YIDDISH
Vol 13 Issue 02,june 2023
ISSN NO: 0364-4308

Modeling of GSM-Based Energy Recharge Scheme for Prepaid Meter

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ABSTRACT
It has been shown that the inaccurate metering and billing system is a major contributor to the massive revenue loss in Nigeria's power sector. Inaccuracies may occur at any point in the energy billing process, from the initial collection of data through the final tally of payments and balances owed. Prepaid energy bills is the solution to this problem. Prepaid systems have been shown to significantly decrease revenue loss in various nations. This study creates a simulation of a GSM-based Energy Recharge Interface, which functions like a mobile SIM card but stores energy instead. The prepaid card talks to the utility company through the GSM network. When the prepaid card's balance is depleted, the latching Relay (contactor) cuts power to the consumer load. In response to consumer requests, the electricity company may remotely add funds to the prepaid card via GSM/SMS mode. The Matlab/Simulink environment has been used to model and simulate the GSM-Based Recharge System (GBRS) for a single phase prepaid meter. The data gathered demonstrates the system's effectiveness. Prepayment of bills and meter reading inaccuracies are eliminated by advance billing, guaranteeing the utility's rightful income.
KEYWORDS; Synonyms: Rechargeable, Prepaid, Microcontroller, GSM, Energy Meter.

I. Introduction

The importance of Global System for Mobile Communications (GSM) technology cannot be overstated in light of the recent trends in digital technologies that have led to enormous advancements in wireless communications. Because of this, the article delves into the prospects of using a GSM-based recharge scheme for an energy prepaid meter (Omijeh, 2012). The GSM-Based Recharge Module (GBRM) is the most novel aspect of the design; it consists of a Microcontroller, a GSM communication module, a prepaid card (specially coded SIM), a latching Relay, and an LCD screen. 1.1 Works Cited

One such microcontroller-based meter is the Digital Tele-wattmeter System, which was introduced in a paper by Shwehdi and Jackson (1996). The meter was set up to send information once a month through a dedicated phone line and a pair of modems to a central location. It is not connected to any other metering infrastructure. Multiple users' power usage in a home environment was measured by Zhang, Oghanna, and Bai (1998) using a DSP-based meter. Using power line communication (PLC), a PC in the control center sent orders to a distant meter, which then relayed data back. The biggest issue with this technology is that it cannot identify customer manipulation.

In their study, Koay, Cheah, Sng, Chong, Shun, and Tong (2003) developed a Bluetooth energy meter that allows several meters in close proximity to exchange data wirelessly through a Master PC. Since Bluetooth technology is most useful at close range, this system's lack of distance coverage is a key drawback.

Scaradozzi and Conte (2003) argued that MAS principles may be used to home-automation systems. The concept of a home automation system for managing electrical appliances and other gadgets at one's residence was presented. However, it does not track users' energy use beyond that of the residence itself.

Automatic Meter Reading (AMR) through wireless networks was suggested in a study by Hong and Ning (2005). The internet is used for data transfer by several commercial AMR devices.

A concept and implementation of SMS -based control for monitoring systems is presented by Stanescu, D., Ciubotaru-Petrescu, Chiciudean, and Cioarga (2006). The sensing unit used in this paper's three modules for keeping tabs on complicated applications. Power outages and other status updates may be sent by SMS. Concerns about the electrical board's billing method were ignored.

The concept of centralized accounting, monitoring, and charging allows for the use of cutting-edge technology like WiMAX in prepaid meters. To facilitate additional Smart Grid applications like Demand Response and Plug-in electric cars, it centers its operations on telecommunications (Khan et al., 2007). Local prepayment and a card reader based energy meter make up prepaid polyphase power metering systems (Ling et al, 2010).

In their work, Malik, Aihab, and Erum (2009) primarily addressed the application of an SMS-based wireless Home Appliance Control to enable remote control of appliances and provide security when the user was away from home.

