Thesis Paper

Microcontroller Based Power Pilferage Detection System

Submitted to the Dept. of Electrical & Electronic Engineering, SECS, BRAC University

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Declaration

We hereby declare that the thesis titled "Microcontroller Based Power Pilferage Detection System" submitted to the Department of EEE, SECS, BRAC University, is our original work. Any information from other sources has been acknowledged in the reference section.

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Abstract

Power distribution loss costs our country a major amount in annual revenues. This is because distribution of electricity involves significant technical as well as non-technical losses. There are ways to calculate and fix technical losses. But illegal consumption of electricity takes a considerable part of the revenue as a non-technical loss. This paper, thus, discusses the methodology for detection of power pilferage and its implementation. The idea is to detect unauthorized tapping on distribution lines by identifying the approximate location of tapping within the implementation area of a distribution network of electrical power supply system. Wireless data transmission and receiving technique and meter reading technique will be used in the lowest possible cost to ascertain the tapped electrical line and notify the respective authority for inspection. Hence, the proposed design in this paper will hopefully improve the current situation of electricity theft in our country.

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CHAPTER 1

Introduction

1.1   Motivation

Annual power sector losses are of about $25 billion monetary value in the world, [1], a large part of which is contributed by non-technical power pilferage losses. Electricity theft is, universally, an extremely emergent problem; especially so for countries with high levels of corruption, unstable political environment, unrestrained crime rates, low government efficiency lacking effective accountability. All these governance indicators indicate our country, Bangladesh, to be one of those countries with higher levels of unchecked theft of electricity. [2]

Losses in the power sector of the country have, for long, been far too huge compared to the revenues collected. These losses are primarily of two kinds – technical and non-technical losses. While technical losses are usually involved with the process of generation of electricity, conversely transmission and distribution of electricity witnesses high levels of power misplacement through illegal measures which constitutes a major portion of the non-technical losses. While it is true that not all transmission and distribution (T&D) losses result from electricity theft, it can easily be assumed from facts and surveys that power sectors with greater than 15 per cent T&D losses are undoubtedly incompetent and usually, are result to electricity theft. According to Thomas Smith's set of guidelines found in a study published in 2004 [2], efficient distribution systems are those, which have less than 6 per cent T&D losses comprising a 1 per cent to 2 per cent of losses owing to electricity theft while less efficient systems will have T&D losses of 9 per cent to 12 per cent. In contrast, an inefficient system would bear testimony to T&D losses of over 15 per cent. Mr. Smith's study suggested that 15 per cent of the 102 surveyed countries reported T&D losses of 16-20 per cent and another 28 per cent reported T&D losses of 21-53 per cent. Thus, Bangladesh is certainly not the only one with high rates of power theft contributing to losses that define its power sector as an inefficient one. In fact, the same

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study by Mr. Smith revealed that compared to countries in the Western Europe, where T&D losses were under 8 per cent, South Asian countries reported the highest T&D losses of 28 per cent (see following table). But unfortunately, in this paper, our drive to present a possible solution to the issues surmounting to such losses is the fact that Bangladesh, indeed is one of the countries with the worst case scenarios of inefficiency, a fact which is proved in the mentioned study showing that the T&D losses for Dhaka, the capital city of Bangladesh were around 40 per cent.

Table 2
T&D Losses by region, 1980 and 2000

Region	Countries	1980 T&D loss percent	2000 T&D loss percent	Change percent
Western Europe	17	7.71	7.56	−0.15
Eastern Europe	24	9.68	18.18	+8.50
Middle-east, North Africa	11	11.18	19.63	+8.45
Africa	11	14.6	19.95	+5.35
North America	3	9.67	9.38	−0.29
South America	9	13.00	17.23	+4.23
Central America, Caribbean	9	15.50	21.68	+6.18
South Asia	5	25.20	27.55	+2.35
Southeast Asia	7	12.14	13.32	+1.18
East Asia, Australasia	6	8.67	7.65	−1.02
Total	102	11.69%	16.22%	+4.54%

Not to forget, these statistics are dated to a much earlier time, meaning that the non-technical losses (NTL) which contributed to the then 40 per cent T&D losses must have risen to a much more formidable state by now owing to the absence of necessary measures to work out the

electricity theft crisis. These NTL losses affect quality of supply, increase load on the generating station, and affect tariff imposed on genuine customers. So, we can say that the unbearably lofty rates of load-shedding, the frequent anomalous change in the supplied voltage (which is supposed to be constant) as well as the pricy utility bills in our country – NTL losses, more precisely, the currently unresolved state of power pilferage bears a large share of the burden of the blame for all of that.

Clearly, in most countries and more often in the developing ones, electricity consumer dishonesty is a problem faced by all power utilities. Implementing effective methods for detecting fraudulent electricity consumption has been an active research area in recent years. Yet, despite huge losses in government revenues owing to power pilferage issues, sadly, our country is yet to come around a solution to the problem and thus, the losses keep mounting while the revenues keep dwindling. This situation might be resulted from the fact that, Bangladesh, being an under-developed country cannot afford the smart but expensive measures taken by many countries against similar crises. Thus, with the motivation to detect and deject illegal consumers, and conserve and effectively utilize energy within a feasible budget, we propose a possible solution in this paper which would make affordable changes to the existing electricity transmission and distribution system and yet decrease the losses resulting from power pilferage to an effectual extent.

1.2   Project Overview

The power pilferage detection model proposed here is expected to detect illegal drawing of power using a microcontroller based system that would feasibly decrease the government revenue losses over electricity theft. This project includes the modification of existing energy meters into energy measuring and transmitting devices (EMTD) and checking measuring and receiving devices (CMRD) which report any abnormal inconsistency higher in energy provided and consumed to the control centre using a GSM modem. The energy meters are connected at individual premises. They measure the energy consumed in those premises. There are different ways in which the energy is pilfered, on most of cases of which the pilfered energy cannot be detected and accounted for. The idea of the project is to monitor a group of meters which register

the energy consumed by the individual premises against a check meter, the CMRD, which is to be kept out of the reach of the individuals and keeps a continuous reading of the energy distributed from the pole of the implementation area. Every building has a number of meters and they get supply from a service drop. The CMRD will be installed at the starting point of the service drop and the individual consumers will each have an EMTD. After comparing the data of consumed power sent from the individual EMTDs of consumer premises to the CMRD with the calculated data representing the power that is passing through the check point, if there is a discrepancy in the balance, the pilferage zone can be detected and an automatically message will be send to the authority.

In detail, energy measuring devices in a specific area are distributed among all buildings within the premises drawing electricity from a pole. The pole itself has a measuring device continuously computing the total amount of power drawn throughout the area. Also, each meter implanted on the buildings calculates the amount of energy consumed by the respective building. The idea is to transmit the values computed in the meters from each building via wireless transmission using an ASK RF transmitter to an ASK RF receiver on the pole side and then checking for any discrepancy between the values measured on both sides. If there is some amount of difference between the two values exceeding a set tolerance value, the control system is immediately notified of the event via wireless transmission using a GSM module.

The analog value, which is the difference between the immediate last reading and the most recent reading taken from the original energy meter and calculated by the code programmed into the microcontroller, is fed to an analog pin of the microcontroller, PIC16F877A best suited for our purpose. This value is then converted to a digital value using the code programmed into the microcontroller. This digital value is then transmitted using the ASK RF transmitter, of 433MHz frequency module, connected to the TX pin of the microcontroller. We have also used a 16x2 LCD module which would be displaying the data that is transmitted from the energy measuring blocks on the user side.
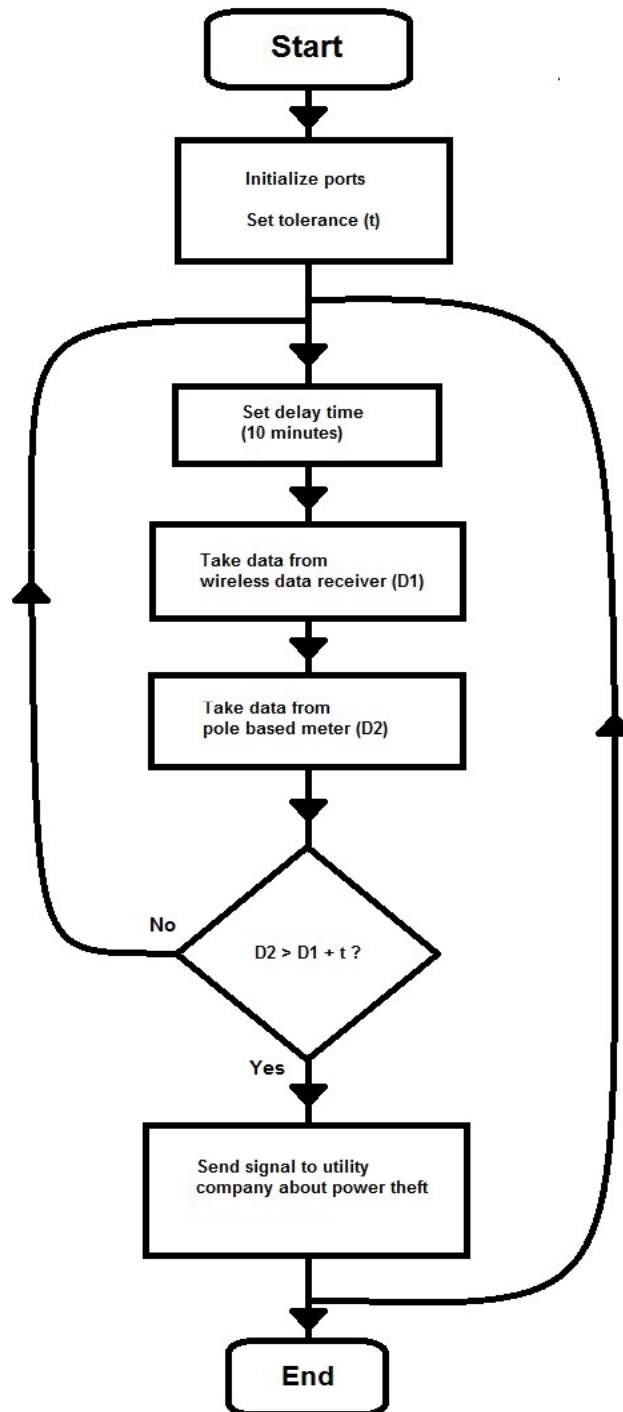
On the pole side, another PIC16F877A microcontroller is used with an ASK RF receiver, of 433MHz frequency module, connected to the RX pin of the microcontroller. The receiver receives the data transmitted from the user side by the ASK RF transmitter through wireless transmission. The pole side energy meter again feeds its reading to another microcontroller

which again calculates the difference between the immediate past and present values from that meter and this analog value, just like the user side, is fed to the analog pin for analog to digital conversion. Then, this digital value along with the data received by the ASK RF receiver is displayed on another 16x2 LCD module used for the pole side. The microcontroller continuously checks for a difference between the two values displayed on the LCD. For any discrepancy in the two values exceeding a set tolerance value, high signals are sent to a digital pin which is connected to yet another microcontroller.

For a high signal sent by the microcontroller from the pole side, a level converter circuit is used to convert the TTL signals of the microcontroller to RS232 signals for the GSM module. Thus, the GSM module is used for sending a message to the control centre notifying the detection of electricity theft in the specified area.

Thus, with a government sanctioned real life implementation of this model, we hope to aid to a recovery of the missing revenues owing to the currently undetectable illegal power pilferage going on in this country.

