FACULTY OF COMPUTING & INFORMATION MANAGEMENT

RESEARCH PROJECT

ON

THE DESIGN & SIMULATION OF AN AUTOMATIC ELECTRICITY TOKEN LOADING SYSTEM

BY

JOHN KIRUI KIMUTAI

12/02837

THIS RESEARCH PROJECT IS SUBMITTED TO THE SCHOOL OF COMPUTING & INFORMATION MANAGEMENT IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE DEGREE IN DATA COMMUNICATION

SEPTEMBER 2014

DECLARATION

I declare that this is my original work and that it has not been presented for a degree in any other University.

Signature……………………… ………………………….

John K. Kimutai Date

(Admission No. 12/02837)

This research project is submitted for examination with my approval as the university supervisor.

Signature……………………………. ………………………….

Prof. Patrick Ogao Date

Faculty of Computing & Information Management

KCA University

For and on behalf of KCA University

Signature……………………………. ……………………………..

Prof. Ddembe Williams (PhD) Date

Dean,

Faculty of Computing & Information Management

KCA University

DEDICATION

I would like to dedicate this Research Project to my dear wife, Nelly and children for their invaluable encouragement, support and perseverance during the period of study. On several occasions, they urged me on with empowering goodwill messages and wishes.

In addition, I also dedicate this project to my late parents Mr. and Mrs. Tapngotwa, whose love, care and guidance have made me what I am today.

Similarly, this work is dedicated to my siblings, relatives and close friends who helped me in various ways. Indeed, I am humbled to extend a word of 'Thank you' for all the efforts harnessed. May God bless you All.

ACKNOWLEDGEMENT

This research project has been accomplished through concerted efforts in the form of material contributions, support and encouragement from several people to whom I am greatly and personally indebted.

First and foremost, many thanks go to the Almighty God for availing the energy and resources. Secondly, I would like to express my sincere gratitude to supervisor, Prof. Patrick Ogao for his invaluable input, support and guidance without which this research would not have seen the light of day.

Finally, I would like to recognize the immense contributions and solidarity of all my classmates and friends for the teamwork and encouragements we shared throughout the course and particularly during the research work period.

LIST OF TABLES AND FIGURES

Page

ABBREVIATIONS AND ACRONYMS

The following acronyms have been used in this project:-

CDU – Credit Dispensing Unit

CVS – Centralized Vending System

ED – Electricity Dispenser

HTTP – Hyper Text Transfer Protocol

IC – Integrated Circuit

IP – Internet Protocol

ISO – International Organization for Standards

LAN – Local Area Network

MAN – Metropolitan Area Network

OSI – Open System Interconnection

PKI – Public Key Infrastructure

POS – Point-of-Sale

STS – Standard Transfer Specifications

STT – Standard Token Translator

TCP – Transport Control Protocol

TM – Transaction Manager

WAN – Wide Area Network

ABSTRACT

The advent of Global Systems for Mobile Communication (GSM) coupled with the technological advancement realized in the industry of Mobile computing and computer networks has culminated in wide application of seamless data communication in the field of electronic commerce. This Project outlines the design and implementation of an electricity Token vending system that loads electricity Tokens directly onto corresponding energy meters.

The Microcontroller based prepaid energy meter system comprises the following key parts; power sensor or Energy Meter IC, Microcontroller, Liquid Crystal Display and Relay Control Units. The energy meter comes in the form of AT89S52 metering chip. The metering IC monitors the instantaneous load current and voltage signals and generates a frequency (pulse) that corresponds to instantaneous active power. The frequency of the instantaneous pulse is fed into the microcontroller (AT89S52), which stores the pulse count and the recharged Token units. Depending on its count constant, the microcontroller decrements the recharge units by one unit each time a specified number of pulses are realized. When the recharged units are finally decremented to zero, the circuit relay is energized and it disconnects the electricity supply until the Tokens are loaded again. On recharge, the Token is received via the GSM based modem. The microcontroller stores the units in the EEPROM and sends the data value to the LCD. At the same time, a boosted current signal is sent to activate the control relay, which finally connects the electricity supply to the premises.

The smart card of the pre-paid energy meter communicates with the power utility server using GSM network, initiated either via power line communication or modem depending on the particular system. Initially, the LCD registers the total amount of recharged units, called Recharged Amount (RA). But as the power is consumed, the LCD value decreases owing to circuit energy expenses, called Expenditure (E) at each instant and then subtracts from the Recharged Amount to obtain a Balance (B). When the balance becomes zero, the Latch Relay is triggered to open and disconnected supply until the meter is recharged again.

Table of contents

CHAPTER ONE: INTRODUCTION

1.0 Background:-

In Kenya, the Kenya Power & Lighting Company (KPLC) is the sole distributor of electricity to consumers. The KPLC undertakes its mandate through two main billing categories namely; pre-paid and post-paid. In the post-paid category, the consumer is billed regularly and the billing consolidates all the units consumed within a given period, usually about one month. The post-paid category consumers pay for their electricity units after use.

In 2011, the Kenya Power & Lighting Company launched the prepaid electricity (PPE) in selected estates of Nairobi and its environs. The PPE uses special digital meters (electricity dispensers) in the place of the previous analogue power meters. In the prepaid electricity category, subscribers purchase Tokens either from Point-of-Sale or from the central utility server and load Tokens (power units) according to their convenience. The new system was well received by many customers who felt that the system reduces the operational costs on their side.

The prepaid electricity (PPE) system is envisaged to eventually phase out the current widely used post-paid system owing to its efficiency and effectiveness. It gives the consumers the control to manage their power consumption and avert power disconnections caused by payment delays. It works just like the popular mobile phone prepaid billing system. The new meter will switch off the power the moment the customer has used all his/her credit. Once reloaded, the system automatically reconnects the power.

This is indeed a very convenient and appropriate technology, especially when almost every operation is being automated.

The pre-paid category consumers pay for their electricity units upfront. The units of power the customers of pre-paid metering (PPM) system purchase for use in their premises are called Tokens. The consumer buys the tokens of his/her convenience,generally dependent on how much power is required and the purchasing power.

Currently, the electricity Tokens are purchased either across a counter at convenient Points-of-Sale (POS) or through electronic transactions from designated dispensing machines. At the POS, the electricity Token customer provides the ED number as well as the amount of energy required. Eventually, the customer collects the Token, which is then later loaded to the ED. Alternatively, a consumer can order for Units from a centralized KPLC Token vending system through authorized electronic data networks. Currently, the two major networks in use for purchasing the tokens are ***M-Pesa*** and ***Airtel Money*** networks. Other providers which have launched similar services include ***Orange Money*** and ***Pesapal***. To subscribe for electricity Tokens from the dispensing unit, the customer provides the meter number and value (amount) of the Tokens required. Once dispensed, the Tokens are transmitted electronically to the consumer who will finally load the same manually to the local electricity dispenser (power meter). To facilitate the loading, the Electricity Dispenser has a keypad incorporated.

Whether the electricity has been purchased electronically or through a POS, the current system is such that the customer has to manually load the Token onto the local Electricity Dispenser (ED) via the respective keypad. The current process of acquiring a Token and the associated manual loading could be dispensed with through the application of an automatic loading system that has the capacity to dispense and directly load the Token to corresponding Electricity Dispenser.

From the aforementioned, the current system whether offline or online is riddled with inherent challenges that impede the current Centralized Token Vending Systems (CVS) from offering optimal service. The following are some of shortcomings of the current Token Vending Systems:-

- Unnecessarily long delays before Tokens are made available
- Some requests for Tokens are never accomplished
- Invalid Tokens are sometimes submitted
- Manual keying of Tokens through the keypad is challenging for some customers

The challenges highlighted above may be reduced by developing an automatic electricity Token loading system. The automatic Token loading system can be realized either by hiring or establishment of a dedicated system that dispenses Tokens and loads them directly to the relevant Electricity Dispensers (ED). This research, therefore seeks to undertake studies that will culminate in a model network design that would practically be relatively faster, cost effective and probably error free.

1.1 Statement of the problem

Automatic electricity Token loading system is a system that has the capacity to dispense and load Tokens directly to respective Electricity Dispensers in real time. The system is therefore relatively faster, more convenient and cost effective compared to the current manual loading system. The current Centralized Vending System (CVS) only generates Tokens which are eventually loaded manually to the local power meter by the customer. The current system has several operational challenges that adversely impact against its efficiency. Besides frauds in Tokens, the system experiences congestion severallyand is sometimes overwhelmed altogether. The system has limited scope of application probably due to inferior system parameters which include limited communication channel capacity and network coverage. The KPLC is convinced that Token vending systems are costly investments that are unlikely to give desired returns, especially since the provision of electricity in Kenya is a social function rather than profit-motivated venture.

Consequently, this research proposes to investigate the feasibility of developing an electricity Token system, capable of loading Tokens directly to the energy meter with satisfactory efficiency, accuracy and minimal implementation cost.

1.2.0 General objective of the study

The main objective of this study is to develop an electricity Token vending system that loads electricity Tokens directly to respective Electricity Dispensers (ED).

1.2.1 Specific Objectives

1. To determine the challenges that impede application of an automatic Electricity Token loading system (case study of KPLC) in Kenya

2. To design and simulate a simple model of an Automatic electricity Token loading System

1.3 Research Questions

The study is expected to realize its stated objectives by solving the following questions:-

- What are the challenges and constraints of an Automatic Token loading System?
- To develop and simulate a simple model of Automatic electricity Token loading system

1.4 Justification of the proposed research

The proposed research is prompted by the prevailing shortcomings of the current Token Vending Systems applied in the industry. The current Token Vending Systems repeatedly experience several operational challenges and limitations that include the following:-

- ➢ Manual keying of electricity Tokens to the ED via a keypad
- ➢ Unnecessary delays in generation of electricity Tokens
- ➢ Occasional generation of invalid Tokens
- ➢ Occasional electronic billing or reconciliation errors
- ➢ None generation of Tokens altogether
- ➢ Diminished business and returns to the Supply authority
- ➢ Unsavory relation between the Supply authority and its customers

1.5 Significance of the study

The study is desired to gather information and knowledge to guide and facilitate identification of appropriate solutions to the stated problem and research questions.

The success of the research project will lead to the ultimate solution of most of the problems currently experienced by customers in the industry. Besides offering a stress free and convenient environment, the major advantages that will accrue to all stakeholders in the electricity industry include the following:-

- ❖ Direct loading of Tokens to Electricity Dispensers (ED)
- ❖ Reduction of system delays in generation of electricity Tokens
- ❖ Reduction of errors in generation of Tokens within the systems
- ❖ Reduced overhead costs to the electricity supply authority
- ❖ No more billing and pending accounts to settle
- ❖ Allows the supply authority to re-direct staff to other functions

Low level of relevant technology, hence the need to upgrade the software.

