DESIGN AND IMPLEMENTATION OF INTERNET OF THINGS BASED SMART ENERGY MONITORING AND CONTROLLING SYSTEM

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PROJECT SUBMITTED IN FULFILMENT FOR THE DEGREE OF
B. SC. IN COMPUTER SCIENCE AND ENGINEERING

INTERNATIONAL ISLAMIC UNIVERSITY CHITTAGONG

DECLARATION

By this I/We announce that the work in this project is my own, except for quotes and summaries properly recognized.

15 February 2021

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I/We declare hereby that we have read this project and I/he think this project is appropriate for the B degree award in terms of reach and consistency in B.Sc. in Computer Science and Engineering.

15 February 2021

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ACKNOWLEDGMENT

The most compassionate and the most merciful in the name of Allah. First, we are thankful to Allah all over our lives for having given us strength and wisdom. We would like to give our gratitude for our honorable supervisor Saiful Islam, Lecturer, Dept. of CSE, IIUC who has given us significant suggestions and inspections during the whole process of the work. His invaluable contribution to the progress of this project has been rendered through positive feedback and recommendations during the project and experiment. We are very thankful, last but not least, to our teachers, colleagues, classmates, elderly, juniors, and assistants who have helped us in all ways limitless. We're very lucky to have good people like them next to us.

Authors

ABSTRACT

With the progress and development of national economy as well as power system, reliability of balanced power system have been more important. Development of metering system has been done in that reason. The measure voltage, current, energy and cost for energy consumed. In the starting, point it takes some times for initializing then it measure voltage and current. Then microcontroller calculates power (watt). Then, it calculate energy in kilowatt-hour(unit) rating and calculate unit cost consumed by the load. Then, microcontroller has shown the output in LCD display. After every two-minute microcontroller sent SMS to distributor mobile by IoT module, which contains total unit and unit cost. In addition, reset the previous data. It count unit from initial point. In previous systems, the series electromagnet is excited by the load current flow through the current coil. The coil of the shunt electromagnet is directly connected with the supply and hence carry the current proportional to the shunt voltage. This coil is called the pressure coil. This system is not as efficient as digitalized systems. And thesre is no option for IoT monitoring. Here this project presents design and implementation of an embedded system to monitor load. The implementation online monitoring system integrates IoT, with single chip microcontroller and sensors. This system contains current sensor, voltage sensor to keep the information visible via IoT could to authority.

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CHAPTER I

INTRODUCTION

1.1 BACKGROUND

Power sector plays strategic role in the process of economic development of a country. Due to increasing demand of electricity, power utilities and governments are facing a number of problems like power shortage. Thus, it has become much easier to calculate electricity bill, minimizing power wastage and reduce bill-manipulating cost. Power supply providers of developing countries are facing a lot of problems with the increasing demand for the electricity. The conventional energy system causes many problems like poor efficiency, lack of reliability, high manpower requirement, energy bill manipulation and insufficient interaction between the consumer and the distributers. Nowadays distributers are also concerned about providing better service as well as consumers except energy measurement with timely billing data. In order to resolve this issue a IOT based energy meter has been developed in this report. A 16x2 LCD display is used for showing real time voltage, current, watt hour with billing for consumer notation. A variable rheostat is being used for calibrating the proposed wattmeter where its value is non linear compared with traditional wattmeter. A Microcontroller is used for measuring the voltage, current comprehensively watt hour and a IOT module is used for notifying distributors about usage alongside with monthly billing in an efficient way. The line voltage and current measured by an immaculate multi meter is perfectly aligned with this Proposed Energy meter.

1.2 PROBLEM STATEMENT

Power shortage is one of the biggest problems of a developing country like Bangladesh. Without a proper management of power usage, it is nearly impossible to reduce power shortage, maintain proper billing as well as consumer satisfaction. Nowadays, electricity consumers are asking for better customer service, high accuracy in energy measurement and timely data. Nevertheless, the electromechanical meters that we use today have many drawbacks like poor accuracy and lack of configurability. They have many moving parts that are prone to wear over the time and varying operating temperature and conditions. In this case, smart metering is the key of better service with high accuracy. Technology is probably a solution to reduce costs and prevent loss of resources.

Many advantages has attributed to smart metering, including lower metering cost, more reliability of supply and accurate pricing scheme. However, in this report a IOT based smart energy meter system has proposed by which a consumer can easily know how much energy has consumed at real time. This measurement system will help the consumer to calculate and compare day-to-day usage. It has also capability of sending monthly as well as real time usage data cost to distributor by notification.

1.3 PROJECT OBJECTIVE

The main objectives of this project has described below.

- To design a circuit for measuring voltage, current.
- To show the result in LCD Display & send the result in consumers mobile.
- To design an IoT panel for data reading from internet.

1.4 REPORT OUTLINE

Six chapters has covered in the course of design and development of this project. The chapters and their contents are as follows:

- Chapter 1 is the introductory chapter that gives the overview, motivation and objective of the project.
- Chapter 2 is literature review. Previous work related of this project has discussed in this chapter.
- Chapter 3 is methodology. In this chapter, all the components used in this project has described elaborately.
- Chapter 4 deals with the system implementation and results, Objective verification and system specification.
- Finally, the summary of this project has discussed in detail in chapter 5. The limitation of the project, advantage and future development has discussed on this topic.

CHAPTER II

LITERATURE REVIEW

2.1 INTRODUCTION

Energy consumption measurement is a major yardstick of a nation's progress today. It keeps the injudicious exploitation of energy in check, thereby reducing the gap between the ordinary and the privileged. The existence and need of energy measurement precede the actual onset of electricity consumption. In early 1870s, the time when gas lamps were the most popular source of energy, there existed gas meters to compute the energy consumed. Since then, the energy calibration process has come a long way. Edison's electrochemical meter for measuring DC didn't gain much popularity as it was labor-intensive to read.

2.2 SCOPE OF THE PROJECT

The currently available meters use the operating principle first implemented in Blathy's meters in 1889. Today's conventional meters use kilowatt-hour as the standard unit of measurement. The billing requires readings to be read once during the period. This creates room for error as it involves human intervention. The history and evolution of energy meter dates back to the 1880s, a little before the widespread use of electricity. The era of gas lamps also contained the energy measurement system where the amount of energy consumed per household was calculated. With the discovery and use of electricity, the electric lamps rapidly replaced the gas lamps, proving to be brighter and more cost efficient. A new system for consumption measurement was required. DC meters measured charge in the unit ampere-hours. With time, the DC meters proved to be insufficient. Then came Edison's meters classified as electrolytic and electrochemical meters. The electrochemical meters, though sufficed the purpose, were labor intensive to read. Therfore automated IoT based system implementation is required in this area.

2.3 REVIEW OF PREVIOUS WORKS

Few of the previous work based on Smart Metering System has described below.

2.3.1 Arduino Based Energy Meter Using GSM

The system brings smartness in terms of bilateral communication and controlling of load [1]. The proposed system senses the number of LED blinks of a conventional metering system which are 3200 blinks per 1 kilowatt-hour, which can be altered only at the time of implementation depending on the metering system used. The proposed system uses LDR as sensor and an amplifying circuit to provide the necessary input signal to the microcontroller. The system waits for the output of RTC thereby serving as an interrupt for the microcontroller and updates the user and server through GSM shield.

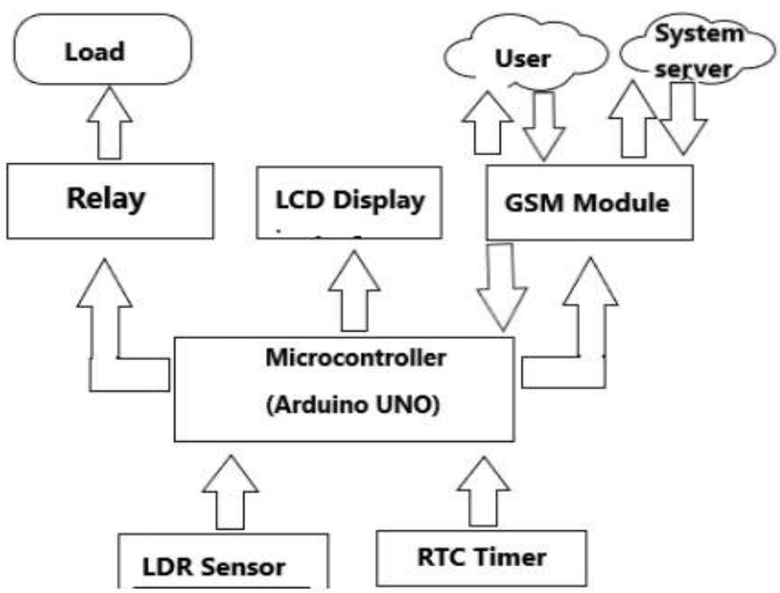

Fig. 2.1 Arduino Based Energy Meter Using GSM [1]

In case the user wants any information regarding the energy or wants to deter the load from the supply in between the period, it can be communicated easily through GSM shield by simply sending a text message, which will generate an interrupt to the microcontroller and it, will revert accordingly. User can also refer to the server for necessary information. There are number of ways through which data can be communicated. For using wired technology, fiber optics or co-axial cables can be used. Whereas for wireless, GSM, Wi-Fi, or Zigbee technology can be used [2] [3] [4] [5],Once bill is generated user has 15 days to pay his bill or else his supply will be disconnected using relay [6]. In the conventional metering system the number of LED blinks are synchronized with the energy consumed which is used effectively in the proposed system for calculating the units through LED sensing. To verify the accuracy of the system, it was examined under various load conditions and results obtained were compared with the readings taken on the conventional meter under same loading and for the same duration. The aim is to create a user-friendly billing system with least human errors, by implementing modern technology that is compatible even with the old metering units. LDR is used to sense the units consumed without tempering the existing mechanism. The system employs GSM for bidirectional communication while timer gives the real time even if there is no supply. This device enables the users to easily monitor and track their energy usage. The system proves to be advantageous in such a way that the user receives updates on consumption through a message and can even disconnect the load from the supply when not required with a simple message. This makes up for an energy and economy-efficient environment. Thus, the entire system is a confluence of modern technology and existing electrical architecture that shall be user-friendly without affecting its simplicity in implementation.

