# REAL TIME MONITORING AND CONTROLLED POWER DISTRIBUTION SYSTEM WITH SMART METER TO SUPPORT SMART GRID

**A Thesis Submitted to the Department of Electrical and Electronic Engineering of BRAC University**


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# DECLARATION

This is to certify that, this is a record of the thesis titled "Real Time Monitoring and Controlled Power Distribution System with SMART Meter to Support Smart Grid", submitted to the Department of Electrical and Electronics Engineering of BRAC University by the students whose names are given bellow in partial fulfillment of the requirements of the degree of Bachelor of Science in Electrical and Electronics Engineering in BRAC University.

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# ABBREVIATIONS

CARC – Control & Applications Research Centre

AMI - Advanced Metering Infrastructure

AMR – Automated Meter Reading

LCD – Liquid Crystal Display

LED – Light Emitting Diode

GSM - Global System for Mobile communication

SMS - Short Message Service

GPRS - General Packet Radio Service

PGEL - Purobi Green Energy Limited

IDCOL - Industrial Development Corporation of Orissa Limited

DESCO - Dhaka Electric Supply Company Limited

TCP - Transmission Control Protocol

UDP - User Datagram Protocol

GPRS - General Packet Radio Service

IP - Internet protocol

SD Card - Squired Data Card

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# ACKNOWLEDGEMENT

We would like to seize the opportunity to express a big thanks to those who helped us for this project. Special thanks to our supervisor, Dr. A.K.M Abdul Malek Azad, Professor, Department of Electrical and Electronic Engineering, BRAC University, Bangladesh. Department of Electrical and Electronic Engineering who made it possible by supervising us from the start to finish. Lastly, thanks to BRAC University for all their logistic support with its resources, such as equipment facilities, workstations which helped smooth finish of the project.

# ABSTRACT

In order to introduce the smart grid system in Bangladesh, Smart Meter can be the first step to make a change in conventional Billing and metering system. Smart meter is a device that is based on two way communication between consumers and suppliers including Smart monitoring system. In our country, prepaid metering system is available in some areas by DESCO. Digital meter don't have two way communication facilities and controlling part is not available as well. Smart meter is more reliable compare to digital meter in terms of billing and tampering. Due to real-time monitoring and over-use alarm system, users will be more concern about their electricity usage. At the same time, Government will also be able to monitor power consumption in a better and organized way through the information received from Smart meters. Therefore, this paper basically focuses on the project titled Smart Meter which is designed by BRAC University, Control & Applications Research Centre (CARC). For this project, microcontroller is used in digital electric meters. For current meter, current sensor (ACS712-20A) is used to sense the amount of current which is being consumed. For voltage meter, to get desired and protected analog reading optocoupler has used which can be tolerated by Arduino Uno. Once Arduino converts analog signals to digital signals, measured voltage, current and power factor are multiplied in order to get power at every second and then it sums them up to get the energy consumed. At every second, all the data are stored in SD Card in a text file to back up during power off. Distributors can trip the whole system through a command using database which is made for this project through SocketTest software. Smart monitor is the special feature which is separately boxed and controlled by Arduino Uno from the Main Meter box. Main Meter Monitor is attached with the Arduino Mega and shows the overall power, voltage, current, PF readings in one single tab. Secondary Monitor has three tabs to be controlled with keypad. The overall current (A), voltage (V), power(kWh), PF are the data transferred to Uno. Through this Secondary monitor, consumers will be able to perceive their room-wise electricity consumption, per-unit cost and get notification for over consumption of the electricity.The main motive of this project is to introduce both way communicationsthrough Smart Meterin Bangladesh which is very efficient as well as feasible for the consumers with cheaper price.

# Chapter 01

# INTRODUCTION

Smart meter is a device based on both way communication system between consumers and suppliers including Smart monitoring system. Smart meter is more reliable compare to digital meter in terms of billing and tampering. It will also increase consumers concern about their electricity usage and at the same time, Government will also be able to monitor power consumption in a better and organized way through the information received from Smart meters. In short, Smart Meter is a next generation device for a better power distribution system and can be the first step to make a change in conventional Billing and metering system which is helpful for effective Smart Grid management system.

## 1.1: Background Information:

The utilization of electronic meters came into administration to the largest customers of the utility and then gradually extended to all customer classes. Due to decrease the cost of technology and advanced billing requirements for all customer classes this migration was made possible. The combination of the electronic meters with two-way communications technology in terms of information, monitor and control is generally referred to as Advanced Metering Infrastructure (AMI). This AMI replaced with Automated Meter Reading (AMR) which utilized one-way communications to collect meter data. According to an EEI-AEIC-UTC White Paper Smart Meter systems are an integral part of Smart Grid infrastructure in data collection and communications. [1]

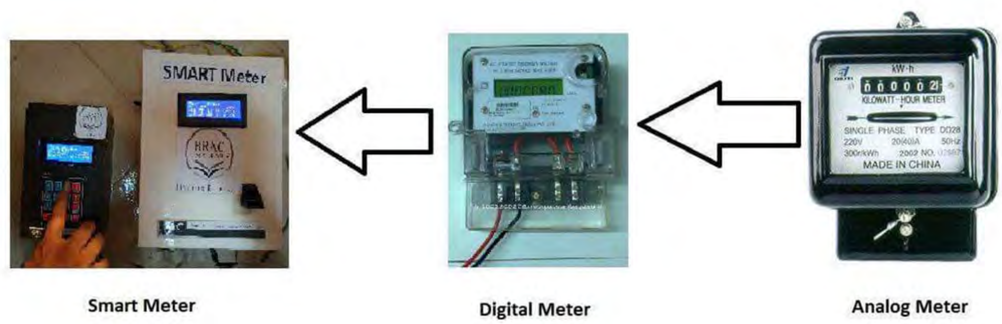



**Figure 1.1:** Analog Meter to Smart Meter Conversion

Figure 1.1 shows Analog Meter to Smart Meter Conversion. The first half of the 19th century brought brilliant discoveries in electromagnetism. In 1820, the French André-Marie Ampere (1775-1836) discovered the electrodynamic interaction between currents [2]. In 1827, the German Georg Simon Ohm (1787-1854) discovered the relationship between voltage and current in a conductor. In 1831, the British Michael Faraday (1791-1867) discovered the law of induction. The earliest meter was Samual Gardiner's (USA) lamphour meter patented in 1872. It measured the time during which energy was supplied to the load. Thomas Alva Edison (1847-1931) introduced the first electrical distribution systems for lighting using direct current. His 'electric meter' patented in 1881 (USA patent No. 251,545) used the electrochemical effect of current. With the time going, digital electronic meter has come which coverts analog reading to digital reading and displays the real-time energy used on an LCD or LED display. Now, this is era of smart meter. With the help of advanced technology, Smart meters enable two-way communication between the meter and the central system. Unlike home energy monitors, smart meters can gather data for remote reporting. Such an advanced metering infrastructure (AMI) [3] differs from traditional automatic meter reading (AMR) [4] in that it enables two-way communications with the meter. The American Council for an Energy-Efficient Economy reviewed more than 36 different residential smart metering and feedback programmed internationally.

## 1.2: Motivation:

At present, many of the developed countries are using Smart technologies for electricity measurement. In Bangladesh, prepaid metering system is available in some areas by DESCO [5] but that does not have two-way communication facilities at all. It is high time to introduce Smart technology which is defined as Smart as Bangladesh already have micro grid system already and still work is going on [6]. To make grid management system Smart in this country, the first component should be the Smart Meter which will make change in traditional billing system and will be more reliable through its Smart technology.

## 1.3 Features

The features we have included in our SMART Meter are,

01. Real time usage information available for consumers both in Meter Display and server
02. Security lock only for admin access
03. Distributor Company has control over smart meter remotely.
04. Usage history is stored in SD Card for future backup
05. Sending real time data to power distribution center through GPRS
06. Observe usage of different rooms separately
07. Control over ‘current limit’.

## 1.4 Advantages

Smart meter is more reliable compare to digital meter in terms of billing and tampering. Due to real-time monitoring and over-use alarm system, users will be able to get their usage data all the time and this will raise more concern about their electricity usage. At the same time, Government will also be able to monitor power consumption in a better and organized way through the information received from Smart meters. Advantages of Smart Meter are given bellow.

01. Consumers will get more accurate bill [7] according to their usage.
02. Consumers will be more concern about their electricity usage due to real time monitoring system.
03. Not everyone can get access to the meter.
04. Distributors can trip the meter for any unusual cases.
05. All Data stored in Database and Consumers can see their usage update using their unique user ID and password.
06. Smart Meter is more reliable compare to Digital Meter.
07. Over Current Protection.
08. A smart power distribution system with smart meter will be able detect and stop ‘Theft of electricity’.

## 1.5 Comparison between Digital Meter & Smart Meter:

Comparison between Digital Meter and Smart Meter is given in Table 1.1.

| | **Digital Meter** | | | **SMART Meter** |
|---|---|---|---|---|
| **01** | Manual Process | | **01** | Both Way Communication |
| **02** | No usage Update through internet | | **02** | Usage update through internet |
| **03** | Misuse of Electricity | | **03** | Enrich Customer's Concern |
| **04** | No Alarm System | | **04** | Alarm on Over Usage |
| **05** | No Security lock System | | **05** | Security lock only for admin access |
| **06** | Not so Reliable in terms of billing and tampering | | **06** | Comparatively Reliable in terms of billing and tampering |
| **07** | No Control | | **07** | Control the entire system |
| **08** | Probability to get inaccurate Reading | | **08** | Ensure Reading with less error |

**Table 1.1:** Comparison between Digital Meter & Smart Meter

## 1.6: Thesis Organization

Rest of the part of this report is organized as follows; Chapter two is about hardware components those are used in this entire project. The title of that chapter is "Hardware Components". Then, chapter three mainly focuses on system Design and analysis. Firstly, overall system block diagram of this project is given and then discussed about Smart Meter design in details. Next, chapter four is totally about the entire project calculations. Chapter five focuses on the secondary monitor part indetails. The sixth chapter gives an overview of the storage portion which is basically database in this project. The seventh chapter is the most important chapter which is data analysis. Finally, the last Chapter is about future plans of this project and concludes the report.

# Chapter 02

# Hardware Components

## 2.1 Introduction

In the project titled “Real Time Monitoring and Controlled Power Distribution System with SMART Meter to Support Smart Grid” two microcontrollers and modules compatible with them were used. For voltage sensor, a step down transformer and an optocoupler are used. For relay circuit IRFZ44N MOSFET has been used.

## 2.2 Components used:

2.2.1: Arduino Mega(Microcontroller)
2.2.2: Arduino Uno(Microcontroller)
2.2.3: SIM 900A (GSM/GPRS Module)
2.2.4: R30X (Finger Print Sensor)
2.2.5: SD Card Module
2.2.6: 30ARelay
2.2.7: ACS712 (Current Sensor)
2.2.8: 5V and 9VAdapter
2.2.9: 4x4 Keypad
2.2.10: 20x4 block LCD Display

### 2.2.1: Arduino Mega

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560 according to datasheet [8]. For this project, Arduino Mega works as brain of the entire smart meter. It gets analogue readings from current sensor and voltage sensor and calculates the consumed current amount, voltage in the line, real time power and consumed energy. Based on these reading, Arduino Mega calculates the bill and display all these information in the display monitor. Fingerprint sensor is also connected with this which ensures the security of the meter from steeling and any kind of manipulations in the code. SD card is connected with Arduino Uno mega which saves the values of the reading in case power cut occurs. Arduino Uno is also connected with Arduino Mega through wire library. Arduino Mega sends all the calculated reading to Arduino Uno and Arduino Uno performs its tasks by using these readings. Figure 2.1 shows Arduino Mega.

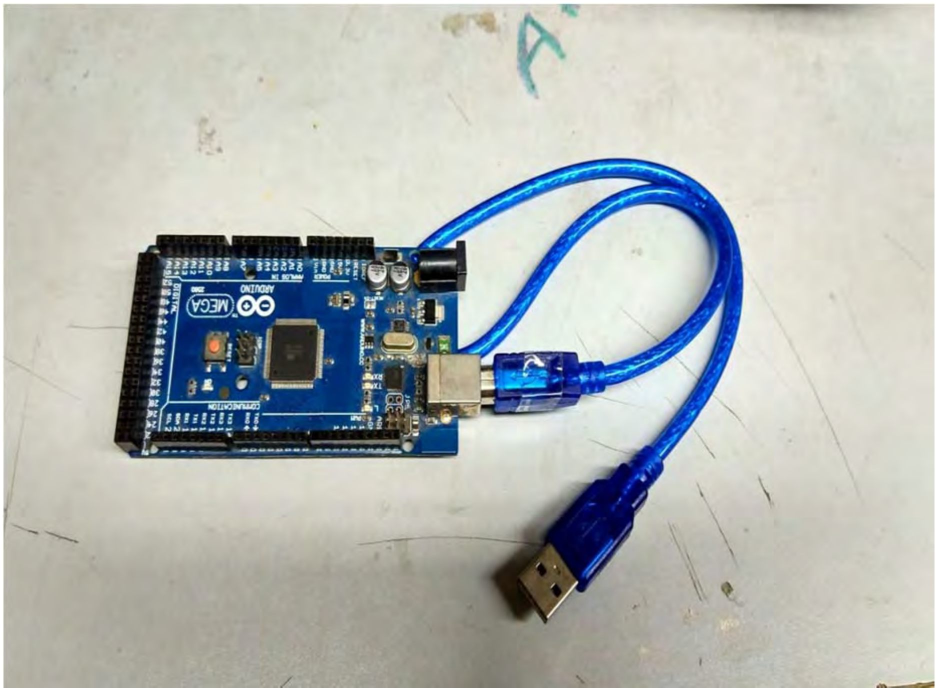


Figure 2.1: Arduino Mega

Specifications of Arduino Mega are given in Table 2.1 according to its' datasheet. [8]

| Specifications of Arduino Mega | | |
|---|---|---|
| 01 | Microcontroller | ATmega2560 |
| 02 | Operating Voltage | 5V |
| 03 | Input Voltage (recommended) | 7-12V |
| 04 | Input Voltage (limits) | 6-20V |
| 05 | Digital I/O Pins | 54 (of which 14 provide PWM output) |
| 06 | Analog Input Pins | 16 |
| 07 | DC Current per I/O Pin | 40 mA |
| 08 | DC Current for 3.3V Pin | 50 mA |
| 09 | Flash Memory | 256 KB of which 8 KB used by bootloader |
| 10 | SRAM | 8 KB |
| 11 | EEPROM | 4 KB |
| 12 | Clock Speed | 16 MHz |

**Table 2.1:** Specifications of ARDUINO Mega [8]

### 2.2.2: Arduino Uno

The Arduino Uno is also a microcontroller board unlike Arduino Mega. After getting different reading from Arduino Mega, it processes those values and performs followings task-

1. To initiate GSM Module and get connection with server remotely using GPRS.
2. To establish stable real time monitoring system from server.
3. To display the real time reading in the secondary display.
4. To ensure room wise monitoring using keypad.

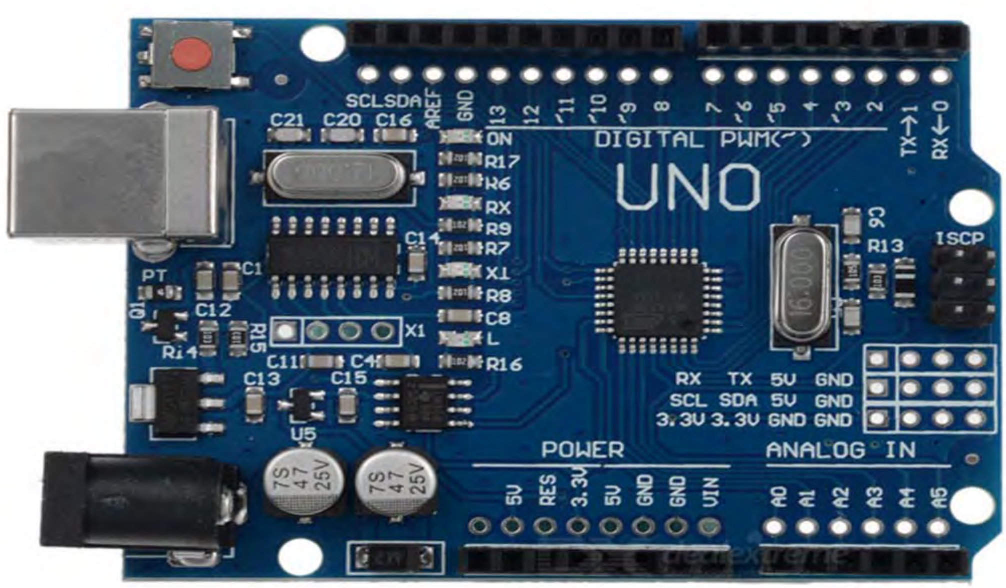



**Figure 2.2: Arduino Uno**

According to datasheet [9] it has 14 digital input/output pins, 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter.The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically. Figure 2.2 shows Arduino Uno.

