Chapter one
Introduction

1.1 Preface

With increasing population, the demand for power is increasing at an exponential rate. Power theft, unpaid bills, poor usage of energy leave the energy market crippled. The rise in use of electronics good due to their cheap cost has distorted power quality. Hence to increase energy consumption efficiency, monitor power quality, closely monitor the energy usage pattern of customers many utilities have employed smart energy meters. The primary goal is to provide a bi-directional communication between customer and the utility. Sudan has introduced pre-payment technology since the year 1997 to replace the traditional meters that preceded the pre-payment meters of modest and simple technologies and techniques which include several manufacturing and economic codes. Due to the success of the prepayment meters experiment in Sudan the Sudanese Electricity Distribution Company (SEDC) has endeavored to localize the industry of digital meters in Sudan as well as developing the industry to keep pace with contemporary development. Now the competition in whole the world is focusing on how to monitor and control the power consumption by acquiring the data from these meters in the real time with a total cost as less as possible, Various communication options are available example wired-Power Line Communication (PLC), Local Area Network (LAN), Wireless- Global System for Mobile (GSM), Wireless Local Area Network (WLAN), General Packet Radio Service (GPRS).

1.2 Problem Statement

As Sudan is adapting the global technologies in the electric power monitoring and controlling using the electronic kw/h meters is facing the same Problem of the GSM and GPRS module which are High operational cost, Unsecure ,Dependency to third person, Power consumption , and Non real time.

1.3 Proposed Solution

In this research, automatic electronic power meter is designed in order to measure instantaneous voltage and current. The consumed power and power factor is calculated by a microcontroller, the consumer monitors these values at home by LCD while the same values are sent to a base station for monitoring and calculating the consumed electric power. XBee kit is used for ZigBee wireless communication. The XBee /XBee-PRO RF (Radio Frequency) Modules are designed to operate within the ZigBee Protocol and support the unique needs of low-cost, low power wireless sensor networks. The module requires minimal power and Provides reliable delivery of data in the real time between remote devices.

1.4 Objectives

This research aims to achieve the following objectives:

- To minimize power consumed by the watt meters those which use PLC, GPRS, GSM and Wi-Fi modules. AS ZigBee is typically used in low data rate applications that require long battery life.
- To reinforce security. As ZigBee networks are secured by 128 bit symmetric encryption keys.
- To keep self-reliance. This network in the time that it has been established it will be Property of the electric distributions company.
- To have watt meter with real time data acquisition.

1.5 Methodology

In this project, the implementation of a basic watt hour meter is carried out with a sample-and-hold circuit that effectively measure both voltage and load current using Current Transformer (CT) for current sensing. The power Kw/h and power factor is calculated by microcontroller (Arduino UNO) which displayed the measured and calculated values in LCD 16X2 while the same readings are sent to base station through communication ZigBee module.

In this Project X-CTU software is used to configure module as:

- XBee transmitter device which connected to power meter through RS232 to receive measurement parameters from Arduino to be send to base station.
- XBee receiver is configured as coordinator device in base station side which connected to pc server through RS232 in order to receive messages of all end devices.

ZigBee end device reads energy measurement information in multifunction electric meter by UART, and transmits them to the network coordinator via ZigBee wireless network, thus it can realize the wireless meter reading of the network coordinator. Therefore, the end device must be able to communicate with the electric power meter and coordinator. The coordinator also has to know which end node that sends the data so the data can be read accurately. Each of ZigBee modules has a unique 64-bit permanent address, so the addressing won't be much difficult.

In the base station the data receiver displays the received reading in the operator PC through Arduino which is programmed to compare the power factor to the limit value which is set to greater than 1, and when it reaches the limit a piezo buzzer goes high and the used GSM module in the same circuit send an alerting SMS to the user.

1.6 Research layout:

This thesis consists of five chapters covering the activities carried out to implement the project idea and the information related to the thesis area.

Chapter one: talking about the thesis area in general, the problem statement, proposed solution and brief talk about the methodology.

Chapter two: discuss the previous ideas, the gab area and literature review about the thesis topic.

Chapter three: design and operation of simulated and H/W system is explained in details.

Chapter four: discuss the results of simulation and H/W system based on comparison between the design results and the objectives of the project.

Chapter five: Finally**,** conclusions are drawn with explanation of future areas of research and the recommendations to bring up this project in picture of perfection as effective project.

Chapter Two

Literature Review and Related Work

2.1 Literature Review

The science of measurements is an integral part of the development of physical science. Most of the laws of electricity were uncovered during the eighteenth and nineteenth centuries and during this short period there has been a phenomenal growth in electrical engineering. Many of the instruments used today are essentially the same as those designed originally by the scientists. The performance of the instruments are improved and made more accurate. In early years, electricity is available only to a specific section of affluent society. The advancement in technology over time encouraged meeting the demands of common people in all parts of the world. The history of electricity meter is well connected involving researchers from past. The general usage of electricity in the earl 1870 is only confined to telegraphs and arc lamps. With the invention of the electric bulb by Thomas Elva Edison, the power energy market became widely opened to the public in the year 1879. Oliver B. Shallenberger introduced his AC ampere hour meter in the year 1888. Eventually, the progressive development in metering technology leads in enlightening the lives of many common people.

2.1.1 Power Meters

The electrical devices that can detect and display energy in the form of readings are termed as electricity meter; there are different types of meters that developed during old and recent years.

2.1.1.1 Traditional Electricity Meters

Traditional meters are used since the late 19th century. Integrating type energy meter is an indicating and recording type instrument. It provides a cumulative value of electrical quantity. It contains a set of dials, pointer, scale or suitable indicator and a recording mechanism. It indicates the value of the quantity under measurement sum up with previous readings. The time of measurement, and keeps a cumulative record of previous values. Energy meters are also called as watt-hour meters. They measures the energy consumed in Kwh. Energy meters are two types: Digital type & Analogue type Analogue type is either induction type (single/three phases) or motor type (mercury motor type/commutator type), In this thesis a single phase induction meter is taken as example for traditional watt meter types. Induction meter has the following three elements:

i) An operating system which produces an operating torque proportional to the current or power in the circuit and which causes the rotation of the rotating system.

ii) A retarding or braking device usually a permanent magnet which produces a braking torque in proportional and opposite to the speed of rotation. It stops the moving system/disc immediately when the meter was disconnected from the supply.

iii) A registering or recording mechanism forms the revolutions of the rotating system. Usually, it consists of a train of wheel driven by the spindle of rotating system. Through wheel arrangement. All these wheels are attached in such a way that if one wheel completes one revolution, the other moves only one tenth of a revolution.

The single phase induction type energy meter works on the principle of electromagnetic induction. A rotating magnetic field is developed due to interaction of current in pressure coil and current coil with aluminium disc placed near coils [1].

The figure 2.1 shows essential parts of single phase induction meter. It consists of a pressure coil made of thin copper wire of many turns (also called shunt magnet); a current coil made of thick copper wire of one or two turns (also called series magnet), an aluminium disc mounted on spindle and placed between two jewelled bearings and a recording mechanism consists of worm and wheel through which the rotation of spindle is recorded on cyclometer

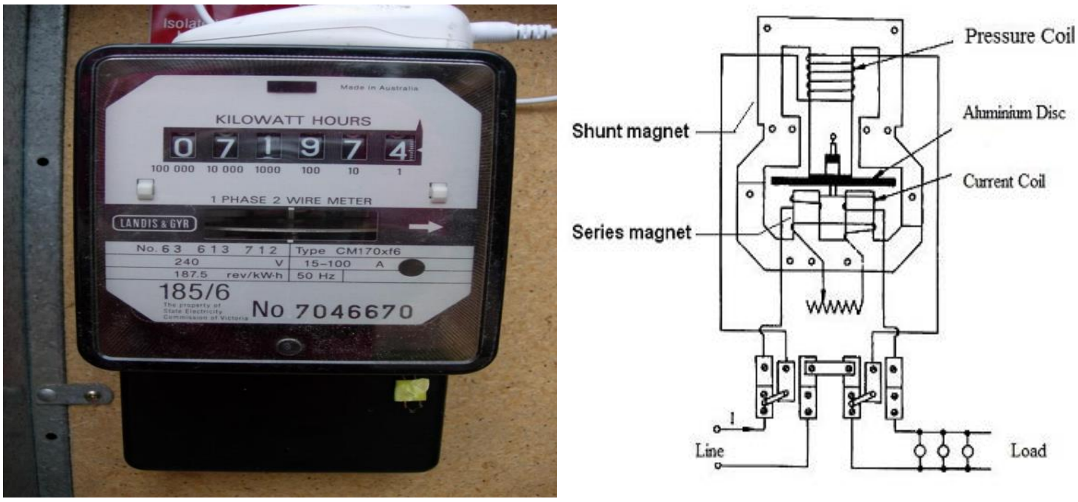


Figure 2-1: Constructional Details of Single Phase Energy meter [1]

A braking magnet is arranged on a disc to control its movement and to stop the movement under no load. It produces a damping torque/force. Here eddy current system of damping is used. A phase difference of 900 is set between current coil and pressure coil with the help of copper shaded rings. The two field fluxes produced by the two coils act on aluminium disc induce eddy currents and hence the disc rotates due to the interaction of the two fluxes developed. The speed of disc is proportional to the energy consumed/power consumed by the load. The number of revolutions completed by the disc for one 'Kwh' is called meter constant. Usually it is printed on name plate of meter.

The single phase induction watt meter has six errors:

1- Phase error or Power factor error: this error is due to improper phase difference between flux and voltage due to shunt coil. With this, the disc rotates faster at low PF loads. It is corrected by adjusting the position of the shading rings.

2- Speed error: some times the speed of disc is not proportion for non-inductive loads. This is due to incorrect adjustment of braking magnet. This can be eliminated by repositioning the brake magnet.

3- Friction Compensation or friction error: in many cases an unwanted braking torque on disc will developed due to frictional forces at disc and register mechanism. This causes for creeping error. This can be adjusted by repositioning the shaded rings on central limb/shunt magnet.

4- Creeping Error: sometimes energy meter runs slowly, even at no load condition. This phenomenon is said to be creeping. This may occur due to over friction compensation, stray magnetic field or mechanical vibrations. This can be prevented by proper adjustment of friction compensation. Usually two small holes are cut near the circumference of the aluminium disc. Sometimes a small piece of iron wire is attached to the edge of the disc which when attracted by braking magnet.

5- Temperature error: the error due to temperature in meter reading is very less. An increase in temperature results in increased resistance to the eddy current path reducing the driving torque and braking torque. It also increase the resistance of the shunt coil causing smaller current to flow, due to which the driving torque is reduced. At higher temperatures the flux from braking magnet is also less. The net result is to neutralize each other effect and error caused due to temperature is not appreciable.

6- Frequency effect: increase in frequency raises the impedance of the coils with the result less current flows through them. The torque produced is also proportionately reduced. Hence the meter has to be adjusted at fixed frequency to obtain minimum error.

2.1.1.2 Smart Grids

Smart Grid is the modern development in electricity grid. Recent electrical grids are becoming weak with respect to the electrical load variation of appliances inside the home. The increase in population is also the indication of electrical grids becoming more fragile. The higher the population, the more load on the grid. Improving the efficiency of grid by remotely controlling and increasing reliability, measuring the consumptions in a communication that is supported by delivering data (real-time) to consumers, supplier and vice versa is termed as Smart Grid [2]. Automated sensors are used in Smart Grids. These sensors are responsible in sending back the measured data to utilities and have the capability to relocate power failures and avoid heating of power lines.

It employs the feature of self-healing operation. Literally, the concept of Smart Meter is commenced from the idea of Smart Grid. A carbon emission reduction of 5% is expected by 2030, annually by its installations and it can show a greater impact on environmental Changes [2]. For a sustainable development and establishment of new grid infrastructure, Smart Grids are recommended for many countries.

2.1.1.3 Smart Meters

According to Pearson education limited 2004, Wattmeter is an instrument for measuring the electric power or the supply rate of electrical energy in watts of any given circuit. Digital Watt meters have become available for home use and are capable of providing users within formation that is far superior to that which was provided by the Watt meters of professionals only twenty years ago. Instead of a very imprecise needle display, a digital Wattmeter measures the current which is passing through its cables at a thousand times a second, measuring every small change, and providing an average which is the true power supply [3].

2.1.1.3.1 Principle of measurement in smart meters:

Basically, a watt hour meter is designed to measure energy or power consumed over time. In simple terms electrical power is the product of voltage and current. If measurements of both instantaneous voltage and current, or V_i and I_i have been repeated for N times, the average power (watt) is.

$$\text{Average Power} = \frac{\left(\sum_{K=1}^{N} V_{ik} * I_{ik}\right)}{N} \quad (1)$$

Where is: N = times of measurements, V_i instantaneous Volt, I_i is instantaneous current and K=1, 2, 3... N

The total energy consumed during specific time can be calculated by multiplying the average power by time.

$$\text{Consumed Energy} = \frac{\left(\sum_{K=1}^{N} V_{ik} * I_{ik}\right)}{F_s} \quad (2)$$

Where is: F_s is specific time or frequency

For alternating current, average power can be calculated by:

$$P = V * \cos\theta$$

Where V and I are average RMS voltage and current, and θ is the phase angle between the V and I.

Instantaneous sampling does not directly use power factor; the value of the phase angle is essentially embedded in the instantaneous current measurement. Recovering the actual phase angle for the purpose of calculating and displaying the power factor can be done separately and is very calculation intensive. It is difficult for a microcontroller to make direct measurements when the supply voltage is 230V at up to 50A. This makes it necessary to indirectly measure line voltage and current at a level consistent with a microcontroller and then rescale these measurements to arrive at the original value. Measuring current here is essentially the same as measuring voltage which transducer has been used to generate a voltage proportional to the load current. The actual voltage and current readings can then be derived. For this application, the derived voltage reading, V_d is related to the actual instantaneous line voltage V_i by the expression, V_d = Vi $*K_d/K_v$ or $V_i=V_d*K_v/K_d$, where K_d is the digitization constant for the ADC in this application and Kv is the voltage proportionality constant for the circuit design. Similarly, the derived current reading, I_d, is related to I_i by the expression, $I_d = I_i *K_d/K_i$ or $I_i = I_d *K_i/K_d$, where Ki is the current proportionality constant specific to this design; it is calculated by dividing the CT turn ratio by the 4 product of the current amplifier gain and the input burden resistance. By substituting the values of V_d and I_d into Equation 2, the total consumed power of indirect voltage and current measurements will as follow:

$$\text{Energy Consumed (watt/second)} = \frac{\left(\sum_{K=1}^{N} V_{dk} * I_{dk}\right) * K_v * K_i}{F_s * {K_d}^2} \quad (3)$$

Where: V_d is derived voltage, K_d is the digitization constant, K_i is the current proportionality constant, I_d is derived current, K_v is volt proportionality constant.