In their work, Maheswari and Sivakumar (2009) sought to use GSM and GPRS to provide a low-cost, energy-efficient alternative to traditional street lighting. The remote operator may save energy by turning off lights when they're not needed, controlling the voltage sent to the streetlights, and keeping track of the number of hours the lights were on each day.

A technique for automating the transfer of data to the server and on to the consumer through SMS and Email was proposed by Sharma and Shoeb (2011) in their article.

Mohnish Amit and Amit J. Patel 2011. Prepaid energy meters, similar to prepaid cell phones, were proposed in their article. A prepaid card, similar to a mobile phone's SIM card, is housed in the meter. The prepaid card interacts with the utility company through cellular networks. The contactor cuts off power to the consumer load when the prepaid card is depleted. In response to consumer requests, the electricity company may remotely add funds to the prepaid card through mobile communication.

. **Second, the dependability of GSM SMS** ***The most widely used mobile phone system worldwide is based on the Global System for Mobile Communications (GSM).There are more over 1.5 billion GSM subscribers, and the number is growing rapidly. brief Message Service (SMS), which allows for the transmission of delay-tolerant brief texts between parties, was also first implemented at cheap cost using GSM. Researchers are thinking about implementing an SMS service due to the widespread availability of cellular networks. However, the GSM network's scalability, stability, and security, particularly under heavy demand, are also up to debate. In 2006, Zerfos et al. studied data from a functioning GSM network in India. The success rate for sending and receiving SMS messages is 94.9%; 73.2% of those sent successfully reach their destination within 10 seconds; roughly 5% take more than an hour and a half. The use of SMS for AMR service will unquestionably raise the volume of communications significantly. For its security, GSM employs a number of different cryptographic methods. In order to increase security, UMTS developers introduced the Universal Subscriber Identity Module (USIM), which authenticates both the network and the user using a longer authentication key.***

I. The Structure of a Global System for Mobile Recharge Billing

Fig.1 shows a block diagram of the recharge billing system that uses a GSM-based network. The Public Utility Control Center (PUCC) server, the GSM-Based Recharge Module, and the Digital Energy Meter are its three primary components.

2. The One Advantage of a Digital Energy MeterThe instantaneous active power is produced by a Metering IC, which monitors the current and voltage signals. The microcontroller regularly checks the value of the active energy register, which contains the integrated instantaneous active power values, using the SPI (Serial Peripheral Interface). The microcontroller determines the amount of active power used by retrieving the value from the active register. The microcontroller has a real-time clock that generates timestamps for use in synchronizing the meter with the PUCC server.