2.3.2 Design and Implementation of an Internet of Things Based Energy Metering

In this section, they introduce the proposed Smart Energy Monitoring (SEM) in details. The proposed system can be used in residential and industrial centers to measure the amount of energy consumed by each electrical device and to apply various controls on electrical appliances [7]. The system can measure power consumption, power line parameters, and send them to a central server in a different way. The data obtained can be used to predict customer consumption and consumption schedules. The system can control the electrical equipment and, if necessary, turn it off in the peak hours and turn it on at non-peak hours. The system is also able to monitor and store other environmental parameters including temperature, humidity, brightness and possible gas leakage. It is possible to design and implement various smart applications on this infrastructure. If the utility companies move forward to dynamic and instantaneous pricing and implementation of demand-side management services, this system can be well designed to instantly inform users of their consumption and the current price in the network. As shown in Fig. 1, the proposed SEM system consists of three major components including sensor nodes, Gateway and Server. The sensor node sends its information to the Gateway, and the Gateway connects to the Internet through a communication technology such as an ADSL modem or 3G/4G/LTE network. Each component is introduced in the following section in details. We have developed an Android HTTP Gateway. The Gateway is responsible for configure the sensor nodes and collects the sensor values by using the standard API RESTful commands. The collected sensor data is transferred to the specific server for permanent storage. Each Customer has a unique API key, which is used for communication between the Gateway and Server. This API key is used for providing required security and authentication process. Each time, which Gateway wants to establish a connection with the Server, uses this API key in the messages. The sensor node is accessible through IP address 192.168.4.1 in the Access Point (AP) mode. In the beginning, the Gateway connects to the AP and programs it. By entering the network SSID and password, the sensor node can connect to the Gateway through the local WiFi network. At the end of this process, the sensor node is connected to the local Wi-Fi network. A spatial web service is designed in the Gateway so that the sensor nodes are able to transfer their information after they connected to the Wi-Fi network In the implementation of this web service, the service feature of Android has been used.

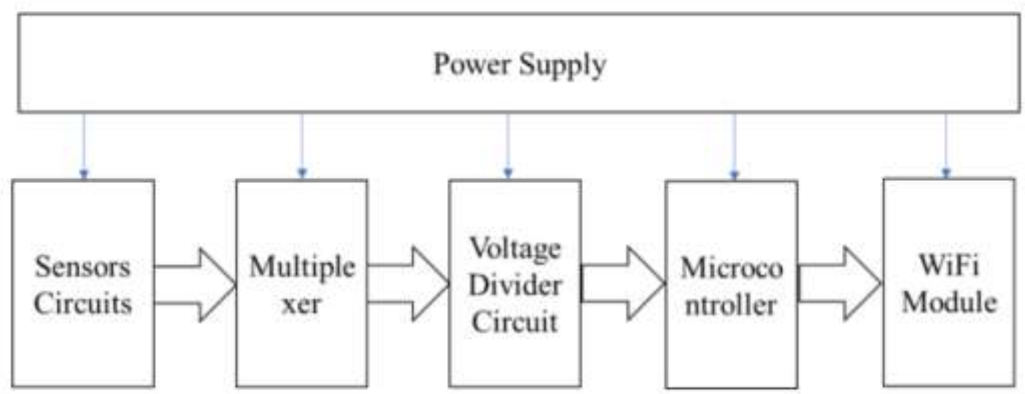

Fig. 2.2 Design and Implementation of an Internet of Things Based Energy Metering [7]

The service is one of the components of the Android apps that can run long behind the scenes, so the web server is constantly running as a service on the Android operating system, and if it stops, Android will automatically start it. We used the Nano HTTPD library to implement the web server in the Android Gateway. With this famous library, you can easily get HTTP messages, extract the information in the body, and send the response as an http message to the client if necessary. Nano HTTPD is a lightweight HTTP server designed for embedding in other applications, released under a Modified BSD license. It can be used as a library component in developing other software. To collect the customer's home information, an IoT board containing DHT22 temperature/humidity sensor, MQ-5 gas sensor, light sensor, current sensor, 5 V relay and an MCU/Wi-Fi controller has been implemented. We have developed the home gateway on a Raspberry Pi 3 with the Raspbian operating system using JavaFX platform. An Android gateway has also been developed. We have also implemented an SCT current sensor to measure the total power consumption of the customers. The proposed architecture can be considered as a backup system for the AMI network. Furthermore, as the energy consumption and the other parameters are collected by the system it is possible to developed and implement many smart grid applications such as AMI, Demand Response and Energy Management System and privacy/security applications.

2.3.3 Smart Energy Meter Surveillance Using IoT

In this system, a unique Id is given for each energy meter. This unique Id number is interlinked with the customer's unique mobile Id number [8]. It constantly monitors the energy meter. The energy consumption from each house is sent to the control station through the web server and the billing and power cut details are sent from the control station to the residential energy meter. In the existing energy meter, the meter shows the energy consumed from the date of installation. In this system, the daily energy consumed is calculated using the arduino micro controller and it is displayed in the LCD. It is also communicated to the consumer's mobile using IoT.

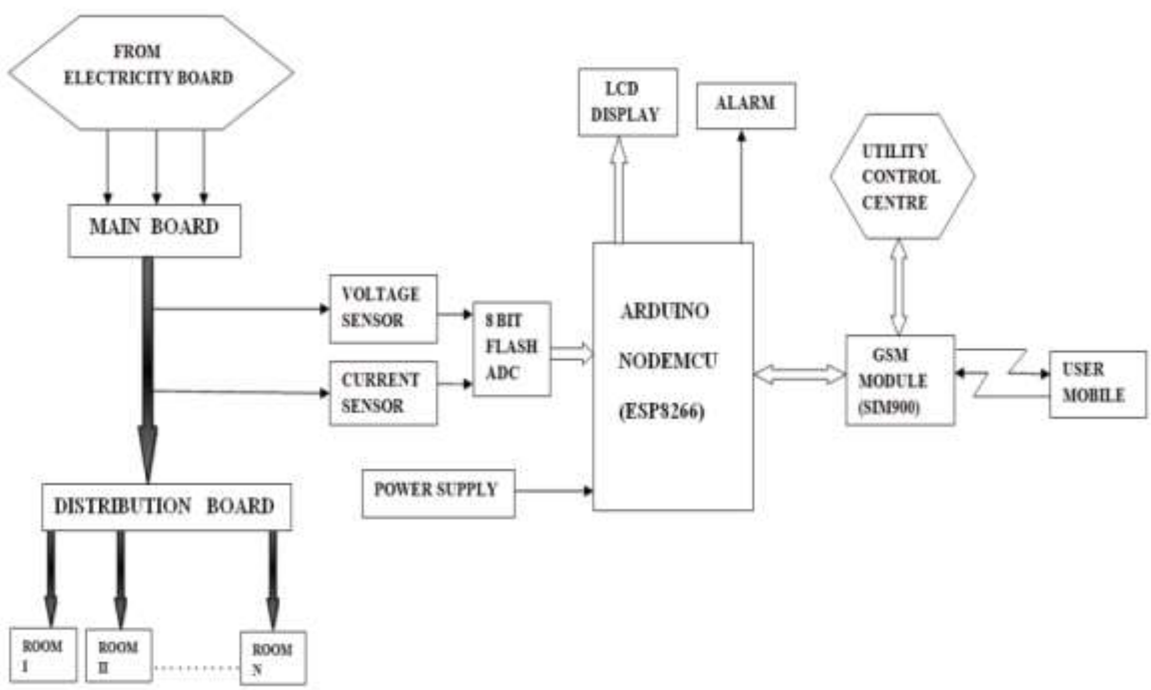

Fig 2.3 Smart Energy Meter Surveillance Using IoT [8]

The billing detail for the energy consumed is communicated to the consumer monthly through the web server using IoT and as a message through the GSM module. The payment is also made through the web server. This helps in eliminating the manual dependency to collect the reading. The sudden power cut causes major problems in hospitals, industries and in public sectors. In order to be aware or to make safety precautions in hospitals, the power cut is announced in advance. The power cut details are sent from EB web server to the consumer's unique ID using IoT and it is also sent to the consumer's mobile as a message through the GSM module. The details are also displayed in the LCD display after an alarm. The alarm is used to indicate the residential that a new message has been received. The existing model is a time consuming process and it needs a lot of labor. The proposed system eliminates the need of labor and it is a cost efficient and a time saving process. The proposed system gives the information about the energy consumption on daily basis, billing and payment through IoT, pre-intimation of shut down details, alert systems when the energy consumption exceeds beyond the critical limit and the disconnection of power through a message when the residential are out of station to prevent the wastage of energy. The idea is being proposed to reduce the human interference to collect the monthly reading and to minimize the technical problems regarding the billing process. From the electricity board section, the information regarding the bill amount, payment and the pre-planned power shut down details are communicated to the consumer. If the customer does not pay the bill in time, the user is informed through a message using IoT. If still the customer does not pay the bill, then as per designated consideration, one alert message will be sent then automatically power connection is disconnected from the remote server. It provides pre-intimation of power cut details and the energy consumption on daily basis. It provides an alert if the energy consumption exceeds beyond the certain limit. It also has the facility of terminating the power supply through a message when the residents are out of station to minimize the wastage of energy. It is an effective way of greater accuracy, improved billing.

