W-CDMA BASED SMART ENERGY METER WITH ANDROID CONTROL

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DEDICATION

From Umair Fiaz: To my family for their loving support and particularly my Mother for their untiring love, prayers, encouragement and support for giving me the confidence of accomplishment in every hurdle I passed through.

I also want to dedicate this accomplishment to my country and environment where I learnt the perspective to think clearly in scientific and engineering way, and to the chaos that make my way towards this.

From Sohaib Hassan: I dedicated this work to the Almighty God, thank you for the guidance, strength, power of mind, protection and skills and for giving me a healthy life.

This study is wholeheartedly dedicated to my beloved parents, who have been my source of inspiration and gave me strength when I thought of giving up, who continually provide their moral, spiritual, emotional, and financial support.

To my relatives, friends, classmates and teachers give special thanks to my best teachers Sir ***Mazhar Iqbal & Sir Nadeem Ghori*** who shared their words of advice and encouragement to finish this study.

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Above everything else, we thank the Lord for seeing us thus far with all this work. His guidance and direction are something we could not do without.

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ABSTRACT

Trend in the IoT based smart devices is tremendously increasing day by day. By time more people are becoming aware of smart technology and its convenience in control and management of daily things seizes their attention. Smart energy meters (SEM) plays one role in this world of smart devices, to progress towards making the whole power system interconnected.

In past three decades people had done much work on making power systems smart and thus there are plenty of published papers on smart meters. This project specifically uses different approach with additional functional development and better accuracy.

Briefly, SEM is a remote monitoring and control device that automatically transmit data to utility, limits load to minimize load shedding trend, use operation techniques for generating stations for demand estimation and provide different options to consumers to manage their budget, like individual appliance power usage and cumulative plots. Transmitting data enables the utility computers to monitor the meter readings regularly to avert electricity theft. With the use of a programmable unit we can operate the meter to continuously monitors and records the readings in its permanent (nonvolatile) memory location in most feasible way.

Whole world is connected through internet, and thus it is the most appropriate and common way of communication for a smart device. With internet there is need for additional security protocols and encrypted channels; but with this complexity meter can lead in many other ways that's not possible through other channels. WIFI adapter connected with router sends data sample to internet after planted sample time. This data will then send towards consumer mobile application and towards utility, where computer will statistically analyze the data and show the results. As, the period end this adapter will receive bill from utility and controller will cut the supply off if payment time limit exceeds. So, with this bidirectional communication technique utility can send ads and other deals to some specific meter by time; and consumer can access direct support from utility.

CONTENTS

CHAPTER 1: INTRODUCTION

1.1 General background

As, the information about smartness is proliferating, smart devices are growing abundantly. In smartness, world is progressing to connect things with each other to share and use the Big Data as needed. For this, people are working iteratively to build standards in different fields, so that each area can interact with other when required. For example, like in this project; it's required to interact electronics and communication for the benefits in power system. Hence, following the IEEE standards used internet adapters for communication; and the IEC metering standard.

Meeting these standards universally is the most basic requisite for smart projects. At this point in time, still devices are not connected by universal standards, as people in different countries have different environments and protocols to follow. So, there are different protocols and standards, that we can use, and choosing the best out of them is really a hard job to complete. Like windows and android are working their way to connect their applications to each other, so that users who want to use best from both can connect the services of both companies to use them whenever they want. Building and choosing proper standards, and to implement them to devices to connect them with the things that most people love to use is an important but a hard task to handle.

When we talk about smart, it's not only limited to the word connected; but it's always required to see the word automate. Most of the problems we are facing are because of human negligence, and humans can't multi-process tasks, their brain power is limited to some level, and most importantly, humans require time to process things. As, the computers emerges in different disciplines, many tasks that were complex were at the distance of simple programming. People begun to use the results provided by computers to use them for their purposes. Now, after the emergence of controllable electronic devices, we started to program smartness into these devices, so that people have to interfere less with simple tasks. Automation idea that we usually see in industrial robotics is progressing, so that the tasks we know will happen can trigger the devices automatically; to work through them.

Traditionally, in induction type Watt-Hour meters; we used electromagnetism phenomenon through series and shunt magnets to rotate the aluminum disk that will then rotate the dial to display the readings. Similarly, in electronic meters we use sensors and other electronic devices like processor, ADC, EEPROM; and digital logic to calculate the kWh and then dispatch it to LCD. Smart meters, much like the electronic meters use digital phenomenon to calculate the readings; but instead of building complex digital logics, these meters are using programmable controllers to implement the logics. And with the aid of programming

we can effortlessly embellish the device by developing different features we want; like budget management and load limiting.

1.2 Problem Statement

Traditional system of energy metering and billing is economically unviable, requires a lot of labor and is technologically old. Discrepancy may creep into system because of human errors and limitations and consumers can't avail their data everywhere in this connected world.

1.3 Project Justification

This project was undertaken to ensure the smart way of metering and to meet the proper standards to establish the suitable measures of security, like theft protection, metering accuracy and minimal occurrence of fault/error. We want to establish a de-règle way of communication to connect the device to world and to make its information accessible to anyone securely; and to manage the data statistically to maintain the usage in equilibrium. We want to append the features for both generating stations, grid stations and to users; so that they can visualize the data appropriately for actions, like forecasting and budget management. This project was designed to address the challenges of accuracy, smartness, automation and security in power systems; and developed in the most economical way possible. The programming platform is established in generic way to give different options of management, visualization and personalization to user.

1.4 Objectives

The project was carried out to satisfy three main objectives:

- To design an efficient encrypted kWh measuring device, with considerable accuracy
- To transmit the information through Internet to make it accessible to anyone securely
- And to analyze this data statistically for forecasting and management

1.5 Scope of this project

This smart meter is designed to enhance the view of people towards smartness. With its implementation people can get information of their electricity usage visually and thus be able to use their energy efficiently, that'll help them in managing their budget and help the utility in minimizing the load shedding. As, this world is progressing towards smart devices, we are hearing about fully automated homes; and for appliances that operate on electricity can be controlled with the help of smart meter with an additional hardware. With this connection users can set limit to when they want to turn the refrigerator on or off and can fully automate them. This device can be considered as the first step in the automating and controlling the electric devices as it's gathering the information for this triggering.

Information of energy in Pakistan is still not automated, and meter readers are assigned to collect this information; which will then be accumulated in local grid stations and then to distribution level. With this hierarchy, chances of negligence are high; and a constant flow of information for proper management is not possible. So, the only way to eradicate this by using a fully automated system.

As, the data grows the percentage of load predictability will increase; and thus, the utility will be able to forecast the demand conveniently. They will be able to use operation techniques to commit the units accordingly; and thus, to develop the sequence of operation will become easier. The major problem in Pakistan, is this lack of big data; it can tremendously solve many problems we are still lacking. This is main application of connected devices, that they can share the information with each other so that people can use them for their prime purposes in future.

1.6 Methodology

We divided the design of smart energy meter into three basic sections shown in figure 1. Design of simple circuit to get the data is required. Here, we implemented the sources of current and voltage, so that we can process it later in Arduino. Other devices like RTC, EEPROM and Graphic LCD were also used and are embedded on the same chip. We also embed Arduino Mega; and ESP8266 module on board with the consideration of making it space effective. In the later section, we programmed the incoming data; calculate energy, and power factor; and display the values to graphic LCD, and code to embellish the display and make it look alluring. For the transmission we used ThingSpeak API and code the ESP module to send the data accordingly. After this we programed EEPROM to store energy, so that when shutdown happen It stores data; and start the data afterwards when power turns on.

This last section of transmitting data through WIFI module, was simple attachment of code that's completed in last section.

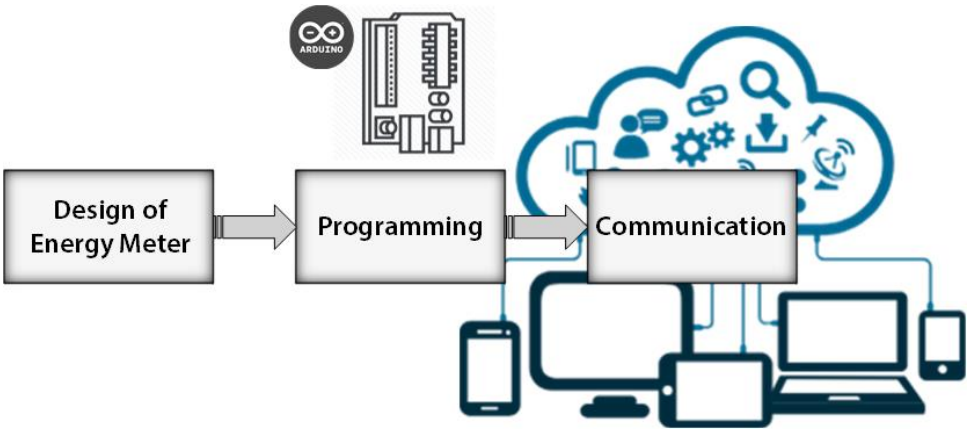


Figure 1.1: Sectional Division

1.7 Project Report Organization

This report is divided into 5 chapters; brief idea about each chapter is given:

Chapter 1: This is the introduction to the project report that describes the justification for doing the project. The objectives, methodology and scope of the work are also described.

Chapter 2: This has the literature review that is based on the background of the problem. The chapter also includes material studied and which is pertinent to the study. There is a brief review of methods used for designing and smartness can be implemented in an electronic device. This chapter discusses the study we have to do before implementation, in which specifically we narrate the protocols, standards and algorithms required.

Chapter 3: The chapter involves the design and implementation of the project.

Chapter 4: It involves design of the system, simulations and hardware implementation.

Chapter 5: This chapter has the discussion, conclusion and recommendations for further work with regard to this project.

CHAPTER 2: LITERATURE REVIEW

2.1 Purpose of the Literature Review

The review will apply a modification of the defined systematic literature review process as the basis for a structured and logical review. It recognizing important contributions to electricity consumption classification research. The consequence is a general overview of what has been completed in the field of smart meter feasting classification and what the authors see as the subsequent step in applying smart meter data.

This review only contains research into documentation of specific appliances such as Non-Intrusive Load Monitoring (NILM), data collection schemes and protocols, smart meter control and progress, data privacy and tariff development are beyond the scope of this paper.

2.2 Evolution of Electricity Meters from the Past

In early years, power is accessible just to a particular segment of wealthy society. The advancement in innovation after some time empowered gathering the requests of every citizens in all pieces of the world. The historical backdrop of power meter is all around associated including analysts from past. The general use of power in the mid 1870's is just restricted to broadcasts and bend lights. With the creation of the electric bulb by Thomas Elva Edison, the power energy advertises turned out to be broadly opened to people in general in the year 1879. Oliver B. Shallenberger presented his AC ampere hour meter in the year 1888. In the long run, the dynamic advancement in metering innovation leads in illuminating the lives of numerous average peoples.

2.3 Traditional Electricity Meters and Types

The electrical gadgets that can identify and show energy in the form of readings are named as power meter. Conventional meters are utilized since the late 19th century They trade information between electronic gadgets in a modernized domain for both power creation and dispersion. In the greater part of the customary power meter aluminum circles are utilized to discover the utilization of intensity. Today's Power meter is digitally worked yet at the same time has a few constraints. A modest 1 Phase 2 Wire energy meter is shown in the below figure 2.1.

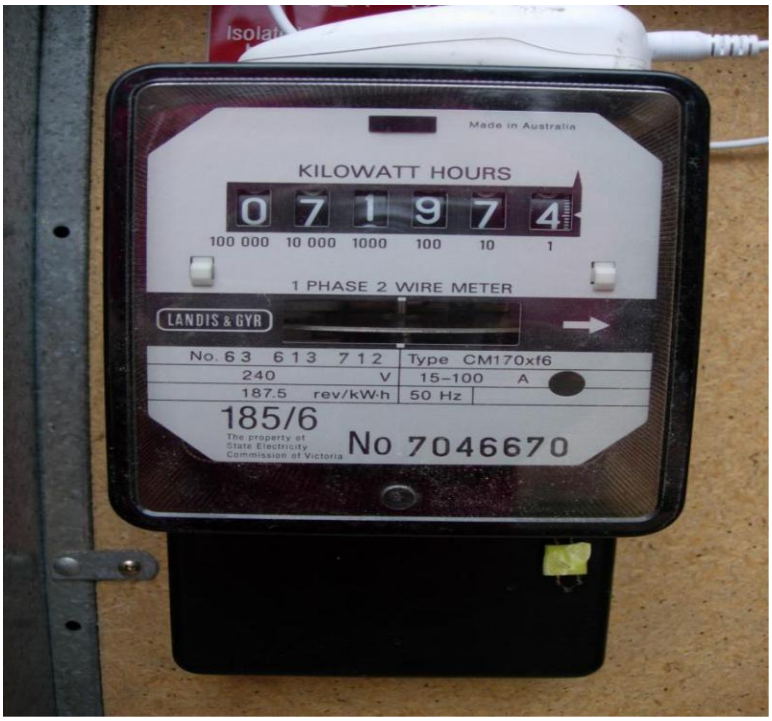


Figure 2.1: Traditional Meter

Some of the **restrictions** handled by the traditional electricity are as follows:

- Meters are defective in nature as purchaser needs to anticipate for the month to month power bill.
- The procedure of estimation is upheld by a particular mechanical structure and thus they are called as electromechanical meters.
- In request to perform meter readings, an incredible number of inspectors have to be employ-ed.
- Payment handling is costly and time consuming.
- Development of meter programming applications and strong system framework is confused.

Other than the previously mentioned constraints, there are additionally a few different components making a gigantic hole between the customer and wholesaler in view of establishment of conventional meters.

Meters are of unmistakable kinds. Despite the fact that convenient improvement of power meters encourages the buyer to pick up information regarding power utilization, insights of the utilization couldn't be changed.

2.4 Types of Meter

Table 2.1: Different Meter Types

Different Types	Outline
Electrolytic Meter	The entire current goes through the electrolyte. The major disadvantage is mechanical contemplations and selection by restricted localities.
Commutator Meter	Brush-shifting device is used to vary the current load and commutator of small diameter facilitates in insulation attention. The major drawbacks are insufficient load characteristics, maintenance cost and lack of proper insulation.
Mercury Motor Meter	There is a satisfactory execution with the presentation of this meter. The selection of rotor made a prominent role in providing the adjustment. The momentary short circuit is decreased or even prevented.
DC Watt-Hour Meter	This meter model is produced for substantial current circuits where the temperature coefficient is high. For sign of interest purposes, a separate time switch is utilized. Likewise, it is a check type meter in which voltage varieties is less with the reduced shunt loss.
Single-Phase Induction Meter	Magnetic conditions are better improved to control the energy utilization and an extensive improvement in execution is moreover done. Meter examination is handily surveyed as the development of this model has accessibility of simplifying assembly.
Poly-Phase Watt-Hour Meter	Lagging power factors in the meter mirrors the qualities of the current transformer. Attempts for improving high level of accuracy have been built to avoid troublesome corrections. Communication impacts, adjustment and increment in the impacts of shunt loss are the best drawbacks of this model.

2.5 Smart Grid

Smart Grid is the advanced improvement in power network. present electrical grids are getting frail as for the electrical burden variety of machines inside the home. The increase in population is also the sign of electrical grids getting progressively delicate. The higher the population, the more burden on the grid.

Improving the productivity of grid by remotely controlling and expanding dependability, estimating the utilization in a correspondence that is supported by conveying information (continuous) to buyers, provider and the other way around is named as Smart Grid. Robotized sensors are utilized in Smart Grids. These sensors are mindful in sending back the deliberate information to utilities and have the ability to move power disappointments and abstain from warming of electrical cables. It utilizes the element of self-recuperating activity. Actually, the idea of Smart Meter is started from Smart Grid. A carbon outflow decreases of 5% is normal by 2030, every year by its establishments and it can show a more noteworthy effect on environmental changes. For a manageable improvement and foundation of new grid infrastructure, Smart Grids are suggested for many countries.

2.6 Smart Meter

Smart Meter is a globally friendly energy meter that is used for calculating the electrical energy in terms of kWh (Kilowatt - hours). It is basically a device that affords a straight help to the consumers who need to save money on their electricity bill. They belong to a division of Innovative Meter Setup and are answerable for transfer meter readings automatically to the energy provider. A simple picture of a Smart Meter is shown below.

