



Enhancement of Electrical Energy Transaction through the Development of a Prepaid Energy Meter using Gsm Technology

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Abstract: This paper presents the development of a prepaid energy meter using GSM technology to enhance electrical energy management. The objectives are to develop an energy meter with mobile payment option, mitigation of electricity theft, and reduction of billing errors as compared to the previous energy meters. The metering system consists of voltage and current sensors. The monitoring and control system consists of GSM module, real time clock, relay and an ATMEGA328 microcontroller programmed in C-Language. The meter is designed to have a peak and off peak period with corresponding meter billings for both periods. It also carries out the following instructions: it automatically sends an SMS informing the consumer whose phone contact have been programmed into the system about his/her units at preset times; whenever the energy units is below a certain value or if a payment has been made, an SMS is sent to the consumer; it also disconnect and connect supply respectively through a connected relay. The results obtained shows that the system responded as programmed: the subscriber's phone number and the meter were registered successfully, the meter was recharged and also a message was sent to the subscriber about his/her recharge status from the service provider, by this, the subscriber would have less contact with the meter and the issue of electricity theft through meter by-pass would be reduced along with the time wasted by consumers to line up for the purchase of energy unit.

Keywords: ATMEGA328, Current sensor, GSM module, Relay, Real time clock and Voltage sensor.

1. INTRODUCTION

Efficient usage of electricity has become an important concern worldwide. This has urged utilities throughout the world to shift from conventional electromechanical meters to smart meters which provide better security and control [1]. A Prepaid Energy Meter enables power utilities to collect electricity bills from the consumers prior to its consumption. The prepaid meter is not only limited to Automated Meter Reading [AMR] but is also attributed with prepaid recharging ability and information exchange with the utilities pertaining to customer's consumption details. The idea of prepaid metering is very important for the new fields of Micro-grid and Smart Grid and is an inevitable step in making any grid smarter than it is now [2]. Electricity theft is not a new phenomenon but it is becoming important because of its impact on the cost of electricity to consumers and the utility companies particularly in developing countries like Nigeria [4]. Unlike other forms of theft, electricity theft hardly carries strict penalties. Recently, there has been the development of more stringent measure to deal with those who take part in the fraudulent extraction of electricity in Nigeria. There are four main ways that electricity can be accessed illegally [3]. Electricity can be fraudulently accessed through illegal hook-ups, meter tampering or bypass, billing irregularities and unpaid bills [5]. Illegal hook-ups occur when electrical wires are directly connected to the grid system from the individual's premises. High risks of electrocution and electrical fires are associated with this type of electricity theft. Meter related theft is found among major households because it is technically easier and usually requires little or no electrical wiring knowledge [6]. Meter tampering can be done by inserting a device into the meter resulting in an inaccurately lower reading on the meter. This tampering can be detected only by an audit on the premises or by discrepancies in the electricity bill. Meter bypass occurs when some of the wiring of the premises is engineered to not pass through the

meter. Like meter tampering, this is also very difficult to detect. Billing irregularities is a manifestation of corruption in the utility company through bribes to utility officials. Usually, the meter reader is compensated for not reporting the accurate electricity usage of the property. Refusal to pay electricity bills is a common practice by all socioeconomic groups [7]. The utility company has the greatest control over this since they are able to disconnect customers for unpaid bills. Disconnections are usually a prelude to another form of electricity fraud. Power theft is a serious problem and when not checked and prevented can derail the growth and progress of an economy [8]. In this research work, a prepaid energy meter using GSM technology to enhance electrical energy management was designed and implemented to provide a high level of energy management through an advance algorithm embedded in a microcontroller to monitor peak and off- peak periods with subsequent energy consumption rate; that is, for the peak period the energy is recorded as it is being consumed while for the off-peak period the energy recorded is 80% the energy consumed. This enables the consumer to manage his/her energy consumption rate at a reduced cost. The energy meter was also designed to communicate to the consumer through a GSM module by sending a message to the consumer's registered phone number which was programmed in the microcontroller, with information about recharge made to the service provider. It also informs the consumer when the preset threshold is reached. If the value of energy gets to 50Whr a message is sent to the consumer to make a recharge; a relay connected to the meter disconnects the consumer from the energy supply when the unit get to zero and recharge is not made. This minimizes the problem of electricity theft as the meter could be install outside the reach of consumer and helps improve energy management as consumers make a conscious effort to reduce energy wastage during peak and off-peak periods; consequently reducing the tariffs.