1.6 Scope of the Study

Presently, the electricity Tokens are loaded manually via the keypad provided on the energy meter. The scope of the study is therefore restricted to provision of an alternative to the manual feeding of the Tokens on the keypad by developing a system that loads the Tokens directly to the Electricity Dispensers (ED).Essentially, the scope is limited to facilitation of direct loading of Tokens to the Electricity Dispensers (ED), which is the interface between the electricity Supply authority and consumer.

1.7.0 Conceptual Framework

The Electricity Dispenser (ED) forms the link between the Supply authority and the power load. In the current systems, a keypad is a vital interface for loading Tokens manually to the ED.

The block diagram below represents a conceptual and implementation model and provides an overview of the conceptual framework of the proposed direct token loading system.

Conceptual framework

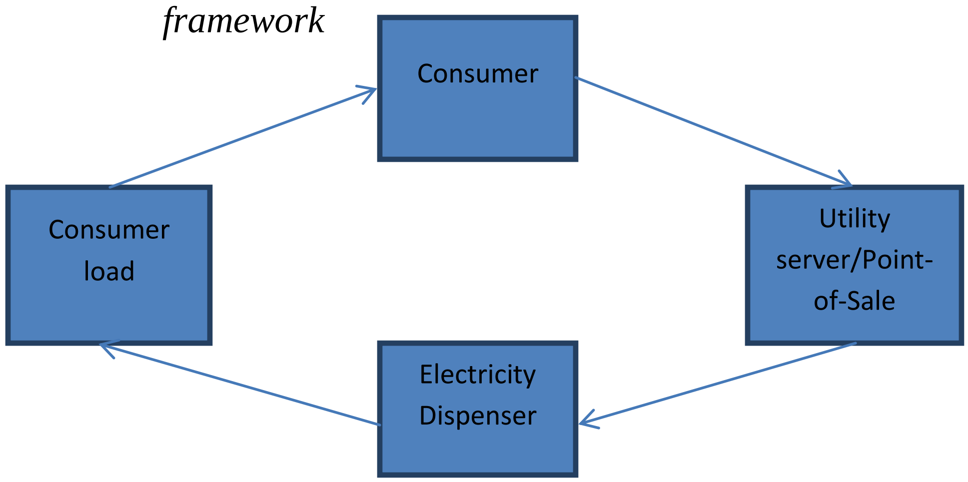

Fig.1.1

The blocks illustratethe relationships between the various components of the prepaid electricity system.

1.7.1 Operation

The consumer sends a request for electricity Tokens to the utility server via a short message service (sms). Upon confirmation of the meter number and credit availability, the server generates and loads the Token directly to the corresponding energy meter through the GSM based modem. Once the Token is successfully loaded, the microcontroller energizes the relay and the power is switched ON. Depending on the load current, the recharge units are decremented gradually until it runs out, when the supply is disconnected. When recharged again, the process repeats.

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

This chapter presents the theoretical literature review of the study and focuses on the basic engineering concepts applied in the domain of data communication and particularly in the electricity Token Vending industry. The fundamental Systems theories, empirical and current practices relevant to the research are explained in detail.

Advances in telecommunication have brought about new applications in the art of sending and receiving information (data communication). Wireless networking is an emerging technology that allows users to access information and services electronically, regardless of their geographic locations. Wireless networks can be classified into two main types namely;infrastructured and infrastructure-less networks. Infrastructurednetworks consist of fixed and wired gateways. A mobile host communicates with a bridge in the network (called base station) within its communication radius. The mobile unit can move geographically while it is communicating. When it goes out of range of one base station, it connects with new base station and starts communicating through it. This is called handoff.

Conversely, in infrastructure-less (Adhoc) networksall nodes are mobile and can be connected dynamically in an arbitrary manner.

2.1 Data Communicationtechnologies

Data communication is the process of sending data electronically from one location to another, connecting one computer to another or to a network, thereby permitting the power and resources of the computers to be shared. Computers that are located in the same room or building communicate data directly through a cable link, while computers located far away from the processor use a special form of data communication – telecommunication or telegraph. For instance, teller and point-of-sale terminals are ordinarily located away from their respective computers; airlines, railways and hotel reservation systems run terminals which are located several miles from the processors.

2.2.0 Categories of Communication architectures

Communication networks can take any of the following three main categories:-

1. Local Area Network –LAN
2. Metropolitan Area Network – MAN
3. Wide Area Network – WAN

2.2.1 Local Area Network – LAN

This is a network of computers connected together within a small, well defined area such as a room, office building or a campus. However, the computers can be located within an area extent of about 200 meters.

2.2.2 Metropolitan Area Network – MAN

A Metropolitan Area Network (MAN) is a network that is larger than a LAN. It is commonly called metropolitan since it usually covers the area of a city. MAN generally covers distances from a few tens to about one hundred kilometers. To effectively cover the said distances, different hardware and transmission media are often applied as appropriate.

2.2.3 Widearea Network - WAN

A Wide Area Network comprises of two or more geographically dispersed computer networks, linked by communication devices such as telecommunication or microwave relays. The most significant characteristic of a WAN network is the involvement of a public telecommunication authority. The application of WAN networks is limited to large organizations and government agencies due to high costs of building and maintenance. In practice, WAN networks are operated in two categories namely:-

1. Enterprise – An enterprise network connects all LANs of a single organization. The term is usually used for networks connecting extremely large organizations, or for cross regional boundaries.
2. Global – A global network is one that spans the earth. However, a global network may not cover the entire globe, but cross multiple national boundaries and may include networks of several organizations.

Both enterprise and Global networks use special devices called repeaters, bridges, routers and gateways to connect their basic or independent networks. Similarly, Local Area Networks, Metropolitan Area Networks and Wide Area Networks use the devices to extend connections within their sphere of coverage.

Note:-Computer manufacturers have developed communication architectures which describe three main facets of communication in an abstract manner, independent of particular hardware or technology. The key aspects include:-

- Data exchange (intercommunications)
- Data interpretation (interoperation)
- System management

2.3.0 TCP/IP Communications Architecture

TCP/IP communication architecture is a structured hardware and software design that supports the interconnection of a number of physical and logical components.The network architecture links terminals in one or several locations with embedded processing ability. The network may have several hosts interacting with multiples of terminals. Consequently, the network architecture defines the set of rules to which interconnecting elements must conform. The International Organization for Standardization (ISO) has developed a model of network architecture called the Open Systems Interconnection (OSI). The objective of this model is to promote the interconnection of all types of networks. The underlying principle exploited by the OSI model is layering. The concept is to create network architecture with several layers where each layer performs certain unique functions. The OSI model defines seven distinct layers based on standard structuring techniques.

In the OSI model, each layer interacts only with its adjacent layersand has no knowledge about any other layers. Information flows down through the layers of the sending host and then up through the layers of the receiving host. Because the layers are isolated from each other by strict interfaces, information that is added by a layer in the sending host is only used by the corresponding layer in the receiving host. In other words, corresponding layers of the sending and receiving hosts communicate in a peer-to-peer relationship.

Each layer adds value to the services provided by the set of lower layers in such a manner that the highest layer is offered the set of services needed to run an application distributed over several networks. In addition, each layer provides services to the layer above and request services from the layer below. Thus, the total network problem is divided into a set of smaller problems. Intermediate networks that merely relay information from one network to another will only need to implement some of the lower three layers to act as transfer agents.

2.3.1 TCP/IP Layeroverview

Transmission Control Protocol/Internet Protocol (TCP/IP) is a networking protocol suite that provides several protocols, which define applications, transport controls, networking management and routing. While the Open System Interconnections (OSI) has seven layers, TCP/IP operates on only four layers namely; Application, Transport, Internetwork and Network interface.

(i) Application

Application is a user process that cooperates with another process on the same or different host. Examples include Telnet (protocol for remote terminal connections), FTP (File Transfer Protocol) and SMTP (Simple Mail Transfer Protocol).

(ii) Transport

The Transport layer provides end-to-end data transfer. The two protocols at this layer are:-

(a) **Transport Control Protocol (TCP),** which is the end-to-end reliable connection-orientated protocol that provides flow control, error-free logical connections between pairs of processes
(b) **User Datagram Protocol (UDP),** which is basically an application interface to IP. It is connectionless, and adds no reliability, flow-control or error recovery to IP but simply serves as “multiplexer/de-multiplexer” for sending/receiving IP datagrams. An IP datagram has a header that contains information for IP and data that is relevant only to higher level protocols.

(iii) Internetwork

The internetwork provides the ‘virtual image’ of the internet, as the layer shields the higher level from the network architecture below it. The protocols at this layer include;

(a) **Internet Protocol (IP)** - This layer hides the underlying physical network by creating a virtual network view, and is a best-effort connectionless packet delivery protocol that moves data between the intermediate nodes, referred to as routers.

(b) **Internet Control Message Protocol (ICMP) –** is the protocol used to report errors and control messages at the IP layer. ICMP is part of the IP protocol.

(c) **Address Resolution Protocol (ARP)** – is the end station to router protocol usedto dynamicallymap internet addresses to physical hardware addresses on the local area networks. The protocol is limited to networks that support hardware broadcast.

(d) **Reverse Address Resolution Protocol (RARP)** – is the protocol that a diskless host (an end node) uses to find its internet address at startup. RARP maps a physical (hardware) address to an internet address.

(e) **Open Shortest Path First (OSPF)** – is an IP routing protocol that uses an algorithm to build a routing table that is used to find the shortest path to every gateway and network the gateway can reach.The protocol uses a link-stat algorithm to compute routes, which is more efficient than the vector-distance protocol used by RIP.

(f) **Routing Information Protocol (RIP)** – is a vector-distance protocol widely used routing protocol for IP networks. However, the protocol cannot handle large network configurations owing to the following:-

- The algorithm is run for every 30 seconds
- The whole routing table is transmitted and hence causes network overload
- Routing decisions are based on the number of hops between stations, which may lead to an inefficient use of the network

(iv) Network Interface

Network Interface is the interface to the actual network hardware. The Interface may be packet or streamed-orientated

2.4.0 Current and Emerging Technologies

2.4.1 Code Division Multiple Access (CDMA)

CDMA is the latest technology applied in global systems for mobile communication because of its superior qualities. In CDMA, no channel is assigned to each conversation. Instead, it is broadcast over spread spectrum (1.25 MHZ wide).The signal is prepared by first being digitized and then multiplied by a wide-bandwidth pseudo noise code sequence. This sequence is recognized by both the phone and the cellular base station. Assigning a unique code to each conversation allows many users to simultaneously share the same RF spectrum region. Ideally, calls will not interfere with one another because all other conversations taking place will be treated as noise and ignored. Another feature of CDMA is that each phone is in contact with up to four cellular base stations at any given time. This enables a conversation to be transferred from cell site to cell site by means of a 'soft handoff', which means that the phone maintains a conversation on more than one cell site and transfers control of the call to a stronger base station before breaking the connection to the weaker base station. This contrasts significantly from the analogue and TDMA hard handoff in which the call is dropped by the weaker base station before being re-established on the stronger one.

