DESIGN AND CONSTRUCTION OF A SHORT MESSAGE SERVICE (SMS) BASED CONSUMER LOAD MONITORING AND CONTROL SYSTEM

BY

OKOROCHA, GOODLUCK CHIBUZOR
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A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF BARCHELOR OF ENGINEERING (B. ENG) DEGREE IN ELECTRICAL AND COMPUTER ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE, NIGERIA.

NOVEMBER, 2011

DECLARATION

I, Okorocha Goodluck Chibuzor, declare that this project work "DESIGN AND CONSTRUCTION OF AN SMS BASED CONSUMER LOAD MONITORING AND CONTROL SYSTEM" was done by me under the supervision of Dr. Tsado Jacob and has never been presented elsewhere for the award of a degree. I also hereby relinquish the copyright to the Federal University of Technology, Minna, Niger State, Nigeria.

OKOROCHA GOODLUCK .C.

(Name of student)
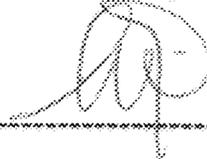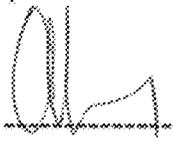
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DR. TSADO JACOB

(Name of Supervisor)

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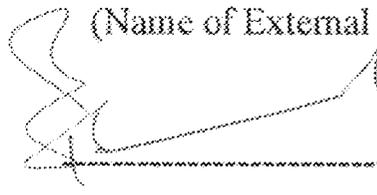
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ACKNOWLEDGEMENT

ABSTRACT

This project presents the design and construction of a short message service (SMS) based consumer load monitoring and control system. Its operation is centered on an AT89C52 microcontroller programmed in assembly language. A dedicated GSM modem with a SIM card is interfaced to the ports of the microcontroller through an NPN transistor (BC557) and a normally closed (NC) relay. The GSM modem is controlled by the microcontroller to send a notification alert via SMS to the user's mobile phone upon the restoration of power supply to his/her premises and whenever the energy consumed by the load exceeds the maximum value set (i.e. 1KW as used). This enables the user to respond promptly by cutting off power supply to the load unit when not needed. With this, a great deal of energy is saved and the consumer enjoys maximum satisfaction of the electrical energy paid for; hence an improvement and stability in the supply of power is achieved.

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CHAPTER ONE

GENERAL INTRODUCTION

1.10   Introduction

As commercial activities in the electrical industry increases, it became increasingly important to develop smart electric energy meters to properly measure and bill customers for the amount of energy consumed, instead of billing for a fixed amount of energy per month. To achieve this, many experimental types of meter were developed. An electrochemical metering system, which used an electrolytic cell to totalize the amount of energy consumed, was first developed [1]. Advancements in technology led to the development of more sophisticated meters like the electromechanical, Electronic and prepaid meters that can measure and display the energy used on an LCD or LED display, transmit readings to remote places, record other parameters of the load and supply: such as maximum demand, power factor and reactive power, support time-of-day billing etc [2].

The design and implementation of this project work helps in the functional improvement of the prepaid energy meter and makes it more useful to the user. By definition, the prepaid energy meter system does not use the classical form of billing (i.e. use now and pay afterwards) but collects money upfront. Its operation is similar to filling a car at the petrol station; the car would simply stop when the fuel tank is empty.

This project work therefore presents the design and construction of a short message service (SMS) based consumer load monitoring and control system, that will operate via SMS facility to help the user manage, save and reduce the amount spent on electrical energy consumed. It can

remotely monitor, control, and notify the user on his/her mobile phone about the load status. It can also cut off supply to the load unit when it is not needed, on request by the user. These are possible because, a dedicated GSM modem is interfaced with an AT89C52 microcontroller to receive the command from the user's mobile phone. The microcontroller then acts on this command to carry out the user's desired function.

1.20   AIMS AND OBJECTIVES

This project work is aimed at saving cost on the electrical energy consumed and reducing the amount of energy being wasted. This provides a means of enhancing the present prepaid energy meter used by the Power Holding Company of Nigeria (PHCN) with the following objectives:

i.   To help the user to remotely monitor and control the energy consumed via his/her mobile phone.

ii.   To alert the user on his/her mobile phone via SMS upon the restoration of power supply to his/her premises and when connected load exceeds maximum value set.

iii.   To enable the user disconnect and reconnect the power supply to the load unit from his/her mobile phone at any distance when not needed and vice versa.

1.30   METHODOLOGY

The steps employed in the design and construction of this system are stated as follows:

➢ The complete circuit diagram of the system was first generated on a paper.

➢ The components contained in the circuit diagram were sourced for in the local electronic market in Minna metropolis.

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- The system hardware was divided into units and each unit was separately constructed on the breadboard and tested.

- The software was then written, using assembly language on a notepad application and transferred into the microcontroller through an EDSIM simulator.

- The entire hardware units were assembled together and soldered onto the veroboard.

- Finally, the programmed chip was mounted onto its socket to the board and the system was then tested again.

1.40   OPERATION OF THE SYSTEM

The designed system demonstrates one of the emerging applications of the GSM technology. It is divided into sections: the hardware and the software. The hardware section is made up of four basic units: the microcontroller unit, the GSM interface unit, the power/load monitoring unit and the power supply unit while the software section is developed using an interactive Assembly language platform. The operation of the system is centered on the AT89C52 microcontroller programmed in assembly language. Whenever power is restored to the user's premises, the power supply unit takes power from the output of the prepaid energy meter and provides power to the system; the microcontroller unit senses the presence of power and sends signal to the GSM interface unit. The GSM interface unit then notifies the user on his/her mobile phone via SMS that power has been restored to his/her premises. The user at this point can decide to either allow the supply or cut it off if not needed, by sending a call alert to the dedicated GSM modem.

Also, whenever the connected load exceeds the maximum preset value (i.e. 1KW as used in this design), the microcontroller unit senses it, and sends signal to the GSM interface unit. The GSM

interface unit again, notifies the user on his/her mobile phone via SMS that maximum load value has been exceeded. The system then, waits for one minute to elapse and automatically cuts off supply to the load unit if the condition is still maintained. The consumer can disconnect and reconnect the supply to the load unit whenever he/she wants by simply sending a call alert to the dedicated GSM modem and will receive an SMS in return as acknowledgment for the command sent. With this, a great deal of energy consumed is saved and the amount spent on energy is reduced. Hence a reduction in amount spent on energy consumption and prompt payment of bills is achievable.
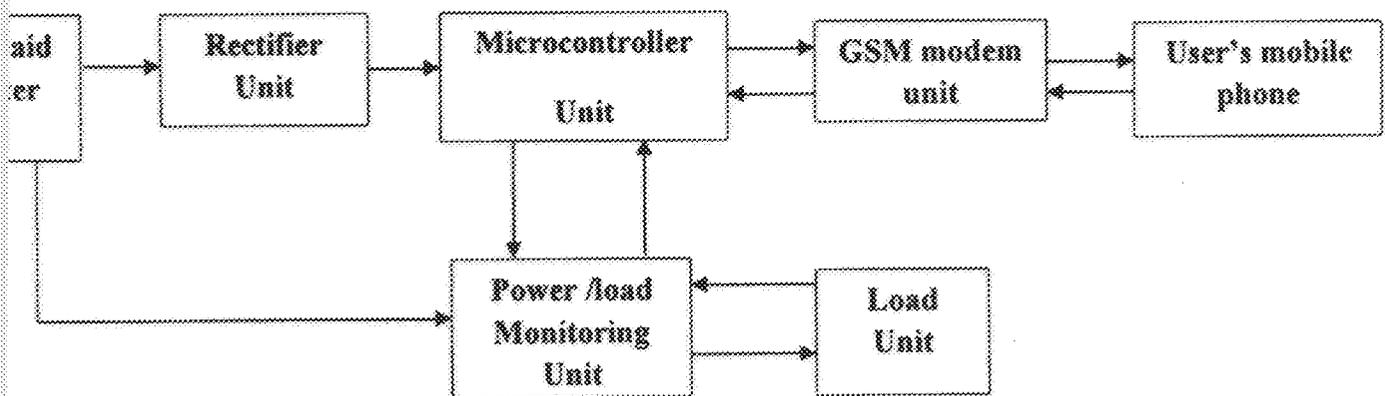
Figure 1.40   Block Diagram of the System

1.50   JUSTIFICATION

In recent years, mobile phone technologies are becoming common day- by- day and accessible. The number of people with cell Phones is on the increase because Land line telephones have become less popular and people now prefer communicating while on the move, especially in the developing countries [6]. When people have a good connectivity at their disposal, with tremendous power of mobile computing to supplement the same, they can think of connecting their home appliances to a mobile Phone wirelessly. With this, people would be able to turn OFF

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and ON, and to some extent control the appliances at their homes from any distance. One of the very basic examples of the utility of this, is that presented in this project work and also the switching ON of the air conditioner in the room just some time before reaching home at a distance so that the room will be sufficiently cool. The usefulness of the long range remote control to home appliances has no limits.