2. MATERIALS AND METHODS

The block diagram in Figure1 shows the monitoring, metering and control System of the design which is discussed below.

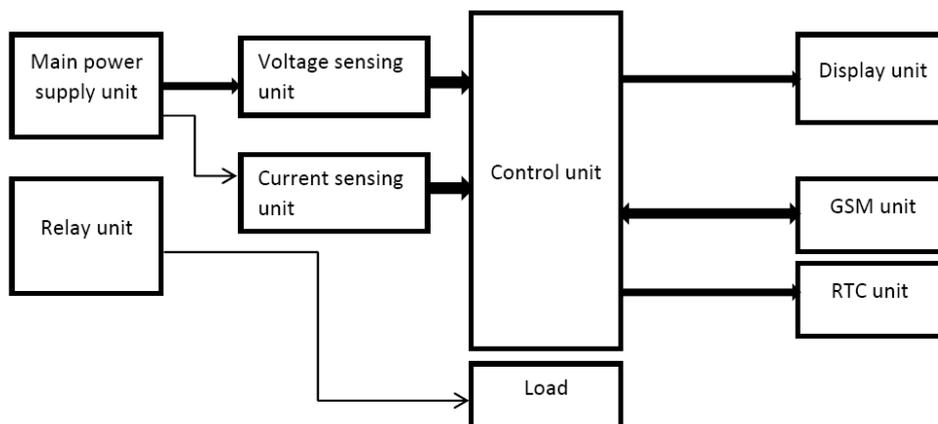


Figure1. Block Diagram of the Monitoring, Metering and Control System Design

2.1. The Power Supply Unit Design

The source of power is from AC mains. The AC power supply was transformed from 220Vac to 15Vac. The transformed voltage was then rectified to DC using a bridge rectifier and filtered using a capacitor. The rectified dc was then regulated to 5Vdc using a 5V regulator (LM7805) and 12Vdc using a 12V regulator (LM7812).

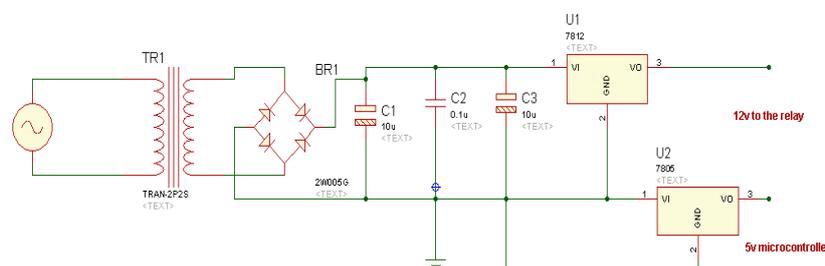


Figure2. The circuit diagram of the power supply

2.2. The Control Unit

The control unit uses a microcontroller ATMEGA328 which has internal ADC and memory. The controller was clocked with a frequency of 16MHz. This is used to achieve a compact system since two ADC is needed to check both the voltage and current. The controller is programmed to communicate with the LCD, GSM module and relay connected to the load which is responsible for the switching. The basic connection of the controller is shown in Figure3.

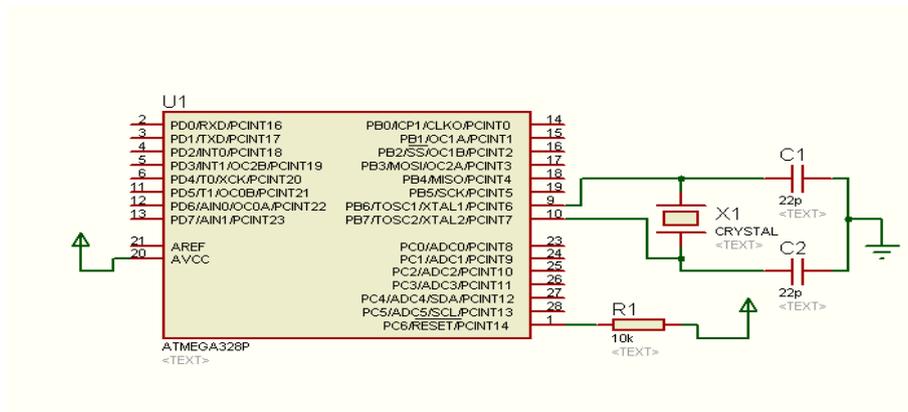


Figure3. Microcontroller Circuit Connection

Pin 7 which is the V_{cc} is connected to 5V as specified in the datasheet which is to power the controller while pin 8 is grounded.