2.4.2 Personal Communication Service (PCS)

Personal Communication Service (PCS) is a wireless phone service somewhat similar to cellular telephone service but emphasizes on personal service and extended mobility. Like cellular, PCS is for mobile users and requires a number of antennas to blanket an area of coverage. As a user moves around, the user's phone signal is picked up by the nearest antenna and then forwarded to a base station that connects to the wired network. Unlike cellular, which was designed for car phone use, PCS is designed for greater user mobility and requires more cell transmitters for coverage hence has fewer blind spots.

2.4.3 Cellular Digital Packet Data (CDPD)

CDPD is a specification for supporting wireless access to the internet and other public packet-switched networks. Both Global Systems for Mobile Communication (GSM) and Personal Communication Service (PCS) apply CDPD in their systems.

CDPD is an open specification that adheres to the layered structure of the Open Systems Interconnections (OSI) model.

2.4.4 Global Systemfor Mobile Communication

Global System for Mobile Communication (GSM) is a cellular network that is currently widely applied, with over 200 networks now in operation in more than 100 countries around the world. It a system of standards developed by the European Telecommunication Standards Institute (ETSI) to describe technologies used for second generation digital communication, and is commonly referred to as 2G technologies. Over time, the standard has been expanded to include first circuit switched data transfer, then packet data transport via General Packet Radio Service (GPRS). Packet data transmission speeds were later increased with the help of Enhanced Data Rate for GSM Evolution (EDGE) technology. The GSM technology is succeeded by third generation (3G) UMTS standard developed by the 3GPP.

There are five different cell sizes in a GSM network namely; macro, micro, pico, femto and umbrella. Macro cells can be regarded as cells where base station is installed on a mast or building above roof top level. Micro cells are those in which base station is installed below the average roof top level. They are typically used in urban areas. Pico cells are the cells whose coverage area is a few dozen meters in diameter and are mainly used indoors. Femto cells are cells designed for use in residential or small business environment and connect to the service provider’s network via a broadband internet connection. Umbrella cells are used to cover shadowed reasons of smaller cells and fill in gaps in coverage between those cells.

The modulation used in GSM is Gaussian Minimum Phase Shift Keying (GMSK), a kind of continuous phase frequency shift keying. In GMSK the signal to be modulated on the carrier is first smoothed with a Gaussian low-pass filter prior to being fed into a frequency modulator which greatly reduces the interference to neighboring channels (adjacent channel interference).

GSM networks operate in a number of carrier frequency bands (separated into GSM frequency range for 2G and UMTS frequency range for 3G). Most 2G GSM networks operate in the 900 MHz or 1800 MHz frequency bands. Where these bands are already occupied 850 MHz or 1950 MHz frequency bands are used e.g.

in USA and Canada. In rare cases 400 and 450 MHz bands are allocated because they were earlier used for first generation communications.

Most of the 3G GSM networks operate in the 2100 MHz frequency band.

2.4.5 General Packet Radio Service

General Packet Radio Service (GPRS) is a packet based communication service for mobile devices that allow data to be sent and received across a mobile telephone network. GPRS is a step towards 3G, and is basically an upgraded GSM outfit.

2.4.6 Mobile Computing

Mobile computing can be defined as a computing environment over physical mobility. The user of a mobile computing device is able to access data, information or other logical objects from another device in any network while on the move. Mobile computing system allows a user to perform a task from anywhere using a computing device in the public (the web), corporate (business information) and personal information. When on the move, the preferred device will be a mobile device, while back at home or in the office the device could be a desktop computer.

To facilitate the mobile computing environment, it is necessary that the communication bearer is spread over both wired and wireless media.

2.4.7 Mobile station

The mobile station (MS) consists of the mobile equipment (the terminal) and a smart card called the Subscriber Identity Module (SIM). The SIM provides personal mobility, so that the user can have access to the subscribed services irrespective of a specific terminal. By inserting the SIM card into another GSM terminal, the user is able to receive calls at that terminal, make calls from that terminal, and receive other subscribed services.

The mobile equipment is uniquely identified by the International Mobile Equipment Identity (IMEI). The SIM card contains the International Mobile Subscriber Identity (IMSI), used to identify the subscriber to the system, a secret key for authentication and other information. The IMEI and IMSI are independent, thereby allowing personal mobility. The SIM card may be protected against unauthorized use by a password or personal identity number.

2.4.8 Security in Mobile Computing

In Mobile computing, the problem of protecting the agent and its results from malicious and faulty servers arises. The most important automated tool for network security is provided by encryption. The two main forms of encryption are symmetric or conventional encryption and asymmetric or public-key encryption. The basic process consists of encryption and decryption. The message to be transmitted is called plain text, while the encrypted version is called cipher text. At the receiver end, a decryption key is used to convert the cipher text to the original message. The intruder or a third party cannot retrieve or change the content of the cipher text without an authenticated key. The technique of breaking ciphers is called cryptanalysis, while the art of devising ciphers and breaking them is collectively is called cryptology.

2.4.9 Authentication

Public key infrastructure (PKI) is a mechanism based on encryption and digital certificates, used to authenticate a sender's identity and provides the encryption keys. The public key encrypts the message while the private key decrypts. The sender holds the private key and makes the public key ready for use by the recipient of the message. Anybody can send an encrypted message, but only the authenticated recipient can decrypt the same.The RSA public key crypto system and digital signature scheme are used for public key infrastructure (PKI). Electronic commerce uses this technology to authenticate documents, transactions and to provide better integrity.

CHAPTER THREE: RESEARCH METHODOLOGY

3.0 Introduction

This chapter outlines how the research was conducted. It explains the research design, methods and testing procedure applied. In addition, this chapter explains how the test results would be harnessed, analyzed and presented to produce the envisaged information for the study**.**

3.1 Background of the Project

Kenya Power and Lighting Company (KPLC) is the sole distributor of electrical power in Kenya. Three years ago, KPLC introduced prepaid electricity regimes on pilot project basis in selected urban areas including Nairobi. In those areas, customers are supposed to purchase Tokens either from designated points-of-sale or electronically from centralized Credit Dispensing Units (CDU). Once acquired, the Tokens are loaded manually to the Electricity Dispenser (ED) via a keypad by customers at their respective premises. Prepaid electricity regimes are preferred owing to the following reasons:-

- No billing is required
- The intensive labor and operational costs are drastically reduced
- Bad debts cannot be incurred by supplier
- Substantial reduction on fraud and tampering of conventional meter reading
- No pending bills (accounts) to be paid because each power unit is paid for before use

However, theKPLC considers prepaid electricity system as an expensive investment with little returns (especially with domestic power users) and does not see its future in Kenya, at least in the next few years.

Prepaid electricity regimes involve the installation of an Electricity Dispenser (ED) at the premises of a customer. In addition, a Centralized Vending System (CVS) and Standards Transfer Specification (STS) are the other essential units of the Token vending infrastructure. Customers can purchase electricity Tokens from KPLC at any Point-of-Sale location designated by the supply authority or on-line through electronic money transfer services. The two main electronic outlets are ***Airtel Money*** and ***M-Pesa*** services. Other outlets that have launched the electronic services include; ***Orange Money*** and ***Pesapal***. Once a Token is purchased, it is loaded manually onto the Electricity Dispenser (ED) through an incorporated keypad. Ultimately, the ED will discharge electrical units for as long as the Token lasts.

However, prepaid electricity systems come with the following disadvantages to their users:-

1) Above average cost of electricity
2) The best energy deals in the market are usually not available to prepaid meter customers
3) Can be inconvenient since customer owing to the need to occasionally 'top up' keys or smart meters
4) Older meters need to have their prices updated manually after price falls or rises and sometimes take considerable time. This means the customer continues to pay old rates.
5) If the customer cannot access Vending or Point-of-Sales outlets, the power can be switched off.

Basically, a Centralized Vending System comprises of Credit Dispensing Unit (CDU), System Master Station and a centralized Database (DB). In addition, a CVS exits in two main forms namely off-line and on-line. In off-line systems, electricity Tokens are generated independently while in on-line systems, electricity Tokens are generated in real time.

The CDU can generate electricity Tokens directly to customers on provision of the following data:-

- Meter number
- Amount of electricity required

To successfully accomplish the process of Token generation, the CDU prompts the Security Module (SM) to encrypt the generated Token appropriately. Besides, CDU has respective keys for encryption of Tokens for specific ED.

Transaction data collected at the CDUs are concentrated at the SMS and subsequently at the TM. The centralized database is part of a high-level management system that records purchases and monitors corresponding electricity usage.

Advantages of off-line CVS

a) The system is less complex and easier to maintain
b) The system is cheaper to acquire and maintain

Disadvantages of off-line CVS

a) Illegitimate Tokens can be generated inadvertently
b) Tokens legitimately sold may not be paid for

Therefore, to reduce the impact of the above cited disadvantages, on-line systems are adopted.

In an on-line vending system, requests are sent to a centralized server that processes the requests in conjunction with a system database. Ordinarily, an appropriate acknowledgement is sent to the customer on completion of the request-response cycle.

On-line Token vending systems require elaborate network infrastructure that facilitates prompt communication between customer and the Credit Dispensing Unit (CDU). Such dedicated networks can be realized, courtesy of LAN, MAN or WAN singly or jointly with the internet. To guard against possible fraudulent transactions in the Token vending system, special security provisions are brought on board. The special security requirement in prepaid electricity systems raises administrative costs and hence constitutes the main disadvantage of the Token vending system.

3.2 ElectricityToken

Present prepaid electricity systems use tokens of either 16 or 20 digits. The group of digits is issued by Vending machine upon payment and representsa specified amount of electricity (in kwh). The token is either proprietary or based on the general standards transfer specification (STS)protocol and used by compliant prepaid meter. Tokens are therefore, simply units of power generated for use by a particular Electricity Dispenser (ED). Tokens are not transferable.There are two types of Token technologies namely; Disposable magnetic card/stripe and the

Numeric.The disposable magnetic stripe uses ISO 7810 Standard series. It is made of paper and as the name suggests, is used only once. Magnetic card reader is provided at the ED.

The numeric Token technology, on the other hand, encodes Token data as a string of twenty (20) digits. Consequently, the physical transport medium varies and can be communicated via e-mail. The corresponding input device at the ED is a numeric keypad. The numeric Token technology is more versatile, as it may not require physical movement.To facilitate smooth operation and management, each ED is allocated a Supply group by the distributor. This is used to enforce control and management of ED. The Supply groups comprise:-

- Unique Supply groups (geographical area)
- Common Supply group (geographical area)
- Default Supply group (at the time of manufacture)

STS meter

- A Standard Transfer Specification meter is a meter that is designed to accept tokens conforming to the STS specification, while a standard Token Translator is a device developed to harmonize proprietary meters to STS machines generated tokens. The STT will then convert the STS tokens from the CDU into the corresponding proprietary format.
- Token Technology is the type of token that the system uses; two digit number to indicate the type of token to generate. Usually, tokens are either encrypted as a numeric or magnetic token.

