

Development of a GSM-Based Smart Energy Meter

¹Egwaile J.O. and ²Odia O.O.

¹Department of Electrical/Electronic Engineering, University of Benin, Benin City

²Department of Computer Engineering, University of Benin, Benin City

¹joeranky@yahoo.com

²osasuyi.odia@uniben.edu

Abstract- In this work, a GSM based smart energy meter has been developed. This smart meter can be remotely queried and recharged via a GSM link. The designed smart meter was built around the ATmega32 Microcontroller programmed in C, which serves as the main controller for the circuit and the ADE7755 metering chip which senses the load current and voltage and gives an output that is equivalent to their product. Wireless communication between the meter and registered GSM line was established with the aid of SIM900 GSM module using AT-commands. A Token Generator was created in Visual Basic Environment which was used to generate tokens/pin code to recharge the meter. The token is an encryption of the Meter Serial Number, Supply Group Code (SGC) and the number of units that a consumer wishes to purchase. The microcontroller is able to decrypt this information, cross check it, before it is accepted. If the token is invalid, an alarm is triggered indicating an invalid token, and this is displayed on the LCD screen. A comparison of the readings from the designed meter and that from a conventional wattmeter shows that the reading from the designed meter is sufficiently accurate as the average percentage error is about 0.6%. The reading can therefore be said to be a true reflection of the energy actually consumed.

Key Words: Token Generator, Supply Group Code, ATmega32 Microcontroller, GSM Link.

1.0 Introduction

Electricity has become one of the principal factors of any economy and it is the catalyst for development in any country. Electric energy is used to drive domestic, commercial and industrial loads as a key source of energy in today's world [1][2]. With the growing demand for electric power, consumers are asking for better customer service, high accuracy of energy measurements, and healthy power supply along with timely data delivery. The need to curb energy theft cannot be overemphasized. It has now become imperative for utility companies to devise better, non-intrusive, environmentally-safe techniques of gauging utilities consumption.

Considering the cost of power generation and transmission, it is necessary that electricity (electric energy) is monitored to ensure it is optimized and accounted for. For these reasons, energy metering system has been put in place in recent times. Metering could be defined as the process of effectively determining and monitoring power consumption [3]. Energy meters could be analogue or digital.

Energy, which is the total power delivered or consumed over the interval of time t , may be expressed as:

$$E(t) = \int_0^t P(t) dt \text{ --- 1.1}$$

The instrument used to measure either quantity of electricity or energy, over a period of time is known as energy meter or watt-hour meter. Energy meters are typically calibrated in billing units, the most common being the kilowatt hour (kWh). Periodic readings of electric meters establish billing cycles and energy used during a cycle [4].

Analogue metering consists of mainly measuring the electrical energy. This process uses electromechanical meters whose mode of measurement is through a coil and rotating disc. The electromechanical meters are installed at the user's end. At periodic intervals, meter readers/inspectors are instructed to read the unit on the meter, this reading is used to determine the energy charges for the user. Analogue billing system systems are subject to human computational errors and utility providers may need to periodically send

representative to private homes, offices and industries to read a customer's energy consumption over a period of time. This could be time consuming and cumbersome, and can add to the overall cost of energy. The fact that these meters cannot be remotely queried makes its suitability limited in today's world. The electromechanical meters cannot display real time information of energy usage. [3]

Smart metering is an upgrade of the analogue metering [4], [5], [6]. In most digital metering systems, communication is established between the meter, user and the utility company. The meters used in the process are digital and smart. The electronic meter differs from the smart meter in the mode of communication. The electronic meter can only establish a simplex (one direction) communication while smart meter can establish a duplex (two directions) communication. In this system, the consumer is updated with electricity usage, cost, tariffs and other notifications sent by the utility. The smart meter developed in this work can also be remotely queried and recharged.

2.0: Literature Survey

Due to the advancement of technology and the demand of consumer for better power supply, Smart meter has been adopted by many. Since smart energy meters have these different functionalities to manage the end user loads and run them in an optimal way to reduce the electricity bill as well as to conserve the energy [7].

