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Design and construction of a smart electric metering system for smart grid applications: Nigeria as a case study

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Abstract— Electricity has become a dominant variable of any economy and there's an urgent demand for a means of managing this resource. The concept of smart metering is an important one and has been touted as the disruptive technology which will enable both residential consumers and utility providers save costs. Smart meters facilitates two-way communications between consumers and utilities and this offers a myriad of opportunities to both parties. This research therefore aims to create a better understanding of the value and importance of smart metering. An introduction to smart metering as well as the general concept of electricity metering is provided in this thesis. Furthermore, a design which is compatible with all types of existing metering systems is proposed and implemented. This prototype will utilize GSM communication protocol to communicate consumption details to the utility for accurate billing. In addition, the system can remotely connect/disconnect consumers' loads according to their priorities. With this proposed design, the current electricity metering systems are not rendered completely obsolete and the cost of smart metering implementation is considerably reduced..

Index Terms— Demand Side Management (DSM), Energy efficiency, Smart Grid, Smart metering.

1 Introduction

THE importance of electrical energy to the economic welfare of a society cannot be overemphasized. Recent advancements in electrical energy distribution technologies has ensured that the energy being generated is being efficiently delivered to the endpoints. In order to provide better services to its customers, implementation of a proper tariff and an accurate billing system for electricity usage by utility companies is very necessary. Therefore, metering is one of the most important aspects of electricity distribution. In the early phase of electricity metering, supply of electricity was completely dependent on traditional electromechanical meters. Many problems are encountered with the use of these traditional meters. The traditional metering approach involves the periodical visits of human readers to customers' premises to take meter readings. This approach is time consuming, expensive, prone to errors, requires huge amount of labour, and may be interrupted if the consumer is not available at the time of visit or due to bad weather conditions.

In order to combat the challenge of metering Nigeria's over 170 million electricity consumers, smart metering would have to be incorporated to check the scourge of estimated billing and unpaid electricity consumption. [1] Smart Metering, although a nascent technology, has attracted worldwide attention. Not only does smart metering address the problems of manual collection of meter data it also opens a channel for the consumers to be involved in energy conservation. Furthermore, besides remote monitoring of energy consumption, smart metering systems can remotely turn ON/OFF power supply, remotely detect cases of energy theft, remotely detect faults and are capable of monitoring power quality. [2]

The electricity market can be restructured with the implementation of smart metering systems as it is a major component for the future smart grid.

2 LITERATURE REVIEW

Researches have been carried out in the area of Smart metering, Automatic Meter Reading and Advanced Metering Infrastructure (AMI) as a way to enhance smart metering and hence improve efficiency of the grid.

Long et al., in their work, [9] studied the impact of smart metering in energy efficiency. The paper gives a detailed review on the benefits of smart metering. Planning studies carried out in this study shows that Smart Metering was feasible provided the right government policies are put in place. The benefits of smart metering on efficiency of the power network were considered. Cases of Smart Metering worldwide were also reviewed. However, the paper did not recommend any smart metering method.

Khan et al, in their paper, [10] reviewed smart metering infrastructure models as well as smart metering infrastructure communication network options that make present metering infrastructure highly efficient and reliable. The paper also outlined smart metering infrastructure and presented Smart Metering Infrastructure (SMI) as a way to overcome the challenge of the lack of two-way communication capabilities in smart grid infrastructure.

Adrianus et al. in their paper, [11] describes the use of Advanced Metering Infrastructure (AMI) as a way of monitoring energy usage, increasing operating efficiencies for the utility, and enabling information flows for supporting energy-saving schemes. Several options for implementing AMI are discussed. They describe how the days of a quarterly drive by meter reading fails to meet the needs of a Smart Grid that can inform the generator of real time loads and can react to the demands placed upon it by the consumer. Their paper proposes the use of ZigBee technology to provide a link between the meter and an in-home display for the consumer, empowering the consumer through information.

