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Domestic Use of Mobile Energy Meter Loads Control System in Nigeria

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Abstract
Electricity consumers are now conscious of energy usage thereby required system to monitor energy consumed and to control the switching ON/OFF of equipments connected home and away. In most cases consumers are far away from home. Whenever electricity is available, the desire to control switching ON/OFF of connected equipments home and away and to eliminate the challenges imposed by distance between the consumers and the equipments that must be put under control created the need for this system and the study. Similar works on this were more on applications of Bluetooth and infrared systems, very few were on the application of mobile communication system.
The system is implemented using a PIC16F877 microcontroller which acts as the on board computer that controls every signal in the circuit. The current sensor was ACS712 current module which converts the load connected to it to voltage which is then converted to current. The mobile communication was implemented using a GSM module which is the interfacing medium between the circuit and phone. The display screen is implemented using a 16x2 LCD screen which is used to display the status of the system while the program was done using C programming language. The GSM module has a SIM card with a mobile number with the ability to display the power consumed in Watts by the load on an LCD screen.
On domestic use of the system, a total of fifty (50) respondents in different household were interviewed and a hundred percent (100%) returned rate of questionnaire were recorded. Empirical findings on type of houses and mode of energy payment of the respondents show that majority (62%) lives in smaller apartments, all (100%) connected to a distributions company (DISCO) and use energy meter, majority (78%) pay monthly, (62%) on estimated billing and (84%) pay >N3,000 monthly. Level of Respondent Satisfaction and Control of Electricity Usage on indices measured is high (58% to 90%). Usage of Remote Control of Energy through GSM reveals that almost all (90% to 98%) strongly agree and agree that the usage will save energy, reduce cost and stress and better than infrared/ Bluetooth control.
Domestic use of Energy Meter load Control System for effective management of utility bills, stress and energy wastes will free energy for other consumers by optimally utilizing existing capacity.
Keywords: Mobile Control, Energy Meter, Load Control System.

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I. Introduction

A smart energy meter is an electronic device that records consumption of electric energy in intervals of hour or less and communicates that information at least daily back to the utility for monitoring and billing. A microcontroller input is effectively interfaced to a digital energy meter that takes the reading from the energy meter and displays it. The reading from the energy meter is also sent to the control room by an SMS via SIM loaded GSM module; the GSM module can also receive commands from the cell phone to control the owner's electrical loads. It uses a standard digital energy meter that delivers output pulses to the microcontroller to perform counting for necessary action. On receiving command it can switch ON/OFF the loads.

1.1.1 BLOCK DIAGRAM
The block diagram is as shown in figure 1.1. The main units are sensor unit, microcontroller unit, GSM module and Display unit.

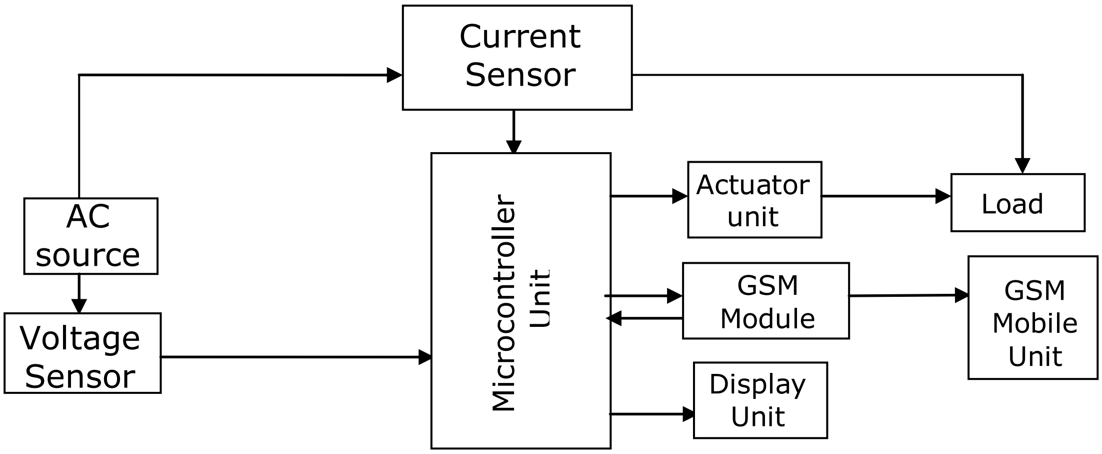

Figure 1.1: The block diagram of a smart energy meter

Sensor Unit: The sensor unit is used to sense the voltage across the load and the current flowing through the load connected to the system.
Microcontroller Unit: The microcontroller unit does all the processing of signals received from the sensor unit and gives output to the display unit and actuator unit.
Actuator Unit: Its function is to switch ON/OFF the load connected to the system depending on the information the microcontroller unit sends to it.
GSM Module: It is used as an interface through which SMS message and command are sent to and from the energy meter.
Display Unit: It is used to show the state and status of the load and also the power consumption of the load connected to the system.