It is more practical to accumulate up to some fixed amount, and then increment a counter to indicate energy consumption. In this paper, for each accumulating 1000 W/h (1 Kw/h) the counter will be incremental. This value represents the resolution limit of the meter. It is equivalent to 3,600,000 watt seconds ($1000W * 60 * 60$). The resolution limit D can be calculated by equation (3).

D (resolution limit) $=\sum_{K=1}^{N} V_{dk} * I_{dk} = \frac{3600 * F_s * K_d^2}{K_v * K_i}$ (4)

Any time that the accumulated sum of the voltage and current products equals or exceeds D, the counter will be increment the Kw/h. Also, any remainder in excess of D will be saved to be used in the next round of accumulation.

2.1.1.3.2 Sampling Voltage and Current

Calculating power assumes that the voltage and current are sampled exactly the same time. By using a single ADC with one sample-and-hold circuit makes this impossible. By using an interpolated voltage value that very closely approximates what the voltage would be when the current is sampled. In this thesis, the sampling time t has been taken in order to measure voltage and current. The procedure has been achieved to calculate the voltage for a particular current measurement: 1. Measure the first voltage sample at time t_0. 2. After an interval of t, measure the current (time t_1). 3. After another interval of t, measure the voltage again (time t_2). 4. Calculate the voltage at t1 as $(V_d t_0 + V_d t_2)/2$.

2.1.2 Wireless Communication

Wireless communications is, by any measure, the fastest growing segment of the communications industry. As such, it has captured the attention of the media and the imagination of the public. Cellular systems have experienced exponential growth over the last decade and there are currently around two billion users worldwide. Indeed, cellular phones have become a critical business tool and part of everyday life in most developed countries, and are rapidly supplanting antiquated wire line systems in many developing countries. In addition, wireless local area networks currently supplement or replace wired networks in many homes, businesses, and campuses. Many new applications, including wireless sensor networks, automated highways and factories, smart homes and appliances, and remote telemedicine, are emerging from research ideas to concrete systems. The explosive growth of wire-less systems coupled with the proliferation of laptop and palmtop computers indicate a bright future for wireless networks, both as stand-alone systems and as part of the larger networking infrastructure. However, many technical challenges remain in designing robust wireless networks that deliver the performance necessary to support emerging applications. In this introductory chapter we will briefly review the history of wireless networks, from the smoke signals of the pre-industrial age to the cellular, satellite, and other wireless networks of today. We then discuss the wireless vision in more detail, including the technical challenges that must be overcome to make this vision a reality. We describe current wireless systems along with emerging systems and standards. The gap between current and emerging systems and the vision for future wireless applications indicates that much work remains to be done to make this vision a reality.

All wireless communication systems have the Transmitter, Receiver and Antennas. Path between the transmitter and the receiver In short, the transmitter feeds a signal of encoded data modulated into RF waves into the antenna. The antenna radiates the signal through the air where it is picked up by the antenna of the receiver. The receiver demodulates the RF waves back into the encoded data stream sent by the transmitter [4].

2.1.2.1 Wireless Network Types

There are a number of different types of networks used in wireless communication. Network types are typically defined by size and location.

2.1.2.2 WPAN A wireless personal area network (WPAN)

WPAN is meant to span a small area such as a private home or an individual workspace. It is used to communicate over a relatively short distance. The specification does not preclude longer ranges being achieved with the trade-off of a lower data rate. In contrast to other network types, there is little to no need for infrastructure with a WPAN. Ad-hoc networking is one of the key concepts in WPANs. This allows devices to be part of the network temporarily; they can join and leave at will. This works well for mobile devices like PDAs, laptops and phones. Some of the protocols employing WPAN include Bluetooth, ZigBee, Ultra wideband (UWB) and IrDA. Each of these is optimized for particular applications or domains. ZigBee, with its sleepy, battery-powered end devices, is a perfect fit for wireless sensors. Typical ZigBee application domains include: agricultural, building and industrial automation, home control, medical monitoring, security and, lest we take ourselves too seriously, toys, toys and more toys.

2.1.2.3 WLAN Wireless local area networks

WLANs are meant to span a relatively small area, e.g., a house, a building, or a college campus. WLANs are becoming more prevalent as costs come down and standards improve. A WLAN can be an extension of a wired local area network (LAN), its access point connected to a LAN technology such as Ethernet. A popular protocol for WLAN is 802.11, also known as Wi-Fi.

2.1.2.4 WWAN A wireless wide area network

WAN is meant to span a large area, such as a city, state or country. It makes use of telephone lines and satellite dishes as well as radio waves to transfer data.

2.1.2.5 Wireless Standards

The demand for wireless solutions continues to grow and with it new standards have come forward and other existing standards have strengthened their position in the marketplace. This section compares three popular wireless standards being used today and lists some of the design considerations that differentiate them.

Each wireless standard addresses the needs of a different market segment. Choosing the best-fit wireless standard is a crucial step in the successful deployment of any wireless application. The requirements of your application will determine the wireless standard to choose.

2.1.2.6 Security in a Wireless Network

This section discusses the added security issues introduced by wireless networks. The salient fact that, signals are travelling through the air means that the communication is less secure than if they were travelling through wires. Someone seeking access to your network need not overcome the obstacle of tapping into physical wires. Anyone in range of the transmission can potentially listen on the channel. Wireless or not, a network needs a security plan. The first thing to do is to decide what level of security is appropriate for the applications running on your network. For instance, a financial institution, such as a bank or credit union offering online account access would have substantially different security concerns than would a business owner offering free Internet access at a coffee shop.

Table 2-1: comparison of different wireless standards [5]

Comparison of Wireless Standards			
Wireless Parameter	**Bluetooth**	**Wi-Fi**	**ZigBee**
Frequency band	2.4 GHz	2.4 GHz	2.4 GHz
Physical/MAC layers	IEEE 802.15.1	IEEE 802.11b	IEEE 802.15.4
Range	9 m	75 to 90 m	Indoors: up to 30 m Outdoors (line of sight): up to 100 m
Current consumption	60 mA (Tx mode)	400 mA (Tx mode) 20 mA (Standby mode)	25-35 mA (Tx mode) 3 μA (Standby mode)
Raw data rate	1 Mbps	11 Mbps	250 Kbps
Protocol stack size	250 KB	1 MB	32 KB 4 KB (for limited function end devices)
Typical network join time	>3 sec	variable, 1 sec typically	30 ms typically
Interference avoidance method	FHSS (frequency-hopping spread spectrum)	DSSS (direct-sequence spread spectrum)	DSSS (direct-sequence spread spectrum)
Minimum quiet bandwidth required	15 MHz (dynamic)	22 MHz (static)	3 MHz (static)
Maximum number of nodes per network	7	32 per access point	64 K
Number of channels	19	13	16

2.1.3 GSM Module

Global System for Mobile communications (GSM) is the most popular standard for mobile phones in the world. GSM is considered a second generation (2G) mobile phone system. Data communication was built into the system from the 3rd Generation Partnership Project (3GPP). GSM is a cellular network, which means that mobile phones connect to it by searching for cells in the immediate vicinity. GSM networks operate in four different frequency ranges. Most GSM networks operate in the 900 MHz or 1800 MHz bands. Some countries, including Canada and the United States, use the 850 MHz and 1900 MHz bands because the 900 and 1800 MHz frequency bands were already allocated. In the 900 MHz band the uplink frequency band is 890-915 MHz, and the downlink frequency band is 935-960 MHz. This 25 MHz bandwidth is subdivided into 124 carrier frequency channels, each spaced 200 kHz apart. Time division multiplexing is used to allow eight full-rate or sixteen half-rate speech channels per radio frequency channel. There are eight radio timeslots (giving eight burst periods) grouped into what is called a Time Division Multiple Access (TDMA) frame. Half rate channels use alternate frames in the same timeslot. The channel data rate is 270.833 kbit/s, and the frame duration is 4.615 msec. The transmission power in the handset is limited to a maximum of 2 watts in GSM850/900 and 1 watt in GSM1800/1900. There are four different cell sizes in a GSM network - macro, micro, pico and umbrella cells. The coverage area of each cell varies according to the implementation environment. Macro cells can be regarded as cells where the base station antenna is installed on a mast or a building above average roof top level. Micro cells are cells whose antenna height is under average roof top level and they are typically used in urban areas. Pico cells are small cells whose coverage diameter is a few dozen meters and they are mainly used indoors.

Umbrella cells are used to cover shadowed regions of smaller cells and fill in gaps in coverage between those cells. Cell horizontal radius varies depending on antenna height, antenna gain and propagation conditions from a couple of hundred meters to several tens of kilometers. The longest distance the GSM specification supports in practical use is 35 km. The Base Station Subsystem (BSS) consists of the Base Stations (BS) and the Base Station Controllers (BSC). The BSS is the section of a traditional cellular telephone network which is responsible for handling traffic and signaling between a mobile phone and the Network Switching Subsystem. The BSS carries out transcoding of speech channels, allocation of radio channels to mobile phones, paging, quality management of transmission and reception over the air interface and many other tasks related to the radio network. The Network Switching Subsystem (NSS) is the component of a GSM system that carries out switching functions and manages the communications between mobile phones and the Public Switched Telephone Network (PSTN). The GPRS Core Network is an optional

part which allows packet based Internet connections in 2.5G mobile phone systems. More specifically the Mobile Switching Centre (MSC) is a sophisticated telephone exchange centre which provides circuit-switched calling, mobility management, and GSM services to the mobile phones roaming within the area that it serves, while the Serving GPRS Support Node (SGSN) is responsible for the delivery of data packets from and to the Mobile Stations (MS) within its geographical service area. Based on this structure the basic location system architecture for GSM/GPRS is shown in Figure (2-2). Additional components include the Serving Mobile Location Center (SMLC) and the Gateway Mobile Location Center (GMLC). The SMLC is the GSM/GPRS network node that operates the location server software, while location data are available to Location Based Services (LBS) applications through the GMLC.

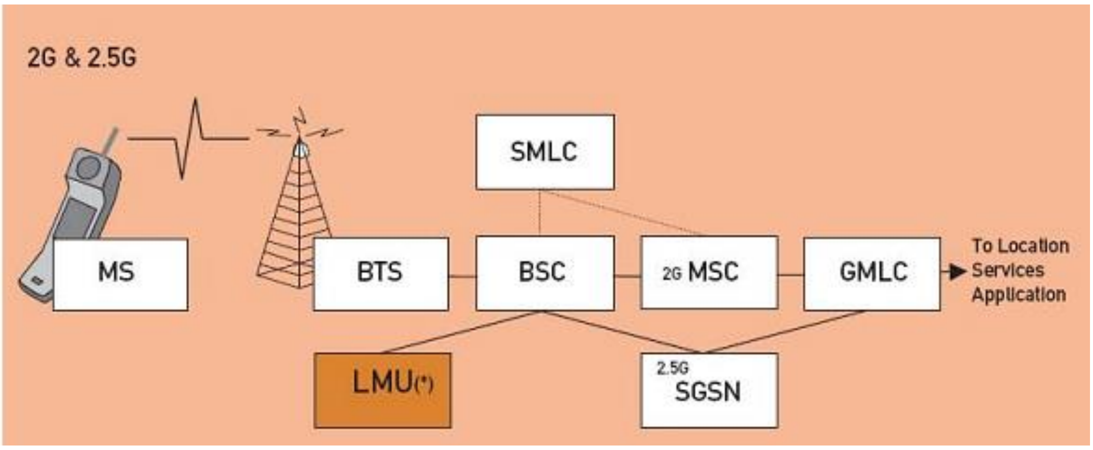


Figure 2-2: Location system architecture for GSM/GPRS networks [6].

Some location dependent parameters, which are always monitored by the terminal, can be used to perform positioning by using the standard Cell-ID technique. These parameters include Network identification through Mobile Country Code (MCC) and Mobile Network Code (MNC), Location Area Code (LAC) and unique identification of serving cell (CI). Timing measurements, available in the mobile networks, can also be employed to determine the position of the terminal. In the GSM standard, Timing Advance (TA) value corresponds to the length of time a signal from the mobile phone takes to reach the BS. GSM uses TDMA technology in the radio interface to share a single frequency between several users, assigning sequential timeslots to the individual users sharing a frequency. Each user transmits periodically for less than one-eighth of the time within one of the eight timeslots. Since the users are various distances from the base station and radio waves travel at the finite speed of light, the precise time at which the phone is allowed to transmit a burst of traffic within a timeslot must be adjusted accordingly. TA is the variable controlling this adjustment [7], [8]. The TA value is normally between 0 and 63, with each step representing an advance of one symbol period, which is approximately 3.69 microseconds. With radio waves travelling at about 300,000,000 metres per second, that is 300 metres per microsecond, one TA step then represents a change in round trip distance (twice the propagation range) of about 1,100 metres. This means that the TA value changes for each 550-metre change in the range between a mobile and the BS. The TA value has been used in order to enhance the accuracy provided by standard Cell-ID techniques. In GSM, time difference measurements which are called Observed Time Differences (OTD), can also be used for positioning purposes. Unlike TA values, OTD measurements from several BSs are made by the terminal without forcing handover, which makes them more attractive for location. An experimental E-OTD network architecture is depicted in figure 2-3. A terminal with modified software is able to report accurate OTD estimates by using sophisticated signal processing algorithms.

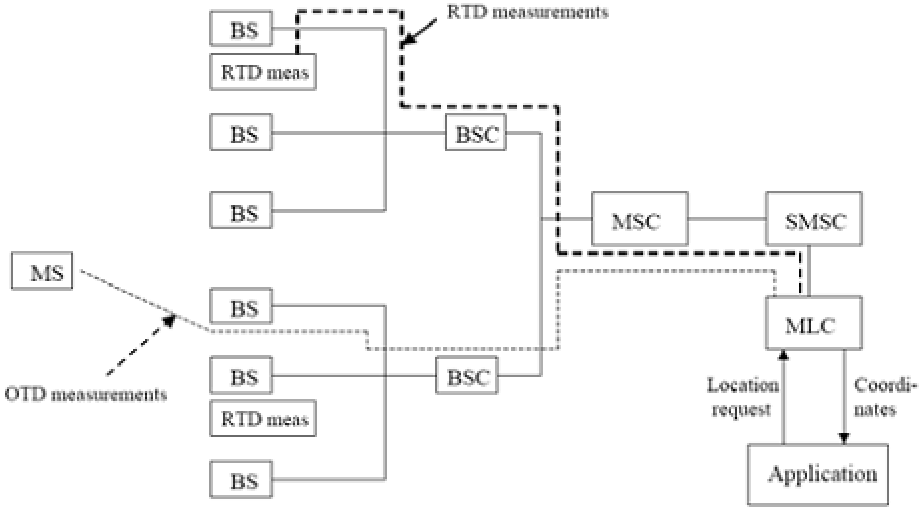


Figure 2-3: Network architecture to support E-OTD [9]

Received Signal Strength (RSS) measurements collected by monitoring the Broadcast Control Channel (BCCH), where transmission is performed with constant power, can also be utilized to support positioning in GSM networks. This kind of measurements is collected by the terminal as part of its standard functionality. While the terminal is in In-session 1 mode, all location dependent parameters, described before and RSS measurements are known at the terminal side, since the RSS values from the Serving cell and up to six neighbouring cells are reported back to the Network through Network Measurement Reports (NMRs) every 480msec for handover and power control purposes. These reports also contain the Base Station Identity Code (BSIC), which uniquely identifies a neighbouring cell when combined with the BCCH value. In the Idle-attached 2 mode the terminal continuously makes RSS measurements and also knows the CI of the serving cell and the CI or BCCH + BSIC of the neighbouring cells. This is a standard functionality according to GSM specifications, to help in the cell selection and re-selection operations. The RSS values are averaged over a period of at least five seconds. According to GSM specifications [10] the RSS level at the receiver input is measured by the terminal over the full range of -110 dBm to -48 dBm with an absolute accuracy of ±4 dB from -110 dBm to -70 dBm under normal conditions and ±6 dB over the full range under both normal and extreme conditions. A resolution of 1 dBm is used, which results in 64 possible values and therefore the RSS values are provided in the [0, 63] range.

