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SMS- based Recharge Protocol for Prepaid Energy Billing System

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***Abstract* – A prepaid energy metering system enables power utilities to collect energy bills from the consumers' prior to the usage of power by delivering only as much as what has been paid for. In Nigeria, the current prepaid meters use the keypad technology or smart card for their energy re-loading or recharging. This poses some challenges because the consumers have to travel a long distance to the utility company, waste a lot of time and energy before getting his/her energy meter activated when out of energy credit. In this paper, an SMS-recharge system for prepaid meter is proposed whereby consumers at the comfort of their homes, without stress or waste of energy or time, can recharge/activate their meters via SMS without the use of keypad by sending a 12-digit Pin number via SMS to the utility company. The aim of this paper is to model an intelligent billing system and develop an SMS protocol for the recharge scheme. This work contains the methodology and developed SMS protocol-link between the GSM modem (M20) and the Microcontroller (PIC 18F2550) for this process .The entire billing process is designed and simulated in Matlab/Simulink environments. Results obtained are very satisfactory. When fully implemented in Nigeria, revenue generation in the power sector will greatly increase as more sales of energy vouchers will be made.**

***Keywords* – Protocol, Algorithm, Prepaid, SMS, Recharge, Microcontroller, GSM Modem.**

I. Introduction

Short Message Service, also commonly referred to as text messaging, is a service that supports the transmission of short messages to and from mobile devicesThe service uses the Short Message Service Center (SMSC) as a hub to accept and forward messages to their destination. The SMSC also acts as a store and forward system, guaranteeing message delivery, where messages that cannot be immediately delivered to a mobile device because it may be out of coverage area or turned off, will be saved and sent later when the device is able to accept messages. SMS messages are sent over the voice control channels. Messages can be received simultaneously with a voice call and messages can be transmitted without activating a voice call or calling a specific number to submit the message into a server. Hence , the application of SMS –based technology in energy recharge and power theft alert for prepaid meters cannot be over-emphasized[1].

II. Related Works

In their paper [2], presented the Digital Tele-wattmeter System as an example of a microcontroller- based meter. The 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.

A DSP-based meter was utilized to measure the electricity consumption of multiple users in a residential area [3]. A Personal Computer (PC) at the control centre was used to send commands to a remote meter, which in turn transmitted data back, using the power Line Communication (PLC) technique. The major problem with this system is that it cannot detect tampering by consumers.

[4] in their work, designed and implemented a Bluetooth energy meter where several meters are in close proximity, communicated wirelessly with a Master PC. Distance coverage is a major set-back for this kind of system because the Bluetooth technology works effectively at close range.

In their paper [5], the viewed home- automation systems as Multiple Agent Systems (MAS) was displayed. Home automation system was proposed where by home appliances and devices are controlled and maintained for home management. It is only a home management system and does not measure the amount of energy consumed by users.

[6] in their paper**,** proposed the use **of** Automatic Meter Reading (AMR) using wireless networks. Some commercial AMR products use the internet for data transmission. A design and implementation of SMS -based control for monitoring systems was presented[7]. The paper has three modules involving sensing unit for monitoring the complex applications. The SMS is used for status reporting such as power failure. Issues on billing system for electricity board usage were not considered.

Prepaid meters can also make use of state of art technologies like WiMAX owing to the idea of centralized accounting, monitoring and charging. It brings telecommunication to the core of its activities to support more Smart Grid applications such as Demand Response and Plug-in electric vehicles [8] Prepayment polyphase electricity metering systems have also been developed consisting of local prepayment and a card reader based energy meter [9]

[10] in their paper, mainly focused on the controlling of home appliances remotely and providing security when the user is away from the place using an SMS- based wireless Home Appliance Control.

In their paper, Maheswari and Sivakumar [11] aimed to develop an energy efficient and low cost solution for street lighting system using Global System for Mobile communication [GSM] and General Packet Radio Service [GPRS]. The whole set-up provides the remote operator to turn off the lights when not required, regulate the voltage supplied to the streetlights and prepare daily reports on glowing hours

[12] in their paper suggested a method where we utilize telecommunication systems for automated transmission of data to facilitate bill generation at the server end and also to the customer via SMS, Email.

A prepaid energy meter behaving like a prepaid mobile phone has also been suggested [13]. The meter contains a prepaid card analogous to mobile SIM card. The prepaid card communicates with the power utility using mobile communication infrastructure. Once the prepaid card is out of balance, the consumer load is disconnected from the utility supply by the contactor. The power utility can recharge the prepaid card remotely through mobile communication based on customer requests.