1.1.2 Problem Statement
The use of prepaid meter to measure domestic and commercial electricity utility is increasingly taking over the analogue meter that was prevalent in Nigeria. Electricity consumers are now conscious of energy usage thereby required system to monitor energy consumed and to control the switching ON/OFF of equipments connected home and away. In most cases consumers are far away from home. The desire to control switching ON/OFF of connected equipments home and away, limit electricity consumption cost to the affordable minimum and to eliminate the challenges imposed by distance between the consumers and the equipments that must be put under control created the need for usage of this system and the study.

1.1.3 Objectives
1. To develop a system that will remotely switch ON/OFF the load connected to the meter.
2. To understand Level of Satisfaction and Control of Electricity Usage.
3. To ensure effective Usage of Remote Control of Energy through GSM

II. Literature Review
An electricity meter, electric meter, electrical meter, or energy meter is a device that measures the amount of electric energy consumed by a residence, a business, or an electrically powered device.

Electric utilities use electric meters installed at customers' premises for billing purposes. They are typically calibrated in billing units, the most common one being the kilowatt hour (kWh). They are usually read once each billing period.

When energy savings during certain periods are desired, some meters may measure demand, the maximum use of power in some interval. "Time of day" metering allows electric rates to be changed during a day, to record usage during peak high-cost periods and off-peak, lower-cost, periods. Also, in some areas meters have relays for demand response load shedding during peak load periods. There are various types of energy meter in existence such as electromechanical, electronics, and smart meters.

2.1 PREVIOUS WORK ON ENERGY METER LOAD CONTROL

The following are some of the past works done relating to this project: single phase electromechanical induction watt hour meter, watt hour meter circuit using microcontroller and digital energy meter.

2.1.1 Single Phase Electromechanical Induction Watt Hour Meter

It is a well-known and most common type of age-old watt-hour meter. It comprises a rotating aluminum disc placed on a spindle between two electromagnets. The rotation speed of the disc is proportional to the power, and this power is integrated by the Use of gear trains and counter mechanism. It is made of two silicon steel laminated electromagnets: shunt and series magnets.

Series magnet carries a coil which is of a few turns of thickness wire connected in series with the line; whereas the shunt magnet carries a coil with numerous turns of thin wire connected across the supply. Braking magnet is a kind of permanent magnet that applies the force opposite to the normal disc rotation to move that disc a balanced position and to stop the disc while power gets off. Series magnet produces a flux which is proportional to the flowing current, and shunt magnet produces a flux proportional to the voltage. These two fluxes lag at 90 degrees di.ie to inductive nature.

The interface of these two fields produces eddy current in the disk, utilizing a force, which is proportional to the product of instantaneous voltage, current and the phase-angle between them. A braking magnet is placed over one side of the disc, which produces a break torque on the disc by a constant field provided by using a permanent magnet. Whenever the braking and driving torques become equal, the speed of the disc becomes steady.

A Shaft or vertical spindle of the aluminum disc is associated with the gear arrangement that records a number proportional to the revolutions of the disc. This gear arrangement sets the number in a series of dials arid indicates energy consumed over a times

This type of energy meter is simple in construction and the accuracy is somewhat less due to creeping and other external fields. A foremost problem with these types of energy meters is their proneness to tampering, which necessitates an electrical-energy- monitoring system. These series and shunt type meters are widely used in domestic and industrial applications.

2.1.2 Watt Hour Meter Circuit Using Microcontroller

This system is implemented by using Atmel AVR microcontroller. This circuit continuously monitors and acquires voltage and current parameters of the mains single phase supply. Microcontroller gets these parameter values from a signal conditioning circuit, which is driven by OP-AMP ICs.

This device has two current transformers connected in series with each supply line: phase and neutral. The current values from these transformers are sent to the respective ADC of the microcontroller, and then the ADC converts these values to digital values, and thus the microcontroller does necessary calculations to find the energy consumption. The Microcontroller is programmed in such a way that the voltage and current values from the ADC are multiplied and integrated over a specified time period, and then correspondingly drive the counter mechanism that displays the number of units consumed (KWs) over a time period.

In addition to the energy measurement, this system also provides earth fault indication in case of any fault or overcurrent that may occur in neutral or earth line and appropriately turns the Light Emitting Diodes indication for earth fault detection as well as for every unit of consumption.

2.1.3 Digital Energy Meter

Digital energy meter system digitizes the instantaneous voltage and current via a high-resolution sigma-delta ADC. Computing the product of the voltage and current gives the instantaneous power in watts. Integration over time gives energy used, which is usually measured in kilowatt hours (kWh).

Here, two basic sensors are employed. These are voltage and current sensors. The voltage sensor built around a step down element and potential divider network senses both the phase voltage and load voltage. The second sensor is a current sensor;this senses the current drawn by the load at any point in time. It is built around a current transformer and other active devices (such asvoltage comparator) which convert the sensed current to voltage for processing. The output from both sensors is then fed into a signal(or voltage) conditioner which ensures matched voltage or signal level to the control circuit, it also contain a signal multiplexer which enable sequential switching of both signal to the analogue input of the peripheral interface controller (PlC). The control circuit centered on a PlC integrated circuit. The PlC is selected because it contain ten bit analogue to digital converter (ADC), very flexible to program and good for peripheral interfacing.

