Power Monitoring and Analytics System

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Certificate of Correction and Approval

It is certified that the work contained in this thesis "POWER MONITORING AND ANALYTICS SYSTEM" carried out by Capt Zeeshan Ali Abbas, Capt Mehtab Anjum, Capt Hamza Ali and Capt Arsalan Khan Dar under the supervision of Lt Col (Dr) HASNAT KURSHEED for the partial fulfilment of B.E Degree in Telecom Engineering does not contain any material previously published or written by another person. Any contribution to the research by other with whom they have worked is explicitly acknowledgment in the thesis.

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Abstract

Power Monitoring and Analytics System plays a vital part in the electricity value chain. The system provides smarter solution such as real time power consumption and log of electrical energy consumed related to time. The requirement for Power Monitoring and Analytics System is the accessibility of metering data in a near real time with accuracy and authentication. The possibility of a consumer reading the statistics remotely, hence avoiding the need for consumer's estimation of consumption basically refers to the "smartness" of the metering substructure. In this project the data acquisition module samples the power flown/ withdrawn from the electric network, these readings will be communicated to the Head End System (HES) via Automated Meter Reading (AMR) infrastructure which waives off the requirement of consumption approximations and self reading, allowing a Time of Use (ToU) or even Real Time Pricing (RTP) regime. A supplementary benefit of the system to consumers about the usage of energy at their connection points, is to help them have an improved mindfulness of their power usage activities, which means more the data is available, greater will be the customer ability to control their own waste full Usage. In order to respond close to the time of consumption will be requiring that metering data to reach them as swiftly as possible. Currently the existing service provider does not provide such data in the near real time with low latency, accuracy add authentication because the data collection procedure of the existing system is not able to cater for this requirement. Hence power monitoring analytics system is the only feasible solution that enables the transmission of raw data from the data acquisition module to the devices located near the customers premises such as smart phones which help the customers to get real time information about their energy usage and cater for the energy conservation.

DECLARATION

No portion of the work presented in this dissertation has been submitted in support of another award or qualification either at this institution or elsewhere.

DEDICATED TO

Allah Almighty, the Lord of the Worlds, our family and friends who believed in us and for their unwavering support.

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We are also thankful to those individuals who have provided particularly useful assistance and guidance either technical or otherwise, during this project.

List of Abbreviations

SM	Smart Meters
HES	Head End System
ToU	Time-of-Use
RTP	Real-Time-Pricing
IHD	In-Home Devices
AMR	Automated Meter Reading
IoT	Internet of Things
HV	High Voltage
LV	Low Voltage
TX	Transmitter
RX	Receiver
ISR	Interrupt Service Routine
IE	Interrupt Enable
TI	Transfer Interrupt
RI	Received Interrupt
WI-FI	Wireless Fidelity
LAN	Local Area Network
WLAN	Wireless Local Area Network
TCP	Transmission Control Protocol
IP	Internet Protocol

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CHAPTER 1

INTRODUCTION

1.1 Background/Motivation

From last few decades energy crisis is one of the main crises confronted by Pakistan, Energy shortages are limping the economy and paying to unrest. Pakistan being a developing country, its need for energy is extremely high and increasing, while industrial segments are escalating, they are facing an energy dearth. The requirement to emphasis on preserving energy rather than depending exclusively on discovering substitute energy sources is the need of time, which demands the limitation of wastage of energy. The foremost step to control these crises by implementation of an effective power control an analytic system and secondly by introducing a sense of awareness in clients about their usage of energy in a real time. When the customer is able to conveniently check his usage in a real time, he would be able to restrict its wasteful use of energy.

In this project, will present an efficient Power Monitoring and Analytic System, illustrated in Figure 1. The system consists of Automated Meter Reading (AMR) for data acquisition which includes digital energy meter and transmission module installed in every consumer's unit. The data acquisition module receipts the meter reading and employs Internet of Things to transmit the energy usage reading to the Data Management Server, where data entries are stored and arranged with respect to time and date. At the customer's end an android based application is installed in the smart phone which is used to display power in term of Time of use (ToU) and Real time Pricing (RTP) and to calculate the billing cost and to update the catalogue and keep an energy usage profile for each consumer. A proof of concept of the complete system has been developed to validate the effectiveness and efficiency of Automatic Meter Reading, billing and notification through the use of Internet of things (IoT).

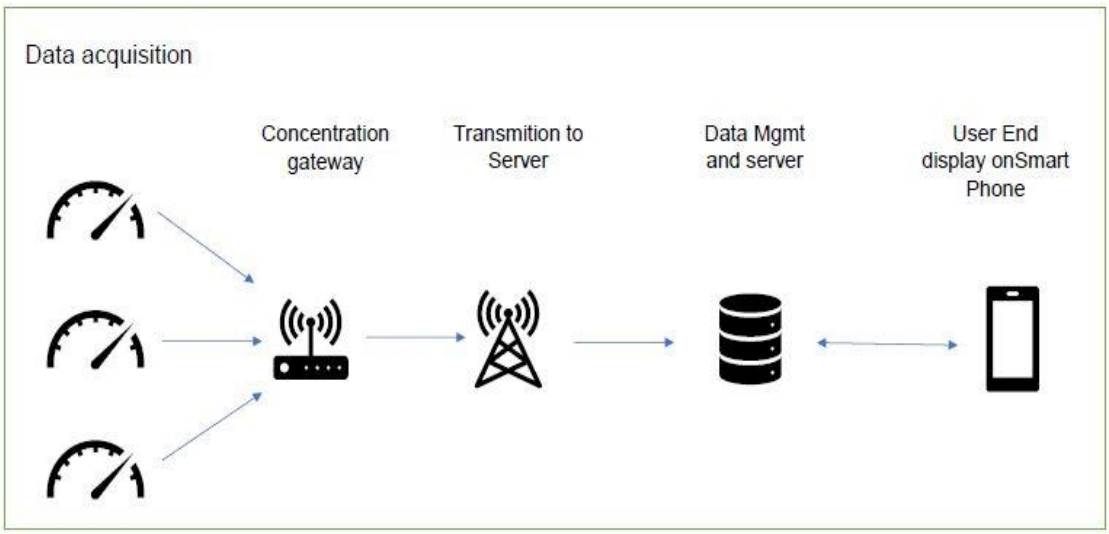

Figure 1: Block Diagram

1.2 Problem Statement

Power crisis are being faced by Pakistan for decades that has a direct Influence on Pakistan's economic an overall Affluence. Industrial evolution, electricity Theft causing high losses, caused the main supply and demand disproportion resulting in an energy deficiency and high tariff rate. Energy deficiencies causes power failure, and without energy Industrial and power sector cannot work properly, Industries also go out of business or due to high tariff rate production is reduced greatly and the end product is not cost effective. Moreover, delivery dates are pinched out, work forces are compact and companies' competitive effectiveness in world markets is severely limited.

To bridge the gap between supply and demand is a possible solution for the current country's energy crisis, which can be achieved by allowing ingenious solutions, by relating the consumption and production capacities with time and customer's identity, solutions like Time-of-Use or Real-Time Pricing. Since the prerequisite of management of energy flow is availability of metering data in a real time between the consumers and the services.

