

DESIGN OF A HYBID ENERGY METERING SYSTEM WITH AN
ALARM

BY

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ABSTRACT

This report aims at proposing a system that reduces power loss and power theft due to the illegal activities. In this report, the prepaid power is monitored using a GSM module and is utilized so that the consumer can be persistently be educated on the energy utilization and if the sum of the energized achieves the base worth, it allans the consumer to add more units.

The major aim of this report is to lessen the long lines at power charging counters and to disconnect or remove the power automatically if the units get done, hence need to recharge.

The system was designed around two modules, the hardware and the software modules

The hardware module consists of ADE7755 used to generate the consumption pulses that are measured and recorded by Atmega328P. Atmega2560 was used to manage the unit consumption; control and monitor the activities of the meter. SIM900 was used to achieve the SMS recharging and communication capability. The server consists of Atmega328P and SIM900 for communication. It is interfaced serially with the PC used for the Application Platform. The software module consists of the Application Platform especially for token generation and Database. The SMS Command format for recharging of the meter was also developed using GSM which is a cell system which implies that the cellular telephones unite with it via looking for cells in the prompt region in the neighboring cells to maintain a strategic distance from contortion in signs with the phone. The GSM-based Energy Metering System developed **worked** satisfactorily. It is reliable and efficient for use by the supply authority and the consumers.

Keywords: GSM-Based Energy Meter, Hybrid Recharging, SMS Command and Application Platform

DEDICATION

The work in this report is dedicated to my Parent Mrs. MUHOOZI EUDIA my siblings for the love, care and support they have given me during this final year project period and more so who I have worked with on several projects that have imparted valuable programming and system design skills onto me.

ACKNOWLEDGEMENT

I thank the almighty God who has blessed me with life and good health which I cannot take for granted. This has enabled me to move smoothly throughout this final year project period.

Special thanks go to my parents and family who have given me all the necessary financial and moral support throughout this training. They have been a pillar to my education and my career path. They have been there for me through thick and thin. They have supported me in all aspects so that I can pursue my dream of being an electrical engineer.

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I extend heartfelt thanks to my classmates for their help and motivation. We shared knowledge and ideas related to engineering and technology during this period which I believe will be of great use towards the development of our careers.

Lastly, a token of appreciation goes to my lecturers, faculty staff and my classmates in the department of electrical engineering at Kabale University for their tireless effort and dedication to make sure I get the best out of my time at the university in pursuit of my career.

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ABBREVIATIONS

Abbreviation	Description
CUI	Consumer User Interface
SMS	short messaging service
Tx.....	Transmitter
Rx	Receiver
LED	Light Emitting Diode
PWM	Pulse width Modulation
MI--IZ	Mega Hertz
DC	Direct Current
USB	Universal Serial Bus
KB	Kilo byte
IDE	Integrated Development Environment
SPI.....	Serial peripheral interface
SDA	Serial Data
SCL	Serial Clock
TCSP	In circuit Serial Programmer
LCD	Liquid Crystal Display
AC.	Alternating Current
RTC	Real Time Clock
AMR	Automatic Meter Reading
PLC	Power Line Carrier
CB	Circuit Breaker
IMP	Impulse
GSM	GJobal System for mobile Communication
IED	Intelligent Electronic Device
BiCMOS	Bi-Complementary Metal Oxide Semi-conductor
SRAM	Static Random-Access Memory
1/O	Input/output
Li-ion	Lithiwn Ion
TTL.	Transistor Transistor Logic
L V-	Low voltage
MV	Medium

CHAPTER ONE

LO BACKGROUND

While there are many advantages to using prepaid electricity, there are also some disadvantages. The energy meters just have a buzzer which starts beeping as soon as the units go below 15. However, this beep cannot be heard if the meter is installed in an isolated place. Quite often the units get depleted and before we can realize it we are in darkness or a production process is stalled resulting into lost time or a production loss.

More so, the energy recharge token(code) that is obtained on pre-payment has to be manually entered into the consumer user interface (CUI) which requires is inconveniencing as someone must be physically present at the point of installation in order to load power units.

Therefore, this project aims at designing a system which can monitor the state of the energy meter and keep alert the customer on their mobile phones as well as being able to remotely load newly purchased tokens onto their user interface at their leisure.

1.1 PROBLEM STATEMENT

The project ensures to cover most of the areas especially rural areas where some people in remote areas are adamant to use the new system.

Some people are of the old generation and they don't easily adapt to changes and this new system will help them to easily use the system as it is easy to learn.

The application of this system is through prepaid energy system and mechanical and hence this makes the system to be hybrid which easily helps to curb the problem associated

One of the biggest disadvantages is when you run out of money on your account the power goes out. Prepaid meters can be disconnected remotely. The electric company does not have to send a warning letter before they turn the power off, so this project helps to curb the problem above. It is an advanced metering technology involving placing intelligent meters to read, process and feedback the data to customers. It measures energy consumption, remotely switches the supply to customers and remotely controls the maximum electricity consumption. Smart metering system uses the advanced metering infrastructure system technology for better performance

1.2 OBJECTIVES

1.2.1. General objective

To design a hybrid smart energy meter with alarm system.

1.2.2. Specific objectives

- a) To design a circuit for monitoring the state of the energy meter credit balance.
- b) To design a communication system for relaying information to and from the customer's mobile phone.
- c) To develop an algorithm for interpreting SMS in order to extract energy meter token for loading onto the consumer interface.

1.2.3 Justification

The hybrid energy metering system based on the Loading of the *units* automatically helps in the easy way of monitoring, control and diagnosing the rural electrification where the cost of grid extension is prohibitive and the price of petrol is high hence the need to use the hybrid energy metering system for easy power and easy monitoring of power by the electricity companies.

1.2.4 Methodology

The methodology I used in this project was dividing the whole project into modules such that each module represents an objective of the system hence easing trouble shooting procedures during the implementation of the system. The modules were combined to come up with an operating final model of the system as shown in the table below.

Specific objective	Method	Expected result
To design a circuit for connecting the calibration pin of the energy meter balance.	This was achieved by Different number of pulses monitoring the state of the pin where achieved and added on credit of the energy meter to digital pin of the Arduino and hence the units where calculated and after achieving the numbers of balance achieved pulses, the units are calculated from the formula.	
To design a communication system for relaying information to and from the customer's mobile phone.	On here, I used the Arduino The system can receive Nano because it is small and balance request and also load affordable with a micro token using a mobile phone. controller at mega 328P on the Arduino Nano.	
c)To develop an algorithm for interpreting SMS in order to extract energy meter token for loading onto the consumer interface.	The customer sends a message with the token to the meter using a mobile phone, the Arduino extracts the units from the token and loads it automatically onto the energy meter.	The credit balance will then be the units loaded minus the units used as displayed on the LCD screen and the consumer takes action.

TABLE 1: METHODOLOGY TABLE WITH OBJECTIVES.

1.2.5: Project out line

Chapter one: This chapter contains the introduction and a brief background about the project 12 Chapter two: This chapter contains the literature review and all the principles used to achieve the project.

Chapter three: This chapter describes the design and implementation methods used to achieve project objectives.

Chapter four: This chapter discusses the results and the outcomes from the methods used to achieve project objectives

Chapter five: This chapter discusses the conclusion and the future improvements that can be undertaken about the project.

CHAPTER TWO

2.10. LITERATURE REVIEW

This chapter discusses the previous works that have been achieved regarding the use of the old energy metering system including theoretical aspects and principles that can be used as a base or foundation to achieve the main objectives of this project successfully. Most of the work under this chapter was obtained from the already published articles, journals, books, documents and related material. This work was used to generate literature which helped in providing guidance to work on the designing of the hybrid energy metering system.

2.11. INTRODUCTION.

This chapter covers the literature review of the activities performed during the design and prototyping of our group project. It contains detailed definitions and explanation of terms used in this report, as well as materials and tools used to bring the project to reality.

These include; Arduino platform, Arduino Nano, breadboard, baud rate, buck converter, full wave rectifier, solenoid valve, relay module, blower, header pins, transformer, hardware serial, software serial, diodes, etc.

Previous works

This sub-section explains some of the past works that have been completed in regards to the use of the energy meter systems hence from this knowledge, we can relate and have the final work outlook for the best of the new project of the hybrid energy meter with an alarm system.

2.12. Arduino platform.

Arduino is an open-source electronics platform which can be described as a small embedded system with a tiny microcontroller chip that can be programmed to process the data from external components connected to the Arduino output and input pins. Hardware boards for Arduino contain sets of analog and digital input and output pins which enable different external expansion boards and other circuits to be interfaced to the Arduino hardware board. The Arduino hardware board also has pins for serial communication and USB provision for loading computer software programs. Arduino integrated development environment (IDE) is the software part that supplies many very good libraries for basic functionalities, and could run on Mac, Windows, and Linux. In comparison to other similar systems, Arduino has some basic advantages which are explained below.

- ✓ Arduino hardware boards are relatively cheaper in comparison to other microcontroller platforms.

- ✓ The Arduino integrated development environment software runs on different platforms such as Windows, Linux operating systems and Macintosh OSX while other microcontroller systems are limited to windows.
- ✓ Arduino software (IDE) is an open-source platform which enables software program expansion through C++ libraries

2.13. Arduino Nano:

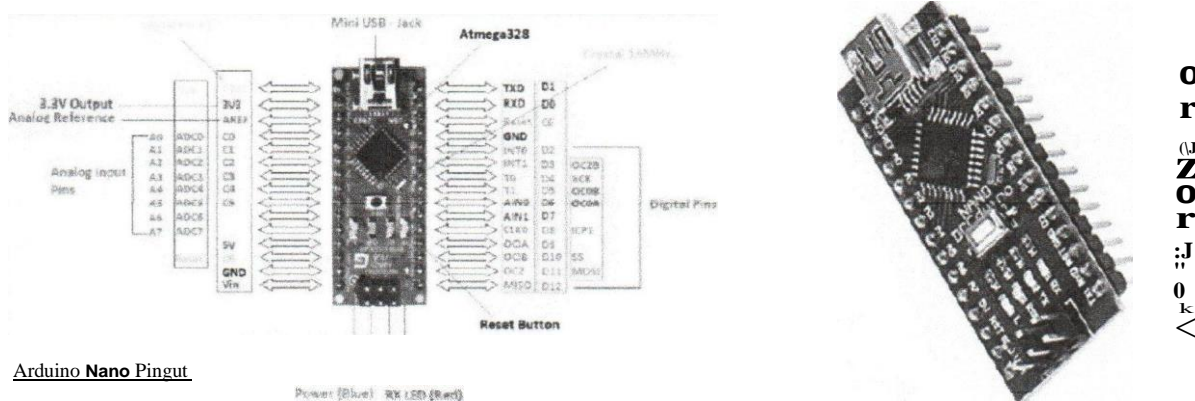


FIGURE 1: AR DUI NO NANO PINOUT

[1]

Pins and their description

1. DO-D 13 Digital Input/ Output Pins.
11. AO - A 7 Analog Input / Output Pins.
111. Pins 3, 5, 6, 9, 11 Pulse Width Modulation (PWM) Pins.
- 1v. Pins 0 (RX), Pin # 1 (TX) Serial Communication Pins.
- v. Pins 10, 11, 12, 13 SPI Communication Pins.
- vi. Pins A4, A5 I2C Communication Pins.
- vii. Pins 13 Built-In LED for Testing.
- vm. D2 & D3 External Interrupt Pins.