The ADC converts the analogue signals to its digital equivalent; both signals from the voltage and current sensors are then multiplied by the means of embedded software in the PlC. Here the error correction is taken as the offset correction by determining the value of the input quality with short-circuited input and storing this value in the memory for use as the correction value device calibration. The PIG is programmed in C language. Such that apart from the multiplier circuit it simulates, it is able to use the received data to calculate power consumption per hour, as well as the expected charges. These are displayed on the liquid crystal display attached to the circuit.

III. The Design

Energy meter with load control is to be used to know, the wattage being consumed by electricity user. The system works in such a way that the wattage being consumed by the user is displayed on the LCD screen and also sends the wattage remotely to the monitoring authorities (the user and the provider). It has an added functionality of controlling the load connected to it remotely using a GSM phone.

The system is implemented using a PIC16f877 microcontroller which acts as the on board computer that controls every signal in the circuit. The current sensor was implemented using ACS712 current module which converts the load connected to it to voltage which is then converted to current, the wireless communication was implemented using a GSM module which is the interfacing medium between the circuit and phone.

The display screen is implemented using a 16x2 LCD screen which is used to display the status of the system while the program was done using C programming language.

3.1 BASIS FUNCTIONAL UNITS OF ENERGY METER LOAD CONTROL SYSTEM

The basic units of this project are Voltage sensor, Current sensor, Microcontroller, and GSM module.

3.1.1 Voltage Sensor

A voltage sensor is a device that converts voltage measured between two points of an ‘electrical circuit into a physical signal proportional to voltage. Connections + and — are electrical conserving ports through which the sensor is connected to the circuit.

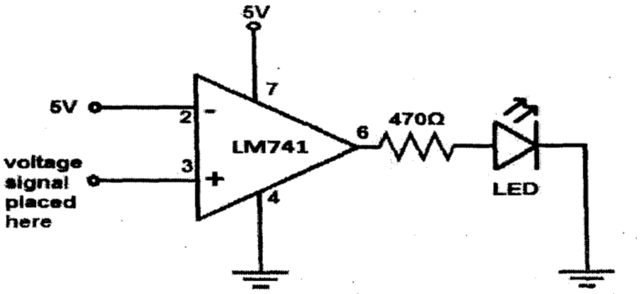

Figure 3.1: Voltage Sensor

3.1.2 Current Sensor

A current sensor is a device that detects electric current in a wire, and generates a signal proportional to that current. The generated signal could be analog or even a digital output. The current sensor was implemented using ACS712 current module which will convert the load connected to it to voltage which is converted to current.

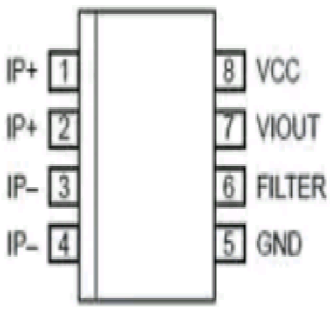

Figure 3.2: Pin-out diagram of ACS71

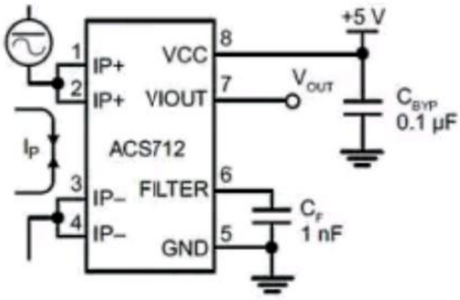

Figure 3.3: Typical application

3.1.3 Microcontroller

A microcontroller is a computer present in a single integrated circuit which is dedicated to perform one task and execute one specific application. It contains memory, programmable input/output peripherals as well as a processor. In this system, the microcontroller does all the processing of signals received from the sensor unit and the GSM module unit and gives output to the display unit and the actuator unit based on the information received. The system is implemented using a P1C16F877A microcontroller which acts as the on board computer that controls every signal in the circuit.

P1C16F877A Microcontroller

The P1C16F877A microcontroller (figure 3.4) is one of the most renowned microcontrollers in the industry. This microcontroller is very convenient to use, the coding or programming of this microcontroller is also easier. One of the main advantages is that it can be write-erase as many times as possible because it uses FLASH memory technology. It has a total of 40 pins and there are 33 pins for input and output. It is used in remote sensors, home automation and in many industrial instruments. An EEPROM is also featured in it which makes it possible to store some of the information permanently.

The P1C16F877A features 256 bytes of EEPROM data memory, self-programming, an ICD, 2 comparators, 8 channels of 10-bit analog- to-digital converter,2 capture/compare functions , the synchronous serial port can be configured as either 3-wire serial peripheral interface or the 2-wire inter-integrated circuit bus and a Universal Synchronous Asynchronous Receiver Transmitter (USART).