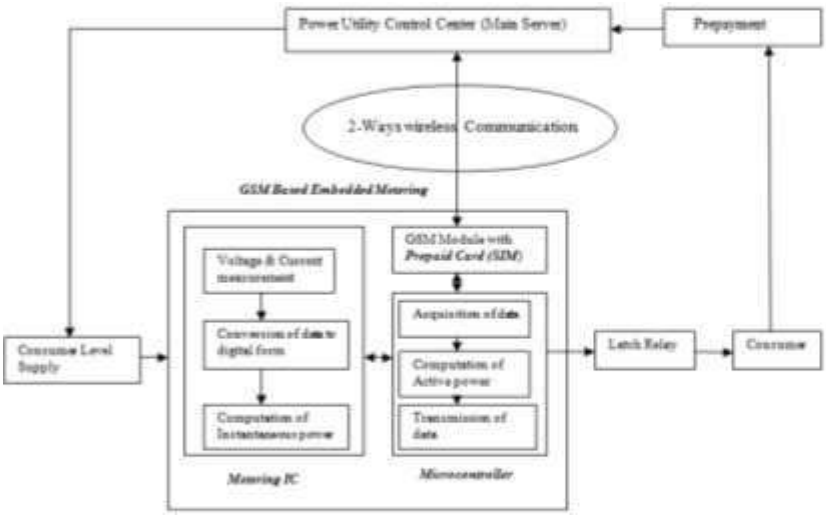

Fig 1: GSM-Based Recharge Billing System Architecture

2.2The microcontroller is set up to poll the metering IC once per second and record the results. Since the metering IC's active meter is not reset after being read, the microcontroller stores the value read from the active register and subtracts it from the next reading to get the true instantaneous power value.The delta value is the difference between the current value and the prior value. Every 52 seconds, the active register of the metering IC cycles, and this is corrected by the software.After each measurement, the delta value is updated and the total is compared to a predetermined limit. The energy measured by the meter over which a pulse is produced is the threshold value.The energy represented by an LED is divided by its visible intensity to get the cutoff value. (LED) pulse by the energy per register count i.e

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

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

Where Epp and Epc represent the energy delivered per pulse and count, respectively; Imax represents the maximum load; and Vnom represents the typical voltage.
*The active register advances at a rate of 32000 samples per second, hence an energy value given in Ws(Watt seconds) is equal to one count. The pulse rate for the meter is typically given in pulses per kilowatt hour. Using the formula Epp(Energy per LED pulse) =1000*3600/Mpr 3, we can determine that a single LED pulse consumes a tiny fraction of a kilowatt-hour. Where Mpr is the meter's pulse rate in pulses per kilowatt hour. The data used in this part was derived from (SAMES, " Single Phase Power/Energy IC with SPI"), where the corresponding formulae may be found. Undated and accessible at http://www.sames.co.za/pages1-12.*

Latching Relay 2.3 To connect the consumer load to the utility supply, a Latching Relay is used. This latching relay opens and closes based on the current balance of the prepaid card. The utility supply to the customer load is maintained while the prepaid card balance is greater than zero. Card opens and disconnects load from supply when balance is exhausted. Since there is insufficient funds on the prepaid card, the voltage supply does not go through the energy meter to the load while the latching relay is on. The electrical energy used by the latching Relay is included into the totals determined by the meter and the prepaid card.

The Recharged Amount(RA) on a prepaid card is determined by the amount the user recharges the card with, and is established by the power company. The card has already had the appropriate tariff rates loaded onto it. The prepaid card receives consumption data from the meter in the form of units, which are then converted into expenditures (E) in real time and subtracted from the recharged amount (R) to provide a balance (B).

Mathematical Model

$$R_A - E = B \ldots 4$$

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

$$E = N_A + VAT + C_c \ldots 5$$

$$C_c = E_C * E_N * M_F \ldots 6$$

$$E_C = L_R - P_R \ldots 7$$

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.

2.3 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.

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ISSN NO: 0364-4308

I. The Matlab/Simulink Modeling of the Energy Billing System
The three components of the energy billing meter concept are shown in Figure 2.
a. A model of a utility company that replicates one that supplies electricity to homes and businesses

b. A model of a customer energy meter used for invoicing purposes
c. The Recharge model, which represents the energy user's preferred method of recharging.
The interpreted MATLAB Fcn block receives a multiplex set of input measurements and outputs the consumer's remaining energy balance, completely realizing the energy billing method. Refer to Figure 3.