FIGURE: BLOCK DIAGRAM FOR THE OVERVIEW OF THE PROJECT WITHIN AN IMPLEMENTION AREA

NOTE :   EMTD : Energy Measuring and Transmitting Device   ASK RF : Amplitude Shift Keying Radio Frequency
          CMRD : Checking, Measuring and Receiving Device   GSM : Global System for Mobile

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Flowchart of the overall project processing:

1.3   Project Objective

To meet present day requirements of the country, the government keeps attempting at generating more power which is not enough, and also, is inefficiently costly. The generated power has to be utilized in a resourceful manner through close monitoring of power consumption and losses because illegal electricity usage may indirectly affect the economic status of a country. Also, the planning of national resources may be difficult in case of unrecorded energy usage. But then again, following the path of many other countries which are making more modern and expensive amendments to their power transmission and distribution sector might not be financially viable for ours. All of the recent reform activities attempted by the Government in Bangladesh were in the sectors of generation and transmission of electricity. Despite the fact that the distribution system of the country, which is characterized by heavy system loss and poor collection performance, is the pressure point of the problem, it seldom got the priority in reform initiatives. Deriving fruitful results from such many initiatives is not possible while leaving the distribution system untouched. This paper proposes a methodology which prioritizes in the reform of the transmission and distribution sector to make it efficient and effective with a restructured administration. Modifications offered for the existing meters would continuously check for abnormal differences between energy supplied and energy consumed by billed customers and would notify the authorities of abnormalities right away addressing the locality of theft so that tampered lines maybe fixed back to normal upon reporting. Also, with a general idea of the scene of theft, it would be possible to trace and apprehend the culprits responsible. All of this is expected to be done using locally available devices and procedures so that it is applicable in the context of a developing country with limited resources and budget. Thus, the objective of this paper is to propose a way out of the issue of power pilferage involving methods and the usage of such apparatus, the expenditure of which would be quite reasonable for the government.

1.4   Scope of Project

The scope of the project covers a system which consists of – programmed microcontrollers placed both at the utility usage measuring device for the legal consumers as well as the measuring device at the distribution point of the implementation area, an ASK RF transmitter at the consumer utility usage measuring block, an ASK RF receiver at the distribution pole, a GSM modem that connects the implementation area to the control centre using wireless transmission signals. In a nutshell, the proposed model is of a real time system which has a consumer utility usage measuring and transmission block that continuously collects data from the measuring device using a microcontroller and transmits the data using an ASK RF transmitter connected to the microcontroller using wireless transmission; on the other side, we have another microcontroller that collects the data sent through wireless transmission from the consumer side using an ASK RF receiver connected to the microcontroller and sums up all the data received from various consumer utility usage meters in the respective implementation area around the power distribution pole and compares the summation with the data collected from the measuring device at the pole which registers the actual energy drawn from the supply; finally, for any discrepancy between the two values above a set tolerance value, a signal is sent from the pole side microcontroller to another microcontroller which, the GSM modem is connected to, through a level converter circuit. Then, the GSM modem, in effect, sends a message through wireless transmission to the control centre reporting the power theft. Later, by physical examination actual cause and location of the pilferage can be pin-pointed.

1.5   Organization of this thesis

This thesis is organized in such a way that it would provide the reader a clear understanding of our work in the right sequence. We first gave a general overview of the whole thesis in the first chapter for the reader to understand our inspiration behind this work, its importance and most importantly, to get the gist of this elaborate thesis in an easy language. The second chapter contained the applications, features and explanation of the working mechanism of the main components of the project so that the reader would know the reasoning behind the choice of apparatus and appreciate better the part played by each of them in the project. Then the third

chapter gives the description of the device representing the transmission block and its components, closely followed by the fourth chapter which explains the second half of the project – the receiving and detecting parts together in one block with its one components working together. Finally, we have the fifth chapter, which is the conclusion to this paper and thus, it ends stating the advantages of the chosen methodology as well as the disadvantages followed by suggestions for future extension to the work.

CHAPTER 2

System Description

2.1   Introduction

In this chapter, we have provided a brief description of the devices and components that were used for the project. An attempt at explaining the general working mechanisms, features, applications and advantages of the system apparatus was made since without having a common idea of all the main components, it would be quite hard for a reader to understand the application and contribution of the individual components in the procedure followed in the project. The major system gears being –

- Microcontroller
- ASK RF Module
- LCD Display
- MAX 232
- GSM Modem

All these components put together, and the features that would serve the purpose of our work used built up the resulting project and proposal presented in this paper.

2.2   Microcontroller (16F877A)

Beginners as well as professionals, amongst all users, PIC16F877A is one of the PIC Micro Family microcontrollers which is currently the most popular owing to its user-friendly features and the application of FLASH memory technology so that the burned code can be erased and over-written again and again for countless times. The superiority of this specific microcontroller compared to the other ones, also with an 8-bit memory is especially the exceptionally high speed

of its code compression. PIC16F877A has 40 pins by 33 paths of input/output (I/O). EEPROM (Electrically Erasable Programmable Read-Only Memory), a type of non-volatile memory makes it easier to apply microcontrollers to devices where permanent storage of various parameters is needed (codes for transmitters, motor speed, receiver frequencies, etc.). Low cost, low power consumption, easy handling and flexibility makes PIC16F877A applicable even in areas where microcontrollers had not previously been considered (example: timer functions, interface replacement in larger systems, co-processor applications, etc.). The feature – 'In System Programmability' of this chip (along with an advantage of using only two pins in data transfer) offers flexibility of a product after the completion of assembling and testing. Creating assembly-line production, storing calibration data otherwise available only after final testing and improving programs on finished products – all of this could be done using this capability. In general, PIC16F877A perfectly fits various uses, from automotive industries and controlling home appliances to industrial instruments, remote sensors, electrical door locks and safety devices, also, ideal for smart cards as well as for battery supplied devices because of its low power consumption.
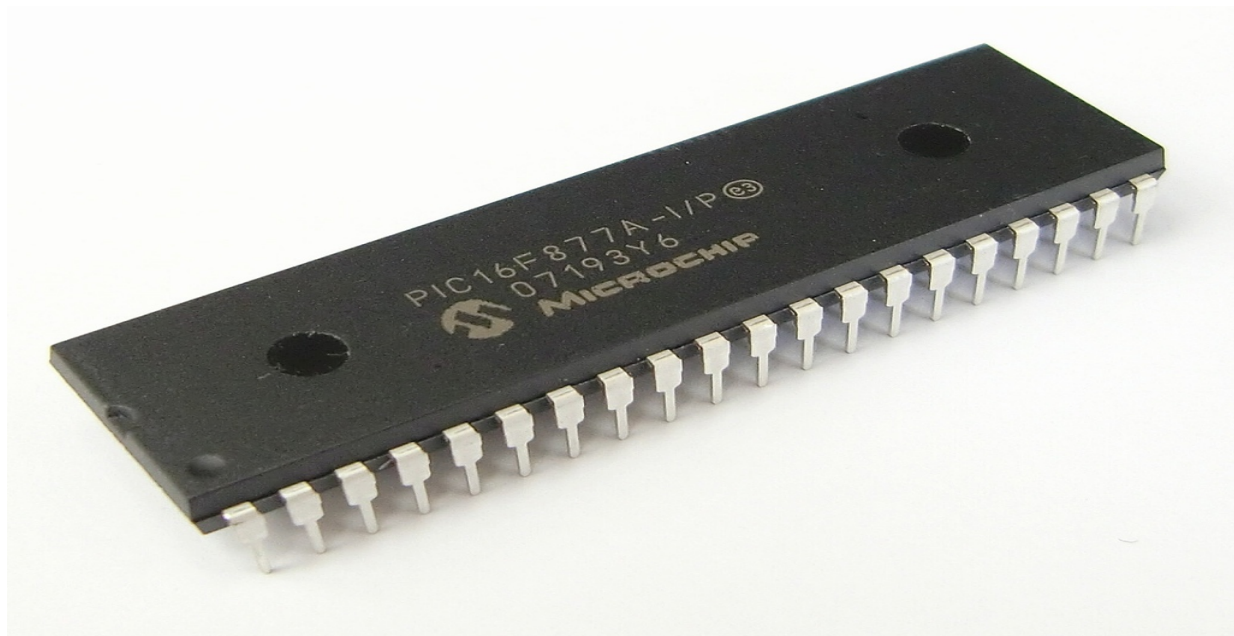

FIGURE: PIC16F877A Microcontroller

2.2.1   Features of PIC16F877A [4]

High-Performance RISC CPU:

- Only 35 single-word instructions to learn

- All single-cycle instructions except for program branches, which are two-cycle

- Operating speed: DC – 20 MHz clock input DC – 200 ns instruction cycle

- Up to 8K x 14 words of Flash Program Memory, Up to 368 x 8 bytes of Data Memory (RAM), Up to 256 x 8 bytes of EEPROM Data Memory

- Pin out compatible to other 28-pin or 40/44-pin PIC16CXXX and PIC16FXXX microcontrollers

Peripheral Features:

- Timer0: 8-bit timer/counter with 8-bit pre scalar

- Timer1: 16-bit timer/counter with pre scalar, can be incremented during Sleep via external crystal/clock

- Timer2: 8-bit timer/counter with 8-bit period register, pre scalar and post scalar

- Two Capture, Compare, PWM modules

- Synchronous Serial Port (SSP) with SPI™ (Master mode) and I2C™ (Master/Slave)

- Universal Synchronous Asynchronous Receiver

- Transmitter (USART/SCI) with 9-bit address detection

- Parallel Slave Port (PSP) – 8 bits wide with external RD, WR and CS controls (40/44-pin only)

- Brown-out detection circuitry for Brown-out Reset (BOR)

Analog Features:

- 10-bit, up to 8-channel Analog-to-Digital Converter (A/D)

- Brown-out Reset (BOR)

- Analog Comparator module (Two analog comparators , Programmable on-chip voltage

reference (VREF) module , Programmable input multiplexing from device inputs and internal voltage reference , Comparator outputs are externally accessible)

Special Microcontroller Features:

- 100,000 erase/write cycle Enhanced Flash program memory typical
- 1,000,000 erase/write cycle Data EEPROM memory typical
- Data EEPROM Retention > 40 years
- Self-reprogrammable under software control
- In-Circuit Serial Programming™ (ICSP™) via two pins
- Single-supply 5V In-Circuit Serial Programming
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code protection
- Power saving Sleep mode
- Selectable oscillator options
- In-Circuit Debug (ICD) via two pins

CMOS Technology:

- Low-power, high-speed Flash/EEPROM technology
- Fully static design
- Wide operating voltage range (2.0V to 5.5V)
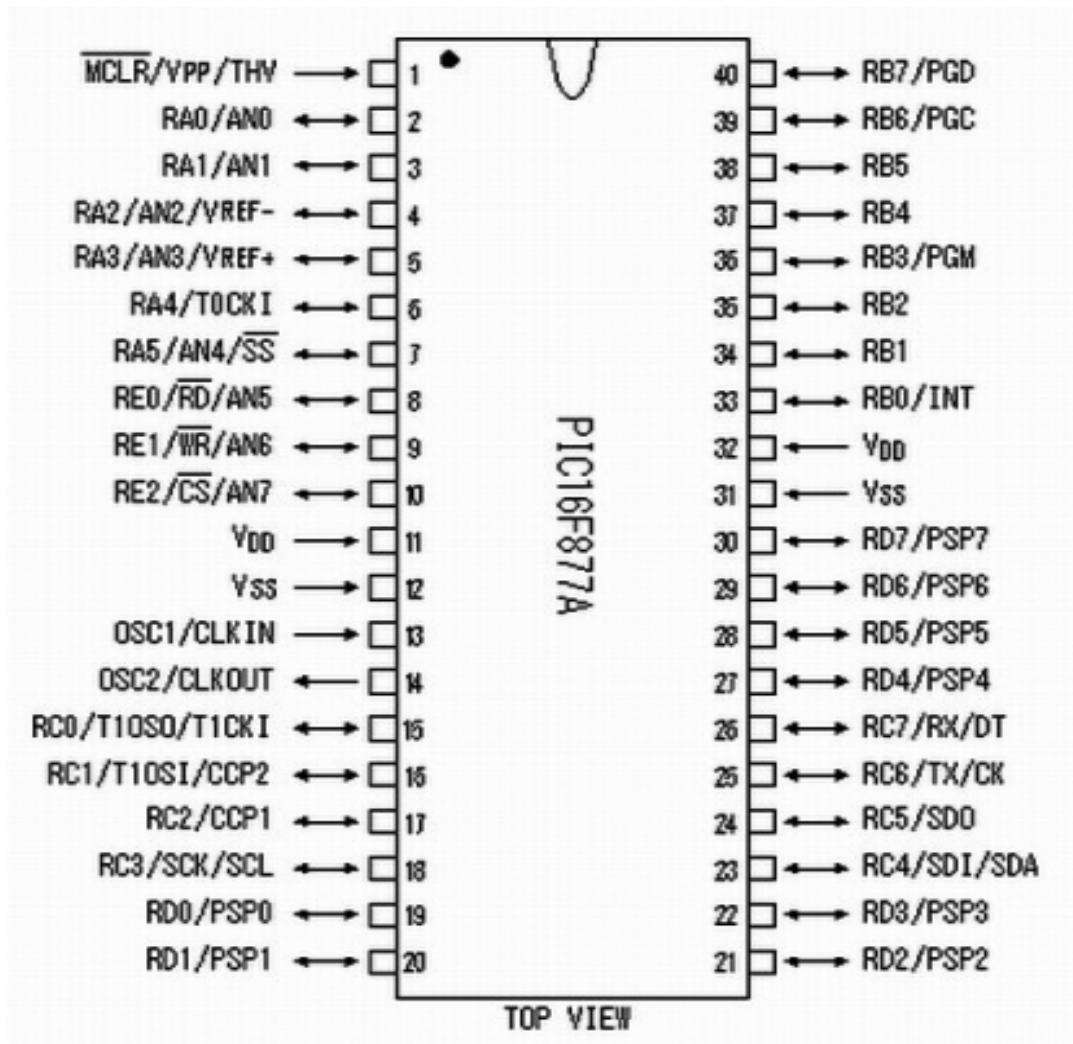- Commercial and Industrial temperature ranges
- Low-power consumption

