Energy Monitoring and Analysis for 3 phase systems

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The Degree of Master of Technology

Department of Electrical Engineering

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Declaration

I declare that this written submission represents my ideas in my own words, and where ideas or words of others have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be a cause for disciplinary action by the Institute and can also evoke penal action from the sources that have thus not been properly cited, or from whom proper permission has not been taken when needed.

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Approval Sheet

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I thank my fellow labmates in for the stimulating discussions, and my brother-in-law and sister for supporting me spiritually throughout writing this thesis and my life in general.

Dedication

To my brother-in-law for his unconditional love and support for putting me through the best education possible. I appreciate his sacrifices and I wouldn't have been able to get to this stage without him.

Abstract

Nearly 26% of energy consumption in India is from commercial buildings. Also, as per US energy information agency, commercial building energy consumption is growing at 2.7% rate every year in India. Because of not having proper energy monitoring systems, most of the energy consumption in buildings is going into waste. In this regards this thesis presents a solution for building energy monitoring and analysis on the data obtained from the 3 phase energy monitoring. The data for energy monitoring is obtained using Multi Functional Meter, which measures electrical qualities like voltage,current,powers etc. The meter supports RS 485 communication, which is used to collected the data from the meter. First, by monitoring the collected data, sending an alert mail to the respective employee to avoid the overloading of power cables is presented. Secondly, data analysis on the obtained data are presented. In the analysis of the data some factors like load factor, Unbalance factor, rise time, high load duration period are calculated from the obtained load curve. These parameters will help the building operator or manager in proper utilization of the energy consumption of a commercial building. Thirdly, interfacing multi functional meter with arduino is proposed in order to get full control over the meter. For validation the proposed solution is applied to a commercial IITH building and the results are presented.

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Chapter 1

Introduction

With the increase in urbanization, energy consumption is increased day by day. Especially energy consumption is more in commercial buildings, industries, hospitals, etc. This leads to imbalance in demand and supply. Energy saving and CO_2 reduction are the main challenges for government of India. Deployment of information and communication technology (ICT) is the basic step for achieving this objective. Since commercial buildings are one of the major contributors in CO_2 emissions, deployment of ICT technology for monitoring of building energy consumption is important [1].

In [2] a low cost solution for energy monitoring and data analytics on the energy consumption of a commercial building is proposed. Advantage of this solution is that the load current monitoring is done without disturbing the existing infrastructure. There is no line or cable cutting or power shutdown required for implementation of the solution proposed. Also, the advantages of energy monitoring in a commercial building is explained by introducing the calculations of some of the factors like load factor, current unbalance factor, rise time, fall time and high load duration.

In [3] voltage unbalance factor is defined for evaluating the voltage unbalances in the industrial building. Also the effects of unbalances are explained which includes mal-operation of relays, voltage regulation of the equipment etc. Functional characteristics in top-down and bottom up approaches for residential load curve analysis is carried out in [4]. Authors concluded that bottom up approach is defined as the best approach for load curve analysis of residential buildings. In [5] authors explained about the peaks and valleys identification using the load curve data.

Fig.1.1 shows the Lighting panel of the IITH academic bulding. Distribution of lighting to the whole building is given from this panel. In this, all multi functional meters are each connected to lighting distribution of the building. The lighting energy consumption is measured by these functional meters. These meters support RS485 communication which is used for the collection of energy consumption data to perform energy monitoring.

Figure 1.1: Lighting Panel

Chapter 2

Energy Monitoring

2.1 Objective

If a phase is getting overloaded during a particular duration of time, an alert email will be sent to respective employee to take necessary action. To achieve this,continuous energy consumption data is required. This data is obtained from the Multi Functional Meters through RS485 communication.

This chapter is divided into six sections. In first section, the description about the Multi Functional Meter and the Slave ID settings, Baud rate settings of the meter are given. In second section, Data retrieval from the meter is explained. In the third, the collected data from the meter is preprocessed followed by the creation of the data base to store the preprocessed data is explained. In fifth, alerting the employee by sending an email is explained. In sixth, experimentation is performed on the collected data.

2.2 Multi Functional Meter

A 3-phase 4-wire Multi Function NOVA L&T Meter measures all the electrical qualities like voltage, current, active power,energy, frequency and power factor etc. As shown in the Fig.2.1 this meter has 3 buttons, those are scroll UP key, scroll DOWN key, select key.

2.2.1 Communication Interface Details

Multi Function Meter supports RS485 communication, which is used to obtain the measured values from the meter. In the pin diagram of the meter given in Fig.2.2, 7 and 8 pins are used for RS485 communication.

The configuration details to communicate with the meter are

- **Standard** is RS485(half duplex).
- **Baud Rate** can be selectable (19200,9600,4800,2400,1200). But default is 9600.

Figure 2.1: 3P4W Multi Function Meter

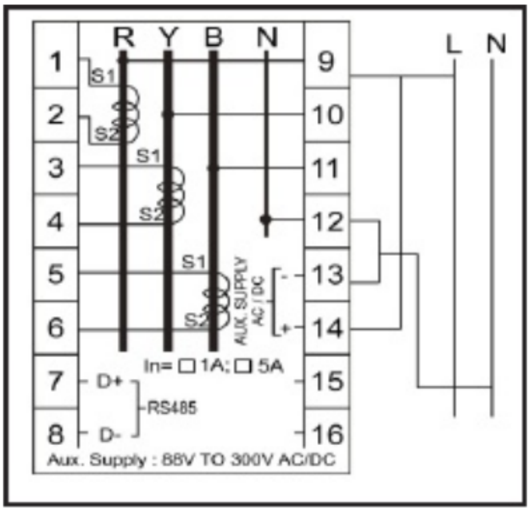

Figure 2.2: Pin Diagram of 3P4W MFM

- **Parity** can be selectable (None, Odd, Even). But default is Even.
- **Protocol** used is MODBUS Protocol in RTU mode for RS485 interface. In this communicating with the meter involves sending commands to the meter for reading and writing the particular register of meter. The meter can be addressed with specific user defined meter address (Slave ID) from 1 to 247.

2.2.2 Communication Parameters Setting

In order to communicate with the meter, it's communication parameters like Baud Rate, Slave ID, Parity have to be configured. To configure these parameters, meter should be changed to programming mode. This can be done by holding the SELECT and scroll UP keys of Multi Functional Meter.

To set the Baud Rate, steps to be followed are

1. In the Programming Menu, press and hold scroll UP key to get "Set Port" and then press SELECT key.
2. **Baud Rate selection(1200 to 19200):** Use UP key to select the desired baud rate then press SELECT key to set.

To set the Parity, steps to be followed are

1. In the Programming Menu, press and hold scroll UP key to get "Set Port" and then press SELECT key.
2. **Parity(Even/Odd/None):** Use UP key to select the desired Parity then press SELECT key to set.

To set the Slave ID, steps to be followed are

1. In the Programming Menu, press and hold scroll UP to get "Set SL Id" and then press SELECT key.
2. Press UP key to increment the SL Id value. Press together UP and SELECT key to shift to next digit.
3. Press select key to set the id. Slave id can be set from 1 to 247.