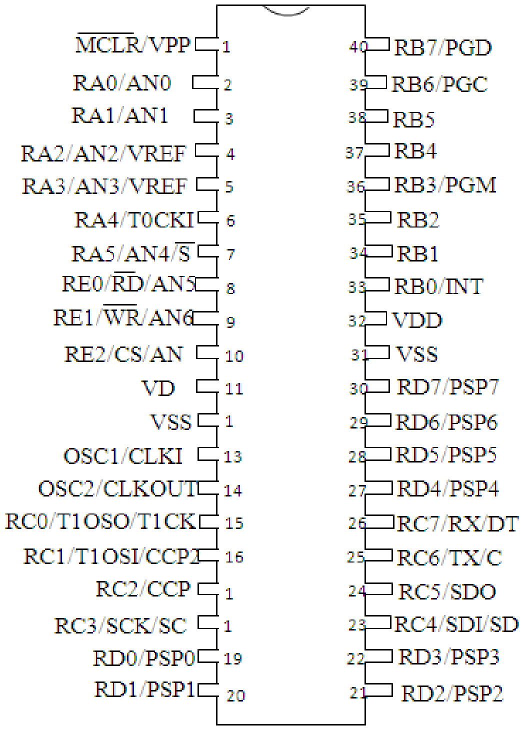

Figure 3.4: Pin connection of the PIC16F877A microcontroller

Table 3.1: Pin description of PIC16F877A microcontroller

PIN NO	DESCRIPTION	FUNCTION
1	MCLR/VRR	It resets the microcontroller
2	RA0/AN0	Bidirectional input/output pin
3	RA1/AN1	Analog input 1
4	RA2/AN2/Vref-	Analog input 2
5	RA3/AN3/Vref+	Analog input 3
6	RA0/TOCKI	Clock input pin
7	RA5/SS/AN4	Analog input 4
8	REO/RD/AN5	Bidirectional input output port
9	RE1/WR/AN6	Analog input 6
10	RE2/CS/A7	Analog input 7
11 AND 32	VDD	Positive supply for input/output and logic pins
12 AND 31	VSS	Ground reference for input/output and logic pins
13	OSC1/CLKIN	Oscillator input pin
14	OSC2/CLKOUT	Oscillator output pin
15	RCO/T1OCO/T1CKI	Bidirectional input output port
16	RC1/T1OSI/CCP2	Oscillator input
17	RC2/CCP1	Capture 1 input
18	RC3/SCK/SCL	Input/output serial clock
23	RC4/SDI/SDA	Data in of SPI
24	RC5/SDO	Data out of SPI
25	RC6/TX/CK	USART transmit pin
26	RC7/RX/DT	USART receive pin
19,20,21,2, 27,28,29,30	PORTD	bidirectional input and output port
33-40	PORTB	Input and output port

3.1.4 GSM Module

A GSM module is a chip or circuit that is used to establish communication between a mobile device or a computing machine and a GSM system. GSM module is a specialized type of modem which accepts a SIM card, and operates over a subscription to a mobile operator, just like a mobile phone. A GSM modem can be a dedicated modem device with a serial, USB or Bluetooth connection, or it can be a mobile phone that provides GSM modem capabilities. The wireless communication of the system was implemented using a GSM module which is used as interface through which SMS message and command are sent to and from the energy meter

3.1.5 Display

It is a flat panel display, electronic visual display that uses the light modulating properties of liquid crystals. Liquid crystals do not emit light directly LCDs are available to display arbitrary images or fixed images which can be displayed. The LCD screen is more efficient and can be disposed of more safely than a CRT.LCDs are used in a wide range of applications including, computer monitors, televisions, instrument panels aircraft cockpit displays and have replaced cathode ray tube displays in most applications. It has low electrical power consumption. The display screen will be implemented using a 16x2 LCD screen which will be used to display the status of the system.

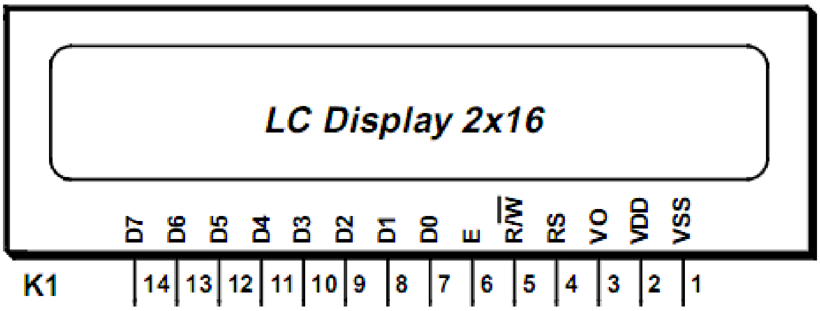

Figure 3.5: A 16x2 LCD Display

IV. The Operation Of The Circuit

In the circuit diagram (figure 4.1), the Transformer (TR1) is a step-down transformer which is used to step-down 240Vac to 12Vac, the bridge diode (R1) is used to rectify the l2Vac to get a 12Vdc source. After rectification the capacitor (C1) is the used to filter off the remaining AC ripples from the output DC voltage.
The voltage regulator (u1) is then used to regulate the output DC voltage to the Voltage required for the microcontroller (u2) and every other circuit element to work effectively.