FIGURE: PIC16F877A Pin Configuration

2.3   ASK RF Module (433 MHz)

The ASK RF module, as the name suggests, operates at Radio Frequency using amplitude shift keying method of modulation with a corresponding frequency range between 30 kHz & 300 GHz. In this system, the digital data is represented as variations in the amplitude of carrier wave and this kind of modulation is basically known as Amplitude Shift Keying (ASK). Signals through RF can travel through large distances making it suitable for long range applications. Also, the RF signals can travel even when there are obstacles between transmitter & receiver. Next, RF transmission is more strong and reliable than IR transmission. RF communication uses

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a specific frequency usually unaffected by other emitting sources. Thus, RF transmission is strong and reliable enough to serve our purpose so that transmission through this module is economically convenient.
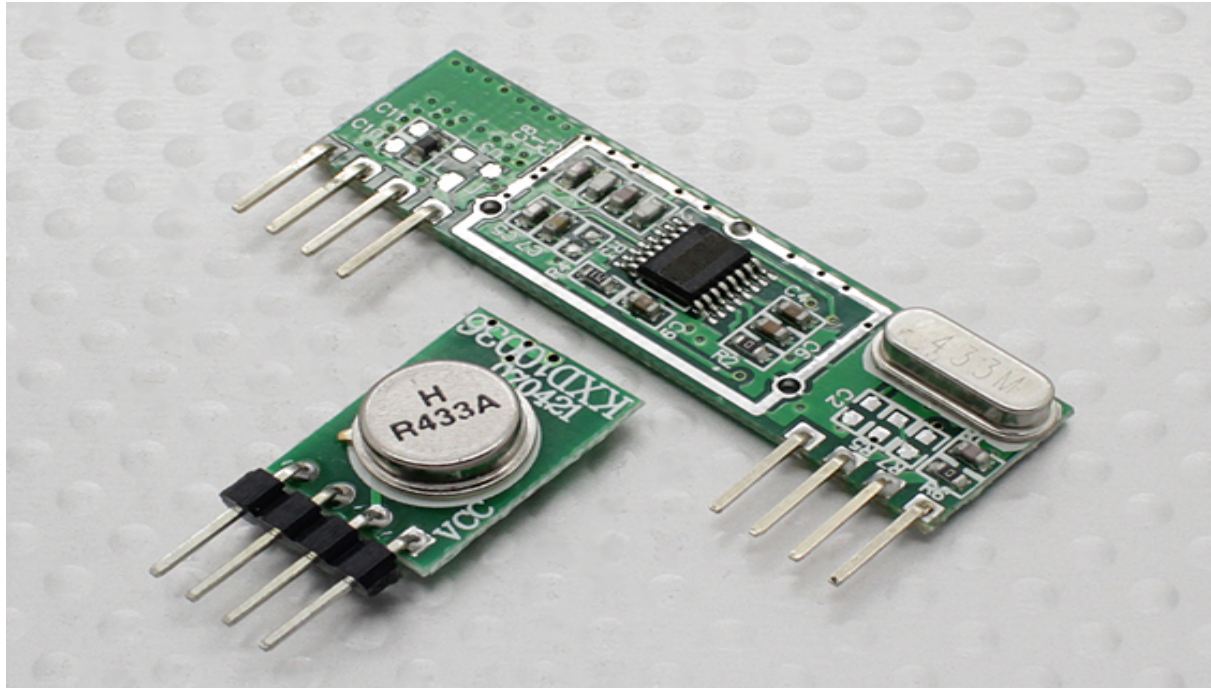

FIGURE: ASK RF Module (433MHz)

2.3.1　RF Transmitter

This RF module comprises of an RF Transmitter and an RF Receiver. The transmitter/receiver (Tx/Rx) pair operates at a frequency of 433MHz. An RF transmitter receives serial data and transmits it wirelessly using RF through its antenna connected at pin#4. The transmission occurs at the rate of 1Kbps - 10Kbps. The transmitted data is received by an RF receiver operating at the same frequency as that of the transmitter.

RF Transmitter

Pin No.	Name	Function
1	GND	Ground (0V)
2	DATA	Serial Data Input
3	Vcc	Supply Voltage (5V)
4	ANT	Antenna Output

FIGURE: RF Transmitter Pin Configuration [5]

RF Receiver

Pin No.	Name	Function
1	GND	Ground (0V)
2	DATA	Serial Data Output
3	NC	No Connection
4	Vcc	Supply Voltage (5V)
5	Vcc	Supply Voltage (5V)
6	GND	Ground (0V)
7	GND	Ground (0V)
8	ANT	Antenna Input

FIGURE: RF Receiver Pin Configuration [5]

- ▪ **Features [5]**
- Range in open space(Standard Conditions) : 100 Meters

- RX Receiver Frequency : 433 MHz

- RX Typical Sensitivity : 105 Dbm

- RX Supply Current : 3.5 mA

- RX IF Frequency : 1MHz

- Low Power Consumption

- Easy For Application

- RX Operating Voltage : 5V

- TX Frequency Range : 433.92 MHz

- TX Supply Voltage : 3V ~ 6V
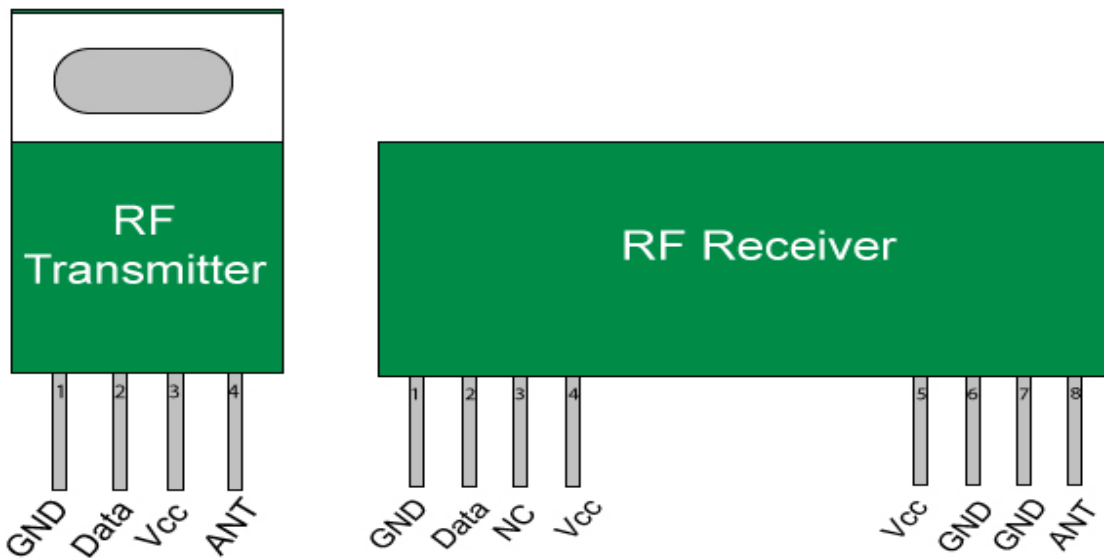
- TX Out Put Power : 4 ~ 12 Dbm

FIGURE: Pin Diagram of RF Module

2.4   LCD Display

With a wide range of applications, the 16x2 LCD (Liquid Crystal Display) display screen used here is a basic electronic display module and is very commonly used in various devices and circuits. This module was better suited to serve our purpose and is generally more preferred over seven segments and other multi segment LEDs because LCDs are economical, easily programmable, have no limitation of displaying special & even custom characters (unlike in seven segments), animations and so on. Using an LCD display is essential for us for displaying the energy usage of and to the providers and users.
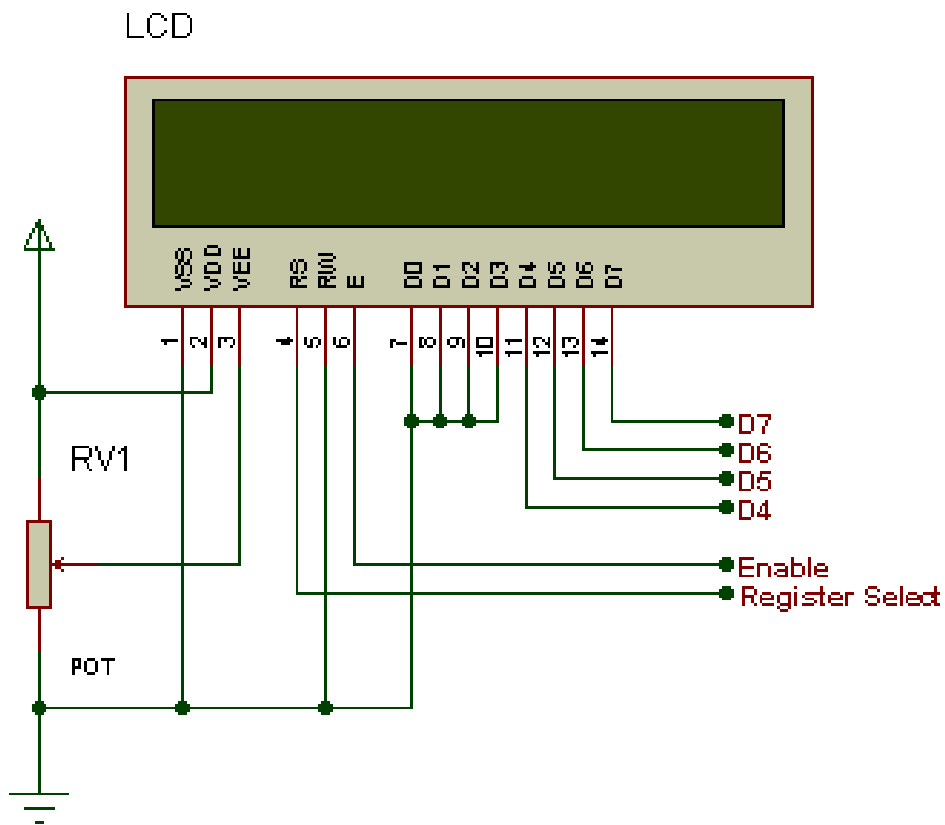
FIGURE: Pin Configuration of an LCD Display

With a standard HD44780 chipset, this 16 character by 2 line display works great with any microcontroller and is very easy to interface. It is possible to use all 8 bits plus 3 control signals or 4 bits plus the control signals of the 8-bit parallel interface of this LCD. The pin diagram of the 16x2 LCD display is shown below. [6]

