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DESIGN AND IMPLEMENTATION OF ENERGY METER MONITORING AND CONTROL SYSTEM

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Abstract

Over the years, in Nigeria and most other African Countries, Energy Theft and Irregularities have been attributed to the reason for epileptic power supply across the Sub-region. Particularly in Nigeria, successive administrations have invested heavily in Power Utility Companies to ensure adequate power supply to meet with the electric power demand of the people, but no successful achievements have been recorded owing to the poor management of the power utility facilities by its staff on one side and incessant stealing of power supply by its customers on the other side. This heinous act both from the side of the staff or the supplier and consumers of electricity have continued to dash government hope of putting an end to the erratic power supply in the country. This paper therefore, presents a smart system to be named EMMs (Energy Meter Monitoring & Control System) for single phase power supply. The system is to be used for monitoring and controlling of Energy Meters using GSM Based technology. The main component used to realize the design of this system is AT89C52 Microcontroller. The input of the microcontroller is connected to a power supply detector circuit with LM315 and LM7805 Regulators respectively. While the output is connected to a Latching Relay and to the Load. Test results showed that this system is robust as it saves time and mitigate labour cost during bill assessment. It also reduces Energy theft and provides freedom to power utility companies to take actions against alien customer and staff who connive to steal power supply.

Keywords: *AT89C52 Microcontroller, Power Supply Detector, Power Utility Companies (PUCs), LM315 Voltage Regulator, LM7805 Voltage Regulator*

1.0 Introduction

It has been observed that for many years, the Electric Power System had undergone negligible changes in Operating Condition, Equipment employed for its measurement, control and monitoring.

At present, most of the houses in Nigeria have traditional mechanical watt hour meters and the billing system is not automated. At the end of each month, an individual from Power Utility Company (PUC) in Nigeria goes to every electricity supply houses and take the meter reading manually. The meter readings are used for electricity bill calculation and the bill is sent to consumers by agents of the power utility companies or by post. Customers go to designated Banks or Electricity Department to pay this bill charges. In this technique great numbers of persons for taking meter readings are needed and the process of sending bills to customers are very laborious and cumbersome[1]. The method encourages Energy Theft as some agents of power utility companies sometimes conspire with some customers to steal public power supply.

But this new system wipes out all cons and drawbacks of the conventional system because it allows companies to take meter readings, monitor and control the Energy Meter automatically [2]. The system is fully automated and therefore reduces human error.

2.0 Design Overview/Related Work

The application of GSM Technology in the control of both home appliances and industrial machines is gradually taking over from the conventional methods of system's control in most recent times [3]. Many articles have been presented on Digital Tele-Wattmeter, an example of such is the microcontroller based meter. The meter was implemented to transmit data on monthly basis to a remote central office through a dedicated telephone line and a pair of modems [4]. A DSP Based meter to measure electricity consumption of multiple users in residential houses was also developed so that a personal computer (PC)

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at the control centre can be used to send commands to the remote meter, which in turn transmit data back using the power line communication (PLC) technique [5,6,7]. The major problem with all these systems is that they do not have tampering alert mechanism to detect intruders.
The reason behind this work therefore, is to mitigate Labour Cost, Collection Time, Energy Theft, Reduced Revenue Losses, by Power Utility Companies and in the long run improved customer's services. All these advantages give the (EMM) an edge over other pragmatically prevailing devices used for electricity billing and metering in Nigeria.

3.0 Design Analysis

The designed Energy Meter Monitoring and Control System was analyzed with the associated theories and mathematical modellings. [7,8] The system is divided into smaller functional units to enable accurate and easy design analysis and implementation. The units are: the micro-controller unit, the power supply unit, energy supply detector unit, the latching relay unit and the GSM unit. The system block diagram is as shown in the figure 1