2.3. Display Unit

This unit is achieved by the use of an LCD. The datasheet instruction is needed in interfacing the LCD with the controller. The different control signals that could initialize the system were specified. All these instructions were adhered to for success in the prototype made. The symbolic representation of the device is shown in Figure4.

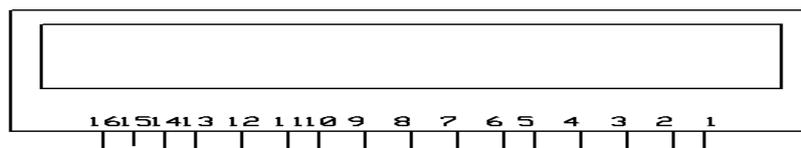


Figure4. Symbolic Representation of an LCD

2.4. Relay Unit

The unit aids in switching between the consumers supplies; that is, when a recharge has been made and vice versa. The diagram in Figure5 is the relay circuit.

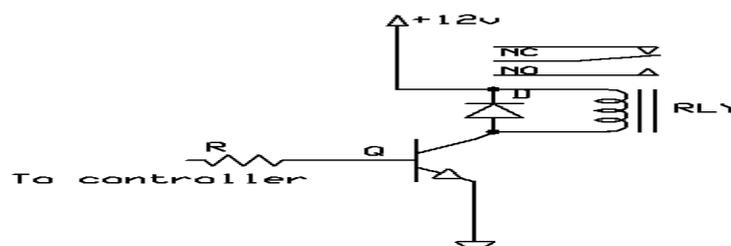


Figure5. Relay Circuit

2.5. Current Sensing Unit

A filament bulb rated 60watts was connected to a supply of 220Vac. Therefore the total current flowing through the load will be:

$$I = \frac{P}{V \cos \phi} \quad (1)$$

Where P is the total power, I is the current, $\cos\phi$ is the power factor and V is the voltage also 0.8 was chosen as the power factor for maximum efficiency. Figure 6 shows the circuit diagram of the current sensing unit.

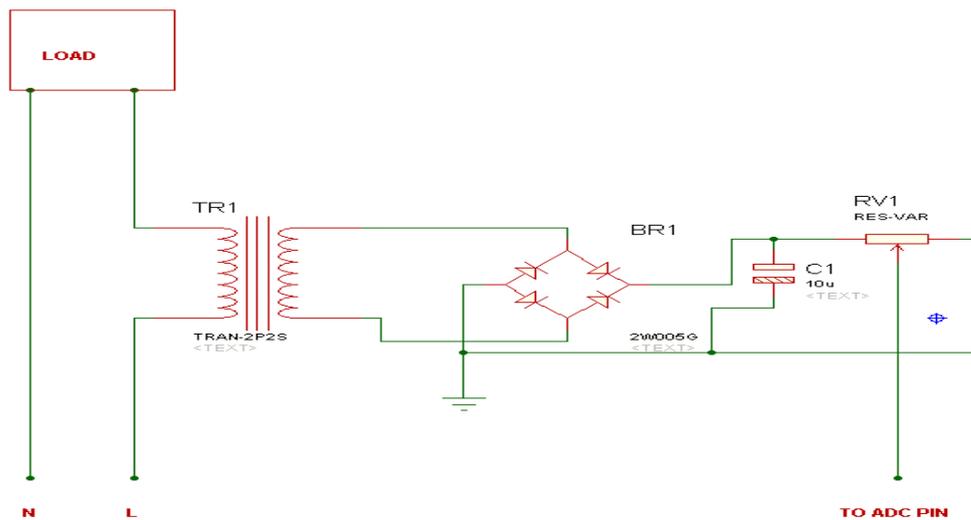


Figure 6. Circuit of the Current Sensing Unit

2.6. Voltage Sensing Unit

The unit was achieved via the use of a step down transformer rated 220/15V. The voltage rating of the transformer was then scale down to 1:100 with the help of variable resistor such that when the input voltage was 220V the voltage at the output of the variable resistor that goes to the microcontroller was 2.2V. Figure 7 shows the circuit diagram of the voltage sensing unit.