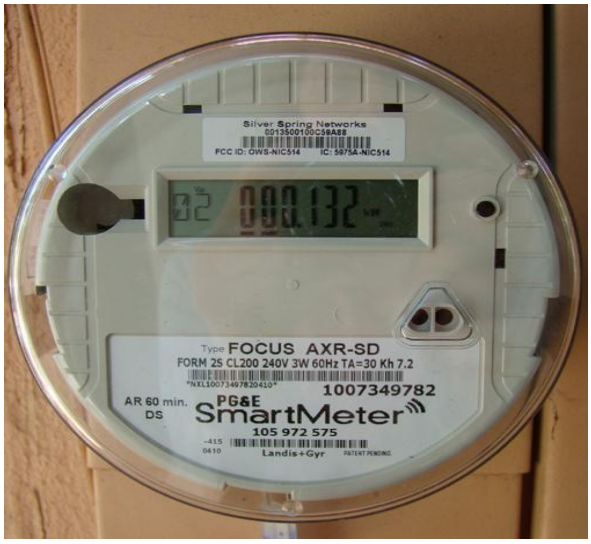


Figure 2.2: Smart Meter

Accurate meter reading will be given the incorporation of firm advantages from the Smart Meter. They record the utilization based on hourly or less then hourly durations. A Smart Meter has non-unpredictable information storage, remote connect or disconnect capacity and two-way correspondence facilities. They perform remote detailing of the gathered information to the central meter. This central meter screens the functionality of the Smart Meter. From an operational viewpoint, utilization of Smart Metering permits an

improved administration and power over the electricity grid. Some of the benefits of Smart Meters are as follows:

- Low working expense.
- Time sparing to the customers and service organizations for reporting the meter reading back to the energy suppliers.
- Online electricity bill payment is permitted.
- Power utilization can be extraordinarily decreased during the high peaks with an implication strategy.

Smart Meter detects all the utilization produced inside the occupants. Meter readings give a more extensive comprehension to the energy utilities with the goal that general energy utilization customs of the habitants can be modified. At long last, all the data that is created by Smart Meter will expand help in noble generation.

2.7 Power Consumption

The grand sum of intensity expended in an individual family unit is alluded as energy utilization. The utilization of energy is a significant part of power supply. With day by day utilization of power, the vitality designs have been gradually changing. This variety of utilization examples can be caused about by climate conditions or unnecessary usage of energy by occupants, for example, increment of apparatuses in separate family units and careless attitude in utilization for example not turning OFF the lights or TV when not watching it. These variables may show more prominent effects on end user. As the power provided by energy suppliers is immense, the vast majority of the individuals are disregarding energy and its reserve funds. The significance of utilization is declining in the mentality of utilities. The energy utilities should assume a significant role in advancing the Smart Meter innovation and should cause individuals to take an interest in decreasing energy results by making awareness about the effect of their present degree of utilization.

2.8 Study of People's Behavior

If the utilization of the client is high, at that point we can identify their use of gadgets is also high, which means cost is legitimately relative to the result of number of employments and the corresponding durations. It is significant for energy organizations in arriving at the expectation of the client. Truth be told a large portion of the purchasers depend on month to month charge they expect for. They typically don't know which apparatuses are expending more energy and how they can deal with their utilization better. These elements assume a significant role in affecting the behavior of the client. The better comprehension of the

people's behavior is just accomplished through investigating how they utilize their energy. An illustration of a Smart Meter introduced in a house while estimating the appliances is shown in figure 2.3.

Figure 2.3: Smart Meter measuring electrical appliances in a household

The above figure expresses the regular actions of household purposes measured by a Smart Meter in a home. Smart Meter is installed outside the house and its hourly consumption data is measured for depressing customer electricity bills. This measurement capability changes simple home to a smart home.

2.9 Communication Techniques for Viable Choice

2.9.1 Zigbee

ZigBee (figure 2.4), as Bluetooth, has a huge introduced base of activity, albeit maybe customarily more in modern settings. ZigBee PRO and ZigBee Remote Control (RF4CE), among other accessible ZigBee profiles, depend on the IEEE802.15.4 convention, which is an industry-standard remote systems administration innovation working at 2.4GHz focusing on applications that require generally rare information trades at low information rates over a confined region and inside a 100m territory, for example, in a home or building. ZigBee/RF4CE has some critical focal points in complex frameworks offering. [1]

Low-power activity, high security, high versatility and robustness with high hub tallies and is all around situated to exploit remote control and sensor organizes in M2M and IoT applications.

Figure 2.4: ZigBee

2.9.2 Wi-Fi Module

Wi-Fi network is frequently a conspicuous decision for some engineers, particularly given the inescapability of Wi-Fi inside the home condition inside LANs (Figure 2.5). It requires minimal further clarification but to express the undeniable that plainly there is a wide existing framework just as offering quick information move and the capacity to deal with high amounts of information.

At present, the most widely recognized Wi-Fi standard utilized in homes and numerous organizations is 802.11n, which offers genuine throughput in the scope of several megabits for each second, which is fine for record moves, yet might be too power-devouring for some IoT applications. A progression of RF advancement packs intended for building Wi-Fi based applications are accessible from RS. [1]

Figure 2.5: WIFI

Standard: 802.11n

Range: ~50m

Frequencies: 2.4GHz & 5GHz bands

2.9.3 Cellular GSM

Any IoT application that requires activity over longer separations can exploit GSM/3G/4G cell correspondence abilities. While cell is obviously equipped for sending high amounts of information, particularly for 4G, the cost and furthermore power utilization will be unreasonably high for some applications, however it very well may be perfect for sensor-based low-transmission capacity information extends that will send extremely low measures of information over the Internet. A key item

right now the scope of items, including the first small CELLv1.0 ease improvement board and a progression of shield interfacing sheets for use with the Raspberry Pi and Arduino stages. [1]

Figure 2.6: Cellular

Standard: GSM/GPRS/EDGE (2G), UMTS/HSPA (3G), LTE (4G)

Frequencies: 900/1800/1900/2100MHz

Range: 35km max for GSM; 200km max for HSPA

2.9.4 SIGFOX

An option wide-extend innovation is SigFox, which regarding range interferes with WIFI and cell. It utilizes the ISM groups, which are allowed to use without the need to get licenses, to transmit information over an exceptionally restricted range to and from associated objects. The thought for SigFox is that for some M2M applications that sudden spike in demand for a little battery and just require low degrees of information move, at that point WI-FI's range is too brief time cell is excessively costly and furthermore expends an excessive amount of intensity. SigFox utilizes an innovation called Ultra Narrow Band (UNB) and is just intended to deal with low information move velocities of 10 to 1,000 bits for each second. It devours just 50 microwatts contrasted with 5000 microwatts for cell correspondence, or can convey a run of the mill remain by time 20 years with a 2.5Ah battery while it is just 0.2 years for cell.

As of now conveyed in a huge number of associated objects, the system is at present being turned out in significant urban areas across Europe, remembering ten urban areas for the UK for instance. The system offers a strong, power-productive and versatile system that can speak with a great many battery-worked gadgets across zones of a few square kilometers, making it reasonable for different M2M applications that are relied upon to incorporate savvy meters, understanding screens, security gadgets, road lighting and ecological sensors. The SigFox framework utilizes silicon, for example, the EZRadioPro remote handsets from Silicon Labs, which convey industry-driving remote execution, broadened go and ultra-low force utilization for remote systems administration applications working in the sub-1GHz band. [1]

- Frequency: 900MHz
- Range: 30-50km (rural environments), 3-10km (urban environments)
- Data Rates: 10-1000bps

2.9.5 NEUL

In the same way the idea to SigFox and working in the sub-1GHz band, NEUL use extremely little cuts of the TV White Space range to convey high adaptability, high inclusion, low power and minimal effort remote systems. Frameworks depend on the Iceni chip, which conveys utilizing the void area radio to get to the great UHF range, presently accessible because of the simple to computerized TV change. The correspondences innovation is called Weightless, which is another wide-zone remote systems administration innovation intended for the IoT that to a great extent goes up against existing GPRS, 3G, CDMA and LTE WAN arrangements. Information rates can be anything from a couple of bits for every second up to 100kbps over a similar single connection; and gadgets can devour as meager as 20 to 30mA from 2xAA batteries, which means 10 to 15 years in the field. [1]

Figure 2.7: NEUL

- Frequency: 900MHz (ISM), 458MHz (UK), 470-790MHz (White Space)
- Range: 10km
- Data Rates: Few bps up to 100kbps

2.9.6 Conclusion – Why WIFI is Most Viable Option

From the options above the most appropriate and preferable method in Pakistan should be cellular network because of its range, power usage and reliability. Cellular network towers are spread everywhere, so to commercialize the project, we should want reliability for convenience of consumers. But with its convenience and reliability, there are many downfalls that we can't ignore. The major demand of this project is to be IoT, and if we want to connect the device with the big data processing in the whole world; with the cellular network it'll be impossible to achieve. If we want more accurate load forecasting, better efficiency and budget management like feature, the only thing we need is to connect the system with a network that's common in world. So, internet is the most viable option we choose for this project.

2.10 Processing Option

We can choose PIC or some ATMEL ATMEGA chip as a microcontroller to process the instructions. With the high range of types and qualities, the most convenient solution to find an appropriate device for processing is this. Although, ATMEL (now MICROCHIP) processors has a complication of lack of libraries and microchip IDE (MPLABX) has a bad interface so understanding it to its deep for a complex project like this could consume a large chunk of time. Alternatively, we have ARM Cortex Processors, that are available in market and used mostly for high processing devices like mobile phone; and now some companies also embedding this to chrome books, and low-cost laptops. But the problem with ARM devices is their cost, and coding complications because of lack of libraries.

Among them the most feasible and appropriate solution is ATMETGA because of its reliability, cost effectiveness and fitted specifications. To minimize its pitfalls and especially for minimal coding complications we could choose the famous Arduino with ATMEGA 3284. Libraries of almost each component is available and with ATMEGA processor; at 16MHz processing our project will run at the most fitted specs.

Range of this type of devices is also vast, so we have to choose the most appropriate one. Specs of each device is given in table 2.2: [2]

The most appropriate device that meets the need is Mega, it's not spaces effective but still if we want to perform the features like load limiting, event detection, date and time and continuous receiving; the only viable option that suits here is Mega. This detail about mega is given in section 3.2.

2.11 IoT and Smart Devices – Definition, and Philosophical Explanation

At this point we can know what smartness is all about and what features does a device (or specifically a THING) should have if we want to make it smart. A thorough detail about smartness, how the world thinks about this and how this idea is evolving is discussed here. [3]

Smart devices equipped with embedded technology collect resources automatically to trigger the things in programmed way. Smartness in devices depends on two things; a sensor and an actuator. A sensor, like RFID and in this case WIFI module sense the change in environment, and actuator action on something, like trigger something when that change happens.

From the scratch of mankind, engineering is working for the same purpose to develop the things in the most standard way, so that it can intersect the artificiality with nature to hold control. The only obstruction in our way is nature, so from scratch the prime need was development of tools to adapt the nature in a symbolic way, to later use them for benefits. [3]

Table 2.2: Arduino Boards (List) and Compatible Systems

Board Name	Frequency (MHz)	Flash (kB)	SRAM (kB)	Digital I/O Pins	Analog Pins	Processor
Esplora	16	32	2.5	--	--	Atmega32U4
Zero	48	256	32	14	6	ATSAMD21G18A
Yun	16, 400	32, 16x1024	2.5, 64x1024	14	12	Atmega32U4, Atheros AR9331
Leonardo	16	32	2.5	20	12	Atmega32U4
Uno	16	32	2	14	6	Atmega328P
Ethernet	16	32	2	14	6	Atmega328P
Pro	16	16, 32	½	1414	6	Atmega168, Atmega328P
Uno **Wi-Fi** (rev 2)	16	48	6	14	6	ATMEGA4809, NINA-W132 Wi-Fi module from u-blox, ECC608 crypto device
10**1**	32	196	24	14	6	Intel® Curie™ module[6] two tiny cores, an x86 (Quark SE) and an ARC
Due	84	512	96	54	12	ATSAM3X8E (Cortex-M3)
Mega	16	256	8	54	16	ATmega2560
Micro	16	32	2.5	20	12	Atmega32U4
Pro Mini	8 (3.3V), 16 (5V)	32	2	14	6	Atmega328
Fio	8	32	2	14	8	ATmega328P
Nano	16	16, 32	½	14	8	ATmega328 (ATmega168 before v3.0)
Lilypad	8	16	1	14	6	ATmega168V or ATmega328V

Everything can be connected_ and it's the main motive of IoT. In our daily life we observe things, and want to control them. A simple example of this can be taken as a switch to control electricity and then we can see some complex digital logic operations and stuff like programming that helps us to operate the tasks in a way we want. They operate standalone, the motive of IoT is to connect them with a special device so that everything can be worked single-handedly. To imagine this, we can consider smart home; a home where boiler, refrigerator, internet and everything can be controlled through a mobile phone in your pocket; you

might be away from your home and want to see how things are working, it's just away from hand. Someday in future, we'll be able to remove this distance from hand; and be able to control things from our mind.

The range of IoT applications is increasing, and with the aid of one standard the slope is covering more distance; and thus, growing exponentially. [3]

- Environmental monitoring
- Healthcare
- Personal and social
- Security and surveillance
- Smart environment (home, offices, cities)
- Transportation and logistics (automotive)

The examination on IoT is presently concentrating on viable applications, for example, the advancement of empowering technologies, semantic web technologies, cloud computing and ad hoc architectures. Be that as it may, as brought up by Lanese Etal, there is an absence of research in formal approaches to show the communications among framework segments, and to check the accuracy of the system arrangement before its usage. The primary objective of the present paper is to propose another procedure math for IoT frameworks which bolsters an unmistakable semantic hypothesis for indicating and thinking on IoT applications. Formulating analytics for displaying another worldview requires understanding and refining, in a clean logarithmic setting, the essential highlights of the worldview. So as to call attention to the fundamental elements of the IoT worldview, we utilize a little model inside the keen condition area.

2.12 Human Computer Interaction/Interface

2.12.1 Introduction

Human Computer Interface (HCI) was recently known as the man-machine studies or man-machine communication. It manages the plan, execution and evaluation of PC frameworks and related marvels that are for human use.

A portion of the zones where HCI can be studied with significance are referenced underneath:

- Software engineering − For application structure and building.
- Brain science − For utilization of hypotheses and explanatory reason.
- Human science − For connection among innovation and association.
- Modern Design − For intuitive items like cell phones, microwave, and so on.

The world's driving association in HCI is ACM − SIGCHI, which represents Association for Computer Machinery − Special Interest Group on Computer–Human Interaction. SIGCHI characterizes Computer

Science to be the central regimen control of HCI. In India, it rose as a communication proposition, for the most part situated in the field of Design.

2.12.2 The Goals of HCI

The goals of HCI are to produce functioning and harmless systems, as well as functional systems. In order to produce computer systems with good usability, inventers must try to:

- Recognize the features that govern how persons use technology
- Grow tools and procedures to permit structure suitable schemes
- Attain effective, effective, and a safe interface
- Put the public initial

Fundamental the entire topic of HCI is the conviction that individuals utilizing a PC framework should start things out. Their requirements, capacities and inclinations for leading different errands should coordinate engineers in the manner that they structure frameworks. Individuals ought not need to change the way that they utilize a framework so as to fit in with it. Rather, the framework ought to be intended to coordinate their necessities.

2.12.3 Usability

Ease of use is one of the key ideas in HCI. It is worried about making frameworks simple to learn and utilize. Especially for smart devices it's always required to learn the framework properly so that it becomes easier for software to interact with users. At this time, the designed app and implemented hardware is easy to understand and interact, as we're using this study in performing.

CHAPTER 3: PROPOSED DESIGN AND IMPLEMENTATION

3.1 Flow Chart

Figure 3.2 shows the basic process we designed to follow for the implementation of project. This chart is based upon the minimum features required for the project, it's like a platform or a base model of project. After the implementation of base model, we add the additional features given in section 3.7 of this chapter. In last chapters we already developed a sense, that how the project is working and what are the requirements and output demand. Now, let's describe it with sequence given in flow chart. From the start, we will get data from ACS sensor and dispatch it in Arduino by converting coding the sense of Arduino to take these voltages as signal. There first condition came as we can see from code, that if data is null then repeat the task in loop or calculate energy. Code will then compare this energy with time from RTC and show both on LCD, save them on EEPROM, and dispatch them to WIFI module. If WIFI module get failed to transmit this data, it'll add this data in waiting list; and repeat until it gets transmitted successfully.

3.2 Design and implementation

Smart meter is mostly design to work in a smart way include smart units' calculations, send to consumer and utility company through some communication channel, monitoring and control of consumption by analyzing the power utilization per time graphically.

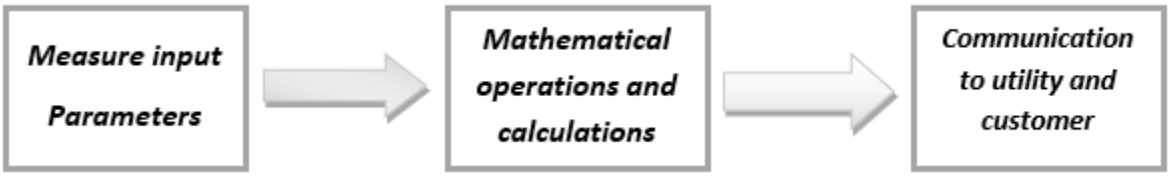


Figure 3.1: Three Stages

The design for our project includes the three major stages;

3.3 Stage 1

In this stage we calculated accurate electricity consumption units by measuring the current using a current sensor ACS712 and voltage by using potential transformer. CS712 is a current sensor used to measure current accurately by using magnetic Hall Effect theory proposed by Edwin Hall in 1879.