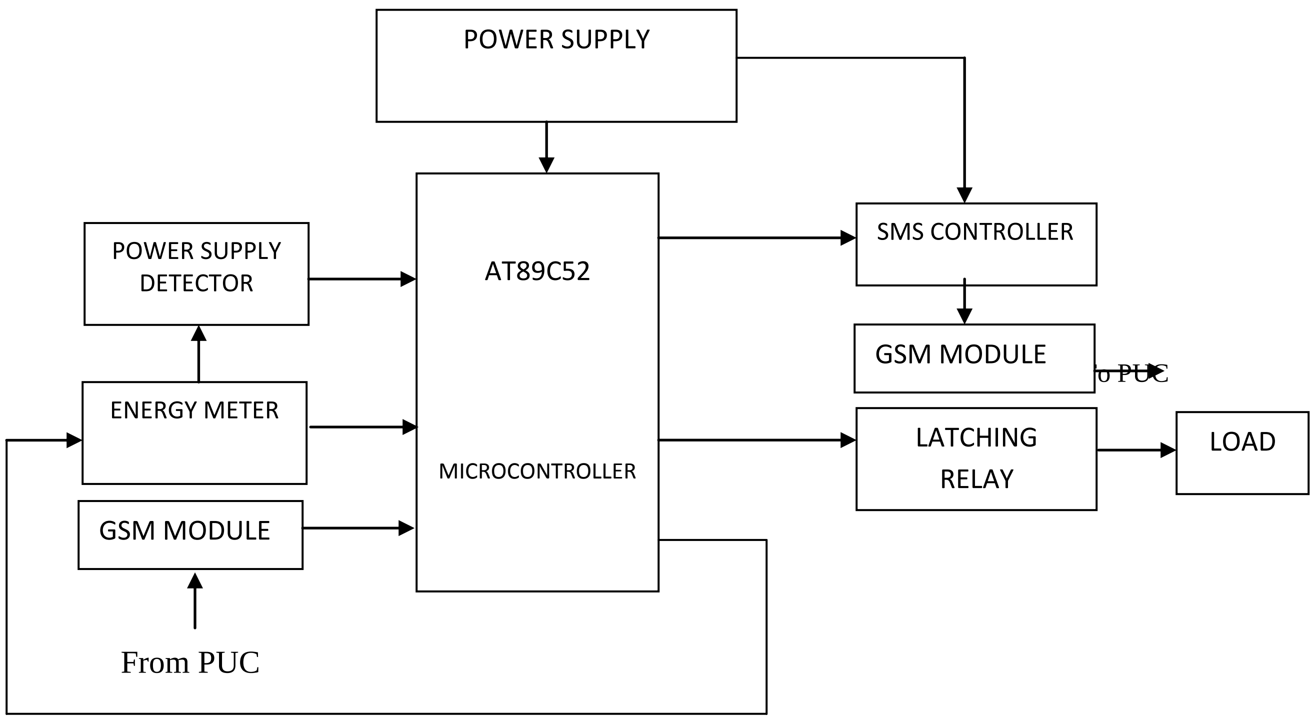

Figure 1: Block diagram of Energy Meter Monitoring and Control System

3.1 Design Analysis of the Power Supply Unit

The power supply pack of the system is designed with a 230/15V, 500mA step down transformer. The power supply unit is connected to the mains, such that it can be activated once there is power supply power utility company from PUC. Diagram of the power supply unit is as shown in figure.2

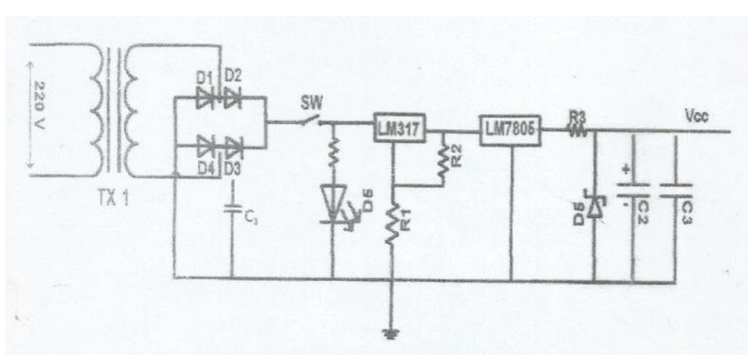

Figure 2: Power Supply Unit

3.1.1 Calculation of the Transformer's Parameters

To determine for the parameters of the transformer,

$\frac{V_p}{V_s} = \frac{N_p}{N_s} = \frac{I_p}{I_s}$………………………………………………………… (1)

Where

V_s = Secondary voltage = 15v,
V_p= Primary voltage = 230v,
I_s = Secondary current = 500mA,
I_p= Primary current
N_s= Number of turns in the secondary winding,
N_p = Number of turns in the primary winding