2.1.3.1 Universal Mobile Telecommunications System

Universal Mobile Telecommunications System (UMTS) is one of the third generation (3G) mobile phone technologies. Currently, the most common form uses Wideband Code Division Multiple Access (W-CDMA) as the underlying air interface and is standardized by the 3GPP. UMTS, using W-CDMA, supports up to 14.0 Mbit/s data transfer rates in theory with High-Speed Downlink Packet Access (HSDPA), although at the moment users in deployed networks can expect a performance up to 384 Kbit/s for R99 terminals, and 3.6 Mbit/s for HSDPA terminals in the downlink connection. This is still much greater than the 9.6 Kbit/s of a single GSM error-corrected circuit switched data channel. The UMTS spectrum allocated in Europe is already used in North America. The 1900 MHz range is used for 2G services, and 2100 MHz range is used for satellite communications. Regulators have however, freed up some of the 2100 MHz range for 3G services, together with the 1700 MHz for the uplink. UMTS operators in North America who want to implement a European style 2100/1900 MHz system will have to share spectrum with existing 2G services in the 1900 MHz band. 2G GSM services elsewhere use 900 MHz and 1800 MHz and therefore do not share any spectrum with planned UMTS services. In the Universal Terrestrial Radio Access Network (UTRAN), a handset (terminal) is called User Equipment (UE) and a base station is called node B. There are two operational modes for UTRAN: Frequency-Division Duplex (FDD) and Time-Division Duplex (TDD). The original standards specifications were developed based on FDD mode. Figure 2-4 illustrates the system architecture of UE positioning (UP). The UTRAN interfaces (Uu, Iub, Iur, and Iupc) are used to communicate among all relevant entities. In this figure SRNC stands for Serving Radio Network Controller, LMU for Location Measurement Unit, SAS for Stand Alone Serving Mobile Location Center (SMLC) and CN for Core Network. LMU type A is a standalone LMU, while type B is integrated with a node B. The Radio Network Controllers (RNCs) are in charge of the network resources managing the node Bs and specific LMUs in the location process. The SRNC works as the SMLC and receives the location request from external LBS application or LBS Client Function in the CN. SRNC both co-ordinates and controls the overall UE positioning.

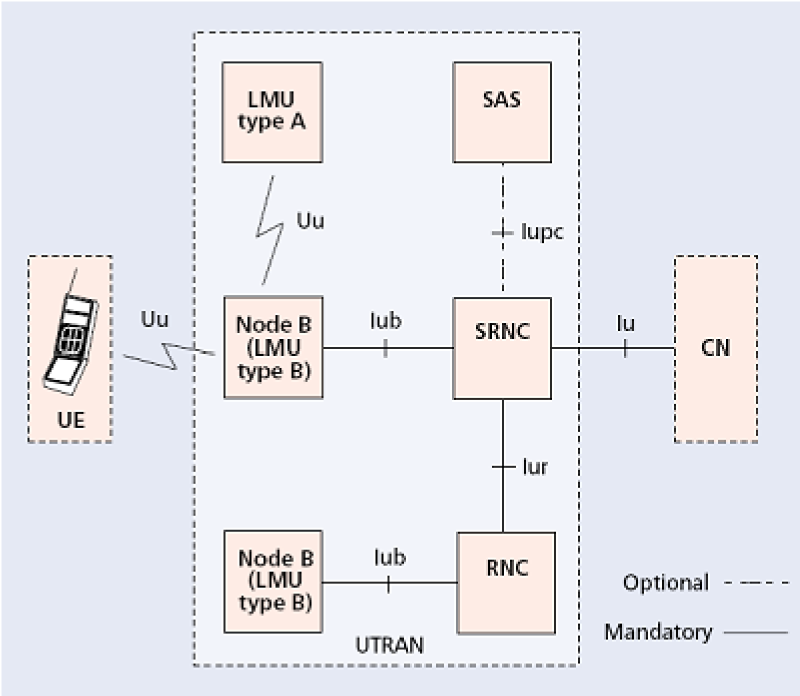


Figure 2-4: System architecture of UE positioning [11].

The SRNC is shown in more detail in Figure 2-5. The LBS System Operation Function (LSOF) works as a database of the needed information in UE position calculations, e.g. the geographic locations of the node Bs, or in other network operations during the location process. The LBS Server Control Function (LSCF) requests the needed measurements from the UE, LMU or one or more node Bs and sends the results to the appropriate Position Calculation Function (PCF) in the network. The PCF makes the needed coordinate transformations for the UE location estimate. For every location estimate result the PCF estimates the QoS level regarding the achieved accuracy and sends it together with the time-of-day information about the measurement as a part of the reported result. The SRNC can also use the UE location information internally e.g. for location-aided handover [12]. The logical positioning architecture in UMTS does not depend on a single measurement and location technique, but it is able to perform with the standard measurements and techniques available

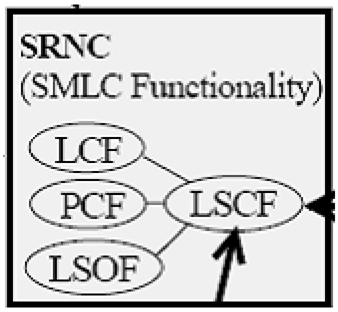


Figure 2-5: Components comprising the SRNC

The position of the UE can be estimated by using the coverage information of its serving node B, in a Cell-ID based method. This knowledge can be obtained by paging, locating area update, cell update, UTRAN registration area (URA) update, or routing area update. Depending on the operational status of the UE, additional operations may be needed in order for the SRNC to determine the cell ID. When the LBS request is received from the CN, the SRNC checks the state of the target UE. If the UE is in a state where the cell ID is not available, the UE is paged so that the SRNC can establish the cell with which the target UE is associated. In states where the cell ID is available, the target cell ID is chosen as the basis for the UE positioning. In soft handover, the UE may have several signal branches connected to different cells while reporting different cell IDs. The SRNC needs to combine the information about all cells associated with the UE to determine a proper cell ID. The SRNC should also map the cell ID to geographical coordinates or a corresponding Service Area Identity (SAI) before sending it from the UTRAN to the CN. This can easily match the service coverage information available in the CN [13]. In order to improve the accuracy of the LBS response, the SRNC may also request additional measurements from node B or the LMU. These measurements are originally specified for soft handover. For FDD mode, Round-Trip Time (RTT) can be used as a radius of a cell to further confine the cell coverage. RTT is the time difference between the transmission of the beginning of a downlink Dedicated Physical Channel (DPCH) frame to a UE and the reception of the beginning of the corresponding uplink from the UE. For TDD mode, received (Rx) timing deviation can be used. Rx timing deviation is the time difference between the reception in node B of the first detected uplink path and the beginning of the respective slot according to the internal timing of node B. The measurements are reported to higher layers, where timing advance values are calculated and signalled to the UE. UMTS bandwidth is 5 MHz and it operates at a high chip rate 3.84 Mcps/s, which contributes to the better resolution in timing measurements compared to GSM. The timing resolution in UMTS with one sample per chip is 0.26 μs which corresponds to the propagation distance of 78 m. RSS measurements are also available in UMTS networks. The most suitable channel for the location measurements in the UE is the primary downlink Common Pilot Channel (CPICH) whose Received Signal Code Power (RSCP) reception level at the UE is used for handover evaluation, downlink and uplink open loop power control and for the pathloss calculations [14]. Every node B sends the Primary CPICH with a fixed data rate of 30 kbps and it is unique for each cell or sector. It is always present on air, under the primary scrambling code with a fixed channel code allocation, thus, the CPICH can be measured at any time by the UEs. The transmission power of CPICH is set to 10% of the maximum i.e. 33 dBm, which makes it possible to use readily available measurements at the UE made on CPICH also for location purposes. In UMTS, RSS measurements may be slightly more reliable due to the wider bandwidth, which allows better smoothing of fast fading. On the other hand, the hearability problem prevents measurements of as many neighbouring BSs as it is possible in GSM. The standardised measurements suitable for UE positioning in the UTRANFDD mode [15] are presented in table 2-2. Similar measurements are available also in UTRA-TDD mode [16]. Possible UE modes for making the measurements are also presented. In idle mode the UE is not actively processing a call. Connected UE mode involves two cases, in an intrafrequency mode the measurements are made within one carrier frequency and in an inter-frequency mode the carrier frequencies between the measured system and the UE are different e.g. the measurements made from the GSM cells.

Table 2-2: Standardized measurements by the UE and UTRAN in FDD mode.

UE measurements	**UE mode of operation**	**Applicable Location Technique**
RSCP, on CPICH (for TDD cells separate measurement)	Idle & Connected Intra/Inter	Signal Strength
RSS Indicator (RSSI) on a DL carrier	Idle & Connected Intra/Inter	Signal Strength
UE Transmitted power	Connected Intra	As a reference level
SFN-SFN observed time difference on CPICH, Type2 (SFN = System Frame Number), relative time difference between cell i and j	Idle & Connected Intra/Inter	OTDoA
UE Rx-Tx time difference, for each cell in the active set	Connected Intra	OTDoA
UTRAN measurements	**Applicable Location Technique**	
Transmitted carrier power	Signal Strength	
Transmitted code power, power on the pilot bits of the DPCCH field	As a reference	
RTT (TRX-TTX) at Node B	OTDoA and hybrids	
SFN-SFN observed time difference on CPICH, measured by a LMU	OTDoA	

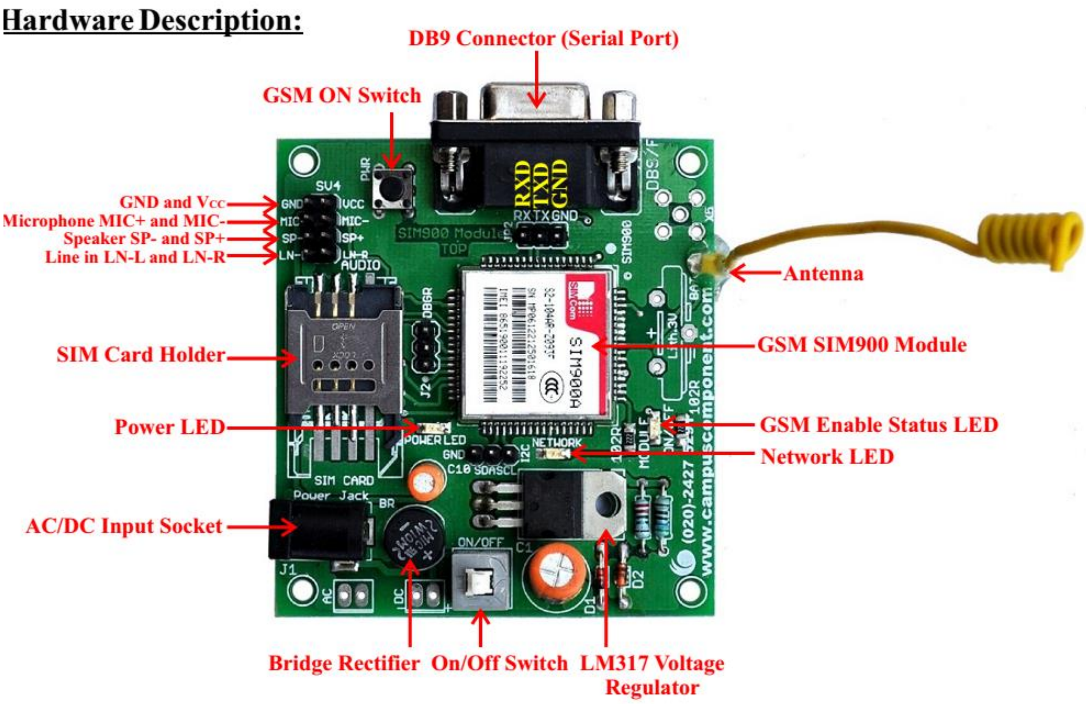


Figure 2-6 GSM interfacing board

2.1.4 GPRS Module

GPRS(General Packet Radio Service), based on GSM by allowing multiples lots of a GSM radio channel be dedicated to an individual user, promises data rate from56 kbps to 114kbps continuous connection to the Internet for mobile phone and computer users, easy access to VPN (Virtual Private Network). The GPRS Core Network is an optional part which allows packet based Internet connections in 2.5G mobile phone systems. More specifically the Mobile Switching Centre (MSC) is a sophisticated telephone exchange centre which provides circuit-switched calling, mobility management, and GSM services to the mobile phones roaming within the area that it serves, while the Serving GPRS Support Node (SGSN) is responsible for the delivery of data packets from and to the Mobile Stations (MS) within its geographical service area. [17]

2.1.5 ZigBee

ZigBee is the most popular industry wireless mesh networking standard for connecting sensors, instrumentation and control systems. ZigBee, a specification for communication in a wireless personal area network (WPAN) has been called the "Internet of things." Theoretically, your ZigBee-enabled coffee maker can communicate with your ZigBee-enabled toaster. ZigBee is an open, global, packet-based protocol designed to provide an easy-to-use architecture for secure, reliable, low power wireless networks. ZigBee and IEEE 802.15.4 are low data rate wireless networking standards that can eliminate the costly and damage prone wiring in industrial control applications. Flow or process control equipment can be place anywhere and still communicate with the rest of the system. It can also be moved, since the network doesn't care about the physical location of a sensor, pump or valve.

The ZigBee RF4CE standard enhances the IEEE 802.15.4 standard by providing a simple networking layer and standard application profiles that can be used to create interoperable multi-vendor consumer electronic solutions [18].