3.3 Fundamentals of Cryptography

Early application of cryptography was by military and diplomatic organizations which used the craft to keep their messages secret or confidential. However, in recent applications, cryptography is used in electronic transactions to prevent incidents of fraud by making payments and transactions records relating to Tokens difficult to copy or alter.Automatic Teller Machines were the first major users of the techniques, followed closely by satellite TV decoders and cellular telephone identity modules. Safe and car burglar alarms have lately embraced the technology.

Cryptography based Tokens in use by KPLC pre-paid electricity meters apply an EEPROM key device, a memory (smart) card and a 20 digit number printed on a slip of paper which is entered at a keypad on the meter.Modern pre-paid meters (PPM) can be split into two parts namely; circuit breaker –usually installed outside the premises and the customer interface unit or the Electricity Dispenser (ED).

It is important to note that on-line Token vending system enhances control in the pre-paid environment, centralizes management of tariffs, transactions and customer data as well as reducing opportunities for fraud. In addition, real time vending allows customers to buy Tokens through cellular phones, ATM or even internet as long as the meter number is known. These operations are facilitated by Standards Transfer Specification (STS).STS is a secure common language protocol used to transfer standard encrypted Tokens between pre-paid meters and common vending systems from different suppliers. STS incorporates security features vital for dispatching management information systems in power infrastructure. The basic technique is realized through the public key infrastructure (PKI).

Other systems use TCP/IP as transport mechanism while still many others apply LAN, MAN or WAN as transporters of Tokens. In both cases, the security of the system is improved since it is no longer necessary to provide vendors with security modules (SM) at the point-of-sale.

3.4 Standard Transfer Specification

Standard Transfer Specification (STS) was first developed in South Africa to facilitate the administration of prepaid electricity. STS defines how electricity is represented by a Token. The Token is interpreted by an Electricity Dispenser (ED) at the customer's premises and corresponding amount of electricity is made available.

Further, STS provides an 'open system' standard in the electricity dispensing industry. This allows compatible electricity dispensing equipment to work with vending equipment from different manufacturers to the benefit of the customer, distributor, vendor and supply authority. The STS enables the Electricity Dispenser (ED) to receive and meaningfully interpret accordingly the information generated by the Credit Dispensing Unit (CDU). However, where necessary, a Standard Token Translator (STT) is applied to harmonize Tokens and energy meter.

Token Technology is the type of token that the system uses; two digit number to indicate the type of token to generate. Usually, tokens are either encrypted as a numeric or magnetic token.

STS provides data transport mechanism through a standard Token for the transfer of management and credit information between the CDU and ED. STS standardizes the representation of the basic items of a Token;

i. The set of Token functions that can be transferred via the Token
ii. The set of Token data field required by the CDU to support the various Token functions
iii. The Token formats corresponding to the various Token functions
iv. The way in which data is encrypted on the Token
v. The technologies that can be used for the transfer of a Token from the CDU to ED and
vi. The encoding of Token data onto each of the Token technologies

3.5 Smart card

A smart card is a plastic card embedded with a microprocessor chip where a large amount of information can be stored, accessed or processed online or offline. The smart card is used to verify the user's identity while logging on to a computer network system. Smart cards are of two types namely; the memory card and the processor card. Memory cards are prepaid, and a specific amount is deducted in the chip during use. Security logic prevents tampering by erasing and rewriting. On the other hand, a processor card stores secret keys and executes cryptographic algorithms to enable secure offline transactions. The smart card provides more security and confidentiality than other modes of information and transaction storage. It is an ideal device to store private keys, account numbers, personal data like biometrics information and to perform offline processes such as public or private key encryption and decryption.

3.6 Electronic Purchase of Tokens

In this method, the customer sends an 'sms' request to the Vending machine, indicating the local meter number and amount of the token required. Once the Token is generated, it is sent electronically to the customer. The customer then loads the Token to the meter via the keypad. Consequently, the Electricity Dispenser (ED) releases the power as long as the Token lasts.

Advantages of Electronic method

The method offers the following advantages:-

i. Fast and convenient to the customer

ii. Administratively cheaper for the supply authority, since it requires little administrative costs

iii. Reduces room for financial fraud

Disadvantages of Electronic method

However, the electronic method has the following demerits:-

i. The method is entirely dependent on the communication link and hence on its availability. When the link is down, the system is also down.

ii. The Token is loaded onto the ED manually

iii. System operates on rigid tariffs

Point-of-Sale

Like in the above case, the power customer can purchase power Token from a designated outlet by providing meter number and stating amount of Token required. Once the Token is purchase, the customer manually loads the same onto the Electricity Dispenser through the keypad.

Advantages of Point-of-Sale

i. Does not experience congestion like the Centralized Vending machine

ii. Does not generate invalid tokens

Disadvantages of Point-of-Sale

The Point-of-Sale method faces the following disadvantages:-

i. Involves physical movement and thus time wasting

ii. The outlets operate under specific time limits and are therefore inaccessible during other hours of the day

iii. Manual loading of the Token

Despite their respective advantages, the above two methods possess one main disadvantage, that of manual loading of the Token. Therefore, there is a gaping necessity of a vending system that loads Tokens directly onto the Electricity Dispenser.

3.7 Method adopted for the project

Recent innovations in digital technologies have resulted in phenomenal advances in wireless and mobile communication and entrenched the place of Global System for Mobile Communication (GSM). This research study explores the simulation and implementation of an Automatic electricity Token loading system for prepaid meters.

Unlike existing systems, what is new in an automatic electricity Token loading system is that the tokens are generated by the server and loaded directly to the corresponding energy meters at customer premises, thereby avoiding the inconvenience of the keypad.Sections of existing systems are assumed, particularly the Token generation and communication networks. Hence, the bulk of the study is centered on the automation of the current functions of the keypad. The energy metering system is an embedded system that consists of opt coupler (Energy Meter chip), Microcontroller, Voltage and Current sensing devices, Relay and Liquid Crystal Display (LCD).

The following block diagram is a typical schematic representation of the present energy meter system andillustrates the various components.However, some systems use a smart card reader that loads the Tokens onto the microcontroller.

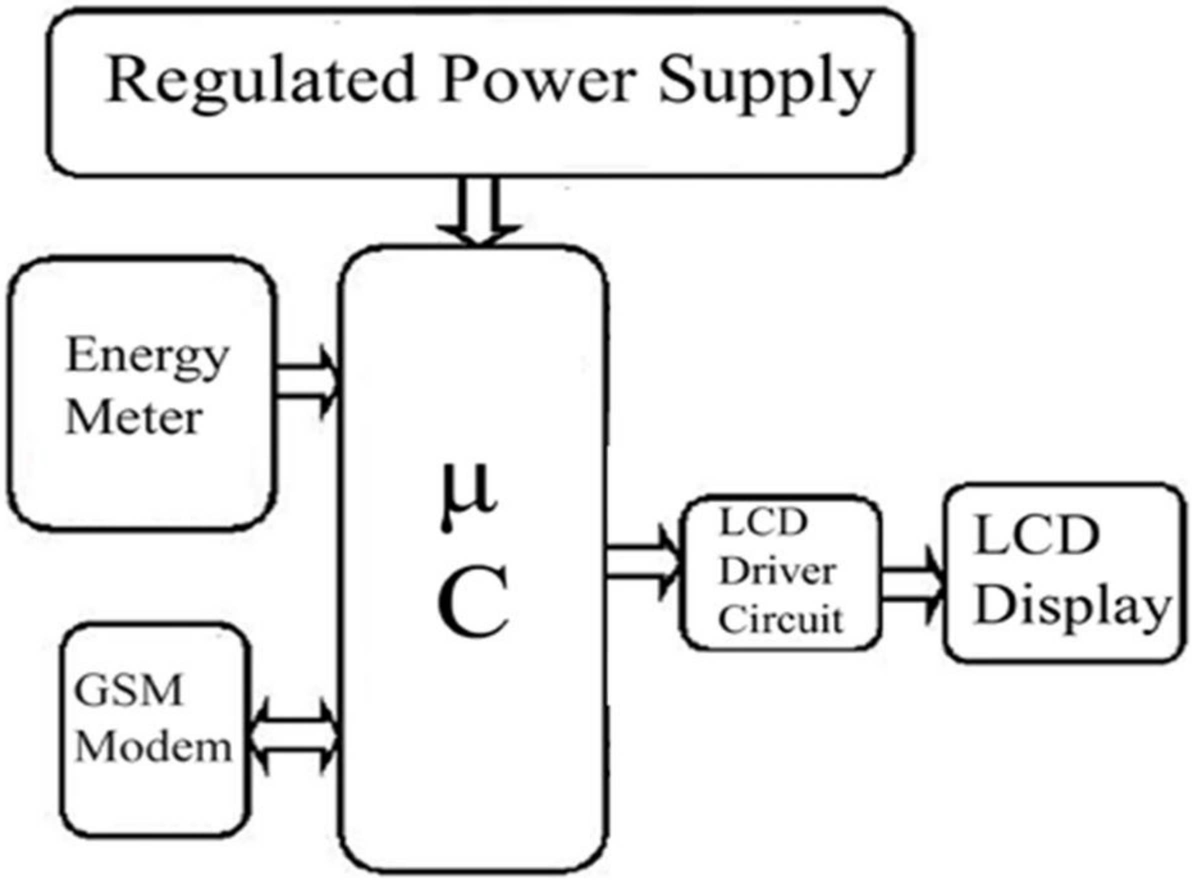

Fig.3.1 Block diagram of Prepaid energy meter

The system architecture of microcontroller based single phase digital prepaid energy meter for improved metering system is shown above, and operates as follows:-

- Energy Meter IC generally produces electrical pulses proportional to the power consumed by the consumer and the power supply of microcontroller.

- Microcontroller calculates the energy consumed by the consumer utilizing the output of Energy Meter Chip and programs loaded on the microcontroller.

- Voltage and Current sensing devices feed the instantaneous current and voltage of load connected to consumer side to the energy meter chip.
- Smart Card interfaces with the microcontroller unit in which the number of units recharged by the consumer is stored.
- Relay mainly performs the opening and closing of a connection between energy meter and load through supply mains depending upon the number of units recharged at a moment.
- Liquid Crystal Display shows the number of units recharged by the consumer, energy consumptionand maximum demand.

3.8 Related works

Initially, Token vending machines operated off-line. Customers purchased their Tokens from designated Point-of-Sale outlets and would manually load the same to the energy meters at their premises. Although, this method was better than centralized vending, it was also inevitably slow. Obviously, better alternatives were required and hence research was necessitated.