Specifications of Arduino Uno are given in Table 2.2 according to its datasheet. [9]

| **Specifications of Arduino Uno** | |
|---|---|
| Microcontroller | ATmega328 |
| Operating Voltage | 5V |
| Input Voltage (recommended) | 7-9V |
| Input Voltage (limits) | 6-20V |
| Digital I/O Pins | 14 (of which 6 provide PWM output) |
| Analog Input Pins | 6 |
| DC Current per I/O Pin | 40mA |
| DC Current for 3.3V Pin | 50 mA |
| Fash Memory | 32 KB (ATmega328) (0.5 KB used by bootloader) |
| SRAM | 2 KB (ATmega328) |
| EEPROM | 1 KB (ATmega328) |
| Clock Speed | 16 MHz |

Table 2.2: Specifications of Arduino Uno [9]

### 2.2.3: SIM 900A Module

There are plenty of commands available for GSM/GPRS module [10]. Among all of the commands we have used AT commands. There are some tasks which can be done by AT commands. They are-

i. Get basic information about the mobile phone or GSM/GPRS modem.
ii. Get basic information about the subscriber.
iii. Get the current status of the mobile phone or GSM/GPRS modem.
iv. Establish a data connection to a remote modem.

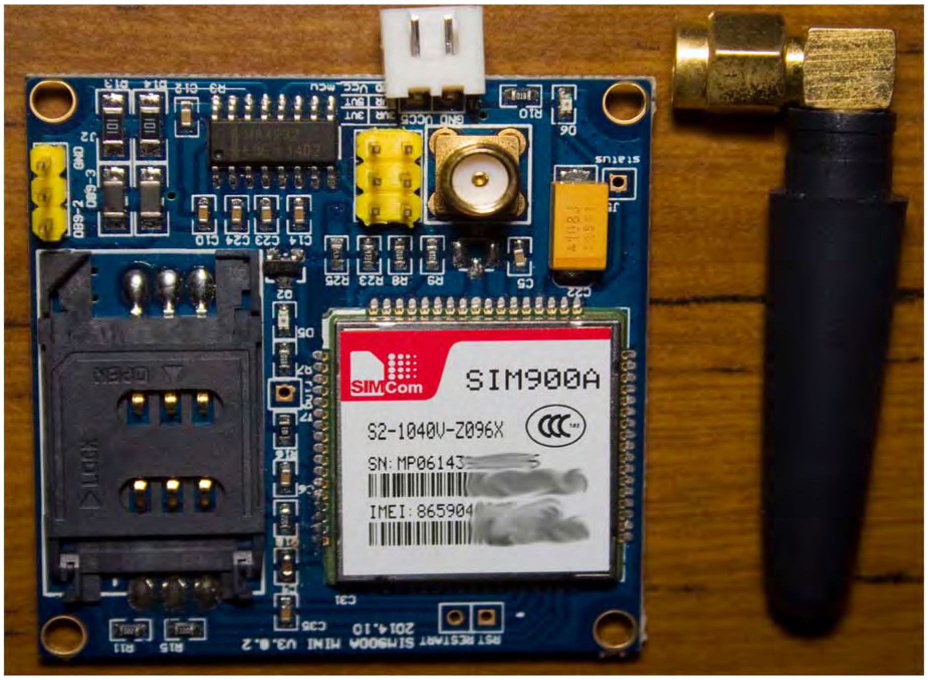



Figure 2.3: SIM900A Module

To make a digital meter into a smart meter, the first step is to create a bridge between consumers and the utility suppliers. This bridge will allow two way communications. Therefore, internet is the only tool to create this bridge wirelessly. By using the GPRS feature and with the help of AT commands we have created server in the utility office and sending values from consumer’s side to utility office. And again, if anything unusual things happened, the utility office will have all the power to control the meter remotely. They can even trip the meter remotely. All these tasks have been done by using GSM/GPRS module. Figure 2.3 shows SIM900A Module.

Specifications of SIM 900A Module are given in Table 2.3 according to its datasheet. [10]

| Specifications of SIM 900A Module | |
|---|---|
| **01** | Dual-Band 900/ 1800 MHz |
| **02** | GPRS multi-slot class 10/8 |
| **03** | GPRS mobile station class B |
| **04** | Compliant to GSM phase 2/2+ |
| **05** | – Class 4 (2 W @900 MHz) |
| **06** | – Class 1 (1 W @ 1800MHz) |
| **07** | Dimensions: 24*24*3 mm |
| **08** | Weight: 3.4g |
| **09** | Control via AT commands (GSM 07.07 ,07.05 and |
| **10** | SIMCOM enhanced AT Commands) |
| **11** | SIM application toolkit |
| **12** | Supply voltage range : 3.1 ... 4.8V |
| **13** | Low power consumption: 1.5mA(sleep mode) |
| **14** | Operation temperature: -40°C to +85 °C |

**Table 2.3:** Specifications of SIM 900A Module [10]

## 2.2.4: Finger Print Sensor

We have used figure print sensor to make our meter more secure. Only the authorized person can access the meter. Fingerprint recognition or fingerprint authentication refers to the automated method of verifying a match between two human fingerprints. Fingerprints are one of many forms of biometrics used to identify individuals and verify their identity. Figure 2.4 shows Finger Print Sensor.

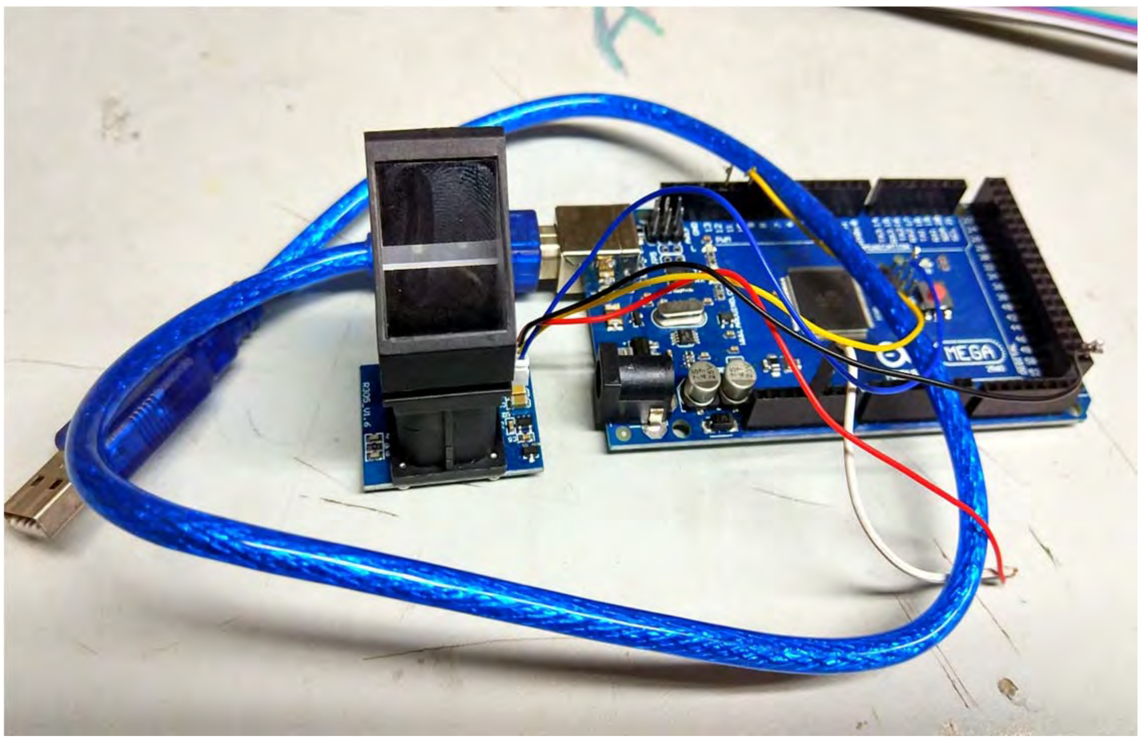


**Figure 2.4:** Finger Print Sensor

### 2.2.5 SD (Secure Digital) Card Module

The main reason of using SD card module in the smart meter is to store real time data and provide backup data at the time of sudden power cut. If the values are not stored in SD Card, all the calculated power, energy and unite values will be lost in the power cut and all the calculation will go in vain. Therefore, we have used SD Card to store the data at the time of power cut and when the power gets back, the meter will automatically start calculating the power, energy and unites values by incorporating the last value before power cut.

The Arduino SD Card Shield [11] which is a simple solution for transferring data to and from a standard SD card. Though, the pinout is directly compatible with ARDUINO, can also be used with other microcontrollers. It allows us to add mass storage and data logging to our project. Figure 2.5 shows SD Card Module.

**Figure 2.5:** SD Card Module

Features of SD Card Module are given in Table 2.4 according to its datasheet. [11]

| | |
|---|---|
| Tolerant voltage | 5V |
| Storage Capacity Size | Based on SD Card Size |
| Power consumption | 1@3.3V,0@5V mA |
| Dimensions | 47*42*7.2mm |
| weight | 16g |

**Table 2.4:** Specifications of SD Card [11]

### 2.2.5.1 Flowchart & Working Principle of SD Card Module:

For SD card module we have used basically three data logging files. Which are-

i. Save
ii. Backup
iii. Data logger

We have programmed in this way so that Data logger will save all the real time value and then it stores that value in save file or backup file. After that it takes another next value and deletes previous value.The flow chart of SD Card module is given in Figure2.6

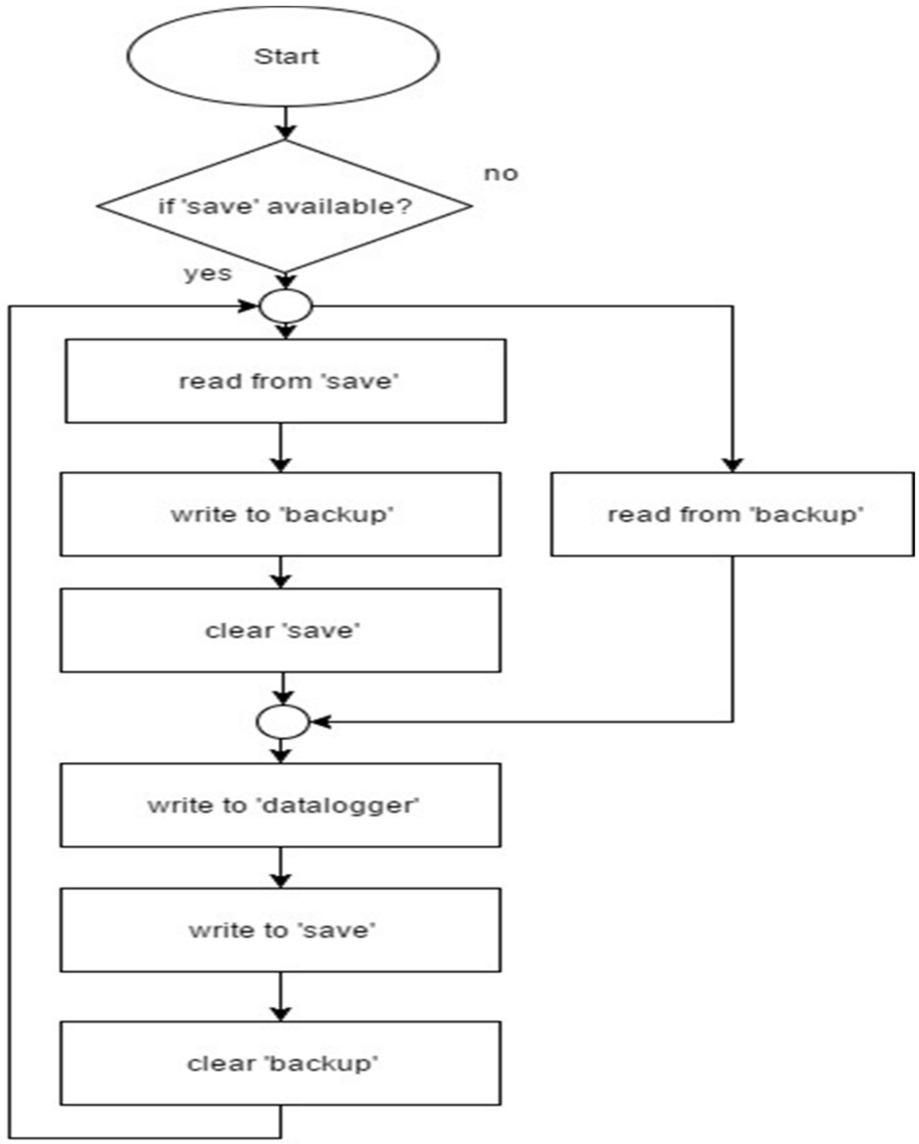



**Figure 2.6:** SD Card Module Flowchart

Figure 2.7 shows sample data of SD card. When the meter starts metering the values, at first it will look for if there is any data available in Save File. If yes, it will read that value from Save file and save it to Backup file and remove that save file. If no, it will read that value from backup file and store it to Save file and remove that Backup file. After that real time data value will be logged in data logger coming from the calculation of power and energy. Then, this value is going to transfer into Save File and removed the previous backup file if there in any. This loop will going in this way. Which ensure that at the time of power cut last value will be saved in either save file or Backup file and start calculating again from that value when the main power comes.

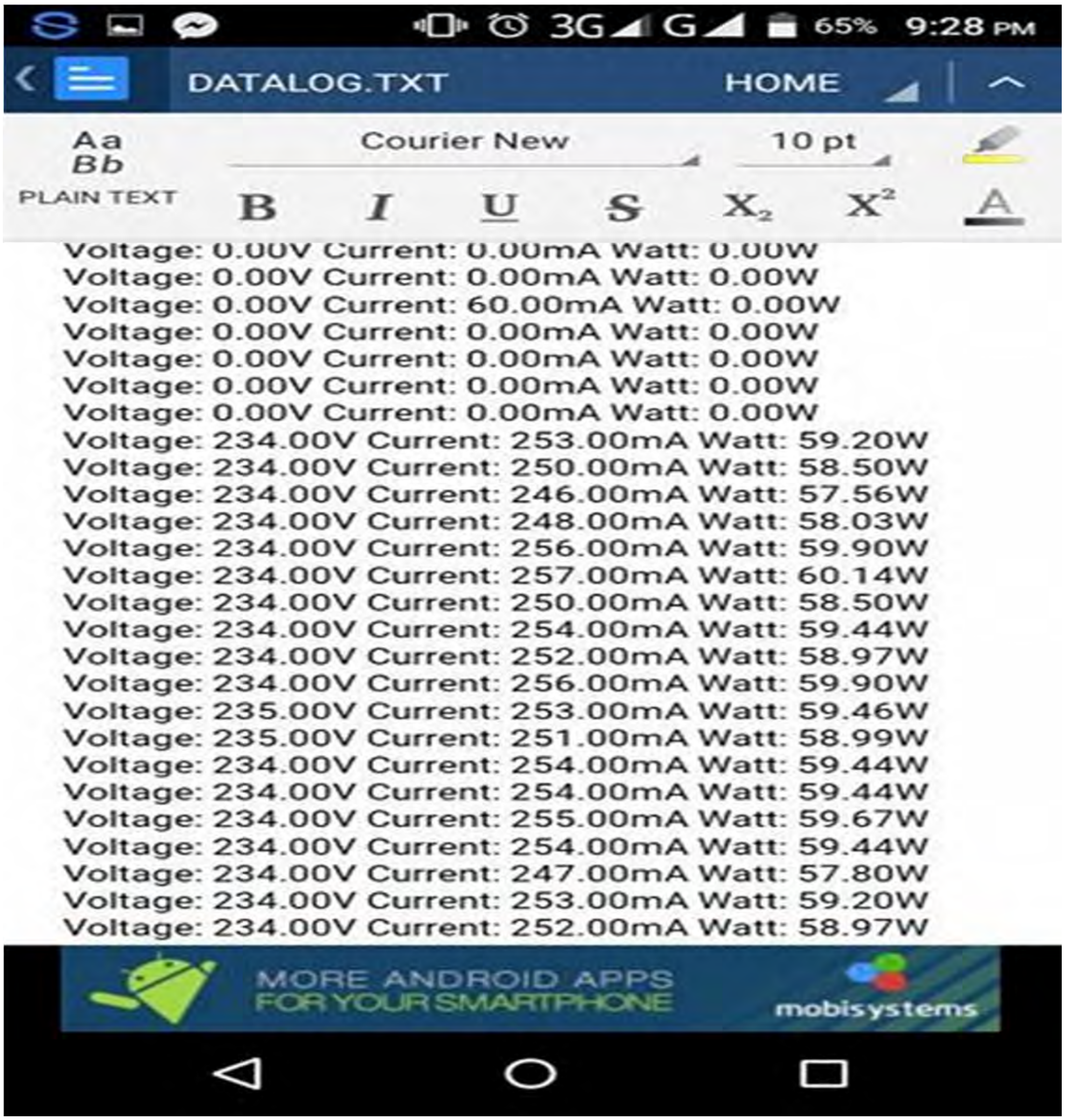



**Figure 2.7:** Sample Data of SD Card

### 2.2.6: Relay

In this project, there are basically three reasons to use relay such as tripping the power supply, retraining the supply back and ensuring protection from over current. A30A Relay is used for that project. SONGLE Power Relay SLA-12VDC-SL-C DC 12V Type T93 30A. It has 6 pins in total. Two of them are for powering, two for power supply and two to indicate NC and NO. This relay is a PCB Type relay. Control input for this relay is 12V DC. Max Load rating is 30A at 250AC and 30A at 30VDC according to SONGLE webpage.