1.3 Project Description and Salient Features

1.3.1 Why we need Power Management System

There are various methods to provide power management by noting different parameters like voltage, current power and frequency of the main power supply all the

data is then transfer remotely to the manager for the decision making process on the basis of which people are deciding to use the electricity efficiently by curtailing the excess use of power in hours of no need (like after office timing, on weekends when there is no particular activity in the department/building), but unfortunately this data is not available in Real Time.

1.3.2 Proposed System

We are going to design a system which is currently not implemented in our country, rather is a new dimension in the sector of Power Management. Power Monitoring and Analytic System not only provides you the Time of Use (ToU), Real time pricing (RTP) with lowest latency rate but also the system has an equal capability on home to industry level working. Power Monitoring and Analytic System enable the manager of the system to get the automated usage of electricity usage in real time with lowest latency. Power management system broadly consists of three modules:

a. Load measurement module

b. Data communication module

c. Data base/ server module

1.4 Scope, Objectives and Specifications of the Project

1.4.1 Scope

Relating the consumption and production capacities with time and customer's identity, enabling smarter solutions, such as Time-of-Use or Real-Time Pricing. Moreover, sending data to the customer in real time with minimum possible latency rate, authentication and high rate of accuracy.

1.4.2 Objectives

The main aim behind this proof of concept was to develop a system which enables / improves the present energy crisis faced by our country. Different goals and objectives were set which are achieved successfully.

Following are the salient features of overall objective while accomplishing this project:

a. Development of a real time system that enables the monitoring of energy consumption in real time regularly, in contrast with the conventional monthly meter reading.

b. Maintaining a descriptive reporting system Which describes the usage of energy and information regarding bill.

c. A user-friendly profiling system leads to an advantage, to the consumer by inculcating alertness and afterwards, flagging the way towards energy conservation.

d. Inducing effectiveness and transparency in the meter reading process by eradicating the requirement for personnel to record the meter readings.

e. Recovering lost meter readings, owing to unfavorable circumstances (bad weather, network congestion, etc.), by providing the supplier with discretion to demand forced feedback from the consumer-polling.

f. To enable the supplier to deploy some level of remote control in the form of alert notifications to the consumer in case of aberrant behavior, or remote shutdown, when needed.

CHAPTER 2

LITERATURE REVIEW

2.1 Background Study

2.1.1 True, Reactive and Apparent power

As the reactive load (capacitors and inductors) doesn't disperse power, however through observations and experiments, it is established that by dropping voltage and drawing current gives the misleading notion that they actually disperse power. It is called reactive power, and determined by the unit volt-Amps-Reactive (VAR, denoted by Q. The real quantity of power is called true power is determined in Watts (represented by letter P). Combining these two powers, we get apparent power. Which is measured in Volts-Amps (VA) and is represented by S.

True power derives from circuits dissipative elements, while apparent power is related to circuits impedance (Z). Given that we are using scalar quantities for power computation, so every complex quantity will be represented by their polar magnitudes. For instance, if from a current and resistance, true power is calculated, polar magnitude must be used. If I calculate apparent power the complex quantities should be replaced with their polar magnitude for the scalar alternatives. Following are three equations relating to the power.

2.1.1.1 Real Power Formula:

Table 1: Real Power Formula

P= V I	(In DC circuits)
P= V I Cosθ	(In Single Phase AC)
P=√3 V I Cosθ	(In Three Phase)

2.1.1.2 Reactive Power Formula:

Table 2: Reactive Power Formula

Reactive power=	V I sin θ
Reactive Power=	√ (Apparent Power^2- True Power^2)
VAR =	√ (VA^2 − P^2)
kVAR =	√ (kVA^2 − kW^2)

2.1.1.3 Apparent Power formula

Table 3: Apparent Power Formula

S =	V I
Apparent Power =	√(True Power^2 + $Reactive\ Power^2$)
kVA =	√(kW^2 + $kVAR^2$)

These three types of power --true, reactive and apparent -- relate to one another integral metric form. We call this cover triangle:

2.1.1.4 THE POWER TRIANGLE

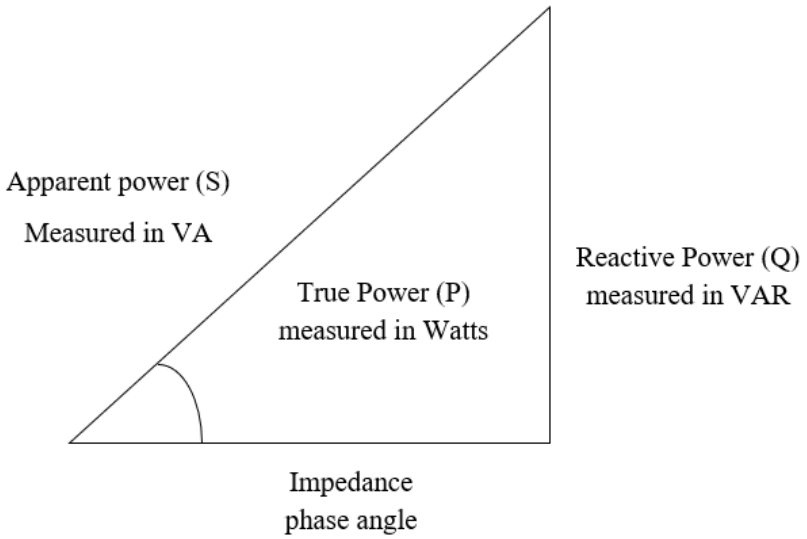

Figure 2: Power Triangle

2.1.2 Power Factor

Power factor is a comparing the real power, divided by supplied power (apparent power). The difference between both is called reactive power. Reactive power doesn't perform any valuable work but should be supplied to the customer, so that the motor and other inductive load operates.

Power factor is the ratio of useful work done by an electrical circuit and the maximum useful work, that could have been done at the supplied voltage and current. For some clients, power factor may not be an issue as their electrical supply system do not have advocate current capacity. Actually, clients often run out of sharing capacity because they do not think seriously about the power factor in their circuit plan. Additionally, some utilities have sufficient economic penalties for small power factor.

Heating devices and Air conditioners have very high-power factor of 1.0, the ideal power factor. Loads unlike resistive (i.e. Motors) have power factor often from 0.5 to 0.95 (Less than 1), which largely depends on how are they operated and their size as well.

$$Power\ Factor = \frac{Real\ Power}{Apperant\ Power} = \frac{Kilowatts}{KVA} = \frac{Kilowatts}{volts\ xAmp\ x1000}$$

Where :

- Power Factor = given as a decimal or a percentage
- Real Power = measured in units of watts or kilo watts.
- Apparent Power = measured in units of volt-amps or thousands of volt amps, kVA

Figure 3: Power Factor Formula

2.1.3 Wireless Fidelity

Wireless fidelity also known as Wi-Fi same like "Wireless Local Area Network" which stands for WLAN. Radio signals are used to communicate between two or more devices. WI-FI uses Gigahertz range of frequencies.