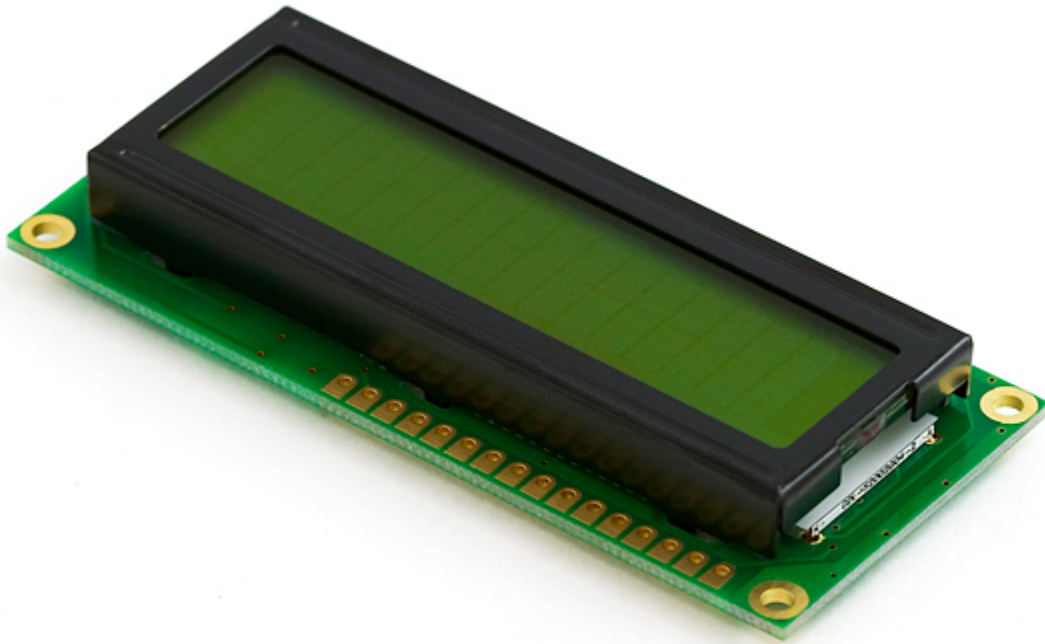| Pin No	Name	Description
1	VSS	Power supply(GROUND)
2	VCC	Power supply(+5V)
3	VEE	Contrast adjust
4	RS	0-Instruction input 1-Data input
5	R/W	0-Write to LCD module 1-Read from LCD module
6	EN	Enable signal
7	D0	Data bus line 0 (LSB)
8	D1	Data bus line 1
9	D2	Data bus line 2
10	D3	Data bus line 3
11	D4	Data bus line 4
12	D5	Data bus line 5
13	D6	Data bus line 6
14	D7	Data bus line 7 (MSB)

FIGURE: A Real Life 16x2 LCD Display

2.4.1 Features

• 16 x 2 Characters

• STN/Transflective/Positive/Y-G

• Yellow-green/bottom-light (LED)

• Operating temp.:-10°C~+60°C

• 1/16 duty cycle, 1/5 bias

• Built-in controller (SPLC780D1 or equivalent)

• Viewing angle: 6 o'clock

2.5   MAX 232

Commonly known as a RS-232 Transceiver, the MAX232 is a hardware layer protocol converter IC manufactured by the Maxim Corporation comprising of a pair of drivers and a pair of receivers. At a very basic level, the driver converts TTL and CMOS voltage levels to TIA/EIA-232-E levels, which are compatible for serial port communications. The receiver performs the reverse conversion.
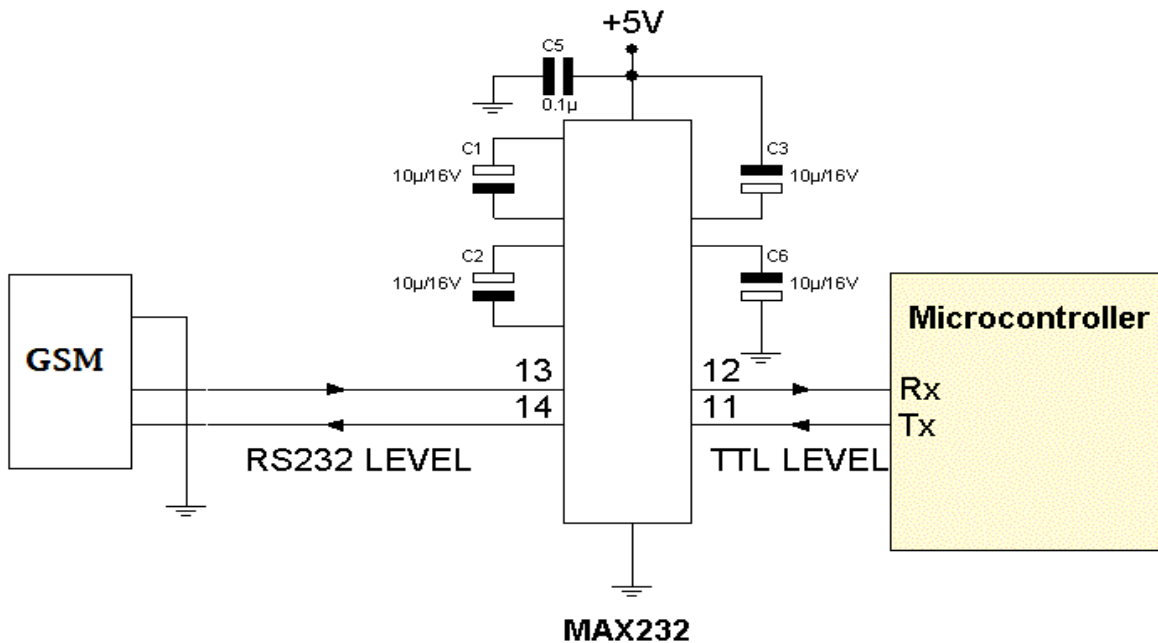

FIGURE: Level converter circuit using MAX232

According to the EIA/TIA-232-E specification in 1962, RS-232, where the letters "RS" refer to Recommended Standards, is a serial communication protocol. This protocol requires a voltage between -3 V to -15 V to represent binary 1, and a voltage between +3 V to +15 V to represent binary 0. Since TTL uses 5 V to represent binary 1 and 0 V to represent binary 0, this is

incompatible for CMOS and TTL communication. This chip therefore performs the necessary protocol conversion of the electrical voltage levels in both directions.

Switched-capacitor charge pump circuits are incorporated within the IC since RS-232 requires higher voltage levels. The doubler doubles the voltage level to produce +10V, whilst the inverter produces the negative voltage supply of -10V.

For more than two decades, this IC has been one of the most popular components in production of embedded microcontroller systems and computers. It is the most preferred chip used for communication through a serial port using a microcontroller.
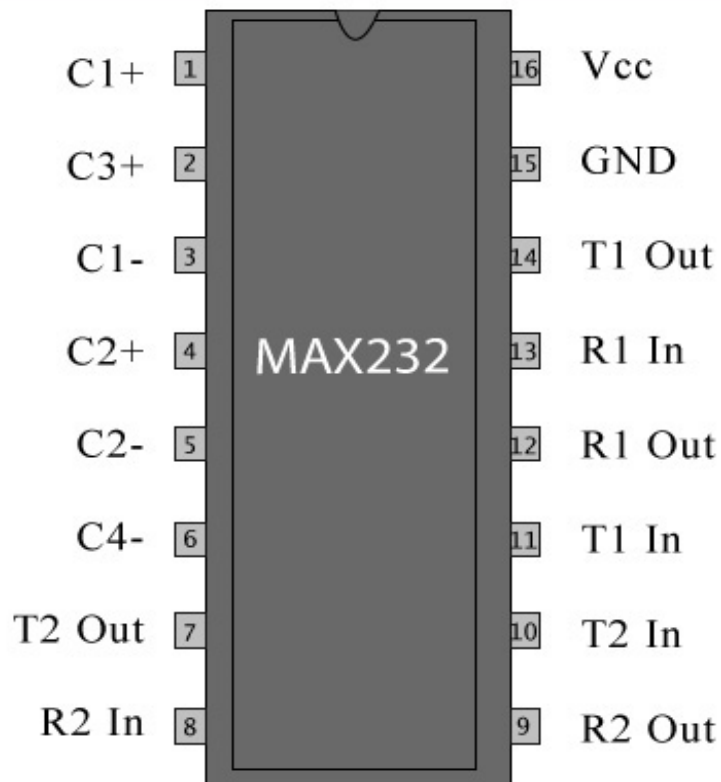
Pin Diagram [7]

Pin No	Function	Name
1	Capacitor connection pins	Capacitor 1 +
2		Capacitor 3 +
3		Capacitor 1 -
4		Capacitor 2 +
5		Capacitor 2 -
6		Capacitor 4 -
7	Output pin; outputs the serially transmitted data at RS232 logic level; connected to receiver pin of PC serial port	T_2 Out
8	Input pin; receives serially transmitted data at RS 232 logic level; connected to transmitter pin of PC serial port	R_2 In
9	Output pin; outputs the serially transmitted data at TTL logic level; connected to receiver pin of controller.	R_2 Out
10	Input pins; receive the serial data at TTL logic level; connected to serial transmitter pin of controller.	T_2 In
11		T_1 In
12	Output pin; outputs the serially transmitted data at TTL logic level; connected to receiver pin of controller.	R_1 Out
13	Input pin; receives serially transmitted data at RS 232 logic level; connected to transmitter pin of PC serial port	R_1 In
14	Output pin; outputs the serially transmitted data at RS232 logic level; connected to receiver pin of PC serial port	T_1 Out
15	Ground (0V)	Ground
16	Supply voltage; 5V (4.5V – 5.5V)	Vcc

Pin Description [7]

2.5.1   Applications [8]
- Portable Computers

- Low-Power Modems

- Interface Translation

- Battery-Powered RS-232 Systems

- Multidrop RS-232 Networks

2.5.1   Features [9]
- Input voltage levels are compatible with standard CMOS levels

- Output voltage levels are compatible with EIA/TIA-232-E levels

- Single Supply voltage: 5V

- Low input current: 0.1µA at TA= 25 °C

- Output current: 24mA

- Latching current not less than 450mA at TA= 25°C

- The transmitter outputs and receiver inputs are protected to ±15kV Air ESD

FIGURE: MAX 232 IC

2.6   GSM Modem

GSM modem is a specialized type of modem, similar to a mobile phone that operates over subscription based wireless networks. A GSM modem accepts a SIM card, and basically acts like a mobile phone for the computer. It operates almost like a traditional modem, except that it sends and receives data through radio waves rather than a telephone line and thus, can also be used for sending and receiving SMS.

The flow of data via a GSM module is such that – a microcontroller sends data to the module which will then send the data to the GSM receiver in mobile phone via wireless media. The mobile phone here acts as a second embedded device which reads the data while the microcontroller is the first embedded device to send the data through a level converter circuit.

FIGURE: GSM Modem

2.6.1   Applications [10]
- Remote Data Monitor and Control
- Water, gas and oil flow metering
- AMR (automatic meter reading)
- Power station monitoring and control
- Remote POS (point of sale) terminals

- Traffic signals monitor and control

- Fleet management

- Power distribution network supervision

- Central heating system supervision

- Weather station data transmission

- Hydrologic data acquisition

- Vending machine

- Traffic info guidance

- Parking meter and Taxi Monitor

- Telecom equipment supervision (Mobile base station, microwave or optical relay station)

2.6.1   Features [10]

- Industrial design with intelligent software capabilities, making it a reliable cellular solution for data collection and transmission

- Plug-and-play design with easy-to-use software interface for easy integration Easily manage and control distributed remote devices over the air Built-in Watch Dog

- Real-time Clock (RTC)

- Remote Data Monitor and Control

- Reliable GSM/GPRS/CDMA/EVDO network connectivity, providing fast and cost-effective long-range wireless communication

- Always-On-Line

- Easy-to-use

- Industrial design with surge protection

- Local and remote configuration over the air

No need to build expensive fixed line network, saving

2.7   Conclusion

With a general picture of each of the individual system apparatus drawn for the readers, we hope that it help them understand better the sequential methodology presented next and also, the part played by all the discussed components in the project. Also, we established the reasoning behind choosing the components for the work which being their superiority to other options in terms of better features within a limited budget. We are confident, and hope that the reader would also see eye to eye with us after the given detailed discussion in thinking that the choices of components made for the complete design of a power pilferage detection system serve as successful selections. In the trial and analysis period for the selection of right kind of equipments, their features, applications, parameters, availability in local market, expense and practical results in comparison to various other options have been taken into account. In light of the findings of the comparison the discussed choices were made for successfully achieving the most efficient system which would also be economic for implementation in the power industry of the country.

