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ENERGY RECHARGE SCHEME MODELING FOR PREPAID METERS UTILIZING GSM TECHNOLOGY

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Abstract: In this article, we detail the planning and development of a prepaid metering system that uses GSM technology for energy recharge. It has been noted that the metering and billing system is one of the subsystems that is causing the massive revenue loss in the Nigerian power sector. Various sources of human error may be found throughout the energy billing process, including electro-mechanical meters, the act of taking the reading by hand, and the processing of both paid and overdue invoices. Prepaid energy bills is the solution to this problem. In several nations, the prepaid system has significantly cut down on income loss, and the consequences are plain to see. A GSM-based Energy Recharge Interface, including a prepaid card that functions similarly to a mobile SIM card, is modelled in this study. There is a GSM connection between the prepaid card and the electricity company. The latching Relay (contactor) cuts power to the consumer load the moment the prepaid card balance drops below a certain threshold. When customers request it, the power provider may remotely top up their prepaid cards over GSM/SMS. GBRS, a GSM-Based Recharge System, has been developed and tested in the Matlab/Simulink environment for use with single-phase prepaid meters. Good system performance is shown by the outcomes. By eliminating the possibility of overdue payments and human mistake in meter readings, a prepayment billing system guarantees the utility a fair return on investment.

Keywords: *GSM, Energy meter, Microcontroller, Prepaid card, Recharge*

I. Introduction

Recent trends in digital technologies have resulted to monumental developments in wireless communications which clearly shows that the place of Global System for Mobile Communications (GSM) technology cannot be over-emphasized. This paper therefore, explores its possibilities in the implementation of a GSM-Based Recharge Scheme for Energy Prepaid Meter (Omijeh, 2012). What is new in the overall design is the GSM-Based Recharge Module (GBRM) which consist primarily of a Microcontroller and a GSM communication module with a prepaid card (specially programmed SIM) along with a latching Relay and a liquid crystal display (LCD).

1.1 Related works

Shwehdi and Jackson (1996) in their paper, 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. Zhang, Oghanna and Bai (1998) utilized a DSP-based meter to measure the electricity consumption of multiple users in a residential area. 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.

Koay, Cheah, Sng, Chong, Shun and Tong (2003) 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, Scaradozzi and Conte (2003) viewed home- automation systems as Multiple Agent Systems (MAS). 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.

Hong and Ning (2005) in their paper**,** proposed the use **of** Automatic Meter Reading (AMR) using wireless networks. Some commercial AMR products use the internet for data transmission.

Stanescu, D, Ciubotaru-Petrescu, Chiciudean, and Cioarga (2006) present 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 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 (Khan *et al*, 2007). Prepayment polyphase electricity metering systems have also been developed consisting of local prepayment and a card reader based energy meter (Ling *et al*, 2010).

Malik, Aihab and Erum (2009) 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 (2009) 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

Sharma and Shoeb (2011), 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.

Amit. J and Mohnish (2011). Suggested in their paper, a prepaid energy meter behaving like a prepaid mobile phone. 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.

1.2 *Reliability of GSM Short Messaging*

Global System for Mobile Communications (GSM) is the world's most popular standard for mobile telephony systems .GSM is used by over 1.5 billion people across more than 212 countries and territories. GSM also pioneered low-cost implementation of the short message service (SMS) which allows parties to exchange delay tolerant short text messages. The popularity and wide coverage of cellular networks have attracted researchers to consider the use of SMS service. However there are certain questionable issues regarding GSM network such as its scalability, reliability and security, especially under high load. Zerfos et al (2006) have analyzed real data taken from a real GSM network in India. SMS delivery success rate was found to be 94.9%; 73.2% of the successfully delivered messages reach to the destination within 10 seconds; about 5% of them require more than an hour and a half. Using SMS for AMR service will definitely increase the flow of messages tremendously. GSM uses several cryptographic algorithms for security. The development of UMTS introduces an optional Universal Subscriber Identity Module (USIM), which uses a longer authentication key to give greater security, as well as mutually authenticating the network and the user.

II. GSM-Based Recharge Billing System Architecture

The block Diagram of the GSM-Based Recharge Billing System is shown in Fig.1. It consist of three main parts, namely: The Digital Energy Meter, the GSM-Based Recharge Module and the Public Utility Control Center (PUCC) server.