The Arduino Nano is a small, complete, and breadboard-friendly board based on the ATmega328 microcontroller. It can be programmed using the Arduino IDE through a mini-B USB cable. Its applications range from controlling micro-components, serial, I2C, wireless communication, controlling equipment through relay and sensor interfaces etc. They can only be limited by your imagination. It can operate through 5v or 3.3v TTL interface.

It automatically detects and selects the higher potential source of power. [2]

2.14. Technical Specifications

Microcontroller	ATmega328
Architecture	AVR
Operating Voltage	5V
Flash Memory	32 KB of which 2 KB used by bootloader 2 KB
SRAM	16MHz
Clock Speed	8
Analog IN Pins	1 KB
EEPROM	40 mA {1/O Pins)
DC Current per I/O Pins	7-12V
Input Voltage	22 (6 of which are PWM) 6
Digital I/O Pins	19 mA
PWM Output	18 x 45 mm
Power Consumption	7g
PCB Size	
Weight	

TABLE 2:SHOWING TECHNICAL SPECIFICATIONS OF THE ARDUINO NANO

Boards	Microcontroller	Operating Voltage/s (V)	Digital I/O Pins	PWM Enabled Pins	Analog I/O Pins	DC per I/O (mA)	Flash Memory (KB)	SRAM (KB)	EEPROM (KB)	Clock (MHz)	Length (mm)	Width (mm)	Cable	Native Network Support
Uno	ATmega328	5	14	6	6	20	32	2		16	68.6	53.4	usb A-B	None
Leonardo	ATmega32u4	5	20	7	12	40	32	25		16	68.6	53.3	micro-USB	None
Hicrow	ATmega32u4	5	20	7	12	40	32	25		16	48	18	micro-USB	None
Nano	ATmega128	5	22	6	8	40	32	2	0.51	16	45	18	mini-B USB	None
Mini	ATmega328	5	14		6	20	32	2		16	30	18	USB-Serial	None
	Atmel													
	SAHIX8E													
Due	ARM Cortex-M3 CPU	3.3	54	12	12	800	512	96	X	84	102	53.3		None
													micro-USB	
Mega	ATmega2560	5	54	15	16	20	256	8	4	16	102	53.3	USB A-B	None
MO	Atmel SAMD21	3.3	20	12	6	7	256	32	X	48	68.6	53.3	micro-USB	None
Yun Mini	ATmega32u4	3.3	20	7	12	40	32	25		400	71.1	23	micro-USB	Ethernet/wifi
Juno Ethernet	ATmega328p	5	20	4	6	20	32	2		16	68.6	53.4	Ethernet	Ethernet
Tian	Atmel SAM021	3.3	20	12	0	7	16000	64000	4	560	68.5	53	micro-USB	Ethernet/wifi
Mega ADK	ATmega2560	5	54	15	16	40	256	8	4	16	102	53.3	USB A-B	None
MO Pro	Atmel SAM021	3.3	20	12	6	7	256	32	X	48	68.6	53.3	micro-USB	None
Industrial IoT	ATmega32u4	5	7	2	4	40	16000	64000		400	51	42	micro-USB	Ethernet/wifi
Uno Wifi	ATmega328	5	20	6	6	20	32	2		16	68.6	53.4	USB A	Wifi
Leonardo Ethernet	ATmega32u4	5	20	7	12	40	32	25		16	68.6	53.3	usb A-e	Ethernet
MKR1000	Atmel SAM021	3.3	8	12	7	7	256	32	X	48	64.6	25	micro-USB	Wifi

TABLE 3: COMPARISON OF DIFFERENT MICRO CONTROLLERS

2.15: Arduino IDE:

This is a programming environment for the Arduino boards which enables the user to easily write and compile code to control the running of his project. It utilizes a combination of C and C++ programming languages with its own compilers which quicken and ease the programming process.

d) A basic layout of the Arduino programming environment is shown below;

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```
// the setup function runs once when you press reset or power the board void
setup() {
  // initialize digital pin LED_BUILTIN as an output.
  pinMode(LED_BUILTIN, OUTPUT);
}

// the loop function runs over and over again forever
void loop() {
  digitalWrite(LED_BUILTIN, HIGH);    // turn the LED on (HIGH is the voltage level) // wait
  delay(1000);                        // for a second
  digitalWrite(LED_BUILTIN, LOW);     // turn the LED off by making the voltage LOW // wait
  delay(1000);                        // for a second
}
```

FIGURE 2: ARDUINO IDE

Arduino software

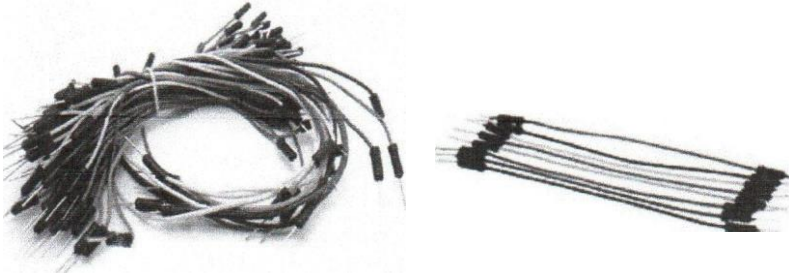
Arduino integrated development environment software was written in Java and is used in writing and editing of computer software programs in form of sketches. The IDE helps in conversion of the software programs into HEX files that can be understood by the hardware Arduino board. IDE is also used for uploading these programs to the Arduino hardware board through the USB. The IDE software program is divided into two parts which contain block of statements as in the enclosure below.