1.60   SCOPE OF THE PROJECT

This project covers the historical development and types of electrical energy meters, operations of the prepaid energy meter and the application of the GSM technology in monitoring and controlling the amount of electrical energy consumed by the user.

1.70   LIMITATIONS

This project is a prototype that is limited to small electrical loads consuming power less than 1000W. To be used for higher electrical loads above 1000W, the rating of the transformer, relay etc. should be increased.

CHAPTER TWO

LITERATURE REVIEW

2.10 Historical Background

An electricity meter is 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 one being the kilowatt hour. Periodic readings of electric meters establish billing cycles and energy used during a cycle [1].

In the 1880s, Edison at first worked on a DC electromechanical meter with a direct reading register, but instead developed an electrochemical metering system, which used an electrolytic cell to totalize current consumption. At periodic intervals the plates were removed, weighed, and the customer billed. The electrochemical meter was labor-intensive to read and not well received by customers. In 1885, Ferranti offered a mercury motor meter with a register similar to gas meters; this had the advantage that the consumer could easily read the meter and verify consumption.[2] The first accurate, recording electricity consumption meter was a DC meter by Dr Hermann Aron, who patented it in 1883. Hugo Hirst of the British General Electric Company introduced it commercially into Great Britain from 1888[3]. Meters had been used prior to this, but they measured the rate of energy consumption at that particular moment, i.e. the electric power. Aron's meter recorded the total energy used over time, and showed it on a series of clock dials.

The first specimen of the AC kilowatt-hour meter produced on the basis of Hungarian Otto Bláthy's patent and named after him was presented by the Ganz Works at the Frankfurt Fair in the autumn of 1889, and the first induction kilowatt-hour meter was already marketed by the factory at the end of the same year. These were the first alternating-current watt meters, known by the name of Bláthy-meters [4]. The AC kilowatt hour meters used at present operate on the same principle as Bláthy's original invention [7]. Also around 1889, Elihu Thomson of the American General Electric company developed a recording watt meter (watt-hour meter) based on an ironless commutator motor. This meter overcame the disadvantages of the electrochemical type and could operate on either alternating or direct current [8].

In 1894 Oliver Shallenberger of the Westinghouse Electric Corporation applied the induction principle previously used [10] only in AC ampere-hour meters to produce a watt-hour meter of the modern electromechanical form, using an induction disk whose rotational speed was made proportional to the power in the circuit [11]. The Bláthy meter was similar to Shallenberger and Thomson meter in that they are two-phase motor meter [12]. Although the induction meter would only work on alternating current, it eliminated the delicate and troublesome commutator of the Thomson design.

2.20   TYPES OF ENERGY METER

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 etc.). Meters for smaller services (such as small residential customers) can be connected directly in-line between source and customer. For larger loads, more than about 200 ampere of load, current transformers

are used, so that the meter can be located other than in line with the service conductors. The meters fall into two basic categories, electromechanical and electronic.

2.2.1 Electromechanical Meters

The most common type of electricity meter is the electromechanical induction watt-hour meter[15]. The electromechanical induction meter operates by counting the revolutions of an aluminium disc which is made to rotate at a speed proportional to the power. The number of revolutions is thus proportional to the energy usage. It consumes a small amount of power, typically around 2 watts. The metallic disc is acted upon by two coils. One coil is connected in such a way that it produces a magnetic flux in proportion to the voltage and the other produces a magnetic flux in proportion to the current. The field of the voltage coil is delayed by 90 degrees using a lag coil [15]. This produces eddy currents in the disc and the effect is such that a force is exerted on the disc in proportion to the product of the instantaneous current and voltage. A permanent magnet exerts an opposing force proportional to the speed of rotation of the disc. The equilibrium between these two opposing forces results in the disc rotating at a speed proportional to the power being used. The disc drives a register mechanism which integrates the speed of the disc over time by counting revolutions, much like the odometer in a car, in order to render a measurement of the total energy used over a period of time. The type of meter described above is used on a single-phase AC supply. Different phase configurations use additional voltage and current coils.

2.2.2 Electronic Meters

Electronic meters display the energy used on an LCD or LED display, and can also transmit readings to remote places. In addition to measuring energy used, electronic meters can also record other parameters of the load and supply such as maximum demand, power factor and reactive power used etc. They can also support time-of-day billing, for example, recording the amount of energy used during on-peak and off-peak hours [1].

2.2.3 Multiple Tariff (Variable Rate) Meters

Electricity retailers may wish to charge customers different tariffs at different times of the day to better reflect the costs of generation and transmission. Since it is typically not cost effective to store significant amounts of electricity during a period of low demand for use during a period of high demand, costs will vary significantly depending on the time of day. Low cost generation capacity (base load) such as nuclear can take many hours to start, meaning a surplus in times of low demand, whereas high cost but flexible generating capacity (such as gas turbines) must be kept available to respond at a moment's notice (spinning reserve) to peak demand, perhaps being used for a few minutes per day, which is very expensive. Some multiple tariff meters use different tariffs for different amounts of demand. These are usually industrial meters.

2.2.4 Appliance Energy Meters

Plug in electricity meters (or "Plug load" meters) measure energy used by individual appliances. There are a variety of models available on the market today but they all work on the same basic principle. The meter is plugged into an outlet, and the appliance to be measured is plugged into the meter. Such meters can help in energy conservation by identifying major energy users, or

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devices that consume excessive standby power. A power meter can often be borrowed from the local power authorities or a local public library [17].

2.2.5 Smart Meters

Smart meters go a step further than simple AMR (automatic meter reading). They offer additional functionality including a real-time or near real-time reads, power outage notification, and power quality monitoring. They allow price setting agencies to introduce different prices for consumption based on the time of day and the season.

These price differences can be used to reduce peaks in demand (load shifting or peak lopping), reducing the need for additional power plants and in particular the higher polluting and costly to operate natural gas powered peaker plants. The feedback they provide to consumers has also been shown to cut overall energy consumption.

Another type of smart meter uses nonintrusive load monitoring to automatically determine the number and type of appliances in a residence, how much energy each uses and when. This meter is used by electric utilities to do surveys of energy use. It eliminates the need to put timers on all of the appliances in a house to determine how much energy each uses.

2.2.6 Prepaid Meters

The prepaid meter is being used in developed countries and rapidly gaining large acceptance in many developing countries. The system of the prepaid energy metering is a relatively new concept in the Nigerian Power Supply system. It was first introduced into Africa in the mid-nineties by companies such as Conlog of South Africa. The system has gained a wide acceptance beyond just the power metering to metering of other basic utilities such as water and telephone

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services. It is not surprising that other companies have also shown interest in the system and as such have developed technologies that can support this system. These companies include Unistar Hitek and Actaris just to mention but a few [3].