III. Design Methodology

The methodology of the proposed SMS-based prepaid billing System is divided into five stages as shown in the block diagram of Fig 1.

Purchase of Energy Vouchers: Based on the tariff structure of Nigeria and putting into consideration the various components of electricity billing as approved by NERC, the power utility rolls out energy vouchers to be sold by vendors. These vouchers would contain PIN numbers generated by the Power Utility server. Energy Credit Unit is in KWh.

Request for Recharge: The consumer buys the energy voucher from the vendor and sends the PIN number to a CODE for the server in the utility company to process.

e.g Text " *6* 1001 1112 1234 1011* 12# to 101 ".

Where number "6" represents "Recharge" in the Task Index of the SMS-protocol; The last digit of the 12-digit pin number is a code that represents the energy credit (KWh) purchased. *See table*

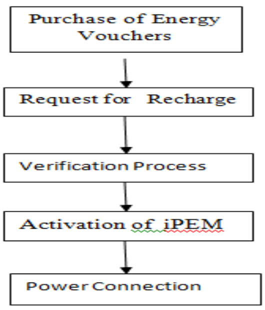

Fig.1. Block Diagram of the SMS Recharge Process

Meter ID is a 2-digit number; number "101" is a code that represents the address of the Utility Server.

Verification Process : The server contains the database of the generated pin numbers, costumer information and meter ID. Upon reception of SMS to recharge, the Server interprets and verifies the pin number and the Meter ID. It also matches Meter ID to the corresponding GSM number of the SIM in the GSM modem embedded in the Meter.

Activation of iPEM : If a pin number and the meter ID are valid the consumer's IPEM is activated and power is connected to load.

Power Connection: Relay is connected between the microcontroller and the Load. Energy flows when relay closes.

The flowchart for the energy recharge billing system is shown in Fig 2.

3.1 SMS Protocol for Recharging:

The basic idea in using GSM communications in the Intelligent Prepaid Energy Meter (IPEM) is to receive specific messages from the utility in SMS form. The PIC executes the proper routine related to the message content and passes its commands to the IPEM through the PIC. Reversly, the system sends its replies, whether they are readings, reports or alerts, to the utility's mainframe again in SMS form via the GSM network. The PIC highly benefits from the M20 feature that it alerts for any action within the GSM network at the serial data terminal, so the PIC can always monitor what is delivered to the M20 from network. The language M20 uses to dialogue with other devices through the serial-data terminal is the AT Hayes Command set.

3.1.1 Hardware Interface of PIC 18F2550 and M20

To obtain a bidirectional communication between the PIC 18f2550 and the M20 in the IPEM, the transmitter pin (TX) of each device is to be connected to the receiver pin (RX) of the other through the

Initialization of GSM modem

At the PIC startup, the PIC sends a byte representing the termination character of the M20, which is the Carriage Return (CR) character, to cancel any previous pending command in the M20 due to error. An ASCII character is output from the PIC as a hexadecimal code representing that character.

New Message Reading

When an SMS message is received by the M20, a "new message" alert is sent to the PIC's USART receiver. The receiver interrupt flag (RCIF) is set due to this alert and the interrupt subroutine is executed. The message reading process is described again briefly in fig.3[14]. Whether a meter reading, quality report, or deficiency alert is to be sent to the utility, a new SMS message needs to be constructed in the Master PIC of the IPEM and turned to the M20 which interfaces with the GSM network. The message-sending process is reviewed again in fig.4 [14][15].

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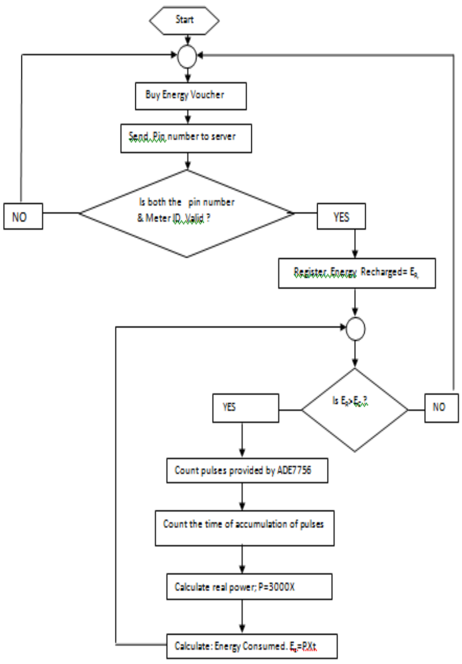