```
Void setup()
{
  Statements;
  Void loop() {
    Statements;
  }
}
```

Both the void setup () and void loop () are necessary for program execution [16]. The setup is only run once while the loop runs continuously during program execution. The setup is used for initialization of ports and setting of pin mode

2.16. Jumper wires:

jumper wire (also known as jumper wire, or jumper) is an electrical wire, or group of them in a cable, with a connector or pin at each end (or sometimes without them - simply "tinned"), which **is** normally used to interconnect the components of a breadboard or other prototype or test circuit, **internally or with other equipment or components, without soldering**



Stranded 224WG jump wires with solid tips.

FIGURE 3: JUMPER WIRES

Individual jumper wires are fitted by inserting their "end connectors" into the slots provided in a breadboard, the header connector of a circuit board, or a piece of test equipment.



Jumper wires with crocodile clips

FIGURE 4: JUMPER WIRE WITH CROCODILE CLIPS

There are different types of jumper wires. Some have the same type of electrical connector at **both** ends, while others have different connectors. Some common connectors are; solid tips, crocodile dips, banana connectors, RJ, RCA, and RF connectors. [3]

2.1 7. Optocoupler

An **Optoconpler**, is an electronic component that interconnects two separate electrical circuits by means of a light sensitive optical interface.

We know from our tutorials about Transformers that they can not only provide a step-down (or step-up) voltage, but they also provide "electrical isolation" between the higher voltage on the primary side and the lower voltage on the secondary side.

In other words, transformers isolate the primary input voltage from the secondary output voltage using electromagnetic coupling and this is achieved using the magnetic flux circulating within their laminated iron core. But we can also provide electrical isolation between an input source and an output load using just light by using a very common and valuable electronic component called an **Optocoupler**.

The basic design of an optocoupler, also known as an **Opto-isolator**, consists of an LED that produces infra-red light and a semiconductor photo-sensitive device that is used to detect the emitted infra-red beam. Both the LED and photo-sensitive device are enclosed in a light-tight body or package with metal legs for the electrical connections as shown.

An optocoupler or opto-isolator consists of a light emitter, the LED and a light sensitive receiver which can be a single photo-diode, photo-transistor, photo-resistor, photo-SCR, or a photo-TRIAC with the basic operation of an optocoupler being very simple

2.18. Optocoupler Applications

Optocouplers and opto-isolators can be used on their own, or to switch a range of other larger electronic devices such as transistors and triacs providing the required electrical isolation between a lower voltage control

Common applications for opto-couplers include microprocessor input/output switching, DC and AC power control, PC communications, signal isolation and power supply regulation which suffer from current ground loops, etc. The electrical signal being transmitted can be either analogue (linear) or digital (pulses). In this application, the optocoupler is used to detect the operation of the switch or another type of digital input signal. This is useful if the switch or signal being detected is within an electrically noisy environment. The output can be used to operate an external circuit, light or as an input to a PC or microprocessor. [4]

f)

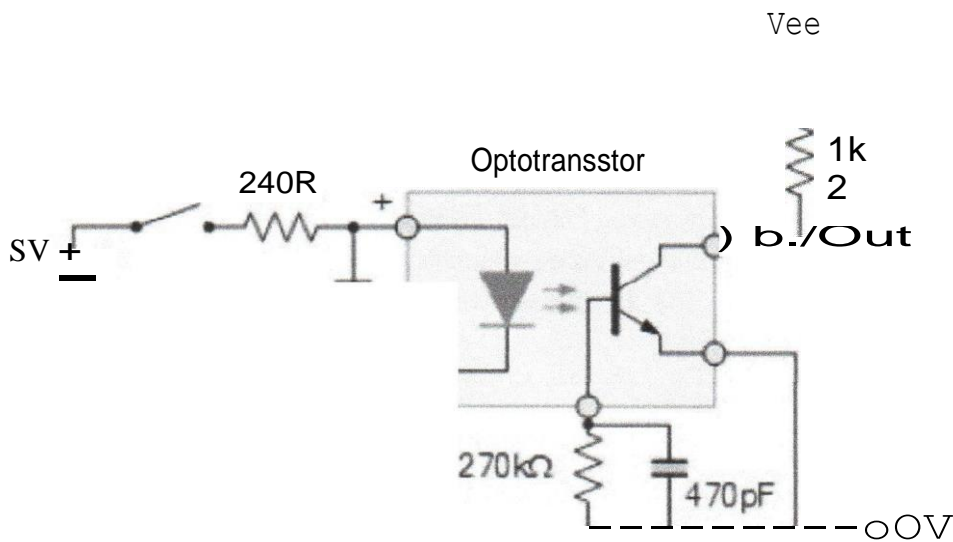


FIGURE 5: OPTO-COUPLER DC SWITCH. [5]

Triac Optocoupler Application

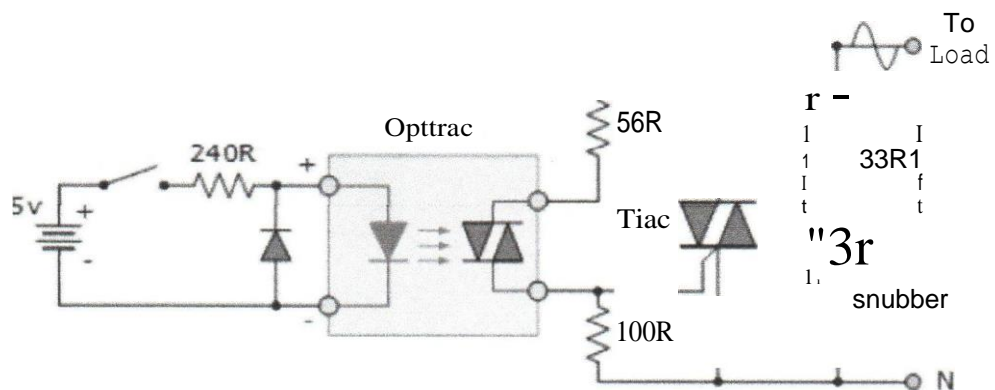


FIGURE 6: SHOWING THE OPTOCOUPLER

This type of optocoupler configuration forms the basis of a very simple solid-state relay application which can be used to control any AC mains powered load such as lamps and motors. Also, unlike a thyristor (SCR), a triac is capable of conducting in both halves of the mains AC cycle with zero-crossing detection allowing the load to receive full power without the heavy inrush currents when switching inductive loads.

Optocouplers and **Opto-isolators** allow devices such as power transistors and triacs to be controlled from a PC's output port, digital switch or from a low voltage data signal such as that from a logic gate. The main advantage of opto-couplers is their high electrical isolation between

the input and output terminals allowing relatively small digital signals to control much large AC voltages, currents and power.

An optocoupler can be used with both DC and AC signals with optocouplers utilizing a SCR (thyristor) or triac as the photo-detecting device are primarily designed for AC power-control applications. The main advantage of photo-SCRs and photo-triacs is the complete isolation from any noise or voltage spikes present on the AC power supply line and zero-crossing detection of the sinusoidal waveform which reduces switching and inrush currents protecting any power semiconductors used from thermal stress and shock. [6]

2.19. SIM800L GSM module

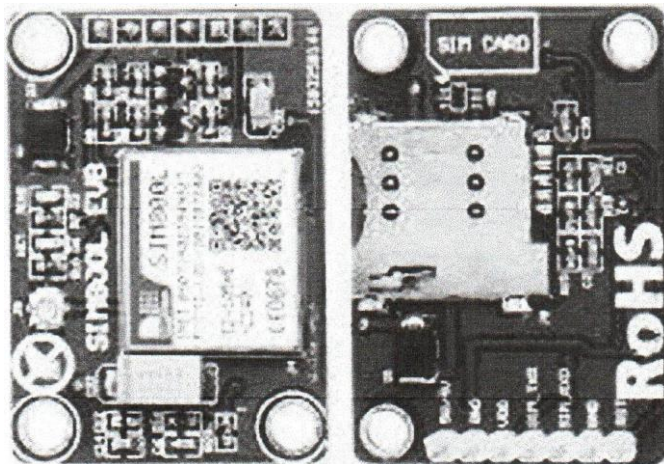


FIGURE 7:SIM800L EVB GSM MODULE

This is a Quad-band GSM/GPRS module. It works on frequencies GSM 850MHZ, EGSM900MHZ, DCS1800MHZ and PCS1900MHZ. It features GPRS multi-slot class 12/class 10(optional) and supports the GPRS coding schemes CS-1, CS-2, CS-3 and CS-4.

It has a small 15.8*17.8*2.4mm configuration which enables it to meet user expectations in terms of space requirement in devices such as mobile phones and hence it creates an easy way of communication throughout, PDA, tablets, and embedded devices. It has 88pin pads of LGA packaging and provides all hardware interfaces between the module and other compatible devices. It helps to allow the attachment of the Sim card. [7]

2.20. Basic functionality

- Support 5*5*2 keypads

i)

- One full modem serial port, user can configure two serial ports
- One USB, the USB interfaces can debug download software
- Audio channel which includes two microphones in put; a receiver output and a speaker output
- Programmable general-purpose input and output
- A SIM card interface
- SupportFM
- Support one PWM

2. 21. Operating modes

TABLE 4: SIM800L GSM MODULE OPERATING MODES

Mode	Function
Normal operation	Module will automatically go into sleep mode if the conditions of sleep mode are met, and there is no on air and no hardware interrupt (such as GPIO interrupt or data on serial port).
Normal operation	In this case, the current consumption of module will reduce to the minimal level.
Normal operation	In sleep mode, the module can still receive paging message and SMS.