SPST 1NO 1NCSince, this meter allows two ways communication which enables the authorization of tripping the meter and retraining the meter sitting from the utility office through Server by giving commands “STOP” and “STaRT”. When the meter gets “STOP” command, it trips the meter and vise verse for “STaRT” command. If short-circuit occurs in house and tremendous current flows, relay trips immediately after excessive flow of current. Figure 2.8 shows Relay.


**Figure 2.8:** Relay

### 2.2.6.1 Relay Module:

The diode is there to clamp the voltage/current spike the relay coil produces when it is switched off. The 33 ohm resistor protects the output from excessive current and allows the diode to do the clamping. When a digital output is turned off it does not go open circuit rather it connect the output pin to GND via a very low resistance. Without the additional 33 ohm resistance, the current spike from the coil would preferentially go back into the microprocessor to GND. Relay module circuit is given in figure 2.9.

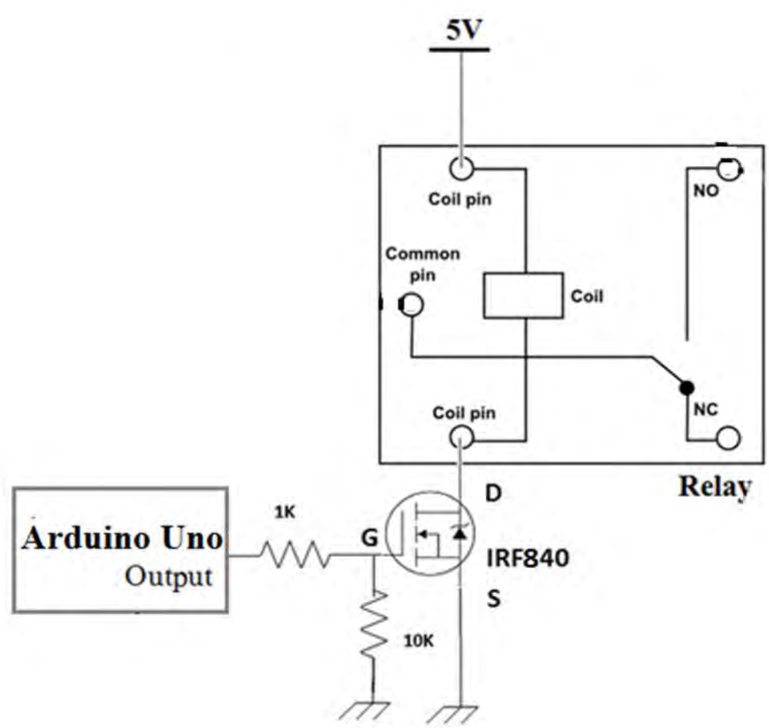



**Figure 2.9:** Relay Module Circuit

Therefore, for either board, connect the relay GND to one of Arduino's GND pins and the relay 5V or Arduino's 5V pin and the relay IN to one of ARDUINO digital outputs. The relay's contacts consist of a Normally Closed (NC) and Normally Open (NO) connection and a COM connection. When the relay is un-powered the NC terminal is connected to the COM terminal and the NO terminal is not connected. When the relay is operated, the COM terminal switches over and is now connected to the NO terminal and NC terminal is not connected. The screw terminals are either marked NO, NC and COM or small drawing is shown like the image below. It the image below, the top terminal is the NO one the centre terminal is the COM and the bottom terminal is the NC one. Figure 2.10 shows Relay Module.


**Figure 2.10:**Relay Module

## 2.2.7 Current Sensor

A current sensor is a device that detects electric current (AC or DC) in a wire, and generates a signal proportional to it. The generated signal could be analog voltage or current or even digital output. It can be then utilized to display the measured current in an ammeter or can be stored for further analysis in a data acquisition system or can be utilized for control purpose. The 20A current sensor which is used is a Hall-effect current sensor and the model is ACS712-20A. It gives analog output signal of 0-5V by getting connected in series connection with the line of which current needs to be measured. The reasons for choosing this model are cheaper, negligible power consumption & Arduino compatible. Figure 2.11 shows Current Sensor.

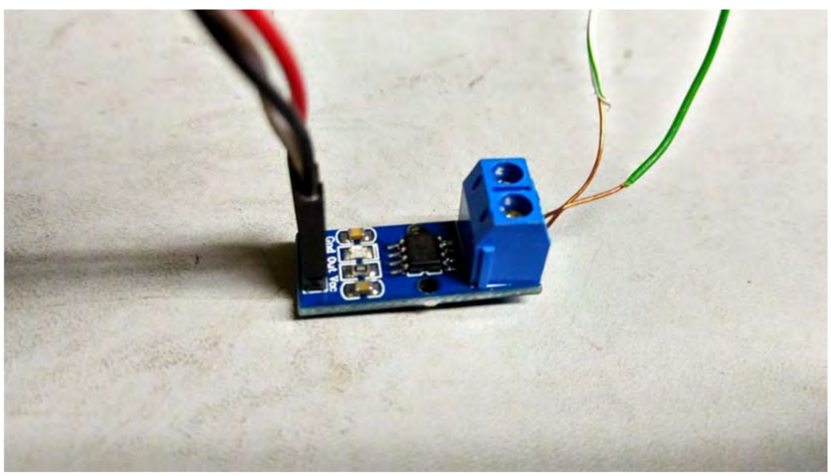


**Figure 2.11:** Current Sensor

### 2.2.8 Adapter

An adapter can be used when the wrapper must respect a particular interface and must support polymorphic behavior .In this project we have used ARDUINO Uno and ARDUINO Mega as the microcontroller of the smart meter and GSM module(sim900A) to enable two way communication by using GPRS internet between consumers and the service provider. All the equipments such as SD Card module, two display monitors, GSM module etc are connected to the ARDUINO. Therefore, to ensure 100% power supply to ARDUINO Uno, ARDUINO mega and GSM module we have used adapter and connected those equipments parallel to the output voltage of the adapter. Figure 2.12 shows Adapter.


**Figure 2.12:** Adapter

An AC adapter, also called a recharger. it is a small power supply that changes household electric current from mains voltage ( either 120 or 230 volts AC) to low voltage suitable for consumer electronics. most AC/DC adapters were linear power supplies, containing a transformer to convert the mains electricity voltage to a lower voltage, a rectifier to convert it to pulsating DC, and a filter to smooth the pulsating waveform to DC, with residual ripple variations small enough to leave the powered device unaffected. Specifications of Adapter are given in Table 2.5 according to its rating.

| | |
|---|---|
| Input voltage | 100v-240v AC |
| Input frequency | 50/60 Hz |
| Input current | .5A |
| Output voltage | 9V DC |
| Output current | 2A |

Table 2.5: Adapter Specification

### 2.2.9 Keypad

We have used keypad in our Secondary monitor for this project to show room wise electricity consumption. Figure 2.13 shows Keypad.


**Figure 2.13:** Keypad

Here, we have written our code in such a way that, pressing 1, consumers can see their electricity consumption for Room-1 and pressing 3, consumers can see their overall electricity consumption.

## 2.2.10: Display

In this project two 20x4 block LCD displays have been used. One is for MainMeter and another one is for Secondary Monitor. The main purpose of theboth display is to show consumed Current, Line Voltage, Cost, Real time Power and most importantly consumed Energy. Figure 2.14 shows Display.

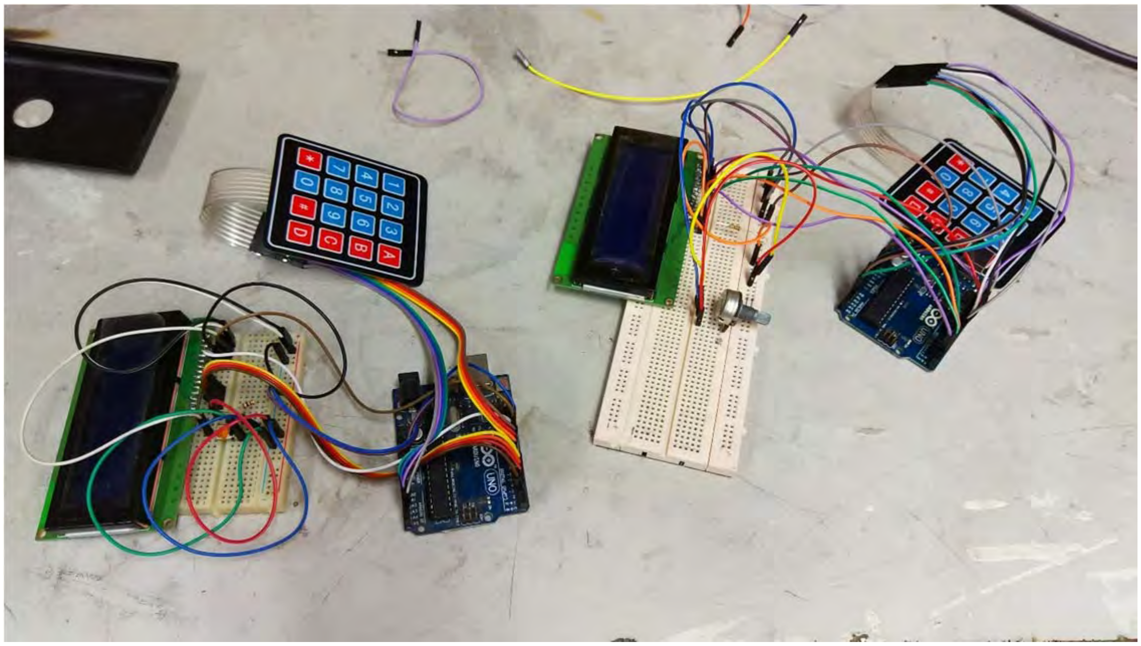


**Figure 2.14:** Display

# Chapter 3

# System Design and Working Principle

## 3.1 Overall System Block Diagram

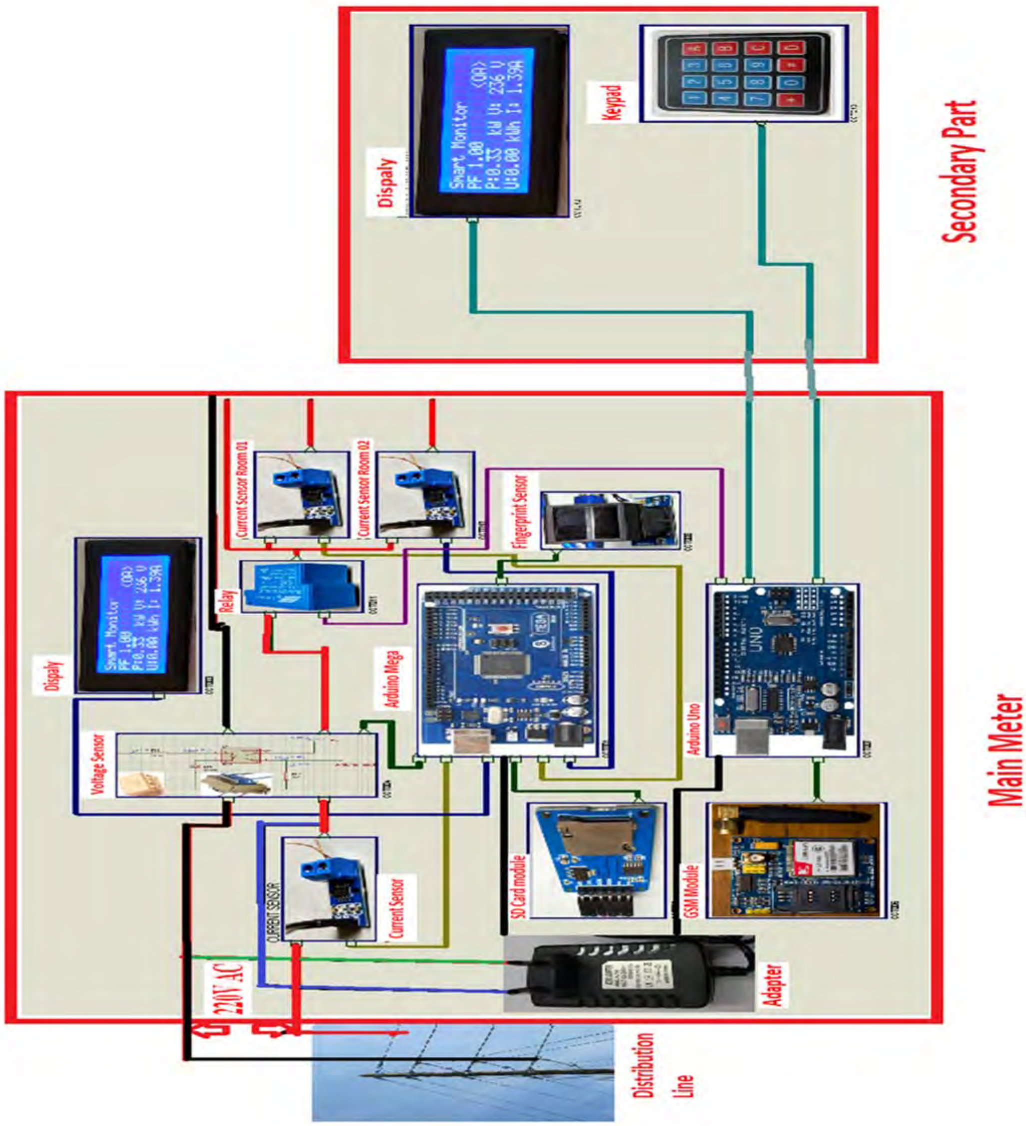



**Figure 3.1:** Overall System Block Diagram

## 3.2 Smart Meter Working Principle

Digital signal processor or high performance microprocessors are used in digital electric meters. Similar to the analog meters, voltage and current transducers are connected to a high resolution ADC [12]. Once it converts analog signals to digital samples, voltage and current samples are multiplied and integrated by digital circuits to measure the energy consumed.

For current meter, we have used 20A current sensor (SEN-00133) to sense the amount of current which is being consumed. Arduino gets analog data from current sensor and converts those values into discrete value by taking 4096 sample in per cycle. Then, Arduino compares the peak values and Converts those discrete values into digital by using codes.

For voltage meter, at first, we have used step down transformer to step the voltage down. Then use voltage division to get desired voltage which can be tolerated by Arduino Uno. After that, values are converted into discrete values and then in digital form by Arduino codes. For extra protection of the system, we have also used optocoupler so that system remains safe in under faulty condition.