Secondary voltage (Vs) is related to the primary voltage (Vp) as

$\frac{V_p}{V_s} = \frac{N_p}{N_s}$…………………………………………………….. (2)

But,$\frac{N_p}{N_s}$ = Turn Ratio

So,$\frac{V_p}{V_s}$ = Turn Ratio (N)…………………….............................. (3)

Therefore,

Turn Ratio (N), =$\frac{230}{15}$ = $\frac{15.33}{1}$= 15.33:1

Ip = $\frac{I_s}{N_p/N_s}$ ………………………………………………………....... (4)

=$\frac{500\,mA}{15.33} = 32.61mA$

3.1.2 Calculation of the Rectifiers parameters

The parameters of the rectifier are: secondary voltage of the bridge rectifier

(VSM) = $\sqrt{2}$ x (Vs)……………………………………………………. (5)

= $\sqrt{2}$ x 15 = 21 21 volts, the rectifier

Circuit Peak Inverse Voltage (PIV), which can be defined as the maximum voltage across the rectifying diodes in the reverse direction and is given as

PIV = 2 x Vsm…………………………………………………………… (6)

= 2 x 21.21 = 42.42 volts, where 2.0 was taken as a multiplying factor in this work.

The rectifier's output voltage Vdc= $\frac{2\ x\ PIV}{\pi}$…………………………………….. (7)

= $\frac{2\ x\ 42.42}{3.142}$ = $\frac{84.84}{3.142}$ =27 volts

From the values of the diode parameter, four (4) IN4001 diodes (D1, D2, D3, and D4) with the specifications as in table 1

Table 1; IN4001 Specification

Parameter	Value
Forward Current	1.0A
Reverse Voltage	50-1000V
Max Peak Reverse Voltage (VIP)	50V
Max DC Blocking Voltage	50V
Max Average Forward Rectified Current (FCAV)	1.0A

3.1.3 Selection of Voltage Regulator

For steady operating voltage to be supplied to each of the different component units of the system as required, voltage regulators are needed. For the latching relay which require 12v to be turned ON, LM317 Regulator is used as the voltage regulator to maintain a constant 12V supply to the relay while LM7805 Regulator is connected to the 12V terminal provide 5V supply to both the microcontroller and other component unit of the system.

Table 2 and 3show the specification of the LM315 and LM7805 respectively used for this study.

Table 2: LM315 Specification

Parameter	Abbreviation	Value
Adjustable pin current	I_{adj}	100µA
Maximum output voltage	$I_{(O)}$ Max	1.5A
Minimum output voltage	V_O Min	1.2V
Maximum output voltage	V_O Max	38 V
Maximum power dissipation	$P_{(D)}$ Max	20W

Voltage output of LM315, $V_{out} = 1.25\ (1+\frac{R1}{R2}) + Iadj(R2)$, ………………………… (8)

Assuming that R1 = 2.2kπ, R2 = 220π and $Iadj = 10\mu A$

$V_{out} = 1.25\ (1+\frac{2.2x1000}{220} + 10x10^{-6}(220) = 13.77V.$

Table 3: LM7805 Specifications

Parameter	Abbreviation	Value
Peak Current	$I_{(PK)}$	2.2A
Output Voltage	$V_{(0)}$	50.V
Reference Voltage	$V_{(REF)}$	3.0V
Max Output Current	Io	5MA
Max Power Dissipation	P_D (MAX)	15W
Input Voltage Range	V_I	5V-18V

Minimum LM7805 input voltage (Vmin) required to obtain 5V regulated output voltage.

Vmin = Vout+VRef ……………………………………………………. (9)

= 5+3 = 8 volts,

It can be seen that Vout is greater than Vmin.The load current is also 0.6mA, so the regulator can handle this without overheating.

3.1.3.1Simple Zener Regulator

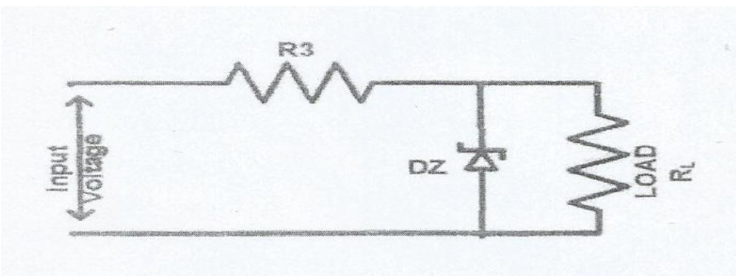

Figure 3: ZenerVoltage Regulator Circuit

The Zener Regulator is employed in this case to take care of the low values of current flowing through the entire circuit and its characteristics is as depicted in figure 3.