2.3 Data Retrieval

Once communication parameters of the meter are configured, obtaining the energy consumption data of the building is the first challenging thing. The solution for this problem is explained in [6]. Here meter is used as a Slave, from where data has to be collected. RaspberryPi is used as the Master, since it is easy to mount the Pi at any place rather than the computer. FTDI based USB to RS485 converter cable is used as an interface between RaspberryPi and the meter, which provides a fast and simple way to connect devices with a RS485 interface to USB.

From the Fig.2.2 it is shown that pins 7,8 are used for RS485 communication. The required hardware to collect the data from the meter is mentioned in TABLE 2.1. Connection between the meter and FTDI based USB to RS485 converter is as shown in TABLE 2.2. When the connection are finished, plug the FTDI based USB to RS485 converter to RaspberryPi.

The meter is accessed by RaspberryPi using the Slave ID of meter and communication parameters like baudrate,parity. The energy consumption data is stored in registers of the meter. The registers corresponding to the required data can be accessed through some functions with input parameters as function code and the register addresses. For example. To read the data from the meter,the function 'read_registers(R1,R2,function code)' can be used, where R1 is the start register, R2 is end register, function code tells whether those registers are read only or writable.

Once data is collected from read registers, Time and Date are appended to the data, so that it can be easily distinguishable with the previously collected data.

The data monitoring is continuous throughout time, so a storage device(Computer) is used to store the collected data. Later it can also be extended to cloud storage. The computer is accessed through the SSH from the RaspberryPi. So the data is send to the computer for storage in the form of text file or csv file. The stored data in computer is as shown in Fig.2.3.

Table 2.1: Components Required

Components	**Quantity**
RaspberryPi	1
3P4W multi function meters	
FTDI based USB to RS-485 converter	1

Table 2.2: RS485 converter to Meter connections

Functional meter	**USB to RS-485 converter**
D+	A
D-	B

2.4 Data Preprocess

The data in Fig.2.3 is stored as line by line. Each line of the file consists the data,and it's collected date and time. The data measured from the meter is actually stored in integer format. In each line total 16 instantaneous parameters are read by the read registers using function code as 4. Each parameter is of 2 words, where each word is of 8 bit length. So the parameters are stored in odd addresses, therefore total registers to be accessed are 32. where half of them will be zero. For example. Phase 1 voltage can be accessed by the address 01 with function code 04 and Phase 2 voltage can be accessed by the address 03 with function code 04.

The preprocessing is done in three steps. Those are

```
2018-04-17 00:45:57.3007[0, 24135, 0, 24284, 0, 24529, 0, 3643, 0, 7119, 0, 0, 0, 8504, 0, 16136, 0, 0, 0, 24316, 0, 3587, 0, 24645, 0, 4991,
93, 37692, 0, 0, 0, 5, 65535, 65440]
2018-04-17 00:45:59.4649[0, 24136, 0, 24280, 0, 24523, 0, 3645, 0, 7055, 0, 0, 0, 8504, 0, 16136, 0, 0, 0, 24313, 0, 3567, 0, 24640, 0, 4990,
93, 37692, 0, 0, 0, 5, 65535, 65440]
2018-04-17 00:46:01.6258[0, 24136, 0, 24281, 0, 24493, 0, 3653, 0, 7085, 0, 0, 0, 8512, 0, 16134, 0, 0, 0, 24303, 0, 3579, 0, 24647, 0, 4990,
93, 37692, 0, 0, 0, 5, 65535, 65440]
2018-04-17 00:46:03.7865[0, 24150, 0, 24233, 0, 24517, 0, 3658, 0, 7118, 0, 0, 0, 8521, 0, 16135, 0, 0, 0, 24300, 0, 3592, 0, 24657, 0, 4990,
93, 37692, 0, 0, 0, 5, 65535, 65440]
2018-04-17 00:46:05.9621[0, 24136, 0, 24265, 0, 24510, 0, 3645, 0, 7104, 0, 0, 0, 8521, 0, 16135, 0, 0, 0, 24304, 0, 3583, 0, 24657, 0, 4990,
93, 37692, 0, 0, 0, 5, 65535, 65440]
2018-04-17 00:46:08.1232[0, 24152, 0, 24259, 0, 24519, 0, 3633, 0, 7056, 0, 0, 0, 8513, 0, 16135, 0, 0, 0, 24310, 0, 3563, 0, 24648, 0, 4989,
93, 37692, 0, 0, 0, 5, 65535, 65440]
2018-04-17 00:46:10.2857[0, 24119, 0, 24256, 0, 24499, 0, 3633, 0, 7108, 0, 0, 0, 8522, 0, 16124, 0, 0, 0, 24291, 0, 3580, 0, 24647, 0, 4989,
93, 37692, 0, 0, 0, 5, 65535, 65440]
2018-04-17 00:46:12.4487[0, 24135, 0, 24253, 0, 24508, 0, 3650, 0, 7080, 0, 0, 0, 8513, 0, 16117, 0, 0, 0, 24299, 0, 3577, 0, 24636, 0, 4989,
93, 37692, 0, 0, 0, 5, 65535, 65440]
2018-04-17 00:46:14.6103[0, 24125, 0, 24238, 0, 24501, 0, 3637, 0, 7073, 0, 0, 0, 8513, 0, 16117, 0, 0, 0, 24288, 0, 3570, 0, 24631, 0, 4988,
93, 37692, 0, 0, 0, 5, 65535, 65440]
2018-04-17 00:46:16.7706[0, 24110, 0, 24234, 0, 24488, 0, 3631, 0, 7069, 0, 0, 0, 8506, 0, 16121, 0, 0, 0, 24277, 0, 3567, 0, 24627, 0, 4988,
93, 37692, 0, 0, 0, 5, 65535, 65440]
2018-04-17 00:46:18.9350[0, 24134, 0, 24261, 0, 24495, 0, 3650, 0, 7118, 0, 0, 0, 8512, 0, 16113, 0, 0, 0, 24297, 0, 3589, 0, 24626, 0, 4988,
93, 37692, 0, 0, 0, 5, 65535, 65440]
```

Figure 2.3: Stored Data

1. **Data separation:**
   The data separation is done in line by line. Each line is accessed in sequence, and is separated into 3 parts. First one comprises of date of the data collected, second one comprises of time of the data collected, and the last one is the measured data itself. The measured data is an array of 34 values. But only the values which are in odd numbered indices are the actual instantaneous parameter values. The odd numbered indices only considered and stored in a new array, in order to get rid of the unnecessary values.

2. **Complement the Data:**
   In a new array indices 3,4,5,6,7,8,11,16 are in $2^{'}$s complement form. So this new array each parameter value is accessed and converted to binary format of length 16 bit. In this binary number, if the 16th bit(MSB) is 1 then that means the number is in $2^{'}$s complement form. So, that number has to be $2^{'}$s complemented.

3. **Data Conversion:**
   Once the complement of the data is finished, the whole data is in integer format. But each parameter actual value can be obtained by multiplying with the multiplying factors corresponding to each parameter as shown in TABLE.2.3. Here it should be observed that, all active powers are considered in kWs after the conversion.