CHAPTER 3

EMTD

3.1 Introduction

EMTD stands for Energy Measuring and Transmitting Device. This device would add to the existing digital energy meters to not only register the energy consumption, but also send the reading over to the CMRD (discussed soon after in the paper) on the distribution pole side. This is done by conversion of the meter reading to digital data compatible for wireless transmission. The data processing is done using a microcontroller while the transmitter of an ASK RF module transmits the converted data collected from the microcontroller. Thus, the proposed design of EMTD would have to have the following features:

- Energy measurement
- Data conversion
- Carrier modulation
- Transmission of signal
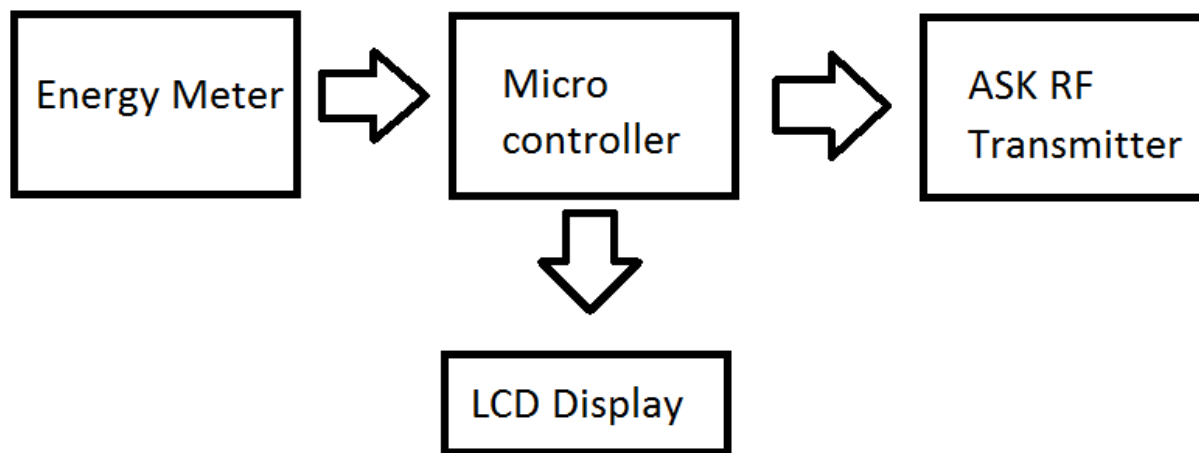
3.2 Transmission

The existing energy meters installed on load side measure the energy consumed by load over time. But the modification we propose, i.e. the EMTD has an additional feature of transmitting that data CMRD (discussed soon after in the paper) using Radio Frequency Communication. A wireless radio frequency (RF) transmitter and receiver can be easily made using a Microcontroller (PIC16F877A) and an ASK RF Module. An RF Module is a small circuit pre-built and tested which comes in pair – the RX or receiver and the TX or transmitter. The module uses ASK mode of modulation.

3.2.1 ASK Modulation

Amplitude-shift keying (ASK) is a form of amplitude modulation that represents digital data as variations in the amplitude of a carrier wave. In an ASK system, the binary symbol 1 is represented by transmitting a fixed-amplitude carrier wave of fixed frequency. If the signal value is 1 then the carrier signal will be transmitted; otherwise, a signal value of 0 will be transmitted.

As shown in the figure given below, ASK system can be divided into three blocks – the first one represents the transmitter, the second one is a linear model of the effects of the channel, and the third one shows the structure of the receiver.
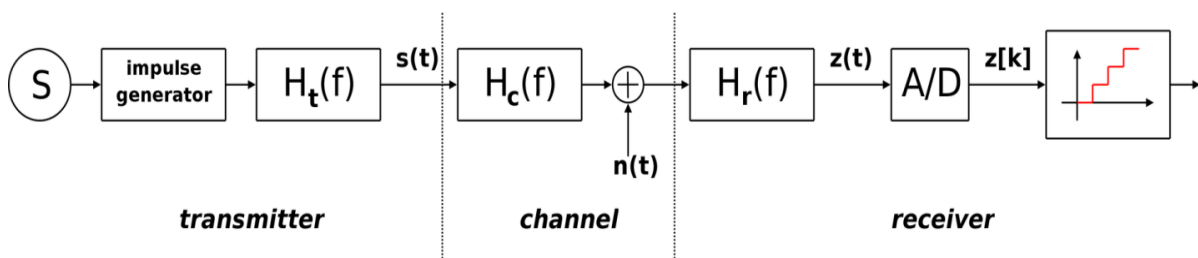

FIGURE: ASK System

The notations used in the figure:

- S is the signal
- ht(f) is the carrier signal for the transmission

- hc(f) is the impulse response of the channel

- n(t) is the noise introduced by the channel
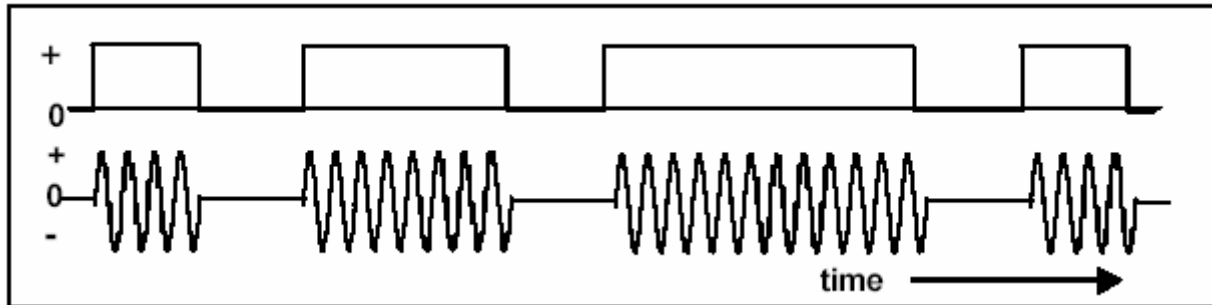
- hr(f) is the filter at the receiver

FIGURE: A binary ASK signal (lower), together with the binary sequence which initiated it (upper).

3.2.2 Interfacing

The data from energy meter registering the energy consumption of the load is extracted and fed to the microcontroller which then sends the data to the RF module for wireless transmission. A general block diagram representing this process is provided below while an overall idea of the interfacing required for the same process is given in this section.
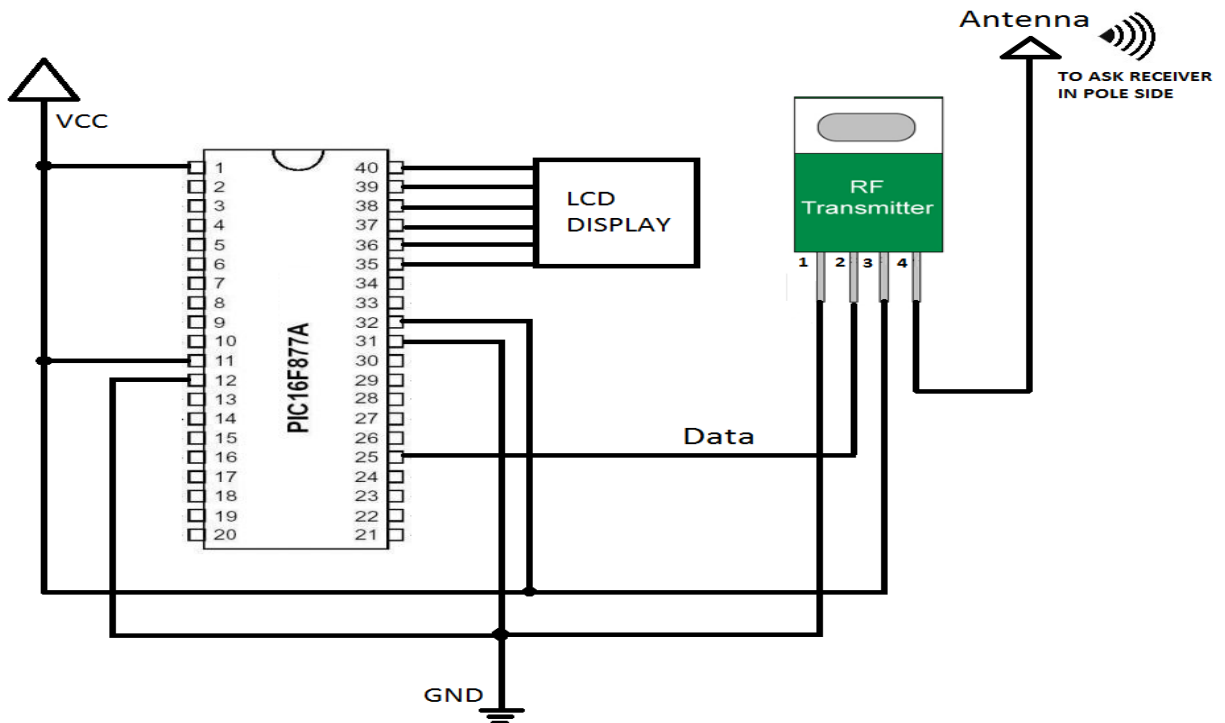
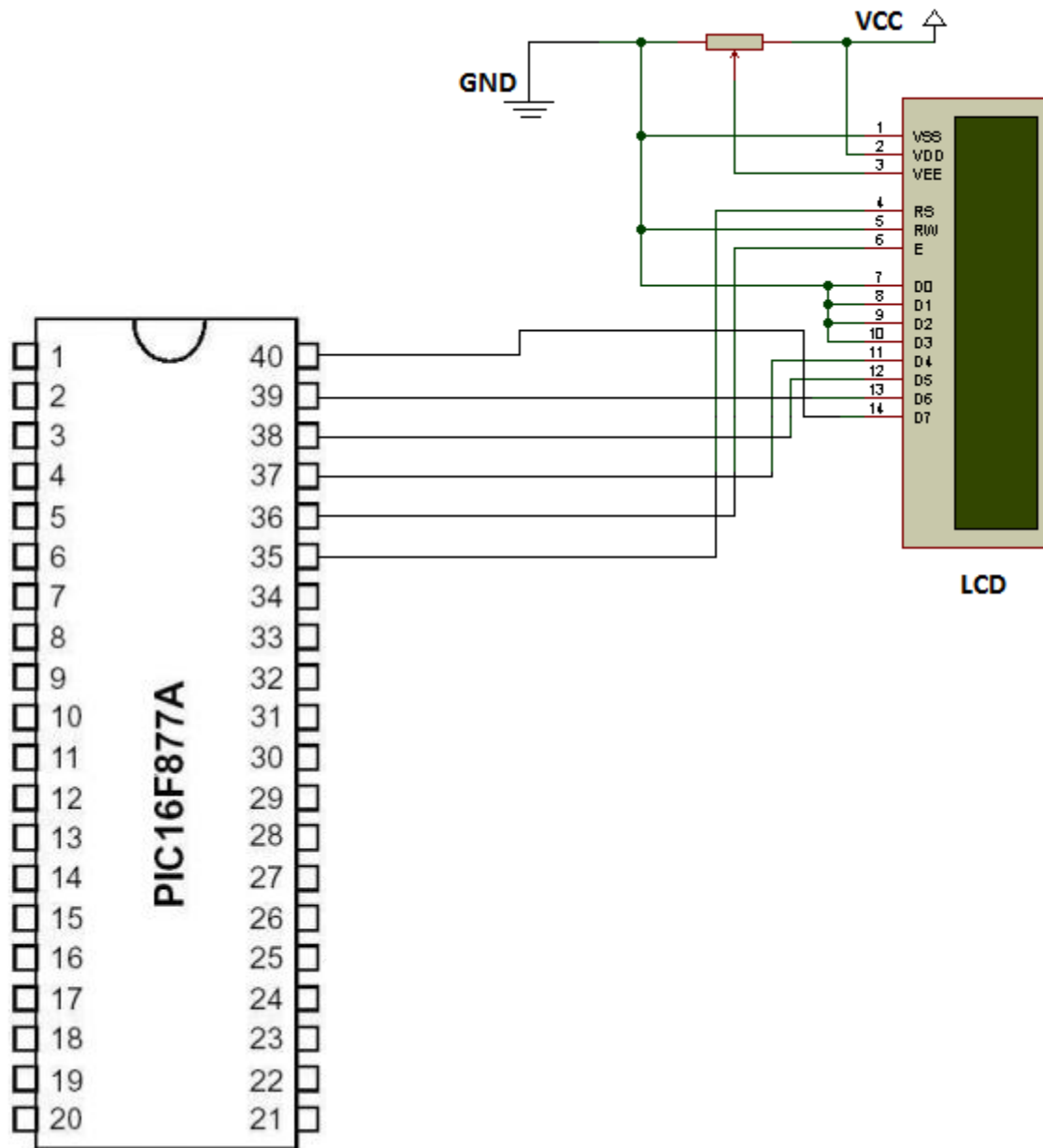FIGURE: Block Diagram of Transmission from Consumer Premises