Choi et al in their study [12] review the various types of smart metering devices and systems have been developed for the remote electricity metering applications that can be applicable to AMR (Automatic Meter Reading), micro grid and smart grid. However, they argue that neither of the end user's energy-efficiency nor user-convenience has been considered. In their paper, a smart metering device is presented, which provides energy efficient functions and easy accessibility for user-convenience. The paper concludes that power consumption of smart metering itself will be reduced through the implementation of this study.

Selvam et al in their research [13] argues that the existing power grid may not support future growing electric demand and advanced technologies can be used to improve efficiencies and moderate electric usage by avoiding the need for new generation, transmission and distribution plants. They propose smart grid technology to aid in optimizing the amount of energy generated. Their paper details the Advanced Metering Infrastructure development particularly the Power Quality Analysis. The paper also briefs National scenario of Advanced Metering Infrastructure to meet smart grid applications and its development.

2.1 Evolution of Electricity Metering

Electricity meters are used to measure the quantity of electricity supplied to customers as well as to calculate energy and transportation charges for electricity retailers and network operators. The most common type of meter is an accumulation meter, which records energy consumption over time. Accumulation meters in consumer premises are read manually to assess how much energy has been used within a billing period. In recent years, industrial and commercial consumers with large loads have increasingly been using more advanced meters, for example, interval meters which record energy use over short intervals, typically every half hour. This allows the energy suppliers to design tariffs and charging structures that reflect wholesale prices and helps the customers understand and manage their pattern of electricity demand. [1]

Technology in Nigeria's Energy Sector has seen a lot of evolutions in the recent past especially in electricity metering. The major aim of these technological advancements and evolutions is to provide the best solutions to our problems. [2] In recent years, domestic and industrial users have shifted from traditional meters to smart meters. Electromechanical meters were a dominant part of electricity measurement before 1970. They could only measure the electrical energy. However, it had been identified that the requirement of a meter which could communicate and measure the electrical energy along with other electrical parameters was necessary. Therefore, solid state electronic meters were introduced to measure the overall electrical parameters. [3]

Eventually, automatic meter reading was added to electronic meters and it was a great achievement since it could send the data in near time. However, it could only provide the one-way communication. This limitation was overcome by the introduction of smart meters which can provide two-way communication. Smart meters can measure all the electrical parameters like electronic meters and communicate data in a meaningful way. The consumer is updated with electricity usage, cost, tariffs and other notifications sent by the utility. Smart meters have different functionality 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.

2.2 The Electromechanical meters

The most common type of meter is the electromechanical induction watt-hour meter. It is capable of measuring only the active energy which is typically displayed on a mechanical counter in kWh. It operates by counting the revolutions of a non-magnetic, but electrically conductive, metal disc which is made to rotate at a speed proportional to the power passing through the meter. The number of revolutions is thus proportional to the energy usage. The voltage coil consumes a small and relatively constant amount of power, typically around 2 watts which is not registered on the meter. The current coil similarly consumes a small amount of power in proportion to the square of the current flowing through it, typically up to a couple of watts at full load, which is registered on the meter. [4]

2.3 Electronic meters

Electronic meters are capable of measuring electricity usage with digital technology. At the same time, they can measure the other electrical parameters such as phase voltages, phase currents, frequency, power factor, active power, reactive power, apparent power, maximum demand, and power quality measurements. Therefore, they perform all the tasks that are done by the other types of meters. They have also the capability of sending the measured data through a communication link. [3]

A Typical electronic meter consists of a power supply, microcontroller, Real Time Clock (RTC), LCD display, and communication ports. [4]

2.3 Smart meters

Smart meters are an advanced form of meters. They differ from electronic meters because of added functionalities. Apart from electricity measurements and automatic meter reading (AMR), they allow two-way communication between the meter and the utility. Load profiling, pre-payment, remote disconnection and reconnection, power outage notification, tamper detection, and multi-tariffing are also possible with smart meters. [3] Unlike home energy monitors, smart meters can gather data for remote reporting. Such an advanced metering infrastructure (AMI) differs from traditional automatic meter reading (AMR) in that it enables two-way communications with the meter. [5] From an operational perspective, use of Smart meters allows an improved management and control over the electricity grid.

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2.4 An overview of Smart meter hardware

The smart meter architecture is split into five sections: signal acquisition, signal conditioning, Analogue to Digital Conversion (ADC), computation and communication.