Once the preprocessing is done, the data looks like in the Fig.2.4. In the Figure it is clearly shown that not only the Date and Time but also the measured data is separated into 16 columns where each column corresponds to the actual instantaneous parameter.

2.5 Database Creation

MariaDB is a community-developed fork of the MySQL relational database management system intended to remain free under the GNU GPL. It is used for creation of the database for the meter data

Table 2.3: Addresses and Multiply Factors for Parameters

Address	**Instantaneous Parameter**	**Multiplying Factor**
30,001	Phase 1 Voltage	0.01
30,003	Phase 2 Voltage	0.01
30,005	Phase 3 Voltage	0.01
30,007	Phase 1 Current	0.001
30,009	Phase 2 Current	0.001
30,011	Phase 2 Current	0.001
30,013	Phase 1 Active Power	0.0001
30,015	Phase 2 Active Power	0.0001
30,017	Phase 3 Active Power	0.0001
30,019	Average Voltage	0.01
30,021	Average Current	0.001
30,023	Total Active Power	0.0001
30,025	Line Frequency	0.01
30,027	Cumulative kWh Energy	0.01
30,029	Power in Mega/Kilo	
30,033	Total Power Factor	0.01

m1date	m1time	P1V	P2V	P3V	P1I	P2I	P3I	P1AP	P2AP	P3AP	AV	AI	TAP	LF	CumE	Power	TPF
2018-04-17	00:45:57	241.35	242.84	245.29	3.643	7.119	0.000	0.8504	1.6136	0.0000	243.16	3.587	2.4645	49.91	278.44	0.00	0.96
2018-04-17	00:45:59	241.36	242.80	245.23	3.645	7.055	0.000	0.8504	1.6136	0.0000	243.13	3.567	2.4640	49.90	278.44	0.00	0.96
2018-04-17	00:46:01	241.36	242.81	244.93	3.653	7.085	0.000	0.8512	1.6134	0.0000	243.03	3.579	2.4647	49.90	278.44	0.00	0.96
2018-04-17	00:46:03	241.50	242.33	245.17	3.658	7.118	0.000	0.8521	1.6135	0.0000	243.00	3.592	2.4657	49.90	278.44	0.00	0.96
2018-04-17	00:46:05	241.36	242.65	245.10	3.645	7.104	0.000	0.8521	1.6135	0.0000	243.04	3.583	2.4657	49.90	278.44	0.00	0.96
2018-04-17	00:46:08	241.52	242.59	245.19	3.633	7.056	0.000	0.8513	1.6135	0.0000	243.10	3.563	2.4648	49.89	278.44	0.00	0.96
2018-04-17	00:46:10	241.19	242.56	244.99	3.633	7.108	0.000	0.8522	1.6124	0.0000	242.91	3.580	2.4647	49.89	278.44	0.00	0.96
2018-04-17	00:46:12	241.35	242.53	245.08	3.650	7.080	0.000	0.8513	1.6117	0.0000	242.99	3.577	2.4636	49.89	278.44	0.00	0.96
2018-04-17	00:46:14	241.25	242.38	245.01	3.637	7.073	0.000	0.8513	1.6117	0.0000	242.88	3.570	2.4631	49.88	278.44	0.00	0.96
2018-04-17	00:46:16	241.10	242.34	244.88	3.631	7.069	0.000	0.8506	1.6121	0.0000	242.77	3.567	2.4627	49.88	278.44	0.00	0.96
2018-04-17	00:46:18	241.34	242.61	244.95	3.650	7.118	0.000	0.8512	1.6113	0.0000	242.97	3.589	2.4626	49.88	278.44	0.00	0.96

Figure 2.4: Preprocessed Data

in computer. To insert the preprocessed data into the database Structured Query Language(SQL) is used. Database creation, insertion and updating of data in database is explained in [7].

Here the database is created for 3 meters, each have a corresponding table format as shown in Fig.2.4. The data is inserted into the table corresponding to the meter line by line. Particular meter data can be accessed by sending a query in the database using SQL. HTML interface is also created to access this database. Through this interface, we can obtain the plots of a particular parameter of a particular meter with in given period of time and date.

2.6 Send Email

The data is processed, stored in a database and can also be seen through the interactive plots. Now this data can be used in many ways. One of the way is to continuously monitor the data and check if any problems occur. One way of finding the solution for problems like overloading of any cable connected to meter, is sending an email to the corresponding employee who can take care of the problem and solve it in time.

Simple Mail Transfer Protocol (SMTP) is an Internet standard for electronic mail (email) transmission. The 'smtplib' module defines an SMTP client session object that can be used to send mail to any Internet machine with an SMTP. However for Google account, Google will not allow logging in via 'smtplib' because it has flagged this type of login as "less secure". To overcome this, go to https://www.google.com/settings/security/lesssecureapps while you're logged into your Google account, and turn on "Allow less secure apps". Now google will allow logging in via 'smtplib'. Given that sender mail details and receiver mail address, any message can be sent through this module.

Every cable connected to the each phase of the meter, has some maximum ratings. These ratings are considered as thresholds, and the data is checked with these thresholds, each and every time before it goes into the database. If any value of the particular parameter crosses the threshold, an email will be sent to the corresponding employee to take an appropriate action in order to avoid overloading or burning of the cable.

2.7 Case Study

For experimentation 3 meters from the lighting panel are considered. From 3 meters, METER1 is selected for checking the above mentioned functions. From the METER1 the data is collected for every two seconds. The collected data is first preprocessed and then stored in the database to access whenever it is required. In this experiment, all the phase currents are considered for checking. But here in the data considered till now, the currents doesn't exceed the maximum rating of the cables. So the trail data is added to check working of the above functions. After the addition of trail data, preprocessing is done and all the 3 phase currents are accessed and checked with the thresholds. As soon as the current value corresponding to the phase exceeds, the alert mail was sent to the respective receiver as shown in Fig.2.5.

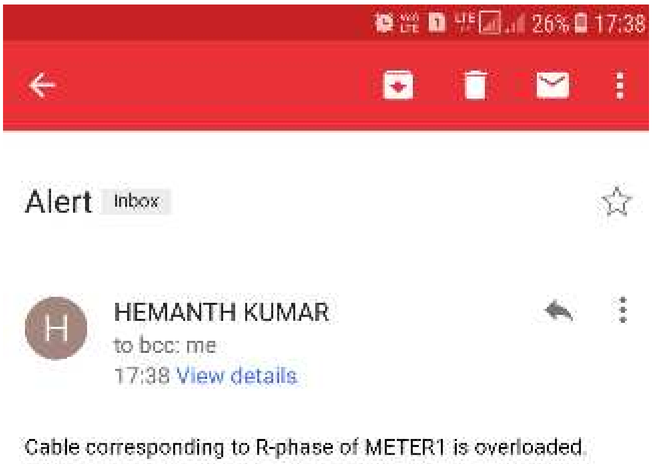

Figure 2.5: Alert

Chapter 3

Analysis of Data

3.1 Objective

The objective of this chapter is to analyse the load curve. In order to perform analysis on the load curve different factors are considered. These factors will help the building operator or manager for managing the load properly. The data can be analysed by plotting the load curve over a day or a week or a month. Many load parameters like Near peak load, Near base load, Maximum demand, rise time, high load duration time etc. can be calculated from the load curve.