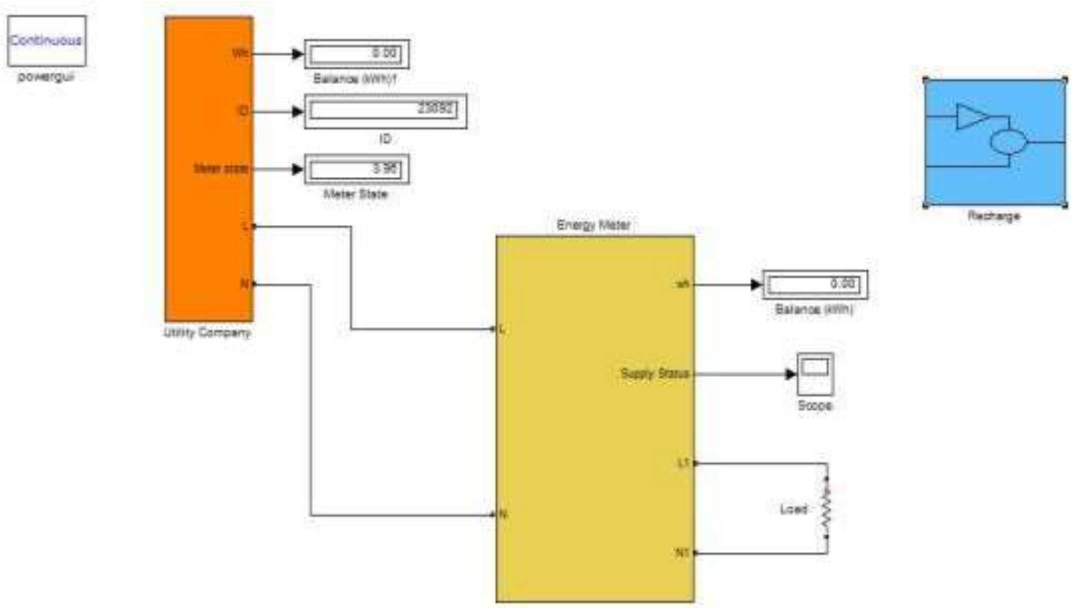

Fig 2: Energy metering and billing system models

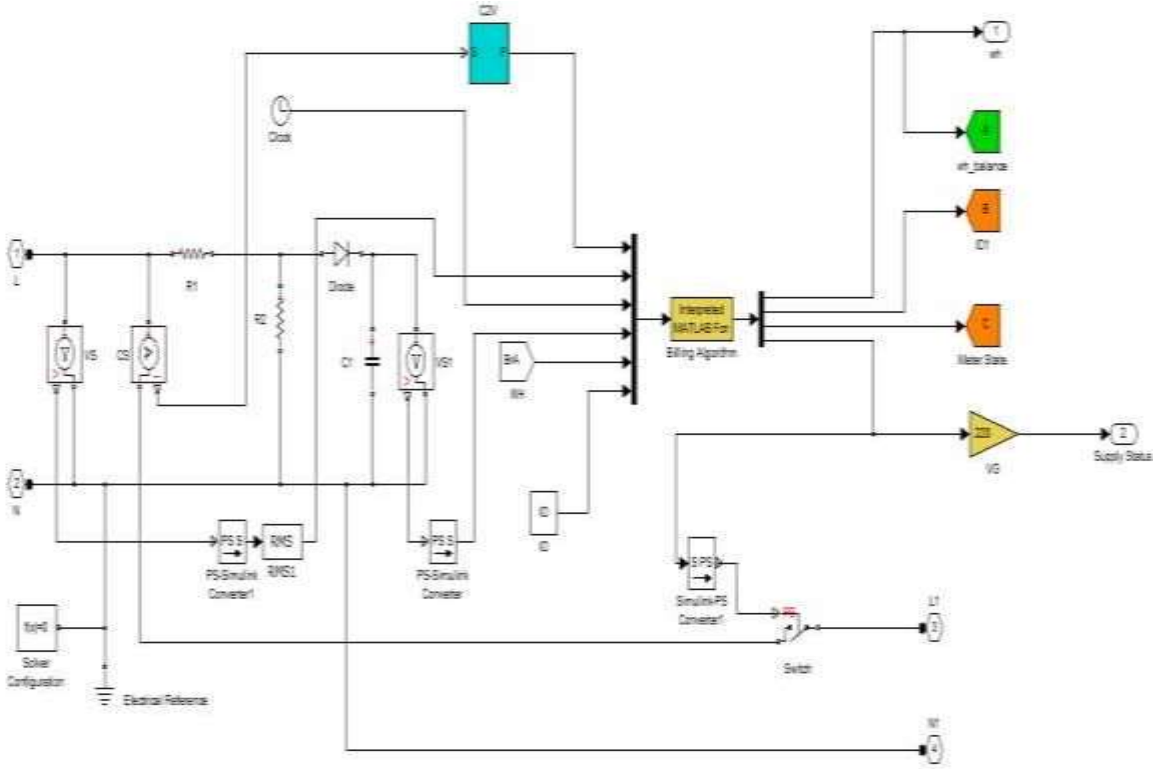

Figure 3: Internal implementation of Energy Meter block

The Energy Billing algorithm

• Get the load voltage, current, simulation duration, meter's internal voltage, purchased watt-hour, and meter ID as their root-mean-squared values. All of them are combined into a single stream and sent to the MATLAB function block for