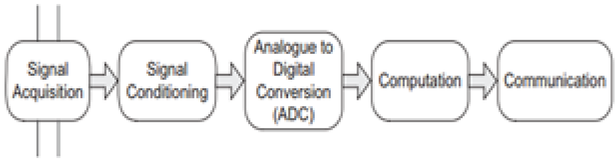

Figure 1: An Overview of Smart meter Hardware

Signal acquisition involves acquiring the fundamentalparameters accurately and continuously. These fundamental parameters include: magnitude and frequency of the voltage and the magnitude and phase displacement (relative to the voltage) of current. Other parameters such as the power factor, the active/reactive power, and Total Harmonic Distortion (THD) are computed using these fundamental quantities. The current into the load and the voltage at the supply are measured by the current and voltage sensors respectively. [1] Signal conditioning involves preparing the input signal for the next step in the process i.e. Analog to Digital Conversion (ADC)

The ADC converts analogue signals coming from the sensors into a digital form. Current and voltage signals obtained from the sensors are first sampled and then digitized to be processed by the metering software. Computation involves arithmetic operations on the input signals, time-stamping of data, preparation of data for communication or output peripherals. Also, payment, tamper detection, system updates, user interaction are carried out in this stage. Communication is a mandatory requirement in all energy measurement systems. The computed data including voltage, current, power, energy, frequency, and power quality measurements should be transmitted to an external MCU. Smart meters employ a wide range of network adapters for communication purposes. The wired options include the Public Switched Telephone Network (PSTN), power line carrier, cable modems and Ethernet. The wireless options include ZigBee, infrared, and GSM/GPRS/CDMA Cellular.

2.5 Communication Protocols for Smart metering

There are various communication protocols used for smart metering. Some of these communication protocols include Power Line Carrier (PLC), GPRS communication, ZigBee communication protocol, Radio Frequency Network, etc.

POWER LINE COMMUNICATION:

Power Line Communication (PLC) is a method of communication where electronic data is transmitted over power lines back to the substation, then relayed to a central computer in the utility's main office. PLC systems operate by imposing a modulated carrier signal on the wiring system. Since these power lines were originally intended to transmit AC power at typical frequencies of 50 – 60Hz, power lines have only a limited ability to carry higher frequencies.

ZIGBEE COMMUNICATION PROTOCOL:

ZigBee is a low power spin off of Wi-Fi. It is a specification for small, low power radios based on IEEE 802.15.4 – 2003 Wireless Personal Area Networks standard. The technology defined by the ZigBee specification is intended to be simpler and less expensive than other wireless personal area networks (WPANs. Applications include wireless light switches, electrical meters with in-home-displays, traffic management systems, and other consumer and industrial equipment that requires short-range low-rate wireless data transfer.

Its low power consumption limits transmission distances to 10–100 meters line-of-sight, depending on power output and environmental characteristics. ZigBee devices can transmit data over long distances by passing data through a mesh network of intermediate devices to reach more distant ones. ZigBee is typically used in low data rate applications that require long battery life and secure networking (ZigBee networks are secured by 128 bit symmetric encryption keys.) ZigBee has a defined rate of 250 Kbit/s, best suited for intermittent data transmissions from a sensor or input device. [6]

RADIO FREQUENCY BASED COMMUNICATION:

Radio frequency based communication can take many forms. The more common ones are handheld, mobile, satellite and fixed network solutions. There are both two-way RF systems and one-way RF systems in use that use both licensed and unlicensed RF bands. In a two-way or "wake up" system, a radio signal is normally sent to a meter's unique serial number, instructing its transceiver to power-up and transmit its data. The meter transceiver and the reading transceiver both send and receive radio signals. In a one-way “bubble-up” or continuous broadcast type system, the meter transmits continuously and data is sent every few seconds. This means the reading device can be a receiver only, and the meter a transmitter only.

3 Methodology

For this research, a survey is conducted to get insights on electricity usage by the customers. The results from this survey proves to aid in the design of the hardware and software technologies used in the implementation of this thesis.