One of the advantage by analysing the load curve on commercial academic building is that preparation of time table for scheduling of classes and labs planning is possible based on the load consumption. So that the building manager could actually reduce the bills.

This chapter is divided into 2 sections. In first section, An HTML interface with python is created to see the interactive plots of the instantaneous parameters like voltage,current etc. In second, the factors used for load curve analysis is explained and also case study is done on the actual load curve.

3.2 HTML interface for interactive plots

An HTML with python interface is created to access the data from the database by inputting the particular dates and time. Here HTML forms are created and those are linked to the database using python flask. Where flask is a micro web framework written in Python.

A home page is created as shown in Fig.3.1. In this page, the all 3 meters which are connected to the RaspberryPi are shown. If a METER1 is clicked then it opens into a new page and it is shown as in Fig.3.2, where there is flexibility to select each and every parameter. From all those parameters if any of the parameter is clicked, new page opens and asks for Date and Time for which you wanted see the plot of particular parameter. For example. If P1V is clicked from Fig.3.2, then Fig. 3.3 will be shown. Input the Date and Time as like in Fig.3.4. for plotting at required period of time. And after submission of date and time, the plot corresponding to the Phase 1 voltage will be displayed like in Fig.3.5.

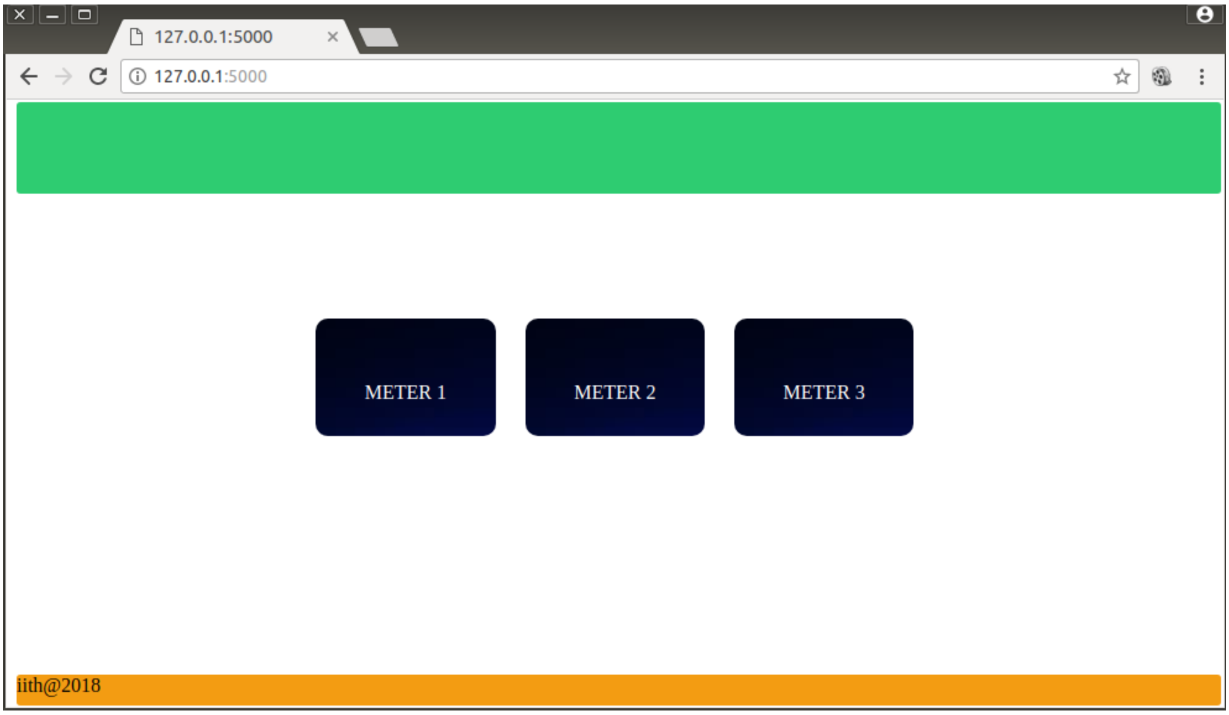

Figure 3.1: Home page

In Fig.3.6 all the 3 phase voltages, currents, active powers as dated on 17th april 2018 are shown. In the figure, whole day data is plotted by considering samples over each 15 minutes, combining 96 samples per day. It is clearly shown from the figure that, less amount of power is consumed during the night time to till 08:30 am since all lights will be switched-off. And from 08:30 am to 05:00 pm, more amount of power is consumed and after that power consumption slowly decreases.

Other parameters like average voltage, average current, total active power, total power factor etc can also be plotted. From the plot of the power factor, we can conclude how much power is consumed by the load in a day or week or month.

3.3 Load Curve Data Analysis

This Load Curve data analysis helps the building operator or manager for managing the load properly. For example if a phase is getting overloaded during a particular duration of time, load corresponding to that time period can either be shifted to other phases or time shifting of load solution is possible. Also, avoiding of unbalances in the load or phases is possible once these parameters are calculated. This analysis is generic for any type load curves. These factors will also help in creating events against different vulnerabilities for building.

Following are the factors that are considered for analysis.