The load connected to the output takes its supply through the current sensor module which gives an output voltage that is directly proportional to the power of the connected load on its output pin.

The output voltage from the current sensor is then send to the microcontroller (u2) which the process the input voltage and convert it to the resulting wattage and thereafter display it on the 16x2 LCD screen.

When the wattage is needed to be viewed remotely a message is sent through SMS from a mobile phone, this message is received by the microcontroller (u2) through the GSM module, the microcontroller (u2) respond by sending the computed wattage back as SMS to the sender through the GSM module1 When the microcontroller(u2) receives another message to cut off the output load the microcontroller(u2) sends a signal to activate relay(RL1) through resistor(R2), and transistor(Q1) which in turn cut off the connected load.

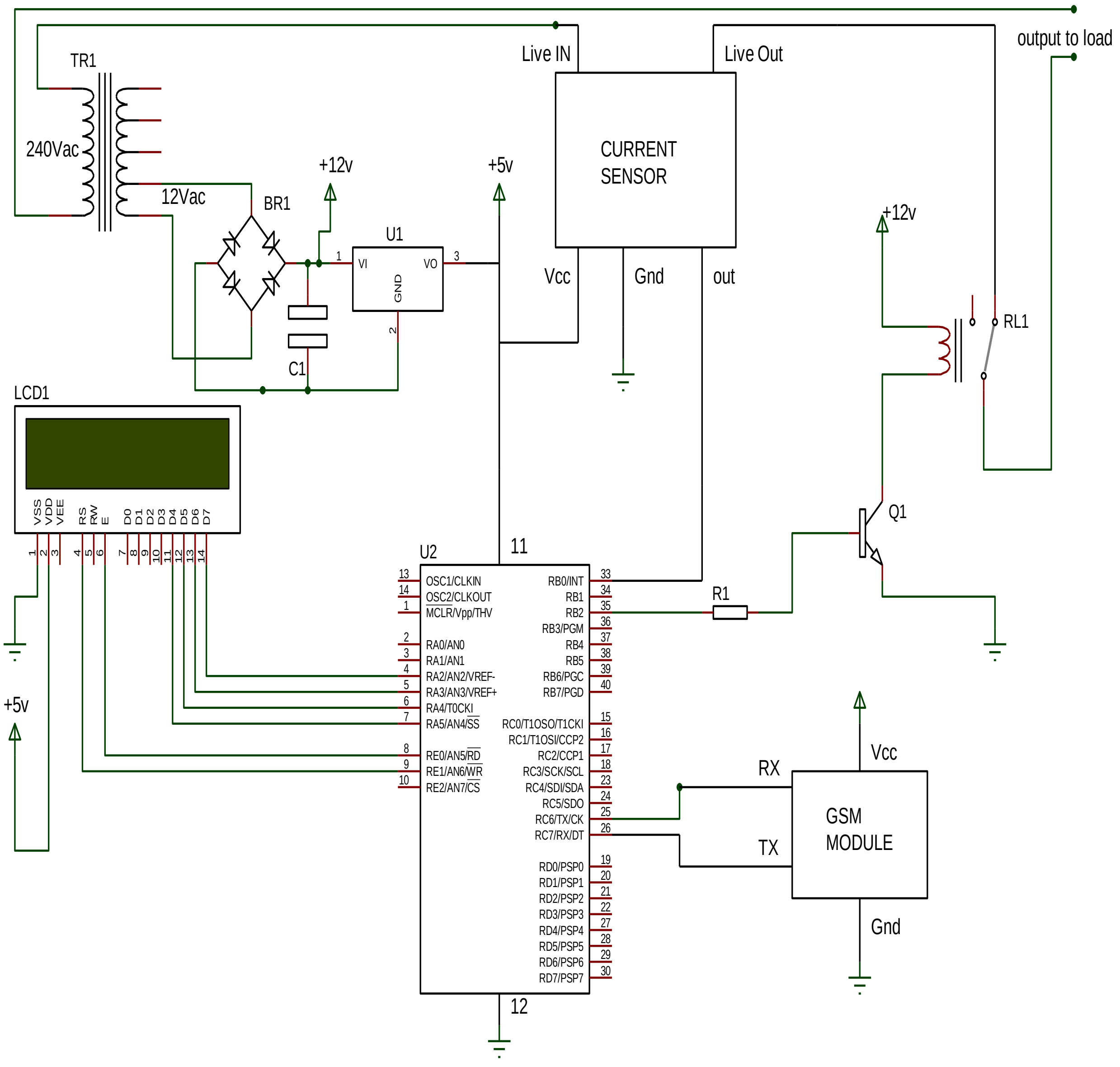

Figure 4.1: Circuit diagram of an energy meter with load control

V. Current Issues Necessitating The Need For This System

The current issue necessitating the need for this research is to make the reading of consumers' wattage simple, less expensive and avoiding the wastage of time. This system makes it easier for consumers to remotely control the loads on the meter and effectively monitor energy consumed. Since the inception of electricity deregulation and market-driven pricing throughout the world, utilities have been looking for a means to match consumption with generation. Traditional electrical meters only measure total consumption, and so provide no information of when the energy was consumed at each metered site. Smart meters provide a way of measuring this site-specific information, allowing utility companies to introduce different prices for consumption based on the time of day and the season.