Normal operation	Software is active. Module is registered on the GSM network, and the module is ready to communicate.
Normal operation	Communication between two subscribers is in progress. In this case, the power consumption depends on network settings such as DTX off/on, FRUEFRHR, hopping sequences, antenna.
Normal operation	Module is ready for GPRS data transfer, but no data is currently sent or received. In this case, power consumption depends on network setting and GPRS configuration.
Normal operation	There is GPRS data transfer (PPP or TCP or UDP) in progress. In this case, power consumption is related with network settings e.g. power control level; uplink/ downlink data rates and GPRS configuration (e.g. used multi-slot settings).
Power down	Normal power by sending "AT+CPQW0,1" or using the VBAT. The power management unit shuts down the power supply for the baseband part of the module, and only the power supply for the RTC is retained. Software is not active. The serial port is not accessible. Power supply (connected to VBAT) remains applied.
Minimum functionality mode	At command "AT+CFUN" can be used to set the module to a minimum functionality mode without removing the power supply. In this mode, the RF part of the module will not work or the SIM card will not be accessible, or both RF part and SIM card will be disabled, and the serial port is still accessible. The power consumption in this mode is lower than normal mode.

[8]

power supply

SIM800L is a power-hungry module and requires 3.4V to 4.4V with 4.0V as the recommended voltage. Transmission bursts can cause a voltage drop so the power supply must be able to handle up to 2A. A low ESR bypass capacitor e.g. 100F is highly recommended. The 33pF and 10pF capacitors can be increased to effectively eliminate high frequency interference.

Status LEDs

The module has 2 status LEDs as explained below;

- a) **Power LED (Ring Indicator)**; This light continuously when the module is connected to the power supply. When the module is called, this LED is pulled low .



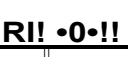


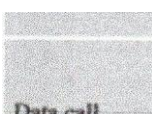
				
Standby	High			
	The pin is changed to low. When any of the following events occur, the pin will be changed to high:			
Voice call	(1) Establish the call (2) Hang up the call			
	The pin is changed to low, and kept low for 120ms when a SMS is received. Then it is changed to high. The pin is changed to low, and kept low for 120ms when some URCs are reported. Then it is changed to high. For more details, please refer to document [10].			
SMS				

TABLE 5: SIM800L RING INDICATOR RESPONSES

- b) **Network LED**; This goes on and off every 0.5 seconds when the module is searching for network signal. Once it connects to the network, the sequence changes to 3seconds between on and off.
 NB: The following responses are necessary for troubleshooting power supply issues.

j)

The module software monitors the VBAT voltage constantly. If the voltage 3.5, the following URC will be reported.

UNDER-VOLTAGE WARNNING

If the voltage 2: 4.3V, the following URC will be reported:

OVER-VOLTAGE WARNNING

If the voltage < 3.4V, the following URC will be reported, and the module will be automatically powered down.

UNDER-VOLTAGE POWER DOWN

If the voltage > 4.4V, the following URC will be reported, and the module will be automatically powered down.

O'ER-VOLTAGE POWER DOWN

At this moment, AT commands can not be executed any more, and only the RTC is still active. Power down mode can also be indicated by STATUS pin, which is at low level at this time.

FIGURE 8: SHOWING THE TROUBLE SHOOTING VOLTAGES

Functional Block diagram

The following figure shows a functional diagram of SIM800L. e

GSM baseband

- GSMRF
- Antenna interface
- Other interface

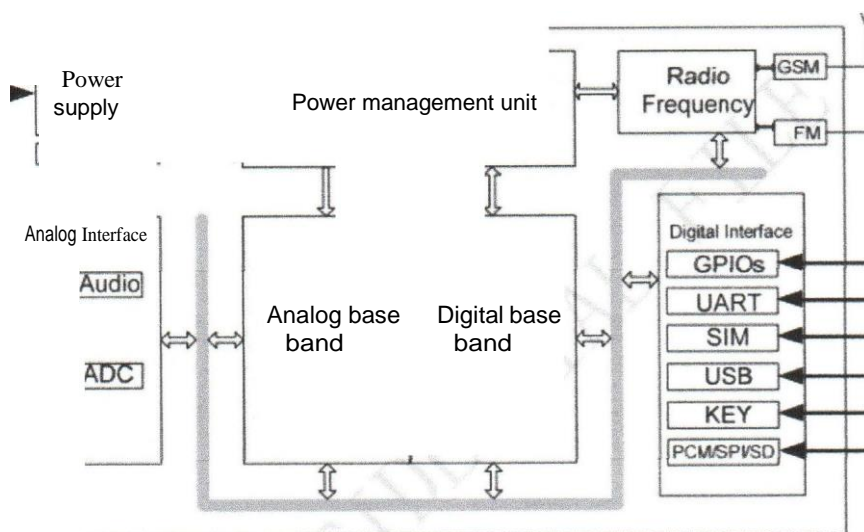


FIGURE 9: SIM800L FUNCTIONAL BLOCK DIAGRAM

[9]

2.22. Energy Meter

An Energy meter is an instrument which measures amount of electrical energy used by the consumers. Utilities install these instruments at every place like homes, industries, organizations to charge the electricity consumption by loads such as lights, fans and other appliances. 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 including 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. Most interesting type are used as prepaid electricity meters. Types of **energy meter** are given below with explanation

Basic unit of power is watts. One thousand watts is one kilowatt. If we use one kilowatt in one hour, it is considered as one unit of energy consumed. These meters measure the instantaneous voltage and currents, calculate its product and gives instantaneous power. This power is integrated over a period which gives the energy utilized over that time period.

Types of Energy Meters

Energy meter are classified in three basic types accordance with various factors such as; Type of display, Technical like single phase, LT, three phases, HT and many more, Type of Usage like domestic, commercial and industrial, Type of metering point.

According to construction energy meter classified as; Electromechanical induction type, Electronic Energy Meter, Smart Energy Meter. According to phase, they are classified as; Single Phase Energy Meter, Three Phase Energy Meter

Electronic Energy Meters

In the Electronic meters display the energy used on an LCD or LED display, and some can also transmit readings to remote places. In addition to measuring energy used, electronic meters can also record other parameters of the load and supply such as instantaneous and maximum rate of usage demands, voltages, power factor and reactive power used etc. They can also support time-of-day billing, for example, recording the amount of energy used during on-peak and off-peak **hours**.

These are of accurate, high precision and reliable types of measuring instruments as compared to conventional mechanical meters. It consumes less power and starts measuring instantaneously when connected to load. These meters might be analog or digital. In analog meters, power is converted to proportional frequency or pulse rate and it is integrated by counters placed inside it.

In digital electric meter power is directly measured by high end processor. The power is integrated by logic circuits to get the energy and also for testing and calibration purpose. It is then converted to frequency or pulse rate.

2.23. Digital electronic Energy Meter:

The Digital signal processor or high-performance microprocessors are used in digital electric meters. Similar to the analog meters, voltage and current transducers are connected to a high-resolution ADC. Once it converts analog signals to digital samples, voltage and current samples are multiplied and integrated by digital circuits to measure the energy consumed.

