MULTIMEDIA UNIVERSITY OF KENYA

FACULTY OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND COMMUNICATION ENGINEERING

FINAL YEAR PROJECT PROPOSAL

SMART PREPAID ENERGY METER

By,

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ENG-219-114/2013

Submitted in partial fulfilment of the requirements for the award of BSc. Degree in Electrical and Telecommunication Engineering at the Multimedia University of Kenya.

ABSTRACT

As the world's electric utility companies move towards a smart grid system, most countries are adopting smart meters that are equipped with Prepayment facilities that facilitate billing. The main drawback of these systems is the current payment methods that are relatively costly. They are also labour and time-consuming.

This research project intends to use prepaid energy meters to read energy consumption. This energy meter will be interfaced with an Arduino microcontroller. The microcontroller takes readings from the meter and passes them on to a GSM module via web-based technology. An LCD display will also be integrated to display these readings. A communication system between the module and the consumers mobile phone (android application) will be achieved using (internet of things) IoT. The consumer will thus be able to use their mobile phones to see their token (utility units) balance, get notifications of low units based on a set minimum value and recharge the electricity units remotely. The automated billing system will keep track of the real-time consumption hence the consumer can efficiently manage consumption.

DEDICATION

This research is dedicated to The Multimedia University of Kenya faculty of Engineering and Technology.

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Chapter 1 INTRODUCTION

1.1 BACKGROUND

Electric meters are the direct billing interface between service utility companies and electricity consumers.

Electrical energy metering technology has evolved over the past years from the original bulky and heavy electromechanical meter introduced by Thomas Alva Edison (1847-1931), which used the magnetic effect of the current [1]. They were proceeded by onward improvements to Motor meters and later induction meters when an Italian Galileo Ferraris (1847- 1897), made a key discovery that two out-of-phase AC fields could make a solid or cylinder rotate and the accidental discovery of effects rotating fields would lead to the development of Ampere-hour meters. The initial improvements of meters continued until 1934. The Discovery of integrated circuits in the 1970s gave way to Digital meters. Initially, highly precise meters were introduced that used the time-division multiplication principle in the 1980s. Later remote metering was introduced giving rise to the currently and most widely used pre-paid energy meters**.** Innovations over the years have led to a reduction in the size and weight of energy meters. It has also led to an improvement in specifications and overall integrated features. High levels of accuracy and better resolutions have also been achieved in recent years hence concurrent improvement in Electricity billing systems. The introduction of digital electronic meters has aided in automating the billing systems of electric energy. Current prepaid energy

meters require costumers to visit electricity utility sales points, buy electricity units, where there are provided in terms of vouchers (or tokens) that are then inputted meter manually through a keypad.

1.2 PROBLEM STATEMENT

Even with the improvement of billing systems and meter technology, the payment methods have not yet seen the light of day. The current pre-paid meter system requires the consumer to visit utility points (or use mobile money) and buy the tokens, which are then manually inputted into the meter through a keyboard in the residence. These methods may be inconvenient to the consumer with the current trends and development from a cash economy to digital finance, moreover, in case the electricity outage caused by insufficient tokens, the period of the blackout may be critical depending on the facility being powered, (Clinics, schools, etc.).

This is research intends to make an advance on the pre-paid meter system by developing a remote meter tokens recharge method and embrace mobile money payment as well.

1.3 AIMS AND OBJECTIVES OF STUDY

The aim of this study is to design and implement an intelligent pre-paid energy meter that will enable remote recharge. The specific objectives include;

- Use GSM technology and ANDROID to enable mobile recharge of electricity hence creating ease to the consumer
- Aid utility companies through monitoring of power consumption and provide more accurate billing,

1.4 JUSTIFICATION OF STUDY

Energy supply systems are undergoing constant profound transformation and in the coming years, there will be great changes in the way electricity is supplied and consumed. Smart metering is one of the consumer empowerment tools that this research intends to bring along with these improvements. Smart metering and payment system will not only aid the consumer but also support the Energy goals of achieving a **smart grid** in the near future and with smart metering being one of the early steps.

1.5 MOTIVATION

Focusing on commercial aspects of electric metering and the development of the latest results in modern technology, smart meters and payment methods are key for the continued success in metering history.