A. **Near Base Load:**

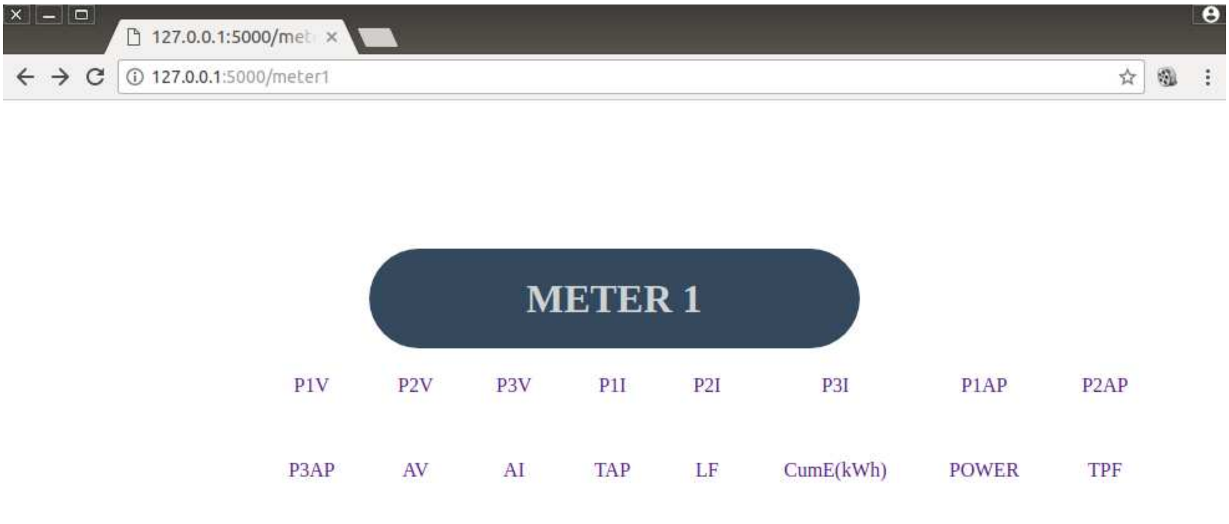

Figure 3.2: METER1

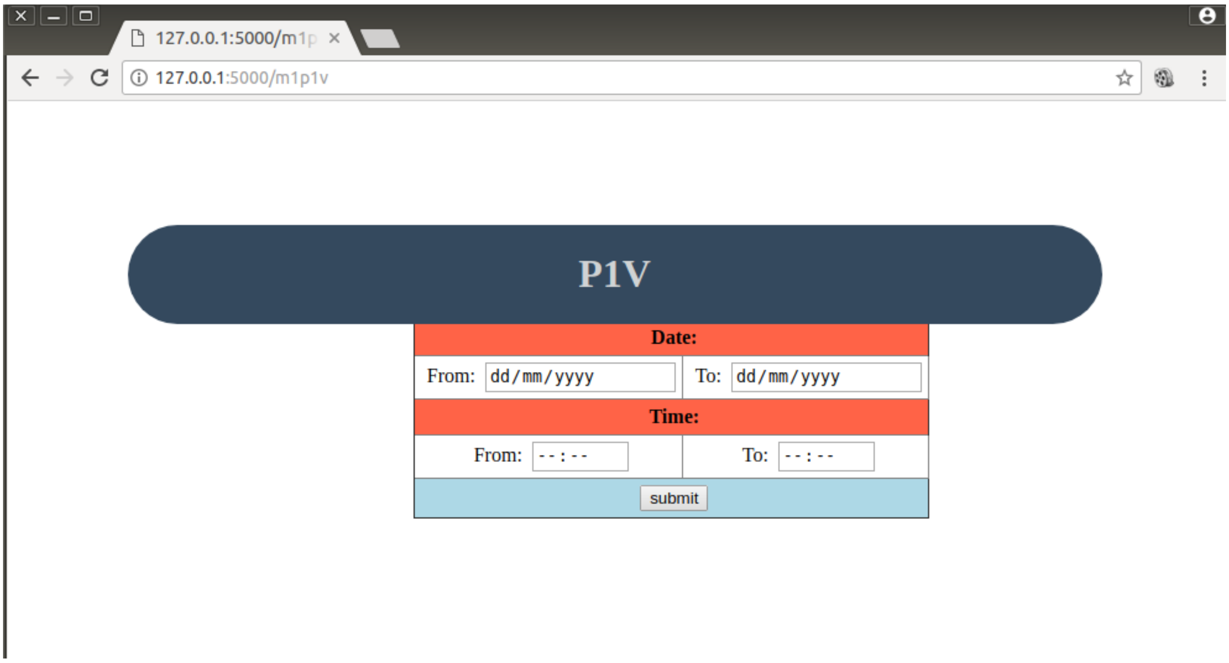

Figure 3.3: METER1, Phase 1 Voltage

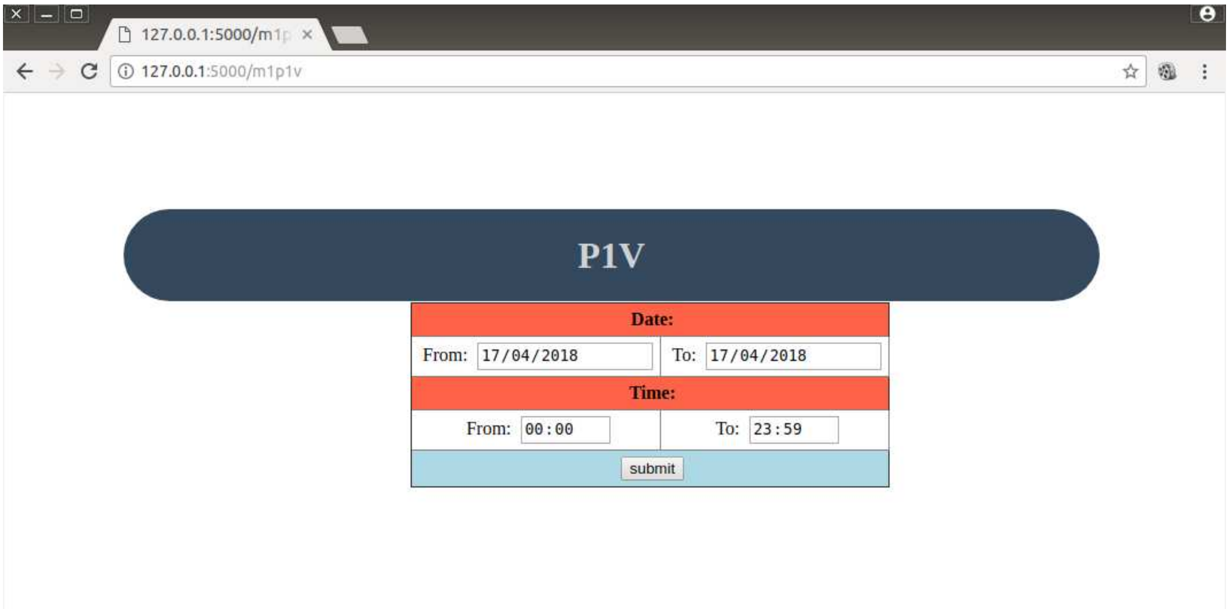

Figure 3.4: Input Date and Time

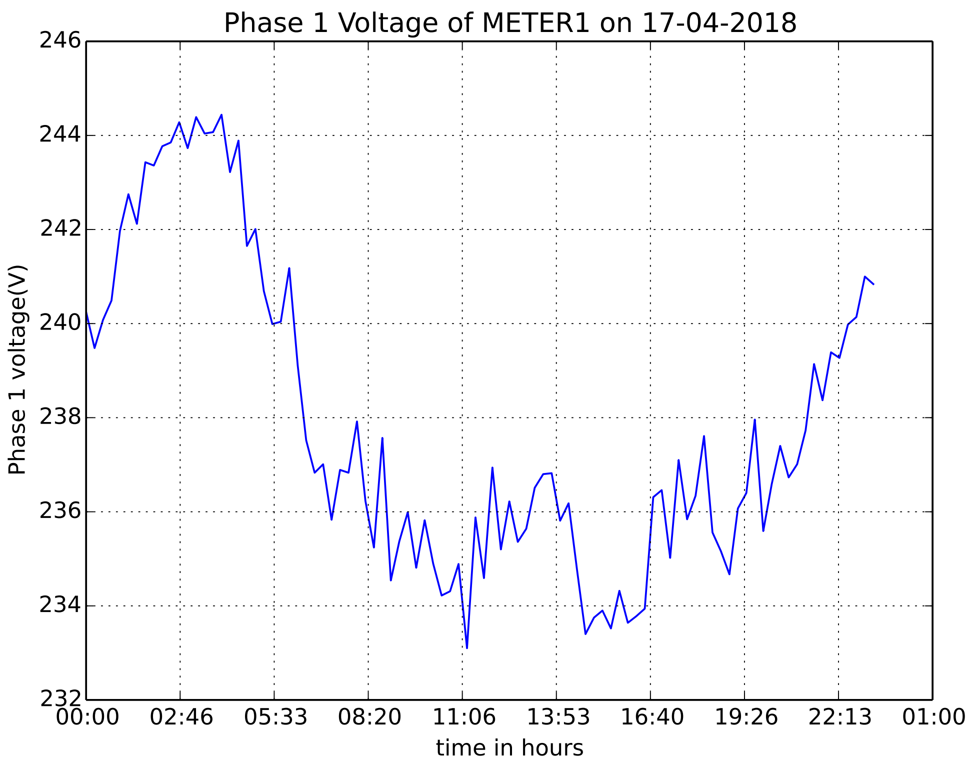

Figure 3.5: Phase 1 Voltage

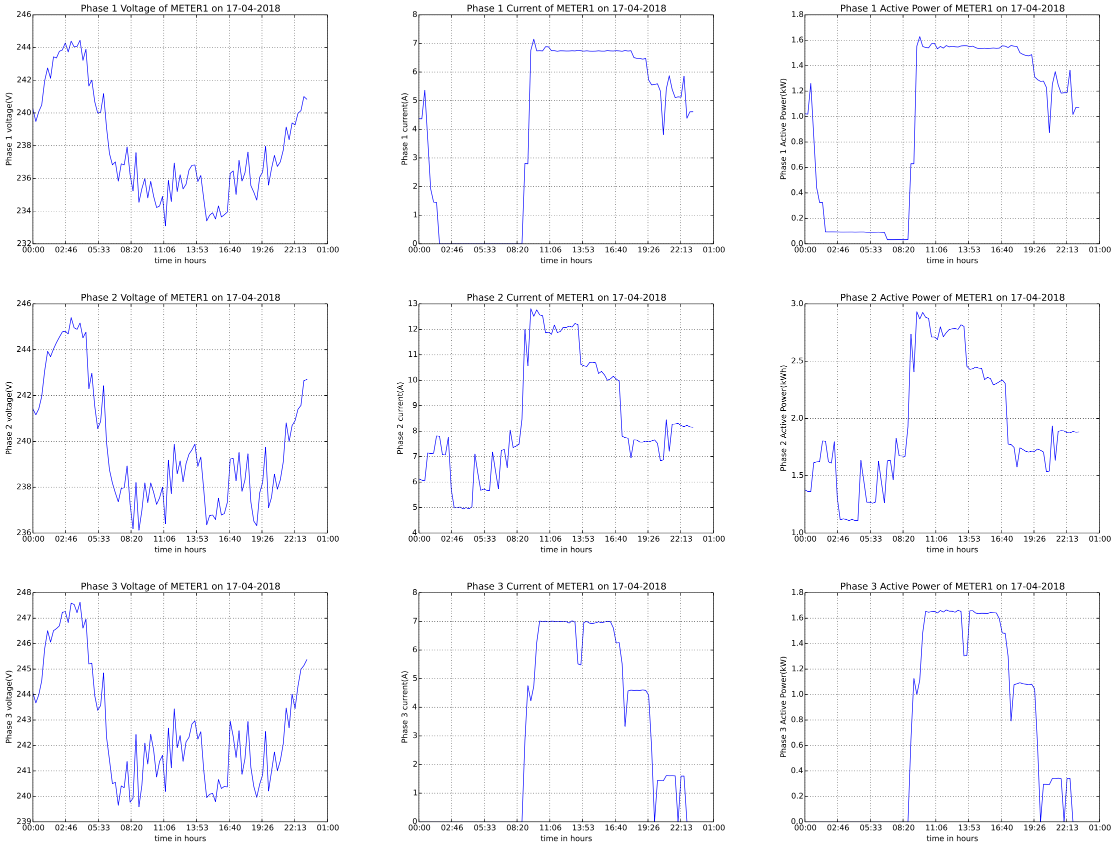

Figure 3.6: Phase Voltages,currents,powers on 17-04-2018

Near Base Load is defined as the 2.5 percentile above the minimum of load curve.

Mathematically it is given by Eq.3.1.

$$NearBaseLoad = 2.5^{th}\ percentile\ above\ (minL) \tag{3.1}$$

where 'min L' is the minimum of load. This load will be the daily load if the analysis is carrying for daily load, this is weekly load if it is weekly load and monthly if the analysis is carried out for monthly load.

B. **Near Peak Load:**
Near peak Load is defined as the 97.5 percentile of the maximum of load curve.

Mathematically it is given by Eq.3.2

$$NearPeakLoad = 97.5^{th}\ percentile\ (maxL) \tag{3.2}$$

where 'max L' is the maximum of load. This load will be the daily load if the analysis is carrying for daily load, this is weekly load if it is weekly load and monthly if the analysis is carried out for monthly load.

C. **Maximum Demand:**
Maximum Demand is the maximum of the total load.