Resistance,which supplies the zener diode currentis given by

$R3 = \frac{Vin - V_z}{I_z + IL}$………..……………………………………………...(10)

Where V_{in}=Input voltage, V_z= Zener diode voltageI_z= Zener diode current,

I_c= Load Current,

So, $R3 = \frac{13.77-5.1}{100x10^{-3}+0.6x10^{-3}} = 86.18\Omega$

3.1.4 Selection of Capacitor

To eliminate the ripples occasioned by the rectification of the AC to DC signals, a capacitor is employed to filter the rippled voltage of the rectifying circuit. The value of the capacitor used in the design of the filter depends on the minimum ripple factor suitable for the efficient operation of the DC circuit.Since $VSm\sqrt{2}$ is the Peak Voltage of the Rectifying Circuit at the alternate half cycle,the voltage rating should be between the range of 1.3 to 3, time $\sqrt{2}$. However, a forward voltage drop (Vdin) of the diode is assumed to be 1volts in order to obtain the voltage rating of the capacitor (Vc).

So, $Vc = 1.5\ (Vsm\sqrt{2} - 2\ (Vdin)$ ………………………………………….. (11)

$1.5\ (21.21\sqrt{2} - 2\ (1) = 42volts$

From the above calculation, a capacitor 50V can be used.

To calculate for the value of the capacitor,

$VR = \frac{Io}{2fC}$ ……………………………………………………….….. (12)

Where Io = DC current from the regulator, selected to 1000mA.

f = Supply Frequency = 50Hz

C = Capacitance of a Capacitor

VR = Ripple Voltage (20% of Vc)

So, VR = 20% 50V = $\frac{20}{100}\ X\ \frac{50}{1}$ = 100

Hence the capacitance of the capacitor used

C = $\frac{Io}{2fVR}$………………………………………………………………….. (13)

$$\frac{1000X10^{-3}}{2X50X10} = 1000uf$$

Therefore 100uf 50volts capacitor is selected.

3.2 **Power Supply Detector Unit**

The power supply detector unit constantly check for power supply at the output of the energy meter. The input terminal of the circuit is connected across the energy meter such that it can receive signal from the energy meter and send it to the microcontroller for processing. If the detector, detects no power supply from the meter, it sends a low signal command to the microcontroller for execution.The most important components of the circuit are transformer, bridge rectifier, optocoupler and a pull down resistor which connects the detector circuit to ground when the meter fails.

3.3 **The Microcontroller Unit**

The AT89C52 microcontroller is used for the design and implementation of this work because of its low power consumption, high performance, low cost and high flexibility to many embedded control systems application.

This unit serves as the brain box of the system and generate control signals to all other sub units of the system. It constantly analyzes signal from the power supply detector circuit. It sends a high logic signal to the SMS controller unit when it receives a low level signal from the detector circuits. It also transreceive signals via the SMS controller whenever a command is issued to that effect. This is as shown in figure 4.

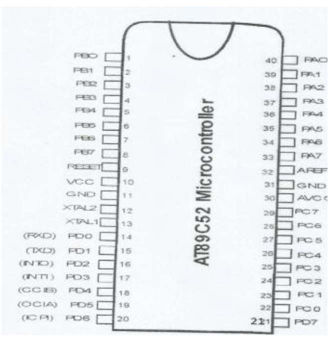

Figure 4: The AT89C52 Microcontroller Pins

3.3.1 Selection of the clock oscillator for the microcontroller

The selection of the clock oscillator for the microcontroller is determined by the operating frequency or clock frequency desired for the controller.