Gareth Brett (2010), in his dissertation presentation, ***Design and implementationof an on-line Token vending system for prepaid electricity via internet,*** developed the current concept and practice of token generation in real time. Prepaid electricity customers are now able to purchase tokens from the utility server and designated POS by simply submitting the particulars of their meters alongside the amount of the desired energy. This system is currently used by KPLC to serve its prepaid customers. However, the Gareth Model has a serious disadvantage in that the tokens are loaded manually to the energy meter, a system that has serious limitations. This project builds on the benefits of on-line Token vending as designed and implemented by Gareth Brett.

D.A.Shomuyiwa and J.O.Ilevbare (2013), in their presentation, ***Design and implementation of remotely monitored single phase smart meter via short message service (SMS)***, developed a model that employs modem and a SIM card as an interface between the supply authority and customer's energy meter. The model allowed the customer to monitor the balance (status) of the charge remaining in the energy meter, anywhere at any time. However, the model does not offer any contributions regarding direct loading of electricity tokens to corresponding meters. This project attempts to fill that gap by offering an alternative procedure of loading Tokens into energy meters.

Omijeh and Ighalo (2013) in their paper presented **Modeling of GSM-based energy Recharge Scheme for prepaid meter**. In the model, customers bought scratch cards and sent special SMS via their cellular phones to the central server that dispenses tokens. The SMS carried customer's meter ID and scratch card pin number. On receipt of the SMS, the central server checks for the validity of the two parameters. On certifying that both are valid and the pin number has not been used, the server sends an encrypted Token to the customer's meter through the GSM modem call number of the customer's meter obtained from the database. Beside security data, the token generated contains information regarding how much balance the meter will be credited with. Upon receipt of the SMS, the energy meter decodes the message and appropriately recharges the balance.

The main disadvantage of the model is that it requires the customers to purchasescratch cards whenever a recharge is required. Because the customer has to purchase particular credits offered by the scratch cards available in the market, choice is severely limited. In addition, the model is prone to unnecessary delays and interruptions because the Token is not loaded directly to the energy meter.

Based on the foregoing industry research reports and technology advances realized in both computer and GSM communication, it is evident that there is an overdue necessity to develop a system that satisfactorily loads tokens directly to the energy meter.

Presently, electricity Tokens are loaded manually into energy meters via an incorporated keypad. The Tokens are purchased from the server (centralized Vending point) through two methods namely; electronic purchases or at a Point-of-Sale (POS).

3.9 Direct/Automatic Token loading System

In the current setup, the Electricity Dispenser (ED) incorporates a keypad, used to load the Token andan energy meter that continuously checks the cumulated units used and the corresponding credit balance. When the credit finally decreases to zero, the electricity supply is disconnected until the customer recharges by purchase extra Tokens.

Conversely, an AutomaticToken loading system loads Tokens directly onto the Electricity Dispenser, ready for use by the customer. Essentially, the system bypasses the keypad, and offers tremendous benefits that include convenience to power users.

The system also offers numerous advantages to the supply authority including reduction of operation costs, and thus a better profit margin.

CHAPTER FOUR: IMPLEMENTATION

4.0 Introduction

An energy meteris a device that measures the amount of electric energy consumed by a residence, business, or an electrically powered device. Electricity meters are typically calibrated in billing units, the most common being the kilowatt hour (kWh).

The microcontroller based single phase digital prepaid energy meter used for improved metering system is shown in the figure 1, below;

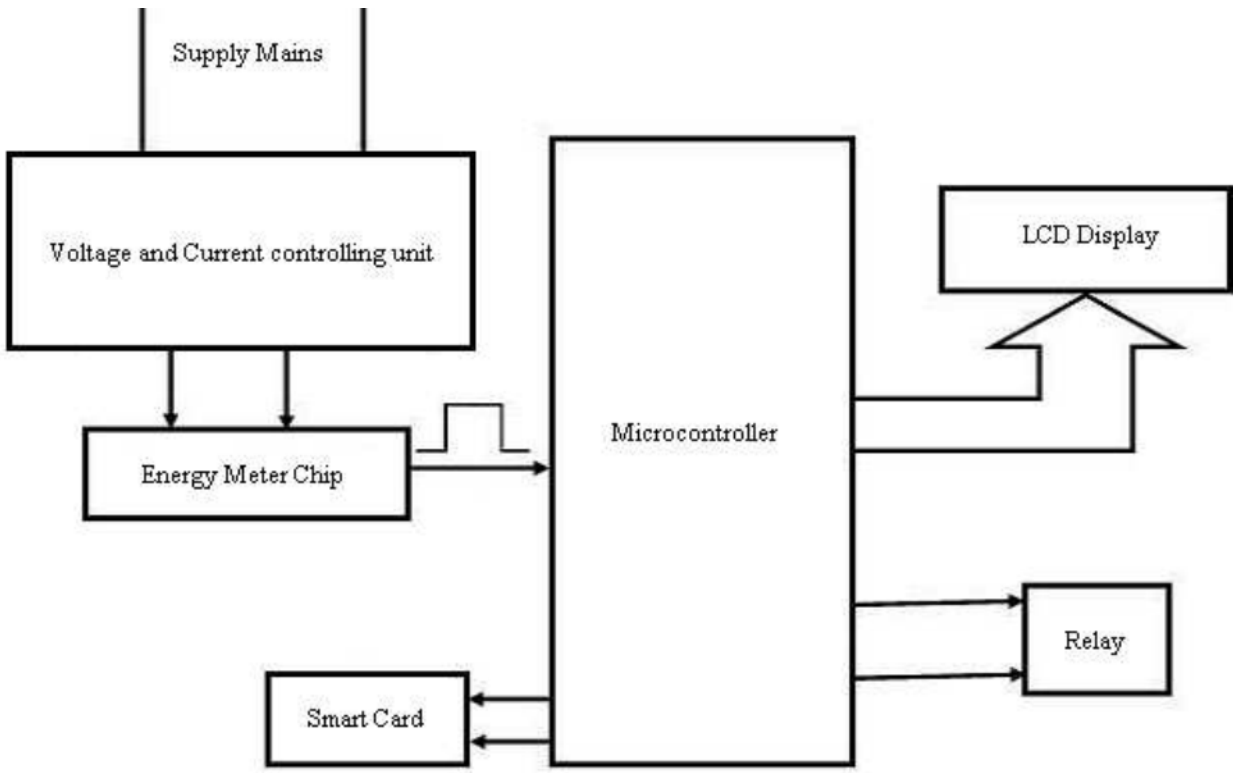

Fig.4.1 Modified block diagram of the Energy meter

The energy metering system consists of an opto coupler, Microcontroller, Voltage and Current meters, Smart cart, Relay and Liquid Crystal Display (LCD).

- Energy Meter IC generally produces electrical pulses proportional to the power consumed by the consumer and the power supply of microcontroller.

- Microcontroller calculates the energy consumed by the consumer utilizing the output of Energy Meter Chip and programs loaded on the microcontroller.

- Voltage and Current controlling unit feeds the actual current and voltage of load connected to consumer side to the energy meter chip.

- Smart Card interfaces with the microcontroller unit in which the number of units recharged by the consumer are written.

- Relay mainly performs the opening and closing of a connection between energy meter and load through supply mains depending upon the number of units present in the smart card at a moment.

- Liquid Crystal Display shows the energy consumption, number of unit recharged by the consumer, rest of the unit and maximum demand.

a) **Microcontroller**

Microcontroller is a programmable device which contains a microprocessor, memory, input-output ports and a timer all embedded together on one chip, and is basically a single chip computer. As microcontroller is a low cost programmable device. It is used in the automatic control application. The microcontroller counts the pulses that appear at pin 12 of Microcontroller (AT89S52) within every 20 seconds. The number of pulses per second appearing at pin 22 of Energy Meter IC is directly proportional to the instantaneous real power information for a particular load. A microcontroller not only accepts data as input but also manipulates it, interfaces the data with various devices, controls the data and thus finally gives the result. The device is usually used to control objects, processes or events.

b) **EEPROM**

AT24C02 is an Electrically Erasable programmable Read Only Memory (EEPROM), hence an instant storage device. It offers many advantages that include selective erasures in contrast to flash memories. In this project, the EEPROM is used to store the available recharge units and the pulse count permanently and the data modified in response with power consumption. In addition, the data is stored in a location where it cannot be erased when power fail and that the data should be allowed to effect changes in it without the system interface, i.e there should be a provision for access to the data to facilitate data modification.

c) **Display Unit**

The liquid crystal display controller displays alphanumeric characters and symbols. It can be configured to drive a dot-matrix liquid crystal display under the control of microcontroller. In this paper, LCD is mainly used to display energy consumption of the load, the number of units recharged by the consumer, rest units, maximum demand of consumer.

d) **Power Supply Unit**

Every electronic circuit needs appropriate power supply for its operation. Basically Microcontrollers, Energy Meter ICs, Liquid crystal display and relays operate on ±5 volts supply. For this reason, we have used a ±5 volt power supply. We have taken into consideration the small energy consumed by the power supply itself that will be paid by the consumers.

e) **Latching Relay**

A relay is an electronic control switch widely used in industrial controls, automobiles and appliances. The relay allows the isolation of two separate sections of a system with two different voltage sources namely; a small amount of voltage current on one side can handle a large amount of voltage current on the other side without a chance that these voltages can mix up.

Operation:-

When current flows through a coil, a magnetic field is created around the coil, that is, the coil is energized. This causes the armature to be attracted to the coil. The armature’s contact acts like a switch that opens or closes the circuit. When the coil is not energized, a spring pulls the armature to its normal state of open or closed.

Sensitive circuit components like ICs and transistors are usually protected from brief high voltage ‘spike’ produced when a relay coil is switched off. To achieve this, a signal diode (IN 4148) is connected ‘backwards’ across the relay coil to provide the protection. In this mode, the diode will not conduct.

However, when the relay is switched off, the current tries to flow through the coil but is safely diverted through the diode. In the absence of the diode, no current could flow and the coil would produce a damaging high voltage ‘spike’ in its attempt to keep the current flowing.

4.1Operation of the energy meter

The energy meter under consideration is an embedded system that uses two EEPROMs, one to count the number of pulses generated (AT89S52) in the circuit while the second is to store the units recharged from the credit card. With zero units in the EEPROM, the system remains in the OFF state until the user recharges. The AT89S52 microcontroller loadsthe Tokens and controls the use of electrical power (Tokens) in the consumer premises. An optocoupler IC (MCT2E) generates clock pulses that correspond to the instantaneous load current. The opto coupler pulse count are registered by the microcontroller and depending on its count constant used to decrement the recharged power units. The rate of pulse count corresponds to the magnitude of the load current and hence the rate at which the recharged units(Token)are decremented. The energy meter system gives a continuous beep sound when the unit value reaches zero. When the number of units becomes zero the relay operates and interrupts supply. At this instant the user has to recharge the power unit by making an appropriate request. Here recharging means loading a new value of power units to the EEPROM. On receipt of recharge units, a message (amount of recharge unis) is displayed on the Liquid Crystal Display (LCD) and the system automatically turns ON.