Hall Effect theory states that:

"The voltage difference across an electrical conductor transverse an electric current in this conductor and applied magnetic field is perpendicular to that current." (figure 3.3)

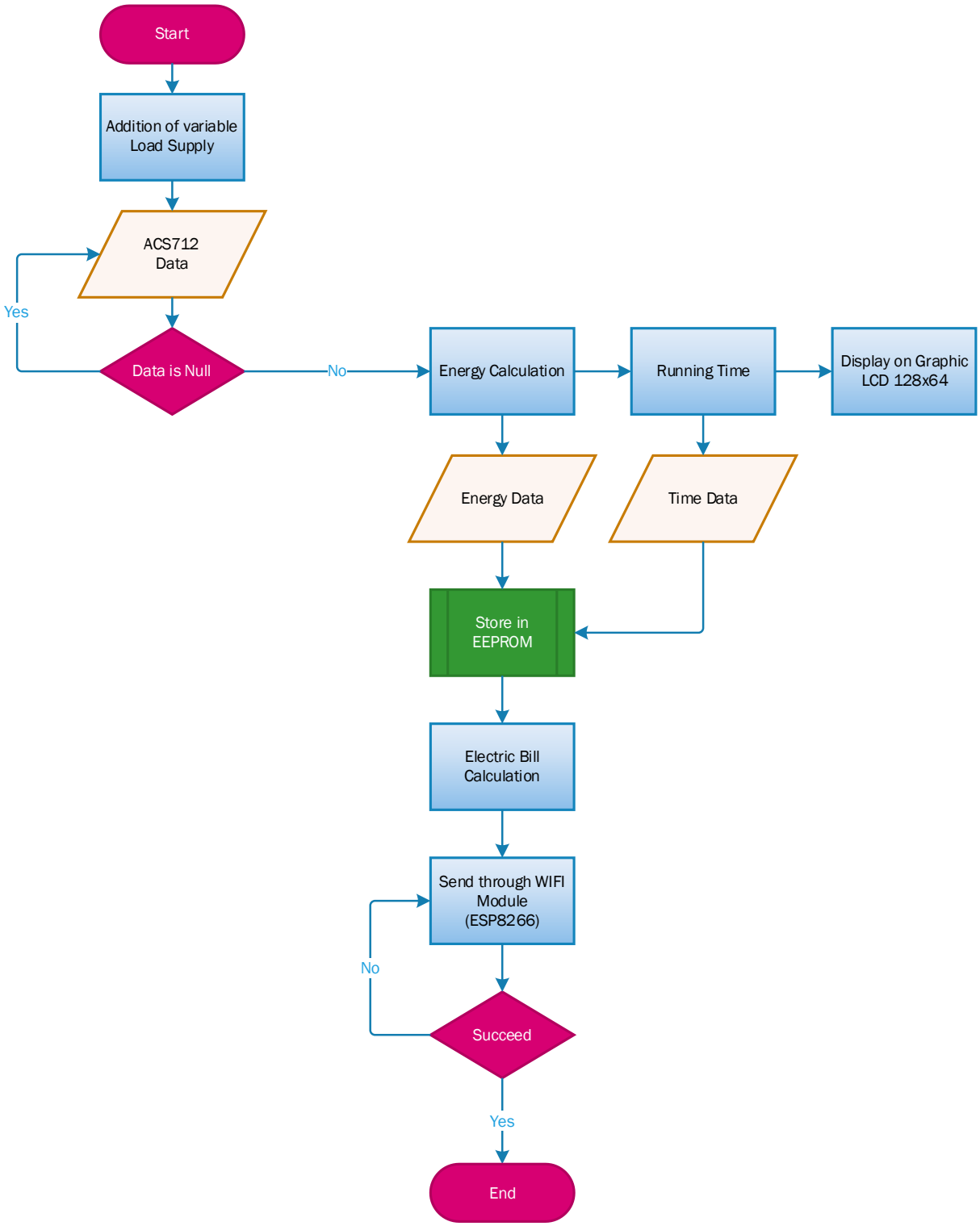


Figure 3.2: Flow-Chart

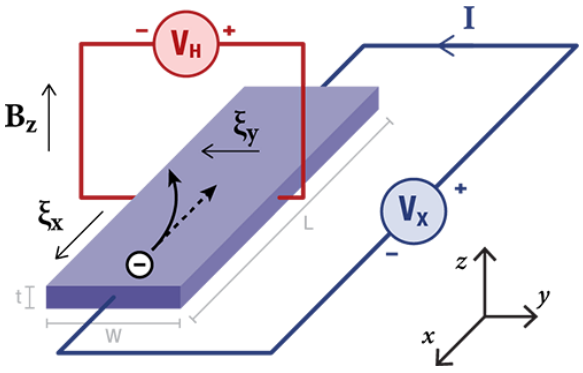


Figure 3.3: Hall Effect sensor working concept

To measure input voltage, we used a potential transformer. The potential transformer may be defined as an instrument transformer used for the transformation of voltage from a higher value to the lower value. This transformer step down the voltage to a safe limit value which can be easily measured by the ordinary low voltage instrument like a voltmeter, wattmeter and watt-hour meters, etc.

Now for time calculations we attached a real time clock RTC.

3.4 Stage 2

In this stage we calculated the KWH by taking the values of time, voltage and current from stage 1. All mathematical operations include reactive power, power factor etc. are performed by microcontroller. All of these parameters would be shown on graphic LCD. Here we used Arduino Mega 2560 and 128x64 ST7920 graphic LCD for this purpose. After the measurement of KWH, we stored these units in the EPROM of Arduino. This is for record when utility is not connected or load shedding occurs then previous utilized units would be saved. Real time clock ran even when system is off so in this way, we can monitor a time for load shedding and isolation of system by breakers and relays in the case of any fault inception.

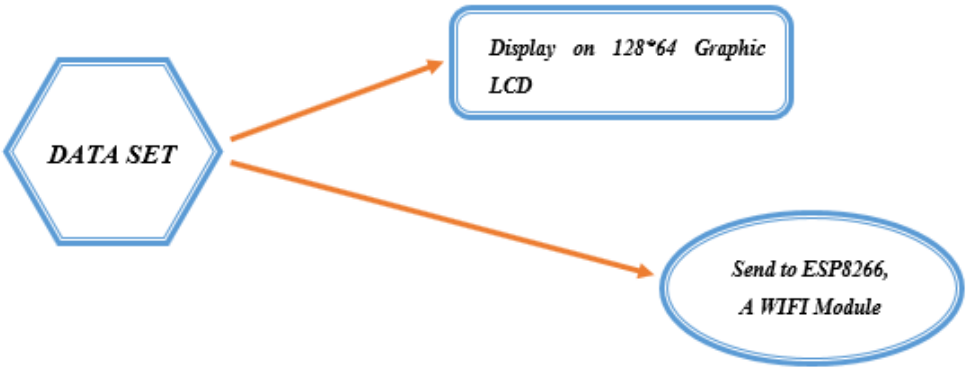


Figure 3.4: Stage 2

Now let’s take a small overview of Arduino Mega 2560;

3.4.1 Arduino Mega 2560

In smart energy meter, we're going to use most feasible microcontroller so that our demands fulfill efficiently and meter would be cost effective as per market value. We're using Arduino Mega 2560 because of the reasons given below.

Some general specification info, that why it meets our requirement mentioned in section 2.10 is given below:

1. Arduino mega is cost feasible with more memory and I/O pins as compared to all other controllers available in the market.
2. It has two voltage regulators (i.e. 5V and 3.3V) which extends the possibilities to regulate the voltage as per requirements.
3. The processor of Arduino mega 2560 is based on Atmega2560 so it also has enough processing speed to evaluate our data as per given instructions.
4. This board has a USB port to transfer data from computer by using wireless connection. So, we can easily engage this controller with our PC.
5. It also contains a dc power jack which is not a common feature in all versions of Arduino. Dc power jack is used to power the Arduino.
6. An oscillator is attached with the board which has a frequency of 16 MHz enough for the purpose.
7. The very important and unique thing about this controller is that it is incorporated with 54 digital and 16 analog I/O pins. 15 out of 54 digital input output pins are used for Pulse width modulation.
8. To program Arduino and upload a code from computer, ICSP header feature is introduced in mega 2560 to make it user friendly.
9. To program an Arduino mega, we use Arduino IDE software which belongs to Arduino family and almost used to program all versions of Arduino.
10. For maximum speed of communication there is also a reset button and four hardware serial ports called UART.
11. We don't need any type of converter to program this board because it has Atmega16 which we can directly connect with PC.
12. When we built and compile a code in Arduino mega, we can supply a power by using a battery at Vin port to operate the controller.
13. It is mostly designed for complex electrical projects which have very complicated circuitry, need more memory and processing speed. Also, it is important in the projects where we need more I/O ports.

3.4.1.1 Specification

Table 3.1: Specifications of Arduino Mega 2560

Microcontroller	Atmega2560
Operating Voltage	5V
Input Voltage	7V – 12V
USB Port	Yes
DC Power Jack	Yes
Current Rating Per I/O Pin	20mA
Current Drawn from Chip	50mA
Digital I/O Pins	54
PWM	15
Analog Pins (Can be used as Digital Pins)	16 (Out of Digital I/O Pins)
Flash Memory	256KB
SRAM	8KB
EEPROM	4KB
Crystal Oscillator	16 MHz
LED	Yes/Attached with Digital Pin 13
Wi-Fi	No
Shield Compatibility	Yes

3.4.1.2 Pin configuration

- **V_{in}**

  This pin is used to provide the input voltage to controller through dc power jack which ranges from 7V to 20V. The output through this pin will always be set up to 5V automatically.

- **Ground GND**

  In complex circuitry where more than one grounds are required, this board comes with 5 ground pins to make it useful.

- **Voltage regulators**

  This board is incorporated with two voltage regulators at two different pins (i. e 5 V and 3.3 V). These two pins are used as an output power source to power up the controller and to excite the other components of the circuit. It can draw 50mA maximum.

- **Reset**

  This is a pin used to reset the Arduino when the processing is getting slow or when we need to increase the speed of communication. Setting this pin LOW will reset the Arduino.

- **Serial communication**

  Two pins RXD and TXD are used to make a serial data communication. RXD is used to transmit the serial data while TXD used to receive it. These pins are used in four different combinations in order to make a serial data communication.

- ✓ Serial 0 has RX(0) and TX(1) pins
- ✓ Serial 1 has RX(19) and TX(18) pins
- ✓ Serial 2 has TX(16) and RX(17) pins
- ✓ Serial 3 has TX(14) and RX(15) pins

❖ **External interrupts**

6 pins are used to provide an external interrupt in Pulse width modulation. Interrupts are provided in different ways for example falling and rising edge, change the value of interrupt pins or provide a LOW value. Interrupt pins are 0, 3, 21, 20, 19, 18.

❖ **LED**

To analyze the processing and compiling and nursing your programming skills, a built in led is designed in Arduino at pin 13 which turns on at high value and tuns off at low value.

❖ **SPI communication**

Some of the pins are used to make a communication between controller and other peripheral components in the circuit. These are SPI communication pins. These are 4 pins i.e MISO (50), MOSI(51), SCK(52) and SS(53)

❖ **Analog pins**

These are 16 labelled as A(0) to A(15). These are also used as digital I/O pins. Each analog pins comes with ten bit data resolution. They are at constant voltage level 5V with respect to ground. But we can change the voltage by using AREF function.

❖ **AREF**

This pin is used for the reference voltage for analog input.

3.4.2 Graphic LCD ST9720

Let's take a small overview of graphic LCD ST9720:

The ST9720 Graphical LCD is totally different from the Ordinary LCDs. Ordinary LCD can only print simple text or numbers within a fixed size. But in Graphical LCDs we have 128*64 which is equal to 8192 dots or 8192/8 = 1024 pixels, so apart from character, we can display any Graphical Image on this GLCD.

This Graphical LCD is having low power consumption and also suitable for battery power portable device. It has wide operating voltage range 2.2v to 5.5v and supports both serial and 8/4-bit parallel communication and comes with ST7290 LCD controller/driver IC. Interface communication mode can be switched between parallel and serial using PSB PIN 15. This graphical LCD has an automatic power on Reset function and can be easily controlled by MCU such as 8051, AVR, ARM, Arduino and Raspberry Pi.

We already interfaced GLCD with 8051, today we will interface Graphical LCD with Arduino to display text and images on it.

3.5 Stage 3

Now, in this stage we're committed to send our data set to utility company and costumer. We used ESP8266 Wi-Fi module as a communication channel. This module sent data to think speak which is basically a database developed for this module only. When data is sent to think speak, we can easily access our data by connecting with internet. Also, we developed an application which read data from think speak and displayed on mobile as well as computer.

The comparison between different communication modules as discussed in section 2.9, where we concluded the most viable option for this project should be WIFI. Here, we'll see the detail description of Wi-Fi adapter for internet communication and see how it works; later we'll develop strategies to use the module in most economical way. With the vast number of features and appropriate standard this device (ESP8266) is the most feasible WIFI-Adapter in market for this project.

ESP8266 can be considered as a low energy WIFI Adapter, as it's connecting itself to internet and making a LAN connection through router, to send and receive information (depends on egress and ingress bandwidth of network). With built-in real-time clock one can program it when certain conditions meet. The sleep current consumption is less than 12µA and when it's connected with some API the consumption ranges from 0.5mW – 1.0mW. [4] The reason of this low power consumption is integrated power management unit. As, this sensor is designed for mobile applications (mostly on battery), so the consumption control is important. It used IEEE 801.11 b/g/n protocol for communication, that's considered as a most standard mode in short range wireless networks. Our computers and mobiles are also using the same protocol in LAN. With the feature of WIFI-direct, LAN communication is also possible and with some programming one can also cast the video information through this small chip.

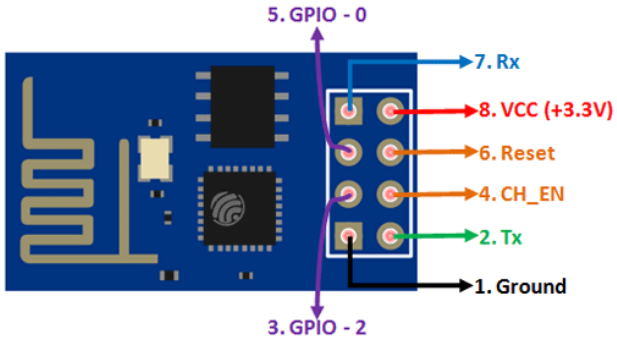


Figure 3.5: ESP8266 WIFI Module Pinout

3.5.1 Pinout

Working and use of each pin (figure 3.6) is given in bullets below:

- Ground → Connected to the ground of circuit
- Tx → Transmitter pin
- GPIO-2 → General Purpose I/O pin
- CH-EN → Chip enable pin, connected to high
- GPIO-0 → General Purpose I/O pin that takes the module into serial programming
- Reset → Reset the module
- Rx → Receiver pin
- VCC → Connect it to 3.3V supply

Let's take a small overview of ESP8266;

- ESP8266 is a cost-effective Wi-Fi module that supports both TCP/IP and microcontrollers. It runs at 3V with maximum voltage range around 3.6V. More often than not, it also comes under name ESP8266 Wireless Transceiver.
- This module stays ahead of its predecessor in terms of processing speed and storage capability. It can be interfaced with the sensors and other devices and requires very little modification and development to make it compatible with other devices.
- Components and GPIO pins interfaced on the little chip are very compact that makes it suitable for hard to reach places.
- It covers little space and everything is laid out on the PCB board quite precisely that no external circuitry is required to put this device in the running condition.
- No external RF circuitry is required as this module comes with self-calibrated RF capability that makes it suitable to work under all operating conditions.
- It is a very useful device for wireless networking, however, there are some limitations i.e. external logic level converter is needed as it doesn't support 5-3V logic shifting.

3.5.2 Technical specifications:

- It is also known as a system-on-chip (SoC) and comes with a 32-bit Tensilica microcontroller, antenna switches, RF balun, power amplifier, standard digital peripheral interfaces, low noise receive amplifier, power management module and filter capability.
- The processor is based on Tensilica Xtensa Diamond Standard 106Micro and runs at 80 MHz.
- It incorporates 64 KB boot ROM, 80 KB user data RAM and 32 KB instruction RAM.