A. HARDWARE DESIGN

The design of a smart system into an existing energy measurement device (energy meter) using a wireless link for control and monitoring of energy consumption could be considerably complex. The device is built around a microcontroller and a GSM modem as a wireless link and is interfaced with the energy meter with its serial port allowing the power company to control the amount of

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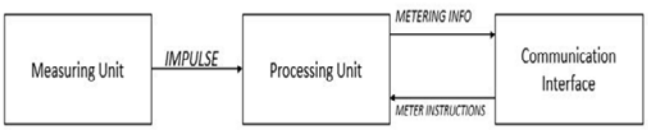
energy consumed by the user and to take accurate meter readings. There are three units involved in the hardware design phase. These include

- Metering unit.
- Processing unit.
- Communication interface.

This is demonstrated as shown in the block diagram below.



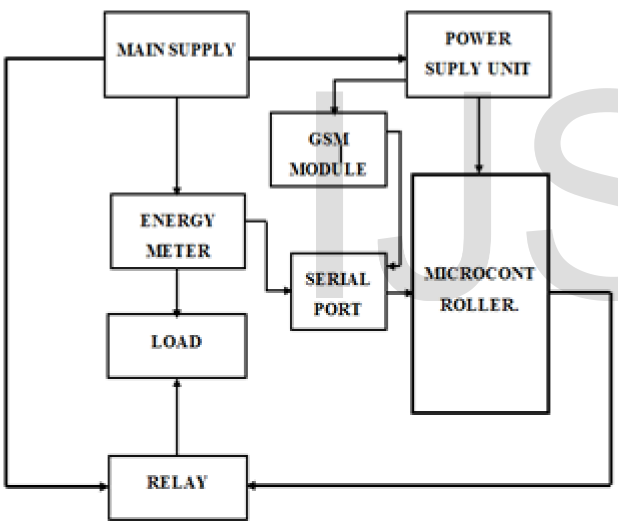


Figure 2: Block diagram of Smart meter hardware

METERING UNIT:

The metering unit is responsible for measuring the amount of load connected to the meter. The major component in the metering unit is the Energy meter.

THE ENERGY METER:

The energy meter is the interface of the smart energy system to the user's power consumption. It measures the amount of power consumed in an hour. A PES-32 AC static watt-hour meter was used. It has a digital screen and operates at 240V, 30A max. The rated frequency is 50Hz while the ambient air temperature it can withstand is 27°C.

PROCESSING UNIT:

The processing unit takes the pulses generated from the metering system and performs calculations on them. The processing unit consists of two main subunits: the microcontroller unit and the control unit.

- THE MICROCONTROLLER:

The microcontroller is the heart of the device as it controls the entire process of the system using a program written on it. A PIC16F876A microcontroller device was used because of its ease of use with serial communication port, its low power consumption and large program memory space. The program is written in assembly language then compiled with MPLAB and transferred to the microcontroller chip using a TOP2007 universal programmer.

The PIC16F876A ¬was chosen for the following reasons:

- It is very cheap and easily available.
- The software development tools for the PIC16F876A is easily obtainable and there are lots of resources online for learning.

The PIC16F876A is a powerful yet easy-to-program CMOS FLASH-based 8-bit microcontroller. The PIC16F876A features 256 bytes of EEPROM data memory, self-programming, an ICD, 2 Comparators, 5 channels of 10-bit Analog-to-Digital (A/D) converter, 2 capture/compare/PWM functions. [14]

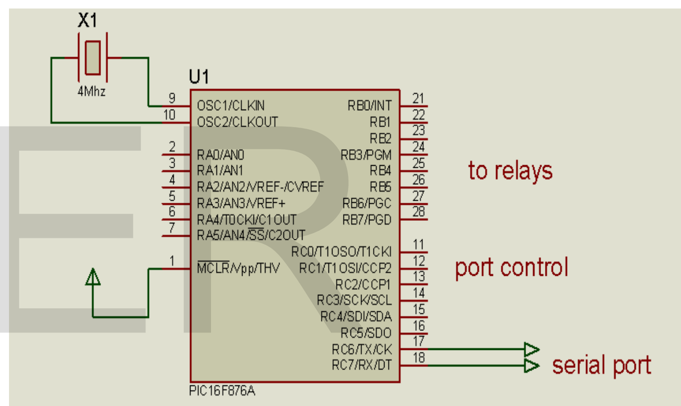


Figure 3: Microcontroller connection

THE RELAY:

A relay is an electrically operated switch. The relay is used to control the flow of voltage to the load through the instructions received from the power company. Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as in solid state relays. Generally, relays are used where it is necessary to control a circuit by a separate low-power signal, or where several circuits must be controlled by one signal.