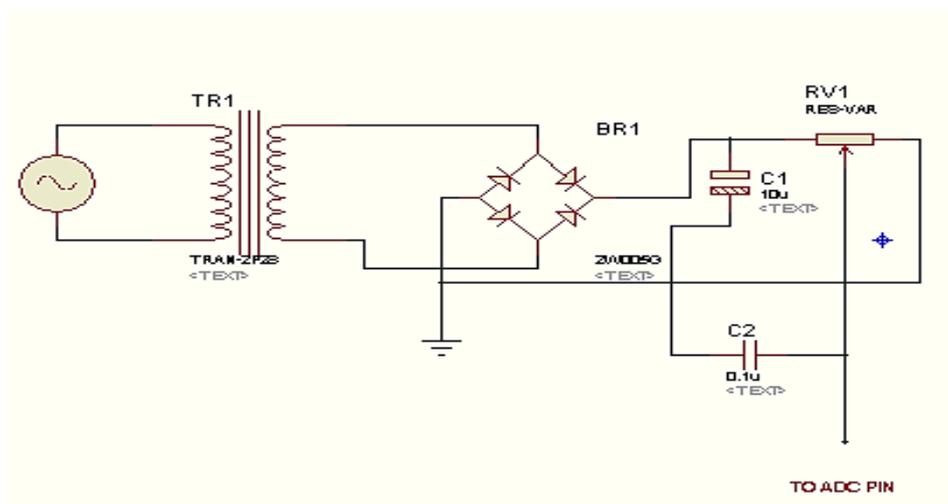


Figure 7. Circuit of the Voltage Sensing Unit

2.7. Real Time Clock Unit

This unit was used to keep the present time and date in the sense that the peak and off peak period depends on time.

2.8. GSM Module Unit

The GSM module used is SIM900. It was set to the baud rate of 9600 bits/sec so it can communicate with the controller. The type of serial communication used is USART (Universal Synchronous Asynchronous Transmission) and this component is controlled using AT (Attention) commands.

3. OVERALL CIRCUIT DIAGRAM OF THE SYSTEM

The overall circuit diagram comprises the metering, monitoring and control unit. This is shown in Figure 8.

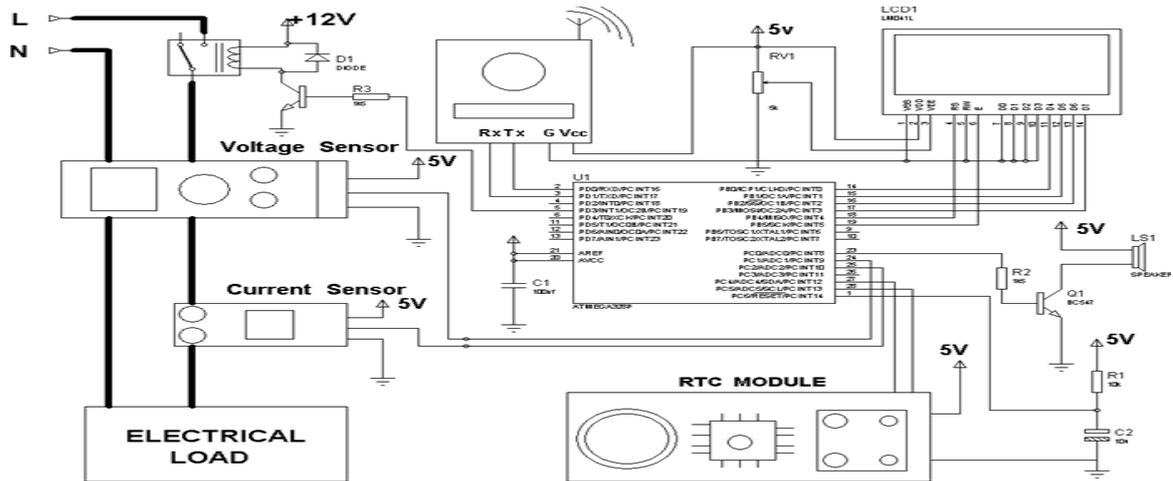


Figure8. Circuit diagram of the Overall Design

3.1. Construction of the Prepaid Energy Meter Casing

The prepaid energy meter casing was locally constructed using plastic in four corners to form a box. The casing constructed is shown in Plate1.