The Microprocessor also calculates phase angle between voltage and current, so that it also measures and indicates reactive power. It is programmed in such a way that it calculates energy according to the tariff and other parameters such as pf, maximum demand, etc. and stores all these values in a nonvolatile memory EEPROM.

It contains real time clock (RTC) for calculating time for power integration, maximum demand calculations and also date and time stamps for particular parameters. It also interacts with liquid crystal display (LCD), communication devices and other meter outputs. Battery is provided for RTC and other significant peripherals for backup power.

2.24 Smart Energy Meter

A **smart meter** is an electronic device which records power consumption and relays the information to the electricity supplier for monitoring and billing. Recording can be done hourly or more frequently, with daily reporting.

The most important aspect is that a Smart meter enable two-way communication between the meter and the central system. Such an advanced metering infrastructure (AMI) differs from automatic meter reading (AMR) in that it the best enables two-way communication between the meter and the supplier. Communications from the meter to the network may be wireless, or via fixed wired connections such as power line carrier (PLC). Wireless in the communication options in common use include cellular communications, Wi-Fi, wireless ad hoc networks over WiFi, wireless mesh networks, low power long range wireless (low power, low data rate wireless), and **Wi-SUN**

This reduces the need for physical visits for also monthly billing. Modems are used in these smart meters to facilitate communication systems such as telephone, wireless, fiber cable, power line communications as well as avoidance of tampering. [10]

2.25. Buck converter

A buck converter steps down a DC voltage from the input to the output.

A **buck converter (step-down converter)** is a DC-to-DC power converter which steps down voltage (**while** stepping up current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) typically containing at least two semiconductors (a diode and a transistor, although modern buck converters frequently replace the diode with a second transistor used for synchronous rectification) and at least one energy storage element, a capacitor,

k)

inductor, or the two combined. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter).

Description

The LM2596 series of regulators are monolithic integrated circuits which provide all the functions for a step-down (buck) switching regulator. With excellent line and load regulation, they can handle up to 3A of load current. They come in fixed output voltages of 3.3 V, 5 V, 12 V, and adjustable output versions. They are simple to use and include internal frequency compensation, and a fixed frequency oscillator. They also operate at a switching frequency of 150 kHz, thus allowing smaller sized filter components than in the case of lower frequency switching.

Self-protection features include a two-stage frequency reducing current limit for the output switch and an over temperature shutdown for complete protection in case of a fault.

The figure below explains the operation of the buck converter following the on state and off state. The buck converter has the current in an inductor controlled by the two switches of the especially the transistor and a diode.

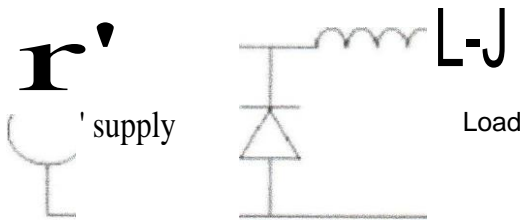


FIGURE 10:THE ON-STATE AND OFF STATE OF A BUCK CONVERTER.

2.26. Sim card

This is also called the subscriber identity module and it contains information that identifies the user on the network. The sim card is portable and can be easily changed from one mobile to another. This is where the message is sent by the mobile user and then it also sends the message to the GSM for further interpretation.

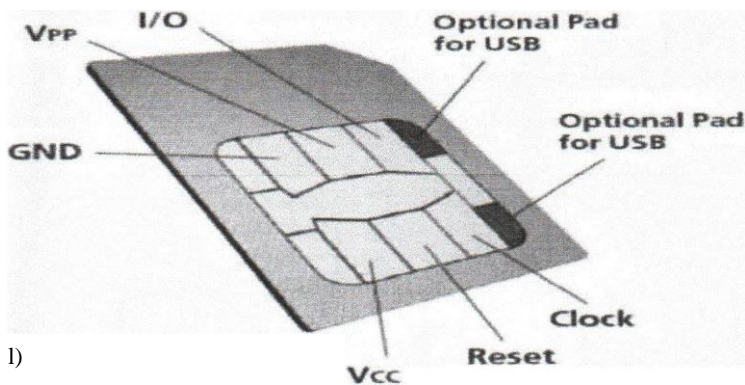


FIGURE 1I: SIM CARD OUT LOOK

Cellular phones

These are portable or mobile devices used for information exchange between two or more people on a GSM network. Some of the advanced cellular phones enable internet connectivity thus enabling use of different software applications.

2.27. Operation and support subsystem (OSS)

The OSS is used for overall monitoring and control of GSM network with its associated elements like the NSS and BSC. The OSS is also used for controlling the BSS traffic load.

2.28. Embedded system design

An embedded system can be defined as an electronic hardware circuit with a computer software program embedded into it. It is built with the help of a microprocessor or microcontroller that is programmed to perform a specific task. Embedded system implementation can be done independently or as part of another complete system. Classification of embedded system is specifically based on the performance and functional requirements of the microcontroller. The most marketable embedded systems are the ones based on real time because of their better functionality and reliability. [11]

Embedded systems are mainly applied in the fields listed in the diagram below.

Types Of Embedded Systems

Based On Performance &
Functional Requirements

Real Time	Stand Alone	Networked	Mobile	Small Scale	Medium Scale	Sophisticated
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FIGURE 12: SHOWING THE TYPES OF EMBEDDED SYSTEMS

2.29. Base Station Subsystem (BSS)

This subsystem consists of two elements and is responsible for communicating with mobiles on the network

2.30. Base Station Transceiver (BTS)

This Station is composed of radio transmitting receivers integrated their antennas that receive and transmit communication directly with the mobiles. The BTS helps in defining the element for each network cell.

2.31. Base station controller (BSC)

This is responsible for controlling a given set of Base station transceivers and it is normally colocated with one of the base station transceivers in its grouping. It also helps in the management of radio resources, controlling of items Like handover within a set of BTSs and allocation of channels. The AbIS interface helps it to communicate with the Base Transceiver Stations. Radio access technology utilized in base stations enables a number of users to access the GSM network at the same time. A base has several channels but each channel supports at most eight users. A cell is an area covered by a base station hence the base station should be strategically located by the network provider to ensure complete coverage of the area. Overlapping of signals between adjacent cells is avoided by using different channels