Utility companies propose that from a consumer perspective, smart metering offers potential benefits to householders. These include:

a) an end to estimated bills, which are a major source of complaints for many customers

b) a tool to help consumers better manage their energy purchases - stating that smart meters with a display outside their homes could provide up-to-date information on electricity consumption and in doing so help people to manage their energy use and reduce their energy bills.

Electricity pricing usually peaks at certain predictable times of the day and the season. In particular, if generation is constrained, prices can rise if power from other jurisdictions or more costly generation is brought online. Proponents assert that billing customers at a higher rate for peak times will encourage consumers to adjust their consumption habits to be more responsive to market prices and assert further, that regulatory and market design agencies hope these "price signals" could delay the construction of additional generation or at least the purchase of energy from higher priced sources, thereby controlling the steady and rapid increase of electricity prices. There are some concerns, however, that low income and vulnerable consumers may not benefit from intraday time-of-use tariffs.

VI. Empirical Findings On Domestic Use Of The System

The section revealed the responses of the people interview through well-structured questionnaire administration for the domestic use of the system. A total of fifty (50) respondents in different household were interviewed and a hundred percent (100%) returned rate of questionnaire were recorded. Thus, based on the returned questionnaires coded and entered into SPSS, presented in table 6.1 is the respondents' information on type of houses and mode of energy payment. See also Figure 6.1 and 6.2.

The spread (Table 6.1) below reveals the categories of houses the respondents involved in the survey were living and the essence is to ensure that the most appropriate respondents were selected for the study. However, the population of the respondents that live in Single room was high in the distribution and it stood at 24%, followed by the respondents living in Bed sitter at 20%, followed by the respondents living in self-contain apartment and Duplex at 18% respectively, followed by the respondents living in Three bedroom flat at 12%, while the respondents living in Two bedroom flat stood at 8%. It quite instructive not to take for granted the fact that majority of the respondents pay their electricity bills monthly, with a percentage that stood at 78%. This was followed by the respondents that pay their electricity bills once in a year, which stood at 12%, followed by twice a year and quarterly in a year with percentage that stood at 4% respectively. This meant that most of the informants were under monthly billing payment. However, all the respondents affirmed that they were connected to public power supply (DISCOS) and use energy (DISCOS) meter in their respective homes.

Table 6.1: Type of Houses and Mode of Energy payment of the Respondents

Variable	Category	Frequency	Percentage
Which type of house do you live in	Single Room	12	24.0
	Bed sitter	10	20.0
	Self-Contained	9	18.0
	Two-bedroom	4	8.0
	Three-bedroom flat	6	8.0
	Duplex	9	18.0
	Total	**50**	**100.0**
Are you connected to the public power supply (DISCO)	Yes	50	100.0
	No	-	-
	Total	**50**	**100.0**
Do you use energy (DISCO) meter in your home	Yes	50	100.0
	No	-	-
	Total	**50**	**100.0**
How often do you pay electricity bill	Monthly	39	78.0
	Bi-monthly	1	2.0
	Quarterly	2	4.0
	Twice yearly	2	4.0

	Once Yearly	6	12.0
	Total	**50**	**100.0**

Source: Field Survey 2019

The chat below revealed the distribution according to the type of meter the respondents used. It is quite interesting that good number of them were on estimated billing without a specific energy meter, the percentage that stood at 62%.This was followed by the respondents that used analogue energy meter at 20%, followed by digital energy meter at 6% and lastly, the respondents that used prepaid stood at 6%.