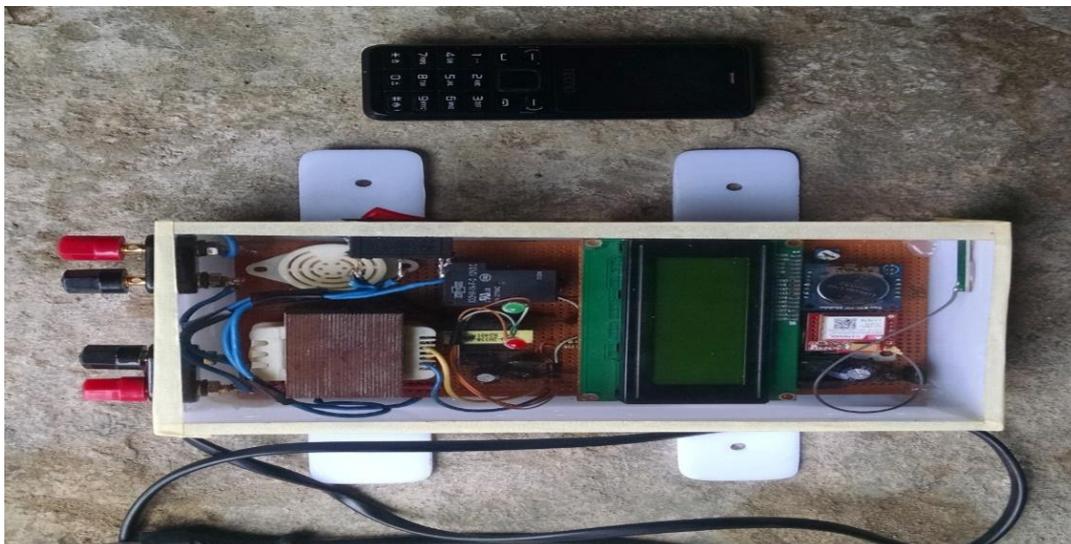


Plate1. Casing of the prepaid energy meter

4. TEST AND RESULTS

The testing of components of the prototype system was carried out before the implementation was made. A multi-meter was used to measure the voltage and current output of the voltage and current sensors. The measured values were recorded. The electronic components used for the monitoring and control circuit was initially tested on a bread board before it was finally soldered to a Vero board.

Table1 shows the communication between the monitoring and control unit when all units are connected. The prototype of the monitoring and control unit is shown in Plate2. The system responded as programmed. A response for status inquiry, unit availability and switching of relay was all tested. The messages displayed on the LCD and phone is shown in Plate3.

Table1. Communication of the monitoring and control circuit

Function	Message Sent	Response Received
To store the number of the subscriber or consumer	A message with the caption; #I AM THE USER: 07030542277. was sent	Subscriber's number saved successfully.
To recharge energy meter	A message with the caption; #RECHARGE: 100. was sent	Meter was recharged with 100WHr successfully.