- It supports Wi-Fi 802.11 b/g/n around 2.4 GHz and other features including 16 GPIO, Inter-Integrated Circuit (I²C), Serial Peripheral Interface (SPI), 10-bit ADC, and I²S interfaces with DMA.
- External QSPI flash memory is accessed through SPI and supports up to 16 MB and 512 KB to 4 MB is initially included in the module.
- It is a major development in terms of wireless communication with little circuitry and contains onboard regulator that helps in providing 3.3V consistent power to the board.
- It supports APSD which makes it an ideal choice for VoIP applications and Bluetooth interfaces.

3.6 Circuit Connections:

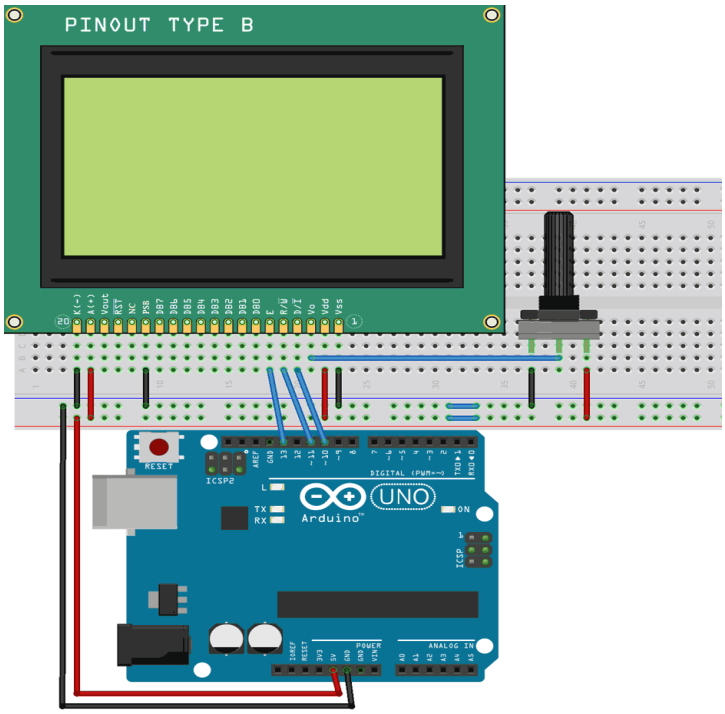


Figure 3.6: Graphic LCD connection interfacing with Arduino

3.7 Server Settings

As, mentioned we used free server ThingSpeak to send and receive data. For now, we are not using it commercially, so the data write time delay should be equal or greater than 15sec. At this time we can compensate on that, the apps (Chapter 4) were also developed with same conditions but has the flexibility in code to change with the conditions.

After creating a free account, we can create a channel, that has a limited 8 fields. We only need 4 out of that 8 fields, reserved for Bill, Units, Power and Amperes. Each channel has its own API keys for writing

and reading data from server. After setting up the fields we'll add visualization, in private view. We can also choose public channel, but considering that at commercial scale each home will have their own channel we preferred to use a private one. Visualization in ThingSpeak ranges from a whole plot, to single digital value; this will give user options to observe the data for proper budget management.

At the end we'll put these API keys into code (at commercial scale each smart meter will have different API keys), and it'll start writing and reading data from server.

3.7.1 Channel Management

This project is not just based on simple prototype, but it's a well-designed planned scheme; can be used commercially with necessary changes. The followed standards make things more convenient, in a way that the product can be used with multiple services for better user operation and utility management control.

In case of large number of consumers with smart meter, each meter should have their own API keys for security. For this we can create as many channels as required for the application on commercial license as shown in figure 3.8 and 3.9. With little-bit of python, we can automate channel creation process; so, as the meter serial gets confirmed, the code will create the respective channel for device.

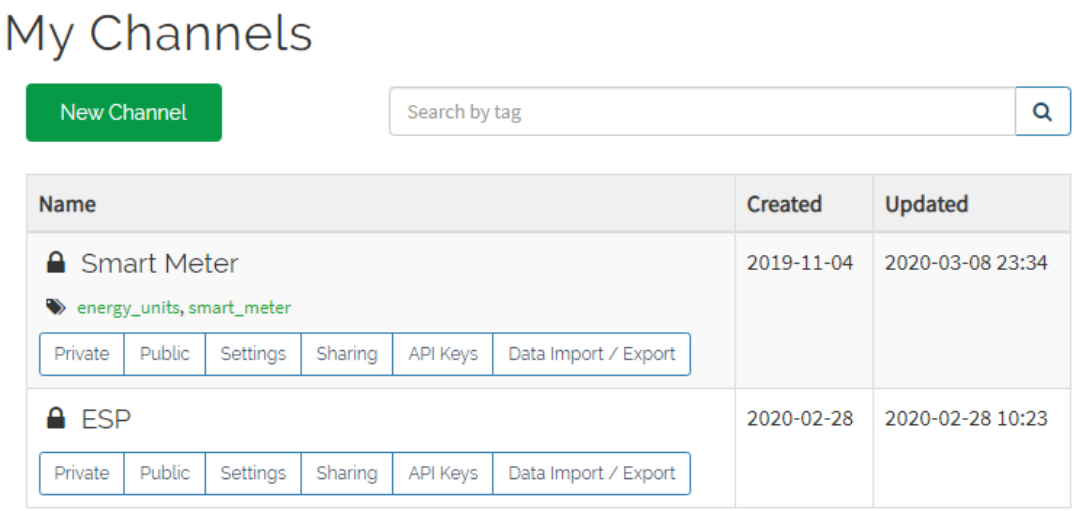


Figure 3.7: Channel Management

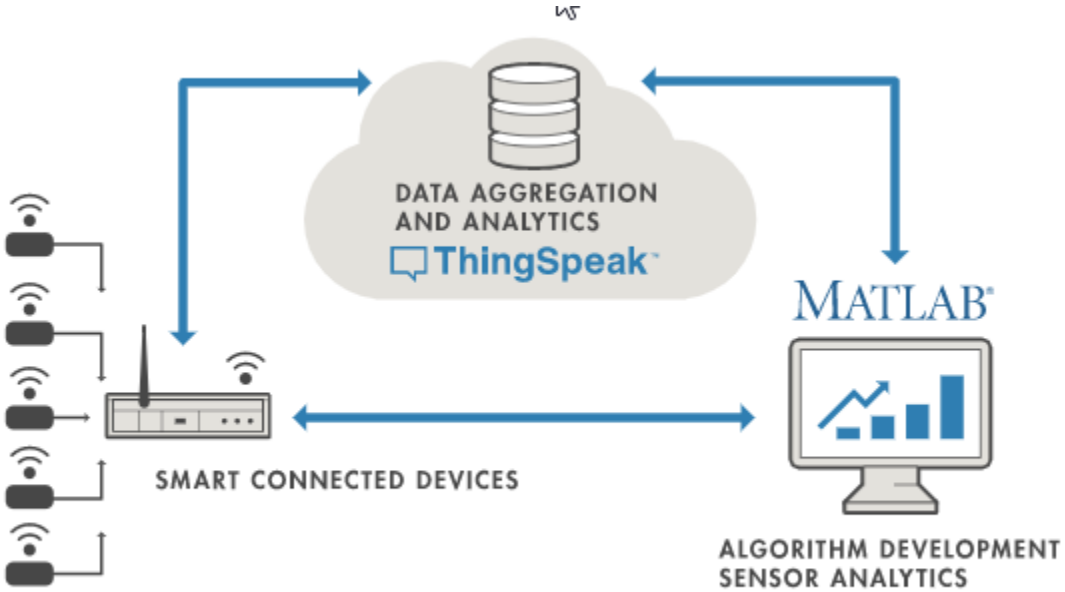


Figure 3.8: Multiple Channels for Multiple Devices that can Separately analyze on MATLAB

3.8 Features:

3.8.1 Load limiting:

In this project a load limiting concept is introduced to limit the consumption and to save the electricity. We set a threshold value of power above which the relay would operate and supply would cut off for a specific time period. In this way, we can handle high power consumption appliances and save the electricity and reduce the hours for load shedding. The concept is that Load Limiting is a warning that your area is about to go through Load Shedding for several hours as per the schedule. However, if you switch of enough devices and appliances during the five-minute warning, you can be avoid having no power at all and continue to have power whilst your neighbors who don't have smart meters or haven't switched off their appliances will sit in the dark. So, it's a way to reduce power consumption, keep lights and TV on, and have limited power, verses having zero power.

3.8.2 Electricity Theft

Theft in electricity produce non-technical losses. To reduce or control theft one can save his economic resources. Smart meter can be the best option to minimize electricity theft, because of its high security, best efficiency, and excellent resistance towards many of theft ideas in electromechanical meters. So, electricity theft can be monitored and trapped by using smart meters.

3.8.3 Accuracy and Efficiency

Smart meters are designed to work in accurate and efficient way. We precisely measure each and every parameter which further used in mathematical formulas to calculate the units in KWH. If we study the data sheets for current sensor and Wi-Fi module, we would see that the these are the efficient modules for this purpose.

3.8.4 Consumption record with respect to time

The best thing about smart meter is that we can keep a consumption record with respect to time. If when meters are burn out, we can easily retrieve data from EEPROM. Also, we can see the peak and lowest demands for certain hours and monitor as per the situation. We can limit our consumption by analyzing the consumption with respect to time.

Here, we used a real time clock for observing our consumption with respect to time. Clock would run even when microcontroller turned off.

3.9 Strategies

3.9.1 Designing an Efficient Coding Scheme for ESP8266 – Transmission

At that point we have a simple technique of data transmission. WIFI module is receiving the data from Arduino and is transferring this to online portal. As, we discussed that this module is mostly used in mobile applications on battery so there should be proper coding scheme, so that we can save power. In this scheme, as module is transmitting data continuously, so the total power consumption can affect the efficiency of system. To overcome this, we have to devise some way so that module can turn off automatically for some amount of time. Data from sensor can't be compensated; this sensor consume a large amount of power, so we have to compensate on number of samples. Increasing the width of samples with respect to time can surely save a lot of power. Factors like current and voltage have no sudden change, so we can send the start command to sensor after a 10 sec. In this way, we'll have each sample after a minute interval.

In the simulation below we are getting the data continually, and it's storing in an array. The data of this array will then can be transferred to some file as Arduino program memory ends. Simulation not shows the transmission through Wi-Fi module, but practically this file will then can be transferred to web through used WIFI module. This is the one way of transferring data, and for less power consumption this is the most efficient technique. As, EP8266 can set conditions for it sleep and wake time so there's a need of proper code for this. The conditions are like when the data in array exceeds limit, turn on the module, transmit the data and turn off the module. With this simple technique we can save a lot of power, the power required for the sensor to stay awake can be saved.

3.9.2 Exception case Calculation due to ACS712

The voltage we are receiving has a constant multiple of current value; in AC this value changes rapidly as ACS is basically sensor commonly used for DC. For a special AC case, we have to develop a strategy. In Pakistan we receive the AC of frequency 50Hz, means each cycle will pass after 0.05sec. So, we'll measure the peak value of voltage signal, and integrate it and find the average of whole cycle. Data dispatch from current sensor can't be stop, so we have to see which value is maximum in the interval of 0.05sec.

Thus, strategy has some flaws, like frequency from WAPDA can't be constant. [5] We can compensate on that as the error due to this wouldn't be much large. But the processing speed addition in this 0.05sec interval is important; but it'll increase more time complexity. So, we'll get data from 10 cycles, average it; and then calculate peak. This will decrease the complexity, or if we want to perform more operation and observe that program is taking more time to proceed then we can increase this number of cycles anytime until the final form of code wouldn't reach.

CHAPTER 4: PROJECT MANAGEMENT

The project management file had been created at the start of project, while filling the details of work sessions, unit's completion and costs, the results like resource management, cost, budget detail, Gantt Chart etc at the end of project have been taken and the details are mentioned in this section.

4.1 Time Management

The management table shows the duration of each project. For the specificity we can use values, while for visualization, Gantt chart is most suitable. *Table and Gantt chart* of the given project generated from MS project can be seen in Table 4.1 and Figure 4.1 respectively. From the starting date (June 15, 2019) till the final (July, 15 2020); everything can be visualized from Gantt chart. The *project timeline* shown in – shows a time frame of major tasks by analyzing the constraints of calendar that includes holidays as an exception and working hour of each resource. The *baseline summary report* in project chart is unavailable as the planning for time management was never done.

4.1.1 Gantt Chart Symbols

Well, to visualize the summary, the way graphs show; it's important to know how they work. So, it's important to know what the symbols of Gantt chart depicts.

- Shows the deadline of corresponding task

- Shows the milestone achieved after certain tasks

- Represents a summary, like a tab of some number of tasks

- It represents a task; it's the length shows the duration.

- The arrow joining two tasks is called link, this is SS (Start-Start link) means both tasks will start simultaneously. For the time management it's important to find the expert resource and assign the tasks so that the more tasks can get completed in short time interval. In this Gantt chart we also used Start-End link.

Table 4.1: Management Table of Project showing Timeline and Duration w.r.t Tasks

Task Name	Duration	Start	Finish
Planning	11.13 days	Sat 15-06-19	Fri 22-11-19
Literature Review and Planning	8.75 days	Sat 15-06-19	Sun 27-10-19
Collecting Realted Papers	1.5 days	Sat 15-06-19	Sun 30-06-19
Studying Papers	7.25 days	Sat 06-07-19	Sun 27-10-19
Document and Management	7.75 days	Sun 08-09-19	Sun 17-11-19
Proposal Submission	1 day	Sun 08-09-19	Sun 15-09-19
Proposal Defense Presenatation	0 days	Tue 17-09-19	Tue 17-09-19
Feasibility Report	1 day	Sun 15-09-19	Fri 27-09-19
Project Management Design	6 days	Fri 27-09-19	Sun 17-11-19
Budget Document	6 days	Fri 27-09-19	Sun 17-11-19
Designing the Model	9.76 days	Sun 30-06-19	Fri 22-11-19
Mechanical Design	6.63 days	Sun 30-06-19	Sun 20-10-19
Cicuit Design	6.63 days	Sun 30-06-19	Sun 20-10-19
Coding Strategy	2.88 days	Sat 26-10-19	Fri 22-11-19
Mathematical Modeling	2.88 days	Sat 26-10-19	Fri 22-11-19
Working	28.13 days	Fri 22-11-19	Fri 27-03-20
Buying Hardware	1.88 days	Fri 22-11-19	Sun 08-12-19
Programming and Debuging	3.13 days	Fri 22-11-19	Sat 21-12-19
Script	1.75 days	Fri 22-11-19	Sat 07-12-19
Temporary Emboidment	1.13 days	Sat 07-12-19	Fri 20-12-19
General Algos Required	3.13 days	Fri 22-11-19	Sat 21-12-19
Main	3.13 days	Fri 22-11-19	Sat 21-12-19
ThingSpeak	0.63 days	Fri 22-11-19	Fri 29-11-19
Channel Creation	2 hrs	Fri 22-11-19	Sat 23-11-19
Designing Read Write Structure on MATLAB	5 hrs	Fri 22-11-19	Fri 29-11-19
App Design	25 days	Sat 21-12-19	Fri 27-03-20
MATLAB App Designer	5 wks	Sat 21-12-19	Fri 27-03-20
Android	2 hrs	Sat 21-12-19	Sun 22-12-19
Simulations and Drawings	15 days	Sat 21-12-19	Fri 28-02-20
Proteus Model	2.5 wks	Sat 21-12-19	Fri 21-02-20
Drawings	0.5 wks	Fri 21-02-20	Fri 28-02-20
Finalizing	22.74 days	Fri 27-03-20	Wed 15-07-20
Assembling + Prototype Structure	1 day	Fri 27-03-20	Sun 29-03-20
Thesis Writing	3.47 days	Fri 27-03-20	Sat 25-04-20
Thesis Submission	0 days	Wed 15-07-20	Wed 15-07-20