As the name implies, the system allows electricity consumers to purchase or make payment for units of electricity upfront. This system is similar to that used by most Telecommunications Networks popularly known as "pay as you go". It is important to note that this system of payment ensures hundred percent prompt payment of electricity charges as at when due by consumers. Therefore, this mode of payment is more suitable than the billing and meter reading technique popularly known to most individuals. The introduction of the prepaid metering is therefore timely at this stage, when the PHCN is undergoing a major restructuring in order to improve its service delivery [5]. Broadly classified, the prepaid system can be grouped into three major types [5]:

➤ Magnetic Strip based Prepaid Meters

➤ IC Card based Prepaid Meters

➤ Standard Transfer Specification (STS) based Prepaid Meters

2.2.6.1 Operational Principle

This prepaid system was designed so that the purchase of electricity, gas, or water is made at a central station such as a gas or electricity utility office. The information regarding the amount of the purchased commodity is then communicated to the consumer site where the utilities are consumed. At the consumer site, a metering device is installed which is designed to receive the prepaid communication information and credit the user with the amount purchased at the central site. These type of proposed prepaid metering system will reduce the overall services cost of

utility distribution, by reducing or eliminating meter reading expenses, bad debt collection, account transfer expenses and credit department expenses, while at the same time providing a greater awareness on the consumer's part as to his/her consumption habit [10].

In the magnetic stripe card metering, there is provided a prepaid system for dispensing utilities using magnetic stripe cards. A sales accounting computer in the office is used in conjunction with point-of-sale machines for encrypting a value message which is written on to the magnetic stripe of the card. The value message contains information relating to the amount of utilities purchased by the costumer, the utility rates, the site identification number, and a unique password formed by the site number, a hidden number, and the transaction number. The magnetic stripe card is carried by mail or in person to the consumer's home or office and inserted into the magnetic stripe card reader attached to the microcontroller based control device. This control device is capable of reading and decoding the card and storing the value information into memory for use in monitoring the utility usage of the customer and disconnecting or connecting the utility based on the amount of utility purchased.

The system provides a method or apparatus for the consumer to purchase the magnetic stripe value card directly from the utility office by either mail order, in person or pre-arranged periodic bank drafts, or from unattended machines in convenient neighborhood locations. These machines are accessible to the consumer 24 hours per day. These unattended machines will recognize and accept local paper currency in common denominations, and provide a properly encoded carded card to the customer [8].

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2.30   WIRELESS COMMUNICATION

One of the greatest invention ever made to make life easy for man, is the communication over a long distance that probable cannot be wired (wireless communication). Over time the mode of communication has included telegraphy, radio and television broadcast, point-to- point mobile communication, radio telemetry and navigation which has now been improved to wireless mobile communication that is not dependent on distance. Wireless communication has been found to be useful beyond just to communicate among individuals but can also be used for industrial and domestic purposes as a remote controller. This proves the fact that telecommunication is very crucial to human existence. The following situations justify the use of wireless telecommunication technology [6]:

* To span a distance beyond the capabilities of typical cabling.
* To provide a backup communications link in case of normal network failure.
* To link portable or temporary workstations.
* To overcome situations where normal cabling is difficult or financially impractical.
* To remotely connect mobile users or networks.

A control system is one which carries some special functions, checks its success and takes up further action until the objectives are achieved. The control system can be used to control various quantities, electrical appliances or even industrial machinery and processes. A remote controller is a component of an electronic device, most common to a television or computer, which is a control system used for operating the devices wirelessly from a short line of sight distance. Remote controller will be highly efficient when not dependent on distance. Being able to control and monitor your appliances from anywhere will rather make its operation much easier and effective.

The application of the microcontrollers to control systems has now caused a tremendous improvement in the functionality and performance of the system. The flexibility of the system is as a result of the programmable nature of the microcontroller which makes it perform rigorous and difficult task like data analysis, control of physical, electrical or mechanical quantities effectively [11].

2.3.1 The GSM Network

About four (4) billion people in the world use the Global System of Mobile Communications (GSM) family of technology as at December 2009. GSM is the most widely used wireless technology in the world, available in more than 219 countries and territories worldwide, with a market share of more than 89 percent. GSM has become the fastest growing wireless technology worldwide. GSM is the legacy network of the evolution to the third generation (3G) technologies Universal Mobile Telecommunication System (UMTS), also known as WCDMA, and High Speed Packet Access (HSPA), commonly referred to as the GSM family of technologies. The oldest member of the GSM family of technologies is the GSM itself; a digital or personal communications system (PCS), 2G technology that provides voice and circuit-switched data services. There are several reasons why GSM is so popular among operators and their customers [12]:

i. Clear voice quality, which helps to make GSM a viable alternative to wire line telephony for customer and businesses.

ii. International roaming with service available in more than 219 countries.

iii. Spectral flexibility, with network infrastructure and user devices available for the 450, 850, 900, 1800 and 1900 MHZ bands.

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iv.   Tight security, including inherent protection from eavesdropping and hacking. This helps to make GSM voice and data an attractive alternative to analog cellular and Wi-Fi in the eyes of users, particularly enterprises.

v.   Subscriber Identity Module (SIM) cards, which allow customers to buy a new or additional phone, or a GSM PC card modem.

vi.   Data support, including SMS and web browsing.

2.3.2   The Short Message Service (SMS)

It is a known fact that SMS is indeed relevant in the advancement of GSM technology, which goes beyond voice communication. SMS has become a phenomenal success that has been a surprise to many both inside and outside the communications industry [14].

The origin of the text messaging services in GSM lies in the historical development of telecommunication services. SMS was created by a small group of people. The work on the standardization of services and the technical realization was approved by the CEPT group special mobile. Text messaging was a known telecommunication service years before the development of GSM started in 1982. Proposals for text messaging as a service in GSM were made by Nordic, German and French operators, who were all co-operating in the task. The Nordic operators focused their work on text messaging by using an access to a message handling system, a service similar to e-mail. This service was standardized by the GSM committee and led to a technical report on the technical realization of the access to message handling systems. The German and French operators focused their work on 'Short Message Transmission'. This service uses a dedicated service centre and transmits the text message over existing signaling paths of the GSM telephony system on a lower priority basis. This transmission method obviously constrains the

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message to be short: the maximum length, initially estimated as 128 octets, later optimized to 160 characters, is still sufficiently long for most personal or professional purposes [14].

The first phase of work, from February 1985 to the end of 1986, saw the GSM committee specifically the service features of SMS, with most contributions coming from Germany and France. From 1987 onwards, the technical realization of SMS was standardized in a small group called Drafting Group Message Handling. The first Chairman of this group and the editor of the key technical specification were provided by Norway (later replaced by UK), and technical work was mostly provided by Finland, France, Norway and the UK. The first phase of the SMS specification comprised items that included service definition, network architecture, topology and protocols, acknowledgement capabilities, functionality for alerting on messages waiting, time stamping and capabilities of identifying application protocols.

The further evolution of the SMS was standardized in the same small group, led by the UK (where the technical work was mostly provided by the UK). Examples of enhancements from this period are automatic replacement of messages, so-called 'flash SMS' and voicemail icons, followed by color and picture capabilities, and long SMS.

2.3.3 Subscriber Identity Module (SIM)

The phone is not active without the SIM card inserted into it. SIMs are used to activate or for network reception from the GSM operator. The SIM is a detachable smart card containing the user's subscription information and the phone book. Every operator has its unique SIM, which differs from other operators, the user can change operator by changing the SIM in the handset.

2.40 THE AT89C52 MICROCONTROLLER

At the modern stage of Scientific and technological development, microelectronics is rapidly gaining ground and its advances today largely determine progress in many branches of industry. The need for lighter, compact, flexible and more reliable radio electronics equipment capable of performing the functions of growing complexity has led to the research into the ways and means of achieving the set goals. Since discrete transistors could not meet the above requirement, search for principal new approaches to microminiaturization, low-cost and reliable electronic system has brought about the concept of producing circuit in only one tiny die or chip [12].