From data sheet, clock frequency range for AT89C52 is from 0-24Hz choosing clock frequency = 16MHz in C4=C5=30pF$\pm$10V, but for the purpose of this work C4=5=33pF. So reset time for the oscillator which is the time taken to execute an instruction before resettling, is

$R_T = \frac{Frequency\ \ of\ oscillation}{Machine\ \ cycle}$ …………………………………………………..(14)

= $\frac{16MH_z}{12}$ = 1.33 seconds, Where 1 machine cycle = 12 pulses

Therefore R_T = 1.33 seconds

3.4 **SMS Controller**

This unit, is the communication linkbetween the system and the energy service providers. It receives signal from the system controller unit and send the appropriate dialing codes to the mobile phone. On the other hand, the Energy Service Providers also can send codes to the mobile phone requesting the system to update the energy meter’s status. These codes enable the mobile phone to automatically send and receive SMS from the Energy suppliers. This two way communication process is realized using a SIM 800L GSM module.

3.5 **Latching Relay**

The Latching Relay is embedded or incorporated into the design of this work to act as a switch mechanism between the microcontroller and the consumer’s load. The relay unit consist of a transistor and a resistor. The relay rating is (10A-12V). the relay unit is connected to one external output of the AT89C52 pin 22, through the transistor. When the relay receives a high level signal from the microcontroller it sends power to the load and if a low level signal is received by the relay, no power is sent to the load. Figure 5 shows complete system circuit diagram.

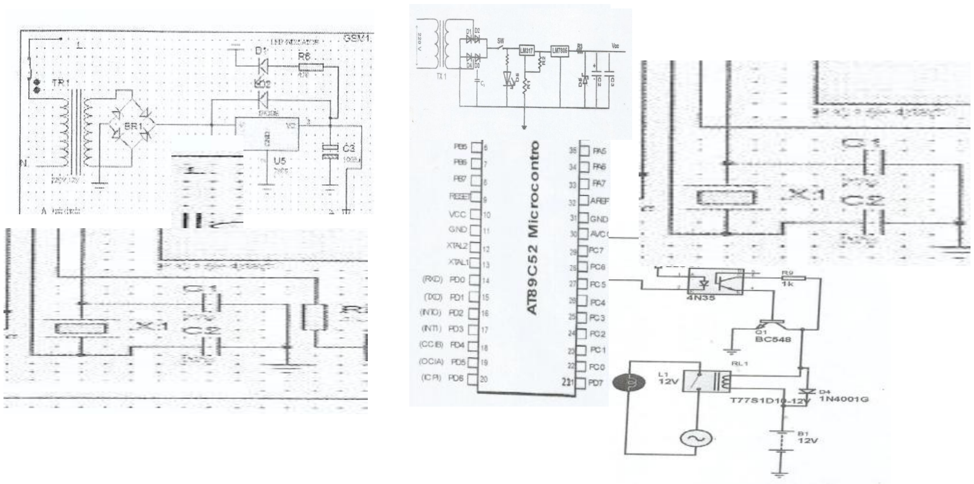

Figure 5: Complete Circuit diagram

4.0 Implementation

This work is implemented using both the hardware and software packages.

4.1 Software Implementation

The software is a major part of the system, without which the system would not perform its task. A sequence of steps and procedures was adopted to enable the microcontroller read inputs and respond accordingly. Embedded "C" Programming Language was employed for this project work because it allows communication between the microcontroller and other sub-units of the main system.