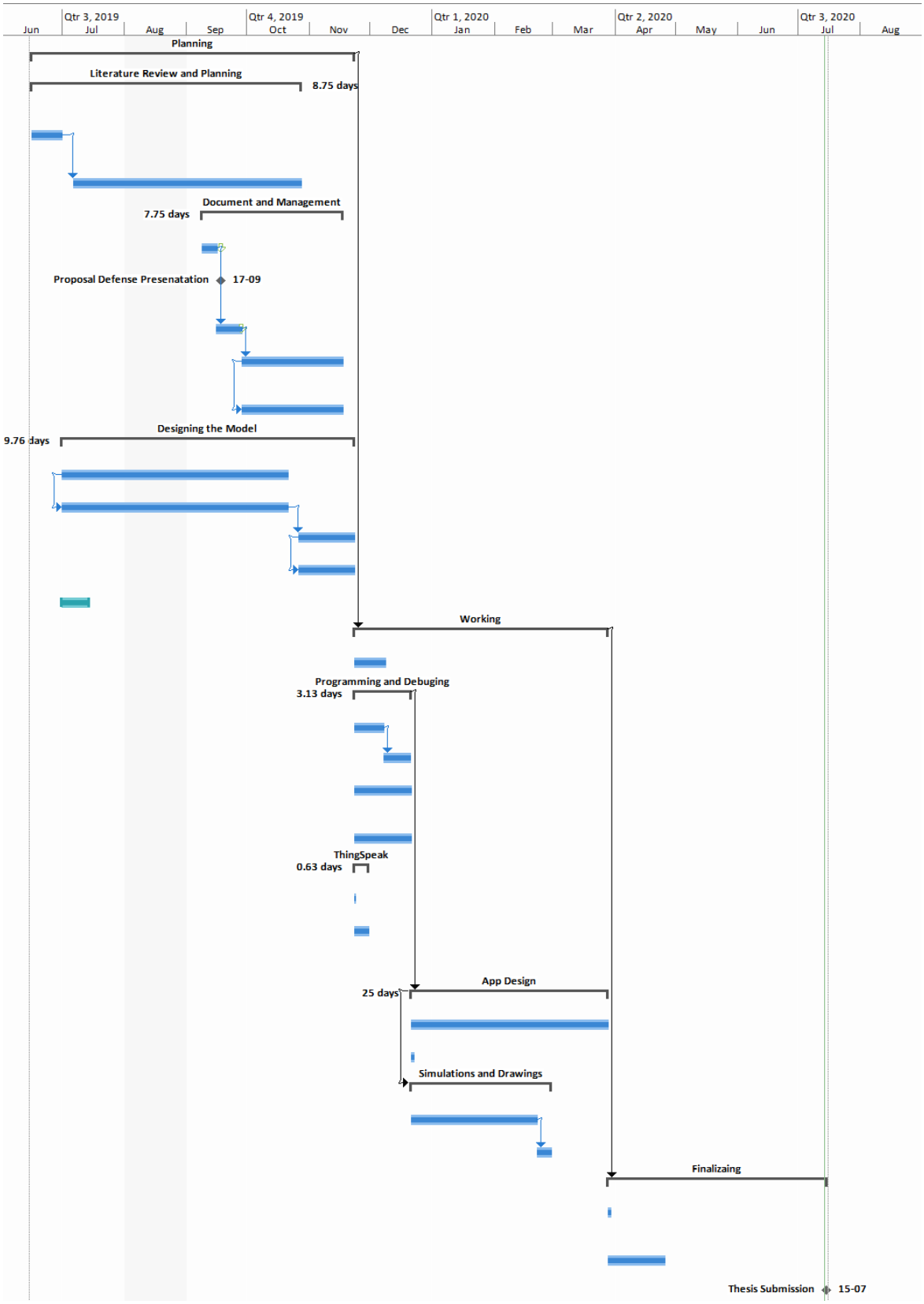


Figure 4.1: Gantt Chart

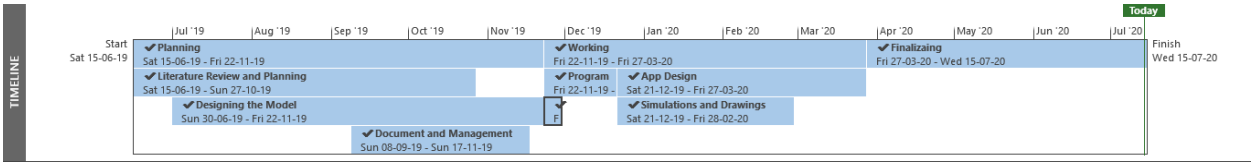


Figure 4.2: Project Timeline

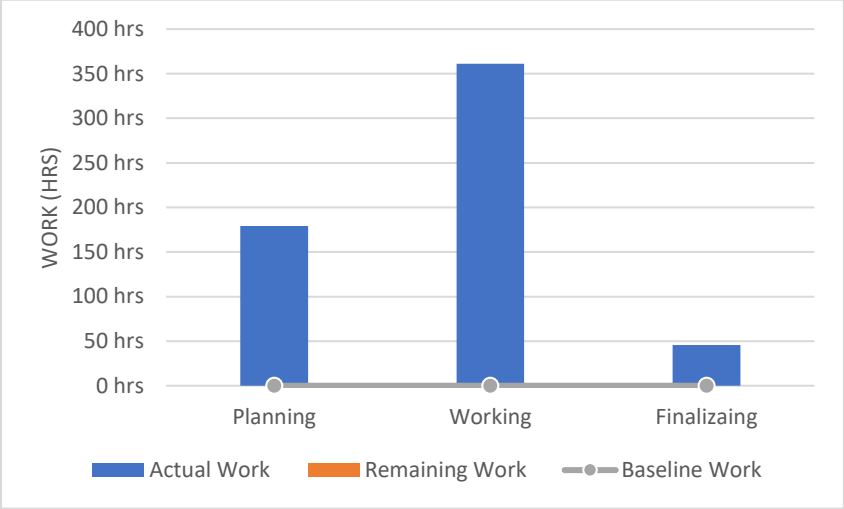


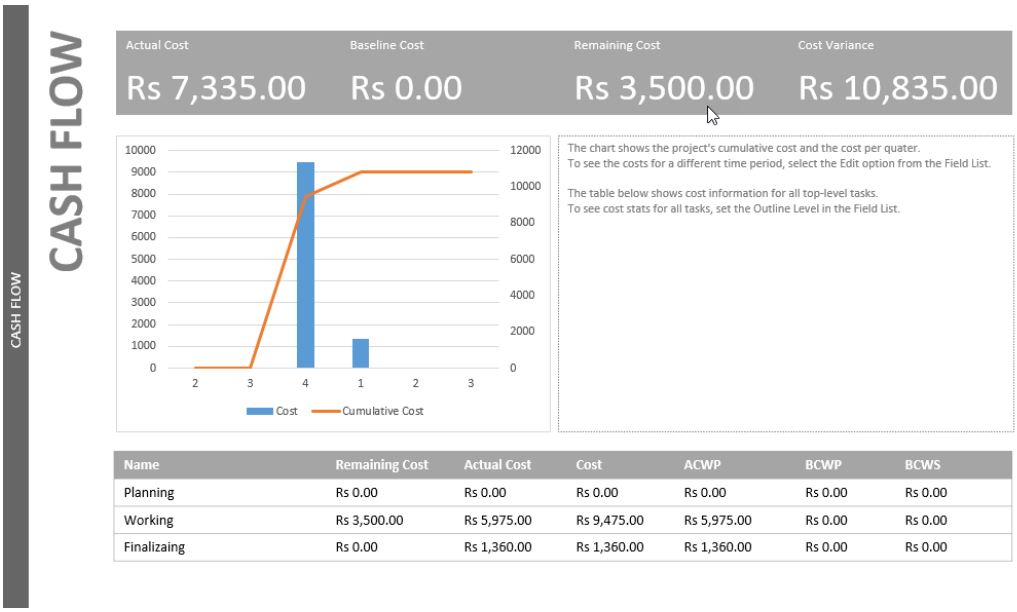
Figure 4.3: Each Section Detailed Histogram

4.2 Resource Management

Resource includes, material, people and general costs required in project. Before starting project, the one of the important things is to estimate the cost, so that for especially for large project the companies can save themselves from bankruptcy. Project budget is also important for the products that you have to sell to public, so checking the feasibility before preluding it into market.

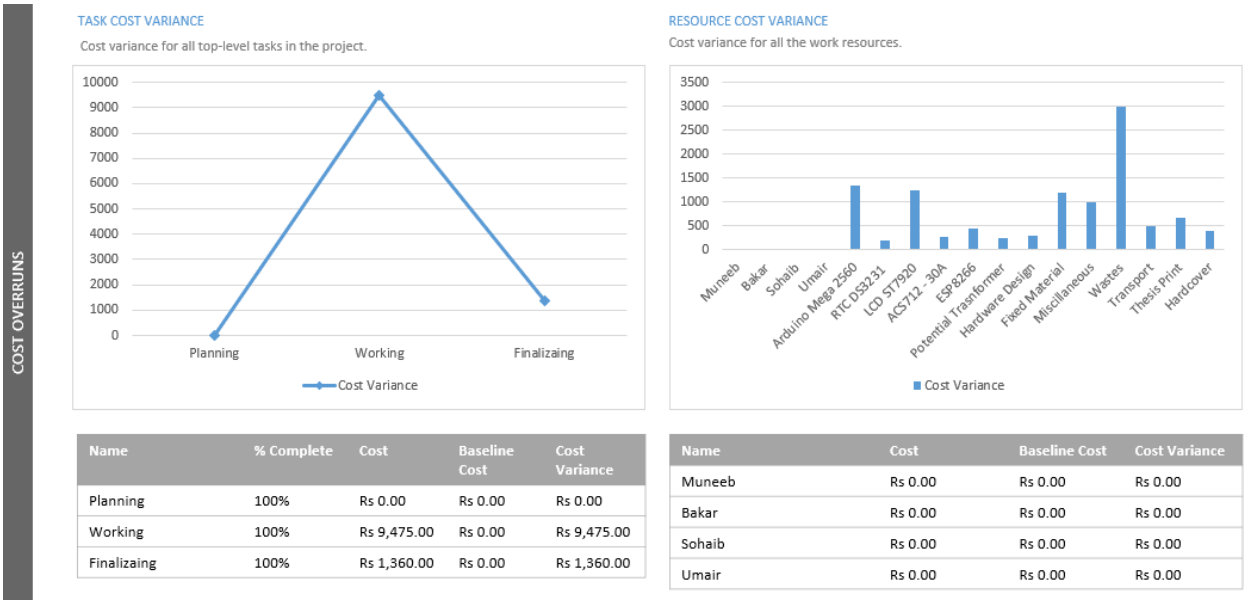
The cost and their use w.r.t time (Budget Report) can be found from Figure 4.4 and Figure 4.5

The workforce charts with respect to time are given in Figure 4.6 and Figure 4.7.



Name	Remaining Cost	Actual Cost	Cost	ACWP	BCWP	BCWS
Planning	Rs 0.00	Rs 0.00	Rs 0.00	Rs 0.00	Rs 0.00	Rs 0.00
Working	Rs 3,500.00	Rs 5,975.00	Rs 9,475.00	Rs 5,975.00	Rs 0.00	Rs 0.00
Finalizaing	Rs 0.00	Rs 1,360.00	Rs 1,360.00	Rs 1,360.00	Rs 0.00	Rs 0.00

Figure 4.4: Cash Flow Report



Name	% Complete	Cost	Baseline Cost	Cost Variance
Planning	100%	Rs 0.00	Rs 0.00	Rs 0.00
Working	100%	Rs 9,475.00	Rs 0.00	Rs 9,475.00
Finalizaing	100%	Rs 1,360.00	Rs 0.00	Rs 1,360.00

Name	Cost	Baseline Cost	Cost Variance
Muneeb	Rs 0.00	Rs 0.00	Rs 0.00
Bakar	Rs 0.00	Rs 0.00	Rs 0.00
Sohaib	Rs 0.00	Rs 0.00	Rs 0.00
Umair	Rs 0.00	Rs 0.00	Rs 0.00

Figure 4.5: Detailed Cost Overflow Charts

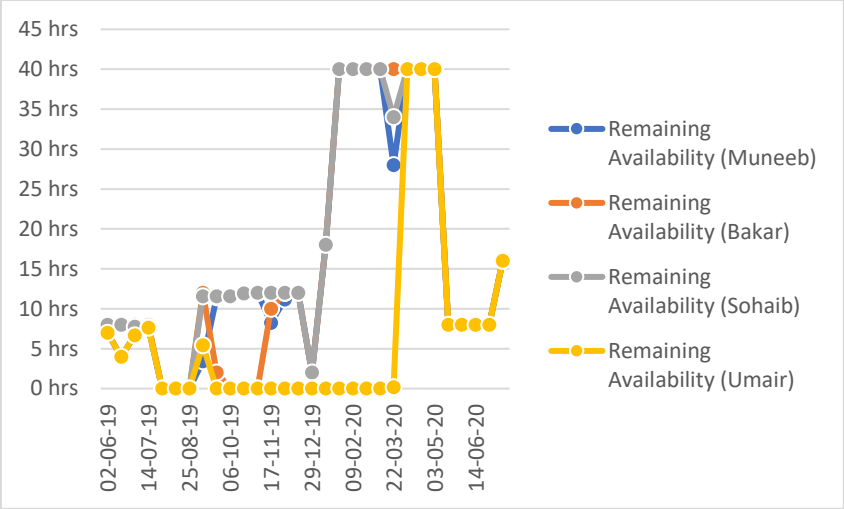


Figure 4.6: Workforce Chart

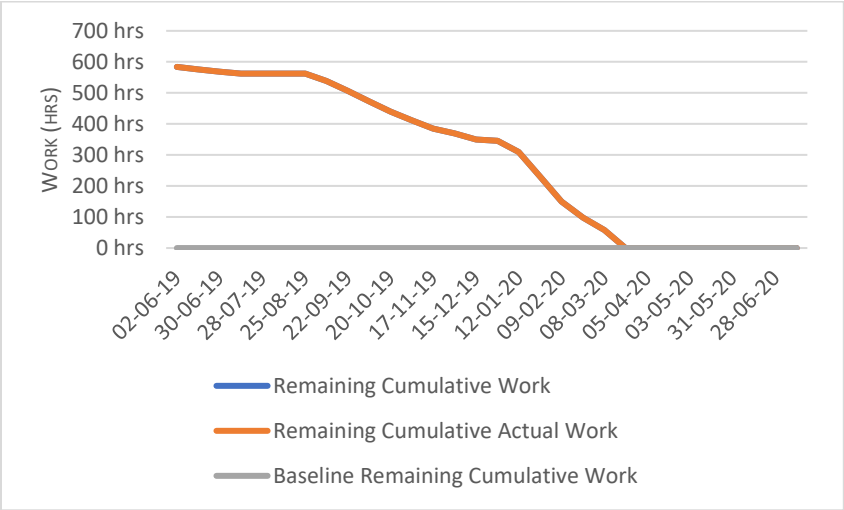


Figure 4.7: Overall Work Chart (Baseline was not set)

4.3 Team Management

Finally, we have team management. As, discussed it's important to find the expertise and assign the work to them properly to get the task done within estimated date. In MS Project we can do this by defining base calendar. Setting up the calendars means to define which days we which person is available to work; when there'll be exceptions of holidays, and for how much hours a person can work. If the amount of work for a resource exceed, it's will be overallocated and thus we can assign it to some other time where he can work easily. It all should be done before the start of project. With the same calendars of each group members, the unequal distribution of task will cause overallocation; an example we faced can be seen from Figure 4.8.

Team management charts, as how the distribution of tasks occur to each resource can be seen in .mpp file can be found in supplementary material of this thesis. [6]

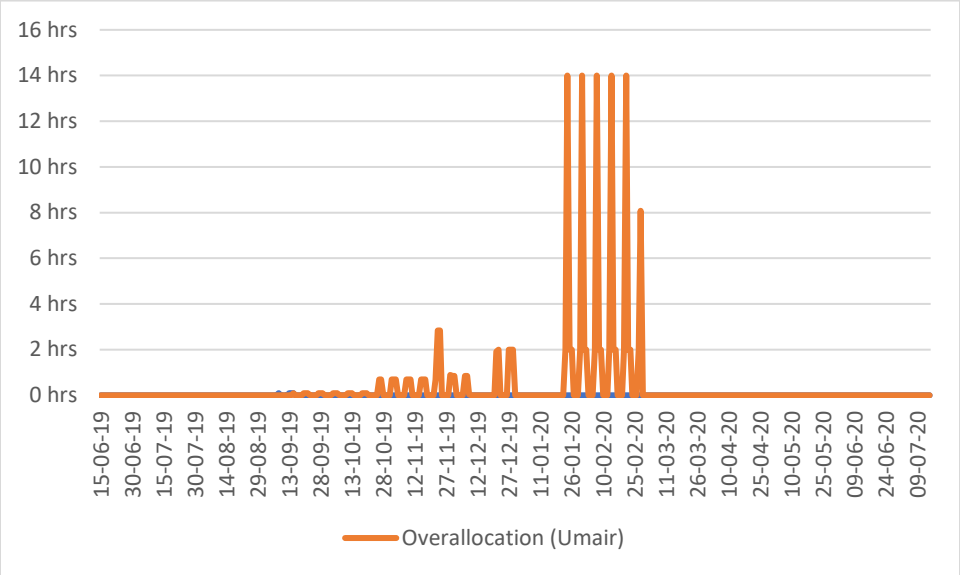


Figure 4.8: Overallocation

CHAPTER 5: RESULTS, SIMULATION AND ANALYSIS

This chapter is reserved for results like display of data to user, final form of meter and apps. We'll discuss some detail about code and see the process in simulation, and observe the interactivity and design of applications developed for more visualized access to data.