The AT89C52 Microcontroller is a single chip microprocessor system which contains information and program memory, input and output, analog to digital converter, internal and external interrupt used for control purposes. It is a low-voltage, high performance CMOS 8-bit microcomputer with 4Kbytes of Flash programmable and erasable read only memory (PEROM). The device is manufactured using Atmel's high density non volatile memory technology. By combining a versatile 8-bit CPU with Flash on a monolithic chip, the Atmel AT89C52 is a powerful microcomputer which provides a highly flexible and cost effective solution to many embedded control applications. It included an instruction set (opcodes), 32 input and output lines, 3 user controllable timers, an integrated and automatic serial port, and 256 byte of the on chip RAM.

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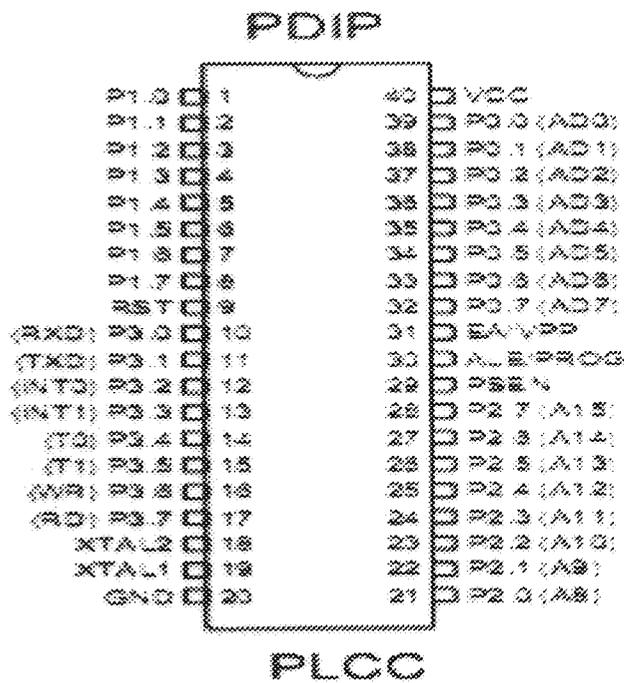
Figure 2.40 A pictorial representation of an AT89C52 microcontroller

2.50 RELAYS

A relay is an electrically operated switch. Current flowing through the coil of the relay creates a magnetic field which attracts a lever and changes the switch contacts. The coil current can be ON or OFF so that the relay can have two switch positions and most have double throw switches.

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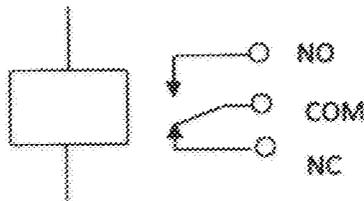
Figure 2.50   A Symbolical representation of a relay

Relays are predecessors to transistors. Solenoids are relays also but the very large types carry huge amount of current. Relays are the smaller types. Relays come in three types: Mechanical, Solid-state and so-called hybrids.

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CHAPTER THREE

DESIGN AND CONSTRUCTION

The design and construction of this project is presented here. It involves the actual assembly and arrangement of the various components and parts that make up the design and built up of the final circuit. The entire work is divided into two sections: the hardware and the software.

3.10 THE HARDWARE SECTION

The hardware section of this system is subdivided into four units that enable the achievement of the desired results. These units subdivision are:

i.   The Power Supply Unit

ii.   The Power Monitoring Unit

iii. The Microcontroller Unit

iv.   The GSM Modem Interface Unit

3.1.1 The Power Supply Unit

Generally, most of the electronic devices and circuits require electrical energy in the form of direct current (DC) for their operations [9]. This unit supplies the entire circuit with the required power needed for operation. The batteries which are the main sources of the direct current cannot be used for this design because of their limited life span and most of them cannot be recharged. However, for efficient and effective supply of power, the Alternating Current (AC) from the 220V, 50HZ Mains supply was converted into the needed direct current (rectification). A typical DC power rectifier consists of four basic stages as shown in the block diagram below:

| Transformer | → | Rectifier | → | Filter | → | Voltage Regulator |
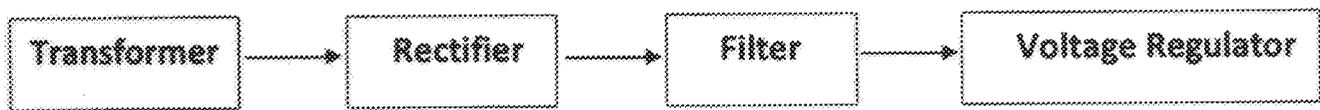
Fig. 3.1.1a   A Typical Power Rectifier Block Diagram

3.1.1.1 The Transformer

The transformer is a stationary piece of apparatus by which electric power in one circuit is transformed into electric power of same frequency in another circuit. It accomplishes its operations by electromagnetic induction [9]. It either steps up or steps down the AC supply voltage to suit the basic required voltage needed by the solid state electronic devices. The transformer used to supply energy for this design is an already made step down type that was bought from the electronics shop and used to step down the 220V from the mains to 24V AC voltage.

3.1.1.2 The Rectifier

The rectifier is a circuit that employs one or more diodes to convert AC supply voltage into a pulsating DC voltage. The circuit can either be a half wave or a full wave rectifier depending on the number of diodes used. A half wave utilizes two diodes while a full wave utilizes four diodes for rectification [9]. A full wave block diode rectifier was used for the rectification in this project design.

3.1.1.3 The Filter

The filter is a circuit element that is used to remove fluctuations or pulsations (called ripples) present in the output voltage of the rectifier. Capacitors are used to achieve filtering in power circuit and are connected to the rectifier output. The output of the filter is almost ripples free as

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that of a dc battery [9]. For this system design, two capacitors, 3300µf and 6800µf, were used for filtering the output voltage as calculated below.

3.1.1.4 The Voltage Regulator

The voltage regulator plays an important role in any power supply unit. Its primary function is to aid the rectifier and the filter to provide a constant DC voltage to the device. Power supplies without the regulator have an inherent problem of changing DC voltage values due to variations in the load or fluctuations in the AC line voltage. With a regulator connected, the DC voltage can be maintained within a closed tolerant region of the desired output. Three regulators, IC7805, IC7806 and IC7812 regulators were used for the supply of regulated power to the components in the circuit of this system design thereby providing voltages of +5V, +6V and +12V supply respectively.
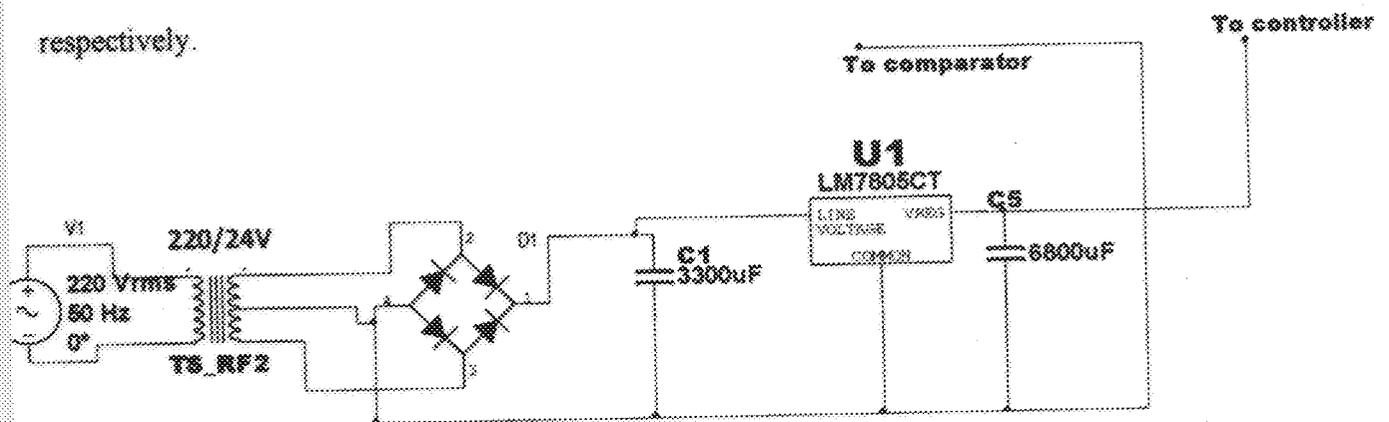
Figure 3.1.1b   A Complete Circuit Diagram of the Power Supply Unit

The load causes the capacitor to discharge and if the load current is constant as it will be for small ripple. Then the load current will be expressed as:

$$I = \frac{cdv}{dt} \quad \text{------------------------------3.1.0}$$

The frequency of the full wave signal is double that of the input frequency. The full wave inverts each negative half cycle so that we get double the number of the positive half cycle. This effect is to double the frequency in the output.

