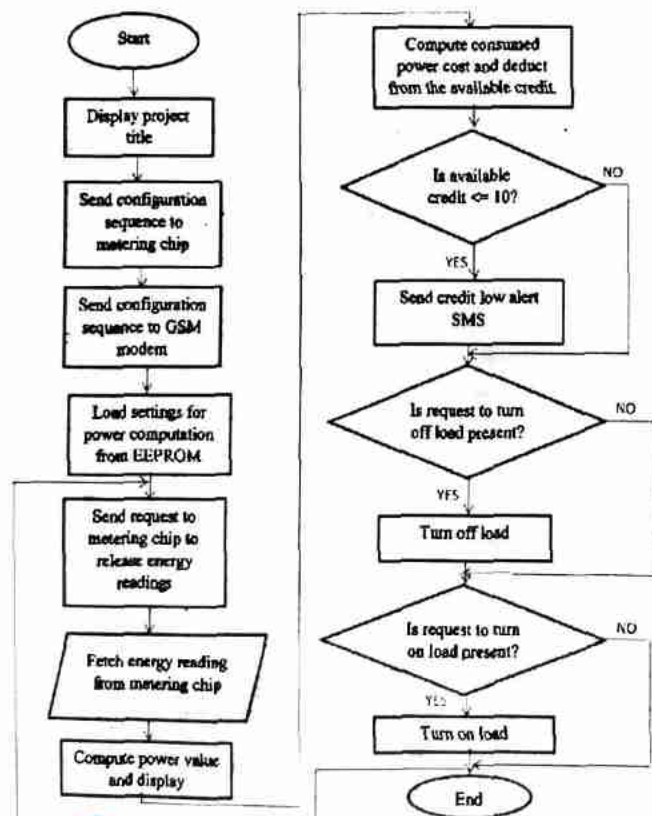


Figure 6: Software flowchart

After the different system components making up the design have been tested individually, the whole sub systems were incorporated together and the final full system testing was carried out. This testing was also carried out through simulation first before hardware implementation and testing.

When all the various sub-units have been integrated and tested to ensure that they work together and independently, the entire system was tested together. Figure 7 shows a picture of the coupled device during operation, and in figure 8, the display of the meter is seen showing current load and the remaining energy credit unit.



Figure 7: Complete view of the system



Figure 8: LCD view of the system showing current load and remaining energy credit unit.

At each of these instances, the user mobile numbers that have been programmed in the microcontroller during the software design stage received the pre-configured message, informing the meter owner of an action which is going on, on the meter (fig 9).

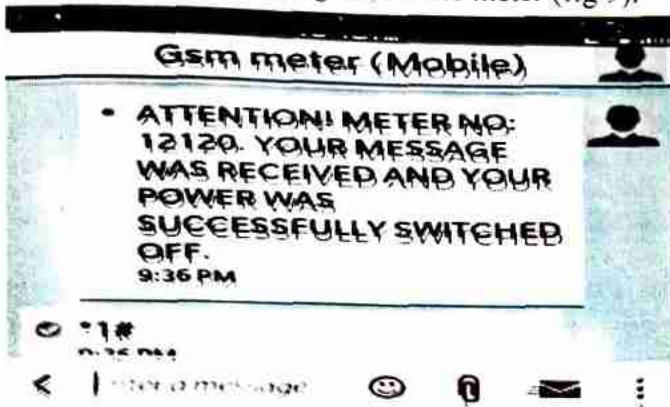


Figure 9: Snapshot of the received message during testing

5.0 Conclusion

Smart metering is obviously the way forward in the pursuit of power efficiency on the part of the power companies as well as their consumers.

This work describes the design and development of Smart Energy metering system for load control. One of the main achievements of this work is the development, using local and available materials, of a smart energy meter. This affords for it to be an economical alternative to its more expensive counterparts in the market. It employs the utilization of a communication channel (GSM) which has the most spread especially in developing countries like Nigeria, thus not requiring an additional setting up of communication infrastructures as is the case with other communication channels like Zigbee, Wifi, PLC etc. The work also provides an efficient means of energy management and conservation as the load can be controlled remotely. It also provides an easy and convenient way of acquiring meter readings (Automatic meter readings) hence ensuring accuracy, lower operational cost and removal of possible corruption and fraud related to meter reading and revenue collection.

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