$$MaxDemand = max(L) \tag{3.3}$$

where L is the total load that is considered either daily or weekly or monthly. Accordingly maximum demand called as monthly demand in a day or week or month.

D. **Average Demand:**
Average Demand is the area under the load curve over a given period of time.
Mathematically it is given by Eq.3.4.

$$AverageDemand = \frac{Area\ under\ load\ curve\ in\ kWh}{total\ number\ of\ hours} \tag{3.4}$$

E. **Load Factor:**
Load factor is a measure of the utilization rate, or efficiency of electrical energy usage. Load Factor is defined as the ratio between the average demand to the maximum demand.
Mathematically it is given by Eq.3.5.

$$LoadFactor = \frac{Average\ Demand}{Maximum\ Demand} \tag{3.5}$$

F. **Unbalance Factor(UF):**
Unbalance factor gives the unbalances in the phases due to loading. This is defined as the ratio of negative sequence component of the power phasors to the positive sequence component of

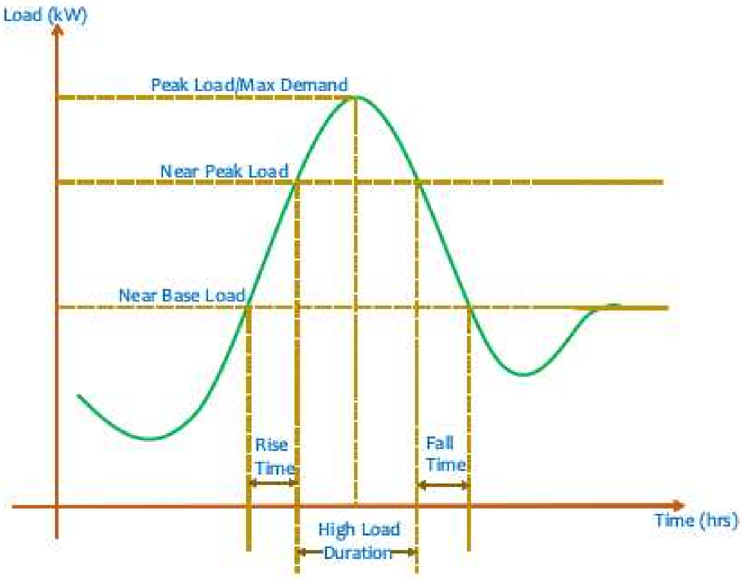

Figure 3.7: Example Load Curve

the power phasors. Permissible limits for this factor is 1.3% and maximum upto 2%. Mathematically this is given by Eq.3.6.

$$CUF = \frac{P_-}{P_+} \tag{3.6}$$

where P_- is the negative sequence component of the power phasor and P_+ is the positive sequence component of the power phasor.