2.3.4 Wireless IoT based Metering System for Energy Efficient Smart Cites

The proposed IoT based metering system is designed to contribute in establishing energy efficient smart cities. Its main aim is to minimize the rapid increase in average electricity consumption issue [9]. Additionally, it provides a more convenient solution to problems faced from using the existing meters, such as the manual readings' errors from the analog electromechanical meter. The conventional electromechanically post-paid metering system, where the consumer is charged on a monthly basis, provides no sense of the energy used until the end of the month. However, it guarantees that customers will always have electricity supplies, except during blackouts. On the other hand, Prepaid meters offer many advantages both to the utility provider and the consumers. To the utility provider, this reduces many issues tremendously arising from meter readers such as delays, wrong and infrequent meter reading resulting in bulk amount of billing that consumers would need to pay and further consequent in not paying, disputes and so forth. Additionally, prepayment-metering system encourages users to control their energy consumption, in order to avoid cut off, due to zero credit [9]. Thus, the proposed metering system uses the prepayment metering as an attempt for building energy efficient new cities. Figure 2 shows the complete proposed system design with the components and building components for each unit block, which will be further discussed in the this and the following sections. The sensing unit comprises of the voltage transformer and the current sensor that are connected to the main supply. The voltage transformer used was a 240v to 6v step down transformer. Whereas, the current sensor was a SCT-013-000 non-intrusive sensor, clipped over a single wire either live or neutral, to sense the passing current [10].

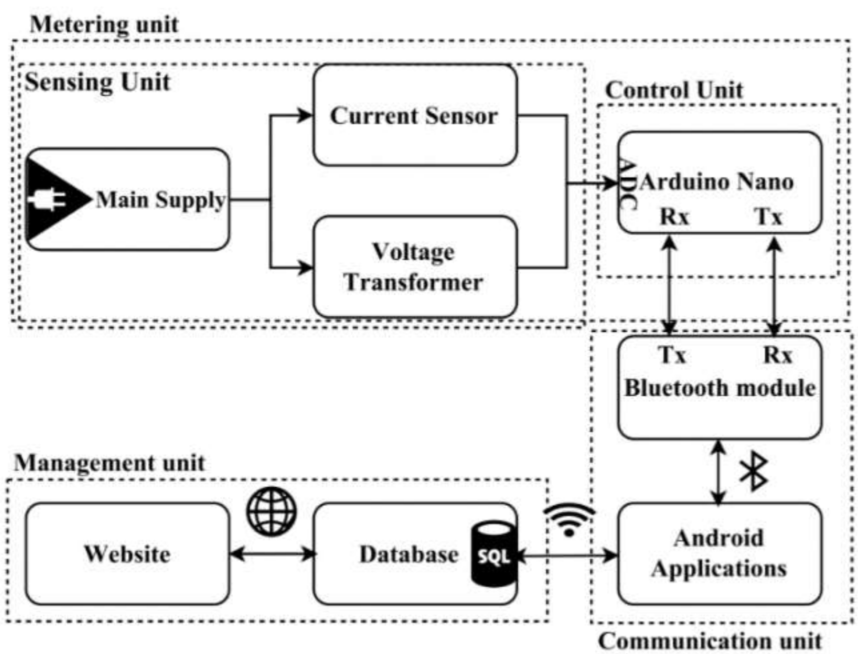

Fig 2.4 Wireless IoT based Metering System for Energy Efficient Smart Cites [9]

This sensor’s output is voltage, so, to get current reading, a burden resistor is connected to the two terminals of the sensor. The reading of both components are transferred to the next unit for processing. The control unit consists mainly of the micro-controller, which is ATmega328 based Arduino Nano. Data received from the sensing unit are passed as an input to the built-in analog to digital converter (ADC) in the microcontroller. Afterwards, the data is processed then used units in kilowatt hour and remaining balance and units. These calculations were performed as follows: first calibration values for the current and voltage are calculated as shown in equations (1) and (2), where 0.707 value is used to convert the measured value to RMS value, 1024 is the maximum reading of Arduino input pins, 36 is the value of the burden resistance used with the current sensor and 240 is the maximum voltage that can be read by the meter. Current value read from the supply is calculated using a loop which takes 200 samples from the micro controller analog pins connected to the sensor and finds the maximum and minimum values. Then the current is calculated as shown in equation (3).

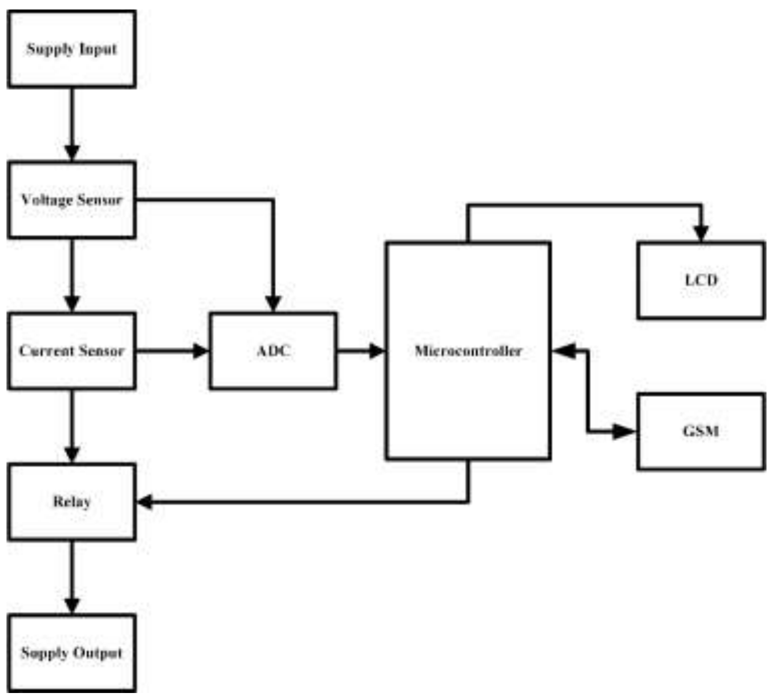

Fig 2.5 Design and development of GSM Based Energy Meter

On the other hand, voltage is calculated by taking the reading of the analog pin of the microcontroller connected to the transformer as shown in equation, using software function analogRead(). This unit's main functionality is to establish the communication between the control unit and the Android application. It is composed of the Bluetooth module, HC-05, and the

Android application. The module is connected to the control unit, in the metering system, serially. The Bluetooth pins, Tx and Rx, are connected to two digital pins in the Arduino Nano.

2.3.5 Design and development of GSM Based Energy Meter

In this project author has used GSM module alongside with ATMega 8L microcontroller. Potential transformer and current transformer has used to sense and measure the voltage and current supply of the input. The authors have configured these two sensor pins with analog pins, as these are analog devices. A LCD has used for showing all the data in the display. In this system, a particular identification number has provided for each meter to keep the tracking safely. Authors has used the sim card number as individual ID numbers which is a very convenient solution. In this system, the author has powered the device by using step down transformer for reliable power source. Then the power source has rectified to DC using diode bridge and later it has brought down to optimum level for onboard usage. The current transformer has mounted onboard in series and potential transformer has mounted in parallel. When user connect loads with the system, the current sensor and potential transformer get the data from the usage and record it. It measures voltage and current separately and then multiply the value with an optimum power factor to determine the watt usage. This system tracks all the data and show it on the LCD. The authors has used logic converter to connect the GSM with the microcontroller.

CHAPTER III

METHODOLOGY

3.1 INTRODUCTION

Hardware is the most important fact for a project. Choosing the necessary hardware is also very difficult. In this chapter, we are going to describe the hardware used for this project. We will also discuss the function of the chosen parts. By the end of this chapter, one will understand the reason behind choosing the used components and their function to this project.

3.2 LIST OF COMPONENTS

- ESP 32
- ACS712 Current Sensor
- LCD
- I2C Adapter
- Relay
- Step Down Transformer
- Diode
- Capacitor
- Voltage Regulator

3.3 ESP 32

ESP 32 is a mini wifi board with 4MB flash based. The ESP 32 is a low-cost Wi-Fi microchip with full TCP/IP stack and microcontroller capability produced Espressif Systems. This module allows microcontrollers to connect to a Wi-Fi network and make simple TCP/IP connections using Hayes-style command.

3.3.1 Features of ESP 32

The features of ESP 32 has described below.

- 11 digital input/output pins
- 1 analog input

- Micro USB connection
- Power jack, 9-24V power input.
- Compatible with Arduino

Fig 3.1 ESP 32 [10]

Table 3.1 describes the pin description of the ESP 32.

Table 3.1 Pin Description of ESP 32

Pin	Function
TX	TXD
RX	RXD
A0	Analog Input, max 3.3V input
D0	I/O
D1	I/O, SCL
D2	I/O, SDA
D3	I/O, 10K Pull-up
D4	I/O, 10k Pull-up, BUILTIN_LED
D5	I/O, SCK
D6	I/O, MISO
D7	I/O, MOSI
D8	I/O, 10k Pull-down, SS
G	Ground
5V	5V
3V3	3.3V
RST	Reset

3.4 ACS712 CURRENT SENSOR

The ACS712 is a bi-directional, Hall Effect current sensing IC. The current is passed through the IC; with little to no effect on the voltage, and the IC measure the magnetic field generated by the current. This is a breakout board for the fully integrated Hall Effect based linear ACS712 current sensor. The sensor gives precise current measurement for both AC and DC signals. Thick copper conductor and signal traces allows for survival of the device up to 5 times overcurrent conditions. The ACS712 outputs an analog voltage output signal that varies linearly with sensed current. The device requires 5VDC for VCC and a couple of filter capacitors.

Fig 3.2 ACS712 Current Sensor Module [11]

Table 3.2 represents the summary of ACS712 Current Sensor.