4.2 Project Simulation

The simulation of the project was accomplished by use of Proteus (ProteusV8) software. The other essential components of the simulation include the following:

- Assigned Tokens
- Server environment
- Microcontroller (AT89S52 and associated elements)
- Relay and
- Bulb(s)

In this project, a microcontroller AT89S52 is used to count the pulses from the opto coupler, to display message and number of units in the LCD and to trip the relay. An EEPROM AT24C02 is provided to store the updated recharge units and energy meter pulse count. At every instant, the count value and unit values are stored in EEPROM so that the data will not be lost even in cases of power failure. Each recharged unit will be decremented after a given number of pulse count is registered (the specific pulse count depends on the microcontroller constant). When 1 unit is decremented from EEPROM, the system will give a beep sound and when the recharge units become zero on power consumption, the system shuts down all the loads connected by giving a continuous beep sound. To use the system again, the user has to reload the units by recharging the EEPROM.

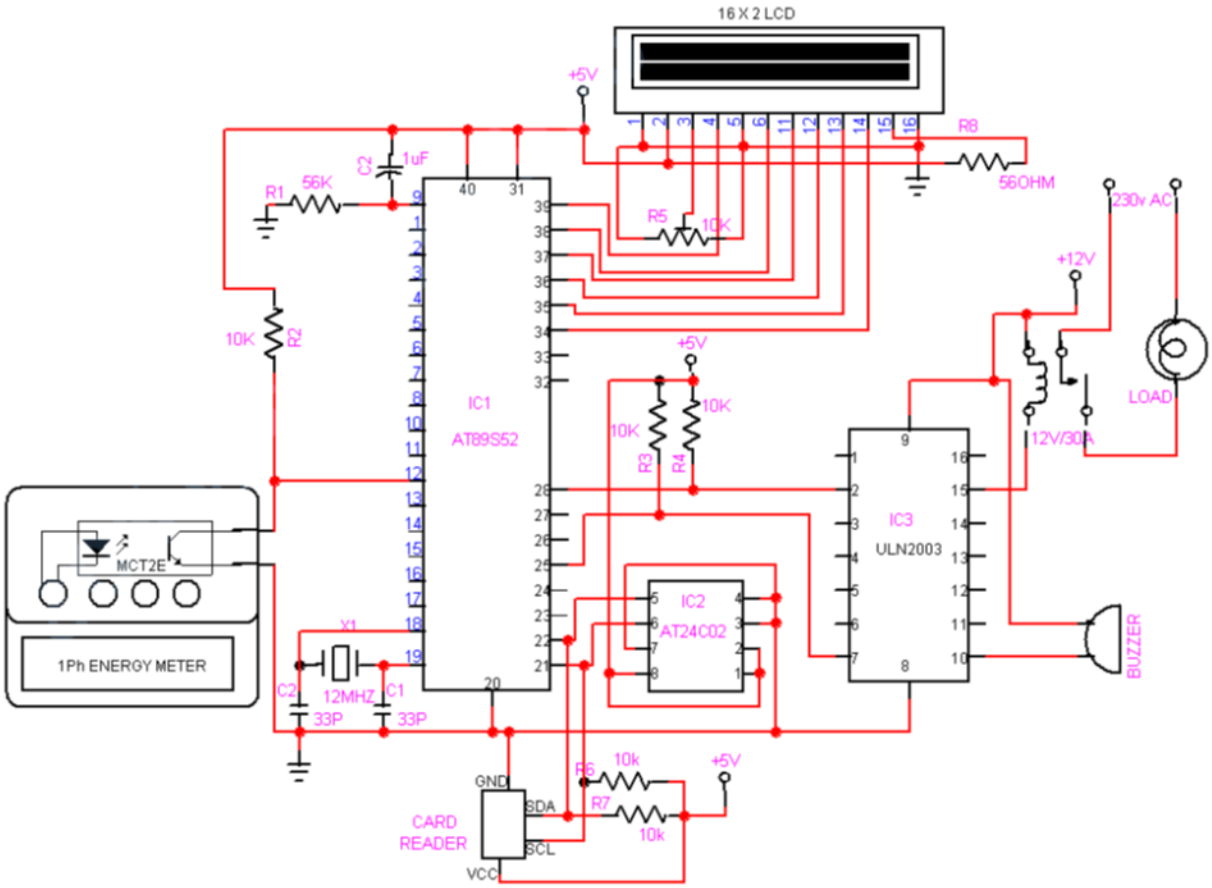

Fig.4.2 Circuit diagram of energy meter

ATMEL 89S52 is a low power high performance 8-bit CMOS microcontroller, with 8Kbytesof Flash programmable (1000 write/erase cycles) and electrically erasable read only memory EEPROM. The device is compatible with the industry standard 8051 instruction set and pin out.

The ATMEL 89S52 microcontroller is used to count the pulses from the optocoupler, display messages and number of units on LCD and to trip the mains supply relay. An EEPROM AT24C02 is provided on the board to store the updated recharge units and energy meter pulse count. At every instant, the count value and unit values are stored in EEPROM so that the data is not lost even in cases of power failure. When one unit is decremented from EEPROM, the system gives a beep sound. When the recharged units become zero on power consumption, the system shuts down all the loads connected until the EEPROM is recharged again.

To recharge, the user places the EEPROM based recharge card in a slot provided on the meter and presses the recharge key. The system will be loaded with units corresponding with recharge value.On successful recharging, the supply is automatically switched ON.

CHAPTER FIVE: SUMMARY OF FINDINGS, DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS

5.0Introduction

This chapter outlines the findings, interpretation and conclusions derived from the results of the simulation procedure.

5.1 Project demonstration

Proteus simulation software was used to demonstrate the operation of the design project. The simulated components of the circuit included microcontroller (AT89S52), EEPROM (AT24C02), LCD, Relay, Bulb and current/voltage meter. However, the software library missed a critical IC (MCT2E), which is supposed to generate a pulse that corresponds to the load current.Besides, the simulation software does not have AT commands, which are essential for network simulation.

For demonstration purposes (hence inaccurate), the pulse frequency was generated externally but corresponds to the instantaneous load current.

5.2 Summary of Main Findings

Proteus software, though the best suited for the project simulation does not have the opto coupler IC and attention (AT) commands. AT commands are network commands which facilitate communication between the central vending serverand in this case the energy meter. In the absence of the IC, a clock frequency was fed externally to the microcontroller.

Therefore, Token loading cannot be simulated with Proteus software. However, arbitrary values of Tokens can be loaded onto the LCD and an Up or **Down** count can be simulated. This is enough to prove that the microcontroller will **Down** count (decrement) the recharge units. In addition, when the Down count reaches zero or the **Up** count reaches the total value, the microcontroller trips the circuit relay which in turn connects the power supply to the premises or device. In the simulation, the presence or absence of supply power is confirmed when the bulb lights or goes off respectively.

Down count of loaded units

Under ideal conditions, the pulse count accumulates and the recharge units are decremented by one unit each time a specific number of pulses are counted. The specific count that must be realized before a decrement by one unit depends on the pulse constant of the microcontroller. The higher the pulse constant, the faster the decrement will be. When the recharge units balance finally reach zero, the power supply is switched OFF. However, owing to the missing IC, the pulse count was not corresponding to the load current, hence the mismatch with decrement of recharge units.

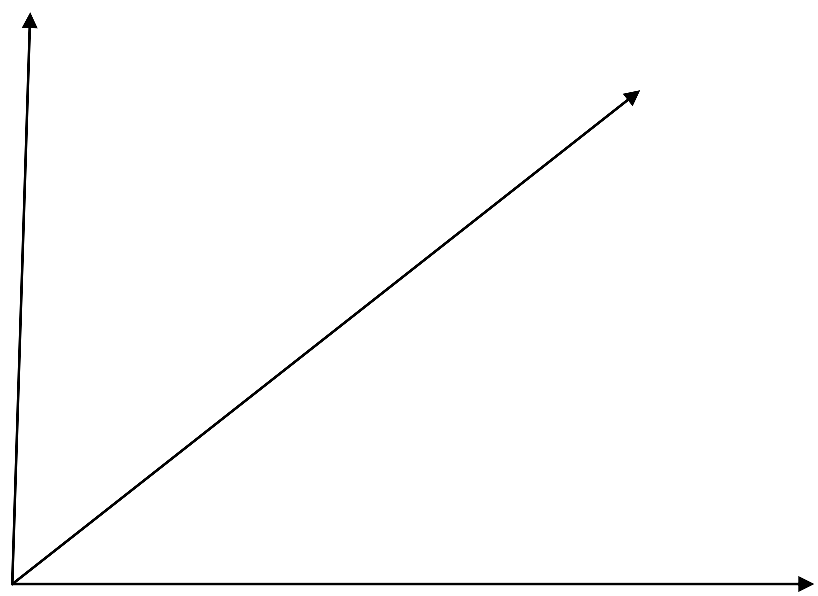

Figure 5.1 Graph showing relationship between load current and pulse frequency

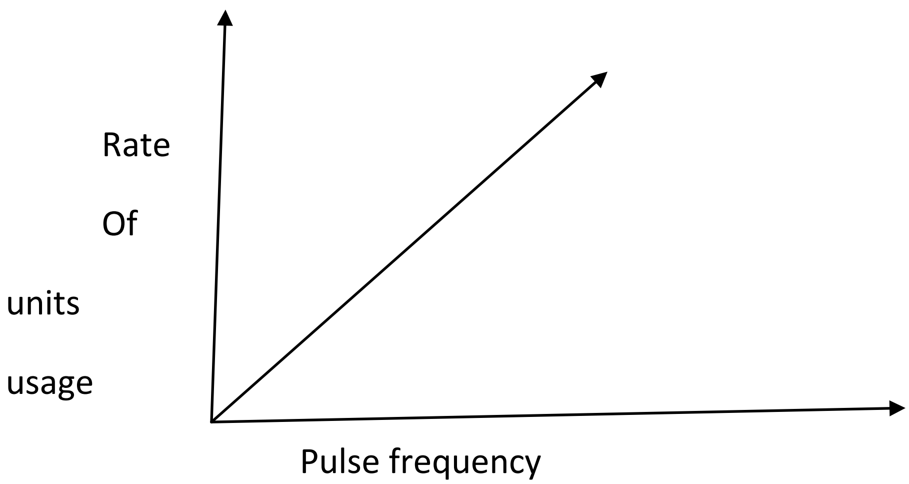

Figure 5.2 Graph showing relationship between pulse frequency and count down rate of recharge units

Observation

The pulse frequency is directly proportional to the load current. Consequently, the rate of decrement of recharge units follows the amount of load current. The higher the load current, the faster the recharge units will decrement.

5.3Discussion of Results

The results achieved were acceptable under the circumstances and indicated the normal functioning of the energy meter. Once, the recharged values is fully decremented (either UP or Down counted), the power is disconnected. On reloading, the power resumes, which is consistent with the normal operation of the energy meter.