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ISSN NO: 0364-4308

interpretation.
Determine the rate in active watt-hours (Wh) that was used up.
To calculate energy balance: • Deduct the rate per active watt-hour used from the rate per watt-hour purchased.
To check for available balance, close the contactor and open it if none is there.

Results and Discussion

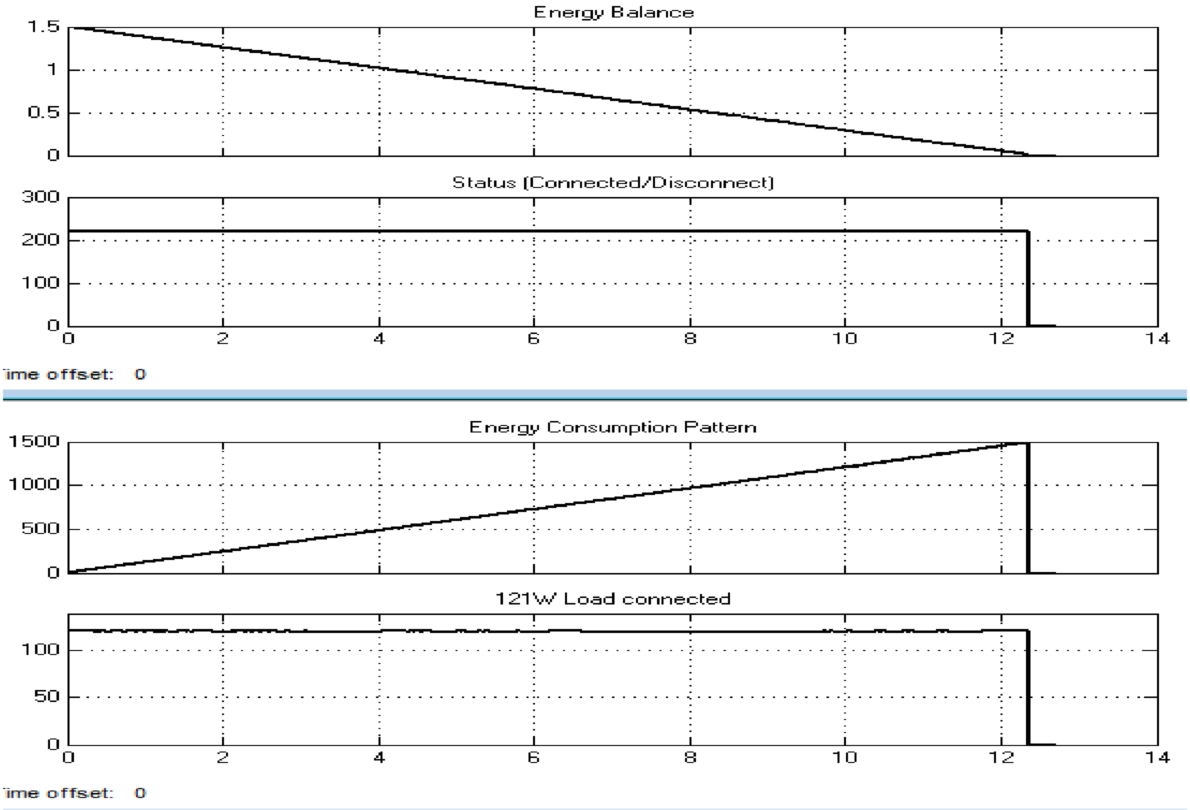


Fig.4: 1500 W Prepaid Billing for 121 W Load

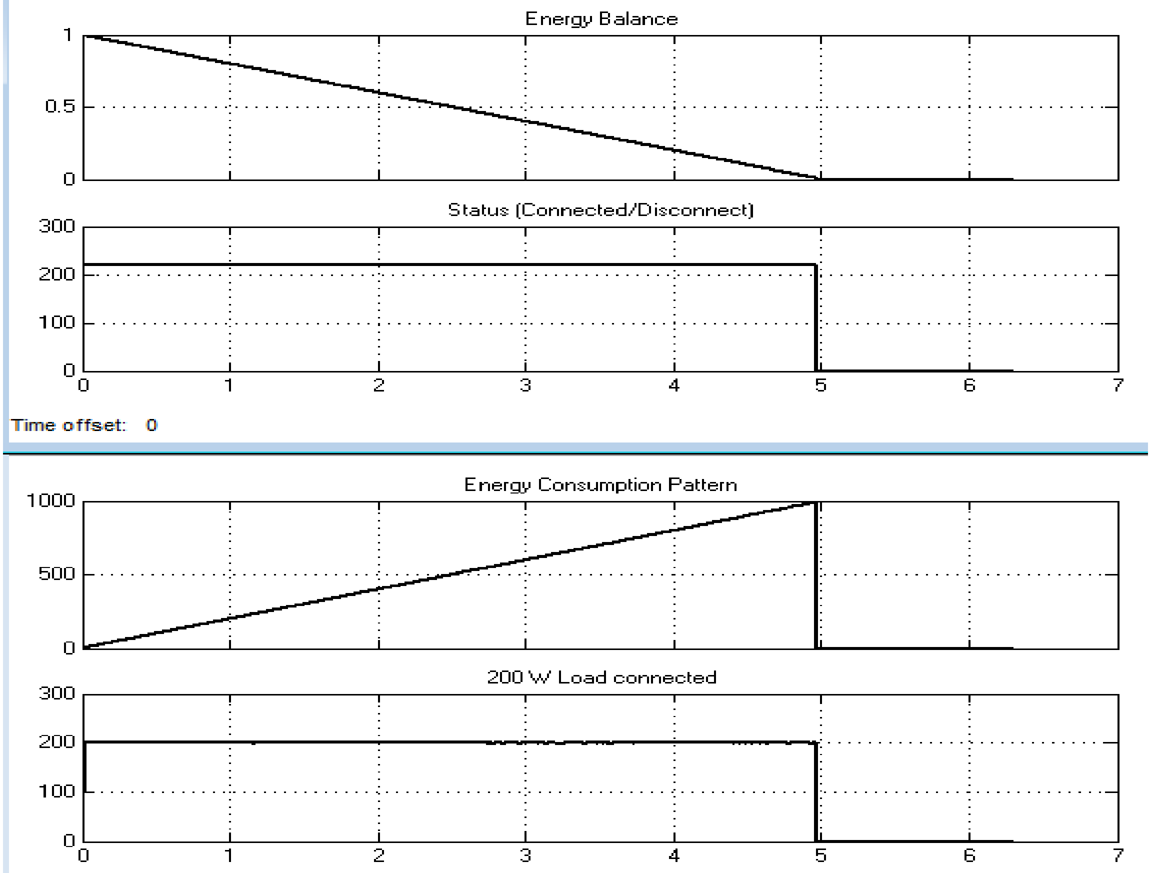
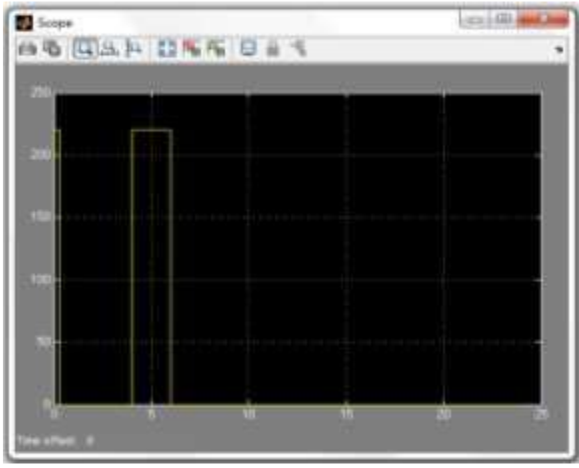


Fig.5: 1000W PREPAID BILLING FOR 200 W LOAD CONNECTED.