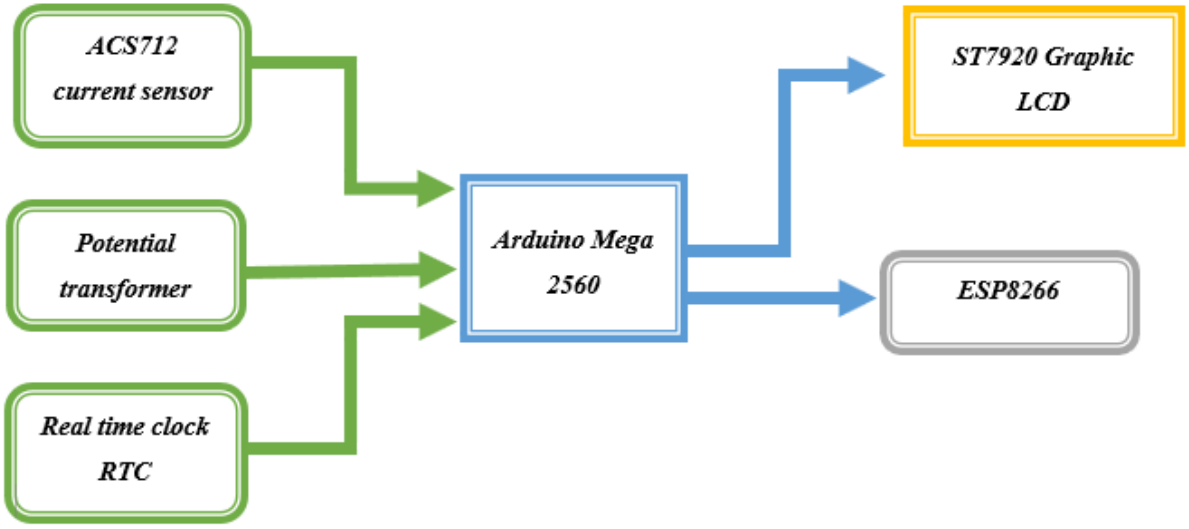


Figure 5.1: Process Diagram

The given block diagram clearly shows the implementation view for this project. By taking values from Current Sensor (ACS712), PT and RTC we did mathematical calculations in Arduino Mega 2560. After making a required data, we displayed it on LCD and transmitted to Wifi module as well.

5.1 Simulation

The simulation results of ACS712 and LCD on proteus are shown below:

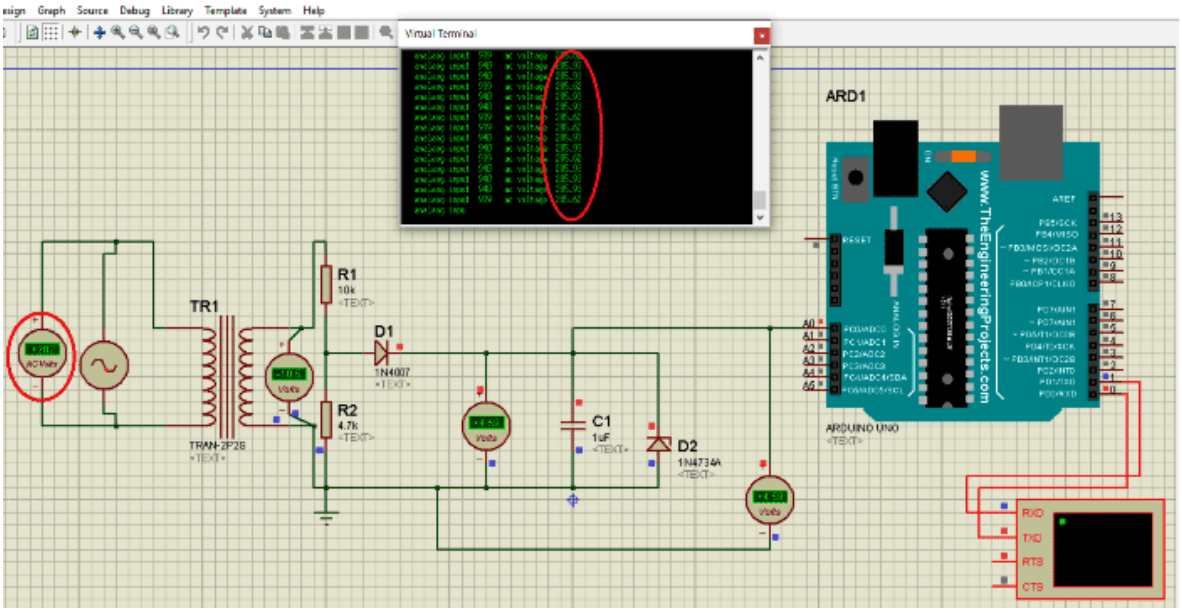


Figure 5.2: Voltage measurement circuitry

Connections for ACS712, LCD and ESP8266 with Arduino are as follow:

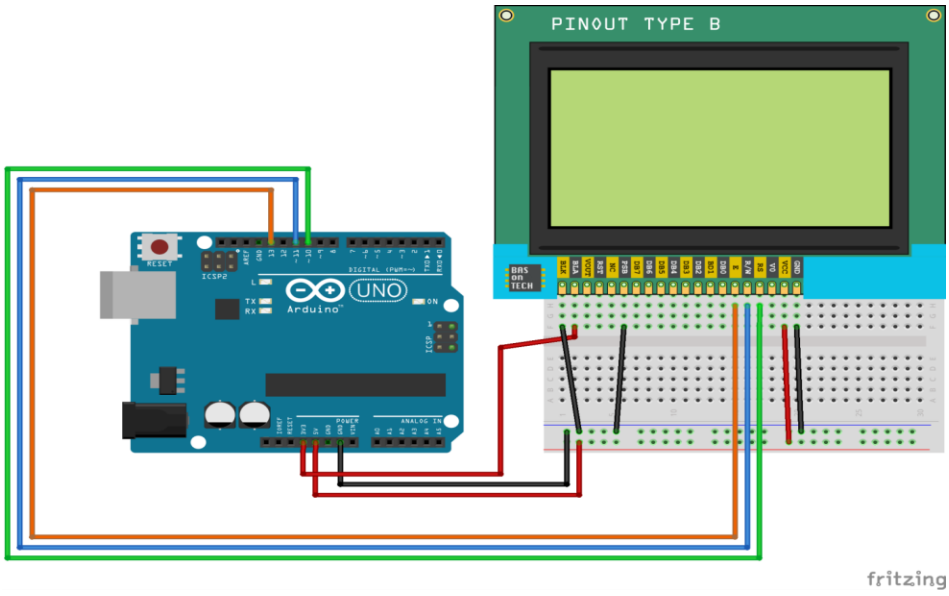


Figure 5.3: LCD interfacing with Arduino

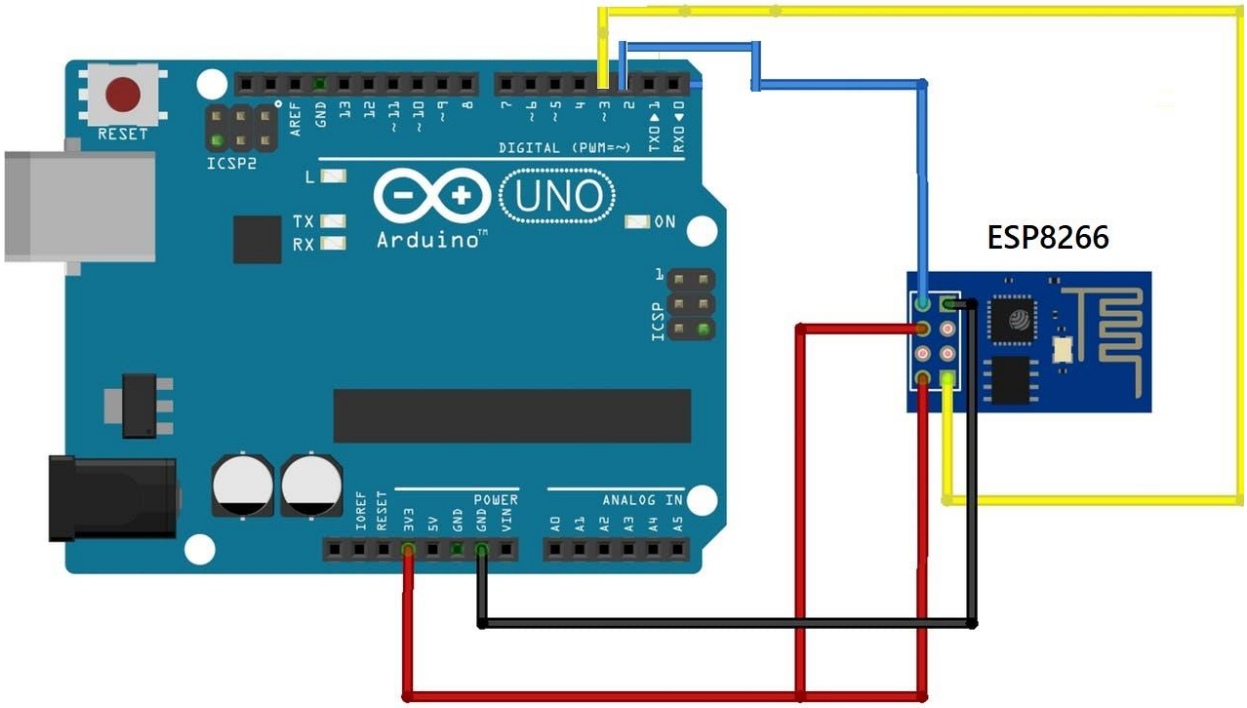


Figure 5.4: Interfacing of ESP8266 with Arduino

5.2 Application Development (MATLAB)

Interface of a simple MATLAB application with thousands of bugs is given below in figure 4.5. This app is not developed professionally as required, as it was the first time with AppDesigner. Still it works, the bugs like stop button not work, and slow performance, and unrecognized variable name can be fixed later (see chapter 5 for development). Fields of time, units and Amps are not for input but they show the value came from API at that instant. As, we discussed the free version of ThingSpeak can only access the writing with the delay of 15sec, so we have also added a spinner to select the time delay. You have to increase the delay if you want to increase the range of plot, because with the short spinner value it'll mess things up in plot. At this time, we only add amperes and units' visualizations, later in development we'll add more features and of course fix the bugs.

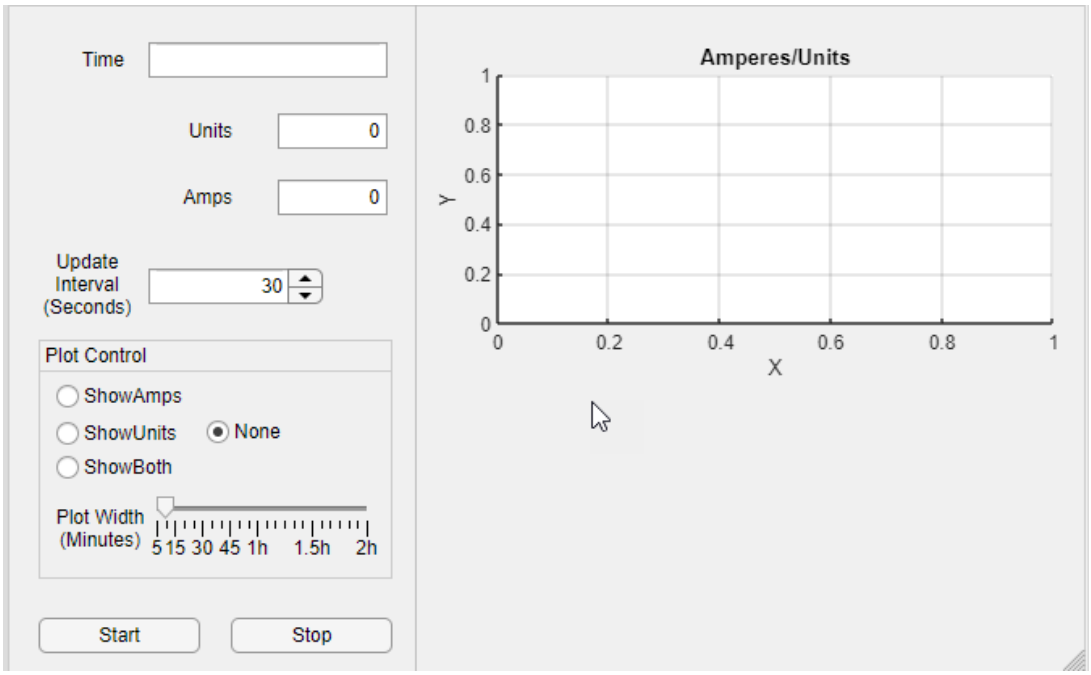


Figure 5.5: Application Interface

The result window is showing below. For this report results are taken with the set of a random value written and thus showing 142A, with 3 bulbs that we are using for this prototype can never consume this much amperes. As, both value of units and amperes are same so presented plots are placed on each other.

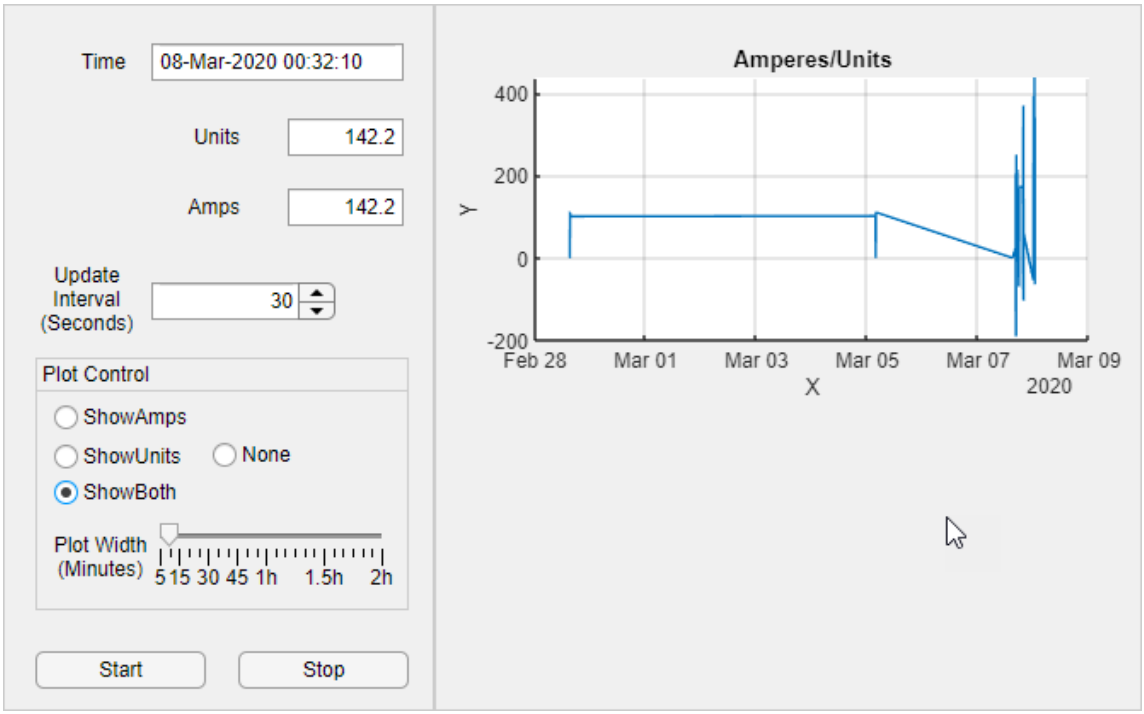


Figure 5.6: Results on MATLAB Application

5.3 ThingsViewer _ Free Android App

As, we can see from figure 4.5 that data from a certain period can be shown visually. However, this app has some drawbacks; it can only show data graphically. If user want to access it in list or instant digital format, he can't avail this. Putting API keys in android app can be done easily, so we can develop our own app and add some statistical analysis, like budget management there.

Figure 5.7: ThingsViewer – Android

CHAPTER 6: DISCUSSION, CONCLUSION AND RECOMMENDATIONS FOR FUTURE WORK

In an IoT device you can find so many features, so the topic like development could require a separate booklet. In this chapter, we'll discuss about the development, its challenges and what will be the future of smart power system. As, we know these smart meters are just single entity of a large smart grid, where we have everything connected and automated.

6.1 Developments in Access

This section will enlighten the details of how could we modify this project with current technology. It'll explain the facts that why smart devices are so flexible if built on standards. We can also observe that why in this project, we consider internet communication prime. With these additional developments we'll also discuss their benefits for consumer and utility and how this product will help in building future of smart power system.

6.1.1 For Utility

A go through to code (Appendix B), can shows us a platform where we can build more. This code is simply using an approach of detecting APIs, calculating energy and then dispatching it to LCD. In this code more could be developed, this feature development for utility is given below:

6.1.1.1 Load Forecasting

With the aid of data, we can predict the future. Chaos increase rapidly, so to predict the future, it's often necessary to get more data, so that math can perform iterations for better prediction. Load forecasting is the most important thing for utility if they want to save money they lose in losses; and with this product in every home, it will be easy to analyze data.