Table 3.2 Summary of ACS712 Current Sensor

Parameter Name	**Value**
Supply Voltage	4.5-5.5V
Supply Current	10mA
Current Measurement Range	30A
Output	Bi-directional Analog Voltage
Sensitivity	66 mV/A

3.5 STEP DOWN TRANSFORMER

A transformer is an electrical device that transfers electrical energy between two or more circuits through electromagnetic induction. A varying current in one coil of the transformer produces a varying magnetic field, which in turn induces a varying electromotive force or "voltage" in a second coil. Power can be transferred between the two coils through the magnetic field, without a metallic connection between the two circuits. Faraday's law of induction discovered in 1831 described this effect. Transformers are used to increase or decrease the alternating voltages in electric power applications. In this project a step down transformer has used where primary coil take 220-volt as input and secondary coil output is 12 volt. This step down transformer has use to energize motors, solenoid valve, hot gun that has used in this project.

3.6 LCD DISPLAY

LCD displays has seen everywhere. Computers, calculators, television sets, mobile phones, digital watches use some kind of display to display the time. An LCD is an electronic display module, which uses liquid crystal to produce a visible image. The 16×2 LCD display is a very basic module commonly used in DIYs and circuits.

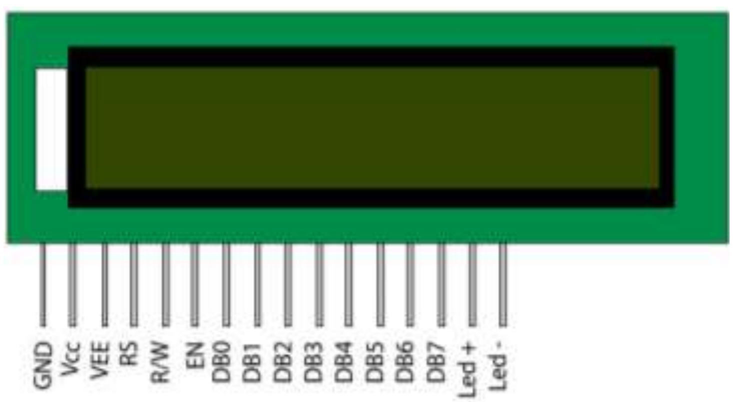

Fig 3.3 16x2 LCD Display [12]

Figure 3.3 shows the pinout of a LCD Display. The 16×2 translates a display 16 characters per line in two such lines. In this LCD, each character has displayed in a 5×7 pixel matrix.

Table 3.3 represents the summary of 16x2 LCD Display.

Table 3.3 Summary of 16x2 LCD Display

Pin No.	Description	Name
1	Ground (0V)	Ground
2	Supply voltage (5V)	Vcc
3	Contrast adjustment	V_0/ V_{ee}
4	Low for command register, high for data register	RS (Register select)
5	Low to write; High to read.	RE (Read/Write)
6	When low use as output device, when high use as input device. Generally grounded it.	E (Enable)
7	8-bit Data Pins	DB0
8		DB1
9		DB2
10		DB3
11		DB4
12		DB5
13		DB6
14		DB7
15	Back light Vcc (5V)	Led+
16	Backlight Ground (0V)	Led-

3.7 I2C LCD ADAPTER

Serial I2C LCD display adapter converts parallel based 16 x 2 character LCD display into a serial i2C LCD that can be controlled through just 2 wires. Adapter uses PCF8574 chip that serves as I/O expander that communicates with Arduino or any other microcontroller by using I2C protocol. A total of 8 LCD displays can be connected to the same two wire I2C bus with each board having a different address. The default i2C address is 0X27 and may be changed to any of the following 0X20~0X27 via soldering A0 A1 A2 pins.

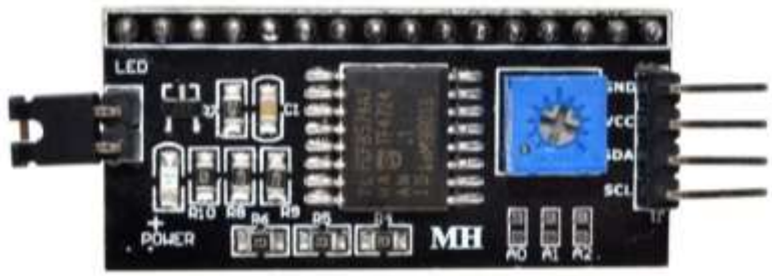

Fig 3.4 I2C LCD Adapter Module [13]

Features of I2C LCD Adapter

- 16 x 2 Character LCD display is controlled via just two wires
- Up to 8 LCD displays with adapters can be connected and controlled by the same two wire I2C bus
- Easy to control using Arduino board
- Compatible with 16 x 2 character LCD displays
- Adapter includes 16-PIN male header connector for soldering to LCD display
- Contrast is adjusted via onboard potentiometer
- Backlight may be turned on/off via jumper
- Standard 5V voltage supply

3.8 RELAY

A relay is an electrically operated switch. Relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid-state relays. Relays are used to control a circuit by a separate low-power signal, or where several circuits must be controlled by one signal. Relays are switches that open and close circuits electromechanically or electronically. Relays control one electrical circuit by opening and closing contacts in another circuit. As relay diagrams show, when a relay contact is normally open (NO), there is an open contact when the relay is not energized. When a relay contact is Normally Closed (NC), there is a closed contact when the relay is not energized. In either case, applying electrical current to the contacts will change their state. Magnetic latching relays require one pulse of coil power to move their contacts in one direction, and another, redirected pulse to move them back. Repeated pulses from the same input have no effect. Magnetic latching relays are useful in applications where interrupted power should not be able to transition the contacts.

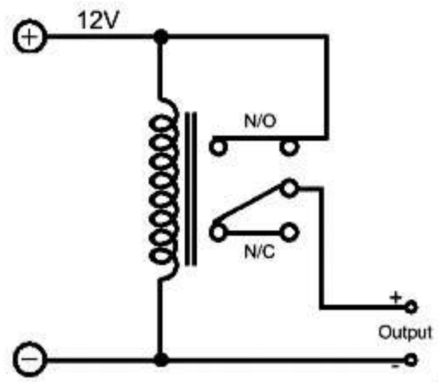

Fig 3.5 Internal Structure of a Relay [14]

3.9 DIODE

A diode is a device, which only allows unidirectional flow of current if operated within a rated specified voltage level. Diode only blocks current in the reverse, direction while the reverse voltage is within a limited range otherwise reverse barrier breaks and the voltage at which this breakdown occurs is called reverse breakdown voltage. The diode acts as a valve in the electronic and electrical circuit. A P-N junction is the simplest form of the diode, which behaves as ideally short circuit when it is in forward biased and behaves as ideally open circuit when it is in the reverse biased. Beside simple PN junction diodes, there are different types of diodes although the fundamental principles are more or less same. Therefore, a particular arrangement of diodes can convert AC to pulsating DC, and hence, it is sometimes called as a rectifier. The symbol of a diode is shown below, the arrowhead points in the direction of conventional current flow. In a PN junction diode when the forward voltage is applied i.e. positive terminal of a source is connected to the p-type side, and the negative terminal of the source is connected to the n-type side, the diode is said to be in forward biased condition. We know that there is a barrier potential across the junction. This barrier potential is directed in the opposite of the forward applied voltage. So a diode can only allow current to flow in the forward direction when forward applied voltage is more than barrier potential of the junction. This voltage is called forward biased voltage.

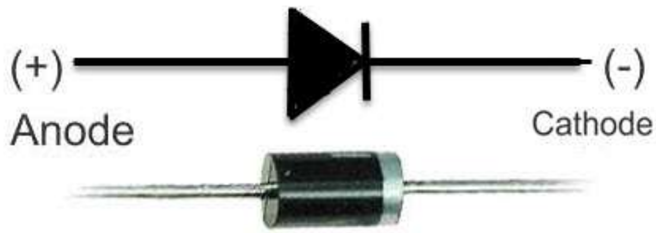

Fig 3.6 Diode Symbol and Polarity [15]

For silicon diode, it is 0.7 volts. For germanium diode, it is 0.3 volts. When forward applied voltage is more than this forward biased voltage, there will be forward current in the diode, and the diode will become short-circuited. Hence, there will be no more voltage drop across the diode beyond this forward biased voltage, and the external resistance connected in series with the diode only limits forward current. Thus, if forward applied voltage increases from zero, the diode will start conducting only after this voltage reaches just above the barrier potential or forward biased voltage of the junction. The time, taken by this input voltage to reach that value or in other words, the time, taken by this input voltage to overcome the forward biased voltage is called recovery time.

3.10 CAPACITOR

Capacitor is an electronic component that stores electric charge. The capacitor is made of 2 close conductors (usually plates) that are separated by a dielectric material. The plates accumulate electric charge when connected to power source. One plate accumulates positive charge and the other plate accumulates negative charge. The capacitance is the amount of electric charge that is stored in the capacitor at voltage of 1 Volt. The capacitance is measured in units of Farad (F). The capacitor disconnects current in direct current (DC) circuits and short circuit in alternating current (AC) circuits. As a capacitor is a passive component, it does not generate any energy but it can store energy from an energy source like a battery or another charged capacitor. When we connect a battery (DC Source) across a capacitor, one plate is attached to the positive end of the battery, and other plate is attached to the negative end of the battery. Now, potential of that battery is applied across that capacitor.

Fig 3.7 Polarity of a Capacitor [16]

At that situation, plate-I is in positive potency with respect to the plate 2. At steady state condition, the current from the battery tries to flow through this capacitor from its positive plate to negative plate but cannot flow due to the separation of these plates with an insulating material. An electric field appears across the capacitor. As time goes on, positive plate will accumulate positive charge from the battery, and negative plate will accumulate negative charge from the battery. After a certain time, the capacitor holds maximum amount of charge as per its capacitance with respect to this voltage. This time span is called charging time of this capacitor.

3.11 VOLTAGE REGULATOR

A voltage regulator is an integrated circuit (IC) that provides a constant fixed output voltage regardless of a change in the load or input voltage. It can do this many ways depending on the topology of the circuit within, but for the purpose of keeping this project basic, we will mainly focus on the linear regulator. A linear voltage regulator works by automatically adjusting the resistance via a feedback loop, accounting for changes in both load and input, all while keeping the output voltage constant. In this project, power supply of 5V and 12V are required. In order to obtain these voltage levels, 7805 and 7812 voltage regulators are to be used. The first number 78 represents positive supply and the numbers 05, 12 represent the required output voltage levels. The L78xx series of three terminal positive regulators is available.