The first relays were used in long distance telegraph circuits as amplifiers: they repeated the signal coming in from one circuit and re-transmitted it on another circuit. Relays were used extensively in telephone exchanges and early computers to perform logical operations.

The relay in this circuit is primarily used to isolate the consumer load from the power grid when either units are exhausted or the generating capacity is low or when the energy meter is being tampered with.

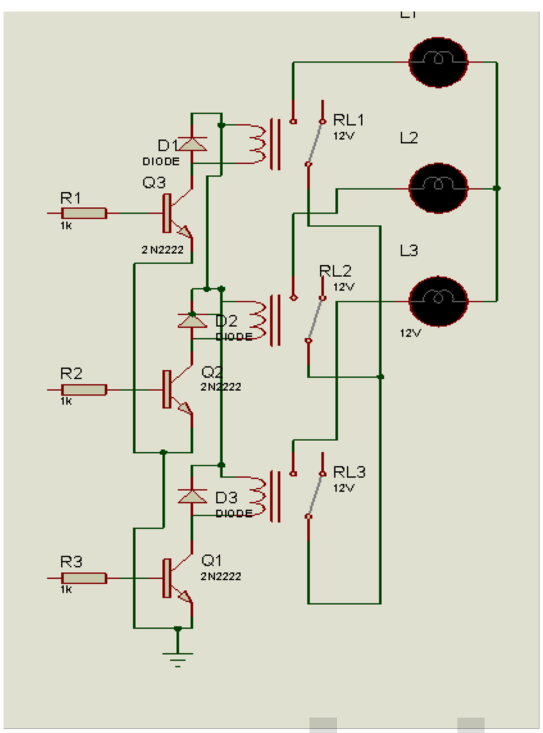


Figure 4: Relay connection.

Transistor Q1 to Q3 is used to amplify the voltage that flows into the relay while resistor R1- R3 limits the current that flows into the base of the transistors, diode D1-D3 is used to block reverse voltage generated at the solenoid of the relay when the transistor is turned OFF.

COMMUNICATION INTERFACE:

The communication unit is solely responsible for sending signals from the energy meter to the utility and to the consumer. It is made of primarily of a communication interface. The GSM modem is used in this project.

GSM MODEM:

The GSM modem is used as a wireless communication link between the power company and the consumers' energy meter. The communication is done with SMS by sending AT commands to the GSM modem to activate a send, receive or delete message from the network.

A SIM800 GSM modem device was used because of its low power consumption and its easy communication protocol through its two wire serial communication port. SIM800 module is a GSM quad band module. It is based on the latest GSM/GPS module SIM808 from SIMCOM, supports GSM/GPRS Quad-Band network and combines GPS technology for satellite navigation. It has high GPS receive sensitivity with 22 tracking and 66 acquisition receiver channels. Besides, it also supports A-GPS that available for indoor localization. The module is controlled by AT command via UART and supports 3.3V and 5V logical level.

FEATURES:

- Quad-band 850/900/1800/1900MHz
- GPRS multi-slot class 12/10
- GPRS mobile station class B
- Compliant to GSM phase 2/2+ Class 4 (2 W @ 850/900MHz) Class 1 (1 W @ 1800/1900MHz)
- Bluetooth: compliant with 3.0+EDR
- Control via AT commands
- Supply voltage range 5V ~ 12V
- Low power consumption
- Operation temperature:-40? ~85?
- Standard SIM Card

INTERFACING THE GSM MODEM WITH THE MICROCONTROLLER.