Fig.2. Flowchart of the SMS based Recharge Prepaid Energy Billing System

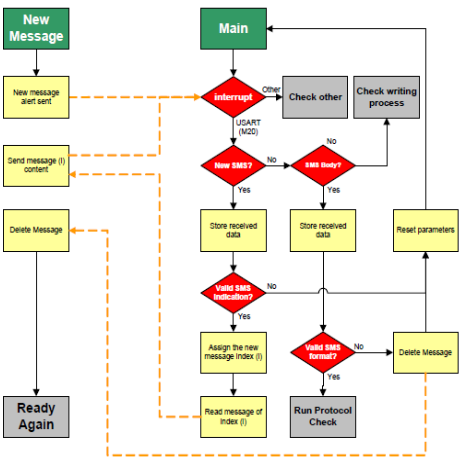


Fig.3. Reading New SMS message

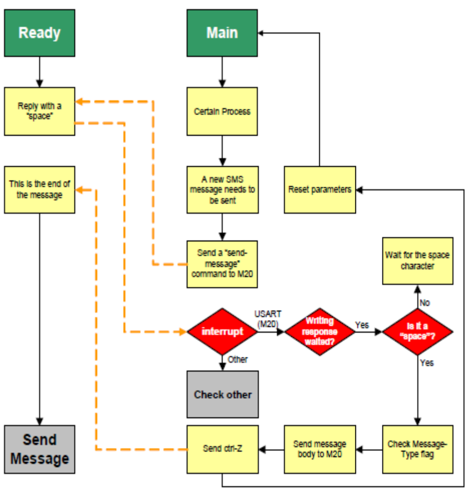
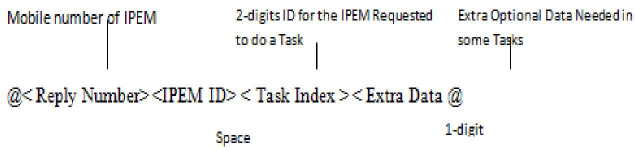


Fig.4. SMS message sending process

3.2 SMS- Link Protocol

3.2.1 Protocol Main Rules

As a part of the protocol, any message sent from the Utility Server to the IPEM must be in the following form.



The possibilities of (Task Index) part of the protocol are shown in table 1, where the (IPEM) column indicates a IPEM-related task. An "Extra" column tells if the task needs any additional values to be attached within the (Extra Data) part of the string

Table 1: Task description

Task Index	Task Description	IPEM	Extra
0	Check Link Status	✓	
1	Read Meter's Accumulated Energy	✓	
2	Read Power Factor	✓	
3	Read Switch Status	✓	
4	Connect /Disconnect Line	✓	✓
5	Reset PIC	✓	
6	Recharge Energy Meter	✓	✓

As shown in table 1, Task Index "6" Recharge Energy Meter needs extra data. See table below

Table 2: Extra data for Recharge Task in this work

Table 2: Recharge task description format

Index	Recharge task description
1	1000 KWh
2	2000 KWh
3	3000 KWh
4	4000 KWh
5	5000 KWh
6	6000 KWh
7	7000 KWh
8	8000 KWh
9	9000 KWh

The energy voucher produced by the Utility company contains a 12-digit pin number for recharge. The last 1-digit determines the amount of energy to be credited. From the table 2, For example index "3" means 3000KWh energy Credit units.

3.2.2 Case Study of the SMS-based Recharge Process.

A consumer, who owes an IPEM with a Meter ID 12 purchased an energy voucher with the pin number "1011 2100 3120 1021". Fig below shows the recharge process.

Recharge Index "1" means 1000KWh Energy Credit. See fig 5.