3.12 BLOCK DIAGRAM

The overall block diagram of this project has shown in **Fig 3.12**. In this project, we have used an ESP32 to connect all the peripherals. Three current sensor has used to measure the load current and a voltage divider has used to measure the AC voltage. A 16x2 LCD display has used to visualize all the results on the display. A 6-channel SPDT relay has used to connect and disconnect the loads in certain condition.

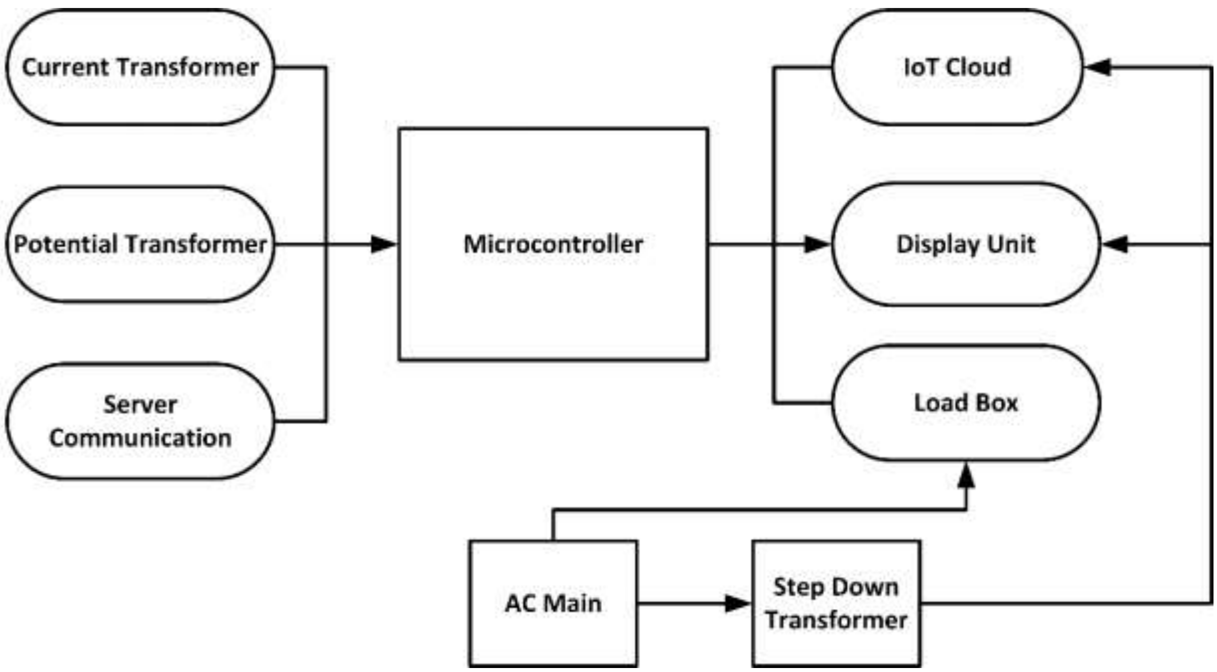

Fig 3.8 Block Diagram of the System

3.13 CIRCUIT DIAGRAM

All the components has interfaced in the circuit by using ESP 32. We have used the analog pins to get the values from the sensor. To measure the current we have used ACS712 current sensor to measure the total current of the circuit. The current sensors have interfaced with the D34, D35, D32 GPIO pin of the ESP 32. To measure the voltage we have prepared a voltage divider circuit with the winding of step down transformer. The output of the voltage divider circuit has connected with the D33 GPIO pin of ESP32. A 16x2 LCD display has used to visualize all the data on the display. This display has interfaced by using an I2C Module. All the peripherals that has used in the circuit has powered by LM2576 regulator, which has set up to provide 5V constant supply. The loads are connected with an electromagnetic relay that has connected with the ESP 32.

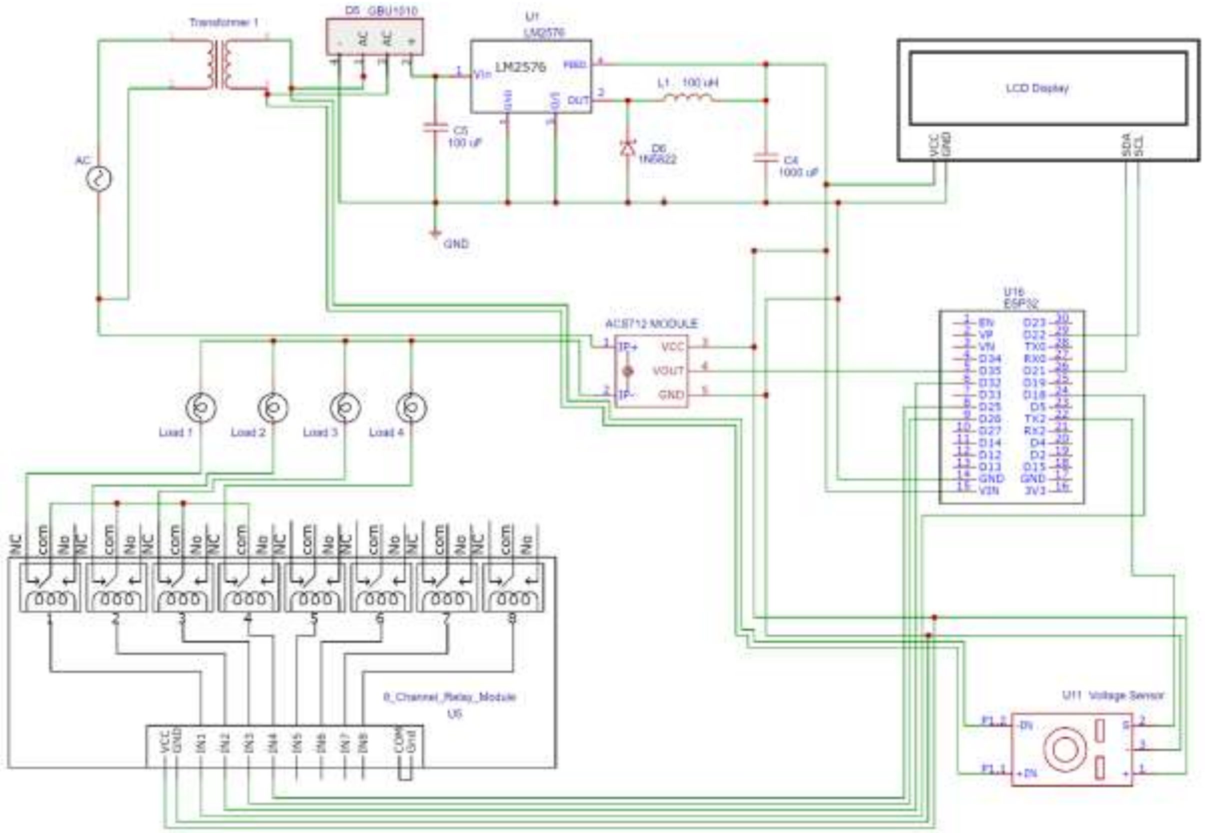

Fig 3.9 Circuit Diagram of the System

3.14 PROGRAMMING

The programming of this whole has system has described in brief below.

3.14.1 Library Files

- Wire.h: This library allows communicating with I2C devices. Arduino communicate with I2C devices through the SDA (data line) and SCL (clock line) pin.
- LiquidCrystal_I2C.h: This library allows an Arduino board to control Liquid Crystal Displays (LCDs) based on the Hitachi HD44780 chipset. The library works with in either 4- or 8-bit mode.

3.14.2 Functions

- void setup(): The void keyword is used only in function declaration. It returns no information to the function from it was called. The setup function initializes variables, pin modes, start using library etc. The setup function will only run once, after each power up.
- void loop(): This function is used for running main program over and over again. This helps continuous execution of certain program simultaneously.
- Serial.begin(9600): Serial.begin(9600) doesn't actually print anything. Rather it initializes the serial connection at 9600 bits per second. Both sides of the serial connection (i.e. the Arduino and computer) need to be set to use the same speed serial connection in order to get any sort of intelligible data.

3.15 FLOW CHART

The flowchart of the whole system has shown in **Fig 3.10**. This flow chart describes all the initialization and procedural of this project. At the beginning, the system will show the intro message. This will provide a basic understanding on topic of our project. We have initialized and declared all the variables here. Then the status of the input output pins has mentioned in the setup function. After executing setup, the program will execute the loop function. Here we have sub divided the system into few user defined functions. As shown in **Fig 3.11**, we have measured the voltage here. The voltage sensor sends analog reading to the microcontroller and the microcontroller than analyze the values to convert into readable values. To measure voltage accurately we have taken the mean of 20 results, therefore the value is stable. Then the system execute the current reading sub process that has demonstrated in **Fig 3.12**. The ACS712 current sensor measure current, which provided an ADC value with proportional to the current through