2.1 ***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 retrieved active register value to calculate the active power consumed. A real time clock is also implemented on the microcontroller, which enables timestamps to be generated, so the synchronization between the PUCC server and the meter can be established.*

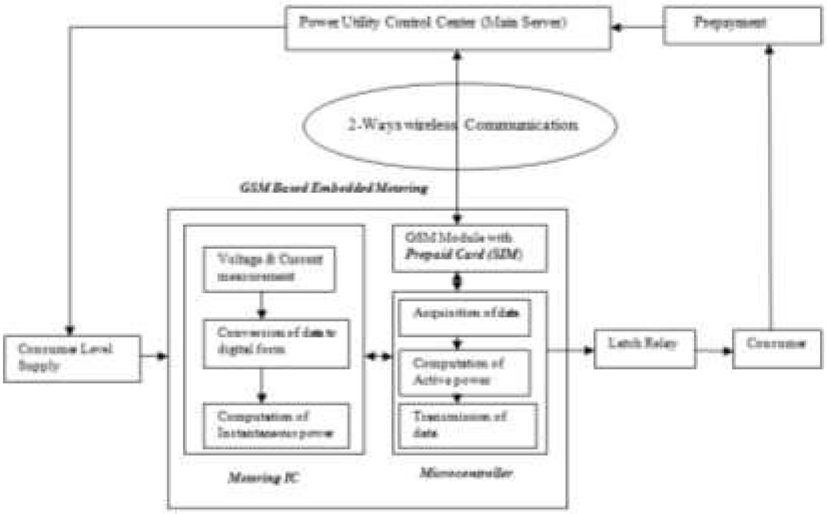

Fig 1: GSM-Based Recharge Billing System Architecture

2.2. ***Microcontroller:*** *The microcontroller is programmed to read data from the metering IC every second. The active meter of the metering IC is not reset after it has been accessed, thus when the microcontroller reads the data from the active register, this value is stored and then subtracted from the next reading to determine the actual instantaneous power value .The difference between the current and previous values is called the delta value. The active register of the metering IC also wraps around every 52 seconds and this is rectified in software.For each reading the new delta value is added to the previous delta values the accumulated is compared to a threshold value. The threshold value is the amount of energy measured by the meter before a pulse is generated.The threshold value is calculated by dividing the energy represented by a light emitting diode (LED) pulse by the energy per register count i.e*

$$Threshold = {}^{Epp}\!/_{Epc} \quad \ldots \quad 1$$

Epc(Energy per count)=I_{max}*V_{nom}*/32000... .... 2*

Where Epp is the energy per pulse, Epc is the energy per count, I_{max} *is the maximum load and* V_{nom} *is the norminal voltage.*

The active register increments at 32000 samples per second, therefore a single count of the energy corresponds to an amount of energy expressed in Ws(Watt seconds). The pulse rate required for the meter is usually expressed in pulses/kWh. A single pulse on an LED is a fraction of a kWh and is converted to energy in Ws/pulse i.e

*Epp(Energy per LED pulse) =1000*3600/Mpr.. 3*

Where Mpr is the pulse rate of the meter in pulses/kWh. The formulas used in this section were based on information obtain from (SAMES, " Single Phase Power/Energy IC with SPI". Available:http://www.sames.co.za,pp.1-12, undated.

2.3 Latching Relay

A Latching Relay is the connecting link between the consumer load and utility supply. The opening and closing of this latching relay depends on the balance present in the prepaid card at a moment. While the prepaid card has some 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 by meter and prepaid card.

2.4 ***GSM-Based Recharge System****:* The power utility sets the amount in the prepaid card to a measure that the consumer recharges the card to, called *Recharged Amount(* R_A*).* The tariff rates are already programmed and fed into the card. As the load is consumed, the meter sends the units consumed to the prepaid card which continuously converts these units into Expenditure (E) at each instant and then subtracts it from the *Recharged Amount to obtain a Balance (B)*.

Mathematical Model

$$R_A - E = B \quad (4)$$

In Nigerian billing structure (Nwaoko,2006)., Expenditure is given by the expression below:

$$E = N_A + VAT + C_c \quad (5)$$

$$C_c = E_C * E_N * M_F \quad (6)$$

$$E_C = L_R - P_R \quad (7)$$

Where N_A=Net Arrears; VAT= Tax; C_C =Current Charge; E_C =Energy Consumed; L_R=Last Reading; P_R = Present Reading; EN= Energy Charge per KWh; M_F= Multiplier Factor.