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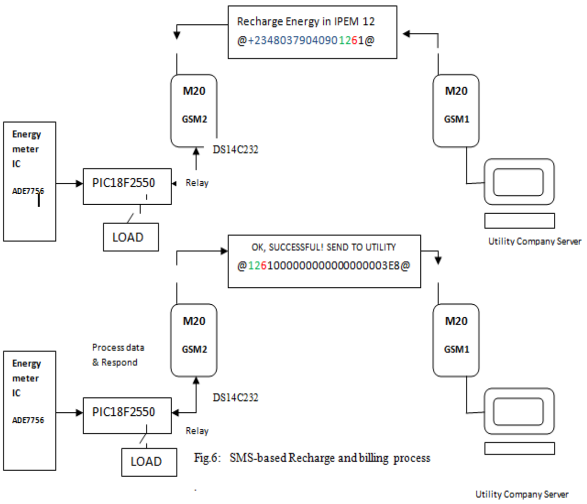

Fig.5. SMS-based Recharge and billing process

3.1.3 MATLAB /SIMULINK based Recharge Billing Model

Simulink is a software package for modeling, simulating, and analyzing dynamical systems. It is integrated into the MATLAB (a high-level computer language for scientific computing and data visualization built around an interactive programming platform) environment. It supports linear and nonlinear systems, modeled in continuous time, sampled time, or a hybrid of the two. The internal architecture of the recharge MATLAB/ SIMULINK recharge unit model is seen in Fig.6.

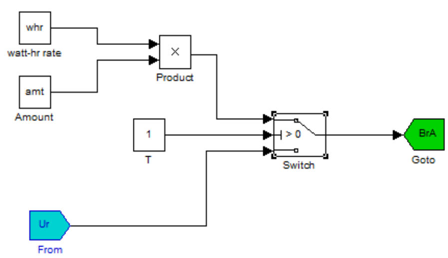

Fig.6. Internal configuration of the recharge model

The output of the multiplier block is the total amount of energy credit (watt-hr rate * amount) in KWh.

The relay (switch) connecting the load to the energy meter remains closed as long as Balance is not equal to zero.

Balance (KWh)= Amount Energy credit recharge – Energy consumed (KWh).

When balance= 0, the relay opens and the consumer is disconnected from the load. The overall billing system MATLAB/SIMULINK model is seen in Fig. 7.

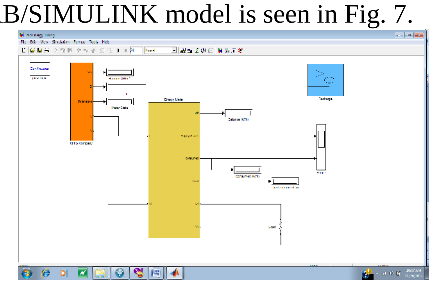

Fig 7: Overall prepaid energy billing Model

It's a combination of three models :
(i) Utility company (ii) Energy meter (iii) Recharge unit

IV. Results And Discussion

1. From Fig.8, Graph 1, the maximum energy level observed is1.5kWh on the y-axis. This represents the amount of Energy purchased. This satisfies the equation;
2. $E_B = E_R - E_C$……. 1
3. At t=0, $E_C = 0$, $E_B = E_R$
4. E_R=Energy Recharged, E_C= Energy Consumed, E_B=Energy balance, t= simulation time.
5. From Fig..8, Graph 1, it was observed that from the count of energy consumption by the consumer, the value of the energy balance decreased gradually until it got to zero. This also satisfies the equation:
   *$E_B = E_R - E_C$
6. From Fig.8, the energy balance pattern in Graph 1is observed to be the reverse of energy consumption pattern in Graph 2.
7. From Fig.8, Graphs 1and 3,it is observed that, the energy balance pattern has a negative slope (gradient) while that of the energy consumption pattern is positive.
8. In Fig.8, Graph 2,The consumers remained connected at 220 volts until energy balance was exhausted (zero). This shows the effectiveness and efficiency of the IPEBS. Whenever the energy balance in the meter is exhausted the consumer is disconnected automatically. Which shows good energy accountability between the consumer and the utility company.
9. From Fig.8, in Graph 4, it is observed that the rated load connected is 121 W.
10. A very important observation is made in Fig 8. The four different graphs terminated at the same time showing the accuracy of the IPEBS model. This means that the energy consumption of the user is regulated by how much Energy Recharge Units (ERU) purchased.
11. Fig.9. shows the behavior of IPEBS when recharge is 1000kWh under a different load.
12. Fig.10shows result under variable resistance.