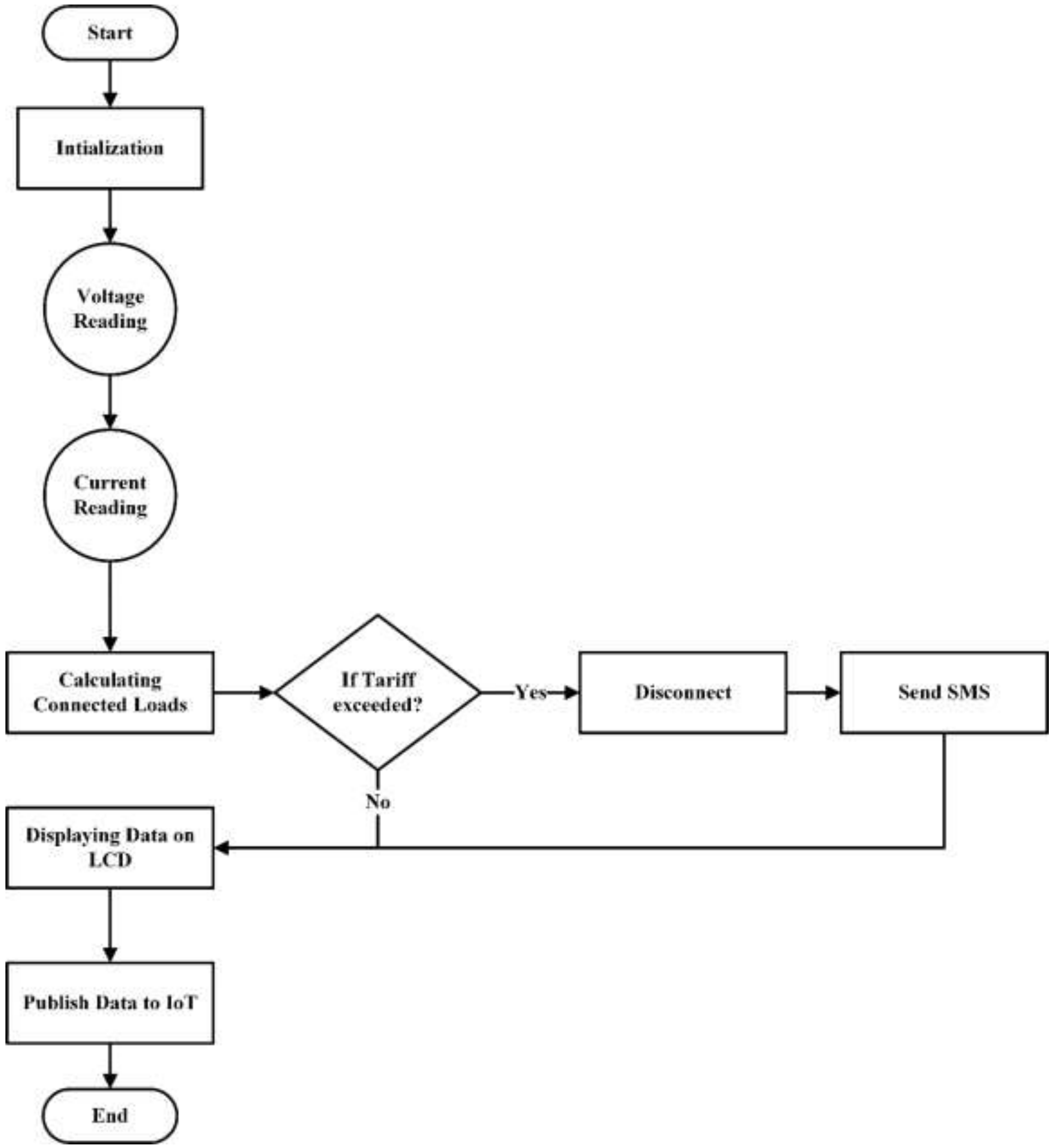

Fig 3.10 Overall Flow Chart

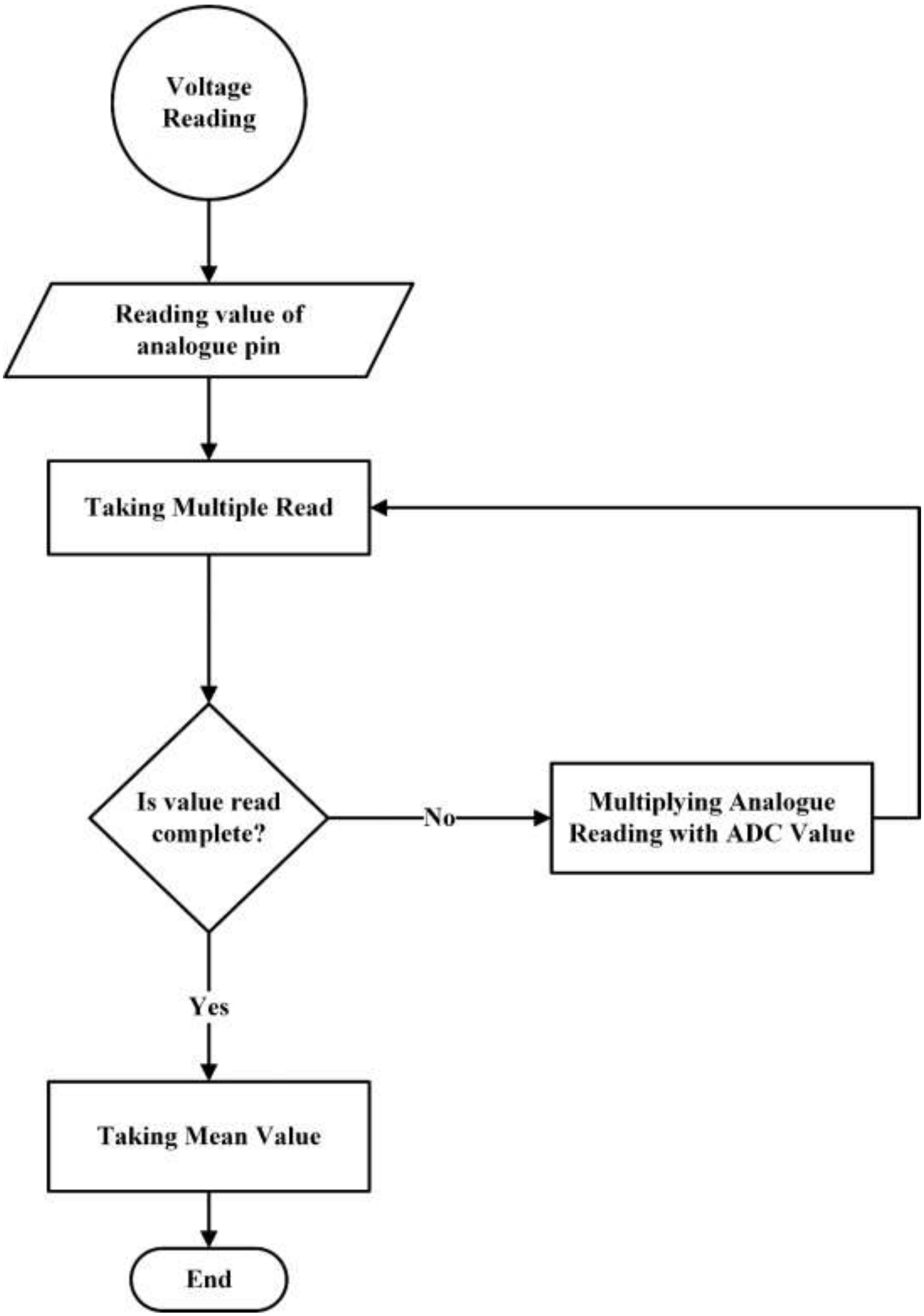

Fig 3.11 Reading Voltage Flow Chart

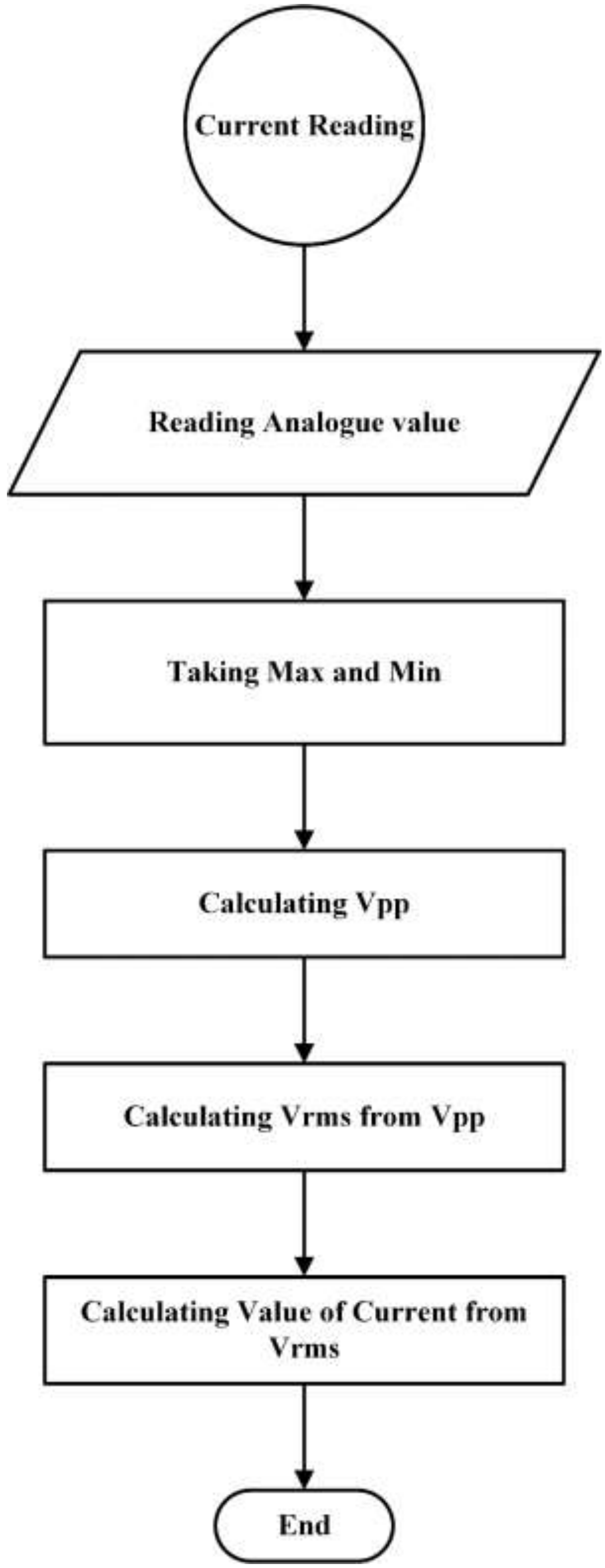

Fig 3.12 Reading Current Flow Chart

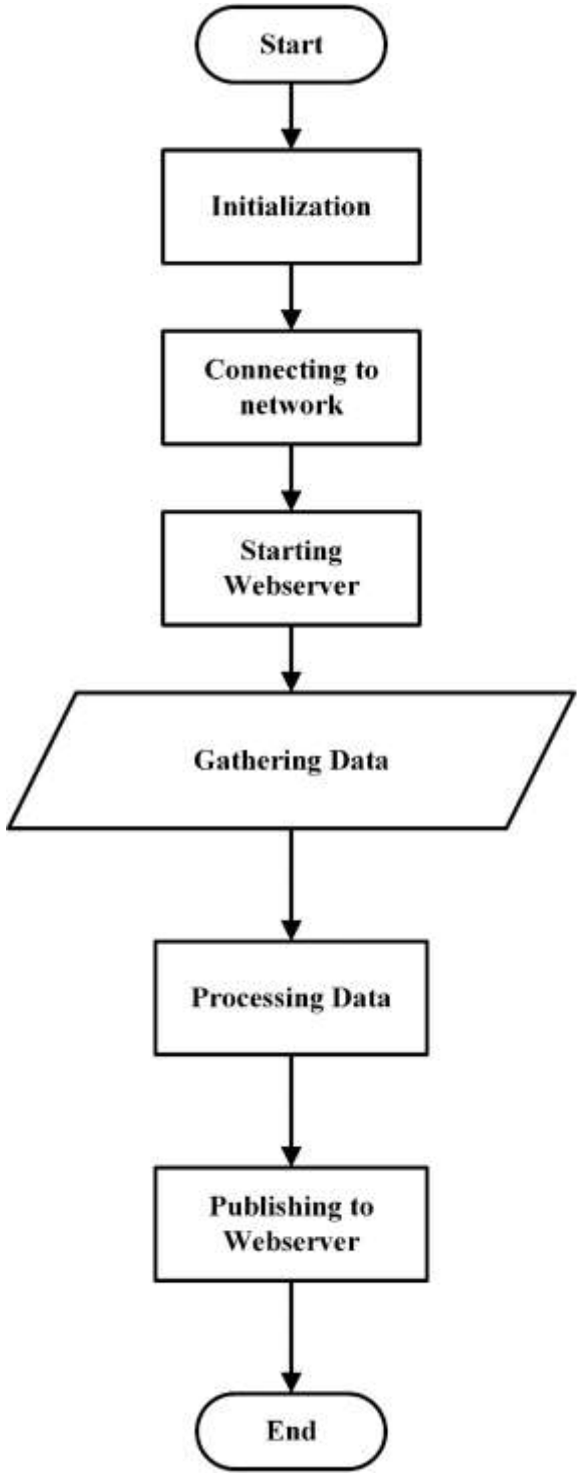

Fig 3.13 IoT Flow Chart

After reading all these values the system checks the values and if any value crosses the threshold point, it will immediately shut down the output section and shows the fault on the display and IoT. It creates a webserver to its localhost and create a connection to the provided network device. A user can monitor the IoT panel by browsing to the host address of the network device and observe the data real-time. the line, measured from another ADC channel. The measured data gives the instantaneous current value. By taking several samples and applying RMS, formula to get average RMS current and then recorded.

3.16 SUMMARY

Many conventional system has designed in the past, where no IoT and automation were introduced. Here we have proposed the methodology having both IoT and remote controlling options.

CHAPTER IV

RESULT AND DISCUSSION

4.1 INTRODUCTION

In this chapter, total result of the project has discussed. Here, picture of hardware has shown. The final result of proposed meter has compared with traditional wattmeter, and this comparison analysis with curves. Finally previous work related to this meter has discussed, and also the benefit this meter compared to previous meter has explained.

4.2 PROJECT OVERVIEW

The complete project overview has shown in **Fig 4.1**. Here we have used a 6 channel relay to control the loads, measured the current using current sensor and measured the voltage using potential transformer.

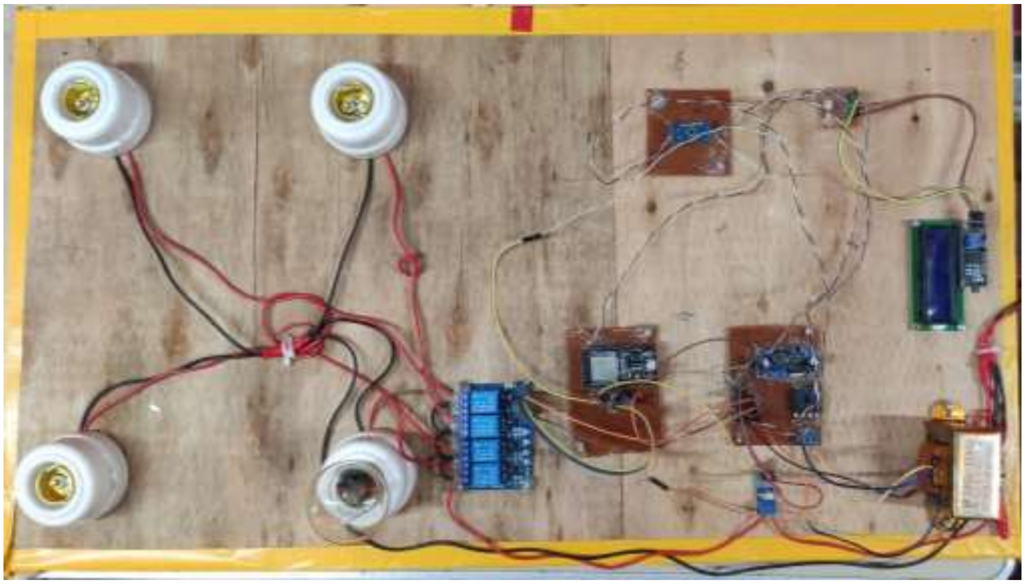

Fig 4.1 Overview of the Project

The power has provided using a voltage regulator and all the peripherals are controlled by using an ESP32.

4.3 RESULT

In this segment, we have showed all result that we have got from our project.

Fig 4.2 Introductory Message on System Boot

Fig 4.3 Introductory Message on System Boot

Fig 4.4 Showing Project Title