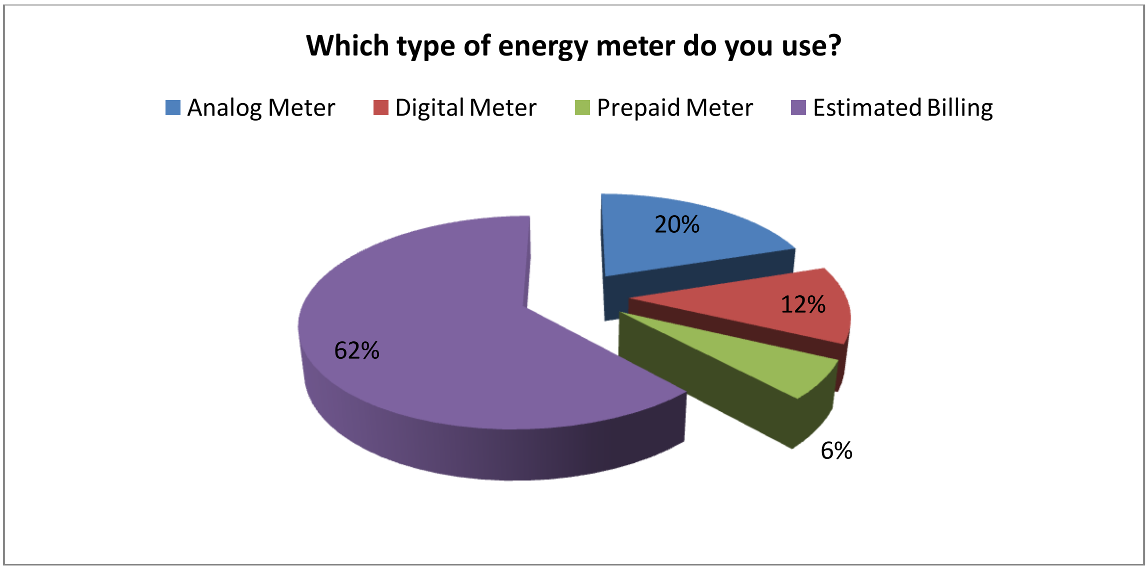

Figure 6.1: Energy meter used by the respondents

Source: Field Survey 2019

Figure 6.3 also revealed the distribution according to average amount of money spent on electricity monthly by the respondents. Majority of the respondents spend between N1,000 to N3,000 monthly on electricity, the percentage that stood at 48%. This was followed by the respondents that spend below N1,000 on electricity monthly at 36%, followed by the respondents that spend between N3,000 to N10, 000 on electricity monthly at 14% and lastly, the respondents that that spend between N10,000 to N20, 000 on electricity monthly stood at 2%.

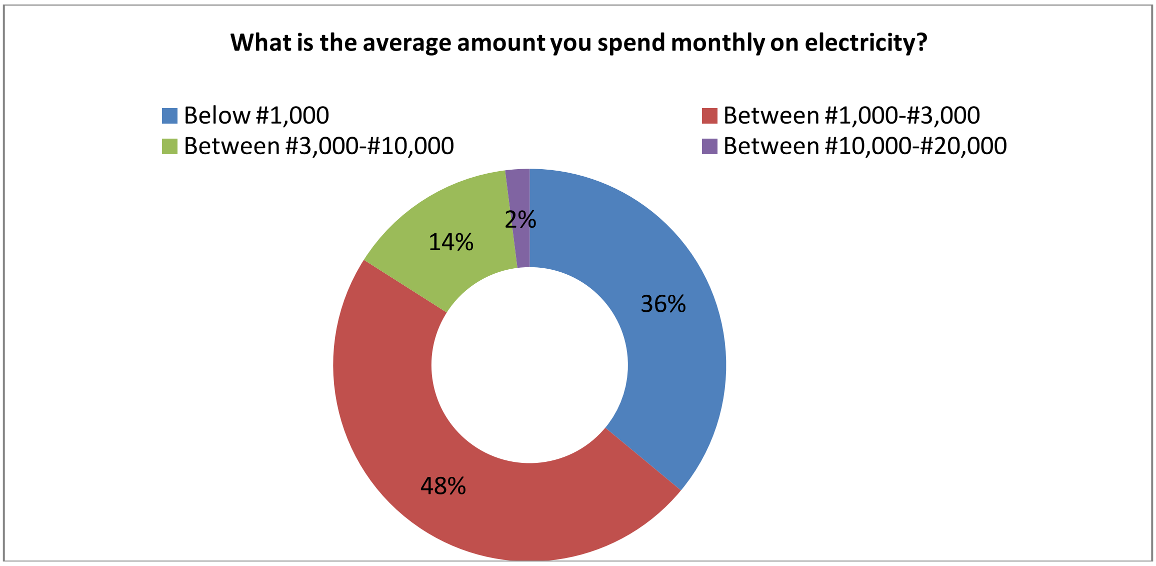

Figure 6.2: Average amount spend on energy by the respondents

Source: Field Survey 2019

The spread below revealed the level of respondent satisfaction and control of electricity usage. The respondents that affirmed strongly agree and agree that *in my area we have regular public power supply* were 6% and 84.0%, while disagree were 10.0%. Seventy-four percent (74.0%) agree that *I am comfortable with the average amount I paid monthly on electricity* and 26.0% of them disagree. Thirty-two percent (32.0%) agree that *I have control over the way members of my household use electricity* and 30.0% of them disagree. However, 2% and 74% of the respondents affirmed strong agree and agree that *it is important to switch- off one's apartment when no one is at home*, while 24.0% of them disagree. Fifty-eight percent (58.0%) agree that *I have been forced to return home from an outing because I did not switch off some appliance* and 42.0% of them disagree.