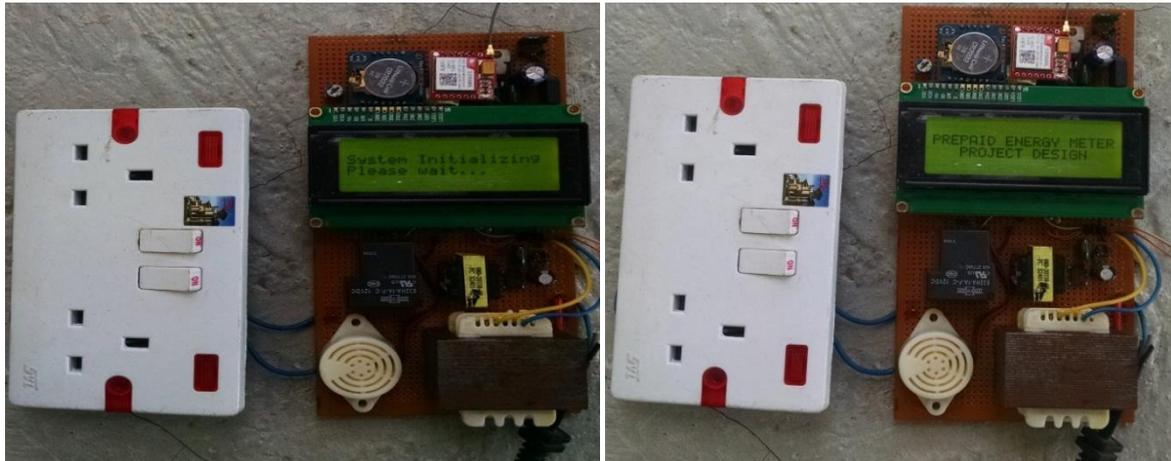


Plate2. Picture Display of the Monitoring and Control System



Plate3. Pictures of Messages Displayed on Phone

4.1. Discussion of Result

The LCD in the circuit of the monitoring and control displays every action taken and message received by the microcontroller.

When the energy level of the energy meter gets to a preset threshold, a message is automatically sent only to the GSM number that was included in the programming of the microcontroller. Figure9, 10, 11 and 12 shows all the actions on the LCD as simulated using Proteus ISIS.