From equation 5, when the *Expenditure* (E) = the *Recharged Amount* (R_A), the Balance (B) becomes zero. Then the microcontroller triggers the Latching Relay to open and the consumer is disconnected. This action is reversed when the consumer recharges again.

2.5 Power Utility Control Center-Recharging Process

The process of purchase and recharge is explained thus, the power utility produces scratch-cards and distribute them to local shops. Customers buy scratch-cards from their nearby shop and then send a special SMS using their personal cellular phone to the central server consisting of the customer's meter ID and the scratch-card's secret pin number. When the central server receives the SMS, it checks the validity of the meter ID and the pin number from the database. If the meter ID is valid and the pin number is also valid and still unused, then the server gets the customer meter's GSM modem call number from the database and sends an encrypted SMS to the customer's meter which contains the information of how much balance will be recharged in the meter. The meter receives the SMS, decode it and recharge the balance. Then it sends an acknowledgement SMS to the server indicating whether the balance is successfully recharged or not. After receiving the acknowledgement from the meter, the server then sends a report SMS to the customer's personal cellular phone mentioning the meter's current balance. The prepaid card sends a signal to the contactor for monitoring the supply to the consumer.

III. Modeling of Energy Billing System in *Matlab/Simulink* Environment

Figure 2 below represents the energy billing meter model consisting of three subsystems:

a. The utility company model that simulates the energy utility company providing the necessary energy for utility consumption
b. The Energy billing meter model that simulates consumer energy metering
c. The Recharge model that simulates the recharge mode used by the energy consumer.

The energy billing algorithm is fully implemented by the *interpreted MATLAB Fcn* block which accepts a multiplex set of input measurements and outputs the energy balance left for the consumer. See Figure 3.