In addition, the respondents that affirmed strongly agree and agree that *fire can result from unmonitored use of electricity* were 30.0 and 70%, while none of them disagree. Lastly, 66.0% of the respondents agree that *I normally switch off my appliances/ apartment when no one is at home*and 34.0% of them disagree

Table 6.2: Level of Respondent Satisfaction and Control of Electricity Usage

Indices Measured	SA (%)	A (%)	D (%)	SD (%)	Total
In my area we have regular public power supply	3 (6.0)	42 (84.0)	5 (10.0)	-	50 (100.0)
I am comfortable with the average amount I paid monthly on electricity	-	37 (74.0)	13 (26.0)	-	50 (100.0)
I have control over the way members of my household use electricity	-	35 (70.0)	15 (30.0)	-	50 (100.0)
It is important to switch- off one's apartment when no one is at home	1 (2.0)	37 (74.0)	12 (24.0)	-	50 (100.0)
I have been forced to return home from an outing because I did not switch off some appliance	-	29 (58.0)	21 (42.0)	-	50 (100.0)
Fire can result from unmonitored use of electricity	15 (30.0)	35 (70.0)	-	-	50 (100.0)
I normally switch off my appliances/ apartment when no one is at home	-	33 (66.0)	17 (34.0)	-	50 (100.0)

Source: Field Survey 2019

The chart below revealed the possession and awareness of respondents on Bluetooth/Infrared remote control. The respondents that affirmed agree that *I am aware that the use of Bluetooth/Infrared remote control is limited to small distance* were 14.0%, while disagree were 86.0%. Ninety-two percent (92.0%) agree that *I am aware that I can use my GSM phone to remotely switch on/off energy to my appliances/apartment from any location*, while 8.0% of them disagree.

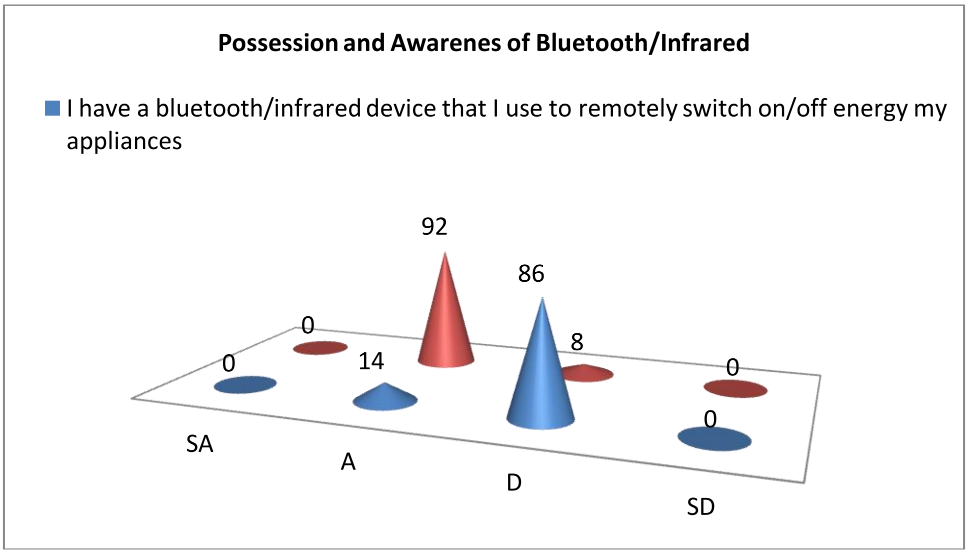

Figure 3: Possession and awareness of the respondents on Bluetooth/Infrared

Source: Field Survey 2019

Table 6.3 below revealed the level of respondent usage of remote control of energy through GSM. Ninety-eight percent (98.0%) agree that *if I can remotely switch my apartment on/ off whenever I want with my GSM phone it* *will save me energy and reduce cost* and just 2.0% of them disagree. Sixteen percent (16.0%) and 82.0% of the respondents strongly agree and agree that *if I can remotely switch my apartment with my GSM phone it will reduce stress* and just 2.0% of them disagree. Lastly, 94% of the respondents affirmed agree that *the control of my appliances/apartment with GSM phone will be better than Bluetooth/infrared control*, while 6.0% of them disagree.

Table 6.3: Usage ofRemoteControl of Energy through GSM

Indices Measured	SA (%)	A (%)	D (%)	SD (%)	Total
If I can remotely switch my apartment on/ off whenever I want with my GSM phone it will save me energy and reduce cost.	-	49 (98.0)	1 (2.0)	-	50 (100.0)
If I can remotely switch my apartment with my GSM phone it will reduce stress	8 (16.0)	41 (82.0)	1 (2.0)	-	50 (100.0)
The control of my appliances/apartment with GSM phone will be better than Bluetooth/infrared control	-	47 (94.0)	3 (6.0)	-	50 (100.0)

Source: Field Survey 2019

VII. Conclusion

Domestic use of mobile Energy Meter Loads Control System for effective management of utility bills, stress and energy wastes is now a means to achieve improvement on availability, accessibility and affordability of electricity in Nigeria. Level of satisfaction with the use of mobile energy meter to control the usage of electricity is high among consumers. Effective usage of mobile control of energy consumption through GSM is also highly welcome by consumers. Load management and wastes limitation will eventually free energy for other consumers by optimally utilizing existing capacity.

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