The GSM modem is configured by a set of instructions called the AT (Attention) commands. These commands are used to send queries and receive responses from the GSM modem. The AT commands are described in the table below [15]:

QUERY AT COMMAND RESPONSE

TEST COMMAND AT+<X>=? This returns a list of parameters and values ranges set with the corresponding write command.

READ COMMAND AT+<X>? This returns the currently set value of the parameters.

WRITE COMMAND AT+<X>=<…> This sets the user defined parameter

Values.

EXECUTION COMMAND AT+<X> This reads non-variable parameters affected by internal processes in the GSM modem.

The GSM modem is connected to the microcontroller serial port through a digital switch (U2) because two serial ports are needed to connect the GSM modem and energy meter to the microcontroller which has only one port.

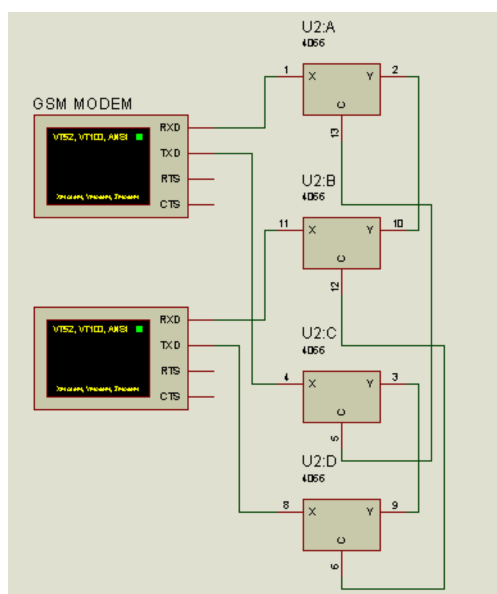


Figure 5: GSM Modem

SERIAL PORT SWITCH:

The serial port switch is used to select the GSM modem or the energy meter by the microcontroller when it needs to **COM**municate, the microcontroller has a single serial port so the serial port switch helps it to switch between the energy meter and GSM modem. The serial port switch is designed using a 4066 bilateral switch device.
The 4066 contains 4 analogue bilateral switches, each with an active-high enable input (A) and two input/outputs (X and Y). When the enable input is set high, the X and Y terminals are connected by low impedance; this is the on condition. When the enable is low, there is a high impedance path between X and Y, and the switch is off.
The 4066 is pin-compatible with the 4016, but has a significantly lower on impedance and more constant on resistance over the full range of input voltage. Therefore, the 4066 is preferable to the 4016 in most cases.
The circuit diagram of the serial port switch section is shown below:

THE POWER SUPPLY UNIT
A power supply unit is a device that converts mains AC to low voltage regulated DC power.
The power supplied to us domestically is always in AC form. This is because AC power is easily distributed. Therefore the value switches from positive to negative with time. It has an r.m.s value of 220v.
Most electronic devices make use of DC power supplies so it is usually required for a PSU (power supply unit) to rectify the AC input supply, smoothen it and then ensure a steady DC voltage at the output terminals.
The process of this conversion from AC to DC is demonstrated by the block diagram shown below:

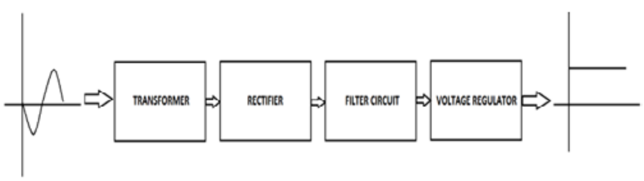


Figure 6: Block diagram of power supply unit

TRANSFORMER: The transformer is used to step down the power supply voltage (0 – 240 V) to (0- 12V) level. Then the secondary of the potential transformer is connected to the full wave bridge rectifier.
RECTIFIER: The bridge rectifier is used for the conversion of an alternating current input to a direct current output. A diode bridge is an arrangement of four (or more) diodes in a bridge circuit configuration that provides the same polarity of output for either polarity of input.
FILTER CIRCUIT: When rectifying with only diodes, there is still some AC component present in the output. This causes some ripple in the output and then a filter circuit is used to smoothen it. That is, it removes the remaining AC component from the rectified output.
VOLTAGE REGULATOR: This is an IC that regulates the output DC voltage. It fixes the output voltage to a particular value. In this project, a LM7805 voltage regulator was used.