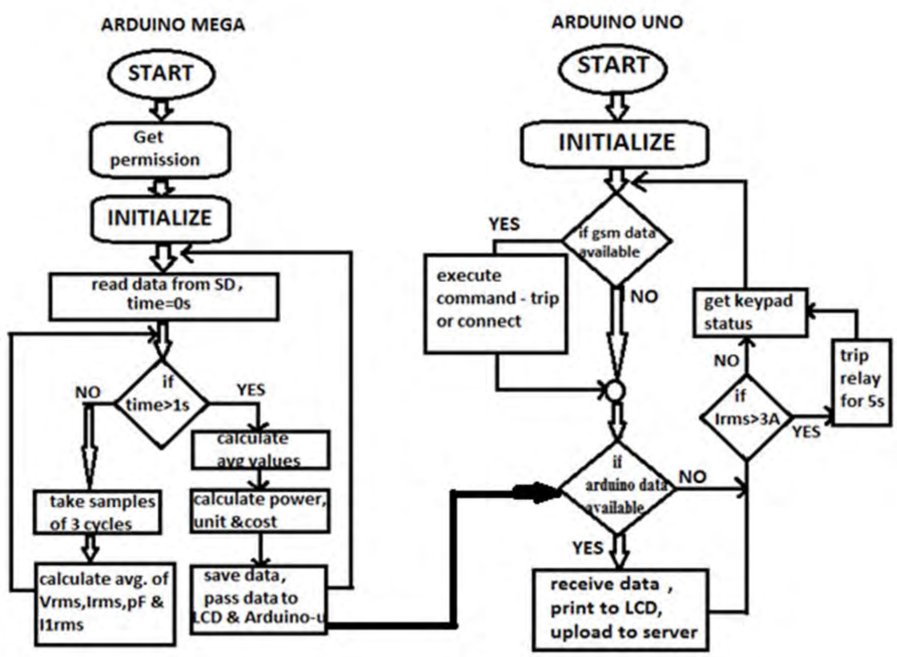



**Figure 3.2: Overall flowchart**

Figure 3.2 is the overall flowchart of whole code. The left one is for Arduino mega which is connected with fingerprint sensor, meter display, energy meter andSD card. The right one is for Arduino Uno which is connected with GSM module, Keypad and secondary display. Both of the Arduinos work simultaneously and independently. They are connected with I2C connection to communicate with each other. After starting the Arduino mega will be waiting for a valid figure print. After getting the authentication it will initialize the SD card and i2c connection. Then it will read the previous data from SD card. After that, it will start its' main job. It will continue a loop for 1 second where it takes samples of voltage and current for 60ms (3 cycles) again and again and average them. Then it will calculate the power, energy consumed and cost. Now ARDUINO mega will pass this information on the Arduino Uno and store them in SD card. So, at every second it will pass information and store them.

The Arduino Uno first initialize I2C connection, GSM module and connects with the server. Then it will turn on the displays and set backgrounds. After that it will be waiting for commands from server and information from other Arduino. If any command is given from the server it will execute it first. In this code it can execute two commands which are “STOP” and “STaRT” to control relay. When information is available from Mega it will print the information on display and upload them to server. As Arduino mega will send information at every second, it will upload value to the server at every second and the displayed value will be changing at every second. During this process if the overall current goes higher than 3A then it will trip relay for 5 seconds and also it will keep checking the keypad status.

### 3.2.1 Optocoupler(4n35)

Figure 3.3 shows Optocoupler which is used to make the voltage sensor. The purpose of using optocoupler is to keep Arduino isolated from AC power line so that if any unexpected condition appears for example too much high voltage in the power line, then it will protect the Arduino. Figure 3.4 shows Pin Configuration of Optocoupler according to its datasheet. [13]


**Figure 3.3:** Optocoupler

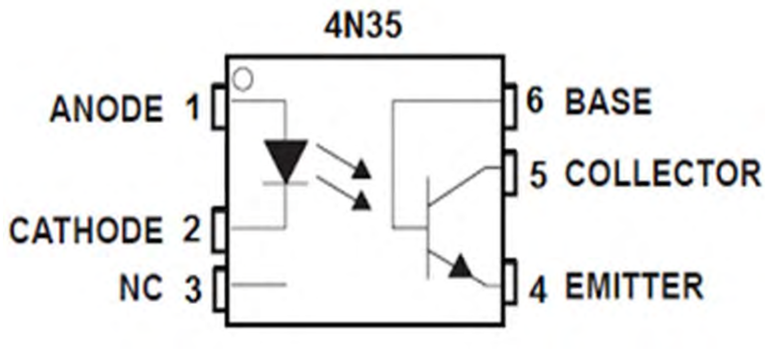



**Figure 3.4:** Optocoupler Pin Configuration [13]

Graph of 4n35 is given in Figure 3.5 according to datasheet. [13]

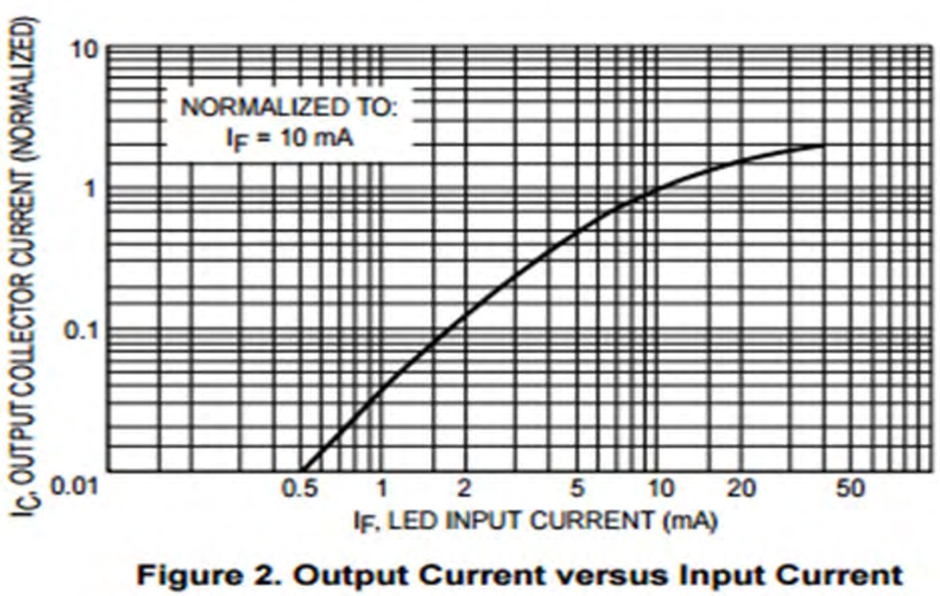



**Figure 3.5:** Graph of 4n35 [13]

Optocoupler transfers information by controlling output current according to the input current. This is a graph taken from the 4n35 datasheet shows relation between input current and output current. We have selected an input current of 13mA for which we will get output of almost 13mA and made circuit for voltage sensor according to that.

### 3.2.1.1 Voltage Sensor

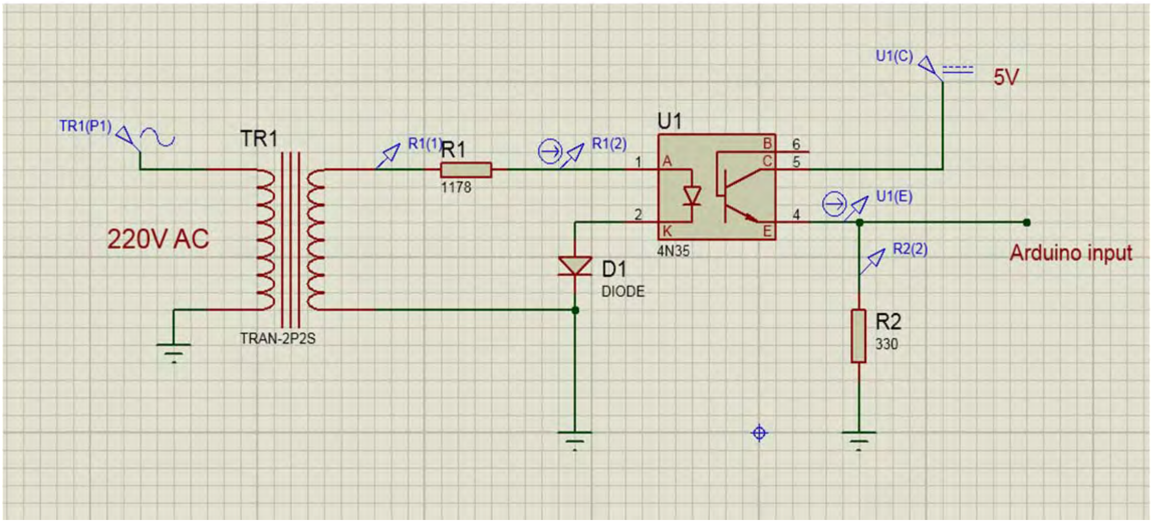



**Figure 3.10:** Voltmeter Circuit

Figure 3.10 is our voltage sensor circuit where the transformer's high side is connected to the 220V power line. This transformer transforms 220V into 12V. A resistor R1, a diode D1 and the optocoupler input is connected here in series connection. R1 limits the input current and D1 works as half-wave rectifier. On the other side of optocoupler a 5V Vcc is connected according to the circuit. Current through R2 depends on the input current of optocoupler. The voltage drop across R2 is the input of arduino to read voltage.

### 3.2.1.2 Optocoupler: Input and Output Current

Figure 3.6 shows Optocoupler Circuit Input and output Current.


**Figure 3.6:** Optocoupler circuit Input and Output Current

We simulated the circuit in Proteus. Here this graph shows the input current and output current of optocoupler.

### 3.2.1.3 Optocoupler: Input and Output Voltage Graph

Figure 3.7 shows Optocoupler circuit Input and Output Voltage graph.

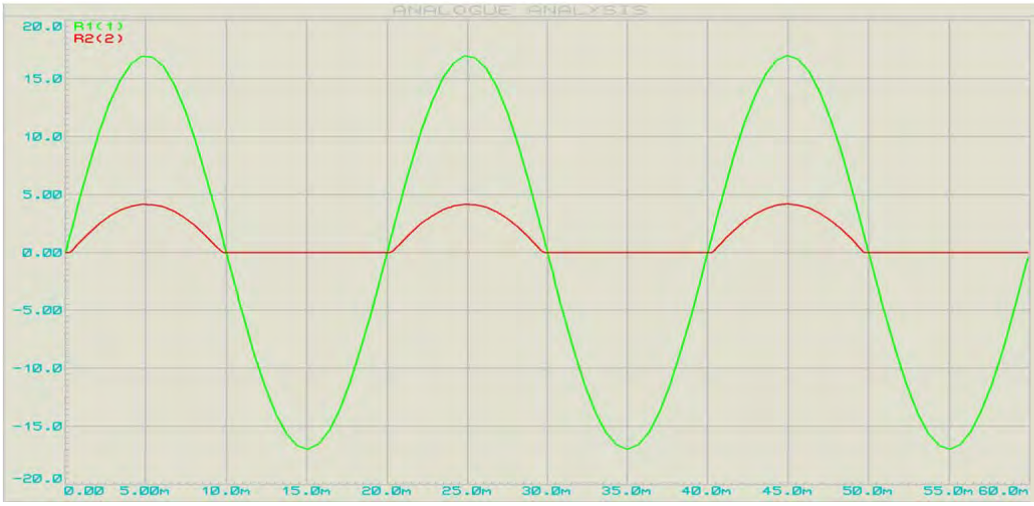



**Figure 3.7:** Optocoupler circuit Input and Output Voltage Graph

Figure 3.8 shows Input Voltage Graph of optocoupler circuit from Digital Oscilloscope.

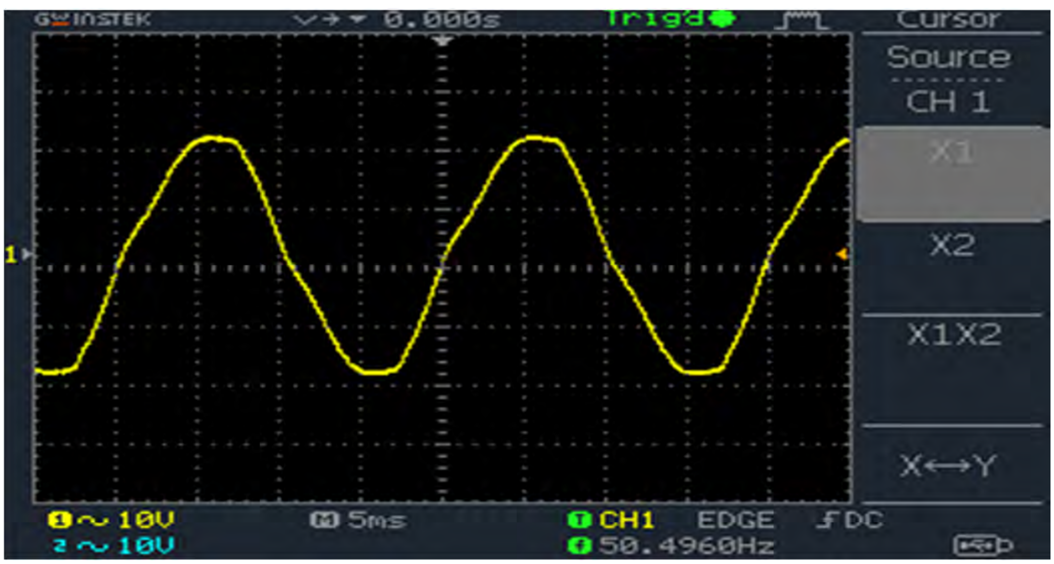



**Figure 3.8:** Input Voltage Graph of optocoupler circuit from Digital Oscilloscope

Figure 3.9 shows Output Voltage Graph of optocoupler circuit from Digital Oscilloscope.

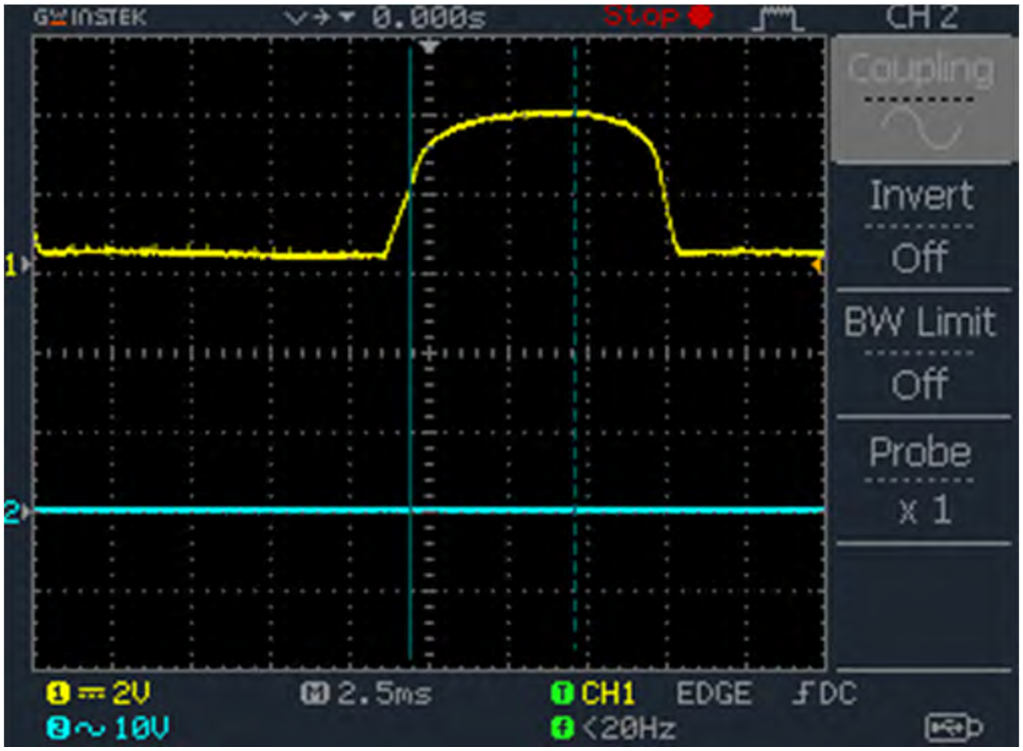



**Figure 3.9:** Output Voltage Graph of optocoupler circuit from Digital Oscilloscope

### 3.2.2 Current Sensor

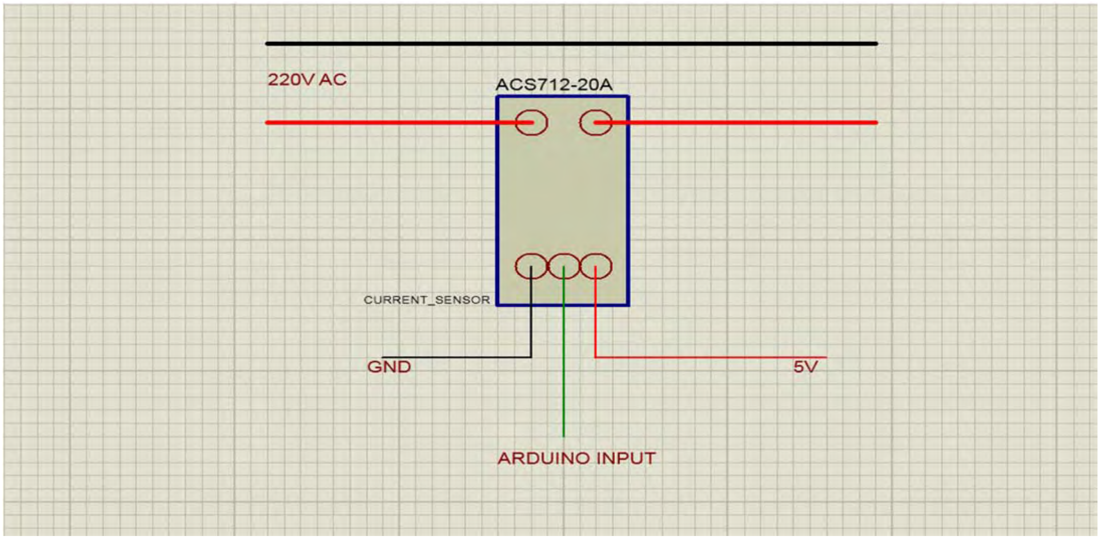



**Figure 3.11:** Current Sensor

Current sensor needs to be connected in series connection. This sensor does not require any extra circuit. It can directly convert current information into analog signal which can be read from ARDUINO. The current sensor which will measure the overall current needs to be get connected before the point where the adapter and the voltage sensor is connected. Otherwise it will not be able to measure the current going through the meter. Figure 3.11 shows Current Sensor connection diagram. Figure 3.11 shows Current Sensor. Resolution of ACS712-20A is given in Table 3.1.