Frequency unit is hertz denoted as Hz to explain it lets us consider we are standing on the dock observing the water waves coming in consisting of crests and trough. By counting the number of the waves in a second will give us the frequency of the waves, if the number of the wave in one second is one then the wave frequency will be one cycle per second or we can say that 1 Hz. To receive data, the radio receiver must be tuned to the corresponding frequencies.

Since Wi-Fi the frequency ranges from 2.4 GHz to 5GHz. These ranges of frequency are the same which are used in the microwave which happens to be 2.450 GHz and the Wi-Fi router has a frequancy range 2.412 GHz - 2.472 GHz to send and receive data.

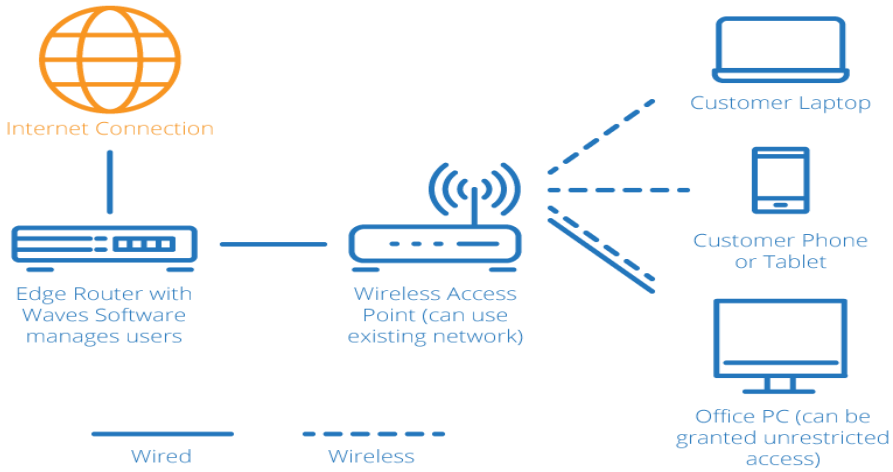

Figure 4: Wireless Fidelity

2.1.4 Networks

Network can be defined as two or more computers that are linked to each other for the purpose of sharing information or resources (like printers, CDs), Files are exchanged. The link may be wired or wireless. LAN, MAN and WAN are major types of networks.

2.1.5 Local Area Network (LAN)

Local Area Network (LAN) is a type of network which is limited to small areas e.g. writing lab, school, or house. In a Network there are broadly two types of computer connected one is a work station and the other is server. Computers which are known as workstations because they have a user which utilizes the network through this computer. Workstations are traditionally considered as desktops (which consist of CPUs, monitor, keyboard, and mouse) or a laptop. Now due to advancement of technology new type of computers are emerging like tablet computers, smart phones, so over definition of work station is also sprouting to include these devices because these devices have the ability to communicate with the others in the network users using network resources. Similarly, servers are the computers which run continuously to provide services to the other computers in the network but are generally not used by humans directly.

In network the workstations are less powerful than servers for example the number of servers may be placed in a secure area which may be away from humans but can only be accessed through the network. In such type of conditions, the server may not have a dedicated display unit or keyboard. However, the cost of the system may dramatically surge by the size and speed of the hard drive, main memory and server's processor. Similarly, on other hand the working stations unlike servers may needs an expensive display to cater for the users need and may not need as much storage or working memory like servers. Each work station / computer on a network is properly organized for its use.

Mostly in a network the servers are connected through the cable because the cables remained intact and are the fastest mean with minimum data losses. On the other hand, the work station in a network can be connected through cables or through wireless access point since the cost of the adopter of wireless access point has dropped to a point that it is preferred to use wireless link.

2.1.6 Wide Area Network

The type of networks, which is meant to connect the multiple devices at larger areas like cities or even different countries. devoted cabling under the sea, on the seabed or satellite links are used to connect this sort of worldwide set of connections.

2.1.7 TCP/IP

TCP/IP is the abbreviation of Transmission Control Protocol / Internet Protocol. Different protocols are used for the internet, this is one of them. These are the set of rules the machines should follow interact among each other over the internet. As its name suggests it defines the set of rules, which the electric devices follow during the transmission of data over the internet, and handling of the data over the networks. If we further break it down, we have following protocols coming inside the umbrella of TCP/IP: -

a. TCP

b. UDP

c. IP

d. ICMP

e. DHCP

2.2 Literature Review

2.2.1 Previous projects related to this concept in MCS (NUST)

2.2.1.1 Remote Energy Monitoring and Profiling System

The project was developed to monitor the energy usage, remotely access the current meter system. This automation will lead to removing the Human errors and will result in well-organized energy metering system. The above-mentioned project also caters for the remote access of the energy usage to supplier company to some extent. The salient features of the project include access to consumers and the energy supply company, users profiling system.

2.2.1.2 Power Management System

To develop GSM based power management system to protect the overloading of the prioritized appliances and then to deliver the current state to the manager of the system.

2.2.2 In Pakistan

Energy crisis in one of the main factors which has the direct impact on the country's progress and prosperity. Some of the factors which are responsible for these crises are industrial growth, huge power losses. Taking a look at what Pakistan has in store regarding this technology, there is no promising project regarding power management.

CHAPTER 3

DESIGN AND DEVELOPMENT

3.1 Hardware Design

3.1.1 Arduino Mega 2560

3.1.1.1 Description

Arduino Mega 2560 is based on Atmega2560 which has more memory and 54 digital and 16 analogs I/O pins. Among 54 digital I/O, 15 are for pulse width modulation (PMW). A 16MHz frequency crystal oscillator is added. There is a USB port which used to connect it to a computer and load codes. There is a DC power jack coupled which can be used to provide power to the board. Additionally, ICSP header is added to Arduino Mega for programming purpose and to upload the code.

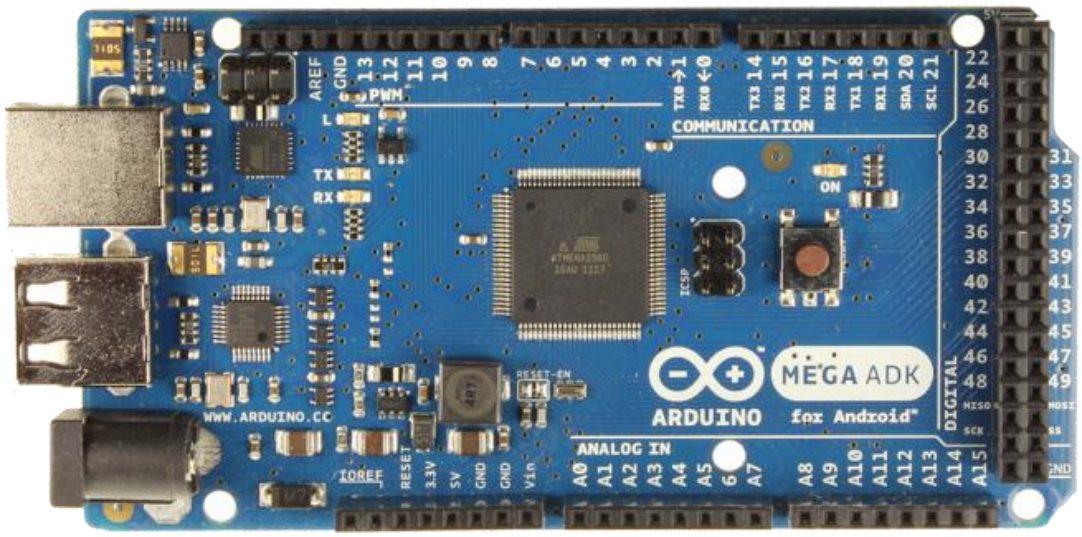

Figure 5: Arduino Mega 2560

3.1.1.2 Features

Table 4: Arduino Mega 2560 Specification

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

Arduino Mega 2560 Specifications

3.1.1.3 Pin Configuration

Pin Configuration of Arduino Mega is shown in the Figure.