FIGURE: Microcontroller & LSD Module Interfacing

The most recent energy reading of the meter fed to pin#2, RA0/AN0, an analog pin of PIC16F877A microcontroller followed by the extraction of the immediate past reading from the same meter to be fed to pin#3, RA1/AN1, another analog pin. Since microcontrollers are TTL compatible, the inputs by the digital meter will be given in TTL logic level. The difference between the two values, calculated by the code burned into the microcontroller is converted to a

digital value, also done by the same code. The TTL input is to be converted into serial data input because RF Communication works on the principle of Serial Communication. Thus, we need something which converts the conventional n-bit (4-bit, 8-bit, 16-bit, etc) data into serial data. For this, we have to use the microcontroller to convert the n-bit data into serial data and vice-versa. This serial data can be directly read using the RF Transmitter, which has 4 pins and can be powered by any voltage (VCC) between 1.5V and 12V. The higher the voltage, the stronger the RF signal becomes. The RF module then performs ASK modulation on it and transmits the data through the antenna. In the receiver side, the RF Receiver receives the modulated signal through the antenna, performs all kinds of processing, filtering, demodulation and gives out a serial data. This serial data is again converted back to a TTL level logic data, which is ideally supposed to be the same data that the digital meter has given as input to the microcontroller of consumer side.
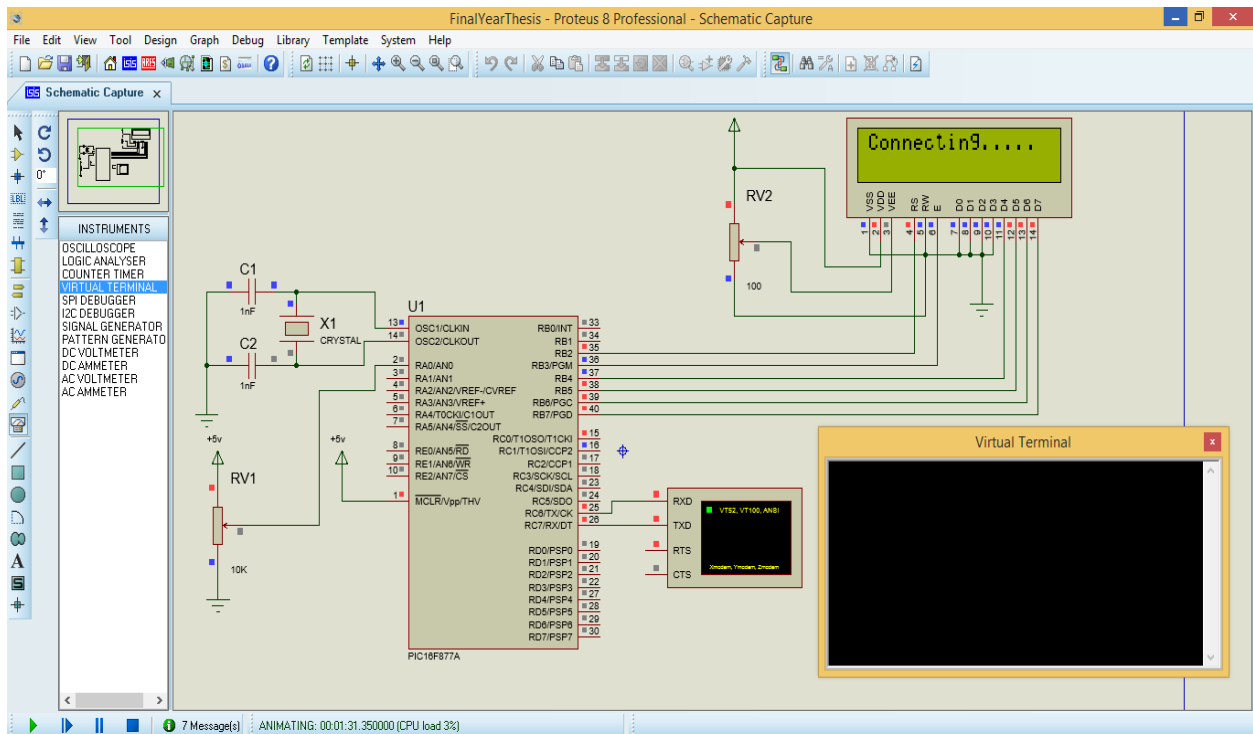

FIGURE: Schematic diagram of Interfacing between Microcontroller, RF Transmitter and LCD Module

Thus, the data from the meter, collected and converted by the microcontroller is transmitted using the ASK RF transmitter, of 433MHz frequency module, connected to pin#25, the TX pin of the microcontroller. We have also used a 16x2 LCD module which would be displaying the data that is transmitted from the energy measuring blocks on the user side.
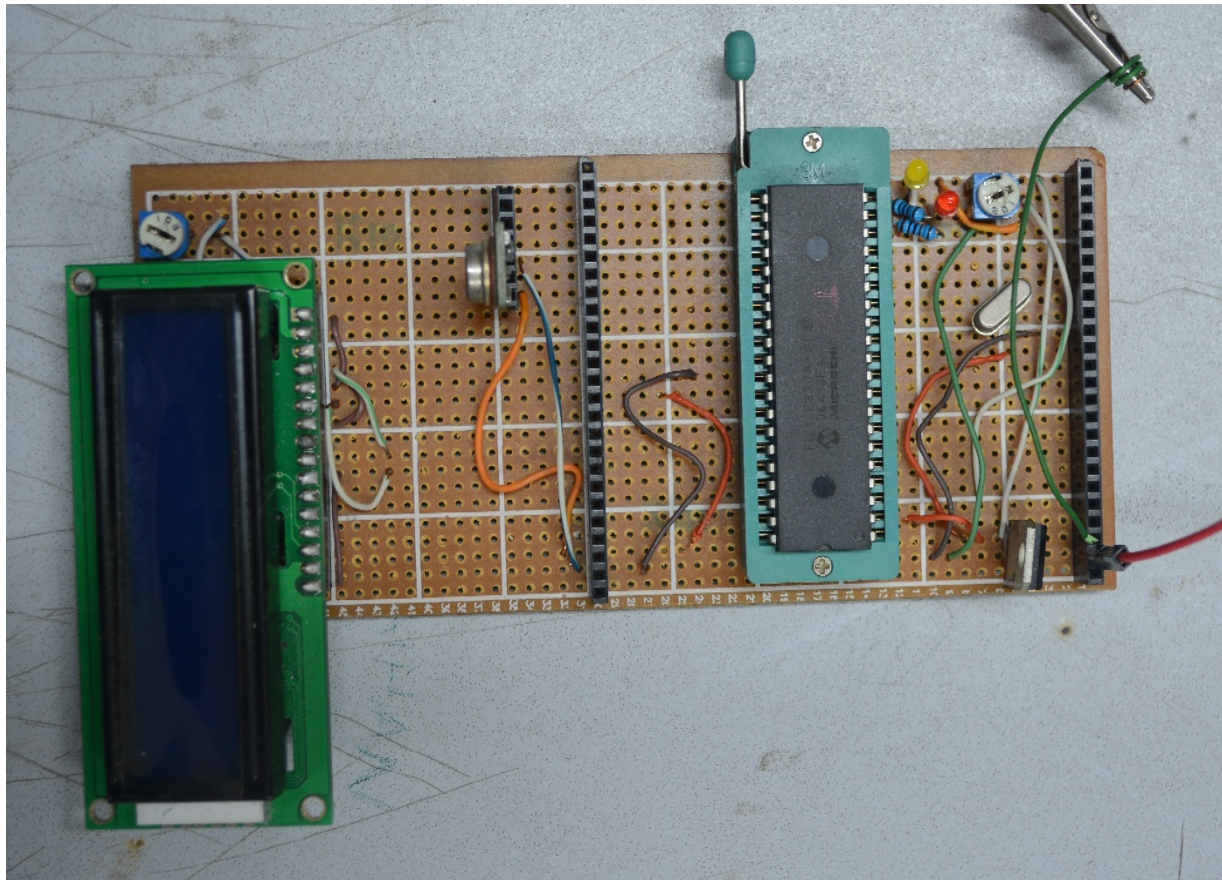

FIGURE: Project Circuitry of EMTD Block

3.3 Conclusion

The provided suggestion of an EMTD requires just a modification of the existing meter reading system. A completely new replacement, which would be hectic as well as expensive, is not required. So, despite the primitiveness of the transmission method used by the proposed EMTD the apparatus and methodology for the required system is easily adaptable. The transmitting system requires only a microcontroller and an RF module which are both economic and productive. Thus, we believe, if the government shared its protocol for the existing meter and made changes to the existing system according to the proposed one, it would most definitely improve the existing meter reading system.

Chapter 4

CMRD

4.1 Introduction

A lot of times we need to keep track of data from a device or a sensor located in a remote location from the point where it is processed. In other situations we desire wireless solutions for ease. For this purpose in our project we propose the implementation of a checking measuring and receiving device (CMRD) which will be installed at the pole side. The CMRD measures the total supply of energy in kWh to the load side and the individual consumers will have an energy measuring and transmitting device (EMTD). The individual EMTD will send the energy data to the checking device which are the consumed energies on the load side. Apart from measuring the energy, the proposed model of CMRD is expected to compare the collected data from the two sides and notify the control centre of any discrepancy using a GSM modem. Thus, the proposed CMRD would have the following features –

- Reception of the signal
- Extracting the individual energy data
- Energy measurement at the check point (same as EMTD)
- Comparing the values
- Modem for sending SMS to the authority

In this section, the CMRD and the interfacing and functioning of its all component parts as a whole are explained.

4.2 Receiver Interfacing

In order to receive the data sent from the EMTD an RF receiver is used along with a PIC16F877A microcontroller. RF transmitter operates at a frequency of 433MHz. The transmitted data is received by an RF receiver operating at the same frequency as that of the transmitter. For this reason interfacing is required between microcontroller and RF receiver.
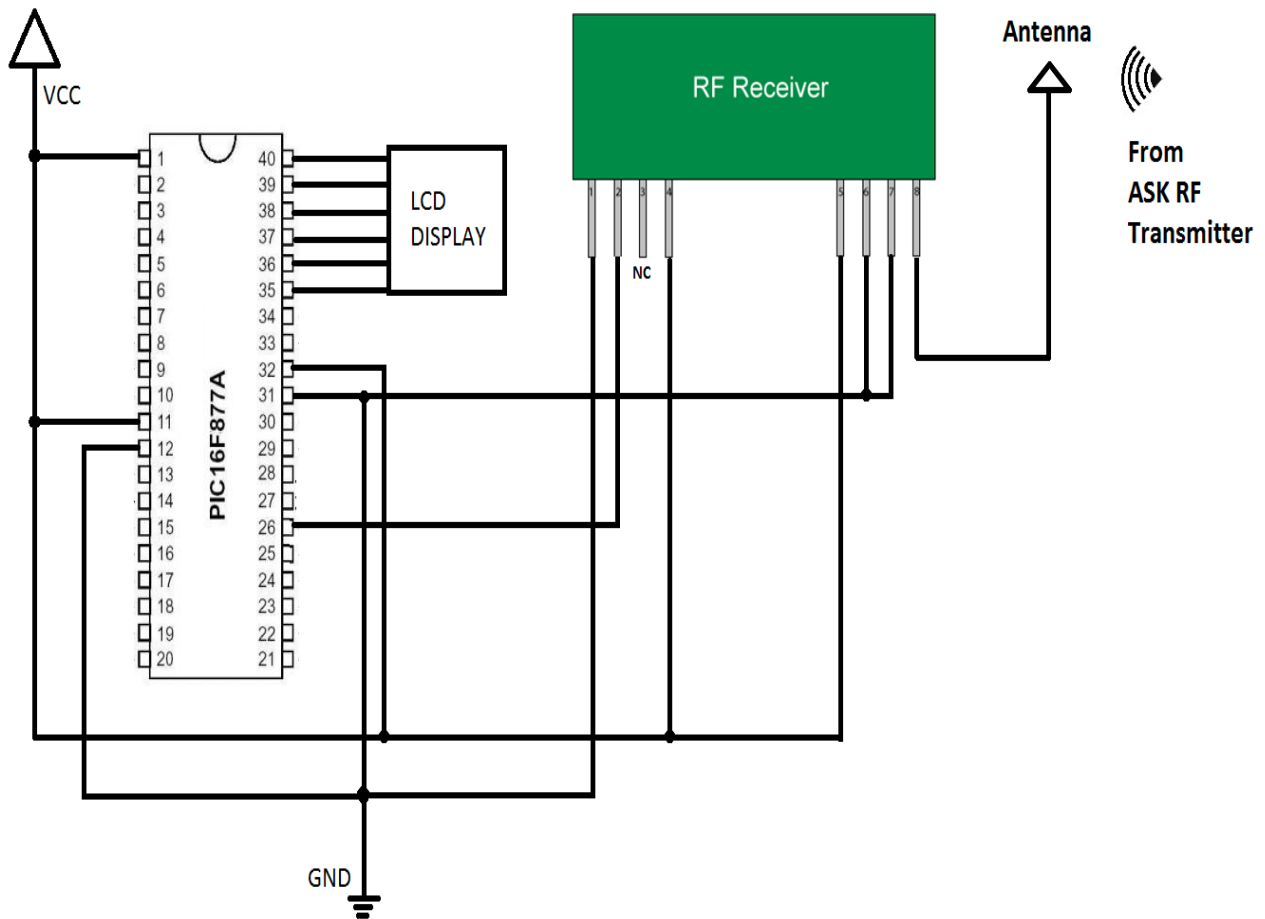