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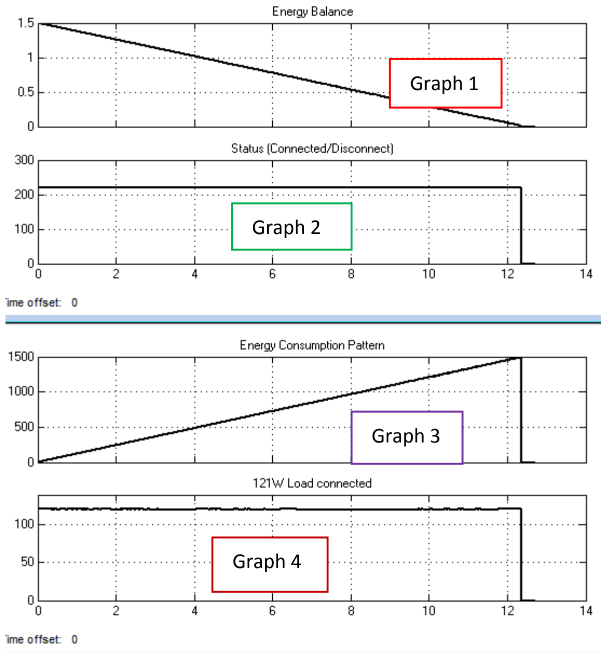

Fig.8. a 1500 Wh Prepaid Billing for 121 W Load

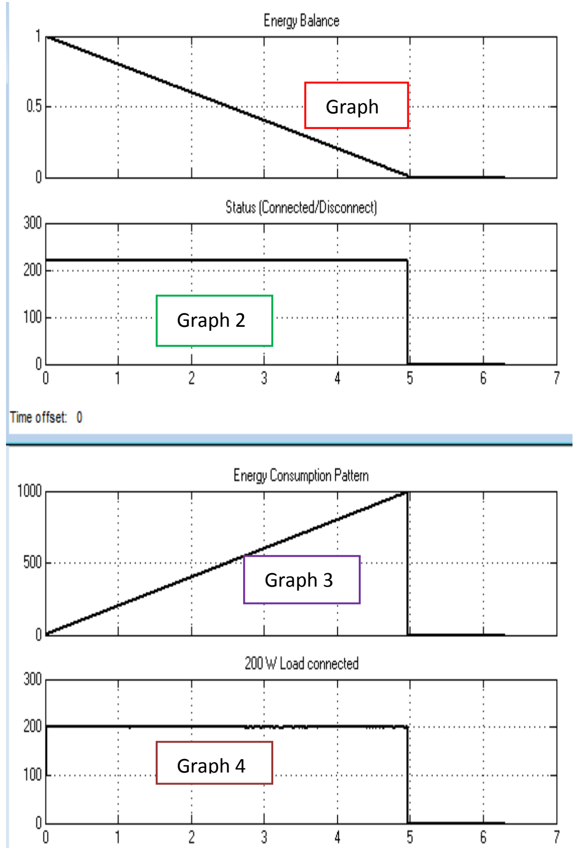

Fig.9. a 1000wh prepaid billing for 200W load connected.

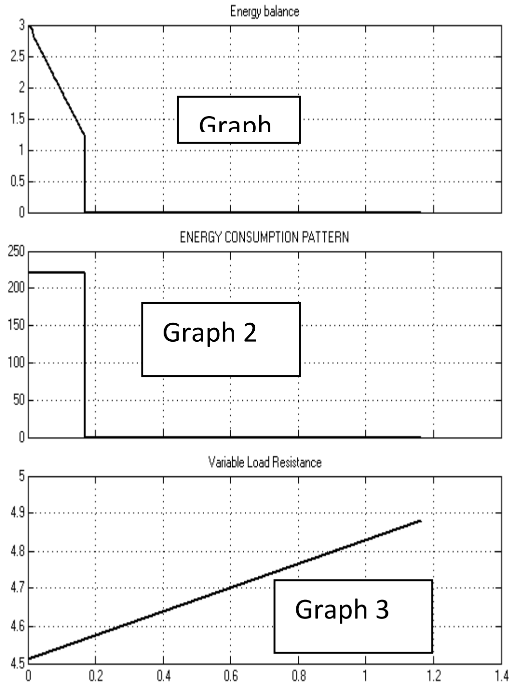

Fig.10. a 3000 Wh prepaid billing under variable Load Resistance.

V. Conclusion

A methodology of the SMS recharge model for prepaid energy meter has been presented. The SMS recharge protocol has been developed and the overall idea has been simulated too. The recharge and billing efficiency of the proposed system have been tested and the results obtained show good system performance. It is strongly observed that the amount of energy recharge units purchased determines the amount of energy consumed by the user. This indicates good reliability, dependability and efficiency of the proposed system. If fully implemented by power utility sector proper energy accountability will be obtained. The rate of energy purchase will increase since consumers can within the comfort of their houses recharge with SMS without the stress of visiting utility company for activation.

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