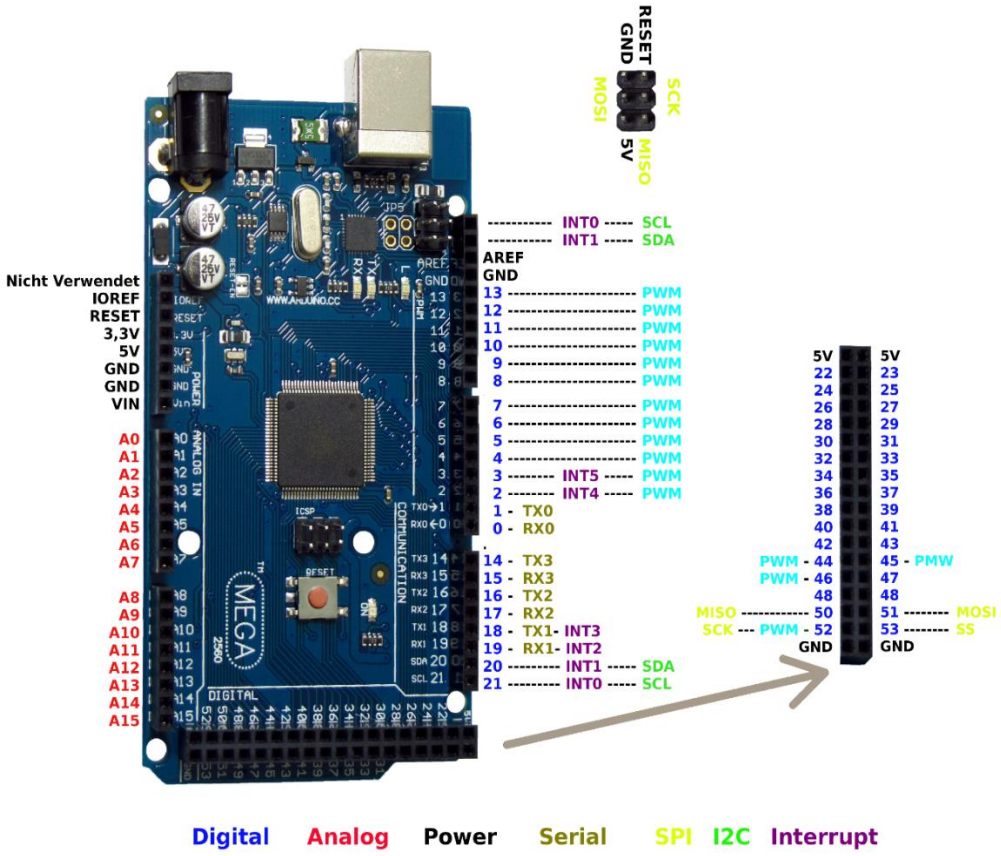

Figure 6: Arduino Mega 2560 Pin Diagram

3.1.2 Electricity Meter

The electronic meter being used in the prototype is A283, manufactured by MicroTech Limited. It is an electronic single-phase meter. It is mainly made for domestic and commercial users. The meter generates pulses at the rate of 3200 pulses per KWh.

3.1.2.1 Meter Components

The core of the meter is TERIDIAN-71M6521DE-FE. It is an integrated system on a chip consist of a Microprocessor core, Real-Time-Clock/RTC. Current Transformers (CT), and Resistive Shunts are used to give current sensor technologies.

3.1.2.2 Meter Working

Current A and current B are connected to transformers which measure current on both phases of the voltage lines. Voltage A and B points are connected to voltage measuring sensors via resistor dividers. Current transformer and voltage divider decreases/step-

down I and V values, respectively. A single analog to digital converter converts the Current(I) and Voltage(V) inputs (IA, IB, VA, VB) and provides the values to the Computation-Engine. The Computation-Engine completes the accurate calculations required to precisely measure energy. Along with other calculations and computations, it increases each current value with its related voltage value to get the energy per sample, when increased with the same sample time, followed by summation of product. Measurements are then accessed by the microprocessor core/MPU, more processed and output using the peripheral devices of microprocessor core/MPU.

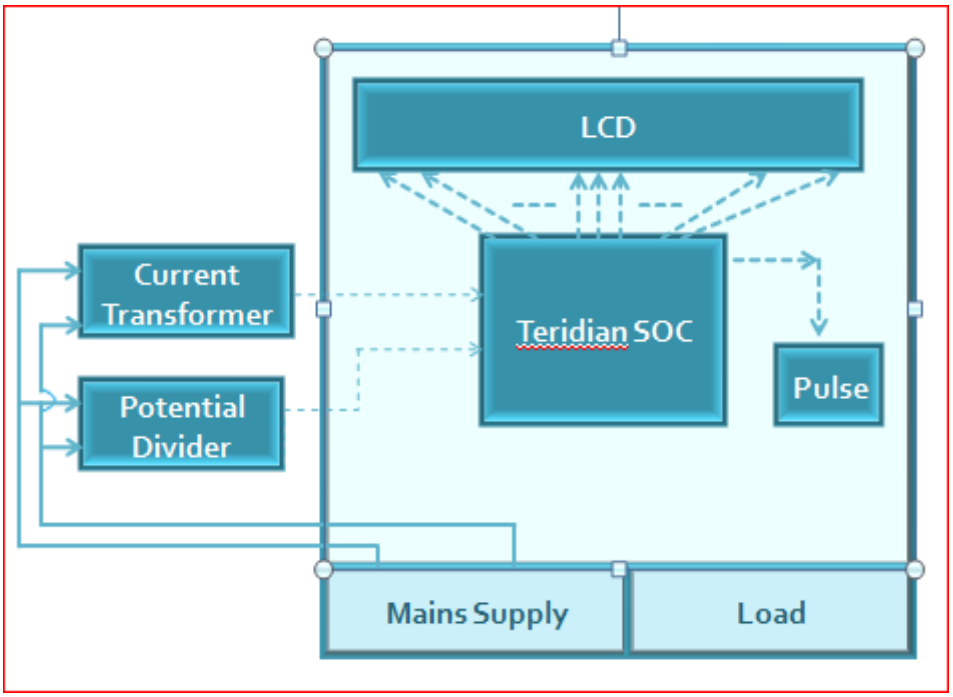

Figure 7: Inside of a single-phase Digital Energy Meter

3.1.3 ESP8266 Wi-Fi module

3.1.3.1 Description

ESP8266 Wi-Fi module is cost effective and supports TCP/IP and microcontrollers. It operates at 3V with voltage range up to 3.6V. Often, it is known as ESP8266 Wireless Transceiver. It is more advance as compared to its predecessor in terms of processing power and storage space. It can interface with different detectors and devices and needs very little changing. Components are installed very compact and GPIO pins occupy very small space. Module occupy less space and PCB board is very precisely designed so that no extra installation is required to run it.