Chapter 2 LITERATURE REVIEW

2.1 Introduction

As commercial use of electric power spread in the 1880s, it became increasingly important that an electrical energy meter was required to bill consumers for the cost of energy. Many experimental types of meters were developed starting from the basic electromechanical meter developed by Edison, to digital meters and later smart meters that are currently being adopted. The methods of payment have also evolved concurrently to the development of energy meters. This chapter addresses the conventional meters and methods of payment being used and the recommended meter improvement. Meters can be categorized into electromechanical and Electrical meters.

2.2 TYPES OF METERS

2.2.1 Electrical Meters

Electricity meters operate by continuously measuring the instantaneous voltage (volts) and current (amperes) and finding the product of these to give instantaneous electrical

power (watts) which is then integrated against time to give energy used (joules, kilowatt-hours). Meters for smaller services (such as small residential customers) can be connected directly in-line between source and customer. The concept of electric meters was the base for development of digital meters.

2.2.2 Digital Meters

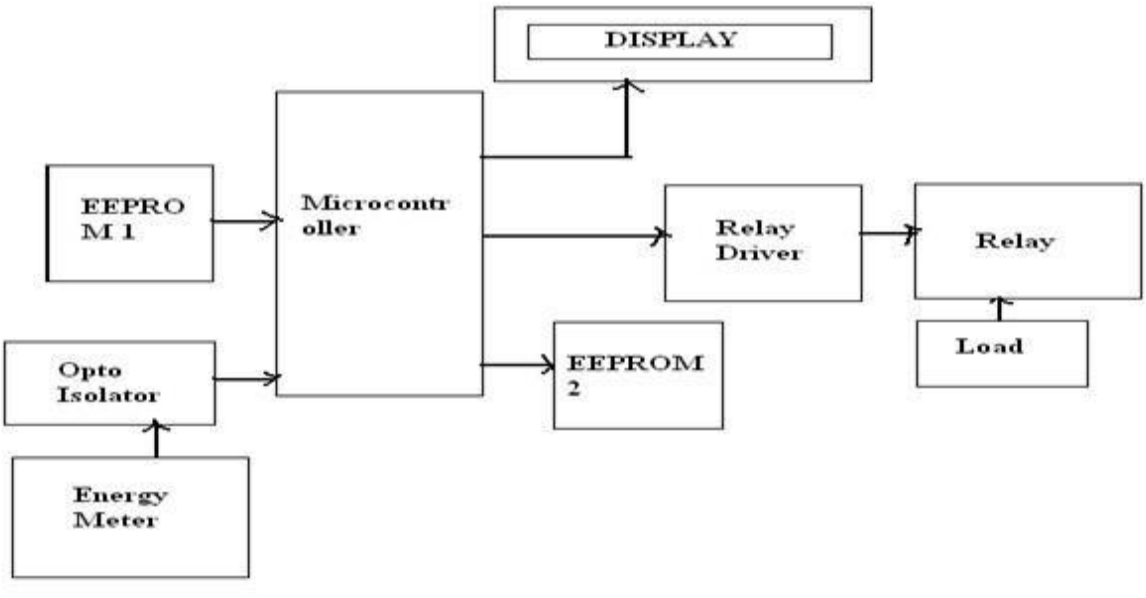
It uses an alternating current (AC) supplied through a current transformer (CT) and a potential transformer (PT) so that any sudden changes in the voltage and currents will not affect the energy meter. These transformers also step down the voltage and the current to circuit levels. The output of the CT and PT is supplied to Energy Meter integrated circuit (IC) which generates the pulses according to the energy supplied to it. The pulse output of the Energy Meter IC is supplied to the microcontroller's counter pin so that the microcontroller can count the number of pulses and calculate the energy supplied to the consumer. Software burned on to the microcontroller performs the usage calculations. The LCD display is used to display the number of units consumed by the consumer [3]. The digital energy meter is fixed in the premise for measuring the usage. Digital meters have solved many of the problems with the preceding Electrical Energy Meter.

The major disadvantage of the digital energy meter is that it does not address the billing which is a labour-consuming process

2.2.3 Prepaid Energy Meters

The use of prepaid energy metering has been widely used in the UK for over 70 years with about 3.5 million consumers [2]. In South Africa, this system was introduced in 1992 installing about 6 million meters. The use of prepaid meters has continued to grow into the Kenyan utility market with about a million installations and is spreading to other countries such as Nigeria, Madagascar and New Zealand with a few thousand installations.