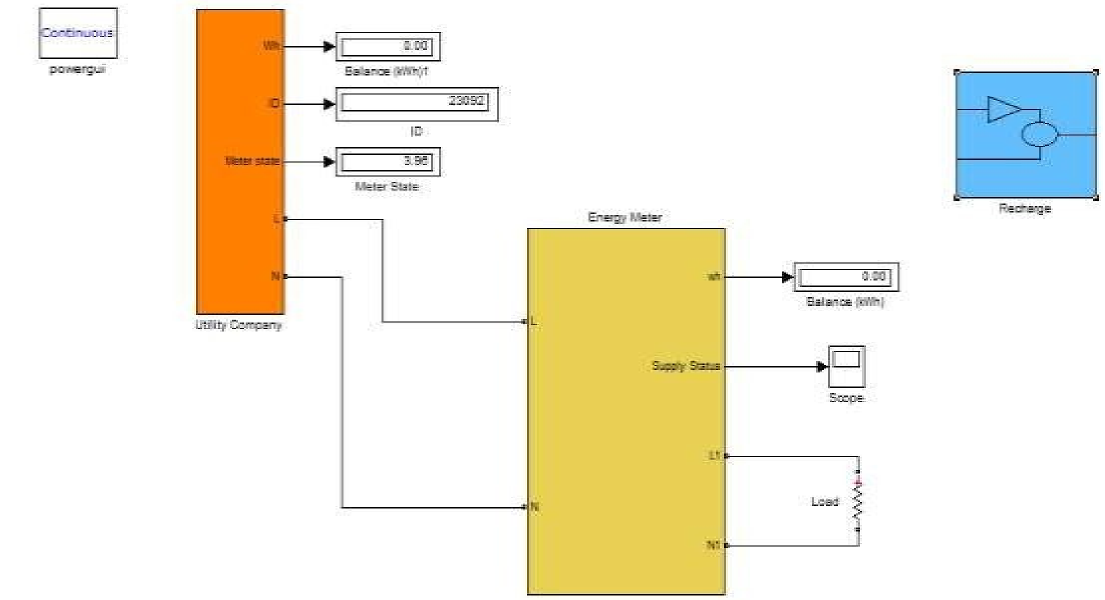

Fig 2: Energy metering and billing system models

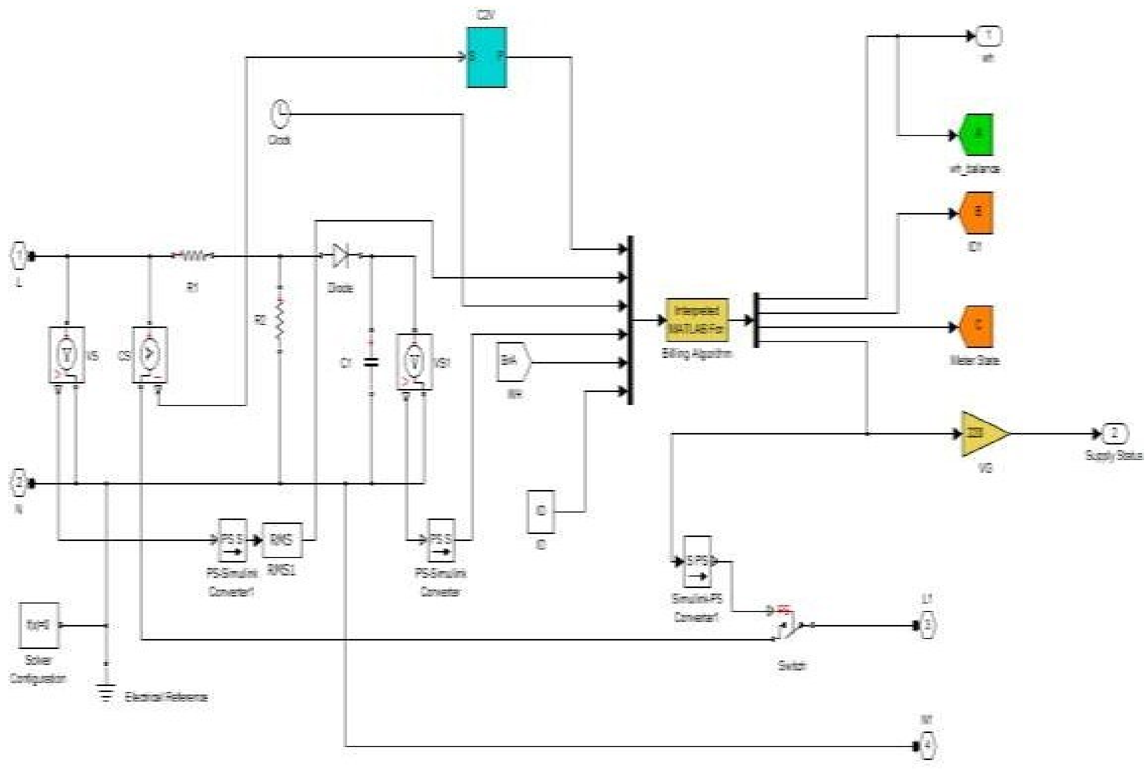

Figure 3: Internal implementation of Energy Meter block

The Energy Billing algorithm

- Read the rms values of the load voltage, current drawn, simulation time, internal meter voltage, Purchased Watt-Hour and meter ID. *These are all multiplexed and supplied as input to the interpreted MATLAB function block.*
- Calculate Consumed active watt-hour rate (Wh)
- Subtract Consumed active watt-hour rate from Purchased Watt-Hour to get energy balance
- Close contactor if balance is available or open it otherwise