ZigBee is poised to become the global control/sensor network standard. It has been designed to provide the features of Low power consumption, simply implemented, users expect batteries to last many months to years, Bluetooth has many different modes and states depending upon your latency and power requirements such as sniff, park, hold, active, etc.; ZigBee/IEEE 802.15.4 has active (transmit/receive) or sleep, Even mains powered equipment needs to be conscious of energy. ZigBee devices will be more ecological than its predecessors saving megawatts at it full deployment. Low cost (device, installation, maintenance) Low cost to the users means low device cost, low installation cost and low maintenance. ZigBee devices allow batteries to last up to years using primary cells (low cost) without any chargers (low cost and easy installation). ZigBee’s simplicity of configuration and redundancy of network devices provides low maintenance. High density of nodes per network ZigBee’s use of the IEEE 802.15.4 PHY and MAC allows networks to handle any number of devices [18]. This attribute is critical for massive sensor arrays and control networks. Simple protocol, global implementation ZigBee’s protocol code stack is estimated to be about 1/4th of Bluetooth’s or 802.11’s. Simplicity is essential to cost, interoperability, and maintenance. The IEEE 802.15.4 PHY adopted by ZigBee has been designed for the 868 MHz band in Europe, the 915 MHz band in N America, Australia, etc; and the 2.4 GHz band is now recognized to be a global band accepted in almost all countries.

2.1.5.1 ZigBee Network Devices and their Operating Modes

Two types of devices can participate in a LR-WPAN: a full function device (FFD) and a reduced function device (RFD). An RFD does not have routing capabilities. RFDs can be configured as end nodes only. They communicate with their parent, which is the node that allowed the RFD to join the network. An FFD has routing capabilities and can be configured as the PAN coordinator. In a star network all nodes communicate with the PAN coordinator only so it does not matter if they are FFDs or RFDs. In a peer to-peer network there is also one PAN coordinator, but there are other Introduction to ZigBee Technology Page 9 FFDs which can communicate with not only the PAN coordinator, but also with other FFDs and RFDs. There are three operating modes supported by IEEE 802.15.4: PAN coordinator, coordinator, and end device [19]. FFDs can be configured for any of the operating modes. In ZigBee terminology the PAN coordinator is referred to as simply "coordinator." The IEEE term "coordinator" is the ZigBee term for "router."

2.1.5.2 How ZigBee works

ZigBee basically uses digital radios to allow devices to communicate with one another. A typical ZigBee network consists of several types of devices. A network coordinator is a device that sets up the network, is aware of all the nodes within its network, and manages both the information about each node as well as the information that is being transmitted/received within the network. Every ZigBee network must contain a network coordinator. Other Full Function Devices (FFD's) may be found in the network, and these devices support all of the 802.15.4 functions. They can serve as network coordinators, network routers, or as devices that interact with the physical world. The final device found in these networks is the Reduced Function Device (RFD), which usually only serve as devices that interact with the physical world. As mentioned above several topologies are supported by ZigBee, including star, mesh, and cluster tree star topology is most useful when several end devices are located close together so that they can communicate with a single router node. That node can then be a part of a larger mesh network that ultimately communicates with the network coordinator. Mesh networking allows for redundancy in node links, so that if one node goes down, devices can find an alternative path to communicate with one another.

2.1.5.3 Transmitter and Receiver of ZigBee

The power output of the transmitter and the sensitivity of the receiver are determining factors of the signal strength and its range. Other factors include any obstacles in the communication path that cause interference with the signal. The higher the transmitter's output power, the longer the range of its signal. On the other side, the receiver's sensitivity determines the minimum power needed for the radio to reliably receive the signal. These values are described using dBm, a relative measurement that compares two signals with 1 milliwatt used as the reference signal. A large negative dBm number means higher receiver sensitivity.

2.1.5.4 ZigBee Addressing

Before joining a ZigBee network, a device with an IEEE 802.15 compliant radio has a 64-bit address. This is a globally unique number made up of an Organizationally Unique Identifier (OUI) plus 40 bits assigned by the manufacturer of the radio module. OUIs are obtained from IEEE to ensure global uniqueness.

When the device joins a ZigBee network, it receives a 16-bit address called the NWK address. Either of these addresses, the 64-bit extended address or the NWK address, can be used within the PAN to communicate with a device. The coordinator of a ZigBee network always has a NWK address of "0." ZigBee provides a way to address the individual components on the device of a node through the use of endpoint addresses. During the process of service discovery the node makes available its endpoint numbers and the cluster IDs associated with the endpoint numbers. If a cluster ID has more than one attribute, the command is used to pass the attribute identifier.

2.1.5.5 ZigBee Messaging

After a device has joined the ZigBee network, it can send commands to other devices on the same network. There are two ways to address a device within the ZigBee network: direct addressing and indirect addressing. Direct addressing requires the sending device to know three kinds of information regarding the receiving device: Address, Endpoint Number and Cluster ID Indirect addressing requires that the above three types of information be committed to a binding table. The sending device only needs to know its own address, endpoint number and cluster ID. The binding table can specify more than one destination address/endpoint for a given source address/endpoint combination.

When an indirect transmission occurs, the entire binding table is searched for any entries where the source address/endpoint and cluster ID matches the values of the transmission. Once a matching entry is found, the packet is sent to the destination address/endpoint. This is repeated for each entry where the source endpoint/address and cluster ID match the transmission values [19].

2.1.5.6 Broadcast Addressing of ZigBee

There are two distinct levels of broadcast addresses used in a ZigBee network. One is a broadcast packet with a MAC layer destination address of 0xFFFF. Any transceiver that is awake will receive the packet. The packet is re-transmitted three times by each device, thus these types of broadcasts should only be used when necessary. The other broadcast address is the use of endpoint number 0xFF to send a message to all of the endpoints on the specified device.

2.1.6 Arduino UNO

Arduino is used for building different types of electronic circuits easily using of both a physical programmable circuit board usually microcontroller and piece of code running on computer with USB connection between the computer and Arduino. Programming language used in Arduino is just a simplified version of C++ that can easily replace thousands of wires with words.

2.1.6.1 Arduino Uno-R3 Physical Components

The most important element in Arduino Uno R3 is ATMEGA328P-PU is an 8-bit Microcontroller with flash memory reach to 32k bytes. Its features as follow**:**

• High Performance, Low Power AVR

• Advanced RISC Architecture.

- 131 Powerful Instructions – Most Single Clock Cycle Execution

- 32 x 8 General Purpose Working Registers
- Up to 20 MIPS Throughput at 20 MHz
- On-chip 2-cycle Multiplier

• High Endurance Non-volatile Memory Segments

- 4/8/16/32K Bytes of In-System Self-Programmable Flash program memory
- 256/512/512/1K Bytes EEPROM
- 512/1K/1K/2K Bytes Internal SRAM
- Write/Erase Cycles: 10,000 Flash/100,000 EEPROM
- Data retention: 20 years at 85°C/100 years at 25°C
- Optional Boot Code Section with Independent Lock Bits
- In-System Programming by On-chip Boot Program
- True Read-While-Write Operation
- Programming Lock for Software Security

• Peripheral Features

- Two 8-bit Timer/Counters with Separate Prescaler and Compare Mode
- One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode
- Real Time Counter with Separate Oscillator
- Six PWM Channels
- 8-channel 10-bit ADC in TQFP and QFN/MLF package
- Temperature Measurement
- 6-channel 10-bit ADC in PDIP Package
- Temperature Measurement
- Programmable Serial USART
- Master/Slave SPI Serial Interface
- Byte-oriented 2-wire Serial Interface (Philips I2 C compatible)
- Programmable Watchdog Timer with Separate On-chip Oscillator

- On-chip Analogue Comparator
- Interrupt and Wake-up on Pin Change
- Special Microcontroller Features
- Power-on Reset and Programmable Brown-out Detection
- Internal Calibrated Oscillator
- External and Internal Interrupt Sources
- Six Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, Standby, and
- Extended Standby

• I/O and Packages

- 23 Programmable I/O Lines
- 28-pin PDIP, 32-lead TQFP, 28-pad QFN/MLF and 32-pad QFN/MLF

• Operating Voltage: 1.8 - 5.5V

• Temperature Range: -40°C to 85°C

• Speed Grade: 0 - 4 MHz@1.8 - 5.5V, 0 - 10 MHz@2.7 - 5.5.V, 0 - 20 MHz @ 4.5 - 5.5V

• Power Consumption at 1 MHz, 1.8V, 25°C

- Active Mode: 0.2 mA
- Power-down Mode: 0.1 µA
- Power-save Mode: 0.75 µA (Including 32 kHz RTC)

2.1.6.2 Input and Output

Each of the 14 digital pins (see figure 2-8) on the Uno can be used as an input or output, using pin Mode, digital Write, and digital Read functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 k Ohms. In addition, some pins have specialized functions [20]:

- Serial: 0 (RX) and 1 (TX). Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.
- External Interrupts: 2 and 3. These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value.
- PWM: 3, 5, 6, 9, 10, and 11. Provide 8-bit PWM output with the analogue Write () function.
- SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK). These pins support SPI communication using the SPI library.
- LED: 13. There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.

The Uno has 6 analogue inputs, labelled A0 through A5, each of which provides 10 bits of resolution (i.e.1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and the analogue Reference function. Additionally, some pins have specialized functionality:

TWI: A4 or SDA pin and A5 or SCL pin. Support TWI communication using the wire library.

There are a couple of other pins on the board:

AREF: Reference voltage for the analogue inputs. Used with analogue reference.

Reset: Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

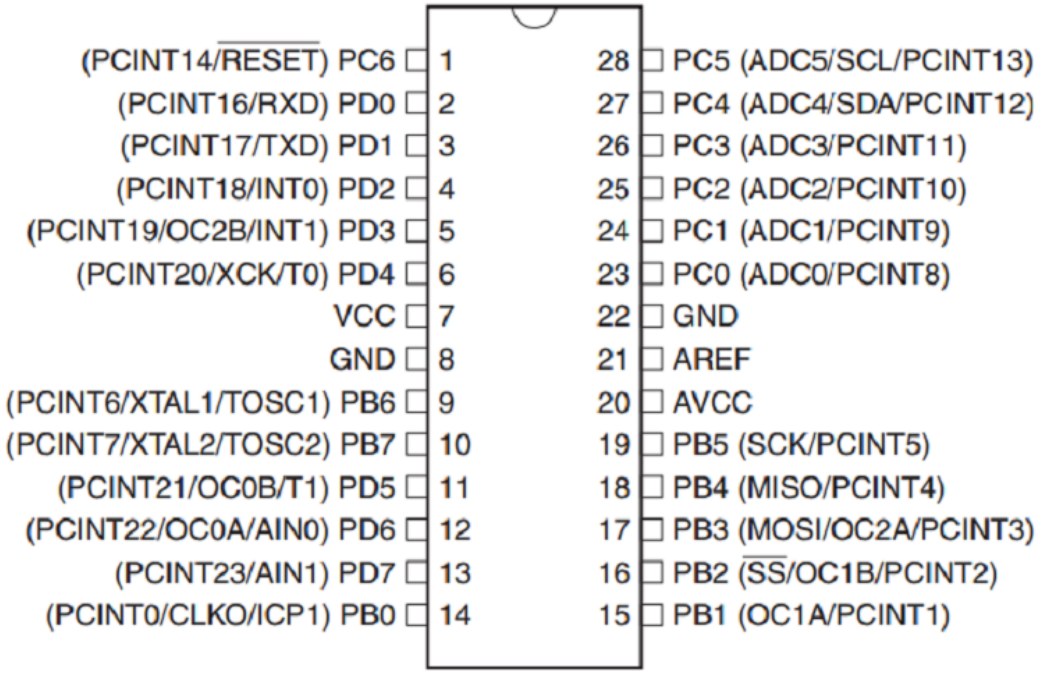


Figure 2-7 Arduino UNO pin configuration [20]

2.2 **Related Work**

The preceding researches in the same area done by P Arun Chandra and others(IEEE International Conference On Recent Trends In Electronics Information Communication Technology, May 20-21, 2016, India) [21] their proposed model uses Raspberry Pi counts the number of pulses detected by Light sensor module. The sensor is placed on the energy meter. The Raspberry Pi counts the number of pulses to calculate the energy consumption in kWh according to the conversion mentioned on the energy meter. This data is then sent to Google Spreadsheets using Google API. The spread sheet can be accessed on a website and android app that were designed. A GSM module is interfaced with the Raspberry Pi to send energy usage data to the respective customer via SMS. They use Raspberry Pi 2 model B board. It has features similar to the Raspberry Pi 1 model B+ such as 4 USB ports, 40 GPIO pins, micro SD card slot etc.. In addition to these above mentioned features, it has 1GB RAM, 900 MHZ quad-core ARM Cortex-A7 CPU. The Raspberry Pi which was used runs on the operating system, Raspbian Wheezy OS which is a Linux distribution. Raspberry Pi based automated energy meter was implemented using ZigBee Protocol. They simplify the design by using Wi-Fi protocol. The ZigBee technology is designed to carry small amounts of data over a short distance while consuming very little power. Clearly it presents the limitation of distance in the design approach using this technology. On the other hand, Wi-Fi is a local area network (LAN) that provides internet access within a limited range. In our model, Wi-Fi seems to be a better option as the data uploaded to the internet is accessible everywhere if wireless networks are present. In addition to the design approach used in , GSM module was used to incorporate the feature of sending the energy consumption statement to the users via SMS. This was done keeping in mind the case where some users cannot have access to internet, they did not get rid of involving GSM and Internet for communication between the customer meter unit and the base station although they used Wi-Fi as local area network (LAN) that Provides internet access within a limited range. In their model, Wi-Fi seems to be a better option as the data uploaded to the internet is accessible everywhere if wireless networks are present. In addition to the design approach used in, GSM module was used to incorporate the feature of sending the energy consumption statement to the users via SMS. This was done keeping in mind the case where some users cannot have access to internet. More over GSM and internet are added cost which affects the price of the Kw/h if that is not kind of dependency as in many countries the communication and electricity are different bodies with separated budgets.

In 2009, an evaluation system about the improvement of smart grid construction was published in America. Different research institutes also reported their research results soon afterwards. Suleiman and his

Colleagues from Tennessee Technological University studied some issues about power quality, efficiency and operating condition of power grid in local areas such as enterprises and colleges. Real monitoring system was also built. But the LAN they used was the wired mode based on IP Protocol, which means heavy cabling workload [22].

Mojtaba Rafiei and Mehdi Eftekhari – Iran (Article Code: mdn_3349) they made smart meter using combination of power line communication (PLC) and Wi-Fi protocols. Smart metering using PLC technology is quite useful and it saves a lot of human efforts, reduces costs and also makes the whole system more efficient. Via using this technology, data of meters is transmitted to utility and if two way communications exist, the meter may be controlled from utility server. PLC Transceiver or PLC modem is the vital component of a PLC system. It is the device by which data is transmitted & received to & from the power lines and acts as a hub between the meters and utility server. They are wired with the electrical voltage lines at home or business and work on two modes – transmit mode and receive mode. In transmit mode, they simply receive data from receiver end installed on the same network and further transmit them. In receive mode, they work the opposite way.