G. **High load duration time:**
High load duration time gives the duration during which the load is high. It is the period during which the total load is more than the near peak load. This factor helps in knowing exactly duration of load shifting or adjusting.

H. **Rise Time:**
Rise Time defines the time taken by the load to reach the near peak load from near base load. Using this factor morning ramp is possible to know which provides the opportunity to the building manager or operator to reduce the ramping.

Fig.3.7. shows the load curve summarizing the above explained parameters. Unbalance factor, load factor and average demand are not mentioned in this figure since these factors are calculated using the above mentioned mathematical expressions.

3.3.1 Case study and Results

Load Curve is plotted over time, considering samples for each 15 mins. Fig.3.8. shows the daily load curve of METER1, Phase 2 of 17th April 2018 is selected. As shown in the figure

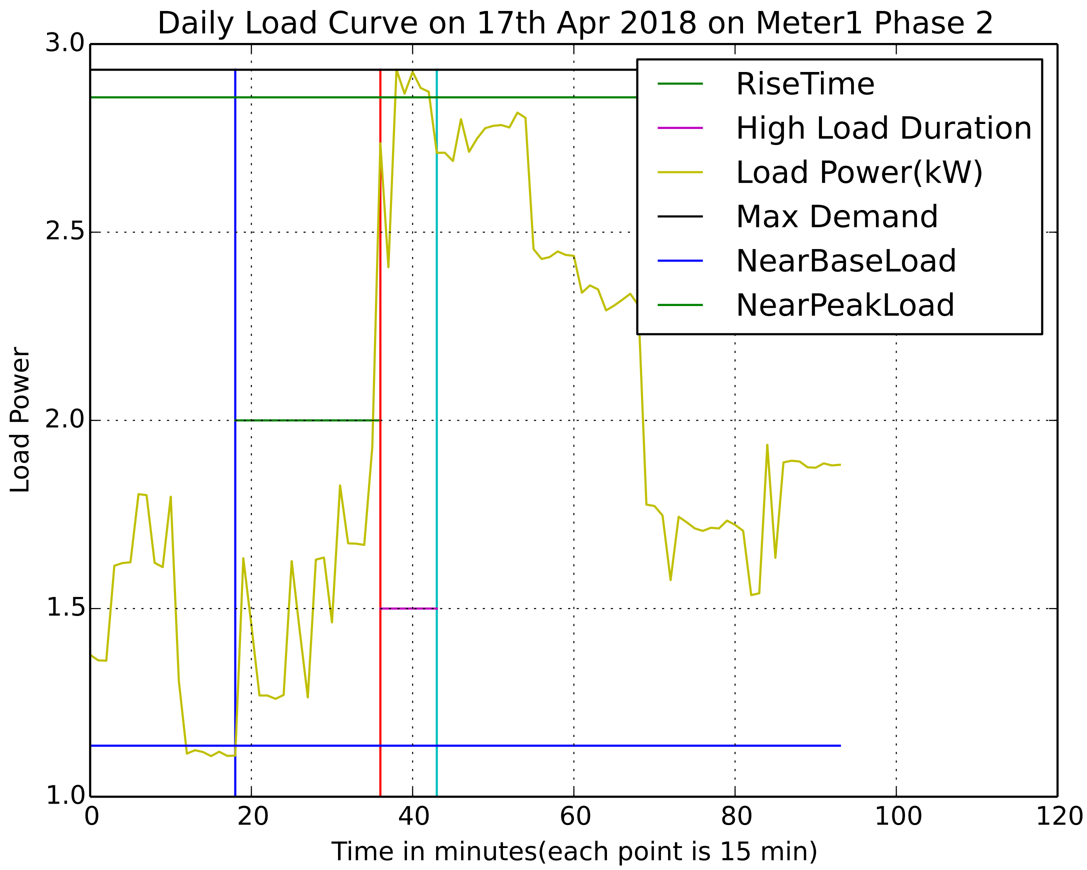

Figure 3.8: Load Curve

rise time is 4:30 hrs. The load curve shows high ramp in the morning time, that is why rise time is high. High load duration time is 1:45 hrs for this load curve, means during the period of 9:00 am to 10:45 am the load uses more power. These values varies depends on the load curve. And the Load Factor is 0.66678. All the three phase Active powers are considered for calculating UF. After calculating UF, it is found that all phases are balanced.

Chapter 4

Interfacing Multi Function Meter with Arduino

4.1 Objective

It's main objective is to make the meter interact with Arduino using external push buttons to configure the communication parameters of the meter.

Multi Function Meter has three buttons. Each button has some specific operation to change the communication parameters of the meter. By using these buttons, Slave ID of the meter can be configured from 1 to 247.So that for single RaspberryPi, around 247 meters are connected. And it more useful if the Baud Rate of meter is selectable for requirement basis.

4.2 Configuring Arduino communication parameters

Some times the Multi Functional Meter buttons wont work properly. So it is difficult to set the Slave ID, Baud Rate, Parity of Meter. One way to overcome this problem is to make the meter interact with Arduino using external push buttons to change the communication parameters of the meter.

Here in Fig.4.1. the arrangement of changing the Slave ID is shown. Here interfacing of arduino with lcd is explained in [8]. Interacting of this hardware with the meter is possible. The buttons shown in the figure, does some operations whenever those are pressed.

The operations of the each button is explained below.

Slave ID Setting : The button B3 is pressed to go into the Slave ID setting. For changing the slave ID, buttons B2,B1 is pressed. B2 and B1 buttons are for increasing,decreasing the Slave ID number respectively. The Slave ID can be set till 247. To exit from the settings button B4 has to be pressed. From the Fig.4.1. it is shown that, the Slave ID of the arduino is set to 9.