The 220v AC input is stepped down to 12v AC by the transformer then convert to 12v DC by the Bridge Rectifier

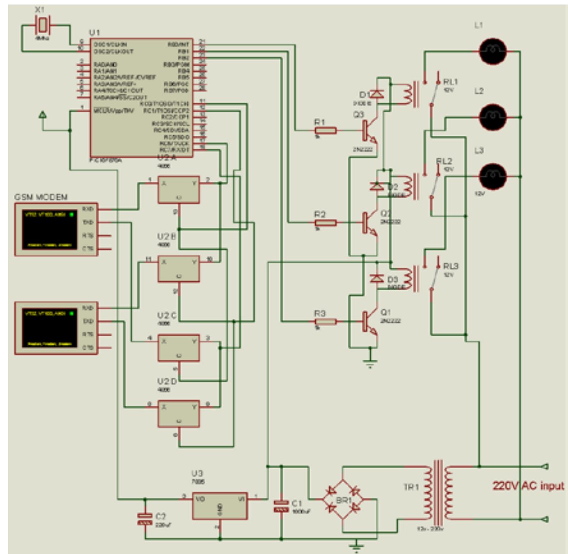
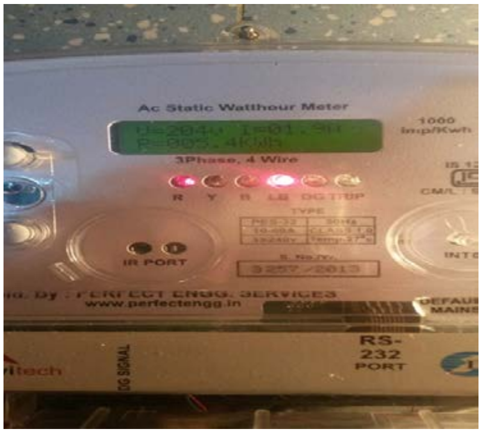
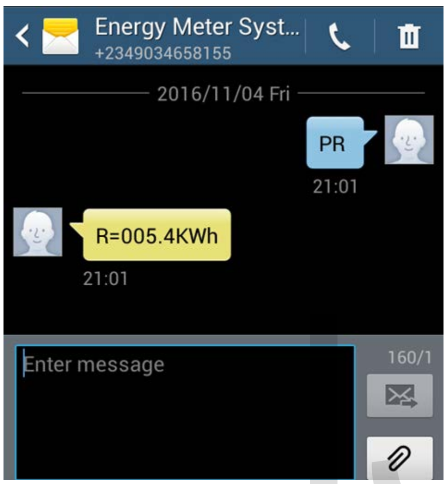


Figure 7: Circuit diagram of system

4 RESULTS AND DISCUSSION.

Here, the results obtained from testing the GSM based Smart Electricity system are detailed and the results from the survey carried out for this study are discussed.
PERFORMANCE TEST:
Upon soldering the components and carrying out continuity tests to ensure the setup was working properly, the components were then packaged and cased. A registered MTN SIM Card was then inserted into the GSM modem. The system was connected to the power source and the load readings were displayed on the meter LCD. An SMS command to request the power reading, 'PR' was sent to obtain the reading from the meter. A report was sent back as a text message detailing the load consumption. Further commands were sent to the "disconnect" the meter, to "reconnect" the meter and to "turn off" and "turn on" loads based on their level of priority. The following figures show the results from the SMS commands





5 CONCLUSIONS AND RECOMMENDATIONS

In this research, a GSM based Smart Electricity Metering System has been constructed and implemented. The Smart electricity metering system was able to take meter readings remotely and connect/disconnect the meter remotely. The system is also designed to turn on/off consumer's loads by the utility based on their level of priority in a case where power generation is low. This provides some sort of automation as a way to conserve energy.