Jiang Bing and others (Southeast University, Nanjing 210096, China 2013) designed Power Information Acquisition System Based on ZigBee Network, The data acquisition terminal collects three-phase currents and three-phase voltages, works out energy information such as RMS voltages, RMS currents, active and reactive energy, and then sends to region server. The communication method between data acquisition terminal and region server is wireless LAN based on ZigBee protocol. To meet the needs of system function, the data acquisition terminal consists of three parts: ATT7022B analogue board, ARM digital board and ZigBee SZ02 network node. The ATT7022B analogue board collects and processes energy information, and provides power interface and SPI interface for ARM digital board. The ARM digital board reads data via SPI interface, realizes data conversion and storage, and then sends data to region server via ZigBee SZ02 according to server demands. Although the research on intelligent power service system is lagging behind in domestic; there still are some researches and practices in related technical fields.

Chapter Three

Methodology

3.1 Design and Operation of Simulated System

In this thesis a simulation is carried out using Proteus software version 7.7 where many of circuit's components are available in the library of the program it is easy to connect these components according to the diagram and, hex. File can be downloaded in Arduino .the run of the circuit is very accessible to make simulation to check the results and to ensure that the diagram fulfilling the required purpose.

3.1.1 Circuit Design

From the library of the Proteus software, two potentiometers are firstly fetched and are used instead of the smart meter to send different values of voltage from the XBee 1 (transmitter) to the XBee 2 (receiver).

Then two of Arduino UNO and LCD 16X2 are selected and dropped in the design page as shown in figure 3.1

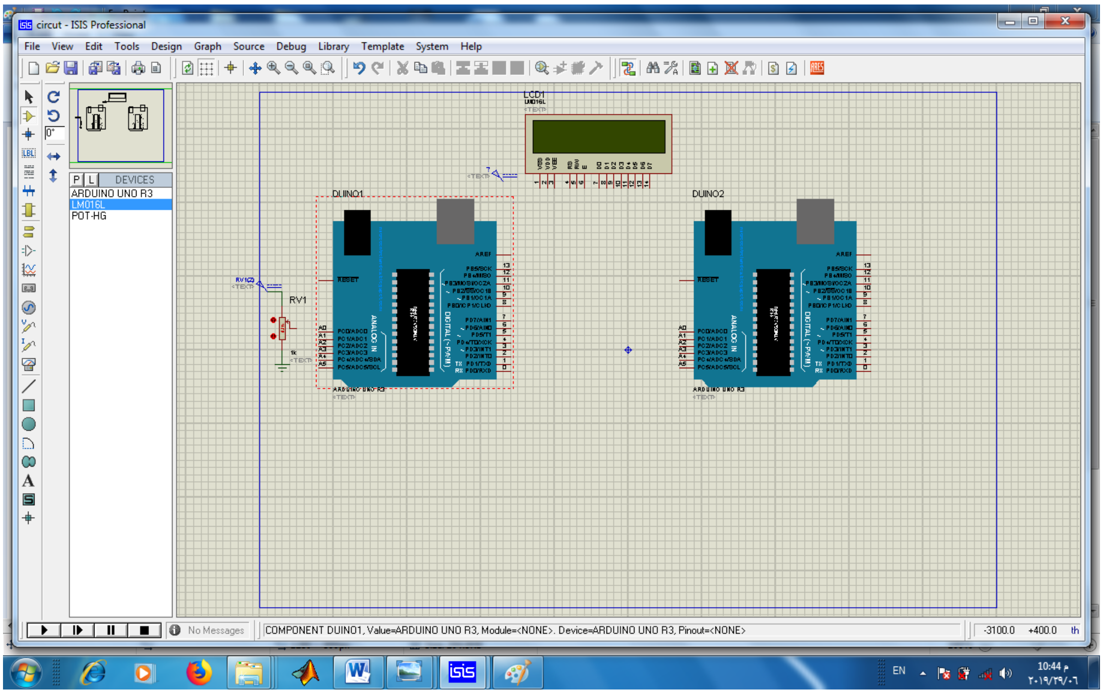


Figure 3-1 Arduino UNO & LM016 (LCD) select from Proteus library

Two of XBee are selected and, all these devices are connected as illustrated in the figure 3-2 below:

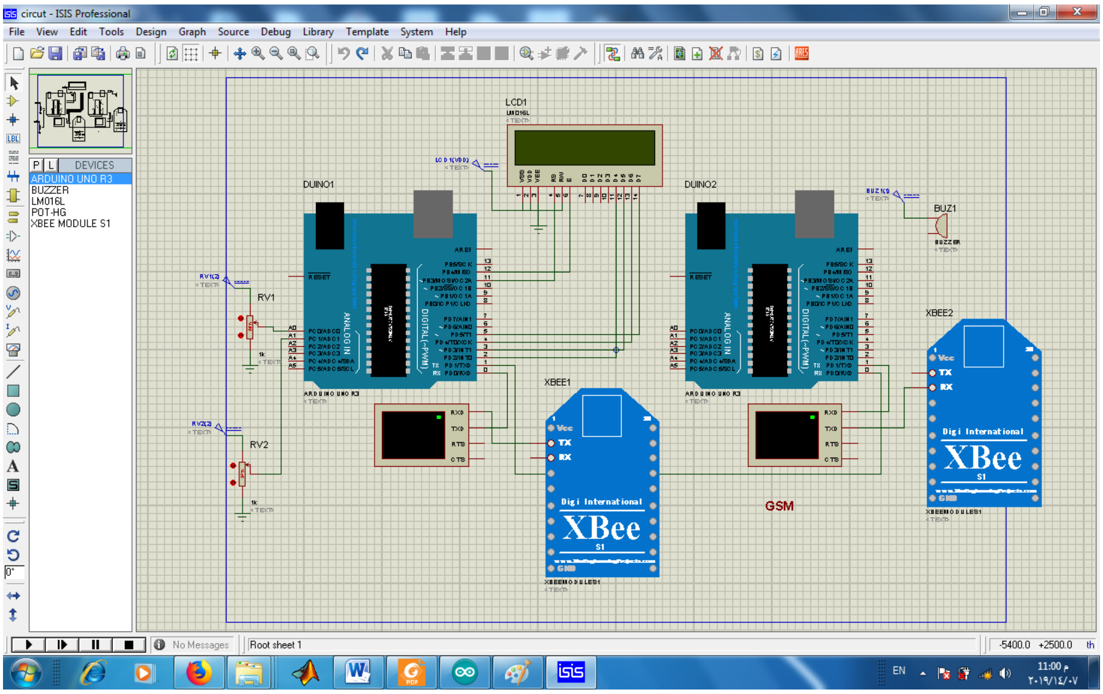


Figure 3-2 full circuit connection

Buzzer and GSM are attached to alert the base station and the user in case power factor reaches the limit value. By double click in the Arduino UNO of the transmitter the program file (hex. File) is selected from its browsed location and then ok, the same is done for the Arduino of receiver.

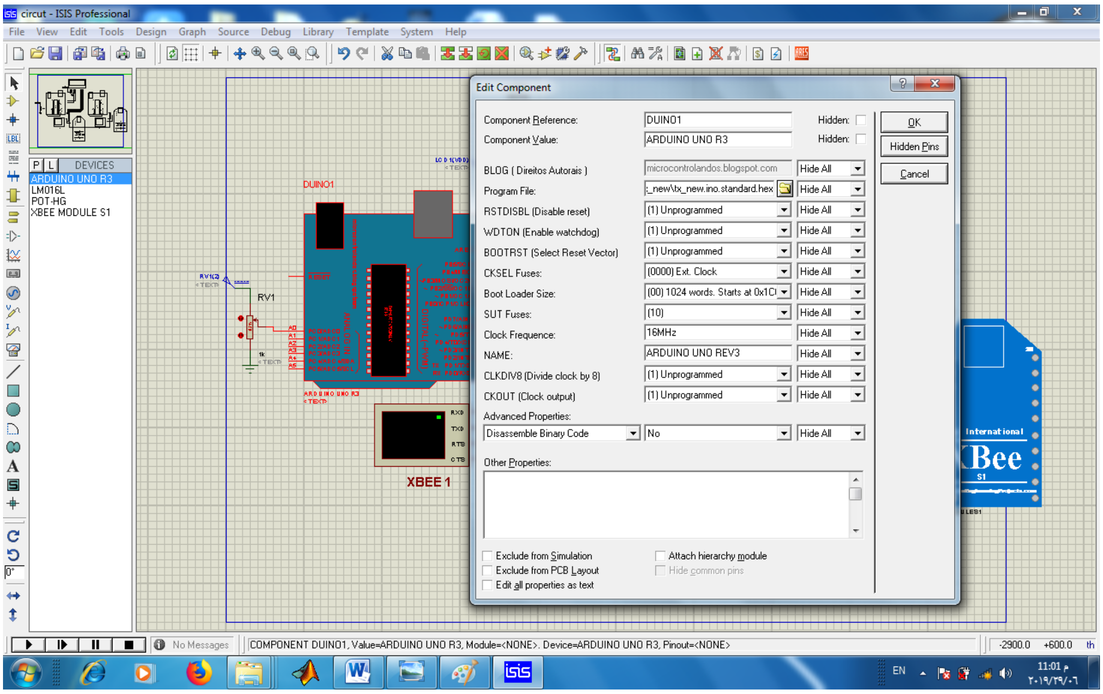
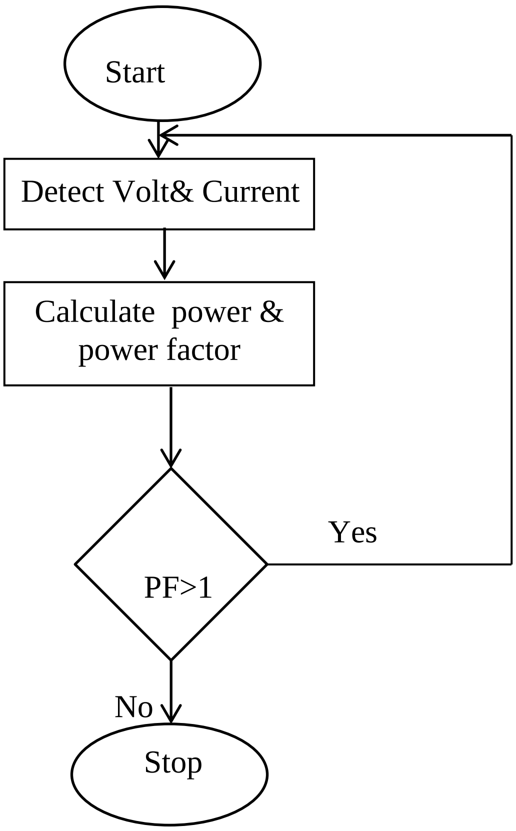


Figure 3-3 load hex. file to Arduino

After loading hex.file in both transmitter and receiver Arduino, the program is run and results are obtained.

Flow chart below illustrates the steps of the model process:



3.2 Design and Operation of Hardware System

The hard ware is consist of measuring circuit, communication circuit and base station data analysis circuit

3.2.1 Components

The diagram of this thesis consists of two parts; part one is in the user side which consist of measurement circuit that related to the design of the watt meters to detect the volt (V) and current (I), a microcontroller (Arduino UNO) to receive the meter reading through the ADC and to make a calculation to obtain Power(watt) and power factor (PF), a LCD (16 x 2) to display the final reading in the user side, XBee transmitter which receive the reading from Arduino and send them to the receiver in the base station. Part two is the base station side which consist of receiver XBee where the operator receive the data for monitoring, Buzzer to make alarm if one of the addresses PF is greater than 1 and GSM module to send SMS automatically to the specific user while buzzer is operating.

3.2.2 Assembling

In the scheme of this thesis the communication circuit should be interfaced to the smart watt meter to send the data required for monitoring to the base station so that the operator can take decision if there is any parameter out of range or it can lead to power loss or any damage.

In reality we will connect potentiometer instead of watt meter to check the results of the communication circuit.

3.2.2.1 Potentiometer Connection

First of all we need to specify the components required to connect the potentiometer to the Microcontroller.

- Arduino Uno board
- breadboard
- 3 jumper wires
- 10k potentiometer

First connect the potentiometer to the breadboard and Better always to have different colour of wires, then as shown in the figure 3-4 use the red wire to supply the pot. With 5Vcc from the Arduino, use the grey wire to connect the pot to GND and wire green to port A analogue point A0

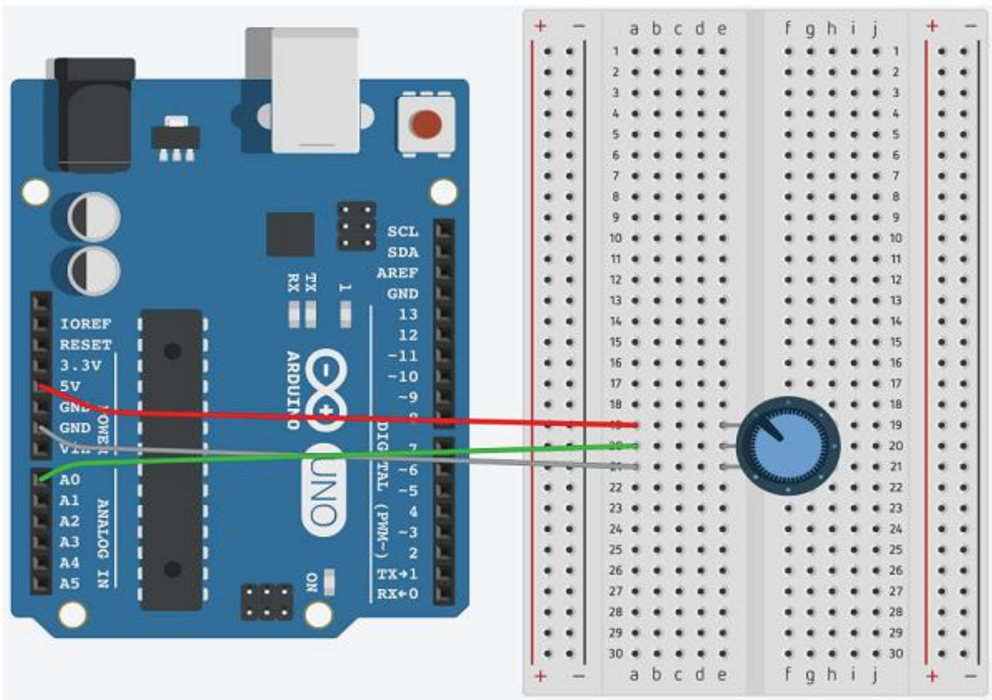


Figure 3-4 pot interfacing to Arduino

3.2.2.2 LCD Connection

To show the reading of the watt meter or the potentiometer as in our simulation, we use a parallel LCD screen. These are extremely common and come in all kinds of shapes and sizes. The most common is a 16×2 character display with a single row of 16 pins (14 if it does not have a backlight). In this chapter, we use a 16-pin LCD display that can show a total of 32 characters (16 columns and 2 rows). the connection of the LCD with the Arduino is to be done according to the table 3-1.