A Bluetooth Energy Meter was developed by Koay B.S et.al. The interface between a Meter Reader, PC and the Energy Meter via a Bluetooth can be categorized into three main distinctive portions. The first portion consists of the interface between a PC and the Bluetooth module. The second comprises of the interface between the Bluetooth module and the microcontroller; the interfaces in the first and second portion are both using the standard RS-232 protocol. The third is about the interface between microcontroller and Energy Meter, whereby the communication link is conforming to the Serial Peripheral Interface (SPI) standard. [8] The communication range is one of the shortcomings of this meter.

Jubian and John demonstrated the design and implementation of Prepaid Energy Meter with GSM Technology with the aim of minimizing the queue at the electricity billing counters and to restrict the usage of electricity automatically, if the bill is not paid [9]. The GSM technology was used so that the consumer would receive messages about the consumption of power (in watts) and if it reaches the minimum amount, it would automatically alert the consumer to recharge. A microcontroller AT89S52 is programmed such that power supply will switch off by using relay when the unit on the energy meter is exhausted. It also brings a solution of creating awareness on unnecessary wastage of power and will tend to reduce wastage of power. The challenge in this work is that meter cannot be recharge remotely. Since it can send alert to the consumer about the low credit unit on the meter, it will be best if the consumer can recharge the meter on their same platform. Hence the system can be improved on by creating a means of recharging the energy meter remotely.

3.0 Methodology

For this work, a hardware/software methodology was used to implement the GSM based Smart Energy Meter.

ATmega32 Microcontroller was programmed in C language-using AVR Studio IDE. Simulation was done with the aid of Proteus and AVR Studio Software.

The energy meter was designed using an ADE7755 metering chip which senses the load current and voltage and gives an output that is equivalent to their product, ATmega32 Microcontroller programmed in C language which serves as the main control unit of the system and other discrete components. Wireless communication with the meter and registered GSM line was established with the aid of SIM900 GSM module using AT-commands. Also, a 4x3-keypad was employed for loading energy tokens (recharging the meter) and obtaining energy information from the meter; the energy data will be viewed on the liquid crystal display unit. Simulation of the electronic circuit designs was carried out using Proteus software, Atmel AVR development kit and a serial port monitor via 232 RS connector.

3.1: System Specification

The specifications for the designed system is presented in Table 1.

Table 1: Systems Specification/ Features

S/N	Parameter	Specification/Feature
1	Operating Voltage	240V
2	Operating Frequency	50z
3	Operating Temperature	-10 ⁰ C to 70 ⁰ C
4	Memory	Non-Volatile Based Energy Ready System
5	GSM Modem	GSM 900/1800 MHz
6	Display System	16 x 2 LCD for active load in Kilowatts and Recharge Balance
7	Auto Disconnect/Reconnect Feature	Automatically disconnects load from Mains when credit is exhausted and reconnects after recharge
8	Meter Reading	It can be automatically queried to determine current consumption and recharge balance
9	Meter Recharge	Codes could be entered via a capacitor touch keypad or remotely via SMS
10	Token Generation	An encryption of three parameters; i.e. Meter Serial Number, State Group Code and number of units to be purchased.

3.2: System Design

Figure 1 presents the block diagram of the system followed by the design of the system.