Fig 4.5 Showing Device Status

Fig 4.6 Showing Device Status

Fig 4.7 Showing Device Status After connecting loads

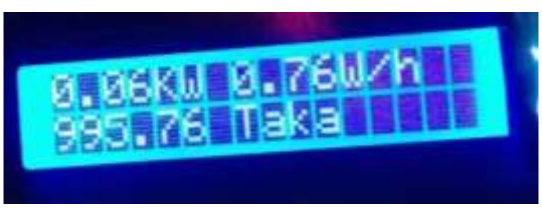

Fig 4.8 Showing Device Status

The result of the project is voltage, current, energy rating and cost. The value of energy consumed by the consumer and unit cost has sent to supplier by a IOT module as a notification. Here, we observe output for different value of load and we calculate that our energy meter accuracy is 97.17%.

Fig 4.9 Load Controlling Panel

Table 4.2: Output Observations

Obs.	Voltage (V)		Current (A)		Power (Watt)	
	Practical	Measured	Practical	Measured	Practical	Measured
1	204	218	0.37	0.35	200	204
2	209	217	0.64	0.66	400	410
3	203	213	0.74	0.74	600	615
4	214	215	1.00	1.01	800	821
5	212	215	1.34	1.34	1000	1034
6	202	219	1.60	1.65	1200	1241

Table 4.3 Load Predictions

Balance Condition	Predication at Full Load (Approximately)
Less than 100	21 days
Less than 70	17 days
Less than 40	10 days
Less than 10	2 days

CHAPTER V

CONCLUSION AND FUTURE WORK

5.1 CONCLUSION

This project is done with a great supervision and care of circuit designing and assembling. The hardest work was interfacing the low voltage electronic components like ESP32 Microcontroller, LCD display, IoT panel etc. with the main line but with great motivation and Effort, final successful implementation of the project has become possible.

5.2 CONTRIBUTION OF THIS SYSTEM

In previous work, many systems configured with Arduino microcontroller with a GSM module. No IoT Panel has used in previous approaches as most of the Arduino board lacks IoT capability. Many approaches introduced a basic web panel has in the system to monitor energy consumption. Yet these system lacks an interactive design. We have improved on these areas.

5.3 FUTURE IMPROVEMENT

Some future work can be implemented later by further research has proposed below.

- It will use a central cell number to collect the messages sent from the consumers Smart Wattmeter.
- It automatically analysis the data and calculate them to gain necessary information that is required by generation station and for the distribution system.