The working of a prepaid meter is achieved by using a removable part that can be loaded (and later reloaded) with a specified amount of energy by the utility (tokens). The prepaid energy meter is the upgraded version of the digital energy meter with an extra feature, i.e. a prepaid system using an Electrically Erasable Programmable Read-Only Memory (EEPROM) chip. In this meter, the EEPROM chip is used for recharging the units to enable that power usage. When the number of units in the EEPROM reaches zero, the timer pin of the microcontroller will activate the relay to disconnect the supply to the consumer. The LCD displays the number of units used by the consumer and the number of units left for use



The advantages of prepaid energy meters include:

1) Improved operational efficiencies
2) Reduced financial risks
3) Better customer service

2.3 EXISTING BILLING AND PAYMENT METHODS

2.3.1 Smart card based prepaid energy meters

A smart card is a credit card-sized plastic card embedded with an integrated circuit (IC) and usually, it consists of a (read-only memory) ROM, EEPROM and a (central processing unit) CPU. A smart card provides both memory capacity and computational capability. Access to data stored on the card is under the control of the smart card operating system. In this method, the consumer has to have the smart card recharged for the amount he chooses and enters the card into the card reader of the energy meter[5]. Then the meter store the number of units recharged and start to measures the energy consumption. When purchased units are used up the meter disconnect the power supply until the next recharge [5].

2.3.2 RFID (Radio-Frequency Identification) based Prepaid Energy Meters

Radio-frequency identification (RFID) is an automatic identification method, relying on storing and remotely retrieving data using devices called RFID tags or transponders [6].

The technology requires some extent of cooperation of an RFID reader and an RFID tag. An RFID tag is an object that can be applied to or incorporated into a product, animal, or person for the purpose of identification and tracking using radio waves. Some tags can be read from several meters away and beyond the line of sight of the reader [6].

In this method RFID cards which are issued by the electricity suppliers to individual consumers are used. This RFID card is unique with a code in it and consumers are free to make flexible recharge. When the consumer wants to use the system he needs to show the card to the reader, then the unique code inside the card is recognized by the reader and starts deducing the amount of the RFID card as per the quantized unit charge. When the user completes the consumer has to recharge the RFID card again.

2.4 TREND IN ELECTRIC SUPPLY AND CONSUMPTION

2.4.1 Smart Grid System

Greentech Media Company Research identifies Smart Grid as the convergence of three sectors – Electric Power which is the physical power layer, Telecommunication Infrastructure which is the communication and control layer and Information Technology which is the application and services layer. Expertise from all three layers is required for a complete end-to-end Smart Grid Infrastructure. Each layer has its own set of challenges that needs to be overcome [7]. With today's technology, the power grid can become a smart grid, capable of recording, analyzing and reacting to transmission data, allowing for more

2.5 PROPOSED SYSTEM

With an aim to achieve and be part of the Smart grid System, development of smart meters and smart methods of utility payment is thus paramount. The proposed system is an innovative solution aimed at facilitating affordability and reducing the cost of utilities. This mechanism, essentially, requires the users to pay for the electricity before its consumption. The development of GSM infrastructure in past two decades made meter reading system wireless. The GSM infrastructure, which has national wide coverage, can be used to request and retrieve power consumption notification over individual houses and flats. Apart from making readings using GSM communication, billing and payment system is needed to be made remotely to avoid unnecessary usage of power and labour.

Following features are included in the proposed digital prepaid energy meter

1) Automated service disconnection and remote meter reading facility.
2) To include a mobile app from which user can remotely monitor his electricity usage.
3) Payments can be made through mobile service providers
4) A web account is allocated to each customer to make online payments and recharge meters through the android app.
5) Customer receives a notification when the remaining energy goes below the first notification level through the mobile app.