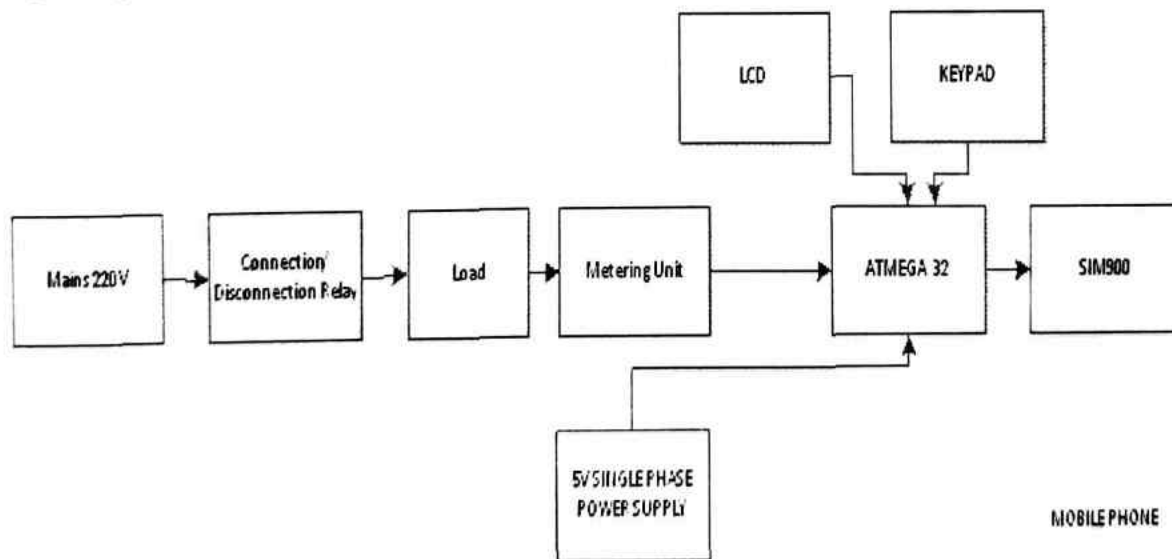


Figure 1: Block Diagram of Smart Energy Meter.

3.3 Design of the Power Supply Unit

The basic components that were used to design the power supply for the integrated circuit are:

- Step down transformer (inside AC/DC adaptor)

- Voltage regulators
- Capacitors
- Diodes

(i) Transformer

Rating: 500VA, 220/12, 1A.

(ii) Voltage Regulator

Since a 5 V output voltage is required, an LM7805 voltage regulator IC was used. This ensures $5V_{dc}$ is supplied as V_{CC} to most of the components.

(iii) Rectifying Circuit

This is a full wave bridge rectifier built around 4 diodes capable of withstanding a high reverse voltage of up to 1000V.