$f_{out} = 2f_{in}$ -------------------------3.1.1   (i.e. output frequency is twice input frequency)

This implies that :

$dt = \frac{1}{2f_{in}} = \frac{1}{2 \times 50} = 0.01s$. This is on the safe side since the capacitor starts charging up in less than half a cycle.

The maximum current that can be drawn is determined by the voltage regulators (7805, 7806 and 7812) following the filtering capacitor. The standard 7800 series regulators provide output current in excess of 1A when used with adequate heat sink [9]. Therefore it can supply a maximum current of 1A which will be drawn from the supply. The value of C can be calculated as:

I_{out}=1A (maximum) ;

From equation 3.1.0,

$C = Idt/dv$

But generally, dv which is the ripple voltage is chosen to be 10% of the peak voltage(V_p) for most electronic circuits[9].

Peak voltage (V_p) = $V_{rms}\sqrt{2}$, --3.1.2

Where V_{rms}=24V since transformer of 220/24V was used.

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$V_p = 24 \times \sqrt{2} = 33.94V$

For bridge rectifier output, $V_{out} = V_{p(in)} - 1.4V$ --3.1.3

Since 0.7V dropped across a diode whenever it conducts and two diodes conducts at a time in this case.

The bridge output voltage is then given as:

$V_{pout} = 33.94 - 1.4 = 32.54V$

Ripple voltage (dv) is:

$dv = \left(\frac{10}{100}\right) \times 32.54 = 3.254V$

Therefore, the capacitor value used is thus calculated from equation 3.1.0 as:

$C = \frac{1 \times 0.01}{3.254} = 3.073 \times 10^{-3}F = 3073.1\mu F$

But a commercial value of 3300µF, 35V was used to perfectly remove the amount of ripples available in the output to the nearest minimum because the higher the capacitance value, the lower will the ripple become.

3.1.2   The Power/Load Monitoring Unit

This unit is primarily responsible for carrying out the following functions:

> Monitoring of the power restoration to the user's premises.

> Monitoring the load consumed by the user.

> Communicating the load status to the microcontroller unit.

The unit is powered directly from the 220V AC mains supply of the prepaid energy meter's output because this is the voltage required by the load unit. Three (3) LED diodes (1 blue and 2 green) serve as external indicators, an LM358 OP-AMP IC with a current limiting resistor (41kΩ) connected to its input terminal acts as a voltage comparator, 12V and 6V relays together with a BC557 transistor (PNP) perform the switching function while a combination of two (2) LDRs and the LEDs is used as the sensors.

3.1.2.1 Operation of the Unit.

Whenever power is restored to the user's premises, the unit monitors the load status through the microcontroller and the relay. The two green LEDs will come ON; this will cause the resistance of the LDR1 to immediately drop from its 600kΩ value to a value of 400Ω. This drop in resistance will cause a signal to be sent to the microcontroller unit. As soon as the load becomes active, one of the green LED will go OFF while the other remains ON to indicate availability of power. The microcontroller unit in turn, operates the GSM modem according to the received signal to alert the user.

When the connected load reaches the maximum set value of 1KW, this will make the voltage on the input (positive) terminal of the voltage comparator to rise higher than that at the negative terminal (1.27V) by default. This voltage rise will cause the blue LED to come ON, and this leads to a drop in the resistance of the LDR2. As a result of this, a signal is sent to the microcontroller unit to act accordingly.
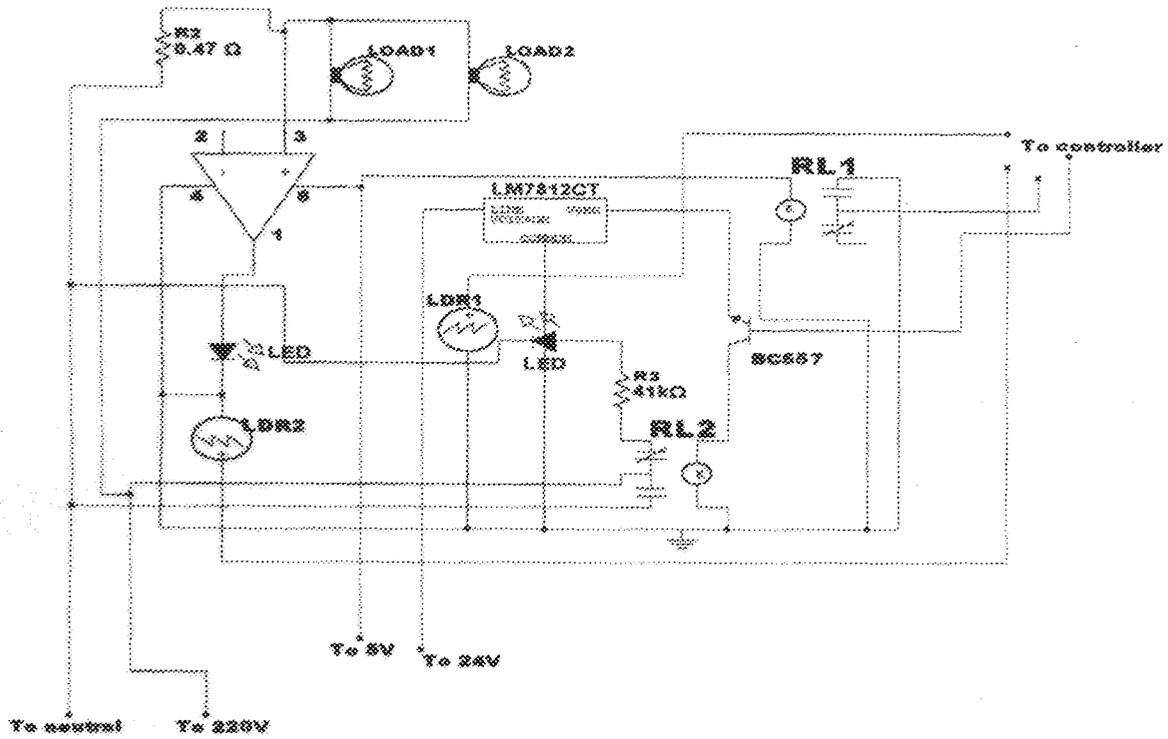
Figure 3.1.2   Circuit Diagram of the Power Monitoring Unit

3.1.3   The Microcontroller Unit

This is an intelligent unit and the heart of the entire work. It performs the following functions:

➤ It receives all the signals from the power monitoring unit and the GSM interface unit concerning the power supply, load condition and user's request.

➤ It controls all the functions of the dedicated GSM modem used for the system design.

➤ It decides when the GSM unit will alert the user about the power supply to his/her premises and the status of his/her loads.

➤ It also responds to the command sent by the user through his/her mobile phone and performs the required operation.

It was designed using an AT89C52 Microcontroller IC that operates at 12MHZ Oscillator frequency and powered by Vcc (5V). Three transistors and relays were connected to the port 1

and 2 of the microcontroller. They are used to connect and disconnect the load and also control the GSM modem.

3.1.3.1 Operation of the Unit

Upon the restoration of power to the user's premises, the microcontroller within 10 seconds initializes the system by switching ON the GSM modem and connecting the load. As soon as the load connects, the microcontroller triggers the GSM modem to send an SMS alert to the user's mobile phone that power has been restored and load active. If the user chooses to cut off power supply to the load unit, he/she will send a call alert to the GSM modem. The microcontroller unit senses this call alert and responds to the user's request to cut off the supply to the load unit.