3.1.3.2 Technical Specification

It has system on chip/SoC configuration and installed with a 32-bit Tensilica micro-controller working at 80 MHz frequency, amplifier, digital peripheral interfaces, low noise receive amplifier, antenna switches, power controller and filter ability. Wi-Fi 802.11 b/g/n around 2.4 GHz is supported by the module and including following features: -

a. 16 GPIO

b. Inter Integrated Circuit/I²C

c. Serial Peripheral Interface/SPI

d. 10bit analog to digital converter

e. Inter IC Sound coupled with direct memory access

f. QSPI flash memory is available via SPI and up to 16MiB is supported which was just 4Mib previously. In wireless communication, having such memory is a huge progress with such a small circuitry. The module also has power controllers to maintain constant 3.3V power.

3.1.4 Real-time Clock (RTC) DS3231

3.1.4.1 Description

The RTC is a cheap, precise inter integrated circuit RTC with an integrated temperature compensated crystal oscillator/TCXO and 16Mhz frequency crystal. The module has the option to install a battery cell which can keep time accurate even when the external power is interrupted. With the help of crystal, it can keep time accurate for longer duration. RTC has the capability to work in high temperatures which are usually occur in industries and during commercial use. it is available in a 16-pin, 300 mil SO package. Time information is available in the form of seconds, minutes, hours, months and years. It works in two formats i.e. 24 hours and 12-hour format with AM / PM indication. It also has active low reset pin to generate µP reset.

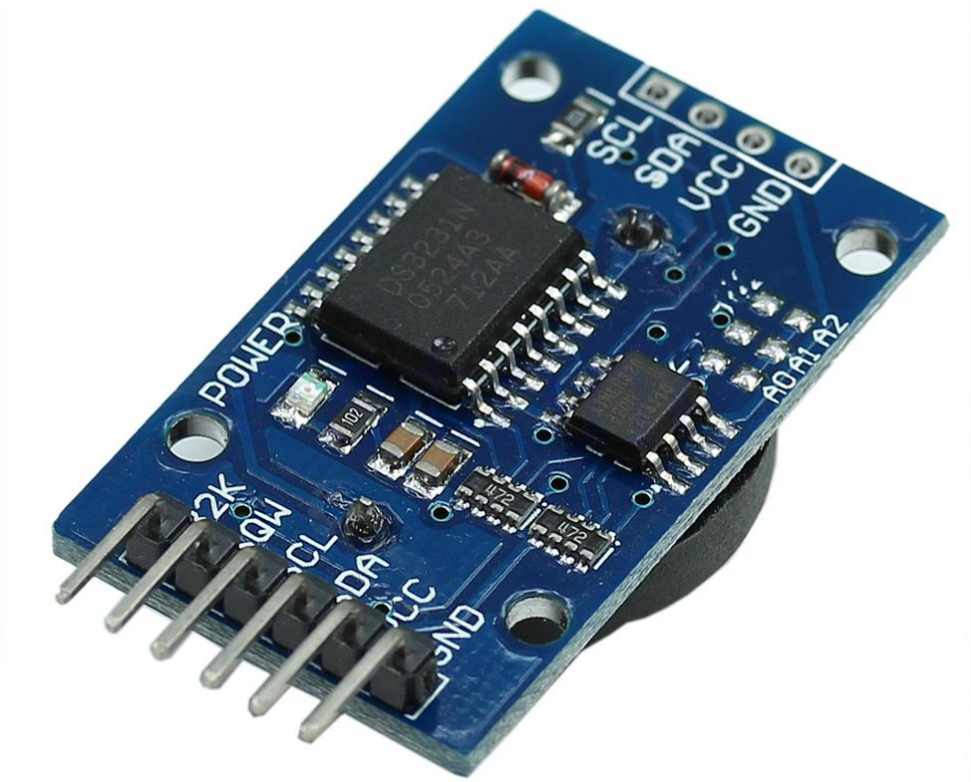

Figure 8: Real-time Clock (RTC) DS3231

3.1.4.2 Key Features

a. A precise RTC manages timekeeping functions

   i. It keeps track of time and date even compensating for leap years up to 2100

   ii. Accuracy ±2 ppm for temperature range 0°C to +40°C and ±3.5 ppm for temperature range -40°C to +85°C