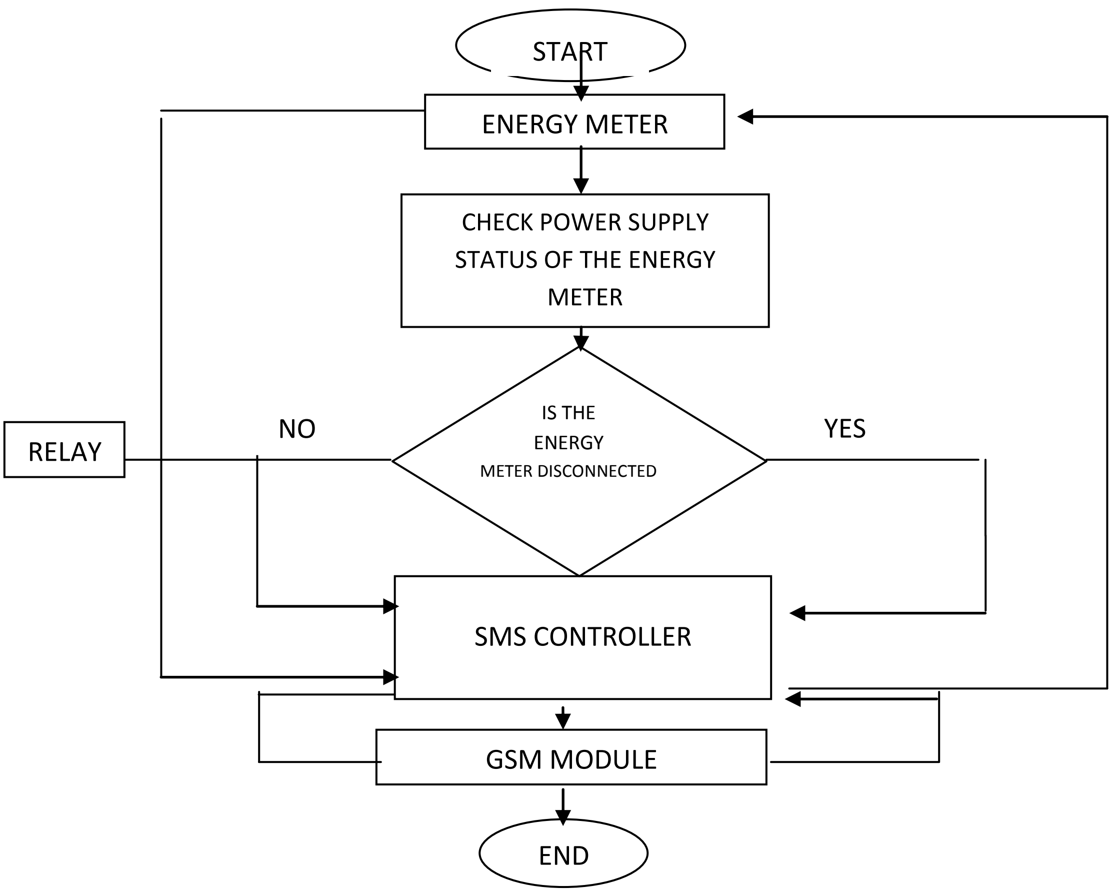

Figure 6: Flow Chart of the System Program

4.2 **Hardware Implementation**

After a successful software implementation of the system using the “C” embedded language, the hardware components of the system was acquired and also implemented using a bread board and then a vero board respectively.

4.2.1 **Bread Board Implementation**

The components was temporarily implemented using a bread board. This was done to test run the functionality of the components ascertain and to see if the design aim and objectives of the project work was realized. Here faulty and malfunctioning components were detected and replaced accordingly.

4.2.2 **Vero Board Implementation and Soldering of Circuit Components**

After the successful implementation of the circuit components on the bread board, the components were then transferred to a vero board for permanent connection. This process was achieved with the help of a soldering iron and a lead that was used to join the terminals of the component to the vero board. Care was taken to ensure that the terminals were not short circuited during soldering. The choice of the vero board implementation was neccesited to ensure that all the circuit connections are tight and that they are fixed to their permanent connection point without shaking. Figure 7 shows implemented circuit components soldered on a vero board.

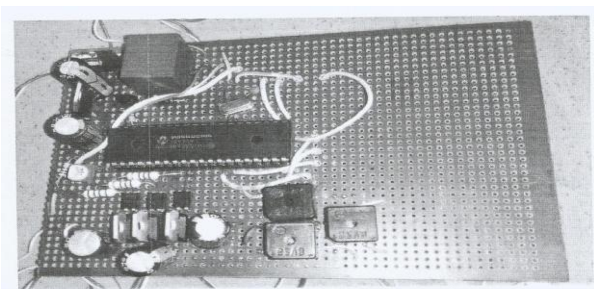

Figure 7: Circuit Components connected on a Vero Board

4.3 **Casing and Packaging**

The implemented circuit on the vero board was packaged in a plastic material to protect it from environmental exposure and hazards. The choice of the plastic material culminated from its excellent properties ranging from high insulation to reduce the risk of electric shock, to high resistance to corrosion. The casing is a rectangular structure of about 300mm x 200mm with 2.0 to 10mm thickness and a height of 75mm. This casing accommodate the entire circuit and it has narrow openings through which the circuit can be aerated. Figure 8 shows the internal view of the implemented system inside the plastic casing.