Table 3-1 Arduino LCD connection pin to pin

Arduino pin	LCD pin
GND	Vss
+5V	Vcc
Pin 2 (wiper) of 10k linear potentiometer	V0
D12	Register Select (RS)
D11	Enable (E)
GND or D10 (optional)	Read/Write (RW)
D5	DB4 (bit 4)
D4	DB5 (bit 5)
D3	DB5 (bit 6)
D2	DB5 (bit 7)
+5V through a series resistor (for example, 68 ohm)	LED+
GND	LED-

As per the circuit photo in figure 3-5, first connect the Vss pin to GND. The next pin, Vcc, supplies power to the LCD and should be connected to +5V on the Arduino (or 3.3V depending on your LCD). Next, we'll want to connect the V0 pin on the LCD to the wiper (middle leg) of a 10k linear potentiometer. Connect the left leg to +5Vand the right to GND. This is used to set the contrast of the LCD, and you may prefer to use a trim pot if the contrast is something you want to set and forget. Connect the Register Select (RS) pin on the LCD to Arduino digital pin 12.This RS pin is used to control where in the LCD's internal memory the Arduino will write the current character. Next, wire the Enable (E) pin to Arduino digital pin 11.Enable is what actually allows writing to those registers. Since we're running in 4-bit mode, the next four pins on the LCD (DB0–DB3) don't need to be connected. That brings us to LCD bits DB4–DB7: DB4 should be connected to Arduino digital pin 5, DB5 to digital pin 4, DB6 to digital pin 3, and DB7 to digital pin 2. If the LCD has a backlight, now would be the time to connect the backlight LED+ to +5V on the Arduino through a series resistor (see the earlier note), and the LED- to GND on the Arduino

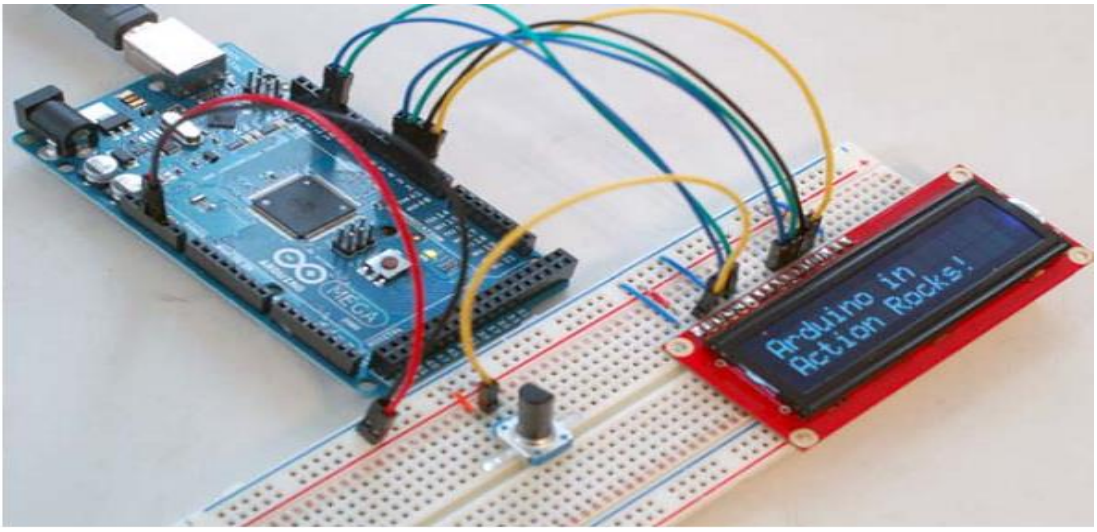


Figure 3-5 LCD interface to Arduino

3.2.2.3 XBee Connection

The number of pins of the XBee device is 20 pins as illustrated in the figure 3-6, but we will use only three of them.

First we connect the pin 1 to the Vcc in the arduino 3.3 v, next connect pin 2 to TX in the Arduino, then pin 3 to RX and lastly pin 10 to GND.

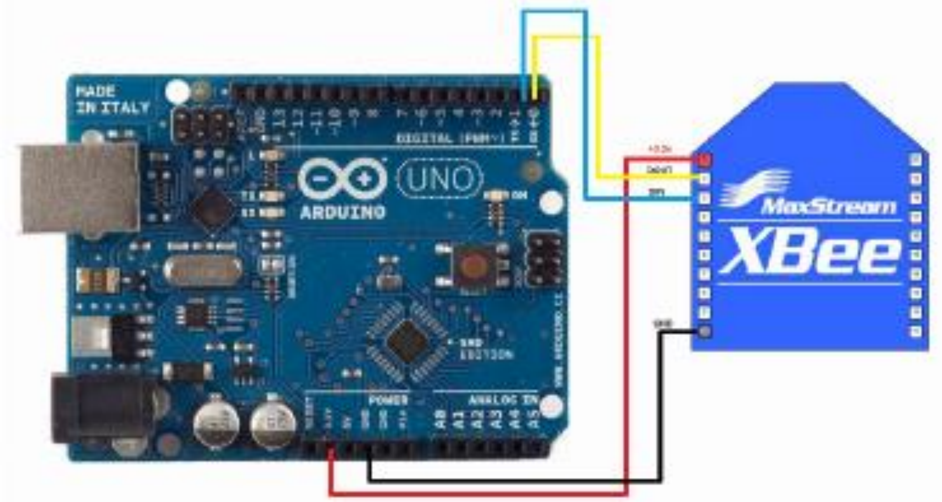


Figure 3-6 XBee interfacing with Arduino Uno

3.2.2.4 GSM Connection

GSM is used in the receiver circuit to inform the user via SMS when the PF is over range. By using power Adapter AC/DC we supply the module through the input socket and insert a valid SIM card in the SIM card holder. GSM has 10 pin out but we use only three of them to connect to Arduino as illustrated in the figure 3-7. The point RXD & TXD in GSM are connected to point 7 & 8 in the Arduino digital output port and the GND to GND in the Arduino.

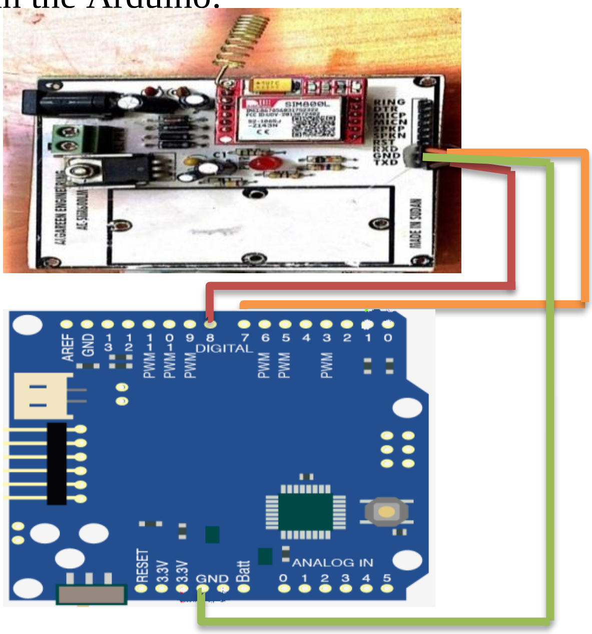


Figure 3-7 GSM connected to Arduino

3.2.2.5 Piezo Buzzer connection

Two wires, red & black (see figures 3-8). Polarity matters: black=ground. apply an oscillating voltage to make a noise, the buzzer case supports the piezo element and has resonant cavity for sound.

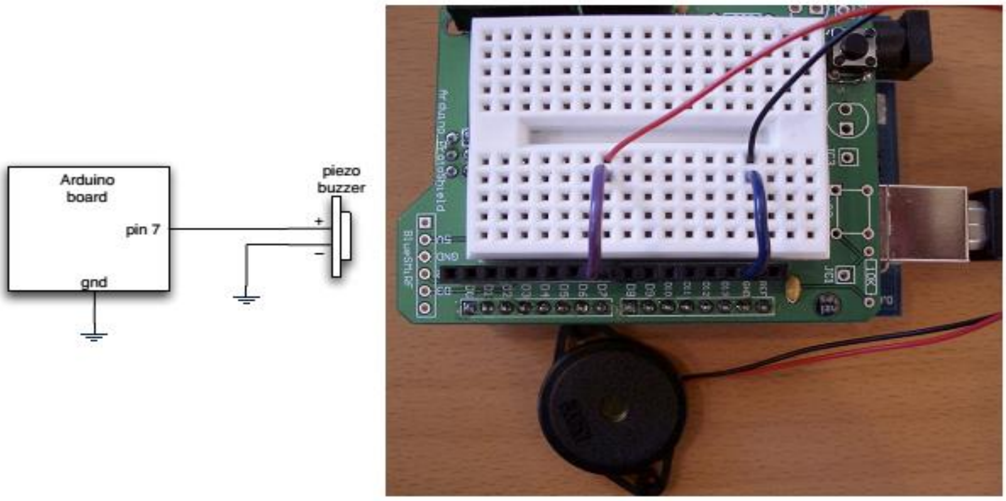


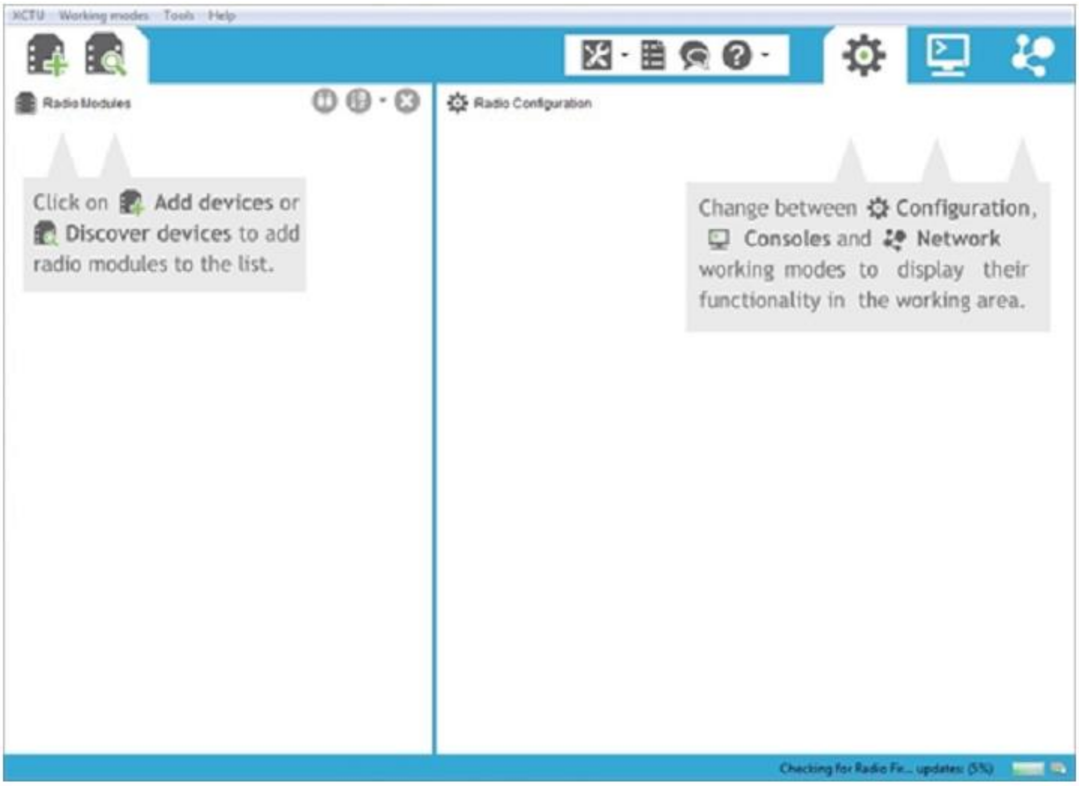
Figure 3-8 buzzer connected to Arduino

3.2.3 Operation of ZigBee

For operation the communication circuit should be configured to work as transmitter and receiver this configuration is done by software program called X_CTU.

XCTU: XCTU supports configuration and communication for most Digi RF modules. XCTU uses a serial link to interact with these radio modules, providing an easy-to-use and intuitive graphical interface**.**

XCTU is divided into five main sections: the menu bar, main toolbar, devices list, working area, and status bar.



The main toolbar is located at the top of the application and is divided into three sections

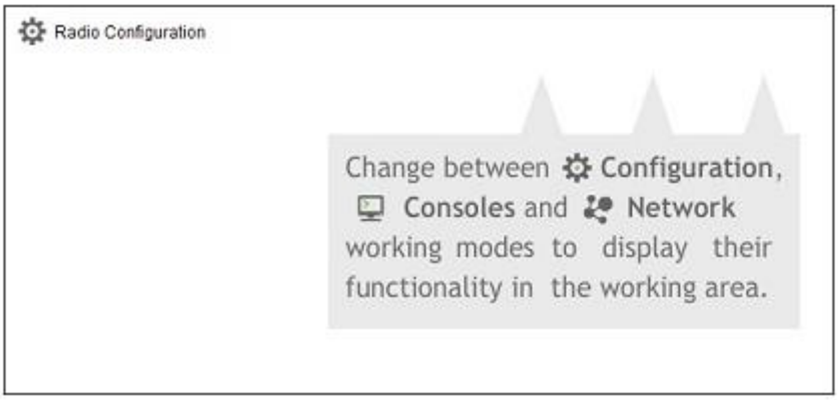
The first section contains two icons used to add radio modules to the radio modules list. See Add radio modules to XCTU.

The second section contains the static XCTU functionality that does not require a radio module. This section includes the XCTU tools, the XCTU configuration, the feedback form, and the help and updates functions. See XCTU tools and Configure XCTU.

The third section contains tabs corresponding to the three XCTU working modes. To use this functionality, you must have added one or more radio modules to the list. See XCTU working modes.

The radio modules list, or devices list, is located on the left side of the tool and displays the radio modules that are connected to your computer. If you know the serial port configuration of a radio module, you can add it to the list directly. You can also use the discovery feature of XCTU to find radio modules connected to your PC and add them to the list. See Add radio modules to XCTU. Depending on the protocol of the local radio modules added, you can also add remote radio modules to the list using the module's search feature.

The working area is the largest section and is located at the right side of the application. The contents of the working area depend on the working mode selected in the toolbar. To interact with the controls displayed in the working area, you must have added one or more radio modules to the list and one of the modules must be selected.



The status bar is located at the bottom of the application and displays the status of specific tasks, such as the firmware download process

Chapter Four

Results and Discussion

4.1 Results and Discussion of Simulated System

When the circuit is connected, the program is run (see figure 4-1) at once the volt and current reading is detected, the readings are changed when tuning the pot up and down.