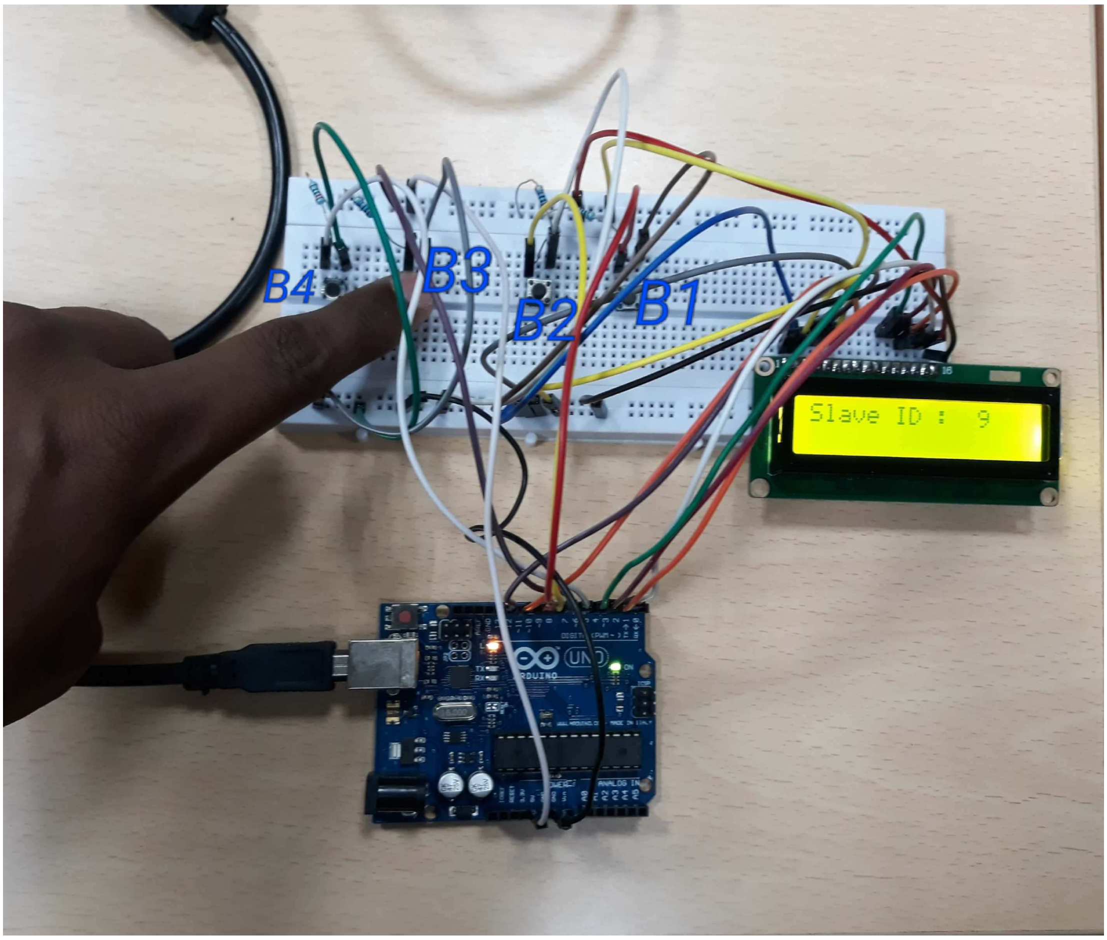

Figure 4.1: Slave ID Setting

Baud Rate : The button B4 is pressed to go into the Baud Rate selection. For changing the Baud Rate, buttons B2,B1 is pressed. B2 and B1 buttons are for increasing,decreasing the Baud Rate respectively. The selectable baud rates are from 1200 to 19200. To exit from the settings button B3 has to be pressed. From the Fig.4.2. it is shown that, the Baud Rate of the arduino is set to 4800.

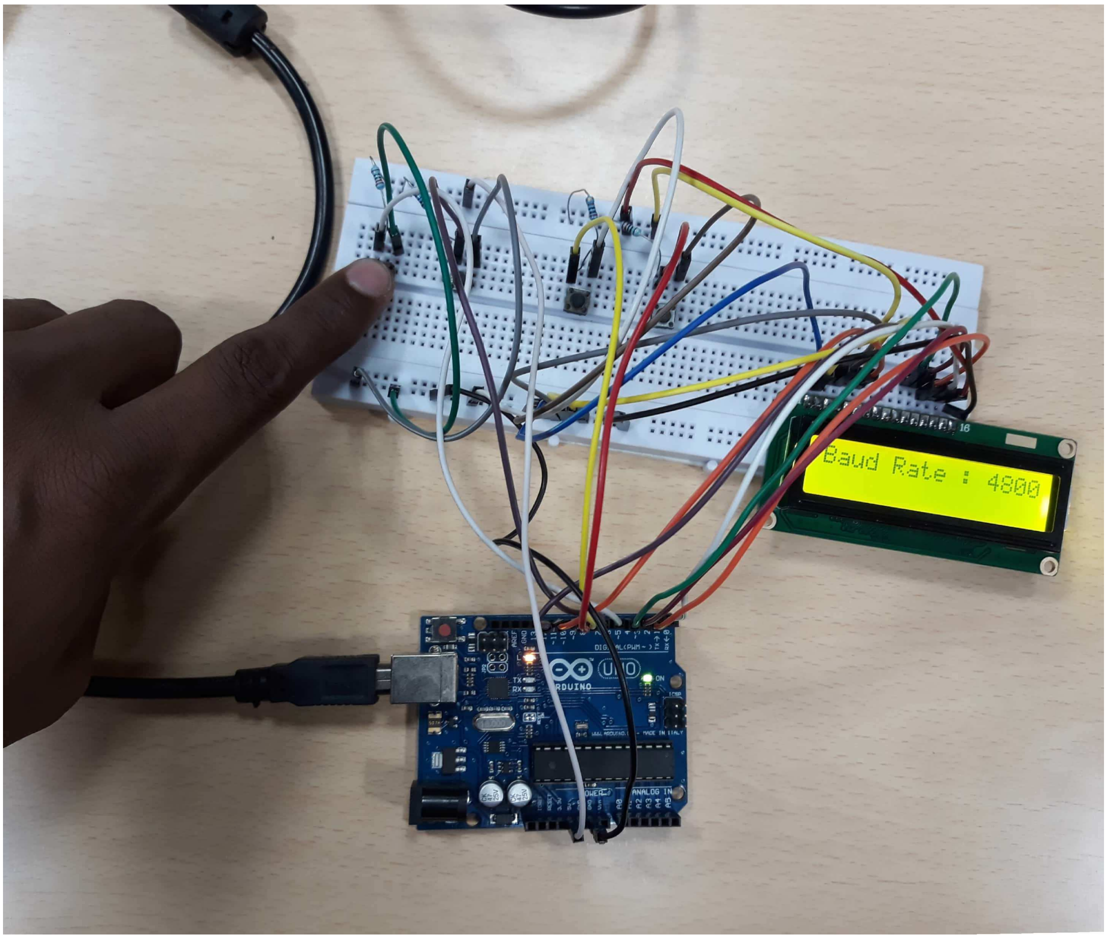

Figure 4.2: Baud Rate Selection

Chapter 5

Conclusion

In this thesis the energy monitoring and data analytics is divided into 3 parts. The first is alerting the employee about the overloading of the cable corresponding to the phase. For validation of the solution, a case study is presented on a commercial IITH building. Once all the meters are connected to the RaspberryPi, no need to shut the power off again and again for this experiment. Also, the advantages of energy monitoring in a commercial building is explained by introducing the calculations of some of the factors like load factor, unbalance factor, rise time, and high load duration period. The Interfacing of the meter with Arduino is also presented and it can be extended to get full control over the meter.

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