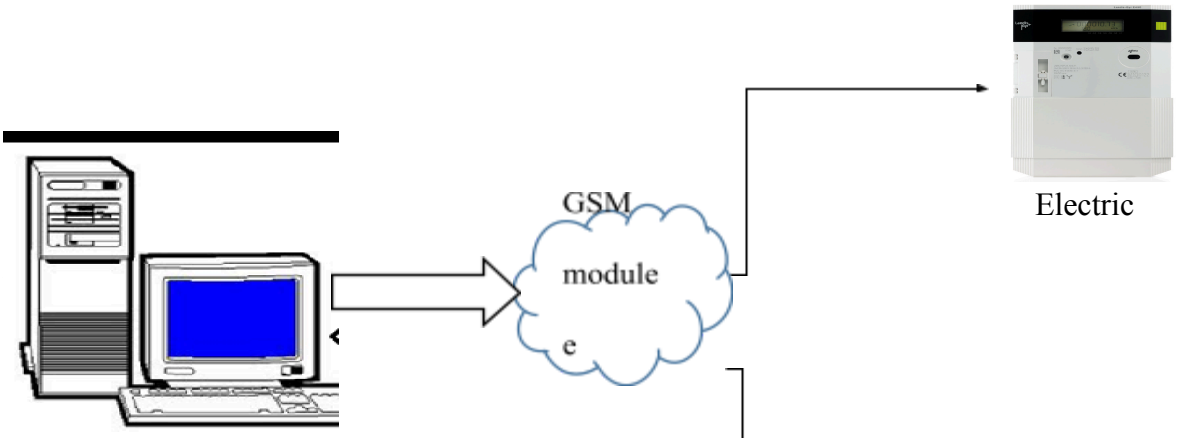


Figure 2-2 : Proposed system architecture

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Chapter 2

Chapter 3 METHODOLOGY

This chapter presents the system design and the architecture to come up with the proposed smart prepaid energy meter system.

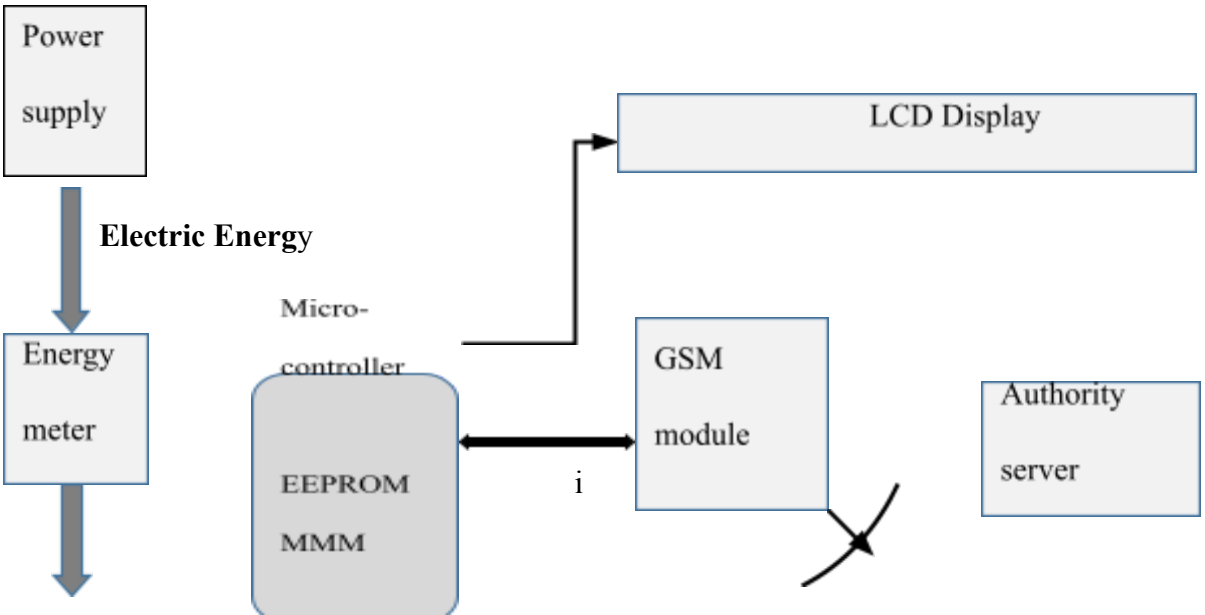
The data collection methods are introduced. A general and wide description of the system design, architecture and system development is then given.