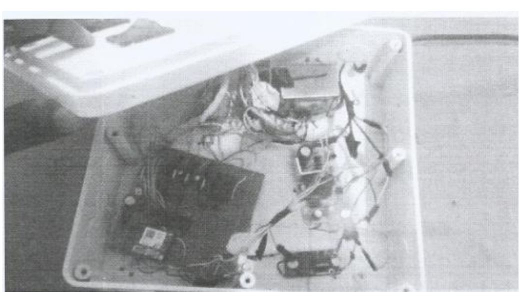

Figure 8: Internal view of the Implemented System in the Plastic Casing

5.0 **Result**

The designed power supply unit of the system is such that when 230/15V AC is connected to a full wave rectifier, a 15V DC is obtained. Thus, this voltage is further allowed to pass through a capacitor to absorb ripples emanating from the rectified circuit. At this stage, LM315 Voltage Regulator is connected across the circuit to maintain a constant voltage level at the output of the voltage rectifier. Then, this stabilized voltage is again passed through another LM7806 voltage regulator to step down and streamline the voltage to a lower voltage of 5VDC which serve as power supply source to other system’s circuit components as shown in fig. 6 and 7.

Assuming power is supplied by power utility company and the energy meter is in save conditions (i.e meter not tampered),the LM7806 voltage regulator produces a 5VDC output, which is supplied to the optocoupler making the output to produce a high logic 1 which is fed to pin 33 of the microcontroller. The microcontroller then sends an output code to activate the relay and SMS controller, and then communicate the Energy Service Providers via the GSM module informing it that the Energy Meter is okay.On the other hand, assuming power is supplied and the energymeter is not in save conditional (ie tempered), then the LM7806 voltage regulator will produce a low logic (0) which is fed to the pin 33 of the microcontroller. Since the output of the microcontroller is low, the microcontroller generate another output code to the SMS controller and then to the Energy Service Providers, via the GSM module informing it again that the Energy meter has been tempered with and at the same time also detects the meter's I.D number and location.

Also, the Energy Service Providers can, from time to time with the meter's I.D. number, send a code to the SMS controller via the GSM module requesting for the energy meter update. The energy meter can also be recharged using this process.

Test Results showed that this system is robust as it saves time mitigate labour cost during Bill Assessments. It also reduces Energy Theft and provides freedom to Power Utility Companies to take actions against alien customer and staff who connive to steal power supply.

5.0 Conclusion

The perennial problem of power theft and illegal connections of power utility installations in our modern day society have called for great concern, both to the stakeholders in the power industries and to the general public. A situation where Power Utility Companies (PUC) can only invest heavily on its system installations and does not monitor or control them automatically may be the reason why the wise saying "Monkey dey work and Bamboo deychoop" can be best used to describe the scenario between the suppliers and consumers of electricity in developing nations, particularly in Nigeria. How can huge sum of money be invested to procure power installation equipment yet the equipment is either not installed at all, or installed and or/not monitored and controlled at all.

Therefore, this work has presented an Electronic Energy Meter Monitoring and Control System to fast track Energy Metering Management system that can engender trust between the supplier and consumer of Electricity and reduce the menace of Energy Theft and illegal connections that has led to huge revenue lost to both government and suppliers of electricity in Nigeria to the barest minimum.

References

[1] Scaradozi and Conte, (2003). Home Billing System as Multiple Agent System (MAS). htt,//www.researchgate.net…12386613…

[2] Amity J. and Mohnish, (2009). Automated Transmission of Data and Bill Generation.

[3] Bello, J.O. (2014). Design Implementation of a GSM Based Transformer Phase Monitoring System. Nigerian Journal of Technology (NIJO TECH), 331-336.

[4] Shwedi and Jackson, (1006). Digital Telewattmeter System htt,//www.researchgate.net…126444959…

[5] Hong and Ning, (2005). Automatic Meter Reading (AMR) Using GSM network.

[6] Koag, Chen, Sng, Chong Shun and Tong (2003). Designed and Implemented Bluetooth Energy Meter.

[7] Sharma and Showeb, (2011). Design of Robust of Prepaid Energy Metering and Billing System http,//pdfs.senanticscholar

[8] Zhang Oghama and Bai (1998). Modeling of GSM Based Energy Recharge Scheme for Prepaid. htt,//www.researchgate.net…126444959…