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APPENDIX A

SOURCE CODE

```
#include  <Wire.h>

#include  <LiquidCrystal_I2C.h>

#define   BLYNK_PRINT Serial

#include  <WiFi.h>

#include  <BlynkSimpleEsp32.h>

#include  <EEPROM.h>

char auth[] = "Zc9JhaT2Nciww4MwXUM9TFsEooaOsXH1";

const int current_sensor_1 = 34;

const int relay_6 = 27;

const int relay_5 = 5;

const int relay_4 = 25;

const int relay_3 = 33;

const int relay_2 = 32;

const int relay_1 = 18;

int relay_1_status = 1;

int relay_2_status = 1;

int relay_3_status = 1;

int relay_4_status = 1;

int relay_5_status = 1;

int relay_6_status = 1;

int button_1_state = 0;

int button_2_state = 0;

int button_3_state = 0;

int button_4_state = 0;

int button_5_state = 0;
```

```
int button_6_state = 0;
float voltage = 250.22;
float watt = 0.0;
float show_watt = 0.0;
float killo_watt = 0.0;
float watt_per_hour = 0.0;
float killo_watt_per_hour = 0.0;
float cost_per_unit = 200.0;
float balance ; //700.00; // read from eeprom
LiquidCrystal_I2C lcd(0x27, 16, 2);
BLYNK_WRITE(V4) {
  balance += param.asInt();
  Serial.print("balance: "); Serial.println(balance);
  String message = "Meter credit updated.\n";
  send_message(message);
  relay_1_status = 1;
  relay_2_status = 1;
  relay_3_status = 1;
  relay_4_status = 1;
  relay_5_status = 1;
  relay_6_status = 1;
  eeprom_balance_write();
}
BLYNK_WRITE(V5) {
  button_1_state = param.asInt();
  Serial.print("button_1_state: "); Serial.println(button_1_state);
}
```

```
BLYNK_WRITE(V6) {
  button_2_state = param.asInt();
  Serial.print("button_2_state: "); Serial.println(button_2_state);
}
BLYNK_WRITE(V7) {
  button_3_state = param.asInt();
  Serial.print("button_3_state: "); Serial.println(button_3_state);
}
BLYNK_WRITE(V8) {
  button_4_state = param.asInt();
  Serial.print("button_4_state: "); Serial.println(button_4_state);
}

BLYNK_WRITE(V9) {
  button_5_state = param.asInt();
  Serial.print("button_5_state: "); Serial.println(button_5_state);
}

BLYNK_WRITE(V10) {
  button_6_state = param.asInt();
  Serial.print("button_6_state: "); Serial.println(button_6_state);
}
void setup() {
  Serial.begin(115200);
  Serial2.begin(115200);
  Blynk.begin   (auth, ssid, pass);
```

```
  pinMode(current_sensor_1, INPUT);
  pinMode(relay_1, OUTPUT);
  pinMode(relay_2, OUTPUT);
  pinMode(relay_3, OUTPUT);
  pinMode(relay_4, OUTPUT);
  pinMode(relay_5, OUTPUT);
  pinMode(relay_6, OUTPUT);
  lcd.init();
  lcd.backlight();
//  eeprom_balance_read();
  intro();
  send_message("Device Online\n");
}
void loop() {
  watt_calculation();
  watt_per_hour_calculation();
  show_data_on_lcd();
  load_usage_notification(); //to lcd
  relay_control();
  Blynk.run();
  Serial.println("__________________________________________________");
}
void watt_calculation() {
  float current_value = current_read(current_sensor_1);
  watt = voltage * current_value;
  //  watt_stablizer();

  killo_watt = watt / 1000;
```

```
  Blynk.virtualWrite(V1, killo_watt);
  delay(200);
  Blynk.run();
  Blynk.virtualWrite(V3, watt);
  delay(200);
  Blynk.run();
  //  show_watt_lcd();


}
void watt_per_hour_calculation() {
  watt_per_hour += watt * (2.05 / 60 / 60);
  killo_watt_per_hour = watt_per_hour / 1000;
  Serial.print("watt_per_hour: "); Serial.println(watt_per_hour);
  Blynk.virtualWrite(V2, watt_per_hour);
  delay(200);
  Blynk.run();
}
void tarrif_calculation() {
  balance = balance - (killo_watt_per_hour * cost_per_unit);
  if (balance < 0) {
    balance = 0;
  }
  Blynk.virtualWrite(V0, balance);
  delay(200);
  Blynk.run();
}
void load_usage_notification() {
  if (watt > 100 && watt < 250) {
```

```
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Running in:        ");
  lcd.setCursor(0, 1);
  lcd.print("PWR SV Mode         ");
  delay(1000);
  //    lcd.clear();
}

else if (watt > 250 && watt < 450) {
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Couple of divices       ");

  lcd.setCursor(0, 1);
  lcd.print("are conected         ");
  delay(1000);
  //    lcd.clear();
}

else if (watt > 450 && watt < 650) {
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Moderate power            ");

  lcd.setCursor(0, 1);
  lcd.print("usage detected           ");
  delay(1000);
```

```
  //    lcd.clear();
}
else if (watt > 650 && watt < 850) {
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Moderate power        ");
  lcd.setCursor(0, 1);
  lcd.print("usage detected      ");
  delay(1000);
  //    lcd.clear();
}
else if (watt > 850 && watt < 1050) {
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Heavy power         ");
  lcd.setCursor(0, 1);
  lcd.print("usage detected      ");
  delay(1000);
  //    lcd.clear();
}
else if (watt > 1050 && watt < 1250) {
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Heavy power         ");
  lcd.setCursor(0, 1);
  lcd.print("usage detected      ");
  delay(1000);
  //    lcd.clear();
```

```
  }
}
void watt_stablizer() {
  float watt_point = 150;

  if (watt > watt_point && watt < watt_point + 150) { // 150 to 300
    watt = 200.00;
  }
  else if (watt > watt_point + 200  && watt < watt_point + 400) { //350 to 550
    watt = 400.00;
  }
  else if (watt > watt_point + 450  && watt < watt_point + 650) { //600 to 800
    watt = 600.00;
  }
  else if (watt > watt_point + 700  && watt < watt_point + 950) { //850 to 1100
    watt = 800.00;
  }
  else if (watt > watt_point + 1050  && watt < watt_point + 1250) { //1200 to 1400
    watt = 1000.00;
  }
  else if (watt > watt_point + 1300  && watt < watt_point + 1650) { //1450 to 1650
    watt = 1200.00;
  }
  else if (watt < watt_point) {
    watt = 0.0;
  }
  show_watt = watt + (random(3, 10) / 1.9);
}
```

```
void show_data_on_lcd() {
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print(killo_watt); lcd.print("KW "); lcd.print(watt_per_hour); lcd.print("W/h              ");
  lcd.setCursor(0, 1);
  lcd. print(balance); lcd.print(" Taka   ");
  delay(2500);
}
void show_watt_lcd() {
  lcd.setCursor(0, 0);
  lcd.print("Watt Consumption: ");
  lcd.setCursor(0, 1);
  lcd. print(show_watt); lcd.print(" W                              ");
  delay(1000);
}
void relay_control() {
  int thres_balance = 0;
  if (balance <= thres_balance) {
    relay_1_status = 0;
    relay_2_status = 0;
    relay_3_status = 0;
    relay_4_status = 0;
    relay_5_status = 0;
    relay_6_status = 0;
    Serial.println("No Credit.");
  }

  else if (balance > thres_balance) {
```

```
if (button_1_state == 0) {
  relay_1_status = 0;
}

else {
  relay_1_status = 1;
}

if (button_2_state == 0) {
  relay_2_status = 0;
}

else {
  relay_2_status = 1;
}

if (button_3_state == 0) {
  relay_3_status = 0;
}

else {
  relay_3_status = 1;
}

if (button_4_state == 0) {
  relay_4_status = 0;
}
else {
```

```
    relay_4_status = 1;
  }

  if (button_5_state == 0) {
    relay_5_status = 0;
  }

  else {
    relay_5_status = 1;
  }

  if (button_6_state == 0) {
    relay_6_status = 0;
  }
  else {
    relay_6_status = 1;
  }
}

if (balance <= 10 && balance >= 5) {
  send_message("Balance is very low.\nPlease Recharge.\n");
}
/*

  if (balance < thres_balance - 100) {
  relay_2_status = 0;
  }
  if (balance < thres_balance - 200) {
```

```
    relay_3_status = 0;
    }
    if (balance < thres_balance - 300) {
    relay_4_status = 0;
    }
    if (balance < thres_balance - 400) {
    relay_5_status = 0;
    }
    if (balance < thres_balance - 500) {
    relay_6_status = 0;
    }
  */
  digitalWrite(relay_1, relay_1_status);
  digitalWrite(relay_2, relay_2_status);
  digitalWrite(relay_3, relay_3_status);
  digitalWrite(relay_4, relay_4_status);
  digitalWrite(relay_5, relay_5_status);
  digitalWrite(relay_6, relay_6_status);

  delay(1000);
}
void send_message (String message)  {
  Serial2.println("AT+CMGF=1");
  delay(1000);
  Serial2.println("AT+CMGS=\"" + number + "\"\r");
  delay(1000);
  Serial2.print(message);
  Serial2.println((char)26);
```

```
  delay(2000);
}
float current_read(int sensor_pin) {
  float current_reading = 0.00;
  float result = 0.0;
  float meanResult = 0.0;
  double VRMS = 0;
  int readValue = 0;
  int maxValue = 0;
  int minValue = 4096;
  for (int i = 0; i < 3; i++) { //taking single time for elimininting initial beep
    uint32_t start_time = millis();
    //sample for 1 Sec
    while ((millis() - start_time) < 1000) {
      readValue = analogRead(sensor_pin);
      if (readValue > maxValue) {
        maxValue = readValue;
      }
      if (readValue < minValue) {
        minValue = readValue;
      }
    }
    result = ((maxValue - minValue) * 3.3) / 4096.0; //Peak to Peak
    meanResult += result;
  }
  result = meanResult / 3;

  VRMS = (result / 2.0) * 0.707;
```

```
  current_reading = ((VRMS * 1000) / 66) - 2.8   ; //Ratiometric value for 30A Model 66 ****** -2.84
  if (current_reading <= 0) {
    current_reading = 0;
  }
  else {
    tarrif_calculation();
  }
  return current_reading;
  Serial.print("current_reading: ");
  Serial.print(current_reading);
  Serial.println(" A");
}
void intro() {
  Serial.println("Rolling Intro");
  lcd.setCursor(4, 0);
  lcd.print("IIUC");
  delay(1000);

  lcd.setCursor(1, 0);
  lcd.print("Department of CSE");
  delay(1000);

  lcd.setCursor(6, 1);
  lcd.print("");
  delay(2000);
  lcd.clear();
```

```
  lcd.setCursor(0, 0);
  lcd.print("  Smart Energy   ");

  lcd.setCursor(0, 1);
  lcd.print("Metering System");
  delay(3000);

  lcd.clear();
}
```