| Range | | Arduino Input Voltage | | Input Value |
|---|---|---|---|---|
| 20,000mA | - | 1023 | - | 5V |
| - | | | | |
| - | | | | |
| 0mA | - | 512 | - | 2.5V |
| - | | | | |
| - | | | | |
| -20,000mA | - | 0 | - | 0V |

**Table 3.1:** Resolution (ACS712-20A)

According to the datasheet of ACS712, [14] the typical application is given in Figure 3.12,

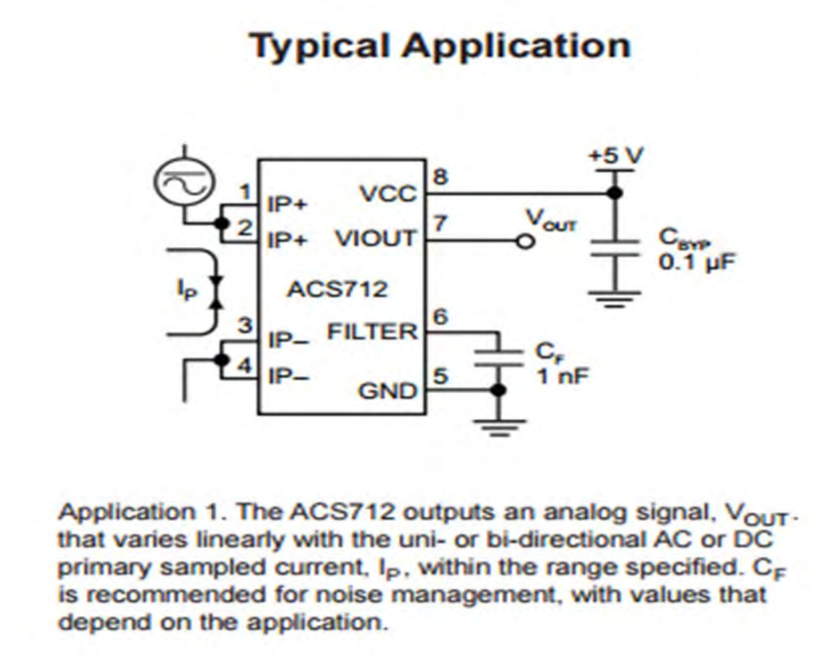
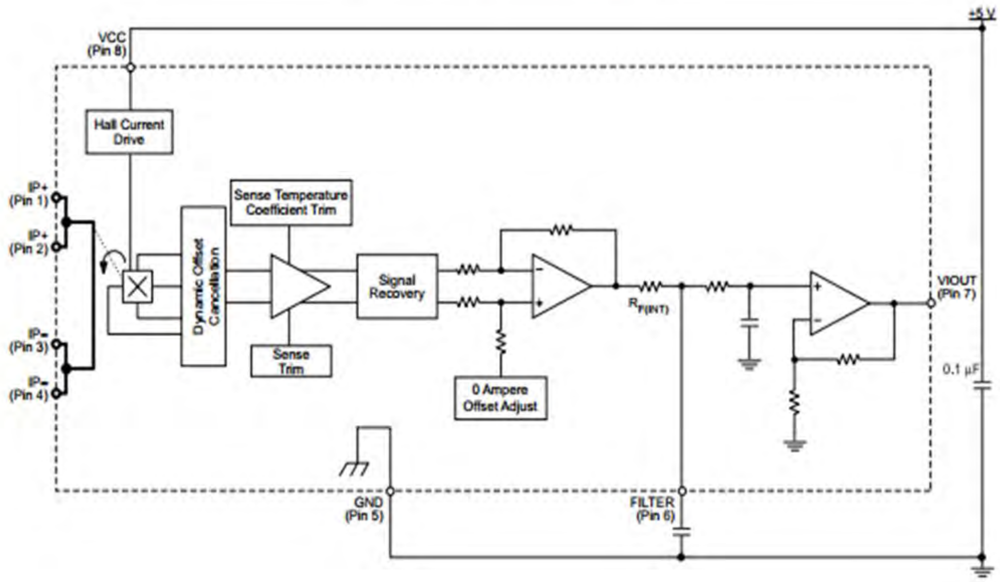


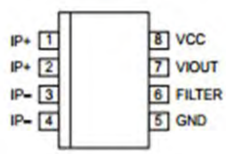

**Figure 3.12:** Typical application of ACS712 [14]

According to Allegro Micro System LLC, [15] the functional Block Diagram of ACS712 is given in Figure 3.13.

**Functional Block Diagram**




**Pin-out Diagram**




**Terminal List Table**

| Number | Name | Description |
|---|---|---|
| 1 and 2 | IP+ | Terminals for current being sampled; fused internally |
| 3 and 4 | IP– | Terminals for current being sampled; fused internally |
| 5 | GND | Signal ground terminal |
| 6 | FILTER | Terminal for external capacitor that sets bandwidth |
| 7 | VIOUT | Analog output signal |
| 8 | VCC | Device power supply terminal |

**Figure 3.13:** Functional Block Diagram ACS712 [15]

# Chapter 4

# Calculation

## 4.1 Introduction

For resistive load power is product of voltage and current, but for inductive load power is product of voltage, current and cosine and angle of phase difference [16]. There are three types of power which could be measured.

1. Real power
2. Reactive power
3. Apparent power

**1.Real power:**

The average active power is defined as:

$$\mathbf{P=V_{rms}\times I_{rms}\times Cos(\text{Ø})\quad Watt}$$

Where;

P= Power

V= Voltage

I= Current

Cos(Ø)= Power Factor

Ø= The angle between $V_{rms}$And $I_{rms}$

The implementation of the active power measurement is relatively easy and is done accurately in most energy meters in the field Where Cos(Ø) is called power factor and Ø is the angle between $V_{rms}$And $I_{rms.}$Depending on the load we get either leading or lagging power factor.

**2. Reactive power:**

The reactive power is defined under the energy measure as:

$$\textbf{Reactive power, } R = V_{rms} \times I_{rms} \times \sin(\text{Ø}) \quad \text{VAR}$$

Where Vn and In are respectively the voltage and current rms values of the nth harmonics of the line frequency, and ϕn is the phase difference between the voltage and the current nthharmonics.

**3. Apparent power:**

The apparent power is the maximum real power that can be delivered to a load. As Vrms and Irms are the effective voltage and current delivered to the load,

$$\textbf{Apparent power, } S = V_{rms} \times I_{rms} \text{ VA}$$

The correct implementation of the apparent energy measurement is bound by the accuracy of the rms measurements

But above all three of them, we are dealing with real power consumed in a home. To calculate real power, it is important to calculate the phase difference between line voltage and current.

Sometimes both have zero phase difference ideally but practically have very minimum phase difference and sometimes they have phase difference depending on the connected loads resistive, inductive and capacitive. So, total power of a cycle is calculated by taking samples in very little time interval, then calculate power and finally make average of complete cycle to get total power.

**Analog to Digital Converter**

When Arduino takes analog read it cascades two 8 bit numbers into one 10 bit number. The command analogRead() reads the value from the specified analog pin. The ARDUINO Mega board contains 16 channels, 10-bit analog to digital converter. This means that it will map input voltages between 0 and 5 volts into integer values between 0 and 1023. This yields a resolution between readings of: 5 volts / 1024 units or, .0049 volts (4.9 mV) per unit. Figure 4.1 shows Continuous and Discrete Time signal. [16]

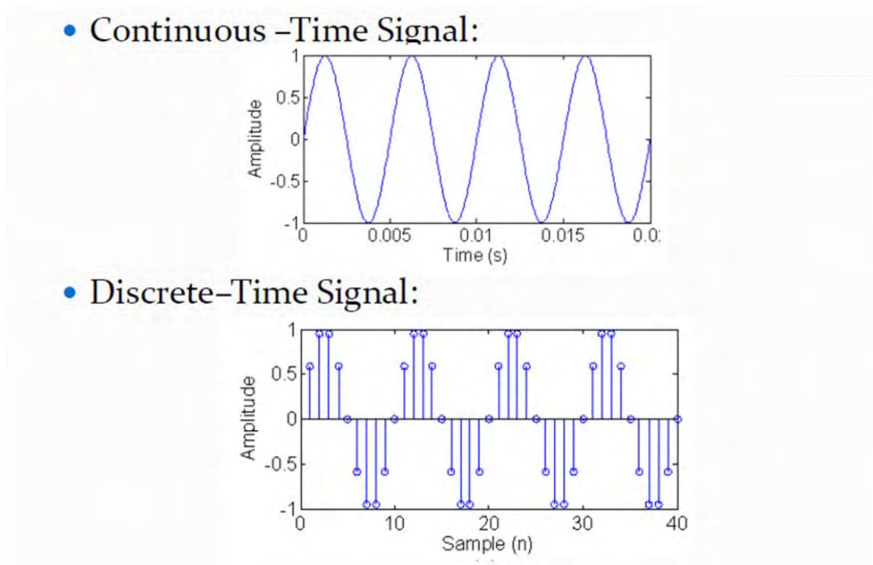



**Figure 4.1:** Continuous and Discrete Time signal [16]

**Samples:**

According to Arduino manufacturers, to execute analog Read() command it takes almost 110 microseconds. However, practically it takes 116 microseconds. We can take 9 samples maximum at every millisecond. We are taking 7 sample of current and 2 sample of voltage at every millisecond.

First, we are taking samples for 60ms and record them in array. So, we will have 420 samples for current and 120 samples of voltage of 3 cycles. The reason of taking current samples more than voltage is to reduce the noise of current sensor.

After intermediate calculations this process will be going on again and again for 1 second before doing the final calculations. The reason for this intermediate calculation is to avoid large array in the code.

So, we will have average of 50 cycles per seconds where at every cycle 140 samples of current and 40 samples of current have been taken.

## 4.2 Current Measurement

ACS712-20A has a resolution of 100mV/A. According to that we will have a output of 2.5V for 0A from sensor after ADC Arduino will get an integer of 512. So, 1023 will indicate 20A and 0 will indicate -20A.So the resolution here is 39.0625mA/unit. Figure 4.2 shows the curve of Current Measurement. [17]

However, due to noise problem 0A does not stay at 2.5V in the output or 512 after ADC always. To get rid of this problem we are simply taking the difference between maximum and minimum value and dividing it into half so that we can have pick current Imax.

$$I_{rms} = Imax \times .707$$

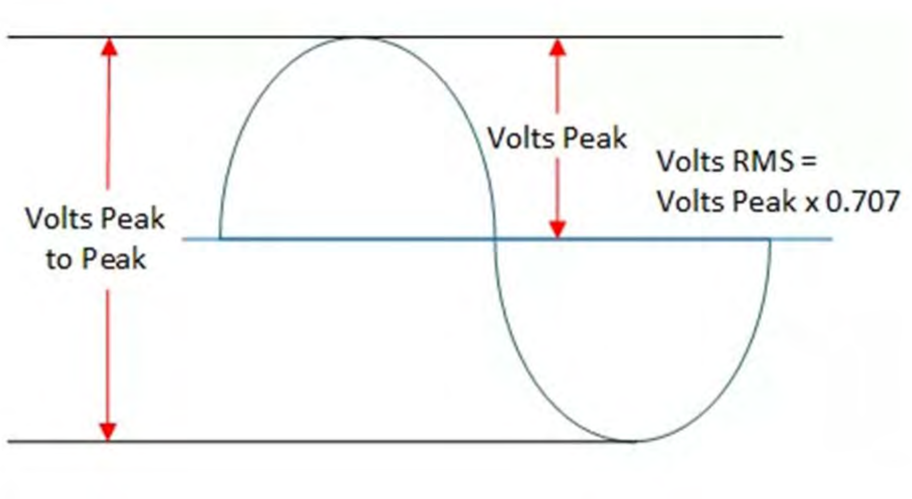



**Figure 4.2:** Current Measurement [17]

## 4.3 Voltage Measurement

**Choosing resistances for sensor circuit:**

We have selected a current of 13mA from the optocoupler datasheet. For 220V(Vrms) in the power line we will have a bit lower than 13mA allowance in the output side of optocoupler. The Vcc here will be 5V coming from the Arduino. We want to have a capability of measuring a bit higher voltage. We chose R2=330ohm so that, (5V/330ohm)=15.1mA

The transformer secondary side will give Vs in rms 12V and to have a current in the input circuit of 13 mA during peak we need a set a resistance by doing KVL.

$$(12/.707) - V_r - V_d - V_o = 0$$

Where, Vd is the voltage drop across diode, Vo is the voltage drop across the input of optocoupler and Vr is the voltage drop across resistor. Here, Vr=15.1V

So,

**R1= (15.1V/13mA**

**= 1.17k**

Figure 4.3 shows LED Forward voltage Vs Forward Current. [18]

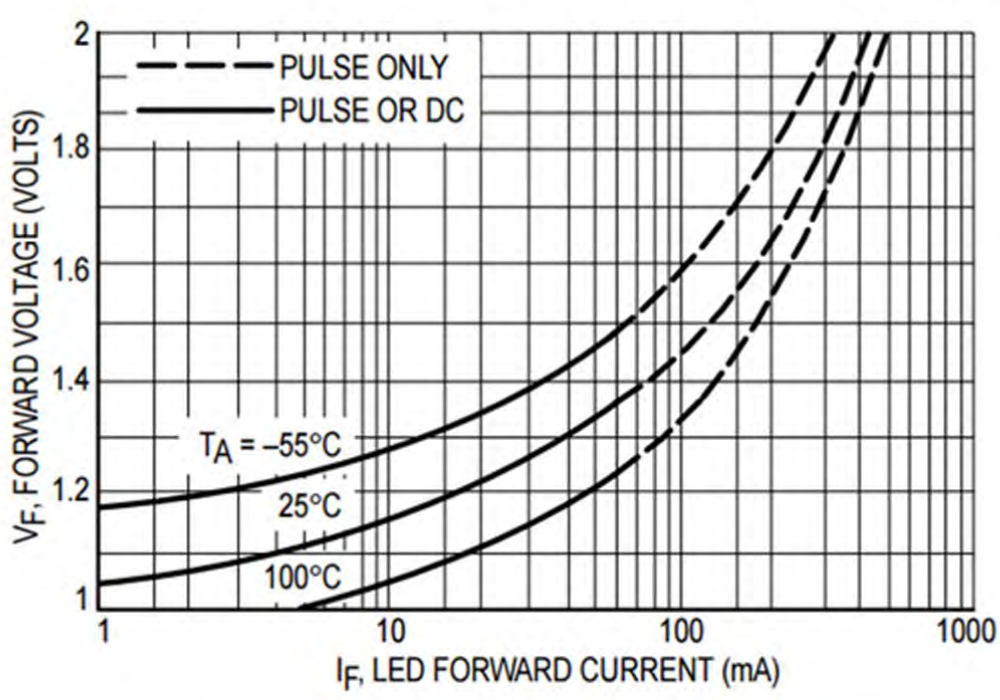



**Figure 4.3:** LED Forward voltage Vs Forward Current [18]

**Measuring voltage:**

An rms voltage of 220V has a peak volt of 311.12V. the transformer has a ratio of 18.33.So, the secondary voltage will be 16.97V. for this peak voltage current through R2 will be almost 13 mA. As a result the ouput voltage will be 4.3V. Here, the ratio of the optocoupler is 3.94.