The GSM based smart metering system offers an upgrade from the old metering system. The cost of employing manpower to take readings from various meters are considerably reduced and accurate billing of consumers based on actual consumption is also made possible with this system. With the design fully implemented, the costs associated with metering is reduced. Power pilfering is also reduced.

Upon testing the constructed prototype using existing GSM infrastructure, it is concluded that the GSM based Smart Electricity Metering system meets the set objectives of its design.

RECOMMENDATIONS:

Further improvements on the system can be done on tampering as this is known to be a major problem in electricity metering. Load control can also be implemented on the consumer's side to encourage consumers to engage in energy conservation. More so, a Graphical User Interface (GUI) can be added to provide a more visual and easy to use system. Graphical description of the consumer's energy consumption details can be provided so that the consumer knows how to cut cost of energy consumption. WIMAX can also be explored as a medium of communication rather than GSM in case the GSM services offered by Telecommunication companies show limitations

REFERENCES

[1] [1] J. Ekanayake, K. Liyanage, J. Wu, A. Yokoyama and N. Jenkins, SMART GRID TECHNOLOGY AND APPLICATIONS, New Delhi: Wiley, 2012.

[2] [2] E. Emmanuel and K. B. Owusu, "Evolution and Efficiencies of Energy Metering Technologies in Ghana," Global Journal of Researches in Engineering: For Electrical and Electronics Engineering, vol. 14, no. 6, pp. 35-42, 2014.

[3] [3] K. S. K. Weranga and S. Kumarawadu, Smart Metering Design and Applications, London: Springer, 2014.

[4] [4] Wikipedia, "Electricity meter," Wikipedia, [Online]. Available: https://en.wikipedia.org/wiki/Electricity_meter. [Accessed 16th May 2016].

[5] [5] Wikipedia, "Smart Meters," [Online]. Available: https://en.wikipedia.org/wiki/Smart_meter. [Accessed 29th May 2016].

[6] [6] Wikipedia, "ZigBee," Wikipedia, [Online]. Available: https://en.wikipedia.org/wiki/ZigBee. [Accessed 22nd May 2016].

[7] [7] E. T. Platform, " SmartGrids: Strategic Deployment Document for Europe's Electricity Networks of the Future," [Online]. Available: http://www.smartgrids.eu/documents/SmartGrids_SDD_FINAL_APRIL2010.pdf. [Accessed 12th June 2016].

[8] [8] Metering.com, "Smart meters in Nigeria: Eko pushes CAPMI; China trains engineers," 15th September 2015. [Online]. Available: http://www.metering.com/smart-meters-in-nigeria-capmi-china-training/. [Accessed 26th June 2016].

ISSN 2229-5518

[9] [9] Z. Long, . X. Fang-Yuan and M. Ying-Nan, “Impact of smart metering on energy efficiency,” in International Conference on Machine Learning and Cybernetics, Qingdao, 2010.

[10] [10] . F. M. Khan, A. Paventhan, V. Arunachalam and A. Jain, “Communication technologies for smart metering infrastructure,” in Electrical, Electronics and Computer Science (SCEECS), 2014 IEEE Students' Conference, Bhopal, 2014.

[11] [11] G. Adrianus, V. Engelen and J. S. Collins, “Choices for smart grid implementation,” in International Conference on System Sciences, Hawaii, 2010.

[12] [12] K. Choi and S. Hong, “New design approaches and implementation of smart metering system,” in The 18th IEEE International Symposium on Consumer Electronics (ISCE 2014), JeJu Island, 2014..

[13] [13] . C. Selvam, M. Venkatachala, Ayyappan and K. Sriniva, “Advanced metering infrastructure for smart grid applications,” in Recent Trends In Information Technology (ICRTIT), 2012 , Chennai, Tamil Nadu, 2012..

[14] [14] Microchip, “PIC16F876A,” Microchip, [Online]. Available: http://www.microchip.com/wwwproducts/en/PIC16F876A. [Accessed 26th September 2016].

[15] [15] N. Agnihotri, “AT Commands, GSM AT command set,” Engineersgarage, [Online]. Available: http://www.engineersgarage.com/tutorials/at-commands. [Accessed 30th September 2016].