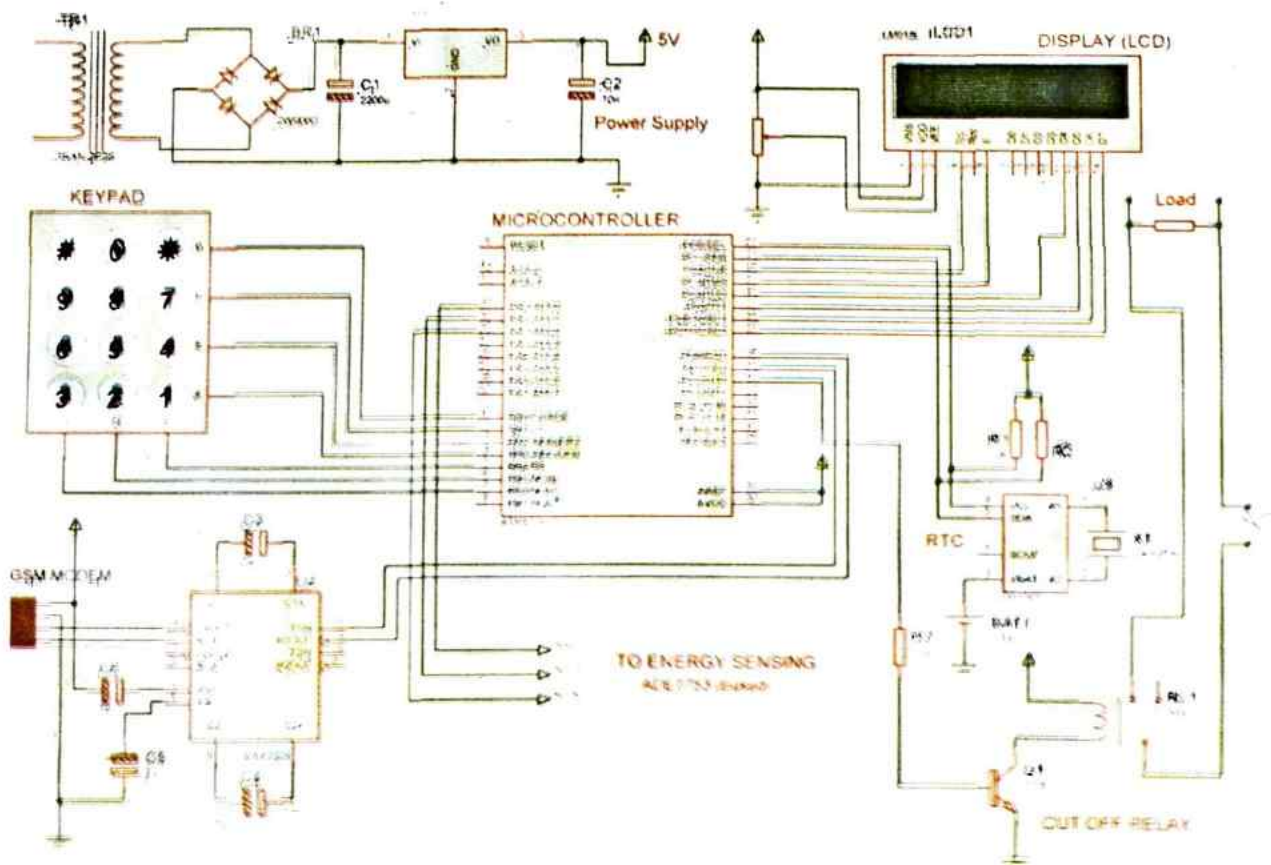
(iv) Filter Capacitors

The datasheet of 7805 prescribes to use of $0.33\mu F$ at the input side of the regulator to filter ripples from the bridge rectifier, and a $0.01\mu F$ capacitor at the output side to avoid transient changes in the voltages at its input due to changes in the load.

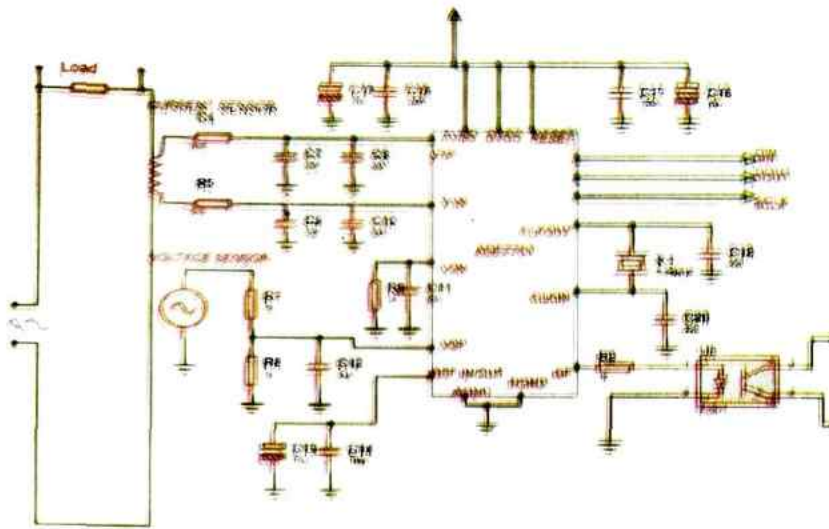
The values of C3-C6 are $1\mu F$ are as specified by the the Max232 datasheet (this serves as interface between the GSM modem and the Atmel microcontroller) [10]. The Value of the

crystal oscillator X1(this sets the time to complete on cycle of instruction) is 32.768kHz which was obtained from the RTC 1307 datasheet [11] as well as the value of the resistors R1 and R2 ($10k\Omega$) each. The pin configuration for the microprocessor, LCD and the metering chip ADE7753 were given from the Atmel ATMEGA 32 datasheet, LCD 016M002B datasheet and ADE7753 datasheet [12] [13] [14]. The Values of R4, R5, R6, R7, R8 and R9 are $10k\Omega$, $10k\Omega$, $1k\Omega$, $1k\Omega$, $1k\Omega$, $1k\Omega$ respectively which were obtained from the ADE7753 datasheets as well as the values of C7, C8, C9, C10, C11, C12, C13, C14, C15, C16, C17, C18, C19, and C20 are 33nF, 33nF, 33nF, 33nF, 33nF, 33nF, 10 μF , 100nF, 10 μF , 100nF, 100nF, 10 μF , 22pF, 22pF respectively. The Value of the internal crystal of the Energy sensing chip ADE7753, X2 is 3.58MHz given in the data sheet of ADE7753 [12][15].