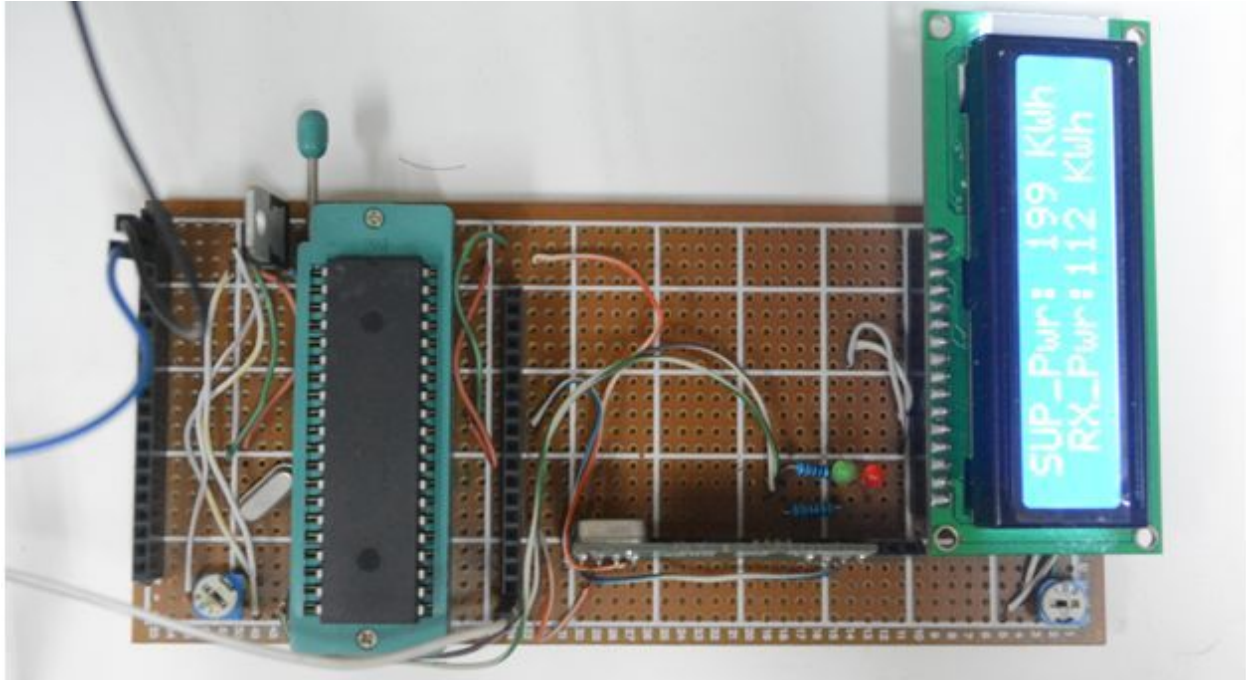FIGURE: Microcontroller, LCD Display, RF Receiver Interfacing

FIGURE: Interfacing Circuitry between Microcontroller and RF receiver

At the receiver end microcontroller is biased in an almost similar way as the transmission end. RF receiver has eight pins. Pin#1, 6, 7 are grounded, pin 2 is connected with the RX pin (pin#26) of the microcontroller, pin#4, 5 is connected with VCC and pin#8 is the antenna. Data is received serially through RX pin from the data pin of the RF receiver. The supplied energy and consumed energy will be displayed on the 16/2 LCD display which is interfaced with the microcontroller. There are several load side meters under a pole side meter. All the data (consumed energy) from the load sides are received by the receiver at every fixed interval and converted back from serial bit to n-bit are stored in the microcontroller.

For example:

Total received data, RX data=RX data1+RX data2+RX data3+……. +RX dataN. That means total energy consumed by the consumers is 'RX data'.

In practical case scenario, there will be a small power loss in the distribution line from the pole side to the load side. Thus, a tolerance value is set considering this loss. The programming of the

microcontroller for detecting electricity theft is done including this tolerance value in the calculation. Assuming total energy supplied to the load sides from the distribution point is 'SUP_POW', which is converted to TTL level, if total energy consumption (RXdata + Tolerance value) is less than total supplied energy then there is a power pilferage on that location in case of which an SMS will be sent to the authority automatically.
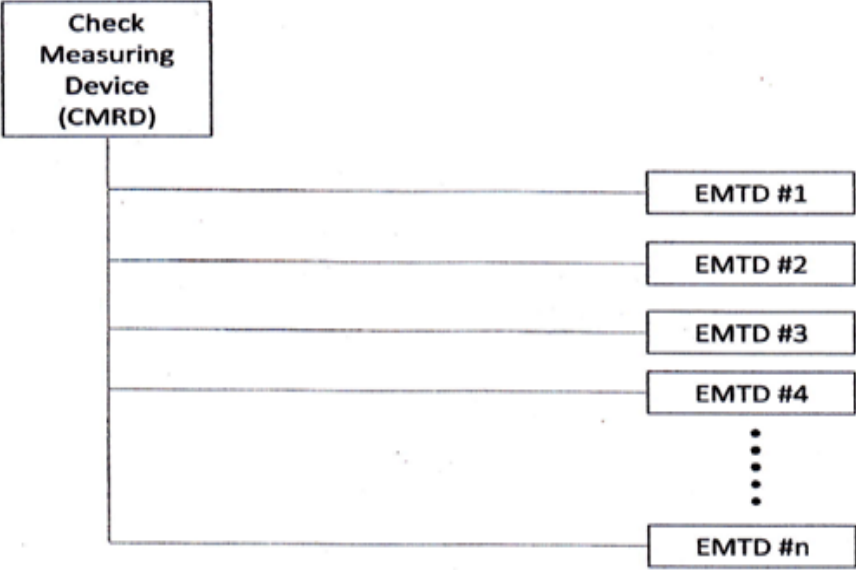

FIGURE: Block diagram of Data exchange between CMRD & EMTD

4.3 Sending SMS to the control centre

The Global System for Mobile (GSM) communication is the Second Generation of mobile technology. Although the world is already moving towards the Third and Fourth generations but GSM has been the most successful and widespread technology in the communication sector. GSM modem is a specialized type of modem that operates over subscription based wireless network, similar to a mobile phone. Hence, we used a GSM modem for serving our purpose of

notifying the control centre of theft. After detecting the power pilferage, a signal would be sent to the modem as a result of which an SMS will be sent to the authority automatically by using a GSM modem.

The diagram below shows the flow of the data via a GSM module. The first embedded device is the microcontroller which sends the data to the module. The module then via wireless link will send the data to the control centre.
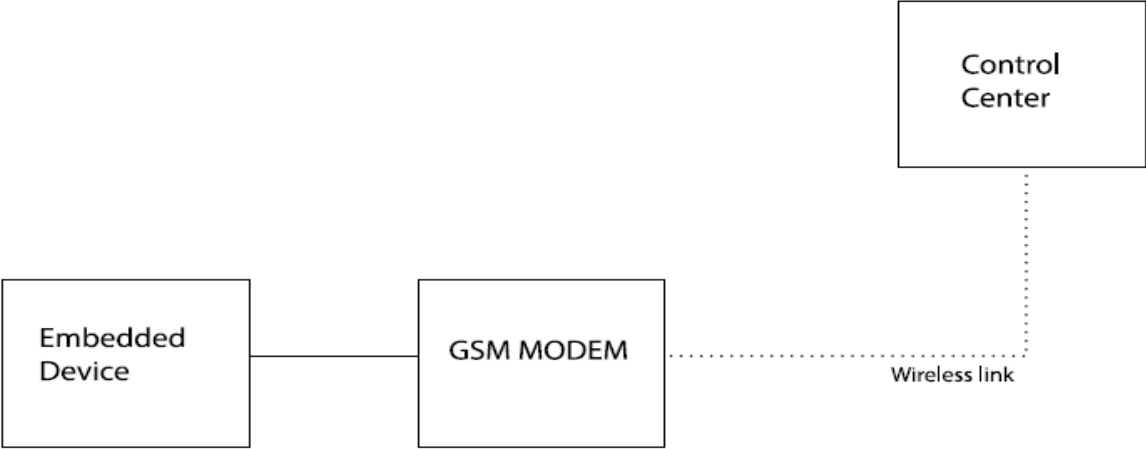

FIGURE: Block Diagram of Interfacing GSM with the Embedded Device and Sending SMS to the Control Centre

4.4 Interfacing GSM modem with Microcontroller

Although microcontroller and GSM modem – these two are compatible from a software perspective, a microcontroller cannot be just simply plugged to a GSM modem because the hardware interfaces are not compatible.

Most microcontrollers these days have built in UARTs (universally asynchronous receiver/transmitter) that can be used to receive and transmit data serially. UARTs transmit one

bit at a time at a specified data rate (i.e. 9600bps, 115200bps, etc.). This method of serial communication is sometimes referred to as TTL serial (transistor-transistor logic). Serial communication at a TTL level will always remain between the limits of 0V and Vcc, which is often 5V or 3.3V. A logic high ('1') is represented by Vcc, while a logic low ('0') is 0V.

The serial port on the GSM modem complies with the RS-232 (Recommended Standard 232) telecommunications standard. RS-232 signals are similar to a microcontroller's serial signals in that they transmit one bit at a time, at a specific baud rate, with or without parity and/or stop bits. These two differ solely at a hardware level. By the RS-232 standard a logic high ('1') is represented by a negative voltage – anywhere from -3V to -25V – while a logic low ('0') transmits a positive voltage that can be anywhere from +3 to +25V. On most GSM modem these signals swing from -13V to +13V.