The rate of decrement of recharge units is directly proportional to the instantaneous load current. In other words, the higher the load current, the higher the decrement rate of the recharge units. This implies that the recharge units will be used up very fast. On the contrary, if the load current is low, the rate of decrement is equally low and the recharge units last longer.

The latching Relay, which switches the supply power to the premises ON or OFF worked perfectly well. During the simulation, the device functioned in sympathy to the status of the recharge units. When the recharge units are diminished to zero, the Relay switched the supply power OFF and switched the same ON after a re-load.

Close to the Relay is a bulb, which was used to indicate the presence or absence of supply power. Whenever, the supply power was switched ON by the Relay, the bulb came on and went off when the Relay disconnected the supply power.This was also consistent with the expected results.

Overall, the design met its objectives despite the noted limitations especially of the simulation software.

5.4 Expected Objectives

5.4.1 Objective 1

Despite implementing the prepaid metering systems, the KPLC considers the system to be expensive particularly in respect of the lower category of power consumers. KPLC argues that the colossal amount of resources required to invest in the purchase, supply and installation of energy meters takes long to regroup especially from domestic power consumers. On the contrary, the supply authority is of the view that the system is probably suitable only for heavy consumers of power. However, with wider application, the supply authority is likely to recover its initial expenses and realize acceptable levels of profit.

In addition, the system is considered appropriate for built up areas where GSM, Wi-Max or Wi-fiare readily available to ease or facilitate uninterruptible communication, which is very essential for the system. The system requires a reliable backbone for communication, hence a huge investment for reliable operation. However, the supply authority can contract dedicated communication links in order to realize very reliable and equally seamless data transmission thereby saving on operational expenses.

5.3.2 Objective 2

The second objective was achieved through circuit design and simulation. Fairly acceptable results were realized despite the missed IC and the inadequacies of the simulated circuit. The missing IC impeded the realization of the envisaged accurate results. Therefore, in the simulation setup, the load current reading bore no relation to the outstanding LCD readings, whereas it essentially should determine its decrement. Nonetheless, the outcome of the simulation was satisfactory in that it provided a general trend for the envisaged results.

5.4 Conclusions

The project was designed to achieve its objectives through the following individual and collective functions:-

- Load Tokens to the energy meter
- The microcontroller to store recharge units
- The microcontroller to load the Liquid Crystal Display
- The microcontroller to trip the latching Relay

The simulation software did not have the capability to load Tokens because it lacks AT commands, which are network circuit commands. Instead, the microcontroller loaded preset values of recharge units on the LCD and tripped the latching Relay. This means that it can load the Token value, once processed it receives from the server.

For correct determination of balances of recharge units displayed by the energy meter LCD, the pulse frequency to the microcontroller must be directly proportional to the amount of the instantaneous load current. The higher the load current grows, the higher the pulse frequency becomes. Consequently, the faster the power consumption rate becomes.

Once the Relay trips, the power supply remains OFF, until the next recharge value is loaded through the microcontroller.

An Automatic or direct Token loading system would provide better and convenient services to prepaid electricity customers, mostly in built up areas where GSM communication is readily available. However, for areas outside this fringe zone, there is need for expansion of universal access to ICT services.

5.5 Recommendations

The backbone of prepaid electricity systems is the availability of an all-time communication system. The Automatic Token loading system depends on a reliable GSM network. Therefore, the electricity supply authority in conjunction with communication service providers must endeavor to spread out communication systems to the furthest or remote area so as to facilitate connection of prepaid electricity systems to as many customers as possible.

Given the numerous advantages of prepaid electricity systems, the supply authority should also embark on wider application of the new regime through enhanced installation of more prepaid meters despite the initial heavy investment. This is because, with time, the advantages will begin to accrue with minimal further effort. In countries like South Africa, where the customer base is wider, the advantages of prepaid electricity systems are noticeable.

Direct or automatic Token loading system attempts to maximize on the benefits of prepaid electricity systems by providing the much needed convenience.

As more and more clients come on board, the communication link is likely to experience traffic congestion especially during peak hours. To mitigate against this setback, the service providers need to secure or reserve more frequency bandwidths to be used during such extreme conditions.

Alternatively, network traffic congestions can be minimized by sectoring the network and assigning each sector with its own vending machine.

In order to encourage more customers to come on board, the electricity supply authority may need to consider introduction of flexible and user friendly tariff regimes, particularly for low power consumers.

Owing to the inadequacies of Proteus simulation software, CISCO simulation software like packet tracer can be used in conjunction with AT commands to for circuit simulation.

5.6 Suggestions for Further Research

Explore the use of two software packages for simulation; one for circuit and the other for the energy meter because the two sections have specific and task-driven commands.

Alternatively, future research should concentrate on developing one common simulation software that can accomplish both functions.

REFERENCES

1. Chauhan,S.P.S and Vishnu Sharma (2009)Mobile computing, S.K.Kataria& Sons, New Delhi
2. Nagpal D.P(2011) Data communications and Networking,S.Chand& Company Ltd, New Delhi
3. Ighalo G.I and B.O. Omijeh(2013) Modeling of GSM-Based Energy Recharge scheme for prepaid meter Journal of Electrical and Electronics Engineering Volume 4 No.1, 2013 pp.46-53
4. IlebareJ.O and ShomuyiwaD.A (2013) Design and implementation of remotely monitored single phase smart energy meter via short message serviceInternational Journal of Computer Applications (0975-8887) volume 74-No9, 2013
5. Gareth B.H (2006)Design and development of an on-line Token vending system for prepaid electricity via the internet
6. Tewar D.D and Tushaar Shah (2003) An assessment of South Africa pre-paid electricity experiment, lessons learned and their policy implications for developing countries
7. International journal of Engineering Science and Technology Vol.3, 2011 pp.160-166
8. International journal of power electronics and Drive systems Vol.1, No.2, 2011 pp139-147, 2013