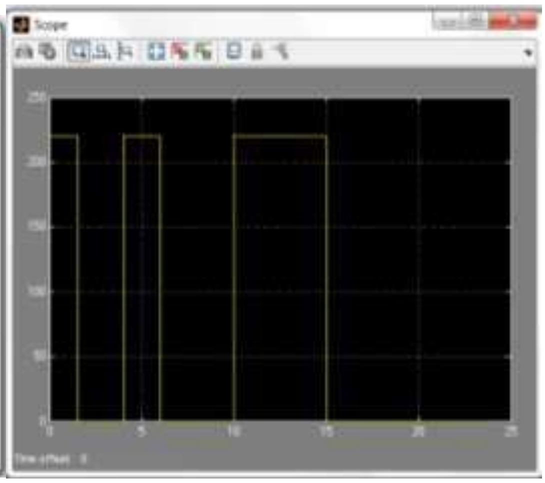


Fig.6: Electrical Output Status based on consumer recharge for load of 484WContinuity of Power Based on Consumer Recharge for 60.5W Load (Figure 7)

I. **II. Discussion** The y-axis maximum of 1.5 kW is clearly seen in Fig.4, Graph 1. This is the cost of the energy that was bought. Since EB = ER-EC 8, the problem is solved.

II. Since EC=0 and EB=ER at t=0,

III. Recharged energy (ER), used energy (EC), excess energy (EB), and elapsed time (t) in a simulation.

IV. Figure 4's Graph 1 shows that the energy balance value progressively declined from the consumer's energy usage count to zero. In addition, this answers the equation:

V. *ER-EC = EB

VI. Third, in Figure 4, we can see that Graph 1's pattern of energy balance is the inverse of Graph 2's pattern of energy use.

VII. Figure 4's graphs 1 and 3 show that the pattern of energy consumption has a positive slope (gradient), whereas the pattern of energy balance has a negative one.

VIII. Until the energy balance was depleted (zero), the consumers in Fig. 4, Graph 2, remained connected at 220 volts. The IPEBS's efficacy and efficiency are shown. When the meter's energy credit is depleted, the customer is immediately cut off. Which demonstrates excellent customer and utility business energy accountability.

IX. The rated load connection is 121 W, as shown in Fig. 4's Graph 4.

X. In Fig. 7, a crucial finding is shown. The precision of the IPEBS model was shown by the simultaneous termination of all four graphs. As a result, the user's energy use is limited by the number of ERUs (Energy Recharge Units) they have bought. The honesty and openness of the Energy industry's invoicing and metering processes are reflected in this as well.

XI. Figure 5's Energy Consumption Endpoint Time is Quicker than Figure 4's. There are two main causes for this: Figure 5's 161 W load is higher than Figure 4's 121 W load, therefore (i).Depending on the rated Load, energy consumption rates might vary significantly.Electrical outputs from various loads with the same recharge are shown in Figures 6 and 7.

VI. Conclusion

For the Nigerian Power Utility Company, this study presents a model of a GSM-based energy recharge scheme. When compared to a system that relies on humans, this one can save businesses substantial time and money without sacrificing efficiency. There would be no room for human mistake in invoicing, and it would be easier to buy energy credits and refill the Energy Meter. It's trustworthy because customers can only use what they pay for, preventing revenue loss from unpaid payments. The Nigerian Power Sector would see a rise in income if all plans are put into action.

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