The more extreme voltages of an RS-232 signal help to make it less susceptible to noise, interference, and degradation. This means that an RS-232 signal can generally travel longer physical distances than their TTL counterparts, while still providing a reliable data transmission.
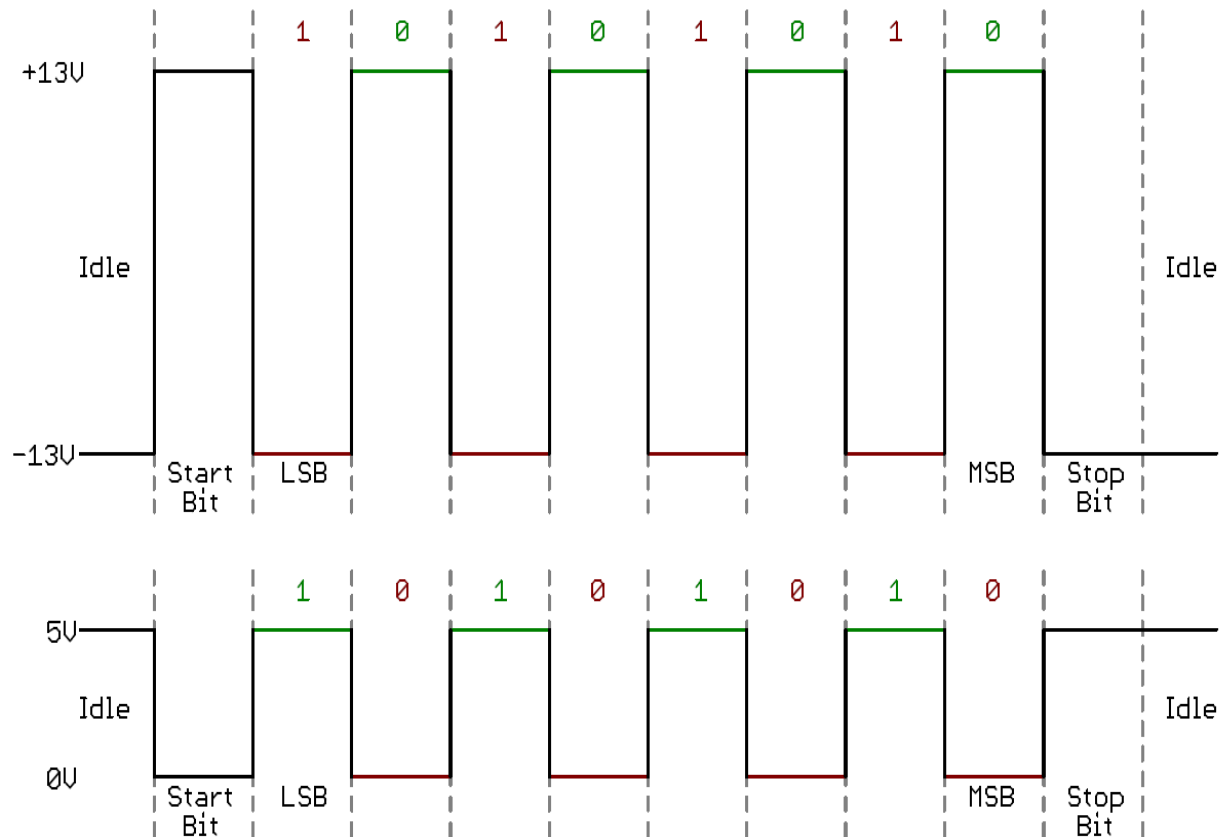
FIGURE: Timing diagram of a TTL (bottom) and RS-232 signal sending 0b01010101

It is clear from the figure given above where the problem lies in interfacing these two signals. To connect these two ports not are the signals needed to be inverted, but also the potentially harmful RS-232 voltages have to be regulated to a level that will not burn a microcontroller's serial pins. There are a handful of solutions to this problem of voltage converting and inverting. The most common and easiest solution, and the one we used is – a MAX-232 IC, plugged in between the two devices as a level converter circuit.
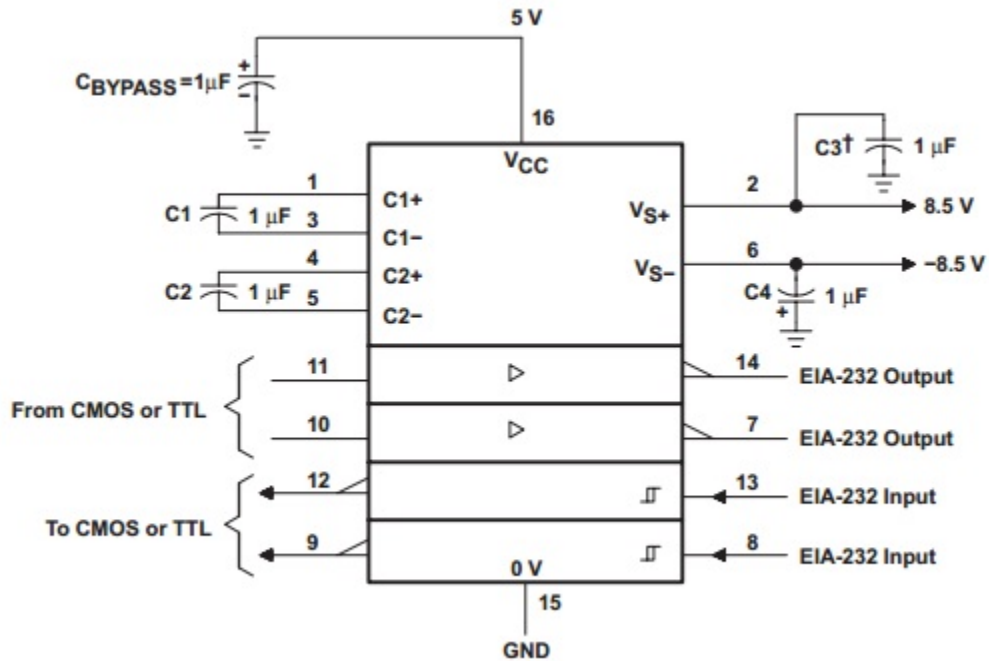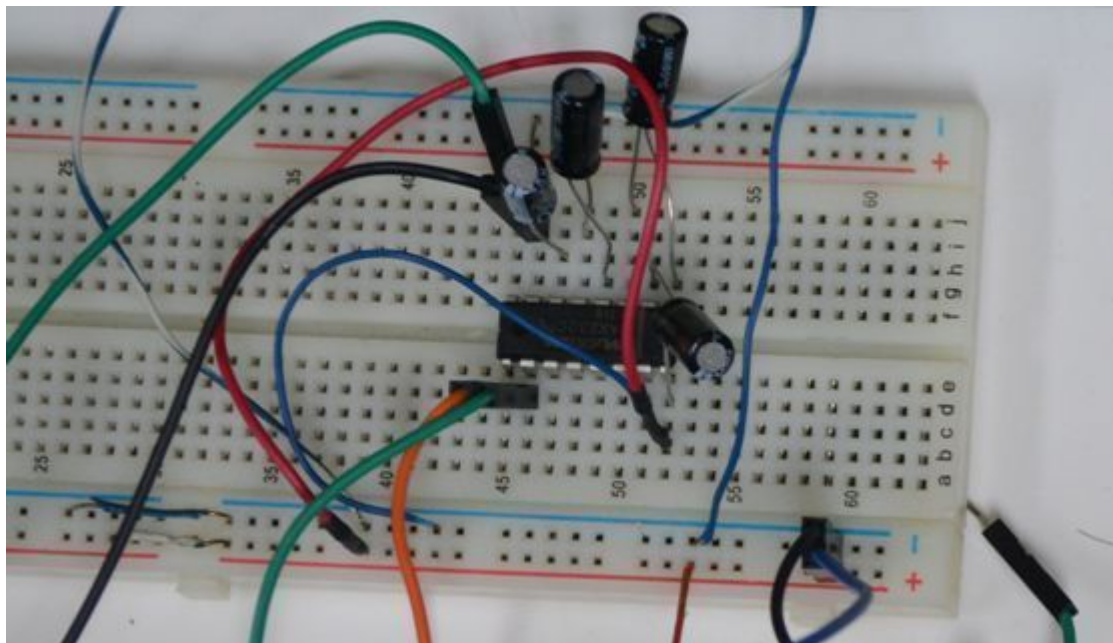
FIGURE: MAX232 Pin Configuration

FIGURE: The Level Converter Circuit Using MAX232

FIGURE: Schematic of the Complete Circuit for Interfacing GSM with PIC16F877A

FIGURE: Project Circuitry for CMRD Block

4.5   Conclusion

It is desirable to provide an inexpensive apparatus and method for communicating utility usage information from one point to a utility usage registering device at another which utilizes low cost components and which is still operable to transmit over a fixed, accurately controlled frequency. With that in mind, the proposed model of CMRD fits the requirements with satisfactory results. True that occasionally some data might go amiss since we could use better equipment but the trade-off here is the reduction of overall cost of the whole project. For further cost reduction instead of using wireless data transmission technique, power line communication could be used, where data signal is modulated on power signal and sent it through a same electrical distribution network, but the system losses and slow response for that method makes our proposed technique a better option. So, finding a balance between performance and cost-effectiveness, we found the proposed modifications to be appropriate for our country.

Chapter 5

Conclusion

Direct connections to the power system, through tapping the power line is one of the methods widely used in our country for electricity theft, a common form of commercial losses. Owing to the lack of information on both commercial and the legitimate loads in the system, commercial losses are nearly impossible to measure using traditional power system analysis tools. The results of commercial losses measurements in our country are often inaccurate at best. And whatever losses measured, are billed on the legitimate consumers, also, with the added disadvantageous condition of load-shedding during power failure. The progress in technology about electrical distribution network is a non-stop process. New things and new technology are being invented. Design of future electricity markets is aimed at providing consumers with highly reliable, flexible, readily accessible, and cost-effective energy services by exploiting advantages of both large centralized generators, as well as small distributed power generation devices. While, we may not be able to apply the latest of technologies to eradicate the problem of transmission and distribution losses in our power theft owing to insufficient funding, we may still use the limited resources in our hands to develop an economic, yet satisfactorily effective modification of the current T&D system to improve the situation. The proposed system, although might seem to be little bit complex as far as distribution network is concerned, but it's an automated system of theft detection that saves time as well as help maximize profit margin for utility company working in electrical distribution network. Utility company can keep a constant eye on its costumer at an affordable cost of this new system.

The most advantageous point to be noted is that every component in our project is chosen to best fit the requirements at extremely low costs and high market availability. Amongst the major components, the microcontroller (PIC16F87A) is locally available in our country for either small or large scale implementation within a very reasonable price range of BDT 160.00 to 180.00

(which is less than 2.40 USD) and the RF (433MHz) module, that includes both transmitter and the receiver, costs approximately BDT 400 (less than 5.25 USD) and is profoundly available in the local market. The GSM (MOD 9001) is also at hand at a reasonable price of BDT 5000 (65.00 USD). Moreover, the devices to be used for the power theft detection system will be plugged in to the existing electricity transmission and distribution system, hence it will be easy to troubleshoot and repair or modify the devices in future if required.

Although there are other technologies available, for instance, Arduino is much easier to program and is a more updated equipment to work with, but it is way more expensive than the PIC16F87A microcontroller that we have chosen. The communication technology (GSM) used in our proposal is widely used throughout the country and is feasible for implementation than any other wired (Optical fibers, Coaxial cables etc.) or wireless (Wi-Fi, WiMAXs etc.) technologies. The biggest setback of the proposed system would be the complicated tracing of the exact pilferage location which would require manual checking of all the consumer premises of the detected locality. But we should also keep in mind that in a country with no provisions for theft detection as of yet, this system would definitely take us a lot farther in the way to a better power distribution system. Despite the fact that there are more available and updated technology to replace the components we chose, the ultra-low cost solution for such a significant problem in our country is yet the strongest point to ponder for the government officials and the power supply authorities.

Further improvement of the system would require the addition of GPS so that the location of the pilferage causing the non-technical losses could be discovered and diagnosed better. Although it's not like that we cannot do that already; that is, with the system proposed in the paper, location of theft can be traced back by tracing the model number of the modules sent over the SMS. But we still cannot deny the fact that the addition of GPS would make the detection a lot easier and faster as well as more precise. What is more, for a wider range and smoother data transmission the RF (433MHz) module could be replaced by another transceiver, NRF105 which also has the additional features of encrypted security and more importantly, better quality of data transmission without the risk of losing any data at a reasonable cost. Also, if possible, the installation of a CMRD for each of the power distribution lines for each of the consumer

premises instead of only one for the service drop of a locality would enable the pin-pointing of the exact pilferage location.

Merely generating more power is not enough to meet present day requirements. The demands for greater power supply keeps ever more increasing with the advancement in civilization and digitalization. Without solving the already existing crisis of huge avoidable non-technical losses, only aiming for further generation of electricity is, indeed unintelligent. For a true way out, power consumption and T&D losses have to be closely monitored so that the generated power is utilized in an efficient manner. This paper is aimed at reducing the heavy power and revenue losses that occur due to power theft by the customers, at the same time, finding the right balance and trade-off between cost-effectiveness and quality of the system. By this design it can be concluded that power theft can be effectively curbed by detecting where the power theft occurs and informing the authorities. The ability of the proposed system to inform or send data digitally to a remote station using wireless radio link adds a large amount of possibilities to the way the power supply is controlled by the electricity board. So, hopefully, with the implementation of the suggested modifications of the existing power system, the country will see an improved power sector and recovered revenues.

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