IV. Results and Discussion

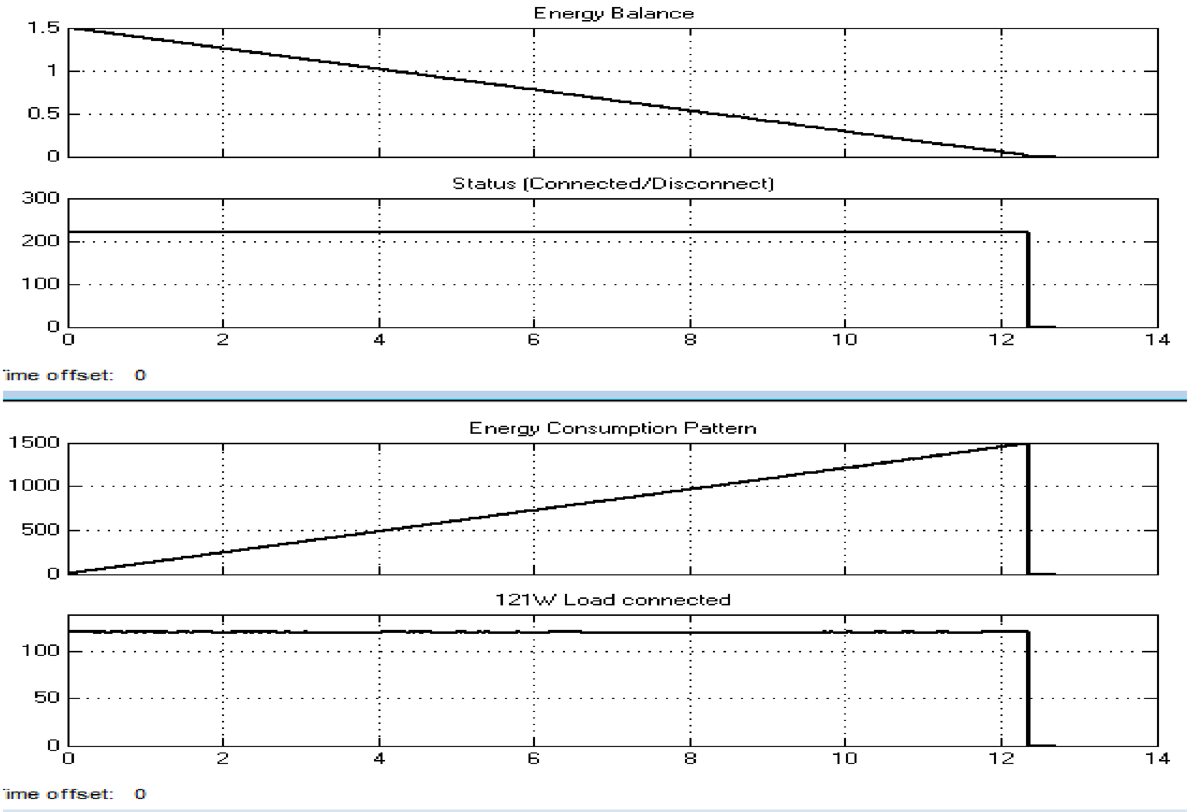

Fig.4: 1500 W Prepaid Billing for 121 W Load

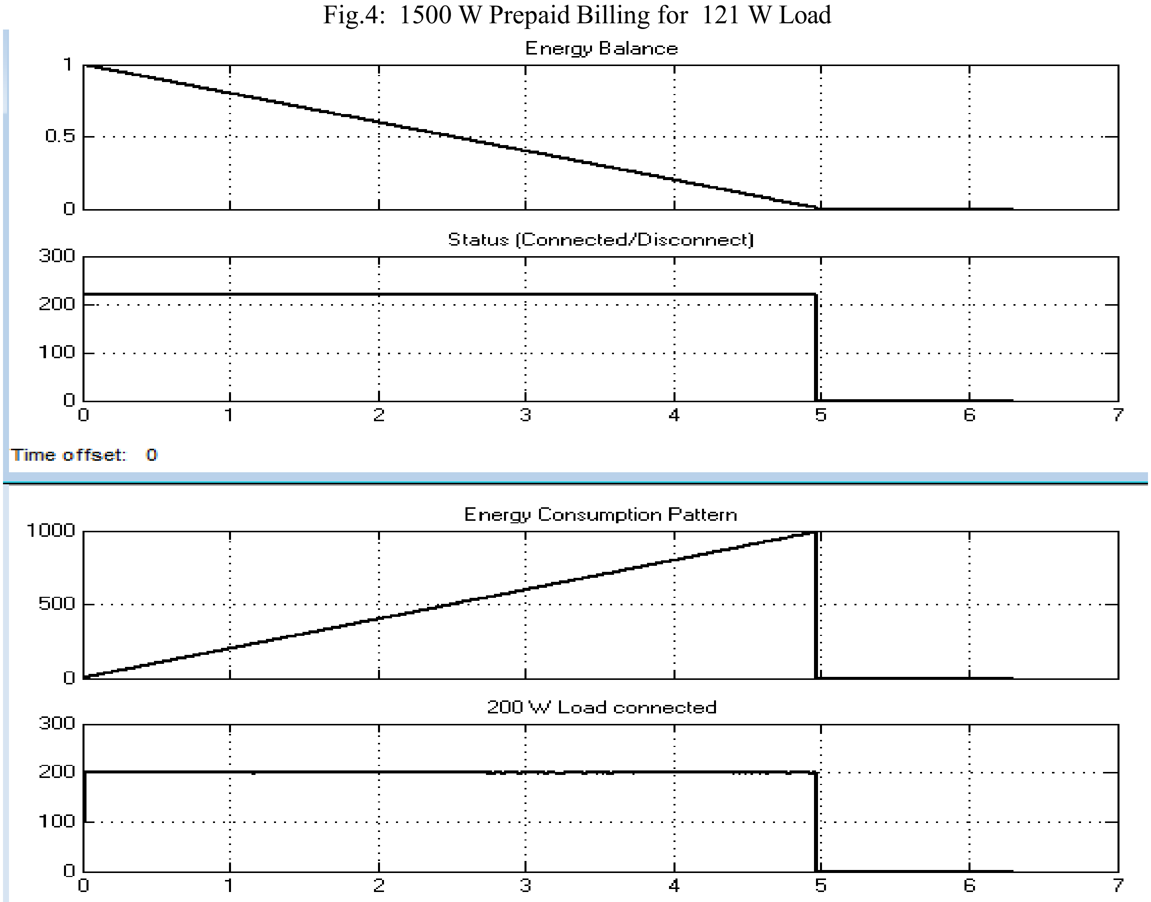

Fig.5: 1000W PREPAID BILLING FOR 200 W LOAD CONNECTED.

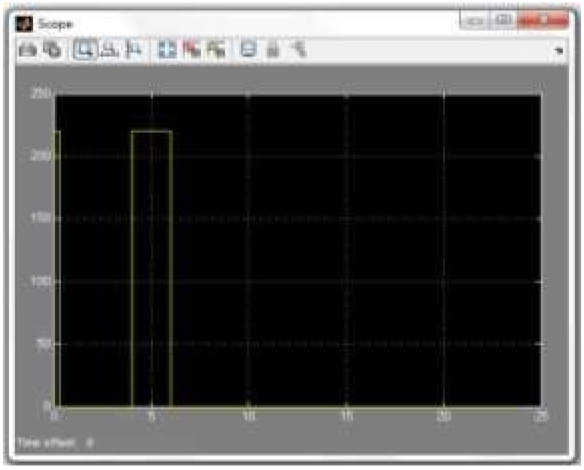

Fig.6: Electrical Output Status based on consumer recharge for load of 484W

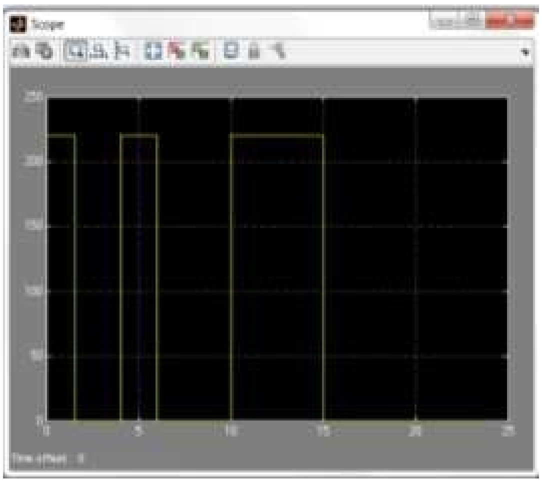

Fig.7: Electrical Output Status based on consumer recharge for load of 60.5W

V. Discussion

I. From Fig.4, Graph 1, the maximum energy level observed is1.5KW on the y-axis. This represents the amount of Energy purchased. This satisfies the equation;

$$E_B = E_R - E_C \quad \text{.........} 8$$

At t=0, $E_C = 0$, $E_B = E_R$

E_R=Energy Recharged, E_C= Energy Consumed, E_B=Energy balance, t= simulation time.

II. From Fig.4, 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:

$$*E_B = E_R - E_C$$

III. From Fig 4, the energy balance pattern in Graph 1is observed to be the reverse of energy consumption pattern in Graph 2.

IV. From Fig 4, 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.

V. In Fig 4, 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.

VI. From Fig 4, in Graph 4, it is observed that the rated load connected is 121 W.

VII. A very important observation is made in Fig 4. 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. This also reflects transparency and integrity of Energy metering and billing transactions.

VIII. In Fig 5, the Energy consumption termination time is shorter than that in Fig 4. This is due to two reasons: (i) the 161 W load connected in Fig 5 is greater than the 121 W load connected in Fig 4 .(ii) The rate of energy consumption is dependent on the rated Load.