The circuit diagram of the smart energy meter is presented in Figure 2



(a)



(b)

Figure 2a & 2b : Circuit Diagram of the Designed Smart Energy Meter

3.4 Operation of the GSM based Smart Energy Meter

Once a correct token (recharge code) is sent to the meter, (this can be from a remote location through a GSM phone or directly entered via the keypad on the meter) the microcontroller recognizes this input, verifies it and sends a signal to the LCD which in turn displays an output which is the KWh equivalent of the recharge. When an electrical load is applied to the meter, the metering chip ADE7755 senses the voltage and current drawn by the load, and generates a digital output which is equivalent to the product of the current and voltage drawn by the load at that instant. This signal is continuously fed to the Microcontroller (ATmega 32). The microcontroller continuously compares the value of the energy being consumed with the KWh equivalent of the recharge and produces an output which is equivalent to their arithmetic difference. This is sent to the LCD for display. The microcontroller has been programmed to send a "cut off" signal to the relay when this difference becomes zero, thus the load is disconnected from supply. The cut off relay can be closed again upon recharge on the meter.

The LCD is interfaced to the microcontroller

using parallel port connection. The GSM modem is serially connected with the controller which is the major communication module between user and meter. The programming makes use of messaging features of GSM AT command.

GSM technology is included to send messages to the customer about their recharge balance, an alert is also sent to the customer by the utility company warning him/her of low energy balance before it is eventually disconnected if no action is taken to recharge.

4.0 Token Generation

The Token Generator used was created in a Visual Basic Environment which was used to generate tokens/pin code for the energy meter.

The PIN code used to recharge the meter is an encryption of three key parameters. These are:

1. The Meter Serial Number
2. Supply Group Code (SGC)
3. The number of units that consumer wishes to purchase.

For this design, the combination of the meter serial number, number of units to be recharged and the state code was used to encrypt the recharge token. When the utility sales personnel insert the user's state code, unique

meter serial number as well as the number of units he/she wants to purchase, the token generator will generate a unique token for the user.

When the generated token is loaded into the meter via the keypad or SMS by the user, the

meter decrypts this information, cross check if it is correct before it loads it. If the token is invalid, the meter makes an alarm sound and invalid token is displayed on the LCD.

The graphical user interface of the token generator is presented in figure 3.



Figure 3: Graphical User Interface (GUI) for Token Generator

5.0 Testing

To determine the accuracy of the designed meter, different load were applied to it,

readings were compared with the readings from a conventional wattmeter, the result is presented in Table 2.

Table 2: Load Readings from Designed Meter and Conventional Meters

Electrical Load	Reading From Conventional Wattmeter (Watts)	Expected Reading (KWh) After 30 Minutes	Reading from the Designed Smart Energy Meter (After 30 Minutes) KWh
200 W incandescFent bulb	207W	0.1035	0.1039
108 W LCD LG Television	115W	0.0575	0.0578
18W energy Savings Bulb	23W	0.0115	0.0119

5.1 Discussion

A comparison of the readings from the designed meter and that from a conventional wattmeter shows that the reading from the designed meter is sufficiently accurate as the average percentage error is about 0.6%. The reading can therefore be said to be a true reflection of the energy actually consumed.

6.0 Conclusion

The GSM based Smart Energy Meter was designed and constructed. The designed meter worked satisfactorily on test.

This work will improve the metering system in Nigeria as well as aid the user to remotely monitor the energy consumption as well as remotely recharging the meter. **References**

[1] Na Wu*, YinjingGuo, Yongqin Wei & Aying Wei (2013): "Design of the Remote Wireless Meter

Vol.11, No.11, November 2013, pp. 6358-6366 e-ISSN: 2087-278X.