   iii. ±3°C Accuracy of Digital temperature Sensor

   iv. Aging Trim register

   v. Active-Low reset Output

   vi. Two alarms for day time

b. Frequency 400kHz I2C Interface

c. Own cell installation for time keeping without external power

d. Long battery life due to low power requirement

e. Operates at 3.3V

f. It performs at ranges: Commercial 0°C to +70°C and Industrial -40°C to +85°C

3.1.4.3 Block Diagram

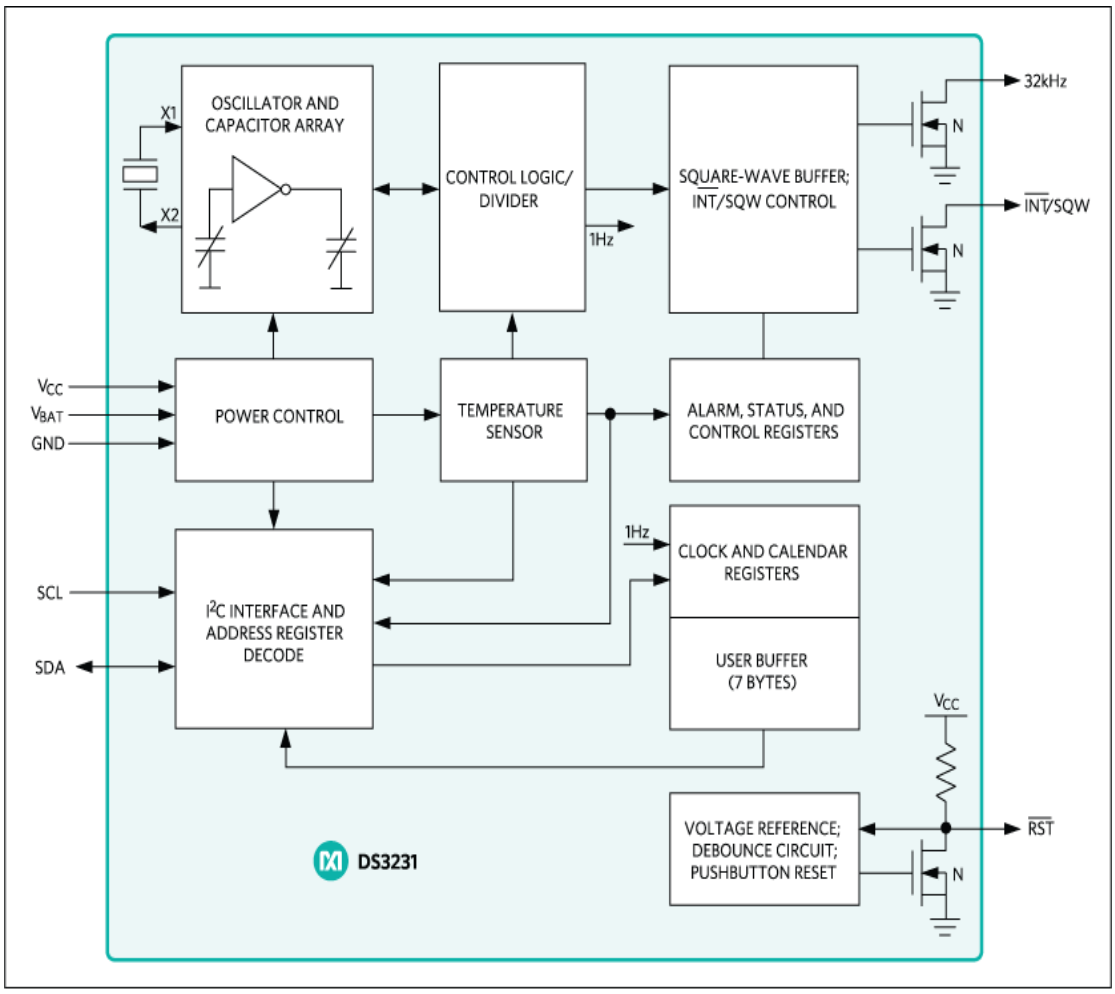

Figure 9: Block Diagram of RTC DC3231

3.1.5 Micro SD Card

3.1.5.1 Description

Micro SD Card Module low cost and small in size. It can store and fetch data from a SD card. It can be used with microcontrollers with any changing directly through output pin. It allows us to add mass storage and data logging to our project. It is installed to give backup to the meter so that data is stored even if meter is not able to transfer it to the server.

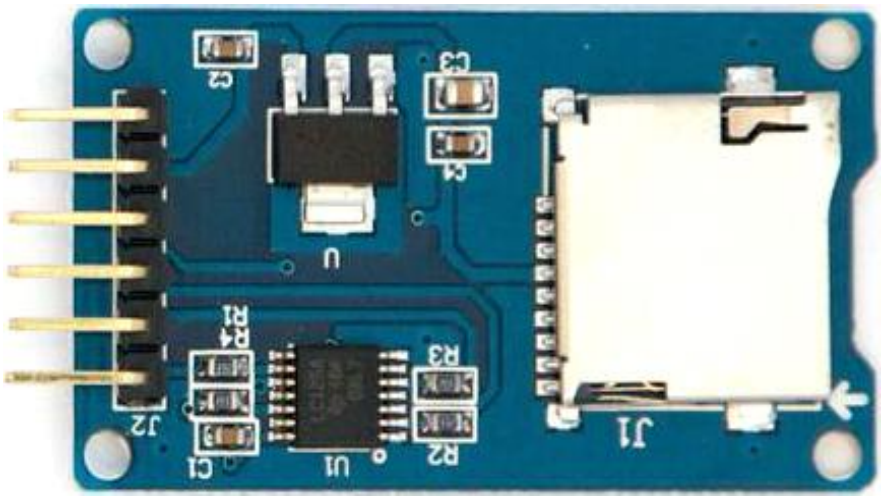

Figure 10: SD Card Module

3.1.5.2 Key Feature

a. Operates at 3.3V and 5V

b. It has SPI pins out MOSI, SCK, MISO and CS

c. Read and Write option to a SD card by using Arduino

d. Simple and easier to use for SD Card applications

e. SPI interface is used to work with Arduino

f. Easy to install Sd Card in its slot and remain secure

g. There are 4 holes to mount it securely

h. 4 I/O pins with Arduino

i. Small size of dimensions 42 mm x 25 mm x 5 mm

3.2 Software

3.2.1 Android Studio

Android Studio software is an INTERGRATED DEVELOPMENT ENVIRONMENT software and created by Google for android operating systems. It is available for windows operating system, LINUX operating system and macOS. It is used to develop android applications. It has made developing applications easy and efficient.

Figure 11: Android Studio

3.2.2 Spring Tool Suite

Spring Tools suite is spring tooling for any coding environment. Mostly built from beginning and supports spring based commercial application for enterprises. It also works/ supports Eclipse, visual studio code and atom IDE.

Figure 12: Spring Tool

3.2.3 MySQL

MySQL is an open source software. It is available under General Public License and a variety of proprietary licenses. MySQL is the combination of two words. “My” is part

of the name of developer's daughter and "SQL" is a language which stands for Structured query language. MySQL is owned by Oracle Corporation. MySQL is part of the LAMP web application software stack which is an abbreviation for Linux, Apache, MySQL and Perl /PHP /Python. MySQL is used as server software.

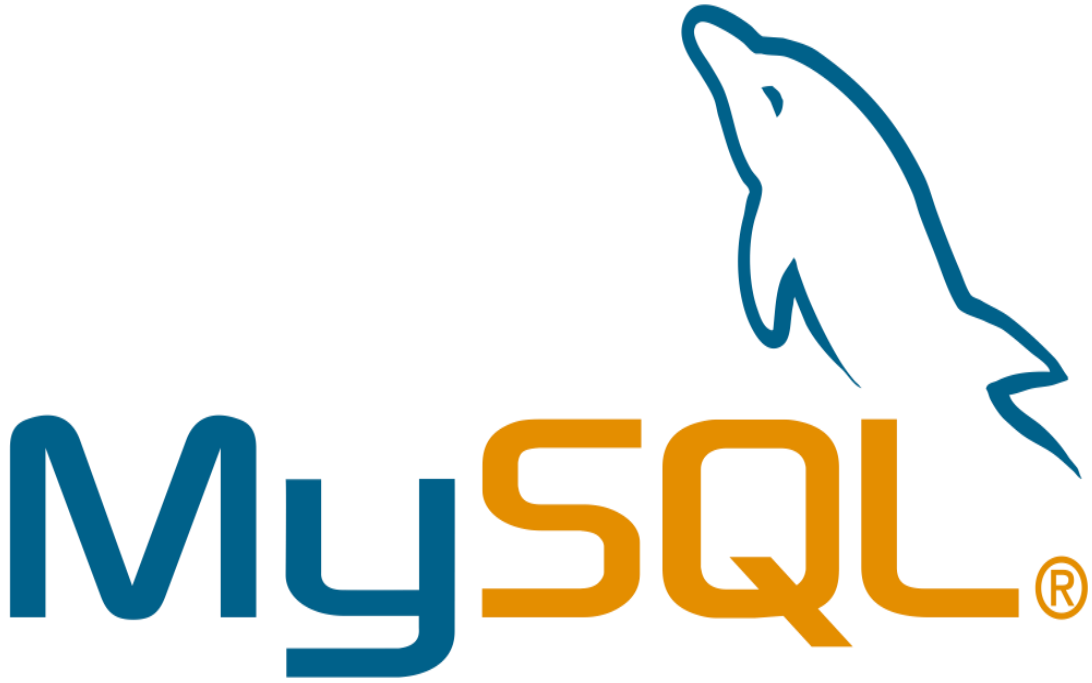

Figure 13: MySQL

3.3 Working Principle Project

3.3.1 Electric Meter

3.3.1.1 Installation

First step is to install the PMAS meter parallel to the incoming electricity. You need to keep in mind that there are four connection points at each meter. Point 1 and Point 2 are for incoming hot wire and outgoing hot wire respectively. Point 3 and Point 4 are for cold wires connection points.