2.32. Home location register (HLR)

The HLR is database which stores specific information about each mobile subscriber and it can help in identification of the recent location of the subscriber hence enabling the GSM network to route calls to a particular base station. A mobile phone registers automatically with the network

whenever it is switched on hence making it possible to identify which base station subsystem it's communicating to which enables appropriate routing of incoming calls.

2.33. Visitor location register (VLR)

HLR selected information for each individual subscriber is stored in the VLR and thus the VLR avails selected services for each subscriber. The VLR can be implemented as a single entity but it is normally integrated with the MSC hence making access much easier and convenient.

2.34. Equipment identity register (EIR)

EIR is an entity which gives permission to the mobile equipment to either be allowed or disallowed to connect the network. Each Mobile Equipment is assigned with an International Mobile Equipment Identity number which must be registered on the network to enable it to access the GSM network.

2.35. Authentication center (AUC)

This database is protected with a secret key also found in the subscriber's Sim card which gives authority for authentication and ciphering on radio channel.

2.36. Gate Way Mobile Switching center (GMSC)

This is point at which call termination for a given mobile equipment is routed without knowing the MSC's location. The GMSC is responsible for getting the mobile station ISDN number from the home location register on the basis of mobile station ISDN number and then routing the call to the appropriate mobile station. The GSMC operation requires no link with the MSC.

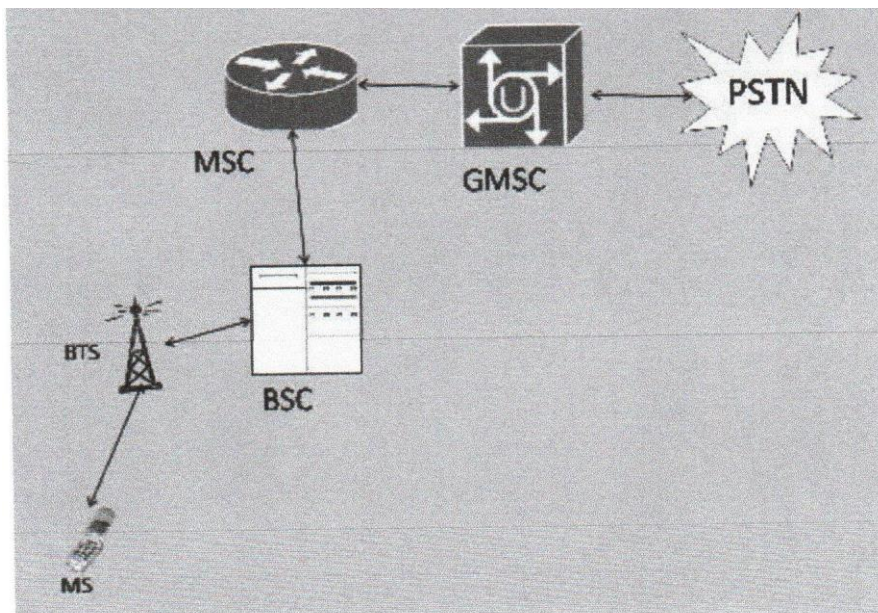


FIGURE 13 SHOWING THE GMSC COMMUNICATION

2.37. SMS Gateway (SMS-G)

This is used in description of two short message service gateways defined in the standards of the GSM network. The two gate ways are explained below;

A. Short Message Service Gateway Mobile switching center is responsible for sending short messages to a mobile Equipment.

B. Short Message Service Gateway mobile inter- working mobile switching center is responsible for short messages generated from a mobile within that network.

CHAPTER THREE

METHODOLOGY

This chapter discusses the implementation methods used to obtain the project objectives and **the hardware components used.**

Here I interfaced electricity energy meter with Arduino using the pulse LED (Calibration or Cal) of electricity Energy meter. I was able to connect CAL LED to Arduino through an Optocoupler IC.

Components used

Arduino

GSM Module sim800l with a frequency range 800-900 MHz

16x2LCD

Analogue Electricity Energy Meter

Optocoupler 4n35

Resistors

Potentiometer

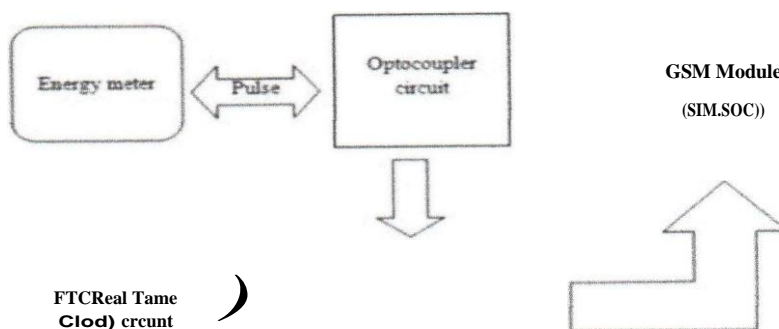
Connecting wires

Bulb and holder[load]

SIM card

Power supply

Mobile Phone.



LCD16x2) Dwplr

[[12]

FIGURE 14 SHOWING THE BLOCK DIAGRAM AND CONNECTION OF THE HYBRID ENERGY METER.

The system block diagram contains the following major units.

- Energy meter
- Opto-coupler
- GSM module w
- Arduino**
- LCD display
- Arduino

3.1. Objective 1

To design a circuit for monitoring the state of the energy meter credit balance

On this objective, we used the Arduino Nano to monitor the state of the energy meter credit balance, consider the diagram below of the Arduino Nano.

Processing unit

The different units of this project require a microprocessor or microcontroller such that they can do the assigned tasks effectively. The major tasks in this project were data acquisition, data processing and serial communication. Therefore, the different components of this project were interfaced to the microcontroller which is an integrated chip that contains the following

devices;

- Random access memory (RAM)
- Central processing unit (CPU)
- Read only memory (ROM)
- Digital to analog converter (DAC)

Various microcontrollers are available on the market but choice has to be made according to the application, advantages and disadvantages of each microcontroller. Also, the hardware board and the cost of the microcontroller are also put into consideration when making choice. The hardware board of the microcontroller is considered on the basis of the physical dimensions, size of the memory, weight, input/output pin capabilities, CPU power, connectivity and on-board peripherals and hence that's why I selected the Arduino Nano for my project compared to other types of micro controllers. Below is a table showing the comparison of different microcontrollers.

((12))

How to Connect Energy Meter with Arduino:

I connected the calibration pin of the energy meter to digital pin of the Arduino

Hence after achieving the numbers of pulses, the units are calculated from the formula below

Calculation of Pulses and Units:

Before proceeding for the calculations, first we have to keep in mind the pulse rate of energy meter I am using is 1600 imp/kwh. For each impulse, I shall have used (1/1600) kwh

Every pulse, the Arduino will be adding the above fraction to the previous value, hence showing the units used.

Following the above information,

$$\begin{aligned}\text{pulse rate} &= 1600 \text{ imp/kwh} \\ \text{1 pulse} &= (1/1600) \text{ kwh} \\ &= 0.000625 \text{ kwh}\end{aligned}$$

Therefore, for each pulse, the calibration LED blinks once and the micro controller adds 0.000625kwh to the previous value.

3.2. Objective 2

To design a communication system for relaying information to and from the customers mobile phone. The Arduino Nano was configured to send and receive messages to and from the customers mobile phone using GSM module.

We used the Arduino Nano because it is small and affordable with a micro controller at mega 328P on the Arduino Nano.

The system can receive balance request and also load token

[13]

SIM800L connection of the SIM800L GSM with Arduino

The following steps were used to connect the SIM800L with the Arduino.

- The TX pin of the GSM module was connected to the RX pin of the Arduino Nano
- The RX pin of the GSM modules was also connected to the TX pin of the Arduino Nano
- One of ground pins of the module was connected to the negative terminal of the power supply
- The second ground of the module was connected to the one of the ground pins of the Arduino Uno
- The +5V pin of the module was connected to the positive terminal of the power supply circuit.

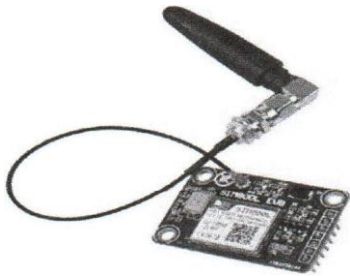


FIGURE 15: SIM800L EVB GSM MODULE.

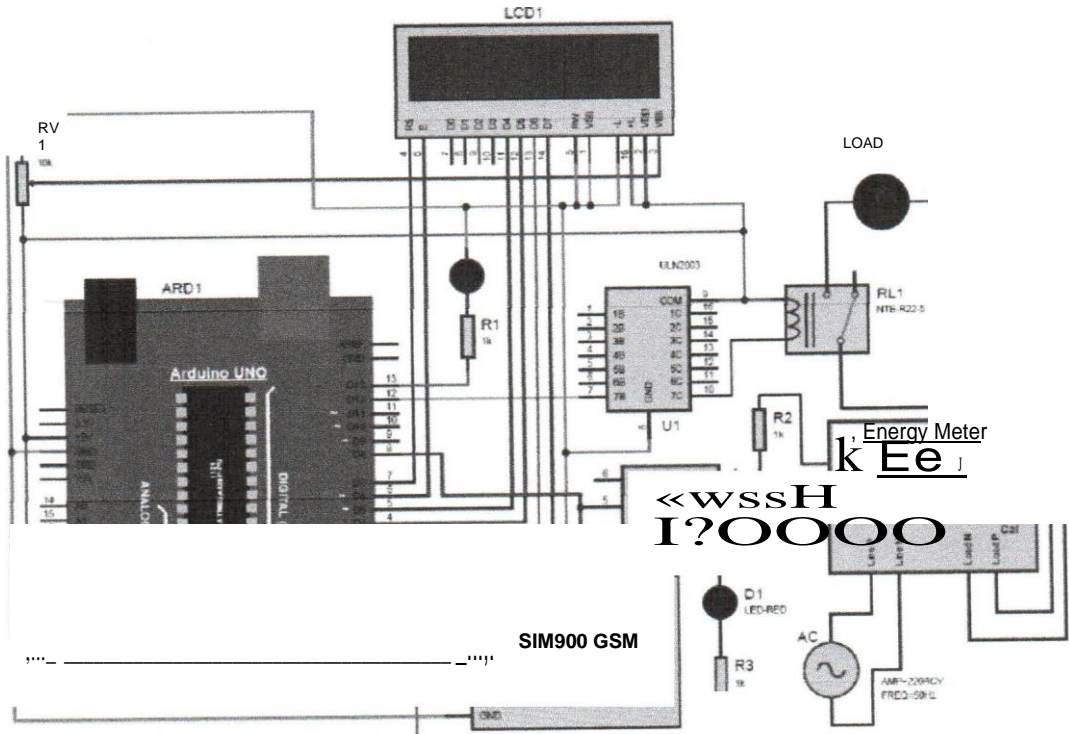
3.3. Objective 3

To develop an algorithm for interpreting SMS in order to extract energy meter token for loading onto the consumer interface.