[2] Satheyamoorthy K.P. (2013) "Smart Energy Meter Load Control in International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering Volume 2, Issue 8, ISSN: 2278-8875, available at www.ijareeie.com.

[3] Shomuyiwa D.A. and Ilevbare J.O. (2013): "Design and Implementation of Remotely Monitored Single Phase Smart Energy Meter via Short Message Service (SMS)" International Journal of Computer Applications (0975 – 8887) Volume 74 – No.9,

[4] Thamarai P., Amudhevali R., (2014) Energy Monitoring System using PLC & SCADAS International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering Volume 3, Issue 2, ISSN: 2278-8875, available at www.ijareeie.com.

[5] Rodney Tan H.G., Lee C.H. & Mok V.H (2007), "Automatic Power Meter Reading System Using GSM Network" The 8th International Power Engineering Conference (IPEC)

[6] Edison Electric Institute, (2011) Smart Meters and Smart Meter Systems: A Metering Industry Perspective pp 7-10

[7] Ekanayaka J., Liyanage K., Jianzhong W., Yokoyama A., Jenkins N. (2012) Smart metering and demand-side integration. In: Smart grid technology and applications, 1st edn. Wiley, Chichester, pp 83-112.

[8] Koay B.S., Cheah S.S., Sng Y.H., Chong P.H.J., Tong Y.C., Wang X.C., Zuo Y.X., Kuek H.W., (2003),

"Design and Implementation of Bluetooth Meter" International Communications and Signal Processing and Fourth Pacific Rim Conference on Multimedia. Proceedings of the 2003 Joint Conference of the Fourth International Conference Volume 3 Singapore, pp 1474-1477, P.ISBN: 0-7803-8185-8

[9] Jubi K., John M., (2013) "Prepaid Energy Meter with GSM Technology," American International Journal of Research in Science, Technology, Engineering & Mathematics, USA, pp195-198 ISSN (online): 2328-3580.

[10] Max232datasheet accessed at www.datasheets.maximintegrated.com/en/ds/MAX220-MAX249.pdf on 27th May 2016.

[11] RTC1307 DataSheet accessed at www.datasheets.maximintegrated.com/en/ds/DS1307.pdf on 27th May 2016

[12] Atmel ATMEGA 32 DataSheet accessed on 27th May 2016 at <https://www.atmel.com/Images/Atmel-8-bit-Microcontroller-with-32Kbytes>.

[13] LCD-016M002B Datasheet accessed at <http://search.datasheetcatalog.net/key/LCD-016M002B> on 12th June 2016

[14] ADE7753 datasheet accessed at www.analog.com/media/en/technical-documentation/data-sheets/ADE7753.pdf on 12th June 2016

[15] Transistor TIP41 datasheet accessed at www.bocasemi.com on 12th June 2016.

Author's Profile

➤ **Dr. Joel Osarumwense Egwaile** was born on the 19th January, 1977. He Holds Bachelors Degree in Electrical/Electronic Engineering (First Class Honours), a Master's Degree in Electronic/Telecommunication Engineering (2007) and a PhD in Power Systems Engineering (2013) both of the University of Benin, Benin City, Edo State, Nigeria. He is a Cooperate member of the Nigerian Society of Engineers and a Registered Engineer with the Council for the Regulation of Engineering in Nigeria (COREN). He is currently a Senior Lecturer in the Department of Electrical/Electronic Engineering, Faculty of Engineering, University of Benin, Edo State, Nigeria. His research interest includes Power Systems Improvement Using Smart Grid Technology.

➤ **Mr. Osasuyi Ozuem Odia** was born on the 16th January, 1988. He Holds a Bachelors (2010) and Master's Degree (2015) in Computer Engineering both of the University of Benin, Benin City, Edo State, Nigeria. He is a Cooperate member of the Nigerian Society of Engineers. He is currently a Graduate Assistant in the Department of Computer Engineering, Faculty of Engineering, University of Benin, Edo State, Nigeria. His research interest includes Wireless Sensor Networks, Computer Architecture, Artificial Intelligence, Internet of Things.