Also, when the connected load exceeds the maximum set value, the microcontroller receives signal from the second sensor but decides to wait for 5 seconds to check if the cause was as a result of power surge. If the cause is not a surge, it then triggers the GSM modem to send the appropriate SMS to the user's mobile phone. It is this microcontroller that performs almost all the desired functions of this system.

3.1.3.2 The Oscillator Characteristics

XTAL1 and XTAL2 are the input and output of the crystal oscillator as shown in figure 3.1.3. The microcontroller operates based on an external crystal. This is an electrical device which when energy is applied, emits pulses at a fixed frequency. This frequency is used to keep track of time as the microcontroller uses the crystal oscillator to synchronize operations. The most common crystal frequencies are 12MHZ and 11.059MHZ but the 11.059MHZ is more common. Therefore, the 11.059MHZ crystal oscillator was used for the design of this system. From the data sheet of AT89C52, it was noted that appropriate capacitance value to be used is:

$C1 = C2 = 30pF \pm 10pF$.

3.1.3.3 Calculation of Baud Rate

The machine cycle frequency of the AT89C52 microcontroller used is 11.0592MHz. A machine cycle in reality is 12 pulses of the crystal oscillator.

Generally baud rate = Machine cycle frequency/pulses per cycle

$$= \frac{11.059MHz}{12} = 921,583HZ$$

Since timer 1 of the microcontroller is used and microcontrollers operate at frequency as low as 32HZ.

Therefore, $\quad \frac{921,583}{32} \approx 28,800$

28800 is the value used for timer 1 to set the baud rate.

Using baud rate constant = 3

Baud rate $= \frac{28800}{3} = 9600$

9600 is the equivalent of FD, this FD will be loaded into the timer high 1 (TH1).

Figure 3.1.3 Circuit diagram of the microcontroller unit

3.1.4 The GSM Modem Interface Unit

The GSM modem is the interface between the user and the microcontroller. It performs these basic functions:

> Sends SMS alert to the mobile phone of the user about the status of the load and receives the call alert sent by the user from his/her mobile phone to carry out a desired operation.

> Communicates the user's command to the microcontroller and relays the information from the microcontroller to the user.

The SMS alert sent to the user is already stored in the draft of the GSM modem. A Nokia N1280 GSM modem was used. It is interfaced with the microcontroller's port 1 and 2 through the transistor and relay as shown in figure 3.1.3. Whenever the microcontroller triggers the transistor connected to the modem, it can either request for the SMS in the draft to be sent to the user or to put ON and OFF the GSM phone.

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3.20 SOFTWARE SECTION

Assembly language program was used for the purpose of this project. The source code was written on the notepad application software and later transferred into the microcontroller chip. Figure 3.20 shows the flow chart of the system's operation and the soft code is shown in appendix B.

3.30 CONSTRUCTION OF THE SYSTEM

3.3.1 Circuit Construction

The circuit construction of the system was carried out systematically as follows:

The circuit diagram of the system was used for the step by step construction of each unit that makes up the system. Each of the unit was separately constructed with all the constituent components arranged on a breadboard and tested.

The constructed units were finally assembled together with the programmed chip in place to form the entire circuit and then tested to ascertain its correctness.

3.3.2 Case Construction

The casing of the constructed circuit was made with polished wood because it is stronger and will withstand more pressure than the plastic. The casing was carefully constructed such that it is table, durable and can be mounted in user's premises without stress.
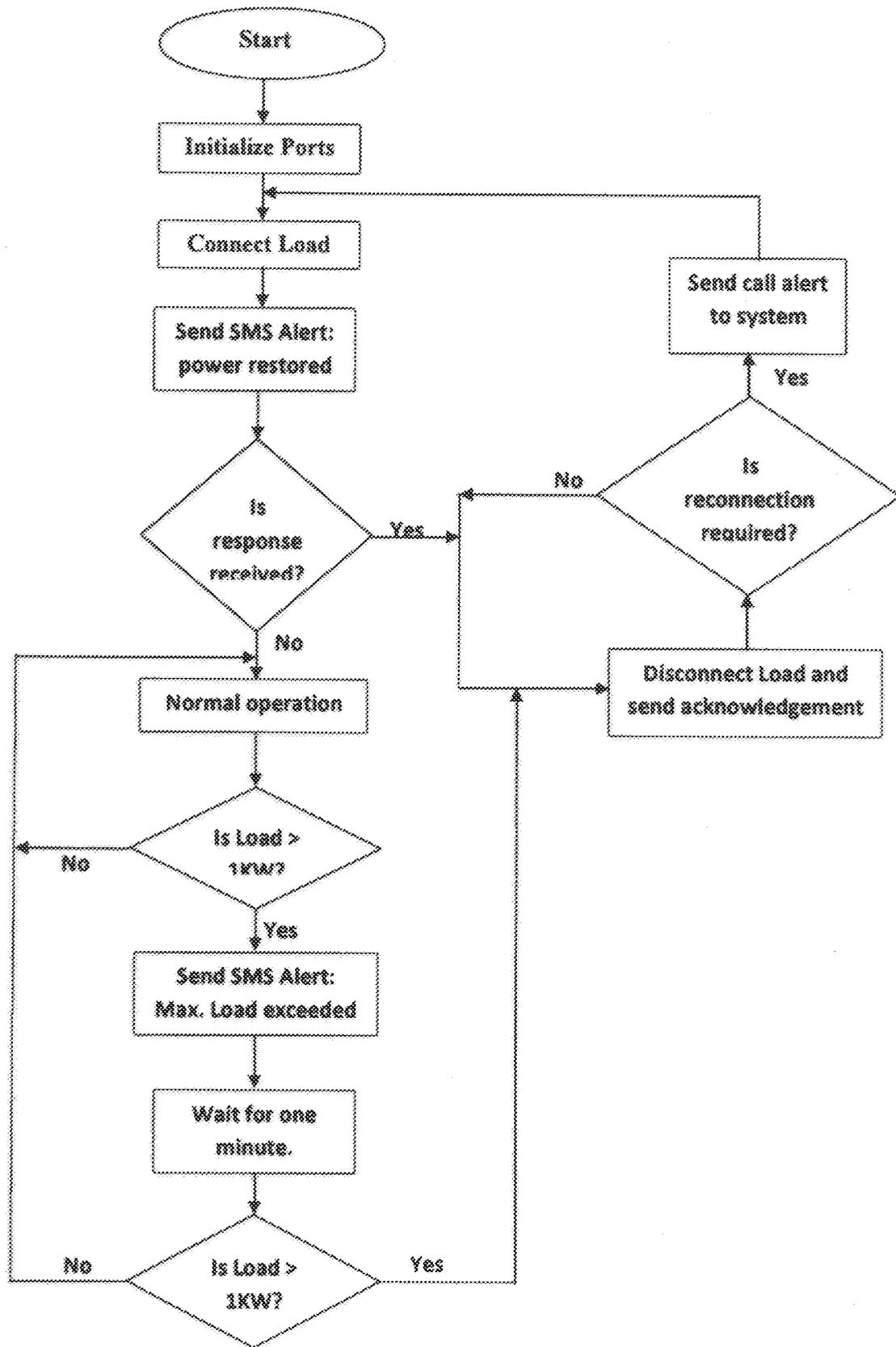
Figure 3.20   The Program Flow Chart.

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CHAPTER FOUR

TESTS, RESULTS AND DISCUSSION

This chapter focuses on the discussion of the various tests carried out and the results obtained.

4.10   TESTING

The testing of the entire work was carried out before and after its construction according to the systematic design of the system. The first step before construction was to test the components purchased using the multimeter to ascertain their workable conditions and identify defects on any of them before they are put to use. Each unit of the system was tested separately after construction, with appropriate adjustments made to ensure that desired result is obtained before assembling them together.