IX. Fig.6 and Fig.7 show that different loads with the same recharge have different electrical outputs.

VI. Conclusion

The model for the Nigerian Power Utility Company's GSM-Based Energy Recharge Scheme is presented in this article. The system as a whole may be economical, and its implementation can save a lot of time and money compared to alternatives that include humans. An easier method of buying energy credits and charging the Energy Meter would be in place, and billing mistakes would be completely eradicated. Because customers may only use what they pay for, there is less revenue loss from unpaid invoices, making it dependable. The Nigerian Power Sector stands to gain more money if this plan is effectively executed.

Reference:

[1] Amit. J and Mohnish (2011). B- A Prepaid Meter using mobile communication International Journal of Engineering, Science and Technology-Vol. 3, No. 3, 2011, pp. 160- 166

[2] Hong. L and Ning.L (2004). Design and Implementation of Remote Intelligent Management System for City Energy Resources base on Wireless Network. Study of Computer Application 12:237-239.

[3] Jawarkar, N. P, Ahmed, V, Ladhake, S. A and Thakare, R. D (2008). Micro-controller based Remote Monitoring using Mobile through Spoken Commands. Journal of Networks 3:58-63.

[4] Koay .B.S, Cheah.S.S, Sng .Y.H,Chong. P.H.J, Shun.P,Tong.Y.C (2003) . Design and implementation of a Blue tooth energy meter. proceedings of the Joint 4th International Conference on Information, Communication and Signal Processing and the 4th Pacific Rim Conference on Multimedia .3: 1474-1477

[5] Maheswari, C; Jejanthi, R (2009). Implementation of Energy Management Structure for street Lighting System. A Journal of Modern Applied Science 5:6-10.

[6] Malik S.H .l, Aihab. K, and Erum .S (2009). SMS Based Wireless Home Appliance Control System (HACS) for Automating Appliances and Security. Issue in informing Science and Information Technology 6:887-894.

[7] Nair, L.R and Maharaj, B.T(2004)-Efficient Digital GSM/GPRS Metering for Rural Electrification.

[8] http://www.ursi.org/Proceedings/ProcGA05/pdf/C01.5%2801208%29.accessed 2010.

[9] Nwaoko kosi JOY (2006). Electrical Energy Accounting Methods. Impressed Publishers, Lagos Nigeria, 1-8.

[10] Omijeh.B.O- “Ph.D Thesis on the Design and Evaluation of GSM-based Intelligent Prepaid Energy Metering System for Nigeria” Ambrose Alli University, Ekpoma, 2012.

[11] Scaradozzi, D and Conte, G. (2003). Viewing home automat ion systems as multiple agents systems. RoboCUP2003,Padova,Italy.Retrievedfrom http://www.robosiri.it/ROBOCUP_2003/ROBOCUPSITOSIRI/articles/pdf/Conte.pdf

[12] Schwendtner.M.F (1996). Technological developments in electricity metering and associated. proceedings of the 8th International Conference on Metering and Tarriffs for Energy Supply 8:240-242.

[13] Sharma.S and Shoeb.S. (2011)- Design and Implementation of wireless automatic meterreading system . International Journal of Engineering Science and Technology (IJEST)- Vol. 3, No. 3,March 2011, pp. 2329-2334.

[14] Shwehdi.M.H and Jackson.C (1996). A microprocessor based digital wattmeter system design. proceedings of the 31 st Intersociety Conference on Energy Conversion Engineering 31:1840-1845.

[15] Stanescu, D, Ciubotaru-Petrescu, B., Chiciudean, D., Cioarga, R.. (2006). Wireless Solutions for Telemetry in Civil Equipment and Infrastructure Monitoring. 3rd Romanian-Hungarian Joint Symposium on Applied Computational Intelligence (SACI) . Retrieved from http://www.bmf.hu/conferences/saci2006/Ciubotaru.pdf

[16] Wasi-ur-Rahman.M, Tanvir.A, and Lutful K.(2009)- Design-of-an-intelligent-SMS-based-remote-metering-system. International Conference on Information and Automation 2009.ICIA’09, pp: 1040-1043

[17] Zhang.J, Oghanna and Bai.C.L (1998). DSP based electricity meter with remote reading. proceedings of the 4th International Conference on Signal Processing 2 :1581-1584

[18] Zerfos.P, Meng.K, Wong.S, Samanta.V, and Lu.S “A study of the short message service of a nationwide cellular network,” in ACM SIGCOMM Internet Measurement Conf., Oct. 2006