Loading units. The customer sends a message with the token to the meter using a mobile phone, the Arduino extracts the units from the token and loads it automatically onto the energy meter. The credit balance will then be the units loaded minus the units used as displayed on the LCD.

Balance. If the user requests for the balance using his mobile phone, the system responds with an SMS by sending it to the user mobile phone.

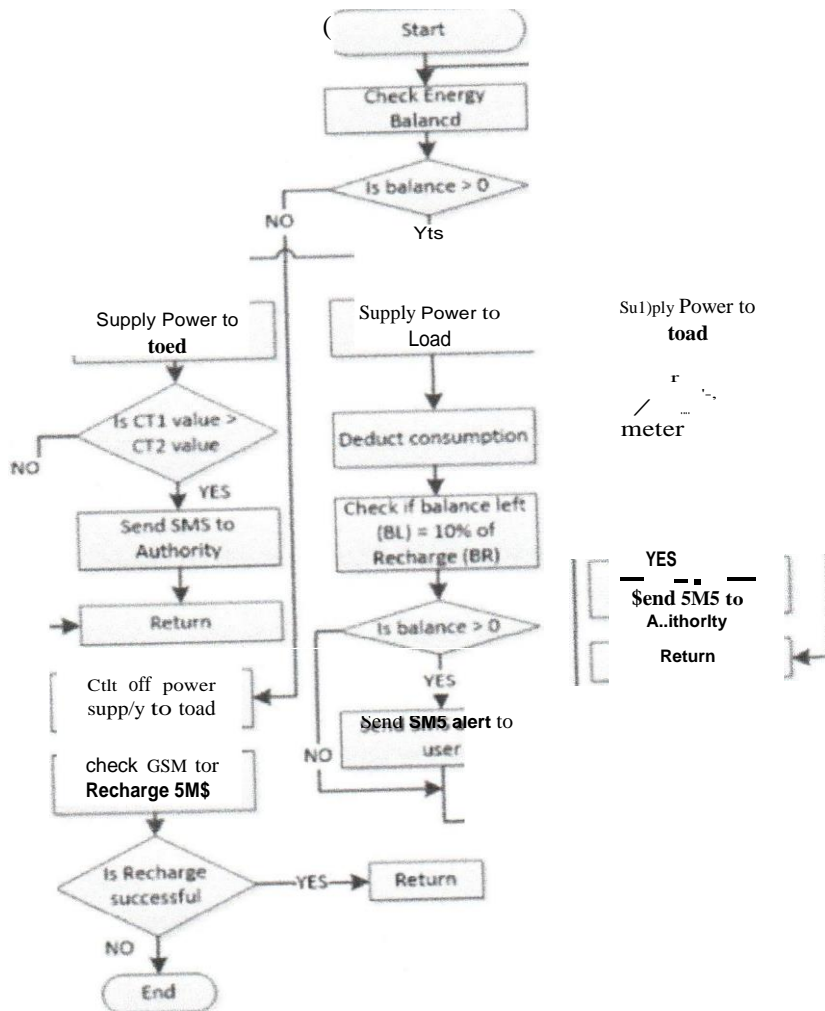
If the balance is less than 15kwh, it sends you an alert message showing that the units are low, and when balance is Okwh, it turns off electricity [14]



[[15]

FIGURE 16: CIRCUIT DIAGRAM OF THE HYBRID ENERGY METER

FLOW CHART DESCRIPTION.



[[161]

FIGURE 17: FLOW CHART SHOWING THE HYBRID ENERGY METERING SYSTEM

The system checks for the balance, if the balance is higher than 0, power is supplied to the load the balance is checked upon. If the balance is 0, then the message is sent to the user and the power goes off.

If the balance is less than 0 power is cut off from the system. The system sends you a message to load the units on your mobile user phone. If the recharge token is successful, then the GSM checks for the recharge SMS and cut off the power to the supply Loads

CHAPTER FOUR

EXPERIMENTS PERFORMED

4.1. Measuring the power consumed

In this experiment, I designed a circuit used for measuring the power consume

4.1.1. Tools and materials used

Analog energy meter

Calibration led

LCD

Arduino Nano

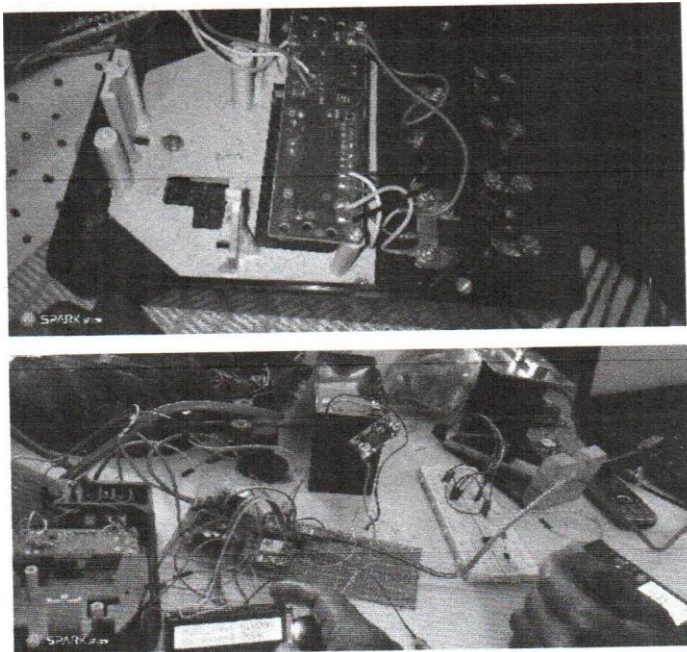
Opto-coupler

4.1.2. procedure

- a) I connected the calibration LED to the energy meter
- b) The output of the calibration LED was connected to one side of the opto-coupler and the other side of the opto-coupler was connected to the other side of the Arduino to the **digital pin.**
- c) I used the digital Read function to read the state of the opto-coupler every time the calibration LED goes high or low.

4.1.3. Precautions taken.

The calibration led was isolated from the micro controller through the opto-coupler



q)

FIGURE I8: SHOWING THE INSIDE OF THE ANALOG ENERGY METER SYSTEM

4.2. Setting up the communication unit

4.2.1. Tools used

GSM

Sim card

Mobile phone

4.2.2. Procedure

- a) I connected the Arduino to the GSM
- b) The Rx and Tx pins of the GSM were connected to software serial pins for communication using the software serial library
- c) AT commands were used for communication between the mobile phones and the GSM.
- d) [17]

4.2.3. Precautions taken

The GSM module had to be connected to a two-amp power supply otherwise it would not connect to the network.

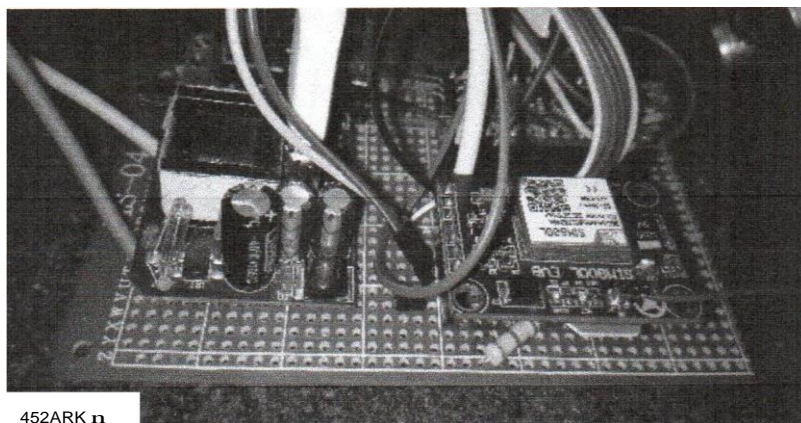


FIGURE 19: SHOWING HOW TO INSERT THE SIM CARD INTO THE GSM MODULE

4.3. SMS interpretation and token extraction.

Here I had to design a software for interpreting SMS received, extracting token and sending messages to the user.

4.3.1. Tools and materials used

- a) Arduino IDE (integrated development environment)
- b) Sim card
- c) Mobile phone
- d) Text messaging application

4.3.2. Procedure

The messages were sent in a string format. The string then was converted into an integer using a `StringToInt ()` function and multiplied by a constant to get the units

The message for extracting balance was indexed by a `*` for example `{BAL}`

4.4. RESULTS AND DISCUSSIONS

4.4.1. Loading units.

The system was able to read, interpret the message sent by the mobile user and extract a token then load it automatically. However, I didn't create a data base for billing customers which will be left for future work.



FIGURE 20: LOADING UNITS

4.4.2. Calculation of pulses.

The metering unit was able to measure how much power was consumed using a pulse rate of 1600 imp/kwh. However, I didn't include the backup power or external memory *in* case power went off.

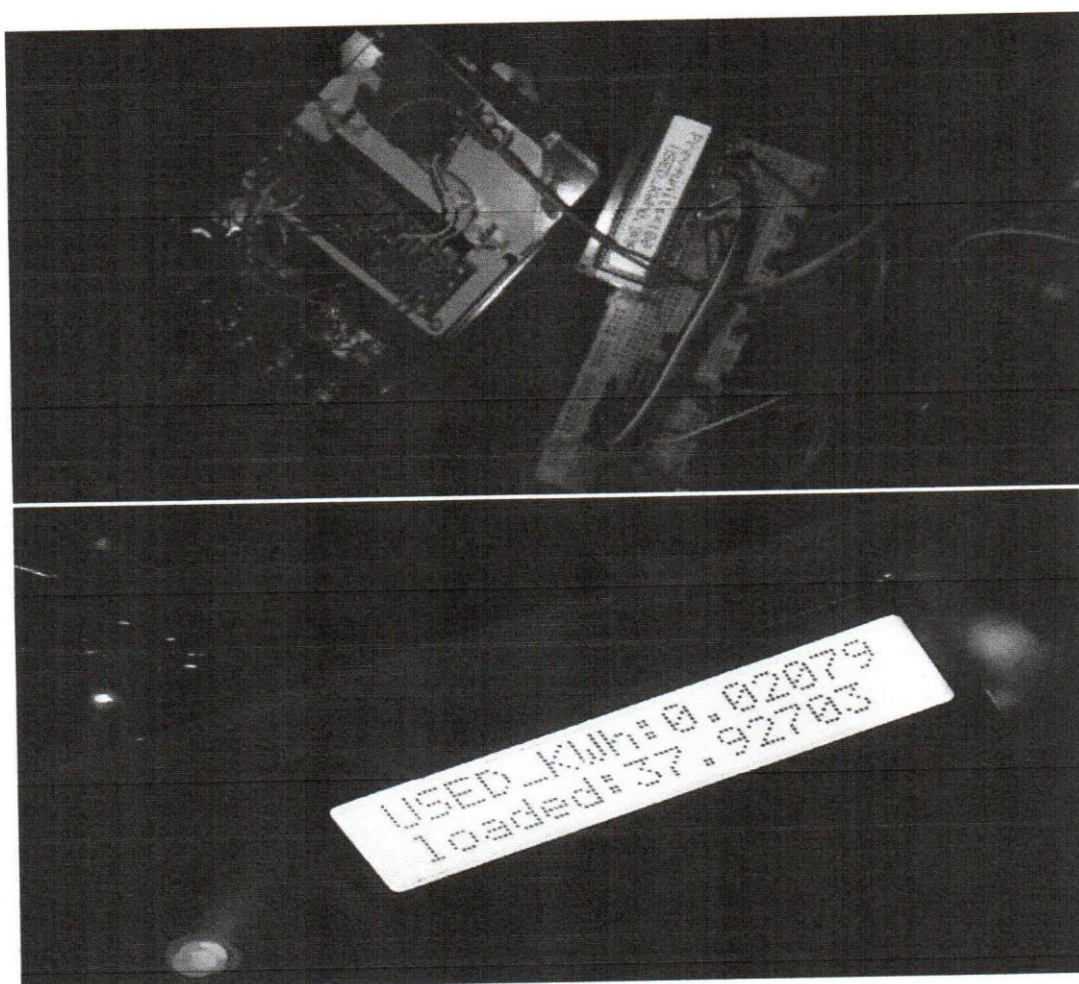


FIGURE 21: CALCULATION OF PULSES

4.4.3. Communication between customer's mobile phone a

The system was able to interpret messages sent by the mobile user

The system was able to interpret the message and reply with the unit's balance

In addition, when the credit balance was low, the system was able to send you the message to recharge the units.



FIGURE 22: SMS RESPONSES AND ALERTS.

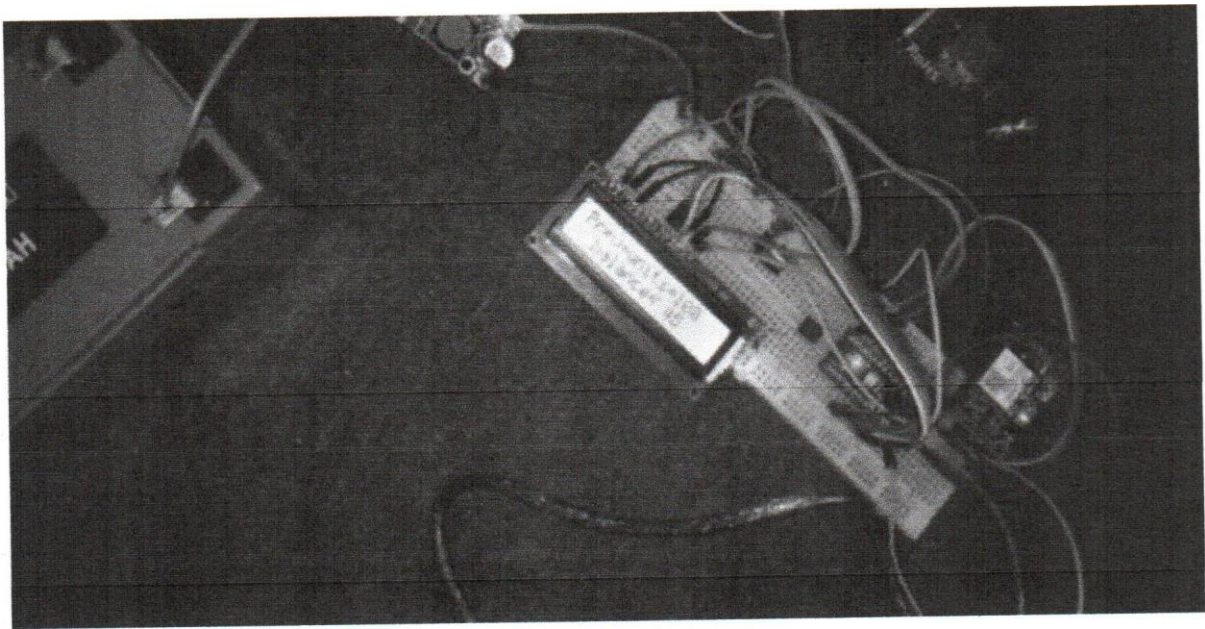


FIGURE 23: SHOWING THE LCD DISPLAYING THE LOADED AI'D USED UNITS.

CHAPTER FIVE

5.1. CONCLUSIONS

The Hybrid smart energy meter describes the design and working of Smart Energy Meter and represents how Smart Energy Meter can be used for Automatic Meter Reading. It is the most economical implementation to develop mankind in this era of technology.

With the present enhancement in the use of technology to facilitate mankind, it is an efficient and practical utilization of present networks. This project also shows that how customer can manage the load by using Smart Energy Meter. It provides ease in taking the meter readings, accuracy, detection of faulty conditions, less operation cost, ease in loading units onto the energy meter and removal of possible corruption related to meter reading.

As I was doing this project, I thought there are few possibilities which can also be done on this project in future as I have provided flexibility in the project especially in controller section. The future research should include the proper methodology for measuring the power factor of the load.

This system has made token recharge more flexible, easy, and reduces the risk of going out to key-in recharge token into meters at odd hours in environments where security is an issue at such time for the consumer

5.2. Recommendations

Instead of GSM networks, some other means of communication should be used.

In case of GSM, there must be security of GSM so that it can't be hacked.

Power factor must be measured by different techniques.

Linking of the data received by GSM to computer and developing a program which incorporates the tariff related to specific consumer and calculating the bill directly on the computer. In this way the computer will calculate the bill directly using the data received through GSM network.

Smart energy Meter can be modified for the detection of illegal use of electricity

REFERENCES

- [1] Abdulrahman Okino Otuoze and Nasir Faruk, "Arduino, "Arduino Nano," [Online]. Available: <https://www.arduino.cc/en/up1oads/Main/ArduinoNanoManual23.pdf..> [Accessed 14th january 1998].
- [2] arduino, "Arduino Nano (V2.3), User manual," [Online]. Available: <https://www.arduino.cc/en/up1oads/Main/ArduinoNanoManual23.pdf.> [Accessed 13 11 2020].