The second step of the testing was carried out after the completion of the entire circuit. Power was supplied to the system and an electric bulb of 60W was first connected to the output. A call alert was sent to the dedicated GSM modem used in the design. Later another load (electric iron) of 1200W was connected to the output and observations were made for each action carried out.
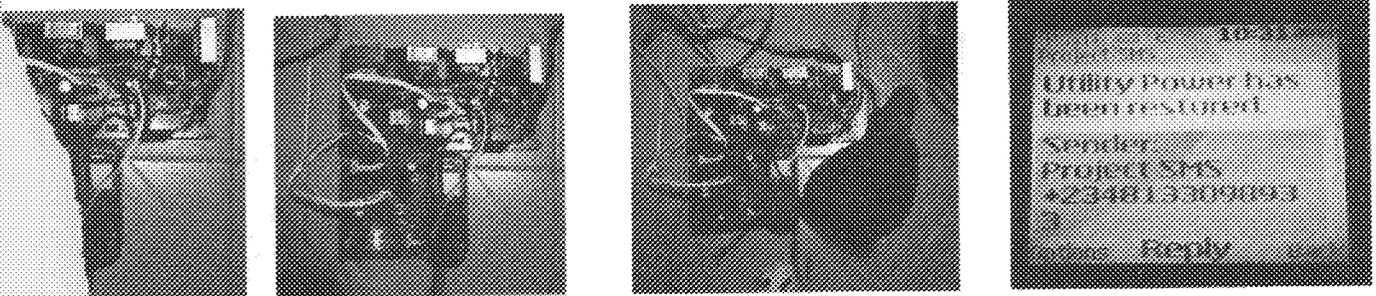
Figure 4.10   Picture of the Constructed Circuit during Testing and SMS received by the user.

4.20   RESULTS

A summary of the results obtained from the tests carried out after the completion of the system is shown in table 4.20 below.

Table 4.20   Representation of the results obtained during testing of the system

ACTION PERFORMED BY USER	RESPONSE FROM THE SYSTEM	INTERPRETATION OF RESPONSE
Power supplied from the socket outlet to the system	Sends SMS alert to user's mobile phone after 10 seconds.	Power supply has been restored and load is active.
Load of 60W connected (Electric Bulb)	No alert sent to user.	Normal system operation
Load of 1200W connected (Electric Iron)	Sends SMS alert to user's mobile phone after 5 seconds	Maximum power consumption exceeded.
Call alert sent from user's mobile phone to the system.	Cuts OFF supply to load and returns acknowledgment to user about load status	Supply to the load unit has been cut off.
Call alert sent the second time / user to the system.	Reconnects supply to load unit.	Load active

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4.30 RESULT DISCUSSION

The results obtained met the desired requirements. The units of the system worked properly as required. When power is supplied to the system, the microcontroller receives signal from the power/ load monitoring unit. It switches ON the GSM modem and connects the load within 10 seconds. The microcontroller then controls the GSM modem to send an SMS notification alert to the user.

As the electrical load of 60W (electric bulb) was connected, the system continued its normal operation. But upon the connection of another load of 1200W (electric iron), the microcontroller receives signal from the power/load monitoring unit and waits after 5 seconds before sending an SMS notification alert to the user through the GSM modem. Power was disconnected from the load unit after one minute elapsed as the load remained connected. The microcontroller unit also cuts off supply to the load unit when the user send a call alert and reconnects the supply if the user send another call alert to the system.

4.40 PROBLEMS ENCOUNTERD

In the course of the design and construction of the system, the following problems were faced:

➢ The initial microcontroller's operation was not in accordance to that which was required, and this was corrected by changing the microcontroller.

➢ During the supply of power to the system, the live and neutral terminals were interchanged and this damaged the microcontroller by supplying a large amount of voltage it.

➢ The search for the components needed for the design posed a challenge to the realization of the design.

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CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.10   CONCLUSIONS

After the design and construction of the system, it performed the specified functions as expected. Therefore, the project aligned with the basic factors embedded in the concept. With this, energy can be saved since the user can control supply to his/her load from any distance. Hence stability of power supply and reduction in the amount spent on energy is ensured.

This project, when used together with the prepaid energy meter, will enhance the performance and utilization of the prepaid energy meter. It will also help the user to efficiently and effectively utilize the energy he/she paid for and reduce amount of energy that is being wasted.

5.20   RECOMMENDATIONS

Supplementary tasks should be carried out on the system in the following areas to improve its performance.

- A charging unit should be built to charge the battery of the GSM modem.
- A display unit might be incorporated to display the amount of energy consumed by the user. With this, a smart energy meter is built.
- More emphasis should be placed on the design and fabrication of mini group projects for students in lower levels. As this will make them to be independent during their final year project work.

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APPENDIX B

PROGRAM SOURCE CODE

```
ORG 0H
MOV R0,#0H
MOV R1,#0H
MOV R2,#0H
MOV R3,#0H
;.................................................SYSTEM
INITIALIZATION
;....................5sec DELAY
LCALL DELAY
LCALL DELAY
LCALL DELAY
LCALL DELAY
LCALL DELAY
;...............................................
CONNECT:CLR P2.4;...........CONNECTS LOAD TO MAINS
        CLR P2.4
;...............................................
CHECK_CONNECTION:JNB P1.0,CONNECT;......CHECKS IF LOAD IS ACTIVE OR
NOT
;...............................................
MOV R2,#5
CLR P1.3;............ON PHONE
CLR P1.3
AGAIN:LCALL DELAY
DJNZ R3,AGAIN
SETB P2.0
SETB P2.0
NOP
NOP
;..........WAITS FOR NETWORK SERVICE
MOV R2,#5
AGAINN:LCALL DELAY
DJNZ R2,AGAINN
;...............................................END OF SYSTEM
INITIALIZATION

;.............................ALARTS THAT MAINS IS RESTORED
ART_SELECT:CLR P1.5
           LCALL DELAY
           SETB P1.5
           LCALL DELAY
           CLR P1.5
           LCALL DELAY
           SETB P1.5
           LCALL DELAY
;................................
N:CLR P1.4
  LCALL DELAY
```

```
        SETB P1.4
        LCALL DELAY
        CLR P1.4
        LCALL DELAY
        SETB P1.4
        LCALL DELAY
        CLR P1.4
        LCALL DELAY
        SETB P1.4
DRAFT:LCALL DELAY
;.................................
SELECT2:CLR P1.5;.......OPENS THE DRAFT
        LCALL DELAY
        SETB P1.5
        LCALL DELAY
    DWN:CLR P1.4;...SCROW DOWN TO SMS2
        LCALL DELAY
        SETB P1.4
        LCALL DELAY
   DWNN:CLR P1.4;...SCROW DOWN TO SMS3
        LCALL DELAY
        SETB P1.4
        LCALL DELAY
        CLR P1.5;......OPENS 3rd SMS IN THE DRAFT TO READ
        LCALL DELAY
        SETB P1.5
        LCALL DELAY
;.................................
CONTINUE:CLR P1.5
        LCALL DELAY
        SETB P1.5
        LCALL DELAY
;.................................
DOWN3:CLR P1.4
        LCALL DELAY
        SETB P1.4
        LCALL DELAY
        CLR P1.4
        LCALL DELAY
        SETB P1.4
        LCALL DELAY
        CLR P1.4;..........FORWORD SMS TO NUMBER
        LCALL DELAY
        SETB P1.4
        LCALL DELAY
.................................
   .ECT4:CLR P1.5;......OPENS FORWORD
        LCALL DELAY
        SETB P1.5
        LCALL DELAY
   .................................
   .RCH_NUMB:CLR P1.5
```