3.1 SYSTEM ARCHITECTURE

3.1.1 Introduction

This Research is useful for billing purposes in Electricity board. Instead of going to every house and taking the readings or using a token as used for the postpaid system or buying tokens and manually inputting them into the meter, by just the use of a mobile phone the readings of the house can be received and the electric bill can be recharged

through an Android application. The microcontroller and the GSM unit are interfaced with the prepaid energy meter of each house. Every house has a separate and unique number, which is given by the corresponding authority. The GSM unit is fixed in the energy meter. The amount of consumption is stored in the microcontroller's Electronic erasable programmable Read-only memory (EEPROM), where consumed units and balance are stored temporarily. Using this system, signals can be sent from the android mobile phone through the GSM Modem to that particular meter number which is assigned by these authorities and the consumer will wait for the response. On other end, the modem will receive the data in the form of a command and informs the controller to do the readings. After the readings the controller will send data to the modem. The modem, in turn sends data to the other end. In the office the GSM unit will receive the data and the total consumption information. The number assigned by the authorities is unique. Using GSM, the response can be obtained very fast, due to which time is saved. After consumption of the entire balance on the meter, the power will be cut-off, and the consumer must send a signal to recharge. This will reduce illegal power using without paying money, and also able to solve by - pass of voltage.



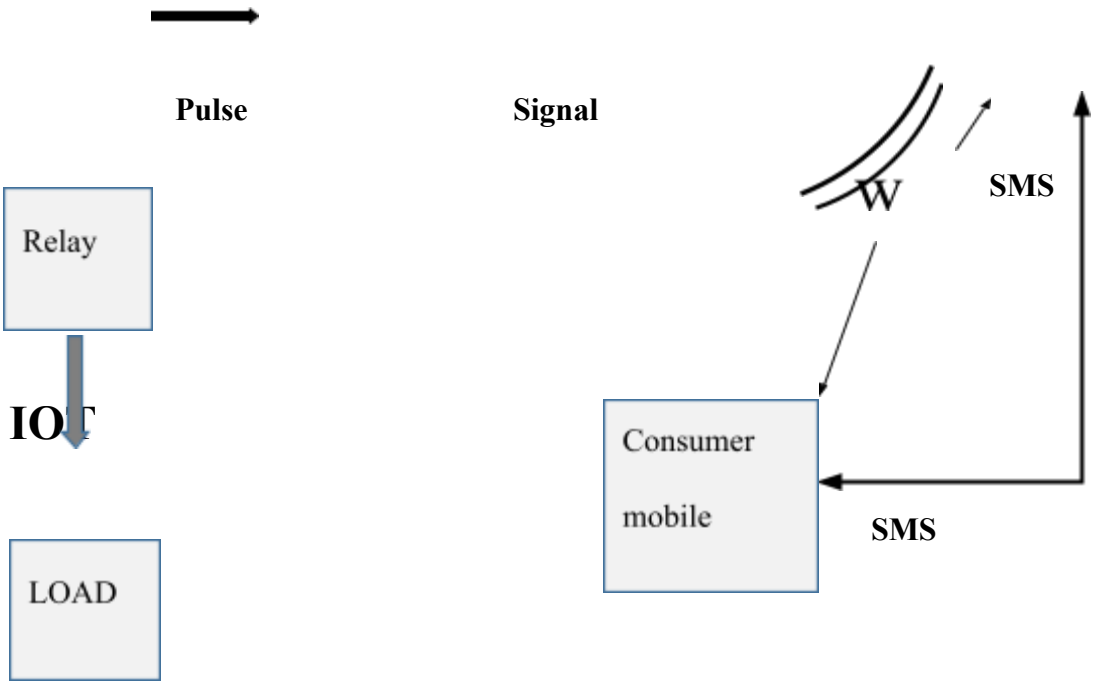


Figure 3-1: Block diagram of a Prepaid Digital Energy Meter [4]

3.2 SYSTEM DEVELOPMENT

3.2.1 Data collection

As the first step of the design process is an online survey conducted in order to decide the most convenient payment method for consumers. The survey will also be purposed to predict the number of electricity consumers that have Android Mobile phones and these that can conveniently get access to one. It will also determine the

number of consumers that are currently using the prepaid meter system hence demine the number of subscribers that can be integrated into the system.

3.2.2 Design of power supply unit

An AC signal is applied directly then a 230 V A.C – 12 V D.C step down transformer is used as power supply. A rectifier circuit is used to convert A.C into D.C. at the output of rectifier circuit +12V power supply is generated.

When an AC signal is applied to the primary coil of the transformer, due to the magnetic effect of these conductors magnetic flux is generated in these conductors (primary) and this flux is transferred to the secondary conductors by the transformer action. Transformer is an electromechanical static device which transforms electrical energy from one conductors to another without any change in its frequency. Here the diodes are connected in a bridge section. The secondary conductors of the transformer is given to the bridge circuit for the purpose of rectification. This is the conversion of AC to DC current.