- [3] A. m. "ACS712, Fully Integrated, Hall-Effect-Based Linear Current Sensor IC," [Online]. Available: <https://www.allegromicro.com/en/products/sense/current-sensor-ics/zero-to-fifty-amp-integrated-conductor-sensor-ics/acs712>. [Accessed 14 11 2020]., "Yu and S Hwang,," [Online]. Available: In First International Conference Proceedings on Information and Communication Technology Development, May 2006. [Accessed 13th april 2006].
- [4] E. Amhenrior,, "Analysis and Development of a GSM Based Recharging and Monitoring of Energy Metering System," [Online]. Available: Texas Instruments, "LM2596 SIMPLE SWITCHER Power **Converter** 150-kHz," 2000. [Online]. Available: https://www.ti.com/lit/ds/symlink/lm2596.pdf?ts=1605487616688&ref_url=https%2534%252F%252Fwww.ti.com%252Fproduct%252FLM2S96. [Accessed 14 11 2020] .. [Accessed 14 february 2009].
- [5] S. [Online]., "E:\my project\ Types of Energy Meter and their working Principles.mhtml," Types of Energy Meter and their working Principles, 2 August 20178 August 2019. [Online]. Available: International Journal of Engineering research and General Science, vol. 2, no. 3, p. 8,2015.. [Accessed 18th April 2009].
- [6] Sourav Gupta, "Types of opto couplers Home/ Miscellaneous Circuits/ Optocoupler Tutorial," [Online]. Available: ANALOG ([HTTPS://CIRCUITDIGEST.COM/ANALOG-ELECTRONICS](https://CIRCUITDIGEST.COM/ANALOG-ELECTRONICS)). [Accessed 07 may 2018].
- [7] Adnan Aqeel, "Introduction to Arduino Nano," [Online]. Available: www.engineeringprojects.com. [Accessed 08th march 2017].
- [g] "E:\my project\Prepaid Energy Meter using GSM and Arduino - Use Arduino for Projects.mhtml" [Online]. Available: E:\my project\Prepaid Energy Meter using GSM and Arduino - Use Arduino for Projects.mhtml. [Accessed 07th june 2016].
- [9] SIMCOM Giri prasad S Akesh R BalaPravin C Gokila devi S gowri, "SIM800L DataSheet," SIMCOM, [Online]. Available: [www."Design of GSM - SMS based system for old structured greenhouses with monitoring and logging network sensors](http://www.simcom.com.tw). [Accessed 27 april 2017}.
- [10] Nazmat Toyin SURAJUDEEN-Bakinde, "Types of Energy Meter and their working Principles," [Online]. Available: [mhtml:file:///E:/my%20project/Types%20of%20Energy%20Meter%20and%20their%20working%20Principles.mhtml!http://learn4electrica1.altervista.org/types-of-energy-meter-and-their-working-principles/](http://E:/my%20project/Types%20of%20Energy%20Meter%20and%20their%20working%20Principles.mhtml!http://learn4electrica1.altervista.org/types-of-energy-meter-and-their-working-principles/). [Accessed 02 august 2017].
- [11] ROBERT KEIM, "electronics projects focus EL-PRO-CUS," [Online]. Available: www.elprocus.com. [Accessed 06th August 2018].
- [12] FA MAHDI, "hybrid electronic meter designn," [Online]. Available: www.tandfonline.com. [Accessed 08TH JUNE 1985].
- [13] Victor Olugbenga Matthews, Peter Aigboviosa Amaize, Joseph Oluwole Oloweni, "Arduino Nano (V2.3), User manual," [Online]. Available:

module&psig==AOvVaw2ixQ4tWciYdFRBfPOsEFER&ust==1606311742539000&source==images&cd==vfe
& ved=2ahUKEwj1eLXp5vtAhUMQBoKHQyHDOoQr4kDegUIARCqAQ. [Accessed 13th december 2004).

- [14] R, BalaPravin. C, Gokila Devi. S, Gowri Devi, "Arduino Based Wireless Power Meter," [Online]. Available: <https://www.google.com/ur?sa=i&url=https%3A%2F%2Fcomponents101.com%2Fsensors%2Facs71l>. [Accessed 05th may 2005].
- [15] M. F. Ismail, Chow Cheeonn and Kamarul Arifin,, "WADa," International electrical Research and Development, vol 4, [Online]. Available: www.international-research-journal-of-applied-and-basic-sciences,AOvVaw2ixQ4tWciY dFRBf POsEFER&ust=1606311742539000&source=images&cd=vfe&ved=2ahUKEwj1eLXp5vtAhUMQBoKHQyHDOoQr4kDegUIARCqAQ. [Accessed 13 august 2012].
- [16] M. Christopher, "EIProCus - Electronic Projects for Engineering Students," [Online]. Available: [https://thesolaruniverse.wordpress.com/2017/08/21/the-ds18b20-temperature-sensor-implementation-wi..](https://thesolaruniverse.wordpress.com/2017/08/21/the-ds18b20-temperature-sensor-implementation-wi/) [Accessed 14 november 2001].
- [17] Anthony Uwakhonye Adoghe, Victor Olugbenga Matthews, "Development of a GSM Based Recharging and Monitoring of Energy Metering System," [Online]. Available: <https://www.google.com/imgres?imgurl=https%34%2F%2Fi.pinimg.com%2Foriginals%2F0c%2F842f07%2F0c84077f8e18ce880edc869eec7d2ada.jpg&imgrefurl=https%3A%2F%2Fwww.pinterest.ca%2Fpin%2F316659417544808169%2F&tbid=ZCTqCB9W3KSM1M&v>. [Accessed 30th july 2007].
- [18] Nazmat Toyin SURAJUDEEN-Bakinde, Sunday Olufenka Ayodele, Timilehin David Oloruntoba, Abdulrahman Okino Otuoze and Nasir Faruk, "Development of an Internet Based Prepaid Energy Meter" IEEE 3rd International Conference on Electro-Technology for National Development," [Online]. Available: Projects.mhtml, E:\my project\Prepaid Energy Meter using GSM and Arduino - Use Arduino for. [Accessed 12th january 2005].
- [19] Bahman Zohuri, "The Electricity: An Essential Necessity," 12 October 2020. [Online]. Available: <https://www.researchgate.net/publication/301260940>. [Accessed 4 11 2020]., "Development of an Internet Based Prepaid Energy Meter" IEEE 3rd International Conference on Electro-Technology for National Development (NGERCON)," [Online]. Available: <https://www.google.com/imgres?imgurl=https%34%2F%2Fi.pinimg.com%2Foriginals%2F0c%2F84%2F07%2F0c84077f8e18ce880edc869eec7d2ada.jpg&imgrefurl=https%3A%2F%2Fwww.pinterest.ca%2Fpin%2F316659417544808169%2F&tbid>. [Accessed 20th may 2008].
- [20] EIProCus - Electronic Projects for Engineering Students, "Bipolar Junction Transistors Working Principle and Applications," [Online]. Available: www.biopolarprojects.com. [Accessed 14 JUNE 2016].
- [21] Sunday Olufenka Ayodele, Timilehin David Oloruntoba, Abdulrahman Okino, "Electronic Projects for Engineering Students," [Online]. Available: [arduino, "Arduino," Github, \[Online\]. Available: https://github.com/arduino/Arduino](https://github.com/arduino/Arduino). [Accessed 13 11 2020]. [Accessed 18th march 2002].
- 22] P. T. M. E. M. Robert Tumwesigye, "Key issues in Uganda's energy sector," [Online]. Available: <https://pubs.iied.org/pdfs/16030IIED.pdf>. [Accessed 4 11 2020]., "Arduino Based Wireless Power Meter in uganda," [Online]. Available: <https://www.google.com/imgres?imgurl=https%3A%2F%2Fi.pinimg.com%2Foriginals%2F0c%2F84%2F0792F084077f8e18ce880edc869eec7d2ada.jpg&imgrefurl=https%34%2F%2>. [Accessed 25th october 2010]
- [23]

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APPENDIX

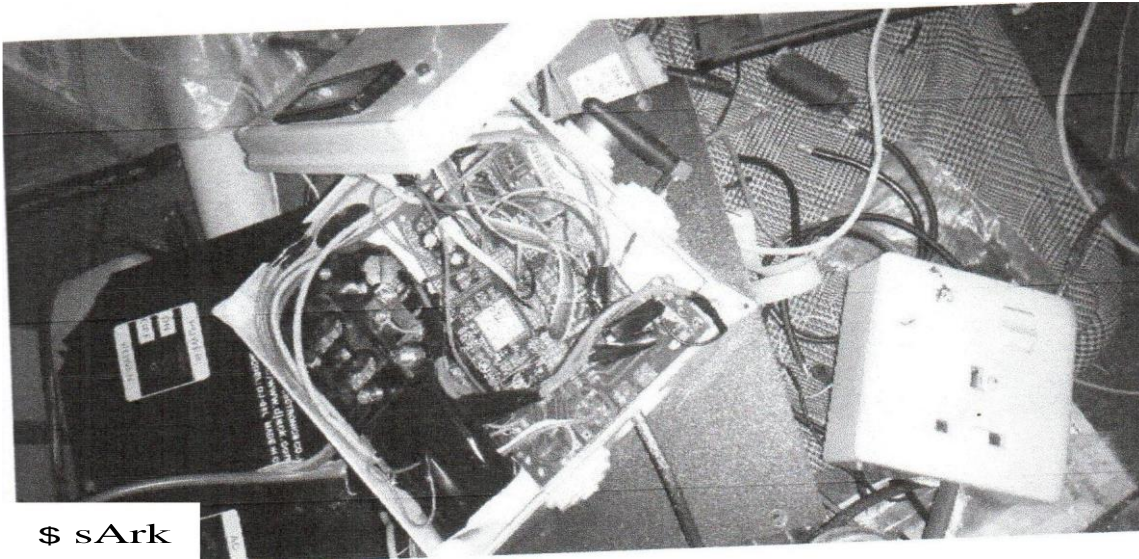


FIGURE 24: CONNECTION TO THE BOARD

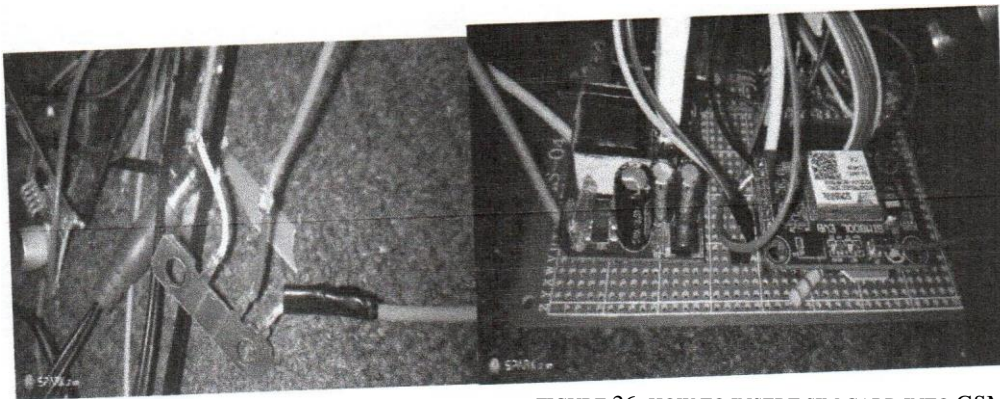


FIGURE 25: METER TERMINAL CONNECTIONS

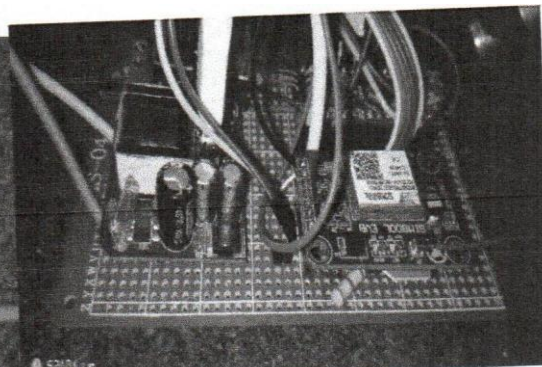


FIGURE 26: HOW TO INSERT SIM CARD INTO GSM

u)

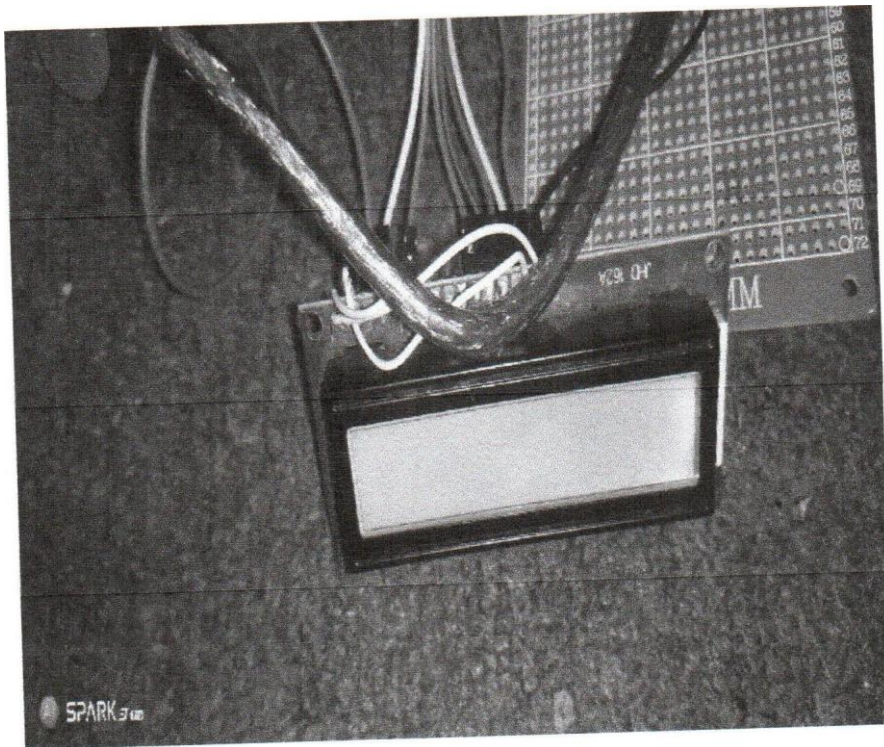


FIGURE 31: LCD DISPLAY

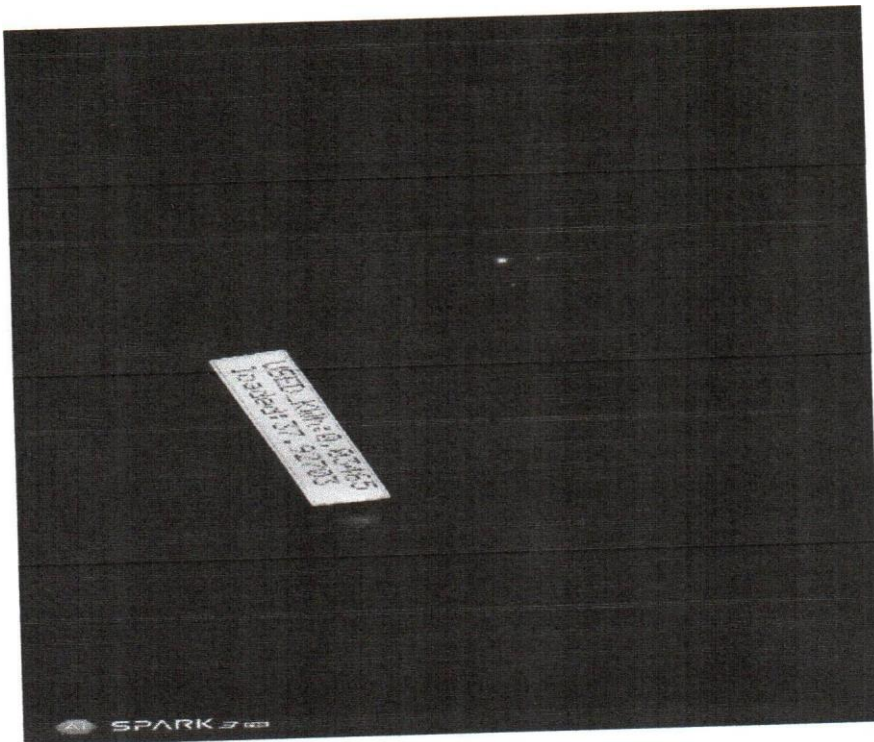


FIGURE 32: LCD DISPLAYING THE UNITS LOADED AND THE BALANCE