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```
              LCALL DELAY
              SETB P1.5
              LCALL DELAY
              CLR P1.5
              LCALL DELAY
              SETB P1.5
              LCALL DELAY
;.................................
SEND_1:CLR P1.5
         LCALL DELAY
         SETB P1.5
         LCALL DELAY
         MOV R1,#7
CON:LCALL DELAY
     DJNZ R1,COM
     CLR P1.3;................RETURN TO SCREEN SAVER
     CLR P1.3
     LCALL DELAY
     SETB P1.3
     SETB P1.3
     LJMP DESITION
;......................................................
...........
POWER_CONSUME_CHECK:JB P1.2,CALLN;......CHECK'S CONSUMPTION RATE
                    LJMP SURGE
                GO:JMP POWER_SMS
              CALLN:JB P2.1,POWER_CONSUME_CHECK;....MONITOR'S
INCOMING CALL
                    LCALL DELAY;.....3sec DELAY BEFOR ENDING CALL
                    LCALL DELAY
                    LCALL DELAY
                    CLR P1.3;................END CALL AFTER 3sec
                    CLR P1.3
                    LCALL DELAY
                    SETB P1.3
                    SETB P1.3
                    LCALL DELAY
                    SETB P2.4;...DISCONNECT LOAD
                    SETB P2.4
                    LCALL DELAY
                    LCALL COFMTION_SMS
                    JB P2.1,$;......PAUSE AND WAIT FOR CALL
                    LCALL DELAY;............3sec DELAY BEFOR ENDING
     L
                    LCALL DELAY
                    LCALL DELAY
                    CLR P1.3;................END CALL AFTER 3sec
                    CLR P1.3
                    LCALL DELAY
                    SETB P1.3
                    SETB P1.3
                    LCALL DELAY
```

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```
                    CLR P2.4;..RECONNECT LOAD
                    CLR P2.4
                    AJMP POWER_CONSUME_CHECK
;.........................................................................
...........
POWER_SMS:CLR P1.5
          LCALL DELAY
          SETB P1.5
          LCALL DELAY
          CLR P1.5
          LCALL DELAY
          SETB P1.5
          LCALL DELAY
;.........................................
DOWN2:CLR P1.4
     LCALL DELAY
     SETB P1.4
     LCALL DELAY
     CLR P1.4
     LCALL DELAY
     SETB P1.4
     LCALL DELAY
     CLR P1.4
     LCALL DELAY
     SETB P1.4
DRAFT2:LCALL DELAY
;.........................................
SELECT22:CLR P1.5;.......OPENS THE DRAFT
         LCALL DELAY
         SETB P1.5
         LCALL DELAY
   DWN2:CLR P1.4;...SCROW DOWN TO SMS2
         LCALL DELAY
         SETB P1.4
         LCALL DELAY
         CLR P1.5;......OPENS 2ND SMS IN THE DRAFT TO READ
         LCALL DELAY
         SETB P1.5
         LCALL DELAY
;.........................................
ONTINUE2:CLR P1.5
         LCALL DELAY
         SETB P1.5
         LCALL DELAY
     .........................................
  DN32:CLR P1.4
     LCALL DELAY
     SETB P1.4
     LCALL DELAY
     CLR P1.4
     LCALL DELAY
     SETB P1.4
```

```
        LCALL DELAY
        CLR P1.4;..........FORWORD SMS TO NUMBER
        LCALL DELAY
        SETB P1.4
        LCALL DELAY
;...............................
SELECT42:CLR P1.5
        LCALL DELAY
        SETB P1.5
        LCALL DELAY
;...............................
SEARCH_NUMB2:CLR P1.5
        LCALL DELAY
        SETB P1.5
        LCALL DELAY
        CLR P1.5
        LCALL DELAY
        SETB P1.5
        LCALL DELAY
;...............................
SEND_12:CLR P1.5
        LCALL DELAY
        SETB P1.5
        LCALL DELAY
        MOV R1,#7
COM2:LCALL DELAY
    DJNZ R1,COM2
    CLR P1.3;...............RETURN TO SCREEN SAVER
    CLR P1.3
    LCALL DELAY
    SETB P1.3
    SETB P1.3
    LCALL DELAY
;...............................
DESITION:JB P2.1,BIGINE;.........MONITOR'S INCOMING CALLS
DESITION2:MOV R3,#0H
        JMP DEAC_IGNORED
BIGINE:MOV R3,#60
COUNT:LCALL DELAY
      JNB P2.1,DESITION2
      DJNZ R3,COUNT
  TO_DEACTIVATE:SETB P2.3;..........AUTOMATIC LOAD DEACTIVATION AFTER
  MUNITE
                SETB P2.3
            LCALL COFMTION_SMS
            JMP WAIT_REPLY
  C_IGNORED:LCALL DELAY;.............3sec DELAY BEFOR ENDING CALL
            LCALL DELAY
            LCALL DELAY
            CLR P1.3;...............END CALL AFTER 3sec
            CLR P1.3
            LCALL DELAY
```

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```
                SETB P1.3
                SETB P1.3
                LCALL DELAY
                LJMP POWER_CONSUME_CHECK
WAIT_REPLY:JB P2.1,$;.......MONITOR'S INCOMING CALL
            LCALL DELAY;.......3sec DELAY BEFOR ENDING CALL
            LCALL DELAY
            LCALL DELAY
            CLR P1.3;.......END CALL AFTER 3sec AND RETURN TO SCREEN
SAVER
            CLR P1.3
            LCALL DELAY
            SETB P1.3
            SETB P1.3
            LCALL DELAY
            CLR P2.4;.......RECONNECT LOAD
            CLR P2.4
            LJMP POWER_CONSUME_CHECK
;...............................................................
.........................
;................CONFERMATION SMS........................
COFMTION_SMS:CLR P1.5
                LCALL DELAY
                SETB P1.5
                LCALL DELAY
                CLR P1.5
                LCALL DELAY
                SETB P1.5
                LCALL DELAY
;..................................
DOWN22:CLR P1.4
    LCALL DELAY
    SETB P1.4
    LCALL DELAY
    CLR P1.4
    LCALL DELAY
    SETB P1.4
    LCALL DELAY
    CLR P1.4
    LCALL DELAY
    SETB P1.4
 AFT22:LCALL DELAY
    ...............................
   ECT222:CLR P1.5;.......OPENS THE DRAFT
        LCALL DELAY
        SETB P1.5
        LCALL DELAY
        CLR P1.5;......OPENS 1st SMS IN THE DRAFT TO READ
        LCALL DELAY
        SETB P1.5
        LCALL DELAY
   ..................................
```

```
CONTINUE32:CLR P1.5
          LCALL DELAY
          SETB P1.5
          LCALL DELAY
;.................................
DOWN322:CLR P1.4
       LCALL DELAY
       SETB P1.4
       LCALL DELAY
       CLR P1.4
       LCALL DELAY
       SETB P1.4
       LCALL DELAY
       CLR P1.4;...........FORWORD SMS TO NUMBER
       LCALL DELAY
       SETB P1.4
       LCALL DELAY
;.................................
SELECT422:CLR P1.5
          LCALL DELAY
          SETB P1.5
          LCALL DELAY
;.................................
SEARCH_NUMB32:CLR P1.5
          LCALL DELAY
          SETB P1.5
          LCALL DELAY
          CLR P1.5
          LCALL DELAY
          SETB P1.5
          LCALL DELAY
;.................................
SEND_122:CLR P1.5
       LCALL DELAY
       SETB P1.5
       LCALL DELAY
       MOV R1,#7
COM32:LCALL DELAY
      DJNZ R1,COM22
      CLR P1.3;...............RETURN TO SCREEN SAVER
      CLR P1.3
      CLR P1.3
      LCALL DELAY
      SETB P1.3
      SETB P1.3
      SETB P1.3
      LCALL DELAY
      RET
      .......................1sec DELAY
      :Y:MOV TMOD,#16;.......USING TIMER 1
         MOV TH1,#3CH
         MOV TL1,#0
```

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```
        SETB TR1
        JNB TF1,$
        CLR TR1
        CLR TF1
        INC R0
        CJNE R0,#20,DELAY
        MOV R0,#0H
        RET
;.............................................
SURGE:MOV TMOD,#1;.......USING TIMER 0
        MOV TH0,#3CH
        MOV TL0,#0
        SETB TR0
        JNB TF0,$
        CLR TR0
        CLR TF0
        INC R0
        CJNE R0,#100,SURGE
        MOV R0,#0H
        JNB P1.2,OK
        LJMP POWER_CONSUME_CHECK
        NOP
        NOP
        NOP
OK:LJMP GO
        END
```