12V 1A is fed into the power input of board. Polarity should be Center +ve and outer –ve DC jack.

3.2.3 Design of energy meter

This unit is composed of a metering device, which will provide measurements of load consumption. The energy meter is also intended to send signals to the prepaid module.

Metering device obtained for this research is designed according to the IEC1036 (1996-09)-Alternating Current Watt-Hour Meters for Active Energy (Classes 1 and 2) using AD7755AAN single-phase unidirectional power metering IC. It generates an output frequency that is proportional to the average real power with a meter constant of 100 imp/kWh [1].

This metering device will use a current sensing device to measure the accurate current consumed by the load. The current sensor is needed to monitor the current flow by measuring and reporting the actual current usage and the current phase angle to the microcontroller. It is also needed to operate accurately and linearly in order to obtain the accurate usage and consequently the accurate power usage. It is expected to be able to hold the maximum current of 10 Amperes. The current sensor was designed to connect directly to the load on the input side and to the Energy meter IC on the output side. The input to the entity is the value of the voltage drop across a shunt resistor and the output to the meter IC is the voltage that is proportional to the input voltage. The ratio of the input and output voltage would depend on the model of the current transformer used in the circuit [8]. These measurements of power consumption are relayed to the microcontroller in the prepaid module.

3.2.4 Design of Prepaid Module

The prepaid module consists of a microcontroller, GSM module, a contactor (Solid-state relay), a backup battery and an LCD display.

3.2.5 Design of the microcontroller

In this work the microcontroller part is playing a major role, which is used to read and store the data received from the consumers' mobile phone. According to the received command from the mobile phone, the microcontroller displays the consumed energy information on the LCD display and at the same time energizes the relay and alarm automatically when the GSM module passes the information, just before exhausting the energy. In this research, a microcontroller unit is programmed for the base unit as well as recharge unit and receiver unit. Micro-controller unit is constructed with an Arduino micro-controller chip with a flash programmable and erasable read only memory (EEPROM). Its high-density non-volatile memory compatible with GSM codes instruction set makes it a powerful controller that provides highly flexible and cost effective solution to control applications.

3.2.6 Design of a LCD display

Information such as No of remaining Units and Recharged units need to be displayed. This is done on the consumer's mobile phone as well as on an liquid crystal display (LCD) unit.

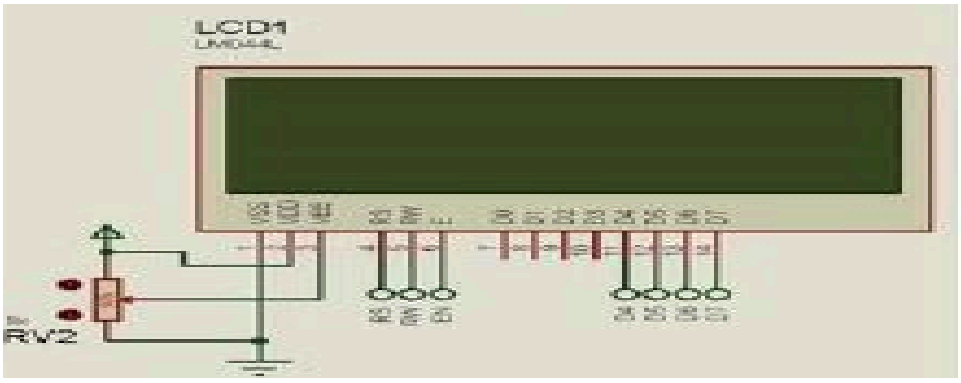


Figure 3-2 : 20x4 LCD

3.2.7 Designing of Relay

Based on the calculation results by the prepaid, if it is deemed to exceed the specified load, the system will disconnect the electrical current. In order to disconnect automatically is necessary to install the circuit breaker module.