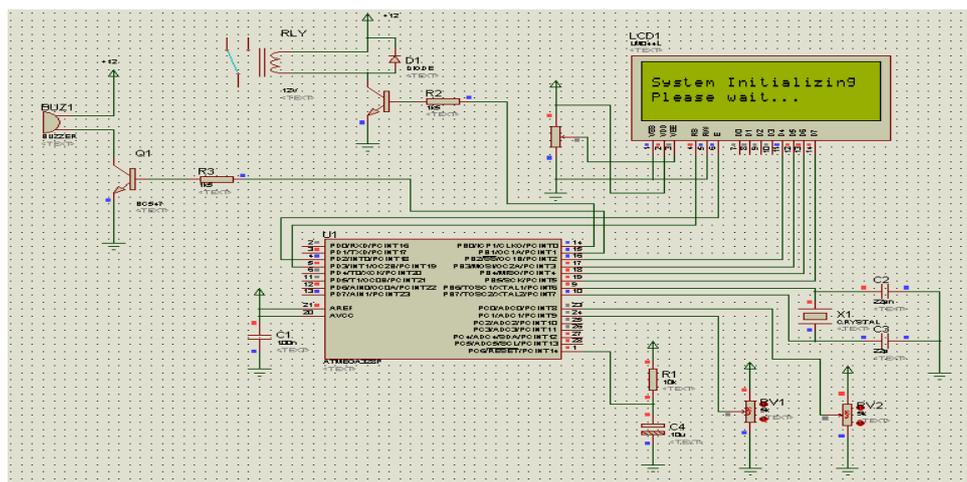


Figure9. Result on initializing display on the LCD

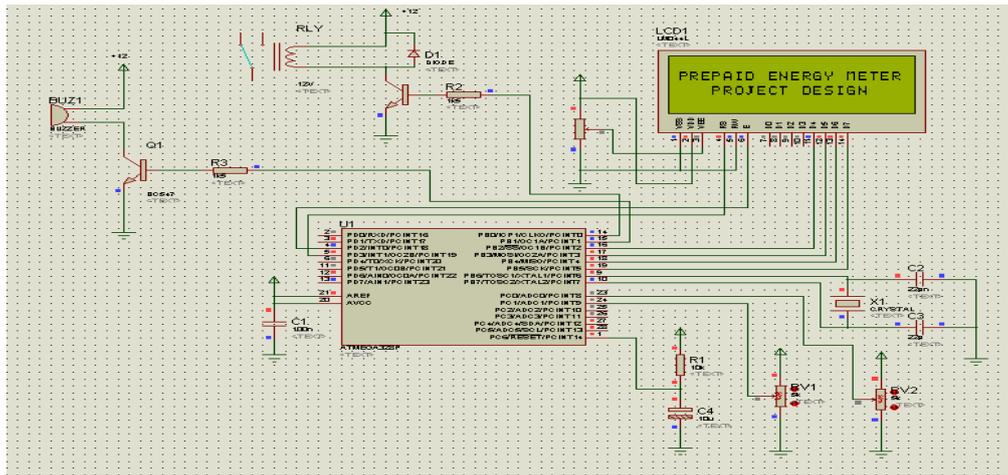


Figure10. Result on LCD of the prepaid energy meter

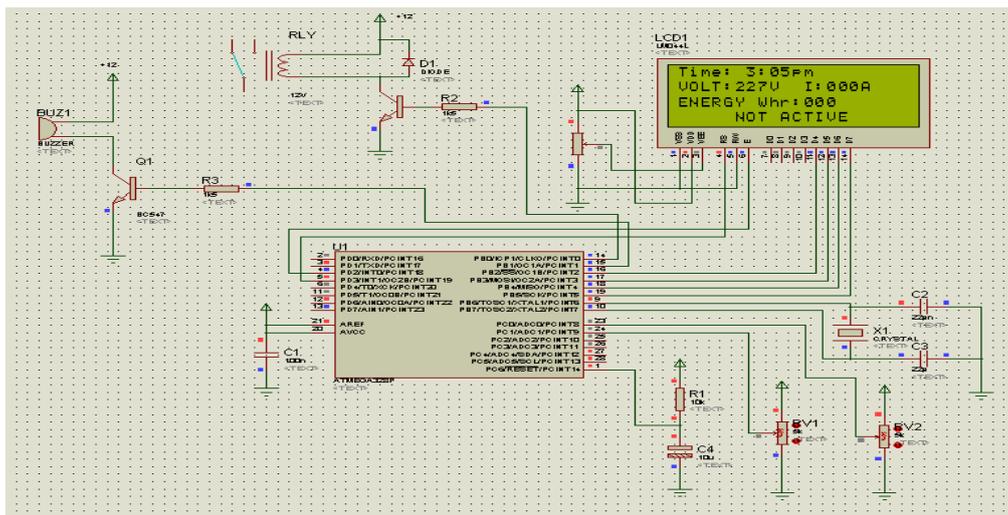


Figure11. Result on LCD when the energy meter is not active

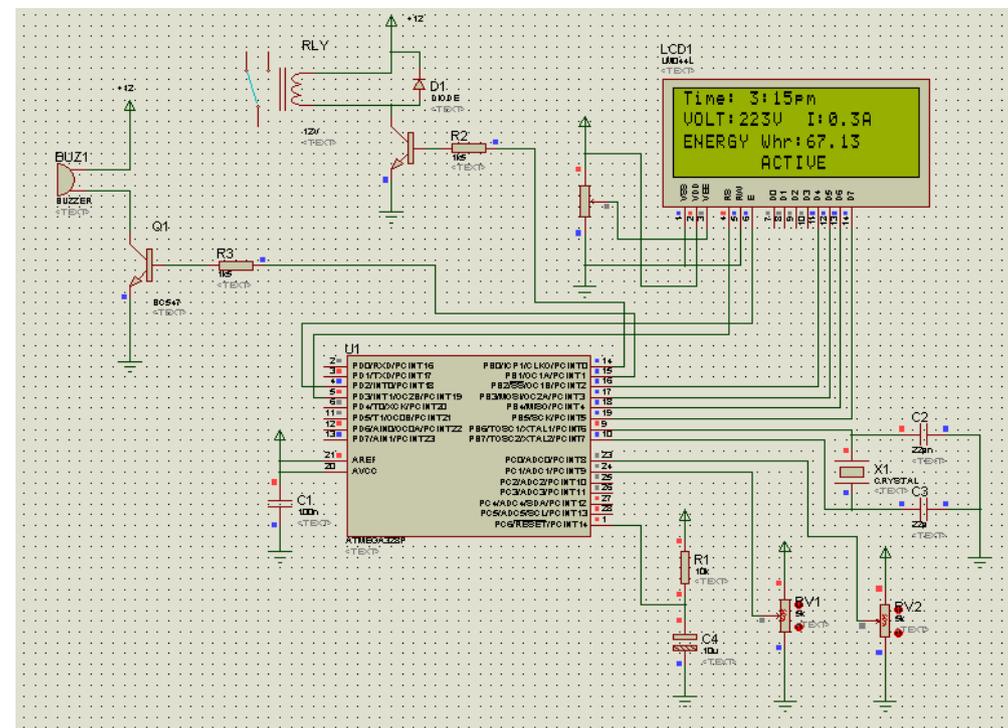


Figure12. Result on LCD when the energy meter is active

5. CONCLUSION

The following conclusions are drawn from this research work; the integration of peak and off peak period match was able to enhance better energy management, an alternative means of monitoring and control of the energy meter created a better means of widening the communication of the status of the meter through text messages thereby reducing the usual regular physical inspection by utility staff also the introduction of GSM technology into the meter provided an easy way of recharging.

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