Due to ADC conversion we need to multiply .0049 with input integer value to get voltage. So if the input is Vi then we the equation for Vrms is,

$$\mathbf{V_{rms} = V_i \times .0049 \times 3.94 \times 18.33 \times .707}$$

## 4.4Getting pF

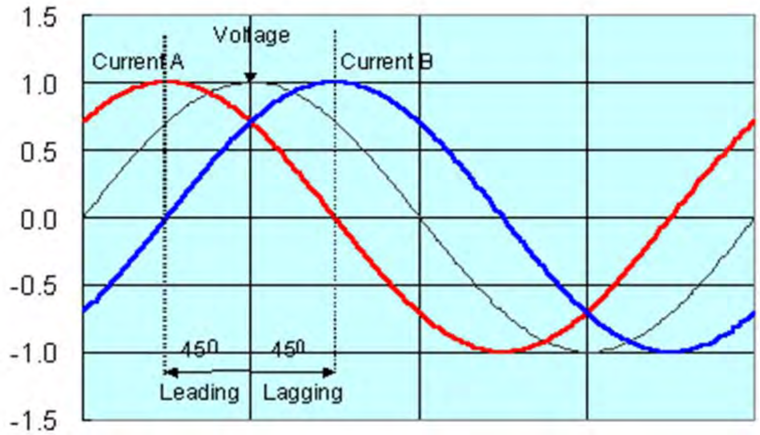



**Figure 4.4:** Getting pf [19]

Arduino has built-in clock that calculates the time has passed after starting the code. Using this we can get the time difference dt between peak voltage and peak current. Figure 4.4 shows the curve of getting power factor. [19]

We are working here with 50Hz frequency. So, at every second we will get 50 peaks for voltage and 50 peaks for current. According to our algorithm, first we are taking samples of 60 milliseconds and divide it into 3 parts so that every part gets a peak and then measuring the difference in time between voltage and current peak. Dividing the samples into parts allows to measure peak difference of voltage and current which are related to each other and prevents other peaks to interrupt. After averaging all the measured differences in one second we can calculate power factor with minimum error by following these equations:

$$\textbf{Theta} = 2 \times 3.1416 \times dt$$

Here, dt= average time difference

$$\textbf{Power factor} = \textbf{Cos(theta)}$$

Figure 4.5 shows Input voltage and current graph for resistive load from Digital Oscilloscope.

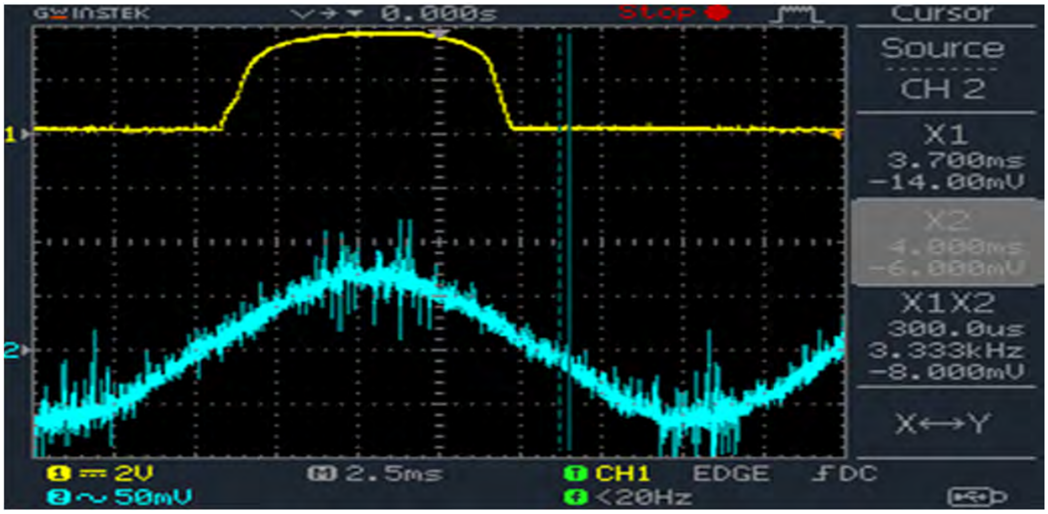



**Figure 4.5:** Input voltage and current graph for resistive load from Digital Oscilloscope

Figure 4.6 shows Input voltage and current graph for inductive load from Digital Oscilloscope

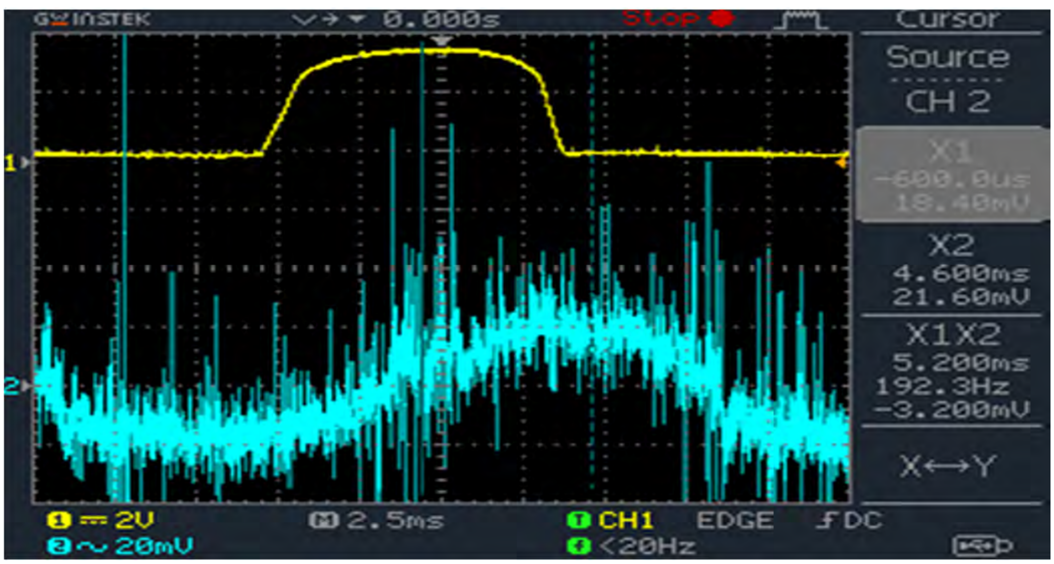



**Figure 4.6:** Input voltage and current graph for inductive load from Digital Oscilloscope

In the both figure the yellow one is the voltage graph and blue one is current graph.

## 4.5 Power Calculation

- Take samples of 60 ms
- Average rms values and power factor
- Run these 2 things for 1 second
- Average rms values and power factor
- Calculate power, $\mathbf{P = (V_{rms} \times I_{rms} \times power\ factor)\ W}$
- Get energy for this 1 second, $\mathbf{E = [\ \{\ (P \times 1) \div 1000\ \} \div 3600\ ] KWh}$

Now to get the total unit we will be adding this energy at every second and then we can find out the cost just by multiplying the per unit cost with it.

# Chapter 05
# Display Monitor

## 5.1 Introduction

Smart Monitor is used as a secondary monitor for the Smart Meter. Smart Monitor Displays Voltage (v), Current (I), Cost (Taka), Unit, Power Factor. There are three different tabs for showing readings for two rooms and overall reading.


**Figure 5.1:** Secondary Monitor

There are two parts of the Smart Monitor.

1) **Secondary Monitor:** Secondary monitor is a boxed separately from the Smart meter. It is connected by wires with the main meter. There are three different tabs for showing readings for two rooms and overall reading.

The default display is set to show overall data of the house.

First two tabs shows the data for room1 and room2 and these tabs appear when 'A' and 'B' is pressed.

Third tab is overall data for the house and it appears when 'C' is pressed.

Secondary monitor helps user to have clear view of the usage and take actions accordingly.


Figure 5.2: Secondary Monitor (Left One) and Main Meter Monitor (Right One)

2) **Main Meter Monitor:** This is the display with the main meter and has only one tab. It shows overall Voltage (V), Current(C), Power Factor, Units and Power (kWh).

Figure 5.2 shows Secondary Monitor (Left One) and Main Meter Monitor (Right One).

## 5.2 Equipment

Following equipment are used to make the circuit for the Smart Monitor.

1. Arduino Uno
2. 20x4 LCD Display Blue LED Backlight
3. Keypad 16 buttons
4. Jumper Wires

## 5.3 Purpose of using Secondary Monitor

We have used secondary monitor for room wise details calculation and alarm system during over usage. That will be placed in consumer's suitable position as consumer can see their real time update and room wise details information. Therefore, consumers will be more concern about their electricity usage.

## 5.4 Pin Configuration

| Arduino Mega | Main Display | Arduino Uno | Secondary Display |
|---|---|---|---|
| 14 | Enable | 4 | Enable |
| 15 | RS | 5 | RS |
| 17 | DS4 | 6 | DS4 |
| 18 | DS5 | 7 | DS5 |
| 19 | DS6 | 8 | DS6 |
| 20 | DS7 | 9 | DS7 |

Table 5.1: Pin Configuration for Display

| Arduino pin | Keypad | Arduino Pin | Keypad |
|---|---|---|---|
| 10 | R0 | | |
| 11 | R1 | A1 | C1 |
| 12 | R2 | A2 | C2 |
| 13 | R3 | A3 | C3 |

**Table 5.2:** pin configuration for keypad

Table 5.1 shows Pin Configuration for Display and Table 5.2 shows pin configuration for keypad.

## 5.5 Circuit Construction

At first the circuit was completed by connecting all the equipment with Arduino. Display circuit was connected according to a standard minimal circuit connection. The display is used in 4bits mode for pin shortage. As 8 bits mode requires 16pins (12 pins of Arduino) in total where 4bit mode requires 12 pins (8 pins of Arduino). Keypad was connected with four digital pins and three analog pins.

## 5.6 Programming

Arduino library from the Arduino IDE were included for smooth and quick process.

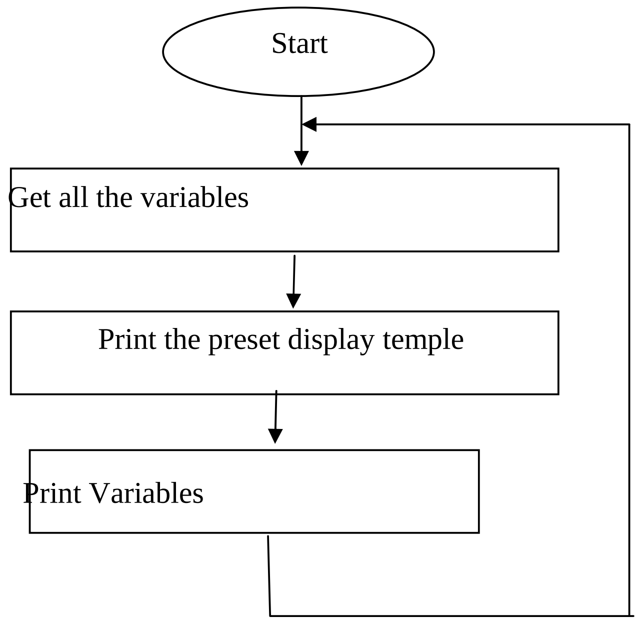
Liquid Crystal: Library for 4bit mode and 8bit mode for 20*4 display

Wire: Library for i2c serial connection over more than one Arduino.

Password: Library for setting only one password using Keypad.

Keypad: Library for standard keypad.

## 5.7Main Monitor Algorithm:



## 5.8 Secondary Monitor Algorithm:

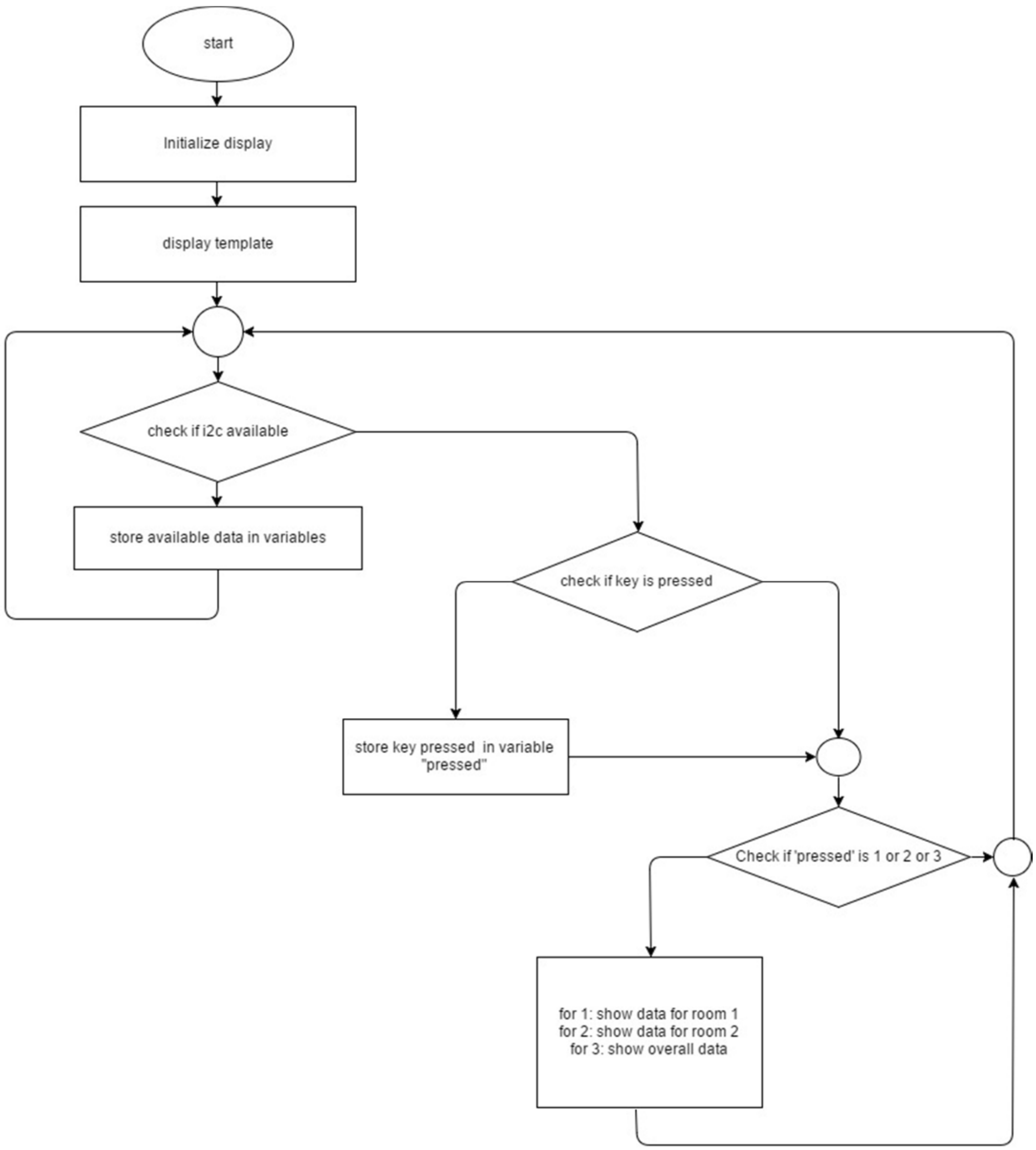



**Figure 5.2:** Secondary Monitor Algorithm

## 5.94bit and 8bit Interfacing Mode

| | 4bit | 8bit |
|---|---|---|
| 1. Pins Used | 4 I/O port pins for data and two or three additional I/O pins for control | 8 I/O port pins for data and two or three additional I/O pins for control |
| 2. Bit transfer rate | requires two 4-bit transfers for each instruction and character that is sent to the display | requires only one 8-bit transfer for each instruction and character that is sent to the display |

**Table 5.3: 4bit mode vs 8bit mode**

Working process of 8 bit mode and 4 bit mode is given bellow,

### 8-bit mode:

1. Put the data in a register

2. Output the data

3. Pulse the enable line

4. Wait until the controller is ready for the next byte of information

### 4-bit mode:

1. Put the data in a register

2. Output the upper four bits of data

3. Pulse the enable line (no delay is needed here)

4. Shift or otherwise manipulate the data

5. Output the data

6. pulse the enable line

7. Wait until the controller is ready for the next byte of information

## 5.10 Choosing 4bit mode

The instructions used to perform the tasks of manipulating the data and pulsing the enable line each takes some small multiple of 62.5nS. The time it takes to do these instructions in either mode is much less than the time that it has to wait until the LCD controller is ready for the next byte of data.

So, if it is sending a string of characters to the LCD it really doesn't matter which mode is use.

LCD displays relatively slow with 16MHz Arduino Uno. It usually like a 4-5ms to update the actual image - much slower than the data transmission time. It can send 16 bytes of data in 1ms in 4-bit mode.

So, 4-bit mode is used in interfacing this LCD display. To make the circuit less complicated.