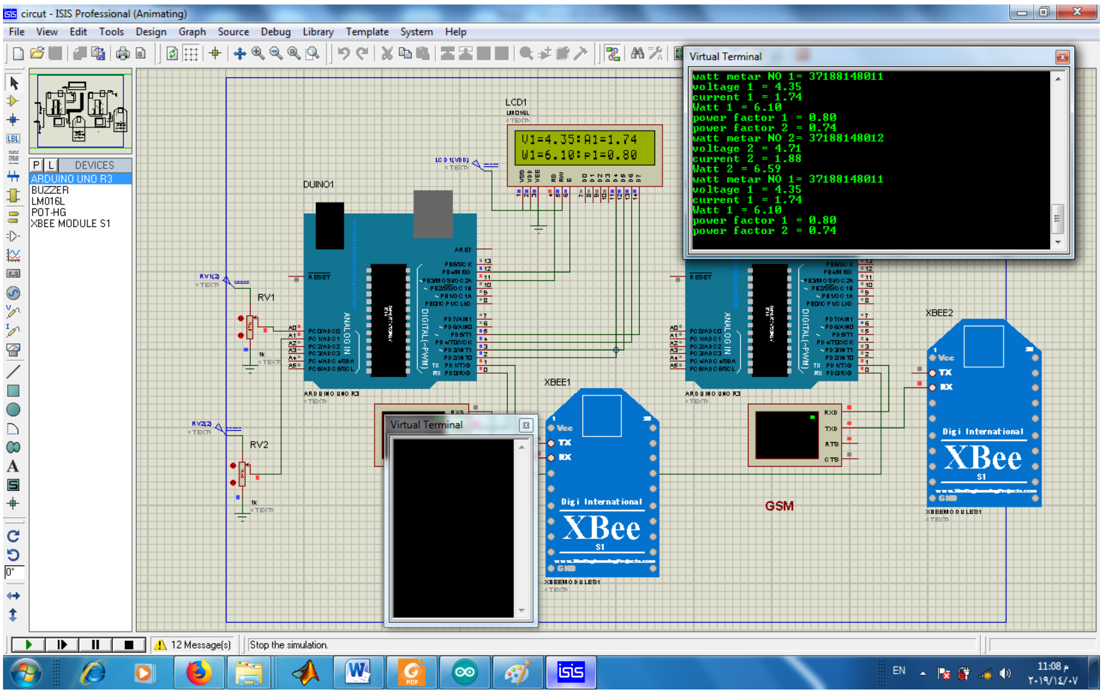


Figure 4-1 run of the program

The Arduino receive the analogue values V & I and calculate the other parameters (Power in watt and Power Factor) and show these values in the LCD of the user for watt meter 1 and watt meter 2. The same values are transmitted through XBee to the base station where the operator watching the readings of each watt meter with their different addresses at the same time. Since the pot value is changed the receiver responds to the new value. Notice the different values in figure 4-1 and figure 4-2.

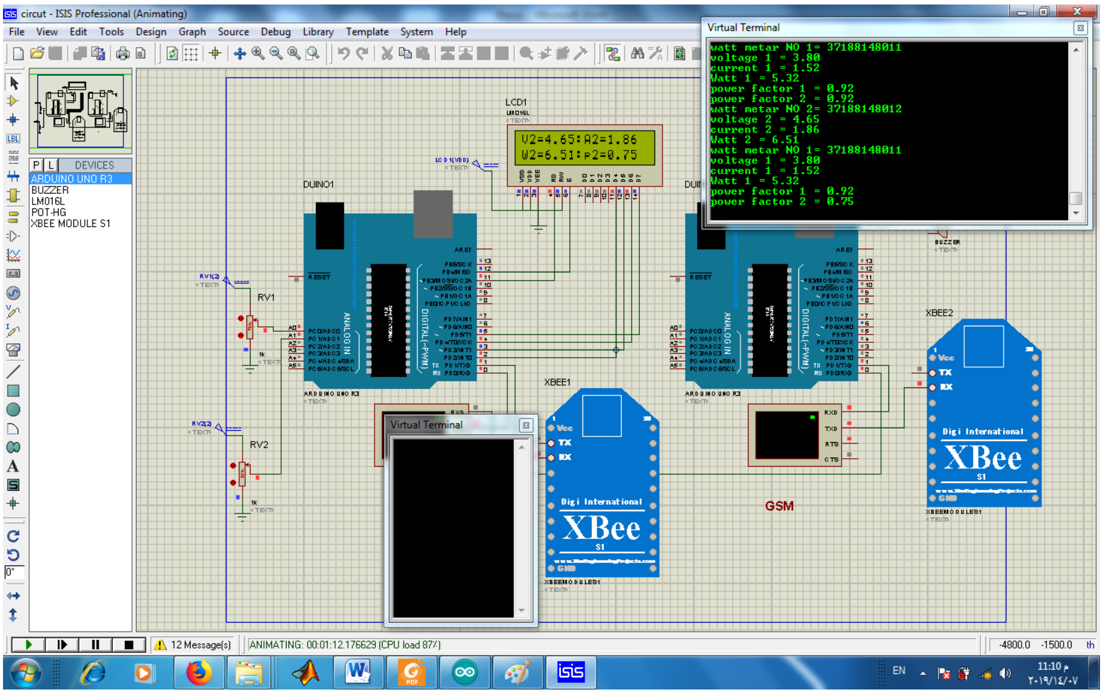


Figure 4-2 different value of output.

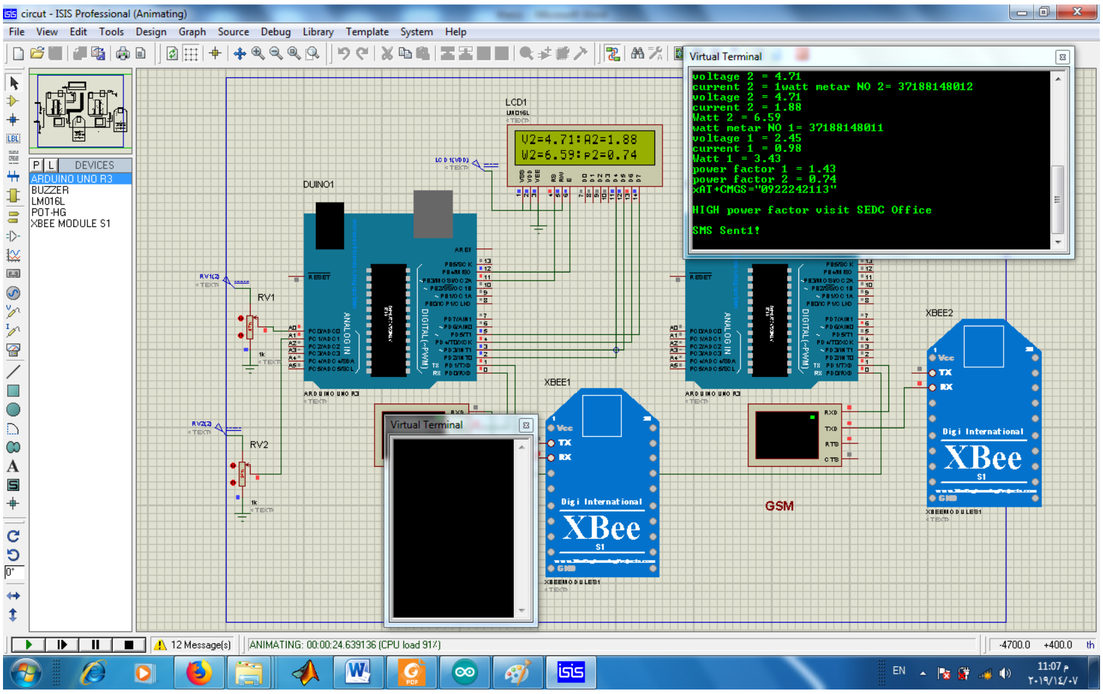


Figure 4-3 power factor of meter No.1 greater than 1.0

When power factor is greater than 1.0 buzzer will go high and GSM will send message to the user as shown in figures 4-3 & 4-4.

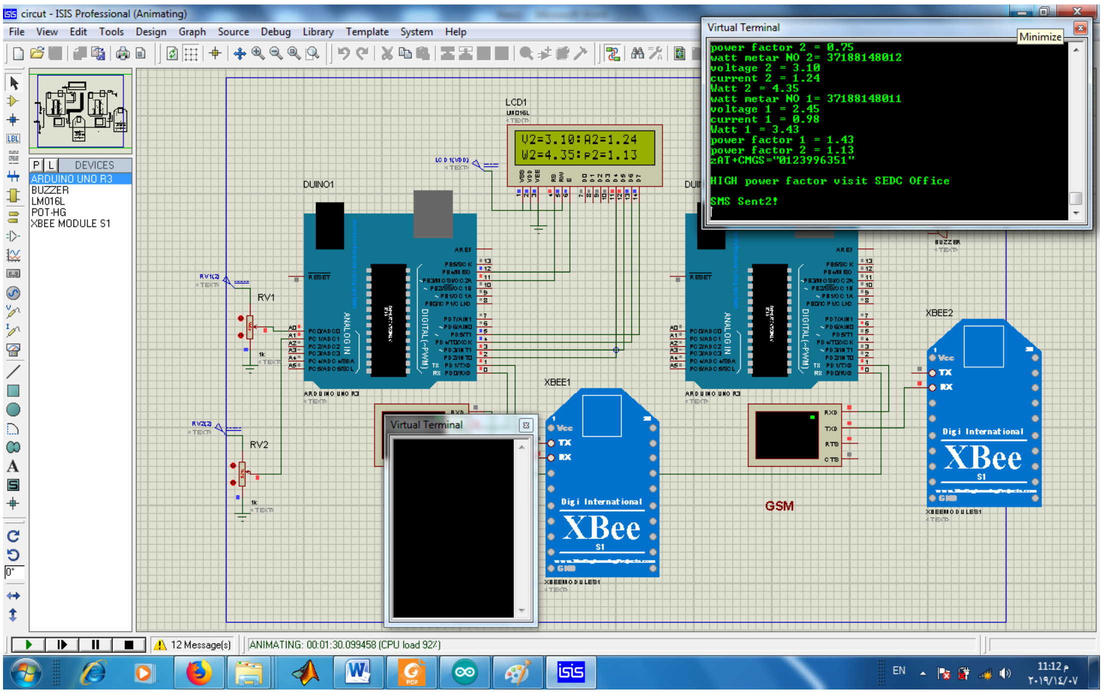


Figure 4-4 power factor of both meters 1&2 are greater than 1.0

4.2 Results and Discussion of H/W System

When the transmitter is connected to power it is observed that the readings of the watt meter No.1 are being displayed in the LCD as shown in figure 4-5. volt (V_1), Current (A_1), power (W_1) and power factor (P_1).

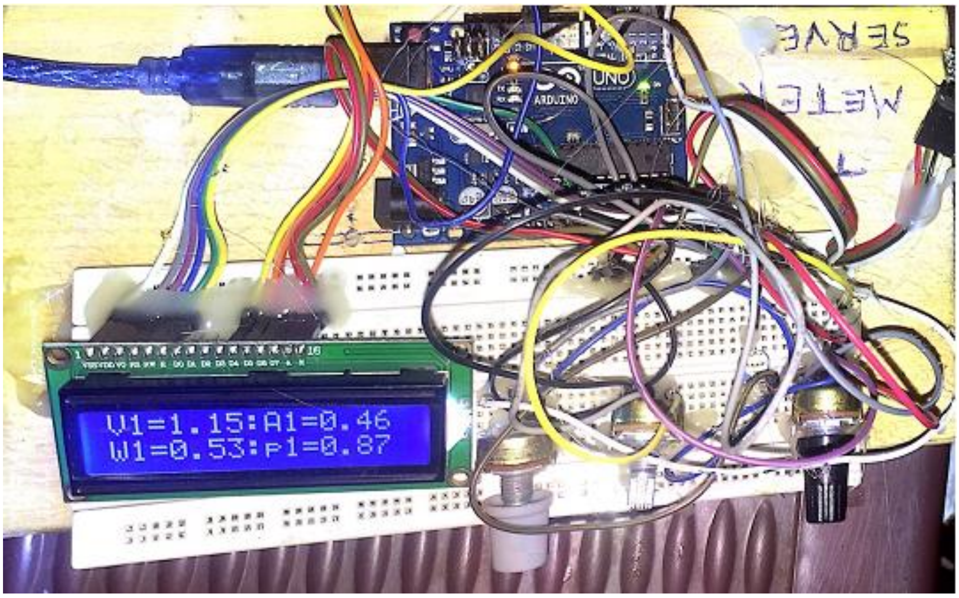


Figure 4-5 watt meter No.1 measured values in the transmitter side

For more than one meter another pot is added to give the same value for meter number 2 (V_1, A_2, W_2 and P_2) as shown in figure 4-6.
The power in watt is calculated from the equation:

$$P = V * I * \cos \emptyset$$

But in this model we calculate the power in VA by equation:

$$P = V * I$$

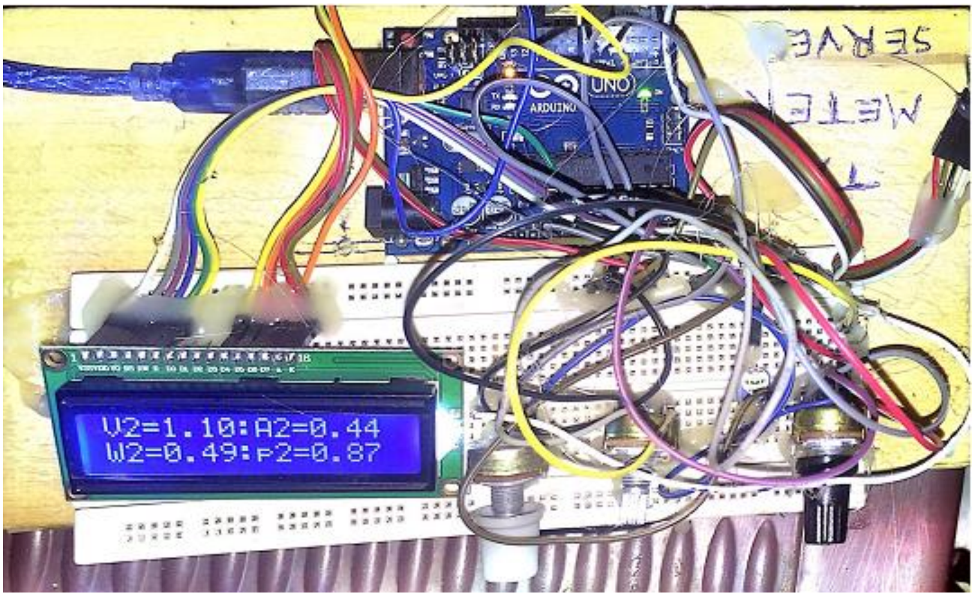


Figure 4-6 wat meter No.2 measured values in the transmitter side

There are two pots connected to act as watt meter No.1 and watt meter No.2, when you slide round any one of the pots the values in the LCD change in the real time. For every wattmeter there is a separate LCD in the user side to monitor the measured values. In the model the both watt meter share the same LCD and display the different values by delay code.

In the base station the receiver XBee (2) receives the data from XBee (1) the transmitter in the real time from different user by specific address for each, and show these measured values by counter number as shown in figure 4-7. The base station operator can monitor the readings and will be able to take decision when there is any reading is out of range or any possibilities of damage or cause of blackout can be avoided in time.

These readings can be then stored in data base program for issuing reports bills and to be saved as records.