Before selecting the location to install PMAS meter make sure it is within range of Wi-Fi router. After the connection with the main electricity source now it is time to give power to the PMAS meter with 5V DC charger. PMAS meter will connect to the local server through router and will sending data.

3.3.1.2 Monitoring Power Consumption

The electric meter being used in the model is an electric single-phase energy meter, made for domestic and commercial use. The meter works at the rate of 3200 pulses per KWh. Set of every 5 pulses is counted with respect to time taken to measure the power used during that interval. This consumption of power is then further logged along with time at which it is consumed in the SD card module installed in each meter. This information is also sent to the server with the help of Wi-Fi module via router. Data received form meter is stored linked with Department name and Meter ID from which it is sent for future analysis.

SD Card provides the backup of data in case the router is off or connection is interrupted. As soon as the connection will resume all saved data will be sent to the server.

3.3.2 Server

Spring Tool is used to store or fetch data to and from the database. Database is based on MySQL workplace.

3.3.3 PMAS App at Smartphone End

Power Monitoring and Analytics System (PMAS) Application is developed for this meter to provide user friendly analysis options to the user at his smartphone. With the help of PMAS app the user will be able to analyze its power usage and optimization will be possible.

PMAS will be installed in the smartphone with the help of .apk file. First of all, user will have to initialize its app by creating his account using unique username and password.

After this user will add PMAS meters info in the account which he has installed in different departments. Now user will be able to use PMAS to analyze and optimize his power usage.

3.3.4 Schematic Diagram

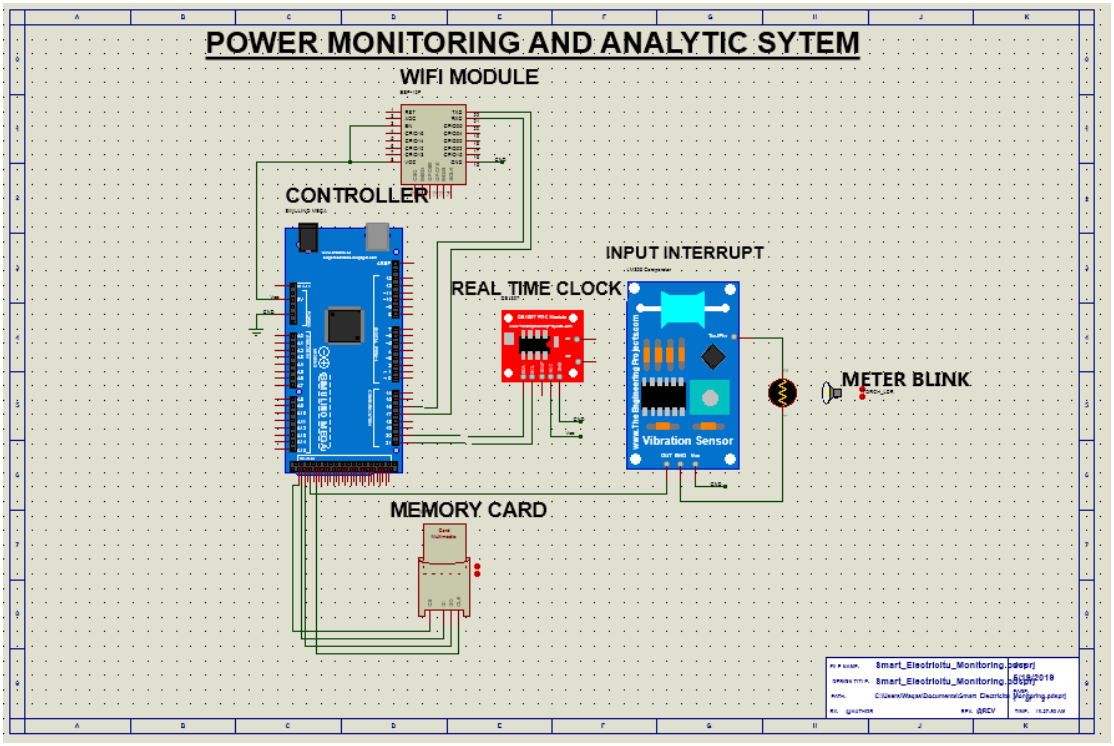

Figure 14: Schematic Diagram

CHAPTER 4

ANALYSIS AND EVALUATION

4.1 ANALYSIS

In the project a proof of concept and working prototype of a power monitoring, profiling and analytic system was designed with the aid from available efficient digital meters.

The advancement in technology enabled analog electromechanical meters to be phased out by digital meters. Digital meters can easily implement the concept of automatic meter reading system. Numerous automatic meter reading system methods and technologies, consist of Power Line Carrier (PLC), Mobile networks, Supervisory Control and Data Acquisition (SCADA), modems, Internet, Optical Fiber, LAN cables, RF module, Wi-Fi, Bluetooth module and ZigBee. They were all developed to provide and validate the solution of proficiency, trustworthiness and usefulness for automatic meter reading system. All the approaches are either too costly for implementation, operation, need intricate setup of infrastructure, brief operating distance, still require field involvement of human operators and are error prone and less reliable either due to noise in transmission line or due to weather conditions. The developed project utilizes the inclusive and previously fixed set-up giving results with a very low latency rate as compared to the above-mentioned projects.

4.1.1 Simple and cost-effective Solution

The prototype uses Arduino Mega which is simple to install, low operating cost and multipurpose controller. It uses the meter reading from its interface, counts pulses and create the string of data containing the power used with respect to time of use device Identification through the transmission medium. It is not necessary to synchronize the pulse count because it sends pulse count as reading, not energy readings in Kilo-Watt hours. In case of a power failure when the Arduino mega restarts it sends a startup message to the server which processes the received pulse counts accordingly so that there is no information loss.

4.1.2 No loss of data

Since the number of consumers is relatively large, the prototype modules are developed and programmed in a way to send their readings at real time so data loss may occur at server because of any network congestion. The retrieval of all individual meter readings may take some time depending on the network traffic of the particular link. If a message is unable to be sent to the server end, this is not an issue since the module sends the collective pulse count starting from the turning on of meter, not the pulse count between consecutive messages.