# Chapter 6

# Database

## 6.1 Basic Information about Database

A database is an organized collection of data. Databases are basically containers for data. Because a public library stores books, we could also say that a library is a database of books. But strictly defined, databases are computer structures that save, organize, protect, and deliver data. A system that contains databases is called a database management system, or DBMS. It is a collection of programs that enables users to perform certain actions on a particular database. Figure 6.1 shows the Database System. According to Sorensen, [20] Database System can simply define as,

Database System = Database + Database Management System

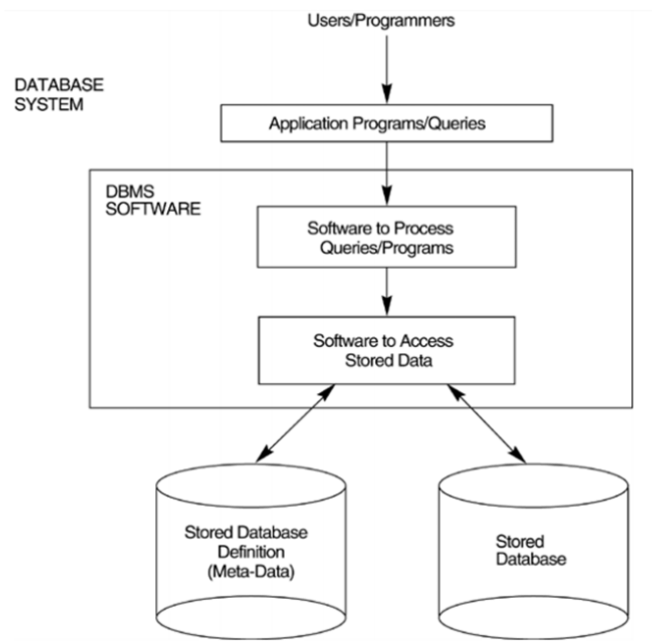



**Figure 6.1:** Database System [20]

## 6.2 Usage OF database

a) To logging data online

b) To get information remotely

c) Allow utility office to control the meter remotely

d) To establish two way communication

## 6.3 Why we are using Database

We have used database for our project to store real time data. For example, to store the values of voltage, current, Power factor and used energy etc in the database of the power distributor companies. But in order to store data in database remotely, at first we need to create server in that computer these data are going to be logged. A server is a computer program that provides services to other computer programs (and their users) in the same or other computers. Servers are often categorized in terms of their purpose. Client–server systems are today most frequently implemented by the request–response model. A client sends a request to the server, which performs some action and sends a response back to the client.

## 6.4 Our Barrier and solution

To create server database we have followed lots of method. But every method has some barriers. The main two barriers were to create two way communications between the consumers and utility suppliers and time delay to upload data.

At First, we logged data in google spreadsheet but that couldn't provide us our desire result. It couldn't create two way communication and time delay was a very important issue in that case. Since, there is no direct path to send data from Arduino to Googlespreadsheet, we have followed several steps to create our database. Firstly, we have made an excel file on Google drive. Then, we have transferred-data from Arduino to that excel file through a specific website named api.pushingbox.com [21]. Figure 6.2 shows the medium of api pushing box. This transformation is done by using code of Google script. This code is basically fetching real time data from Arduino and store them in Google excel sheet.

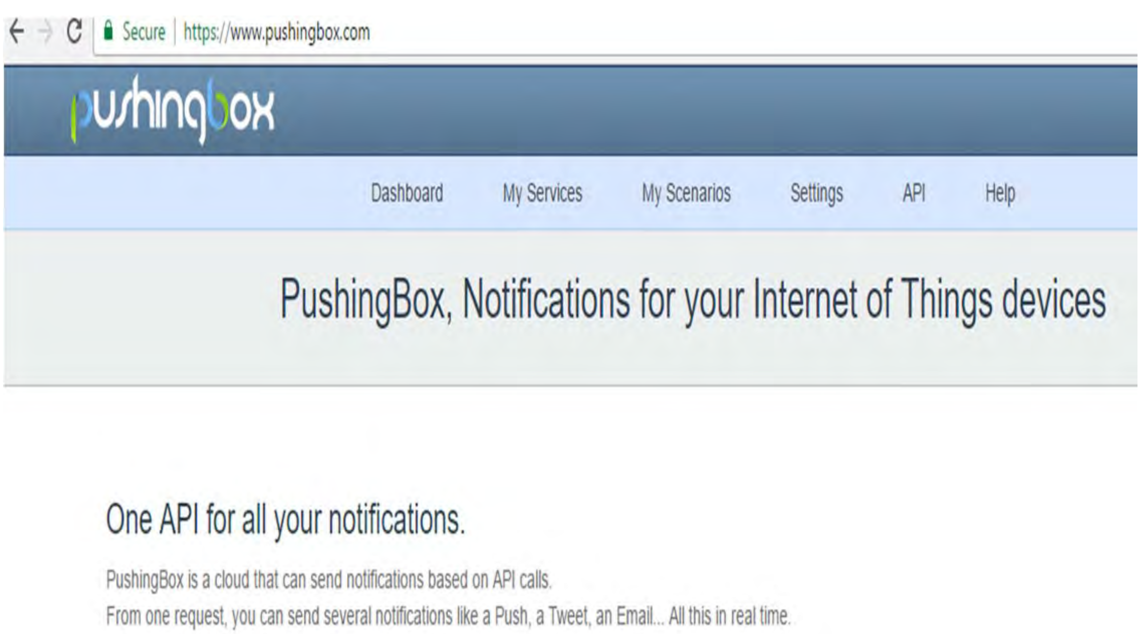



**Figure 6.2:** Medium (api.pushingbox.com) [21]

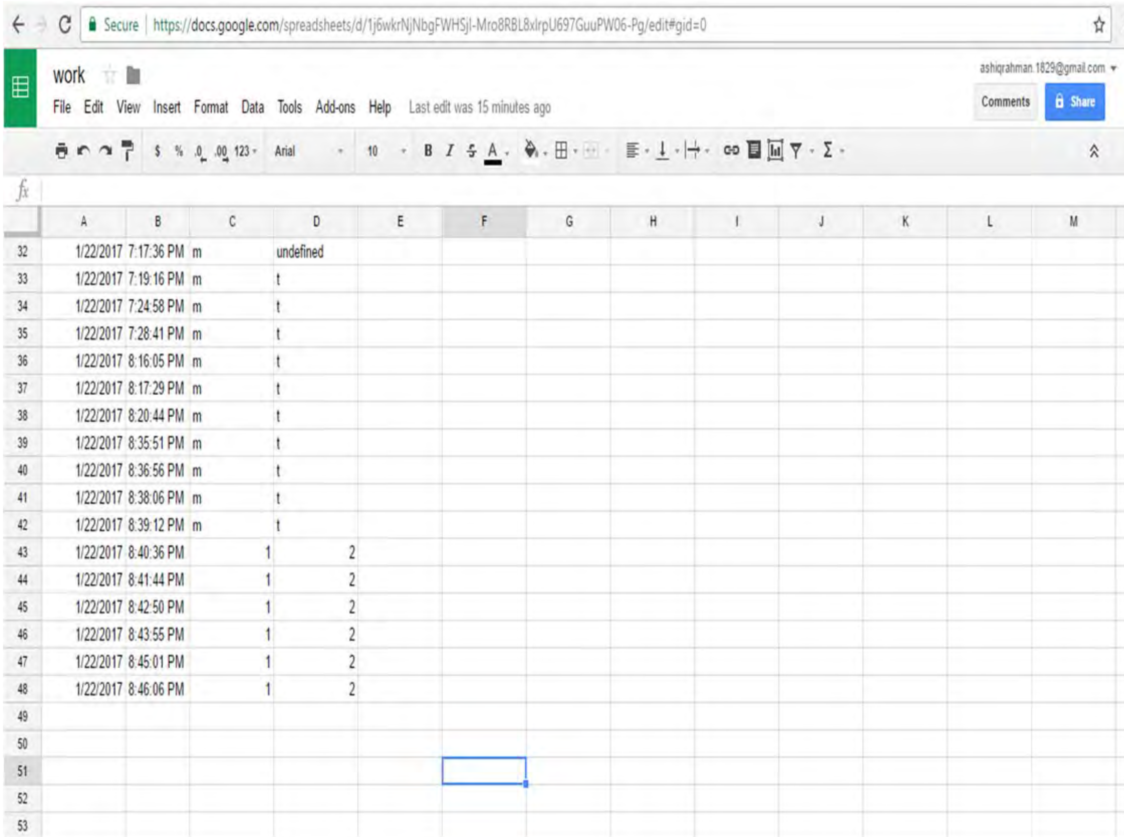



**Figure 6.3:** Google spreadsheet

Figure 6.3 shows Google spreadsheet. After that we have gone for another method. We tried some websites that provide domain to create a server. But what we have found is that none of them provides free domain and none of them able to create two way communications which is the core of the smart meter.

Then, finally we have found out the solution. With the help of software named Socket Test, we are able to create a server in the computer. What all we need is real IP (internet protocol).we have solved this issue by using the real IP of BRAC University which is provided by the BRAC University IT department. We are very grateful to them for their co-operation.

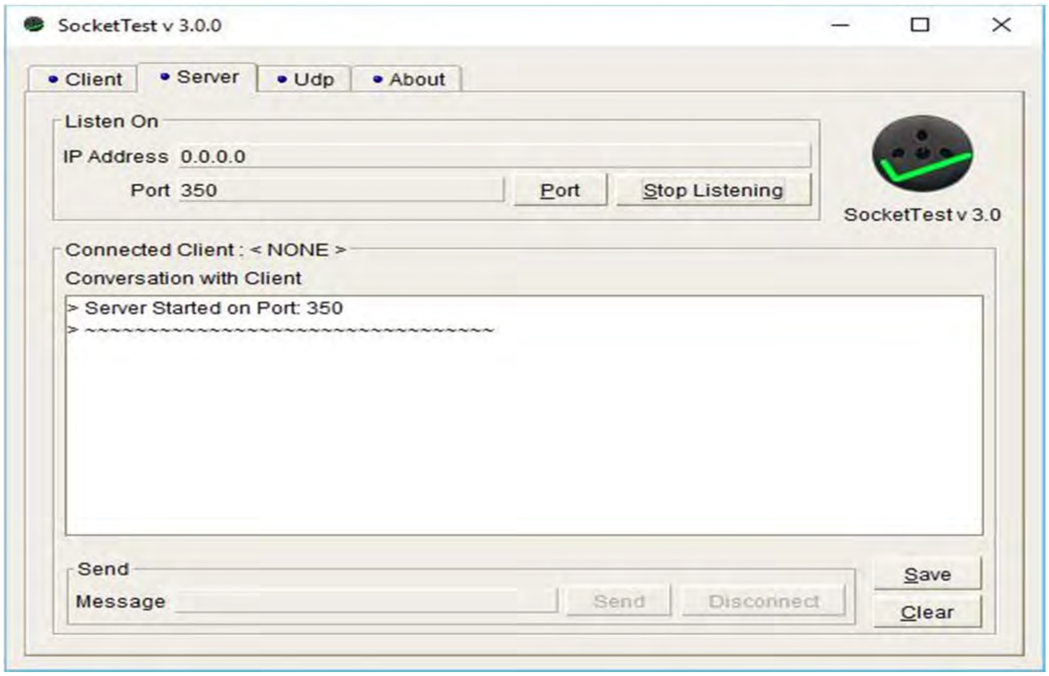



**Figure 6.4:** Socket Test V3.0.0

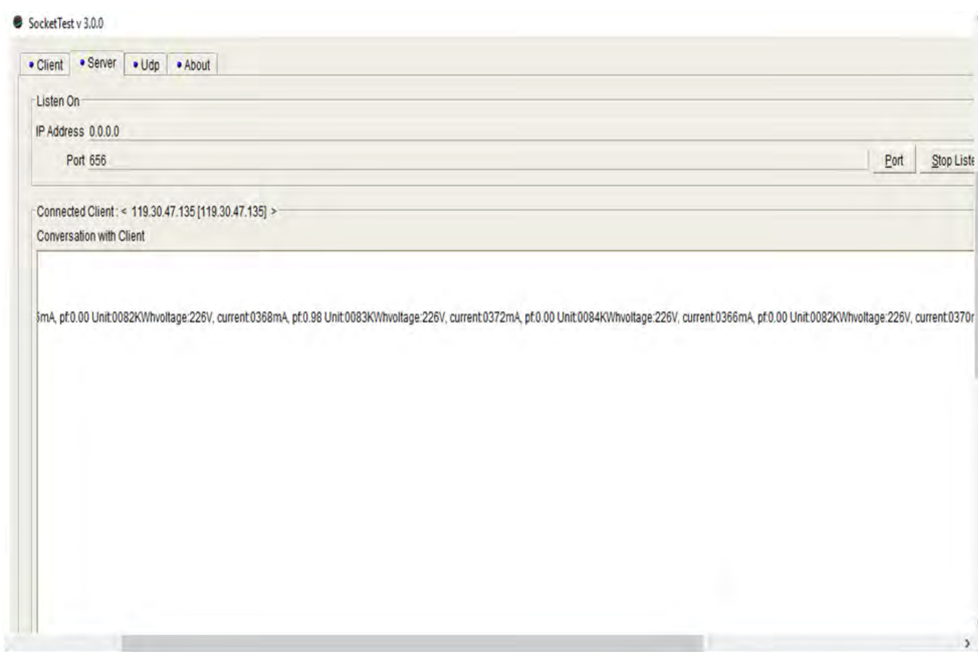



**Figure 6.5:** Data Logging Sample

## 6.5 Working Principle

By using Socket Test software we are declaring a port number in that computer. According to the IP address and port number we can send data and get access to that computer remotely through the General Packet Radio Service (GPRS) and Internet. After getting access we can log data and we can also provide command to the Smart Meter to trip the relay and again command the meter to start metering.

## 6.6 Socket Test V3.0.0

SocketTestcan create both TCP and UDP [22] client and server. It can be used to test any server or client that uses TCP or UDP protocol to communicate.

Overall working diagram of server in the computer is given in Figure 6.6.

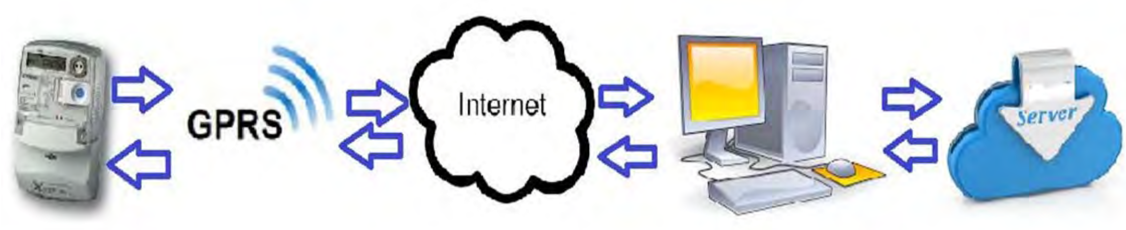



**Figure 6.6:** Overall working Diagram of database [20]

## 6.7 Server type

There are mainly two types of server we could use.

### 1. UDP ( User Datagram Protocol):

The User Datagram Protocol (UDP) [23] is a transport layer protocol defined for use with the IP network layer protocol. Butwe didn't go for UDP because it is less reliable and provide more error-checked delivery of data. Figure 6.7 shows User Datagram Protocol. [23]

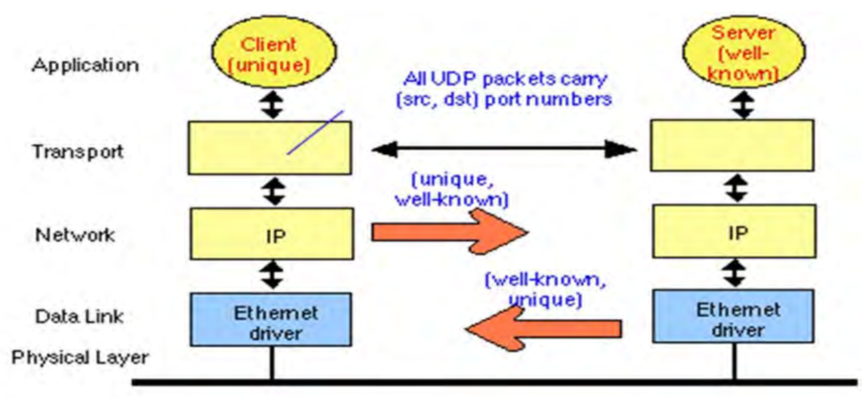



**Figure 6.7:** User Datagram Protocol [23]

## 2. TCP(Transmission Control Protocol):

The Transmission Control Protocol (**TCP**) [24] is one of the main protocols of the Internet protocol suite. It originated in the initial network implementation in which it complemented the Internet Protocol (IP). Therefore, the entire suite is commonly referred to as TCP/IP. Figure 6.8 shows Transmission Control Protocol. [24]

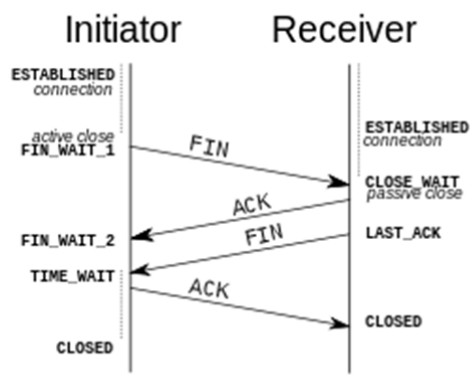



**Figure 6.8:** Transmission Control Protocol [24]

Features:

- main protocol of the Internet protocol suite
- originated in the initial network implementation
- provides reliable, ordered, and error-checked delivery of data

For, all these mentioned reasons we logged our data to a TCP server in the utility providers computer by using Socket Test software and real IP

# Chapter 7

# Data Analysis

## 7.1 Connection Setup during Test:


**Figure 7.1:** Connection Set up

This is the setup we have done for collecting data for Smart Meter. Light box is used as variable load as we can change the number of lights by switching them On or Off.