Techniques to predict load could be smart (neural intelligent) or statistical. We can use some statistical techniques, without making things more complex for better forecasting. However, if we want better accuracy then neural network scheme could be used.

Some statistical techniques are given below in bullets:

- Regression
- Time Series (Kalman Filter Method & Box-Jenkins Method)
- Holt-Winters Exponential Smoothing Method
- Time of day Model

6.1.1.2 Power System Operation

Power System Operation, especially in Pakistan, as discussed always lacked because of the lack of data. Identifying the number of units consumed by each area is important, as it could help us to forecast the load (as seen) and thus we can use this load demand variable to develop equations for unit commitment and economic dispatch. Generally saying, data always has its advantages in every field; we predict either with equations developed from the facts we observe in nature; or large number of observations. The second one (Big Data) is important, its time taking but we can now it'll work to predict the chaos in environment; but with the first one finding the relations or patterns is like revelation.

Economic dispatch can be calculated by finding the optimum value of Lambda in LaGrange's equation. The equation shows lambda-p relationship can be written as: [7]

$$\lambda = \frac{P_d + \sum_{i=1}^{n_g} \frac{\beta_i}{2 \cdot \gamma_i}}{\sum_{i=1}^{n_g} \frac{1}{2 \cdot \gamma_i}} \qquad \textbf{Equation 6-1}$$

With the cost equations of the form:

$$\alpha + \beta P_i + \gamma P_i^2 = C_i \qquad \textbf{Equation 6-2}$$

We can put the values to find the optimum value for λ, we can use coordination equation 5-3 to find powers of each unit and then can use cost equations for cost.

$$P_i = \frac{\lambda - \beta_i}{2 \cdot \gamma_i} \qquad \textbf{Equation 6-3}$$

Developing these cost equations here is important, and the developing them in the most accurate manner is important; which can only be possible with data. In this project as the data will transmit from the meters of a specific area (see Section 3.7.1), utility will accumulate it in local computers and process them to develop the equations constantly. One method to develop these equations is to use polynomial curve fitting (in this case we'll use polynomial of degree 2); or we can use Newton's interpolation for this. In this way each local grid will have the data of their own area; and further this data can be sent towards the main generating stations to predict the unit commitment sequence, so that more cost could be saved.

We can use this link (https://www.desmos.com/calculator/qxdijmrrqn), to visualize the economic dispatch. I have created this on Desmos, is available for public to see, how λ changes, with some change in equation.

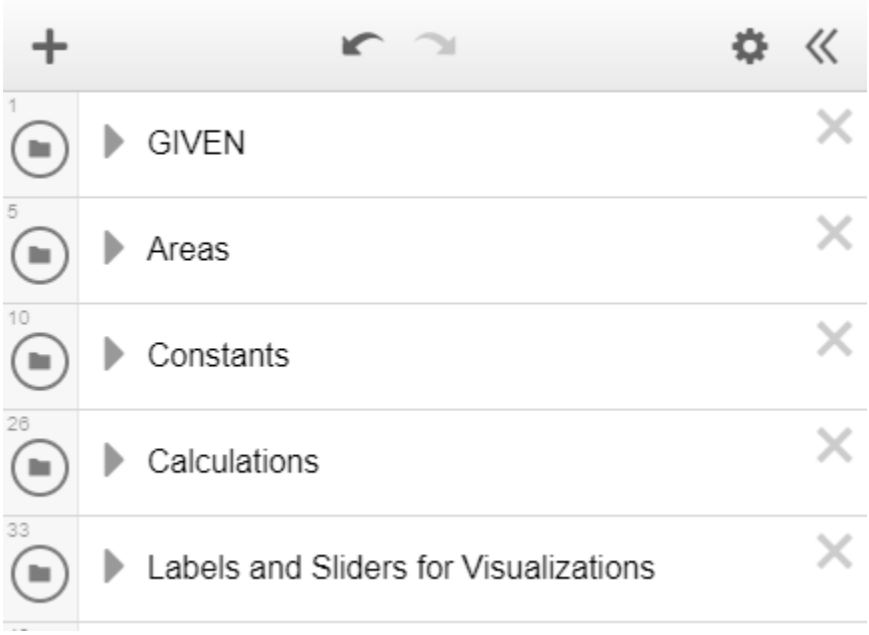


Figure 6.1: Economic Dispatch

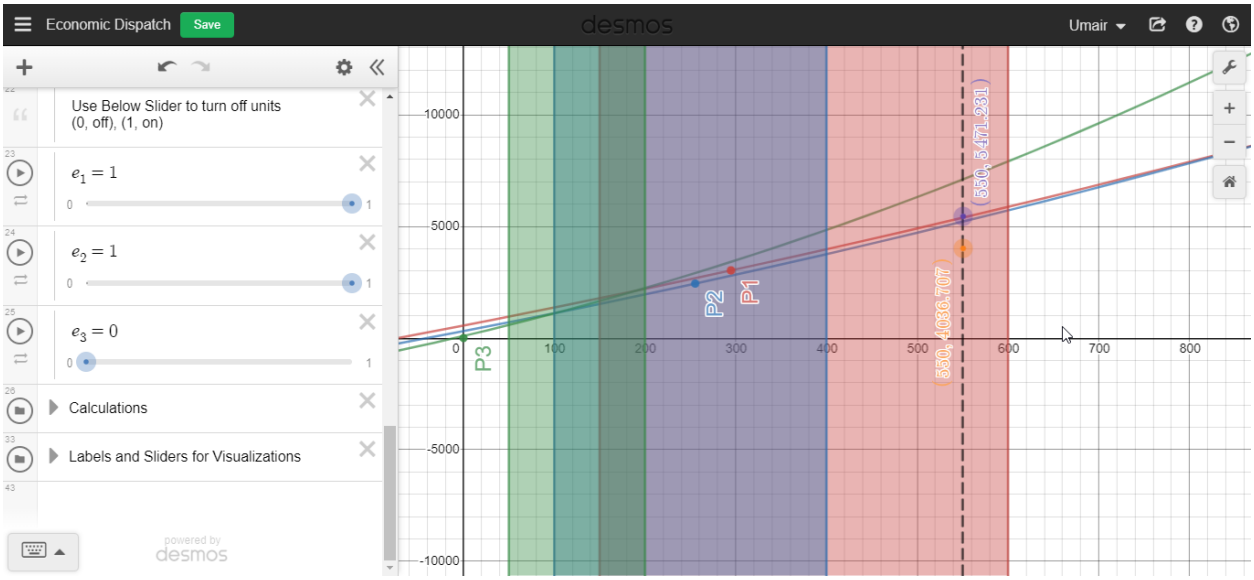


Figure 6.2: Graphical Representation

The areas are showing limits, we can set these limits as a generating capacity to see if equations are satisfying the limits or not. If they are not satisfying, this program will not recalculate this. It will just show if limits are satisfying or not.

6.1.2 For Consumers

6.1.2.1 Prepaid

User should have options for billing, as the title shows; the main purpose of this project was to develop the most efficient and feasible technique for metering and billing. We were planning to add this in a simple way, which will be discussed later in this section, but due to mismanagement of time; this task is still pending.

Prepaid means to access the user to pay bills at the start the start of month, by entering a security key. Meter will scan this key, check if it's correct or not. If correct it'll add 'n' units in meter. After the consumption of these units + some compensated units_ which will be taken away after next recharge, meter will turn the supply off.

A simple method we want to implement was an encryption equation; without going into complex md5 or sha encryption schemes; in this we want to add an equation for random data (see more about cryptography in Appendix D), that scans if last putting 'n' digits are giving the result same to original value or not. These security keys can be developed with this feature, and each meter will have this encryption scheme to detect the key offline. For security purpose we can change this equation periodically; but no matter how much security we use, it's still not that secure. Hacking enigma from probabilistic techniques in a day interval was also possible 50 years ago, and now it's so easy to break. Still the better method is the use of some encryption algorithms like sha.

6.1.2.2 Statistical Analysis

Statistics from data could lead countless visuals for users; mathematics is vast and finding patterns in data from every perspective is possible. We can use sites like Intellectual Statistics, to analyze data; or some other that could send the data plots directly to user.

Some simple statistical analysis for visuals we can add are given below: [8]

- Mean
- Standard Deviation
- Regression
- Sample Size Determination
- Hypothesis Testing

We could also add curves to compare the present unit's consumption with past, and add feature like how much bill you can manage in your budget; and thus, software will show the budget management in real time and forecast if it could exceed limit or not.

6.1.2.3 Earth leakage relay

Earth leakage relay protection can identify the fault position. Instead of finding the faults using complex engineering techniques and tools; it can be used to detect why the breaker is tripping again. At this time, we use different breakers for different rooms, in this system we just have to connect the relays of each breaker in sequence and with Arduino. So, in this way the data of where the fault occur can be shown on mobile devices, to operate accordingly. [9]

6.1.2.4 IFTTT and Adafruit Technologies – Home Interconnected Devices

With the relaying scheme described in above section, we can develop a feature in app; that sends data to ThingsSpeak using write API, and Arduino catches this information and trigger the relay to connect or disconnect an appliance in home. But for this we have to change the whole housing wiring scheme; but still instead of buying smart power sockets/adaptors we can simplify the switching operation of smart homes with a simple meter once and for all.

If this then that (IFTTT) is a web service to create the sequence of triggers (conditional statements), called applets. In the same way, with Adafruit server we can use MQT service to connect the internet with some Adafruit module like ESP8266 (in this case). What it'll do and how will it work can be explained easily.

After creating an applet, we can use some assistant service (like Google, or Alexa) _ by clicking on 'This'. After this we'll add Adafruit service to 'Then'. In this, we can add some sentences, which we'll say to google assistant so that it can send the command Adafruit sensor for trigger. On Adafruit dashboard we'll design simple trigger buttons, and add key to this dashboard to ESP module. So, when we say some specific word in google assistant, Adafruit send trigger signal to device and this device (say actuator) will operate mechanically. [10]

In this project we can control appliances (turn on/off) with this technique, with the same operating processor we used in meter. So, in this case, an additional hardware will be required, but with the combination of that relay scheme (from section 5.1.2.3), this can be implemented easily.

In development, if we want to make everything connected; Arduino behave as central unit for metering, billing, appliance control and fault detection.

6.2 Developments with Future Technology

As said earlier that this project is basically an entity for smart power systems, where we'll have everything connected. People are still working in fields like automation, and presenting ideas to make the system smarter. With machine learning algorithms; in future we can implement more ideas like automatic appliance control.

The only thing I can think to add more in this section is Intelligence, at this point it’s not possible. But we can imagine that how a fully automated intelligent system will look like. For this meter, with intelligent firmware, meters will operate automatically and manage the whole, like when generation power is going down and it’ll shut the electricity for calculated period, of those users whose usage is high competitively. Intelligent firmware can manage the data in the smartest way possible, that humans can never do. Implementing machine algorithms require ideas and with these limited brain power it’s slow; but for computers it’s not.

6.3 Visuals of future_ IoT based power system

6.3.1 Internet of Things

The IoT is characterized as a system that can associate any object with the Internet dependent on a convention for trading data and correspondence among different brilliant gadgets so as to accomplish checking, following, the board and area unique proof targets. The IoT centers around the acknowledgment of three primary ideas, in particular things-arranged, Internet-situated and semantic-arranged. The things situated idea includes perception gadgets, for example, RFID labels, sensors, actuators, cameras, laser scanners, the Global Positioning System (GPS) and NFC. The Internet arranged idea empowers correspondence among savvy gadgets through different correspondence advancements, for example, ZigBee, Wi-Fi, Bluetooth and cell interchanges. what's more, interfaces them to the Internet. The semantic arranged idea understands an assortment of utilizations with the assistance of bright gadgets.

IoT devices are normal objects that are equipped with transceivers, micro-controller and protocol stacks, allowing their message with other devices, as well as with outdoor units (e.g., humans) to allow the awareness of fully automated systems that style them an important part of the Internet.

6.3.2 Integration of the IoT into a SG

The SG has just accomplished wide appropriation in data detecting, transmission and handling, and now IoT innovation 7 assumes a huge job in matrix development. The main impetus behind the activity of SG is to improve arranging, upkeep and tasks by guaranteeing that every part of the force framework is capable 'tune in' and 'talk', and to empower computerization in SG. For instance, in customary force lattice, the service organization possibly thinks about the disturbance of administration when a client illuminates himself/herself. Here, the IoT assumes the key job in empowering this situation since all the parts of the network must have IP addresses and ought to be equipped for two-way correspondence. This is empowered by the IoT. IoT innovation gives intelligent ongoing system association with the clients and gadgets through different correspondence advancements, power hardware through different IoT keen gadgets, and the collaboration required to acknowledge continuous, two-way and rapid information sharing across different

applications, upgrading the general effectiveness of a SG. The use of the IoT in SGs can be arranged into three kinds dependent on the three layered IoT engineering. Right off the bat, IoT is applied for sending different IoT smart gadgets for the observing of hardware states (i.e., at observation layer of IoT). Also, IoT is applied for data assortment from gear with the assistance of its associated IoT smart gadgets through different correspondence advancements (i.e., at arrange layer of IoT).

IoT detecting gadgets are commonly included remote sensors, RFIDs, M2M (machine-to-machine) gadgets, cameras, infrared sensors, laser scanners, GPSs and different information assortment gadgets. The data detecting in a SG can be exceptionally bolstered and improved by IoT innovation. The IoT innovation likewise assumes a fundamental job in the foundation arrangement of information detecting and transmission for the SG, aiding system development, activity, wellbeing the executives, upkeep, security checking, data assortment, estimation, client communication and so on. Besides, the IoT additionally empowers the incorporation of data stream, power stream and conveyance stream in a SG.

6.3.3 Subsystems

A SG is comprised of four main subsystems:

- Power Generation
- Power Transmission
- Power Distribution
- Power Utilization

IoT can be utilized for the observing and control of transmission lines and substations, just as for transmission tower insurance. In the area of power circulation, IoT can be utilized for disseminated mechanization, just as in the administration of activities and hardware. In the ground of intensity use, the IoT can be utilized for information homes, programmed meter checking, electric vehicle charging and releasing, for gathering data about home apparatuses' energy utilization, power load controlling, energy effectiveness observing and the board, power request the board and multi organize utilization.