APPENDICES

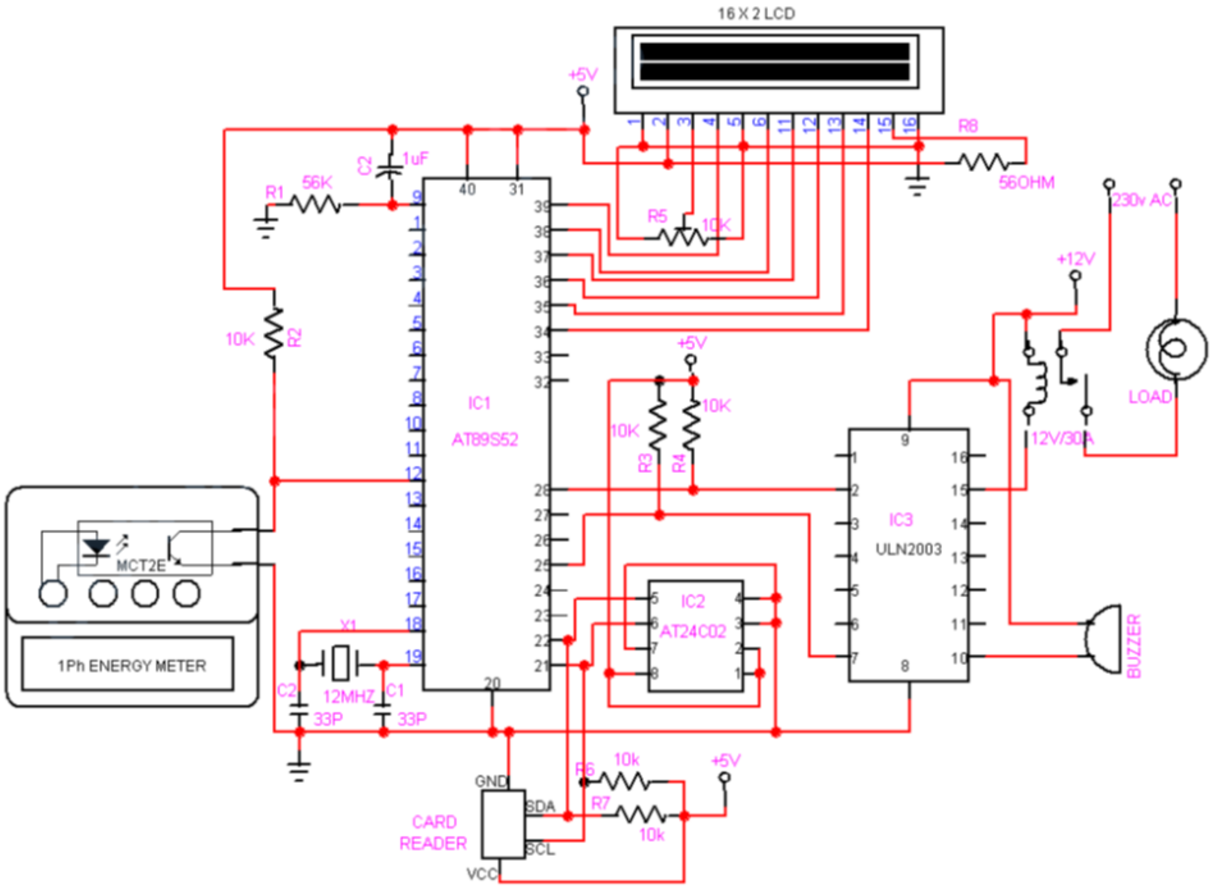

Fig.4.2 Circuit diagram of energy meter

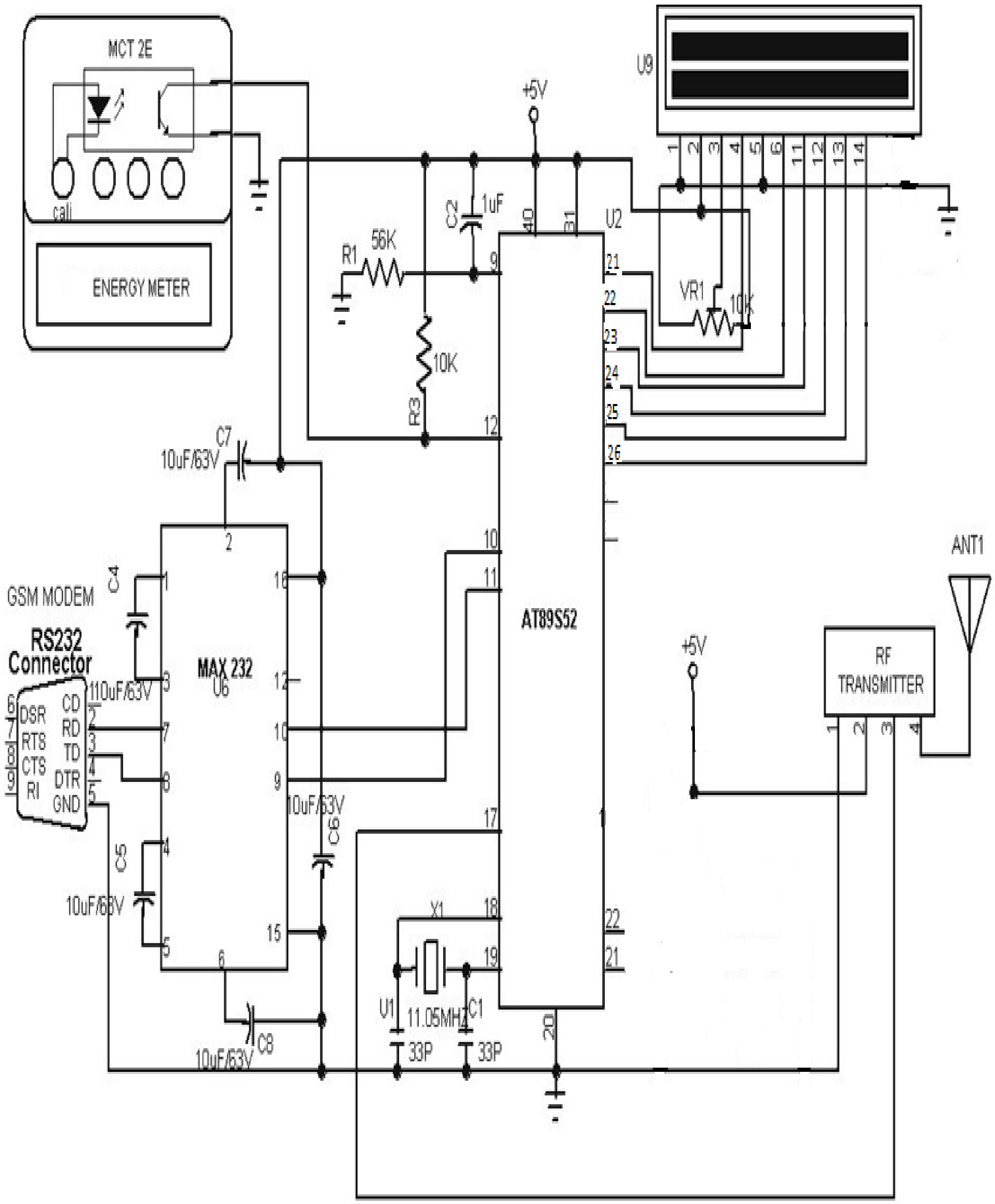

Figure 4.2 Complete circuit diagram with Modem connection

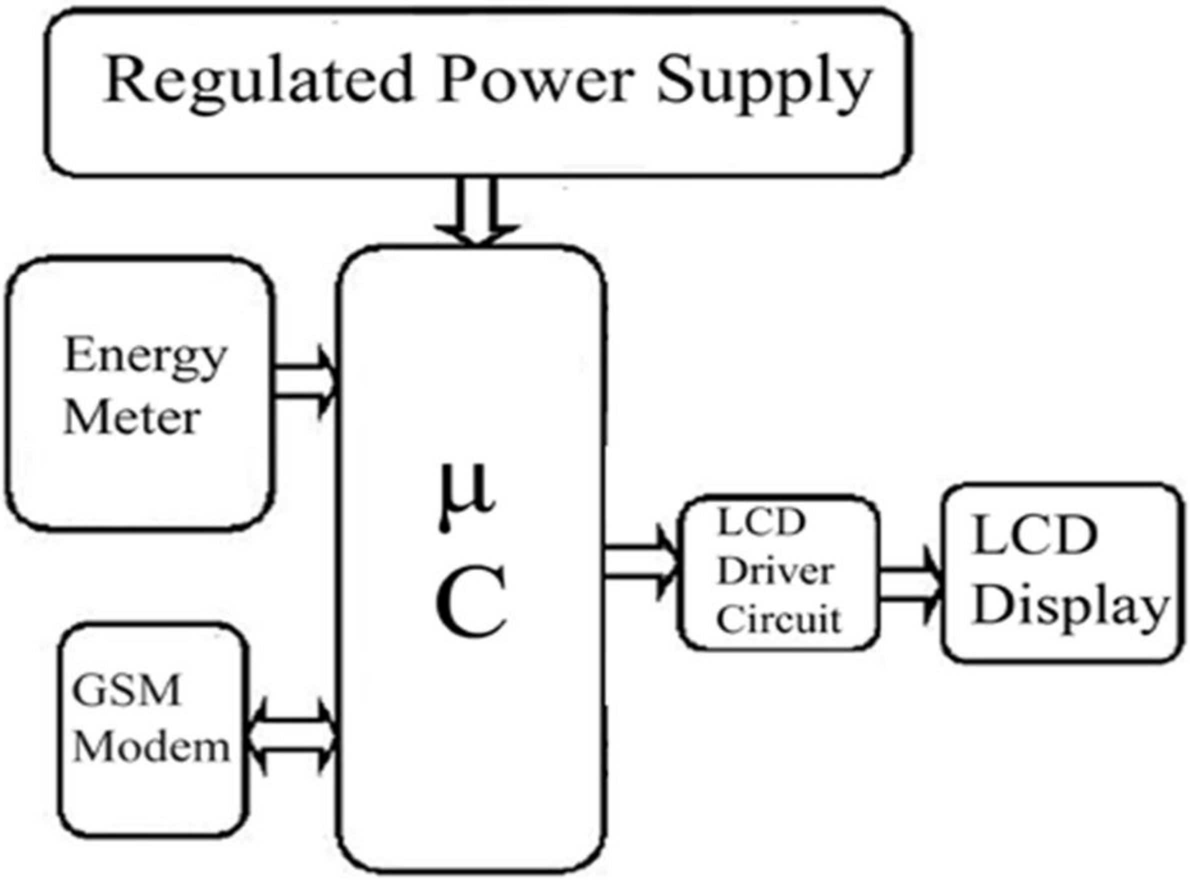

Fig.4.1 Block diagram of the energy meter

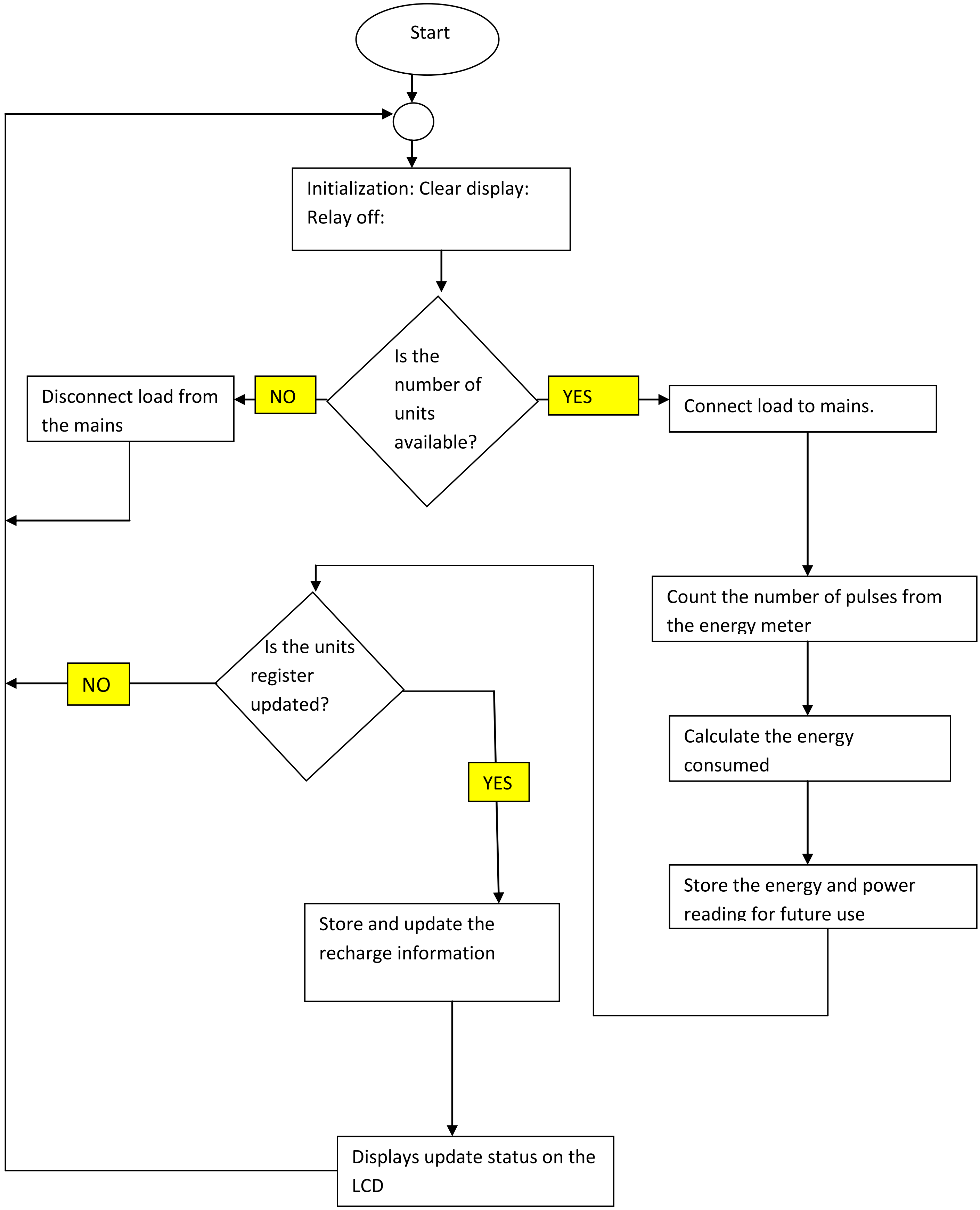

Figure 4.3 Flow chart of the energy meter

List of Important AT Commands:

Overview of AT Commands	Description
AT+CMGD	DELETE SMS MESSAGE
AT+CMGF	SELECT SMS MESSAGE FORMAT
AT+CMGL	LIST SMS MESSAGES FROM PREFERRED STORE
AT+CMGR	READ SMS MESSAGE
AT+CMGS	SEND SMS MESSAGE
AT+CMGW	WRITE SMS MESSAGE TO MEMORY
AT+CMSS	SEND SMS MESSAGE FROM STORAGE
AT+CMGC	SEND SMS COMMAND
AT+CNMI	NEW SMS MESSAGE INDICATIONS
AT+CPMS	PREFERRED SMS MESSAGE STORAGE
AT+CRES	RESTORE SMS SETTINGS
AT+CSAS	SAVE SMS SETTINGS
AT+CSCA	SMS SERVICE CENTER ADDRESS
AT+CSCB	SELECT CELL BROADCAST SMS MESSAGES
AT+CSDH	SHOW SMS TEXT MODE PARAMETERS
AT+CSMP	SET SMS TEXT MODE PARAMETERS
AT+CSMS	SELECT MESSAGE SERVICE