Here we have considered two lines coming from the power supply and connected with the meter in series as input. Meanwhile, as output we have considered both side load as overall consumption and Load on the right side as Room 01 Consumption.

Two lines coming out from power supply were connected to the input of the meter.There are two output lines, one for overall and one for room1 only.


**Figure 7.2:** Clamp Meter

To compare the current readings that we are getting from the smart meter, we have used clamp meter which is showed in figure 7.2. We have used clamp meter to do error analysis basically so that we can reduce the error of the meter.

## 7.2 Testing

After checking all the connections perfectly, we switched on the power line.

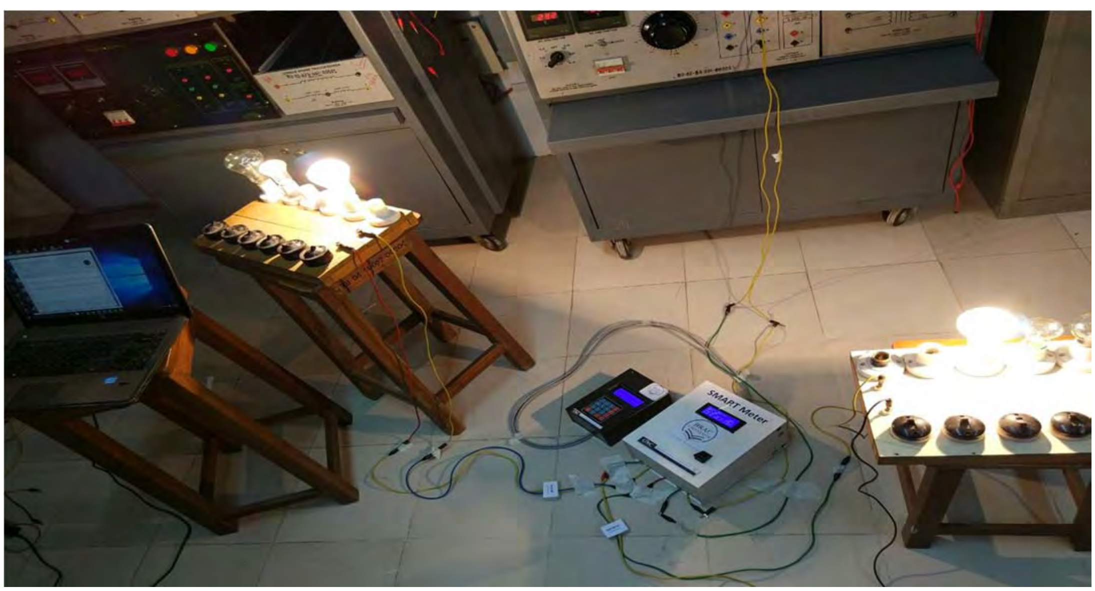



**Figure 7.3:** Switch on the connection

In Figure 7.3, we have considered left side load as Overall consumption and Right side load as Room 01 Consumption. The laptop that is shown in that given picture is considered as Suppliers side server. From suppliers end, suppliers can monitor and trip whole the system.


**Figure 7.4:** Getting Overall Electricity Consumption from Meter

In Figure 7.4, left one is our Secondary Monitor and right one is our main monitor. In Main Monitor will show in total five(05) things, these are power factor, Voltage, Current, Power and Energy. On the other hand, Secondary monitor will show overall consumption as well as room wise consumption. Here, pressing room three (03) means to show the overall consumption. In that case, secondary monitor will show exactly same thing which is displayed in the main meter except one additional value which is cost. Consumers can see their real time cost over there.


**Figure 7.5:** Getting Electricity Consumption for Room1 from Meter

In Figure 7.5, pressing one (01), consumers can see their electricity consumption of room 01. Like this, consumers will see their room wise electricity consumption and through this consumers concern will increase about their electricity usage which will create a positive impact to save our electricity.

## 7.3 Tripping Portion

Since, this meter allows two ways communication which enables the authorization of tripping the meter and retraining the meter sitting from the utility office through Server by giving commands “STOP” (Which is given in figure 7.6) to trip the overall system and “STaRT” (Which is given in figure 7.7) to reconnect the system.

## 7.4Data Analysis

### 7.4.1 Current:

| Ammeter(A) | Meter reading(A) | Error (%) |
|---|---|---|
| 0.18 | 0.19 | 5.55 |
| 0.27 | 0.26 | -3.46 |
| 0.46 | 0.45 | -2.17 |
| 0.52 | 0.54 | 3.84 |
| 0.84 | 0.86 | 1.17 |
| 0.95 | 0.94 | -1.10 |
| 1.08 | 1.06 | -1.38 |
| 1.20 | 1.21 | 0.83 |
| 1.99 | 2.00 | 0.50 |
| 2.50 | 2.51 | 0.40 |
| 2.80 | 2.82 | 0.71 |
| 3.23 | 3.22 | -0.31 |
| 3.44 | 3.45 | 0.30 |
| 3.69 | 3.71 | 0.54 |
| 4.21 | 4.19 | -0.47 |
| 4.71 | 4.72 | 0.21 |
| 4.99 | 5.00 | 0.20 |

**Table 7.1:** Current analysis

According to manufacturer Acs712-20A has a resolution of 100mV/A and it has a noise of 11mV which means there will be a noise of 110mA. To minimize the error as many as possible samples have been taken. Their average value gives significantly less error. These data shows that the meter reading gives an error of 20mA highest. However, it reads a bit higher in some seconds again reads a bit lower in some seconds. As a result we can say that it gives almost accurate reading.

### 7.4.2 Voltage:

| Voltmeter | Meter Reading | Error |
|---|---|---|
| 0-50 | 0 | 0-100 |
| 60 | 141 | 135 |
| 80 | 165 | 106.25 |
| 110 | 186 | 69.1 |
| 140 | 202 | 44.2 |
| 170 | 210 | 23.52 |
| 200 | 215 | 7.5 |
| 220 | 221 | 0.45 |
| 222 | 222 | 0 |
| 224 | 223 | -0.44 |
| 226 | 228 | 0.88 |
| 230 | 230 | 0 |
| 235 | 231 | -1.7 |
| 237 | 232 | -2.11 |

**Table 7.2:** Voltage Analysis

The voltage read by meter from 0-100V is considered a 0V. This has been done by the algorithm to minimize error. That is why for 0-50V in the power line there was no meter reading. According to the circuit and our chosen current through the optocoupler the operating voltage was 220. The multiplication factor was set in the algorithm according to that. To have the operating voltage range from 220-230V two multiplication factor was set. That is why the error in this range is significantly lesser than others.

### 7.4.3 Power factor

| Load(ohm) | Calculated power factor | Meter reading | Difference | Error (%) |
|---|---|---|---|---|
| 194 | 1.00 | 1.00 | 0 | 0 |
| 388 | 1.00 | 1.00 | 0 | 0 |
| 490 | 1.00 | 0.99 | .01 | -1 |
| 388+j408.4 | 0.95 | 0.93 | .02 | -2.1 |
| 388+j471.24 | 0.82 | 0.80 | .02 | -2.4 |
| 388+j596.9 | 0.65 | 0.67 | .02 | 3.07 |

**Table 7.3:** Power Factor analysis

Power factor calculation is really a sophisticated measurement because here the time delays are within millisecond and microsecond range. For resistive load our meter works fine but for inductive load some error appears.

### 7.4.4 Watt

| Wattmeter | Meter reading | Error |
|---|---|---|
| 56.7 | 58 | 2.29 |
| 95.1 | 96.6 | 1.57 |
| 125 | 126.5 | 1.21 |
| 185 | 187.4 | 1.29 |
| 210 | 209.1 | -0.42 |
| 237.5 | 234.6 | -1.30 |
| 265 | 265.8 | 0.30 |
| 330 | 333.5 | 1.05 |
| 377.5 | 380.1 | 0.68 |
| 440 | 438.1 | -0.43 |
| 555 | 557.7 | 0.48 |
| 660 | 660.5 | 0.07 |
| 740 | 739 | -0.13 |
| 800 | 805.1 | 0.63 |
| 960 | 962.3 | 0.24 |
| 1100 | 1098 | -0.18 |

**Table 7.4:** Watt Analysis

Above data were taken by connecting wattmeter with light bulbs at 230V.

# Chapter 08

# Future Work and Conclusion

To take this project even further, we are planning to add two new features. First one is, Gas Meter and another one is prepaid system. We already have prepaid meter in our country. According to DESCO's official website [25] they installed 10,000 single phase meter and 1000 three phase meter in Uttara residential area. Another 1,00,000 prepaid meters are all most complete for other residential area like Gulshan, Banani, Mirpur and Baridhara.

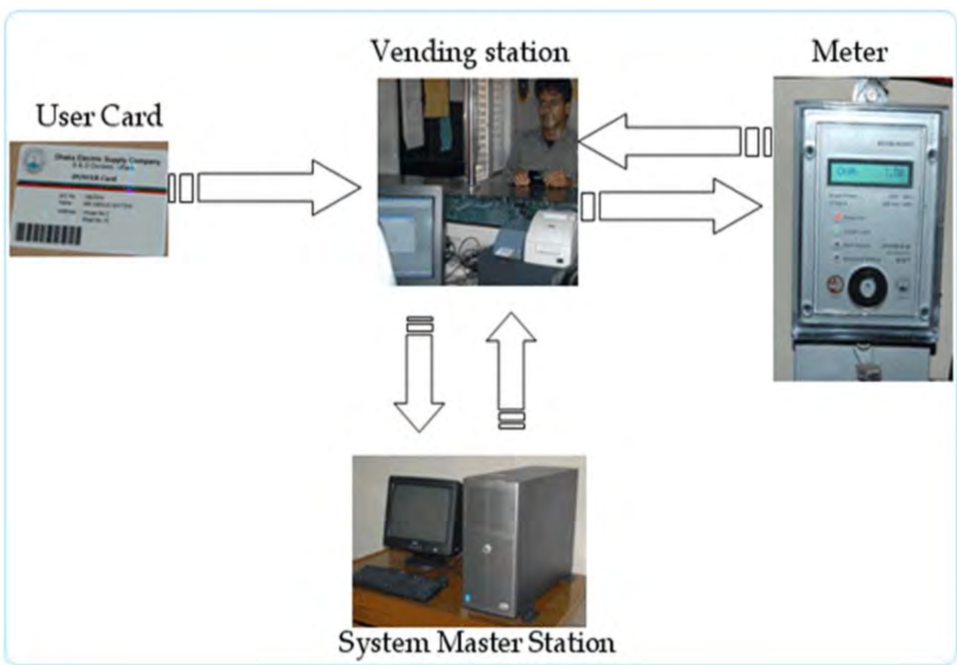



**Figure 53:** Prepaid System by DESCO [25]

A Gas Meter is specialized flow meter [26], used to measure the volume of fuel gases such as natural gas and propane. Bangladesh is the seventh largest producer of natural gas in Asia. Due to huge amount of misuse our Gas reserve is decreasing day by day. If consumers supposed to pay their Gas Bill like electricity bill then they might be more concern about their usage. The only way to stop misuse of gas is Gas Meter. For that there is no need to use a spate meter for Gas measurement. One Smart meter can handle both Gas and Electric Meter.

In brief, our future work will be to include gas meter and prepaid system in our Smart Meter. Finally that will be the complete Smart Meter including all the features.

The main objective of this project was to introduce both way communications through internet using Smart Meter. This meter will ensure a more secure and transparent billing and monitoring system. Users will get more clear bills and real-time usage availability will rise concern about wasting electricity. This will bring benefit to both consumers and country as the vision 2021 of making electricity available to 100% population will get a big boost if energy wastage is used.This meter designed in a different way from the exiting meter. Distributors will be able to have more control over the distribution system and the country will get a more advance and smart power distribution system. Moreover, the electricity stealing will reduce and government will be able to get more revenue and less loss. In short, to introduce a smart and advance grid aka ‘Smart Grid’ to developing countries like Bangladesh, Smart Meter will be the first step of a new era in case of Power Management and Distribution.

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# Appendix

```
/**************************************************
  This is the code for Arduino Mega which includes:
  1.Fingerprint sensor code
  2.Energy meter code
  3.SD card code
  4.Meter display code
  5.Transmission to other arduino code

  The code has been written by Smart Meter Group.
  For fingerprint sensor we took help and modified  from:
  ----> http://www.adafruit.com/products/751
 **************************************************/
// these libraries have been used
#include <Adafruit_Fingerprint.h>
#include <SoftwareSerial.h>
#include <Wire.h>
#include <SPI.h>
#include <SD.h>
#include <LiquidCrystal.h>

//Initializing…
LiquidCrystallcd(19, 18, 17, 16, 15, 14);
```

```
lcd.begin(20, 4);
finger.begin(57600);
Wire.begin();
 if(!SD.begin(4)) {
Serial.println("initialization failed!");
  return;
 }
 else  {Serial.println("initialization done.");}

//Waiting for valid fingerprint…
lcd.clear();
lcd.setCursor(1, 1);                                  //setting lcd display
lcd.write("Waiting for a");
lcd.setCursor(1, 2);
lcd.write("valid  finger...");
Serial.println("Waiting for valid finger...");
 while (1 == 1) {                                     // These loop continuously check for
fingerprint
intgetFingerprintIDez();                              // and breaks out when given one is valid

// looking for previous data…
 if (SD.exists("example3.txt")) {

myFile = SD.open("example3.txt");
  if (myFile) {
```

```
     while (myFile.available()) {
....
else {
   if (SD.exists("backup2.txt")) {
myFile = SD.open("backup2.txt");
     if (myFile) {
      // read from the file until there's nothing else in it:
      while (myFile.available()) {
…
//Reading samples…
unsigned long at = millis();
   count = 1;
i = 1;
   v = 1;
   while ((millis() - at) < 60) {
     a[i] = analogRead(A0);      //1
i = i + 1;
     a[i] = analogRead(A0);   //2
i = i + 1;
     b[v] = analogRead(A1);     //1 v
     v = v + 1;
//transmitting..
Wire.beginTransmission(8);       // transmit to device #8
Wire.write(mn);
Wire.endTransmission();
```

```
/*************************************************
  This is the code for Arduino Uno which includes:
  1.GSM code
  2.Secondary display Code
  3.Keypad code
  4.reception from the other arduino code

  The code has been written by Smart Meter Group.
  For the Keypad code we took help and modified from:
   //http://www.arduino.cc/playground/uploads/Code/Keypad.zip
 *************************************************/
// These libraries have been used…
#include <SoftwareSerial.h>
#include <LiquidCrystal.h>
#include <Keypad.h>
#include <Wire.h>
//Initializing…
LiquidCrystallcd(8, 9, 10, 11, 12, 13);
SoftwareSerial GPRS(2, 3);
Wire.begin(8);
//connecting to sever…
GPRS.println("AT");           // Signal quality check
  delay(200);
ShowSerialData();              //this method also shows if any command is available from server
```

```
…
//keypad command check
  if ( pressed != NO_KEY){
    pressed1 = pressed;
    switch ( pressed) {
      case 'A':
lcd.clear();
lcd.setCursor(0, 0);
lcd.print("Smart Monitor");
lcd.setCursor(15, 1);
//receive event from other arduino…
void receiveEvent(inthowMany) {
  char mn[30];
inti = 0;
  while (1 <Wire.available())      // loop through all but the last
  { mn[i] = Wire.read();                // receive byte as a character
// Converting data into Char array for uploading…
  V[15] = ((w - 1000 * V[13]) - 100 * V[14]) / 10;
  V[16] = (((w - 1000 * V[13]) - 100 * V[14]) - 10 * V[15]);
  char u[51] = "voltage:***V, current:****mA, pf:*.** Unit:****KWh";
  u[8] = V[0] + 48;
  u[9] = V[1] + 48;
  u[10] = V[2] + 48;
```