APPENDIXES

Appendix A: Hardware View

Figure A.1: Hardware View

Appendix B: Used Code

```
/* OVERVIEW:
I have a variable of current signals, first I have
to convert it into voltages.

  PINS of NANO:
  A0 -- Input Value of Current Signals
  A1 -- Input Voltage measurement pin from
Transformer Circuit
*/
```

```
#include "ThingSpeak.h"
#include "WiFiEsp.h"
#include "secrets.h"

#include <EEPROM.h>
#include <Arduino.h>
#include <U8g2lib.h>
```

```
#include <Wire.h>
#include "RTClib.h"

RTC_DS1307 rtc;
//char daysOfTheWeek[7][12] = {"Sunday",
"Monday", "Tuesday", "Wednesday",
"Thursday", "Friday", "Saturday"};

char ssid[] = SECRET_SSID;   // your network
SSID (name)
char pass[] = SECRET_PASS;   // your network
password
int keyIndex = 0;            // your network key
Index number (needed only for WEP)
WiFiEspClient  client;

// Emulate Serial1 on pins 6/7 if not present
#ifndef HAVE_HWSERIAL1
#include <SoftwareSerial.h>
SoftwareSerial Serial1(2,3); // RX, TX
#define ESP_BAUDRATE  19200
#else
#define ESP_BAUDRATE  115200
#endif
unsigned long myChannelNumber =
SECRET_CH_ID;
const char * myWriteAPIKey =
SECRET_WRITE_APIKEY;
String myStatus = "";
void thingSpeak_init();
void thingSpeak_update(int v1,int v2,int v3,int
v4);
void setEspBaudRate(unsigned long baudrate);
////////////////////////////////////////////////
const int unitPrice=27;
int totalBill=0;
////////////////////////////////////////////////
int memoryAddress=0;
int valueSave    =0;
////////////////////////////////////////////////
#ifdef U8X8_HAVE_HW_SPI
#include <SPI.h>
#endif
#ifdef U8X8_HAVE_HW_I2C
#include <Wire.h>
#endif
#define volt_S A0              // voltage from
sensor ACS712
#define volt_IP A1             // Input voltage
measured through combination circuit
#define outRelay 7
boolean overLoad=0;
//+++++++LCD++++++++>
U8G2_ST7920_128X64_1_SW_SPI
u8g2(U8G2_R0, /* E=*/ 13, /* data=*/ 11, /*
R/W=*/ 10, /* reset=*/ 8);
//int ISC = 0;    //InitialScreen Count

//+++Calculations+++>
float
avg_v=0,avg_i=0,avg_p=0,avg_e=0,t_energy=0,
KWH = 0;

//const float VCC   = 5.0;// supply voltage is
from 4.5 to 5.5V. Normally 5V.
//const int model = 2;   // enter the model number
(see below)
const uint8_t cutOffLimit = 1;// set the current
```

```
which below that value, doesn't matter. Or set 0.5
const uint8_t mVperAmp = 100; // use 100 for 20A Module and 66 for 30A Module


//float voltage;// internal variable for voltage

float ACSVoltage = 0;
float VRMS    = 0;
float AmpsRMS = 0;


//+++Calculations+++<

//+++++++Time+++++++>
unsigned int start_t = 0, end_t = 0;
double time_intervel = 0.0;
//+++++++Time+++++++<

////////////////////////////
float IP_voltage();
float IP_curr();
float power(float IP_curr);
float Energy(float IP_curr);
void u8g2_prepare(void);
void Parameters(uint8_t a);
////////////////////////////
//int getSensorData();
void draw(void);
float getVPP();
float getACS712();
//////////////////////
uint8_t draw_state = 0;
float E_Store = 0;
unsigned int calibration = 75;
unsigned int pF = 90;
float energyCostpermonth = 0;
void setup(){
  Serial.begin(9600);
  thingSpeak_init();
  u8g2.begin();
////////////////////////////
  pinMode(volt_S, INPUT);
  pinMode(volt_IP, INPUT);
  pinMode(outRelay,OUTPUT);
  digitalWrite(outRelay,HIGH);
////////////////////////////
  if(! rtc.begin()) {Serial.println("Couldn't find RTC");while (1);}
  if(! rtc.isrunning()){
   Serial.println("RTC is NOT running!");
//   rtc.adjust(DateTime(F(__DATE__), F(__TIME__)));
}
//   rtc.adjust(DateTime(F(__DATE__), F(__TIME__)));

/*
////////////////////////////
  u8g2.firstPage();
  for (int i = 0; i < 10; i++) {
    do {
      u8g2.setFont(u8g2_font_6x10_tf);
      u8g2.drawStr( 50 , 10, "WELCOME");
      u8g2.drawStr( 5, 20, "Smart Energy Meter");
      u8g2.drawStr( 10, 35, "Group Memebers");
      u8g2.setFont(u8g2_font_u8glib_4_tr);
```

```
    u8g2.drawStr( 10, 50, "Umair, Muneeb, Sohaib, Abubakar");
   } while (u8g2.nextPage());
   delay(5);
 }
 */

t_energy = EEPROM.get(0,t_energy);

}
////////////////////
void loop(){
 start_t = millis();
 //++++++++++CALCULATIONS+++++++++++++++
 int n = 10;
 int ni=0;
 float var = 0, curr = 0, store = 0;
// Serial.println("_______CURRENT DATA_________");
 for (int i = 1; i <= n;i++){
   curr=getACS712();
   ni++;
//    curr = IP_curr();
   //if(curr<0.2){curr=0;}else{ni++;Serial.print(curr);}///remove garbage
   var = curr + store;
   store = var;
 }
//  Serial.println("_______CURRENT DATA_________");

 end_t = millis();
 time_intervel = (end_t-start_t)/10;
 Serial.print("Time Intervel in ms:");Serial.println(time_intervel);
 if(ni==0){avg_i=0;}else{avg_i = var/ni;}///avoid to 0/0=nan
 ////////////////////////////////
 avg_v=IP_voltage();
 avg_p = power(avg_i,avg_v);
 avg_e = Energy(avg_p);//////watt per hour
 t_energy =t_energy +  avg_e;///unit
 totalBill=t_energy*unitPrice;

 if(avg_p>150){overLoad=HIGH;}else{overLoad=LOW;}

 Serial.print(" VOLT   : ");Serial.print(avg_v);
 Serial.print(" Current: ");Serial.print(avg_i);
 Serial.print(" Power : ");Serial.println(avg_p);
 Serial.print(" Unit :");Serial.print(t_energy);
 Serial.print(" Total  Bill: ");Serial.println(totalBill);

 EEPROM.put(0,t_energy);
 //+++++++++LCD DISPLAY++++++++++++
 //"nextPage" is 8 in this case --> see contractor line reset argument (so for change we have to process 8 statements --> (1/16M)*8 = time for change)
 u8g2.firstPage();
 do {
   draw();
```

```
  } while ( u8g2.nextPage() );

  // increase the state
  draw_state++;
  if (draw_state >= 1 * 1) {  //Here, 2 is the number of cases in draw()////1 * 8
    draw_state = 0;
  }
  if(overLoad==HIGH){Serial.println("Over Load");digitalWrite(outRelay,LOW);}
  if(overLoad==LOW){digitalWrite(outRelay,HIGH);}

//+++++++++++++++WIFI+++++++++++++++
thingSpeak_update(avg_i*1000,avg_p,t_energy, totalBill);
}
////////////////////////////////////////////////
////////////////-loop End-//////////////////////
//------------------------------Voltage, Current, Power, Energy------------------------------>
float IP_voltage(){  //Input Voltage
   int m = analogRead(volt_IP); // read analog values from pin A1 across capacitor
   int n = (m * .304177);  // converts analog
//  int n = 220; //For now
  return n;
}
/////////////////////////////////////////
float IP_curr(){
ACSVoltage = getVPP();
VRMS = (ACSVoltage/2.0) *0.707;  //root 2 is 0.707
AmpsRMS = (VRMS * 1000)/mVperAmp;
//////////////////////////
  return AmpsRMS;
}
float getACS712(){  // for AC
  ACSVoltage = getVPP();
  VRMS = (ACSVoltage/2.0) *0.707;
  VRMS = VRMS - (calibration / 10000.0);     // calibtrate to zero with slider
  AmpsRMS = (VRMS * 1000)/mVperAmp;
  if((AmpsRMS > -0.2) && (AmpsRMS < 0.2)){  // remove low end chatter
    AmpsRMS = 0.0;
  }
return AmpsRMS;
}
////////////////////////////////////////////////
float power(float IP_curr, float IP_volt){   //For putting average value of current in loop
  float p = IP_curr * IP_volt;         //live Power
  return p;
}
float Energy(float IP_power){ //Average power will be given to
//  Serial.println();
//  Serial.print("Energy ---->");
  //float kW = IP_power/1000;
  //Serial.print("kW ="); Serial.print(kW);

  //Serial.print("; h ="); Serial.print(h);

  //Serial.print("; KWH =");
Serial.println(KWH);

    double W_1 = (IP_power/1000) * (pF /
```

```
100.0);////kw
   double h = double(time_intervel) /
double(3600);
   double WH_1 = W_1 * h;
   return WH_1;
}

void u8g2_prepare(void){
  u8g2.setFont(u8g2_font_6x10_tf);
  u8g2.setFontRefHeightExtendedText();
  u8g2.setDrawColor(1);
  u8g2.setFontPosTop();
  u8g2.setFontDirection(0);
}
//////////////////////////////////////////
void Parameters(uint8_t a){

DateTime now = rtc.now();
Serial.print(now.hour());Serial.print(" :
");Serial.print(now.minute());Serial.print(" :
");Serial.println(now.second());
//now.day();/
//now.month();
//now.year();



//itoa(speed, tmp_string, 10);
//8g_DrawStr(&u8g, 0, 60, tmp_string);

  /*Strings*/
  String str1 = String("V :"+String(avg_v));
  String str2 = String("I :"+String(avg_i));
  String str3 = String("P :"+String(avg_p));
  String str4 = String("U :"+String(t_energy));
  String str5 = String("B :"+String(totalBill));

  char char_array1[str1.length() + 1];
str1.toCharArray(char_array1, str1.length() + 1);
char char_array2[str2.length() + 1];
str2.toCharArray(char_array2, str2.length() + 1);
char char_array3[str3.length() + 1];
 str3.toCharArray(char_array3, str3.length() +1);
char char_array4[str4.length() + 1];

 str4.toCharArray(char_array4, str4.length() +1);
 char char_array5[str5.length() + 1];
 str5.toCharArray(char_array5, str5.length() +1);

  u8g2.drawStr(05 , 5, char_array1);
  u8g2.drawStr(75 , 5, char_array2);
  u8g2.drawStr(05, 20, char_array3);
  u8g2.drawStr(75, 20, char_array4);
  u8g2.drawStr(05, 35, char_array5);

if(overLoad==HIGH)
{
  u8g2.drawStr(50,35,"OVER LOAD");
}



u8g2.drawStr  (5,50,"T:");
u8g2.setCursor(15,50);u8g2.print(now.hour(),D
```

```
EC);
u8g2.setCursor(25,50);u8g2.print(":");

u8g2.setCursor(30,50);u8g2.print(now.minute(),
DEC);
u8g2.setCursor(40,50);u8g2.print(":");

u8g2.setCursor(45,50);u8g2.print(now.second(),
DEC);
u8g2.drawStr  (60,50,"D:");

u8g2.setCursor(75,50);u8g2.print(now.day(),DE
C);
u8g2.setCursor(85,50);u8g2.print(":");
 u8g2.setCursor(90,50);u8g2.print(now.month()
,DEC);
 u8g2.setCursor(100,50);u8g2.print(":");
 u8g2.setCursor(105,50);u8g2.print(now.year(),
DEC);



 u8g2.drawFrame(0, 0, u8g2.getDisplayWidth(),
u8g2.getDisplayHeight() );

}
//Right shift of 3 means, each case will run 8
times (including 0) --> 2^3=8 (shifts to right)
//AND operation (FOR SCROLLING) with 7
means, when draw_state=7 --> it gives 0
(NOTE: Increase above 8 (like use 4 bit right
shift) to scroll more)
void draw(void){
 u8g2_prepare();
 switch (draw_state >> 3) {
  case 0: Parameters(draw_state & 7); break;
 }
}
//////////////////////////////////////////
float getVPP(){
 float result;
 int readValue;            //value read from the
sensor
 int maxValue = 0;         // store max value here
 int minValue = 1024;          // store min value
here

  uint32_t start_time = millis();
  while((millis()-start_time) < 1000) //sample
for 1 Sec
  {
     readValue = analogRead(volt_S);
     // see if you have a new maxValue
    // Serial.print("raw Cur:
");       Serial.println(readValue);
     if (readValue > maxValue)
     {
        /*record the maximum sensor value*/
        maxValue = readValue;
     }
     if (readValue < minValue)
     {
        /*record the minimum sensor value*/
        minValue = readValue;
     }
  }

  // Subtract min from max
  result = ((maxValue - minValue) *
5.0)/1024.0;
```

```
  return result;
}
//////////////////////
//////////////////////////
void thingSpeak_update(int v1,int v2,int v3,int v4){
 // Connect or reconnect to WiFi
 if(WiFi.status() != WL_CONNECTED){
  Serial.print("Attempting to connect to SSID: ");
  Serial.println(SECRET_SSID);
  while(WiFi.status() != WL_CONNECTED){
   WiFi.begin(ssid, pass);  // Connect to WPA/WPA2 network. Change this line if using open or WEP network
    Serial.print(".");
    delay(5000);
  }
  Serial.println("\nConnected.");
 }

 // set the fields with the values
 ThingSpeak.setField(1,v1);
 ThingSpeak.setField(2,v2);
 ThingSpeak.setField(3,v3);
 ThingSpeak.setField(4,v4);
 // set the status
 ThingSpeak.setStatus(myStatus);
 // write to the ThingSpeak channel
 int x = ThingSpeak.writeFields(myChannelNumber, myWriteAPIKey);
//  if(x == 200){Serial.println("Channel update successful.");}
//  else{Serial.println("Problem updating channel. HTTP error code " + String(x));}

}
//////////////////////
void thingSpeak_init(){
 // initialize serial for ESP module
 setEspBaudRate(ESP_BAUDRATE);
 while (!Serial){; // wait for serial port to connect. Needed for Leonardo native USB port only
}
// Serial.print("Searching for ESP8266...");
 //initialize ESP module

 WiFi.init(&Serial1);
 // check for the presence of the shield
 if (WiFi.status() == WL_NO_SHIELD){
  Serial.println("WiFi shield not present");
  // don't continue
  while (true);
 }
 Serial.println("found it!");

 ThingSpeak.begin(client);
}

void setEspBaudRate(unsigned long baudrate){
 long rates[6] = {115200,74880,57600,38400,19200,9600};
 Serial.print("Setting ESP8266 baudrate to ");
 Serial.print(baudrate);
 Serial.println("...");
```

```
  for(int i = 0; i < 6; i++){
    Serial1.begin(rates[i]);
    delay(100);
    Serial1.print("AT+UART_DEF=");
    Serial1.print(baudrate);
    Serial1.print(",8,1,0,0\r\n");
    delay(100);
  }
  Serial1.begin(baudrate);

}
}
```

Appendix C: Model for ACS712 – AC measurement

Modeling coding scheme for ACS712 so that it can calculate alternating current is simple if we imagine this by sine wave. The process is given below in bullets:

- Select ‘n’ sec interval (should be small_ 4000 samples per cycle)
- Select maximum and minimum amplitude sample among these n*4000 samples
- Calculate RMS (divide by root 2) _ same as integration we discussed
- Calculate AMPS using $\frac{V_{rms} \times 1000}{mV}$ – Here mV is 185 for 20A sensor (we used) [11]

Appendix D: Basic Computer Cryptography

Encryption and decryption can be done though several methods like symmetric key encryption and public key encryption (using public key infrastructure_ PKI). We’ll only take the first one into account.

Symmetric key encryption involves substitution cipher, transposition cipher, one-time pad, data encryption standard like methods. Each one has its own advantage and flaws, like one-time pad can only be used one-time for encrypting and decrypting_ as it uses the random math.

Substitution cypher is simple as it involves the substitution of keys; like one-one correspondence between keys that only encrypter knows. An example in Figure D.1 shows the cipher correspondence with plain text.

Plain text	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Cipher text	W	Y	A	C	Q	G	I	K	M	O	E	S	U	X	Z	B	D	F	H	J	L	N	P	R	T	V

Figure D.1: Substitution Cypher

In transposition, encrypting sequence becomes complex as here plain text will be formed in 2D array, corresponding to the secret key; example is this encryption is given in Figure D.2.

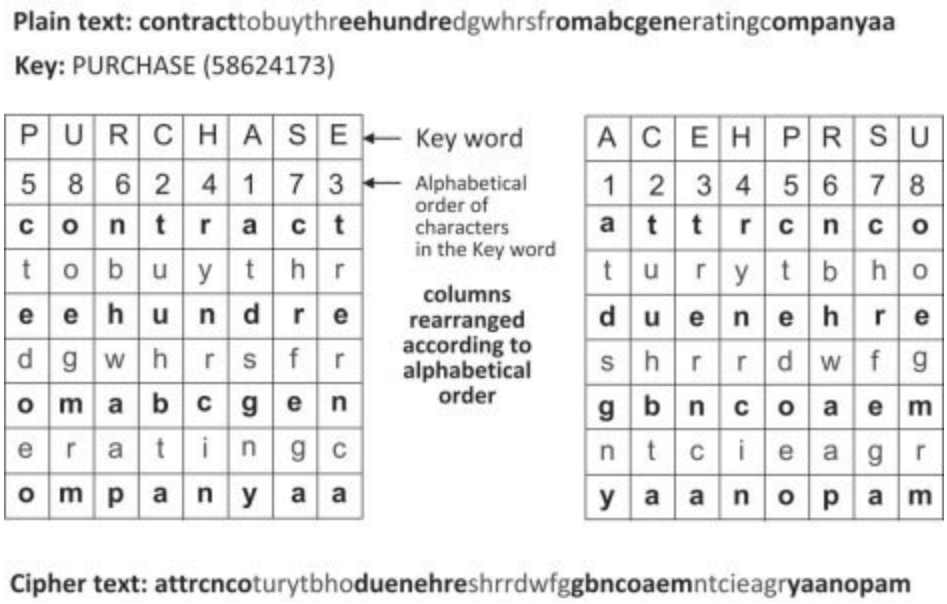


Figure D.2: Transposition Cypher

One-time pad uses this XOR gate in a format shown in Figure D.3 for generating the random one-time number, that one can encrypt and decrypt only once. It'll not give the same value again

$$C_1 = K \oplus M_1$$

$$C_2 = K \oplus M_2$$

$$Hence\ C_1 \oplus C_2 = M_1 \oplus M_2$$

Figure D.3: One-Time Pad

In this method, both Sender and Receiver have to carry the same random bit string Key of encryption. This is not an easy task as a Key can only be used once and the amount of data that can be transferred with a given Key is limited by the length of the Key. [12]

Appendix E: Datasheets and other Resources

For datasheet of used components and other supplementary materials read the data from the DVD attached.

CHAPTER 7: BIBLIOGRAPHY

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