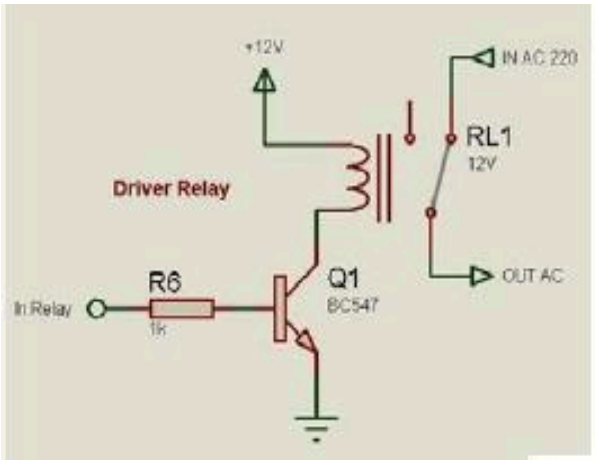


Figure 3-3: circuit braker [9]

3.2.8 Programming of the Arduino microcontroller to measure current, voltage, and effectively calculate the power consumed from the load.

Here the Arduino microcontroller is installed with programs that will calculate power consumpton. The EEPROM installed into the microcontroller keeps rocord of the consumed and remaining units. It is programmed to display these values on to the LCD

and also send these readings to the consumer mobile app on request, through the GSM module.

On recharge of units, the EEPROM will update this information crediting the meter with the recharged units. An algorithm is designed so that the number of units/ tokens gradually reduce as the consumption increases.

3.2.9 Configuring Communication with the utility server, consumer and the GSM module

This GSM Modem can accept any network operator SIM card and act just like a mobile phone. Advantage of using this modem is serial communication possible wirelessly. We use RS232 port to communicate and develop embedded applications. Embedded applications like data transfer, remote control and data logging can be developed easily. The modem connects to PC serial port either directly or to any microcontroller. This GSM modem is a highly flexible plug and play quad band modem for direct and easy integration to RS232 applications and supports features like Voice, SMS, Data/Fax, GPRS and integrated TCP/IP stack.

The GSM module is programmed to send and receive signals from the authority's server. Signals received are convey to the microcontroller, which then transmits this messages in terms of signals to the microcontroller to execute the defined function.

3.2.10 The Server

The server part of the system is a PC. The server PC contains the server program and MySQL server 5.1. The server program manages the connections with the clients (one at a time) and checks and updates the database. Fig. 6 shows the server program.

3.2.11 The client,

The client's mobile phone is installed with a mobile application using java programming language. This programming language will provide a platform for the mobile phone to communicate with the authority's server and the GSM module.

3.3 SIMULATION

LabVIEW system is used to simulate the smart prepaid energy meter system to give results according to the design purpose.

3.4 EXPECTED RESULTS

The simulation and the implemented module as well is expected to give the following results;

- A communication system established between the client's mobile phone app and the server. Then the mobile application is initiated it should generate a signal to read the consumption of the load and display units not consumed

- The system is expected to relay a signal from the utility authority to the relay (circuit breaker)to switch OFF power supply when the units get exhausted.
- The system is expected to add the number of units when the consumer use consumer uses the mobile to recharge their meter account. A signal is send to the relay to switch ON power supply in this case.

Chapter 3

Chapter 4 CONCLUSION

This proposed simple and economic digital prepaid energy meter controlled by GSM, based communication can cover rural area as well as urban areas. This is an effort to improve the present conventional prepaid meter payment methods. This is through the fusion of analog and digital circuits that have an aim of making it convenient for the consumer to pay their bills for consumption of power. This will also improve the revenue collection for scheduled supply. This is beneficial for Kenyan like developing country which having huge population. It will also help in adopting to the cashless economy.

	4th year 2nd semester				5th year 1st semester				5th year 2nd semester			
	Mar	Apr	May	June	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April
Proposal writing & presentation												
Equipment acquisition												
Data Collection												
System Design												
System coding and simulation												
Building of prototype												
Testing and error fixing												
Final testing and Improvement												
Final Project presentation												

PROJECT TIME PERIOD

(GANT CHART)

BUDGET

QTY	DESCRIPTION	UNIT PRICE (KSH)	LINE TOTAL (KSH)
1	Arduino UNO AT board	1200	1200
1	GSM module	6000	6000
1	20 x 4 LCD	1200	1200
1	Circuit breaker (5V 4 Channel Relay)	400	400

--	Power supply	___	0
1	Bulb and bulb holder	200	200
--	Connecting wires	200	200
1	Mobile Phone	___	0
1	Computer (sever)	___	0
1	Bread Board	300	300
		Subtotal (KSH)	10,200
		Sales Tax (ksh)	0
		Total (ksh)	10,200

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