4.1.3 Compact Design

The compact design of the model enables it to be easily being integrated in existing digital meter casing. Moreover, it will save both time and money to design new meter system by incorporating more hardware components.

4.1.4 Automated System

The process of retrieving data from input stream of arrays being sent by Arduino Mega is totally automatic. Server Identifies the Mac address of Mega to identify and extract details from the input stream, this avoids the process of assigning, transmitting and maintaining unique user ID's. Hence this makes it error free due to lack of human interference.

4.1.5 Efficient Monitoring

The consumption of electricity is efficiently monitored by a comprehensive and efficient infographic using pie charts and graphs. This enables the user to visualize the energy consumption and can relate it to previous data.

Figure 15: Hourly Unit Consumption Graph

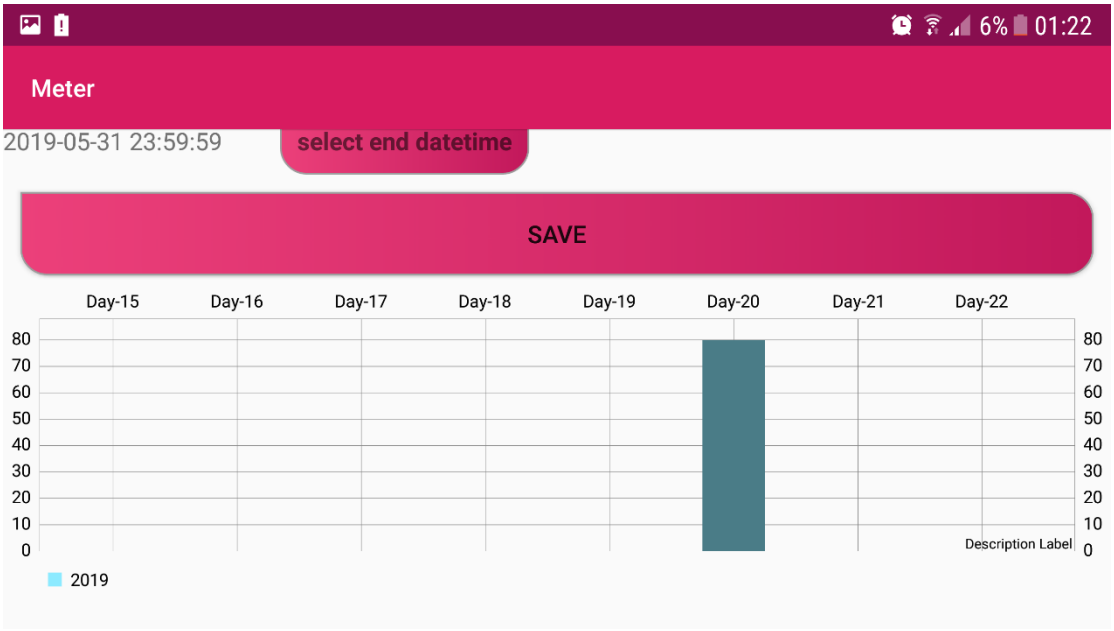

Figure 16: Daily Unit Consumption Graph

4.1.6 Pervasive Android Application Interface

A user-friendly Android application enables the consumer to check is consumption remotely anywhere in the world. It helps to easily view his consumption in tabular as well as in graphical form. The application also enables the user to get the information as the time and date of consumed units as well as provides all the previous data so that user can relate to his consumption from previous time. This in turn enables him to optimize his usage and monitor it strictly for any unwanted usage. The data available to app is being constantly updated real time and contains all the elaborate information.

4.1.7 Transparent Billing

Since the consumer has all the necessary information of his meter so he can exactly know the cost of his consumption. This curbs any blunder of extravagant billing done by electricity provider. Moreover, it enables the consumer to keep a strict eye on his billing so that consumer can optimize his appliances or machines at his place to save the cost of electricity.

4.1.8 Elaborate Profiling

Elaborate profiling of consumer is done so that user may see his cumulative as well as individual meters consumption. All the readings are shown the form of graphs. Consumer can see his overall consumption as well as his individual meters readings of real time and previously maintained data. User may see his records of any month and any time

RECOMMENDATIONS

a. The inspiration behind this proof of concept is to take up this project is the existing ineffective use of the electrical power all over Pakistan, and a solemn attempt to contrivance this system throughout the country to efficiently and economic use electricity.

b. This project must be incorporated in the industrial and domestic sectors.

c. The project can be incorporated with a database software to maintain and monitor the received data over the time from users.

d. This project provides the basic knowledge of functionality of electrical system so this project can be extended to carryout phase shifting.

e. The project can be source of power auditing and management for both public and private sector.

f. The project should be implemented commercially to bridge a gap between energy supply and demand imbalance.

g. Project should be implemented on Industrial level to ensure economy of productivity and stability.

CONCLUSION

6.1 Overview

In this project, will present an efficient Power Monitoring and Analytic System. The system consists of Automated Meter Reading (AMR) for data acquisition which includes digital energy meter and transmission module installed in every consumer's unit. It takes the meter reading and utilizes the Internet of things (IoT) to transmit the power consumption readings to the Data Management Server, where data entries are stored and arranged with respect to time and date. At the customer's end an android based application is installed in the smart phone which is used to display power in term of Time of use (ToU) and Real time Pricing (RTP), calculate billing price, database updating and maintaining profiles for each individual user. A proof of concept of the complete system has been developed to demonstrate the effectiveness and efficiency of Automatic Meter Reading, billing and notification through the use of Internet of things (IoT).

Power Monitoring and Analytic System not only provides you the Time of Use (ToU), Real time pricing (RTP) with lowest latency rate but also the system has an equal capability on home to industry level working. Power Monitoring and Analytic System enable the manager of the system to get the automated usage of electricity usage in real time with lowest latency. Power management system broadly consists of three modules:

a. Load measurement module

b. Data transmission module

c. Data base/ server module

6.2 Objectives Achieved

a. Use and employment of Arduino including its programming is learnt.

b. Understanding of Networking and use of its topologies is achieved.

c. Energy conservation is achieved by the detection of unlawful use of electricity.

d. Team spirit is achieved.

6.3 Limitations

We designed this project for low voltage values and smaller values of current ranging from (220V and 2A) respectively considering the meagre resources and budgetary constraints, however the real time implementation calls for the increased sizes hardware with increased current values as well as a healthy budget to implement this system throughout the industry.

6.4 Applications

It can be equally good at both industries and at home level implementation

6.5 Previous Work Done on The Subject Globally:

Following patent exist on the subject:

a. AMR (Automatic Meter Reading) augmented by wireless communication system of energy meter used with relay control and GPRS.

b. Measuring of energy meter and monitoring of IR sensor (placed in the screw portion of energy meter seal) through PIC microcontroller.

6.6 AT MCS

No previous work has been done on this project at MCS, however another dimension in the same context has been exploited in this year that has resulted in development of smart meters with theft control system.

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