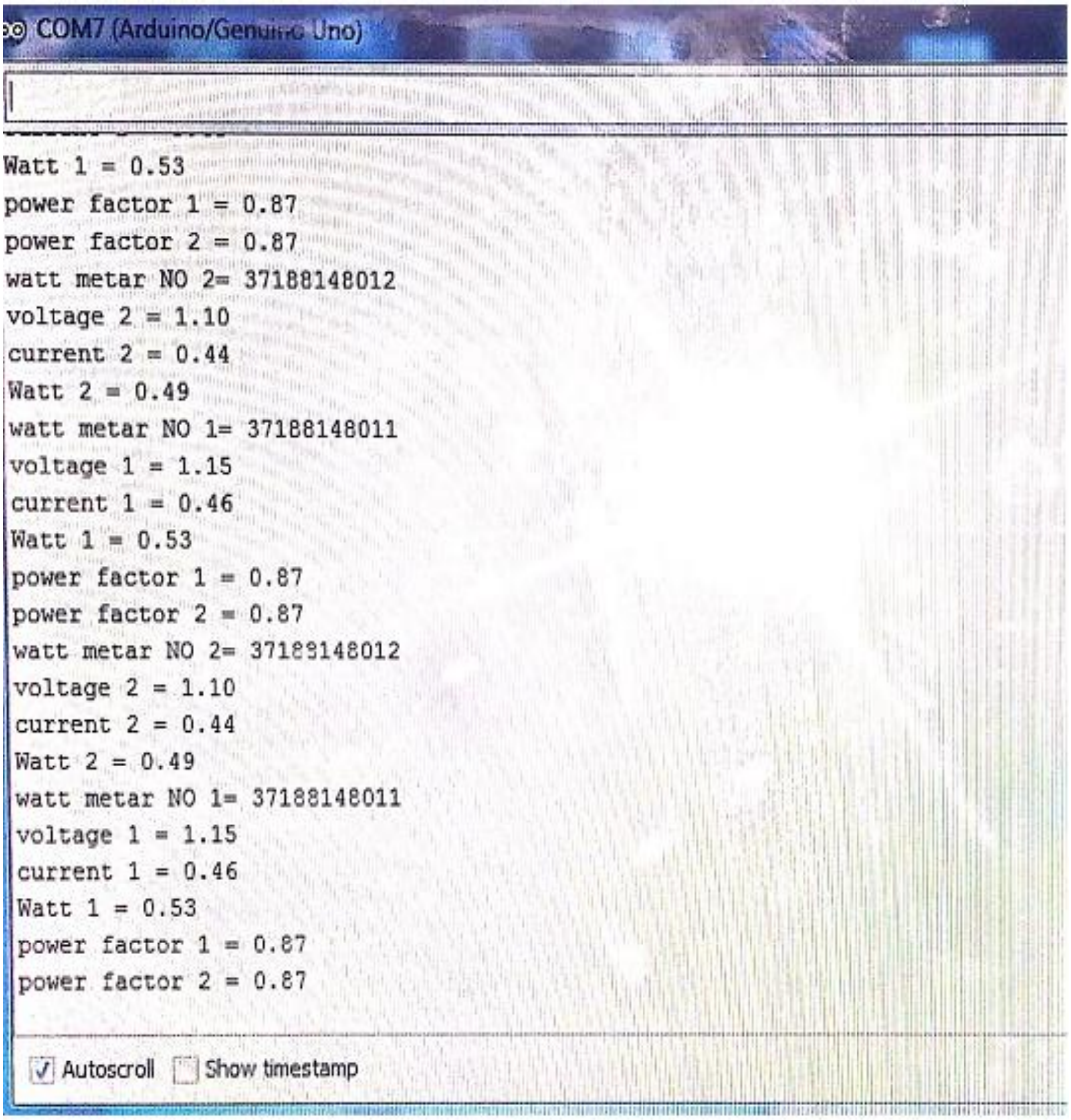


Figure 4-7 different watt meter measured values in the receiver side

For the power factor there is a limit for the measured value less than 0.5 is lag and more than 0.85 is lead.

In the model we specify only the lead power factor by the limit 1^+, and is calculated by the formula:

$$PF = Watt/VA$$

When PF reaches the value greater than 1.0 alarm of the buzzer grows high and SMS through GSM module is to be sent to the user concerned in case he is not monitoring his LCD or far from the location to check the system and visit the electricity distributor company. The figure 4-8 show the power factor value in the transmitter LCD is 1.06 and in the receiver side (base station) the same value is received as shown in figure 4-9.

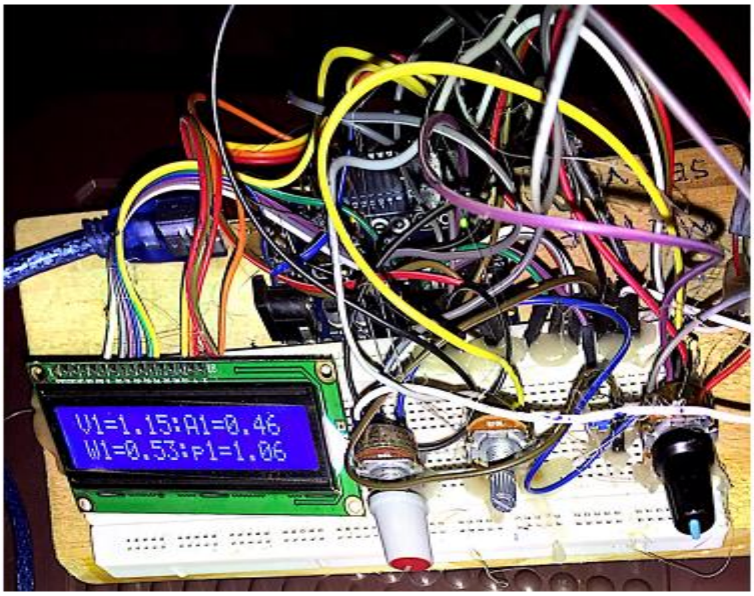


Figure 4-8 power factor in the transmitter side value greater than 1.0

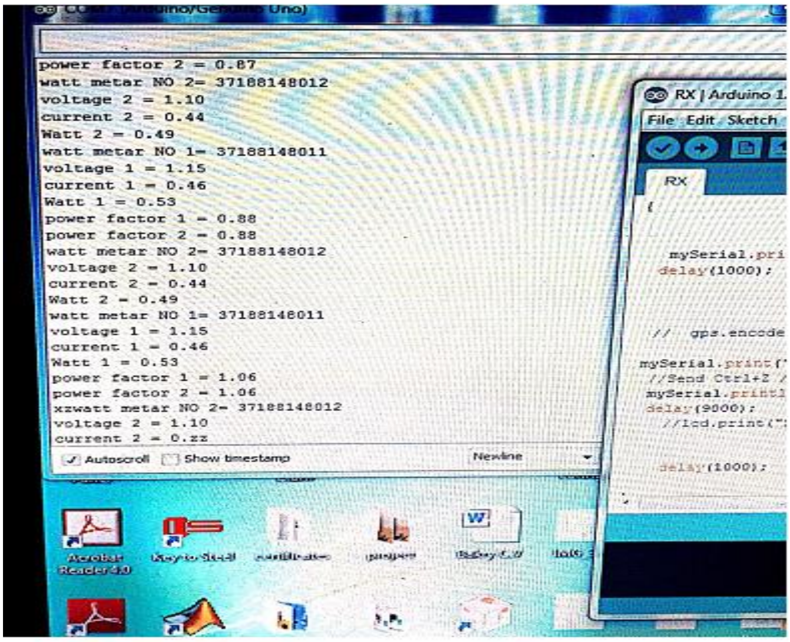


Figure 4-9 power factor in the receiver side is greater than 1.0

In the program of the transmitter the condition is, when the power factor greater than 1.0, serial print (x) in case watt meter No.1 and serial print (z) for meter No.2, in the receiver program the buzzer digital pin goes high when incoming byte is (x) or (z) and then back low by delay. During buzzer is high the serial print ("high power factor visit SEDC office") and throw GSM the message is sent to the user concerned (see program code appendix A).

Figure 4-10 receiving SMS by user

In the figure 4-10 the message sent by the GSM from the base station is received by the user, and that prove how smart is this model up to this step there is no human interference for the whole process.

Chapter Five

Conclusion and Recommendation

5.1 conclusion:

The results obtained fulfilled the objectives of the project, the real time results of the parameters displayed form the watt meter which is important for the base station operator, the simplicity of communication circuit and low cost of establishing and operation, Low power consumption as the module device takes 3.3 volt only to send big amount of data in real time, the ability of data protection by using by 128 bit symmetric encryption, privacy and independency avoid exposing to data hacking and the availability problem of the third party, the meter is smart in all process transmitting, receiving and feed back to operator and user.

This model of smart meter will be very useful for the Sudanese Electricity Distribution Company according to points mentioned above, now the range of the module is up to 1.6 km distance, in the future and due to the progress of the technology it is expected that ZigBee module working range will be extended to reach longer distance of communication.

The benefits of this project in the information aspect are good enough to make you in touch by different types of mechatronics area, such as communication systems, embedded systems, electronic circuits, electric power and programming.

5.2 Recommendations:

To make the model effective for the SEDC I recommend doing following things:

1- To Establish data base software in the base station by visual basic.net to save the readings of different user for billing or to keep as records.
2- Don't use ZigBee Module with build-in battery as SEDC change the wattmeter every 15 years and the battery life is only 5 years that leads to watt meter change 3 times before the schedule time.
3- Data to be collected from other states can be done from every base station through SCADA system or any appropriate automation system.
4- This meter is bidirectional communication device with simple program you can feed your balance directly through the base station.
5- The GSM in the base station makes it so easy to charge up your meter through your phone balance.

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Appendices

Appendix A Watt Meter Program Code

```
#include <LiquidCrystal.h>

// initialize the library with the numbers of the interface
pins
LiquidCrystal lcd(12, 11, 2, 3, 4, 5);
// the setup routine runs once when you press reset:
void setup() {
  // initialize serial communication at 9600 bits per second:
  Serial.begin(9600);
  lcd.begin(16, 2);
  // Print a message to the LCD.
  //lcd.print("hellow");
  delay(1000);
}

void loop() {

  int s1 = analogRead(A0);
  int s2 = analogRead(A1);
   //int s3 = analogRead(A2);
   float voltage2 = s2 * (5.0 / 1023.0);
    float current2;
    current2=voltage2/2.5;
        float watt2;
        watt2=voltage2*current2;


  float voltage = s1 * (5.0 / 1023.0);
    float current;
    current=voltage/2.5;
        float watt;
        float av;
        av=voltage*current;
float w=5*current;
watt=w*coso;
    float power_factor = watt/av;
   float av2;
           av2=voltage2*current2;
           float w2=5*current2;
watt2=w2*coso;

    float power_factor2 = watt2/av2;


          Serial.print("watt metar NO 2= ");
  Serial.println("37188148012");

  Serial.print("voltage 2 = ");
```

```
  Serial.println(voltage2);

   Serial.print("current 2 = ");
  Serial.println(current2);
    Serial.print("Watt 2 = ");
  Serial.println(watt2);

  // print out the value you read:
  Serial.print("watt metar NO 1= ");
  Serial.println("37188148011");

  Serial.print("voltage 1 = ");
  Serial.println(voltage);

   Serial.print("current 1 = ");
  Serial.println(current);
    Serial.print("Watt 1 = ");
  Serial.println(watt);

 // delay(500);


    Serial.print("power factor 1 = ");
  Serial.println(power_factor);
 Serial.print("power factor 2 = ");
  Serial.println(power_factor2);

    if (power_factor2>=1){
     Serial.println("z");
    }

    if (power_factor>=1){
     Serial.println("x");
    }
lcd.setCursor(0,0);
    lcd.print("V1=");
    lcd.setCursor(3,0);
    lcd.print(voltage);
     lcd.setCursor(7,0);
    lcd.print(":A1=");

    lcd.setCursor(11,0);
    lcd.print(current);

  lcd.setCursor(0,1);
    lcd.print("W1=");
    lcd.setCursor(3,1);
    lcd.print(watt);
  lcd.setCursor(7,1);
    lcd.print(":p1=");
    lcd.setCursor(11,1);
    lcd.print(power_factor);
    delay(1000);


  lcd.setCursor(0,0);
```

```
    lcd.print("V2=");
    lcd.setCursor(3,0);
    lcd.print(voltage2);
     lcd.setCursor(7,0);
    lcd.print(":A2=");

    lcd.setCursor(11,0);
    lcd.print(current2);
  lcd.setCursor(0,1);
    lcd.print("W2=");
    lcd.setCursor(3,1);
    lcd.print(watt2);
  lcd.setCursor(7,1);
    lcd.print(":p2=");
    lcd.setCursor(11,1);
    lcd.print(power_factor2);
    delay(1000);


}
#include <SoftwareSerial.h>

SoftwareSerial mySerial(8,7); // RX, TX


int incomingByte;      // a variable to read incoming serial
data into

void setup() {
    pinMode(buzzer, OUTPUT);
  // set up the LCD's number of columns and rows:
  //lcd.begin(16, 2);
  // initialize the serial communications:
  Serial.begin(9600);

  mySerial.begin(9600);
 mySerial.println("AT+CMGF=1\r\n");
  delay(1000);
}

void loop() {
  // when characters arrive over the serial port...


  if (Serial.available()>0) {

    // wait a bit for the entire message to arrive
   // delay(10);
    // clear the screen
    //lcd.clear();
    // read all the available characters
      incomingByte = Serial.read();
      Serial.write(incomingByte);
    // if it's a capital H (ASCII 72), turn on the LED:
    if (incomingByte == 'x') {
```

```
        digitalWrite(buzzer, HIGH);
    SendMessage();
        digitalWrite(buzzer, LOW);
  }

    if (incomingByte == 'z') {
    digitalWrite(buzzer, HIGH);
   SendMessage2();
        digitalWrite(buzzer, LOW);
  }
    }

  }

void SendMessage()
{


   mySerial.println("AT+CMGS=\"enter phone number\"\r\n");
  delay(1000);



  //  gps.encode(serial_connection.read());//This feeds the
serial NMEA data into the library one char at a time
  mySerial.print("HIGH power factor visit SEDC office");
  //  delay(1000);
  //Send Ctrl+Z / ESC to denote SMS message is complete
  mySerial.println((char)26);
  delay(9000);
   // lcd.print("SMS Sent1!");


    delay(1000);

}


void SendMessage2()
{


   mySerial.println("AT+CMGS=\"enter phone number\"\r\n");
  delay(1000);



  //  gps.encode(serial_connection.read());//This feeds the
serial NMEA data into the library one char at a time

 mySerial.print("HIGH power factor visit SEDC office");
  //Send Ctrl+Z / ESC to denote SMS message is complete
  mySerial.println((char)26);
  delay(9000);
    //lcd.print("SMS Sent2!");
```

```
    delay(1000);

}
  /*
  while (Serial.available() > 0) {
      // display each character to the LCD


      Serial.write(incomingByte);

    }
    */
//}
```