# Design of an IOT Based Energy Monitoring System and Home Automation

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***Abstract:*** In the most of the developing countries, the effort of collecting electricity utility meter reading and detecting illegal usage of electricity is a very difficult and time consuming task which requires a lot of human resources. Energy monitoring system using Internet of Things (IOT) present an efficient and cost-effective way to transfer the information of energy consumed by the consumer wirelessly. Aim of this study is to measure electricity consumption in the household and generate its bill automatically using IOT and telemetric communication techniques. In this paper, the use of GSM module provides a feature of notification through SMS. One can easily access the meter working through web page that we designed. Current reading with cost can be seen on web page. Automatic ON & OFF of meter is possible. In addition to this in this project home automation will also be done using IOT technology.

***Keywords –*** IoT (Internet of Things), GSM, Energy Monitoring system, Home Automation

## 1. INTRODUCTION

### 1.1. INTERNET OF THINGS (IOT)

The Internet of Things (IoT) is becoming more widely used technology nowadays. It is often used to refer to the growing network for connected devices, or “things”, that are capable of exchange data over on a low bandwidth network. IoT is being used in various areas, such as automotive industry, logistics, healthcare, smart grid and smart cities.

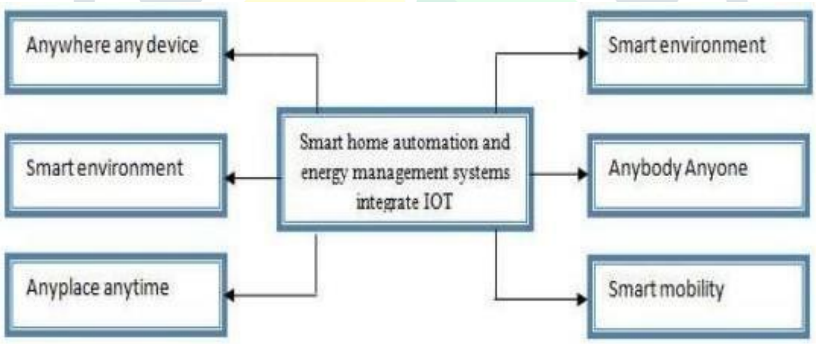


figure 1.1.1. relation with various phases

The figure (1.1.1) shows the various advantages of the internet of things like the different methods for connecting our devices and appliance to the internet from any place anywhere in this world and integrating this connectivity with our home and the devices connected. IOT technology is the connection of various networks in embedded devices used in the everyday life integrated into the Internet. It aims to automate the operation of different domains such as home appliances, health care systems, security and surveillance systems, industrial systems, transportation systems, military systems, electrical systems, and many others. In order to achieve a fully automated process, devices in the different domains must be equipped with micro-controllers, transceivers, and protocols to facilitate and standardize their communication with each other and with external entities.

## 2. LITERATURE REVIEW:

Nowadays, electricity consumption has become one of the basic needs in every sector. Thus to improve the efficiency of all electrical appliances and to reduce wastage of electricity is one of the challenges faced by the world. The objective is to develop load monitoring and controlling system for electric appliances to reduce energy consumption and energy usage in an efficient way.

IOT based energy monitoring system is designed based on three major objectives. They are :-

1. To provide automated load energy reading over an immediate basis.
2. To use the electricity in an optimized manner.
3. Reduce the power wastage.

In the present billing system the distribution companies are unable to keep track of the changing maximum demand of consumers. The consumer is facing problems like receiving due bills for bills that have already been paid as well as poor reliability of electricity supply and quality even if bills are paid regularly. The remedy for all these problems is to keep track of the consumers load on timely basis, which will held to assure accurate billing, track maximum demand and to detect threshold value. These are all the features to be taken into account for designing an efficient energy billing system. The present project "IoT Based Energy monitoring system" addresses the problems faced by both the consumers and the distribution companies. The paper mainly deals with smart energy meter, which utilizes the features of embedded systems i.e. combination of hardware and software in order to implement desired functionality.

## 3. EXISTING SYSTEM METHODOLOGY

The electric meter installed in your home is the device that allows the utility department to charge you monthly on the amount of energy you have consumed. The electric meter measures the current flow through the service entrance and into your personal electrical service panel. As you would already know, electric meters can be mechanical or analogue and digital or smart meters. In the first case, a utility service person would visit your home to read the meter on a monthly basis. With the newer smart meters, the information is directly sent over radio or internet signals.

The consumption of electricity is measured in kilowatt hours. This means we are measuring the watts consumed over a period of time. The power consumption meter does this work i.e. it records the electricity that is consumed in kilowatt-hours.

## 4. PROPOSED METHODOLOGY

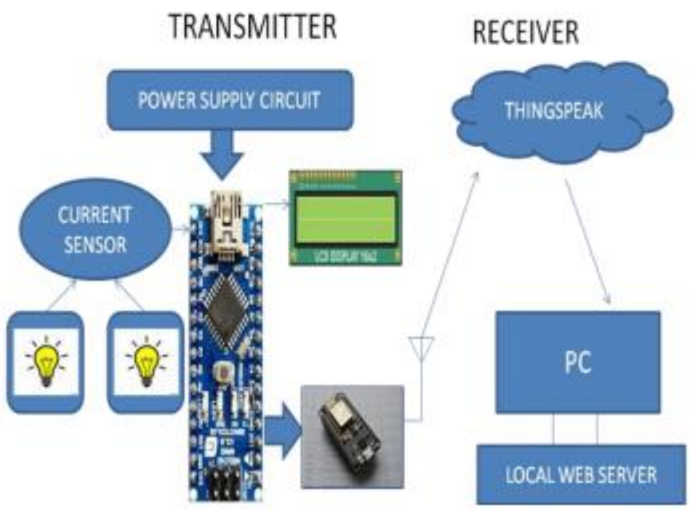


figure 4.1. basic concept

The data from the system is displayed on a webpage which can be accessed by both the consumer and service provider. The system is designed on an Arduino micro controller [2]. It can be structurally differentiated into three parts controller, theft detection circuit and a WiFi unit. The controller performs the basic calculations and processes the information. Theft detection circuit provides information about any meter tampering and the most important role is played by the Wi-Fi unit to send the information from the controller over the Internet. The Arduino controller is programmed on the Arduino software IDE which is a prerequisite to operate on the Arduino board. Its code is derivative of the c language.

The block diagram consists of an Arduino UNO board, an ESP 8266 Wi-Fi module and a 16*2 LCD display. The WiFi module is the main component used in the IOT operation. The centre piece being the Arduino board provides the connection between the different components of the proposed system .The Arduino UNO board is based on the ATmega 328p processor. It is the core of the system which is necessary for the principle operations that are necessary to be carried out such as the automatic electricity billing and tampering detection inputs from the tampering circuit.

The load represents the devices that require the electricity to operate. The ac supply is connected to the system through the transformers to power the system. The Meter is also connected to the system to automate the power usage of the household. The readings from the energy meter are then processed and are updated over the Wi-Fi through the ESP 8266 Wi-Fi Module.

If any tampering is detected the system updates the situation on the webpage used to display the energy readings. After updating the energy readings on the webpage, the system then displays the energy readings on the LCD display. In case of any tampering the buzzer will go off making a loud noise. All the information from the system is readily available on a webpage called Thingspeak.com.

**5. BLOCK DIAGRAM:**

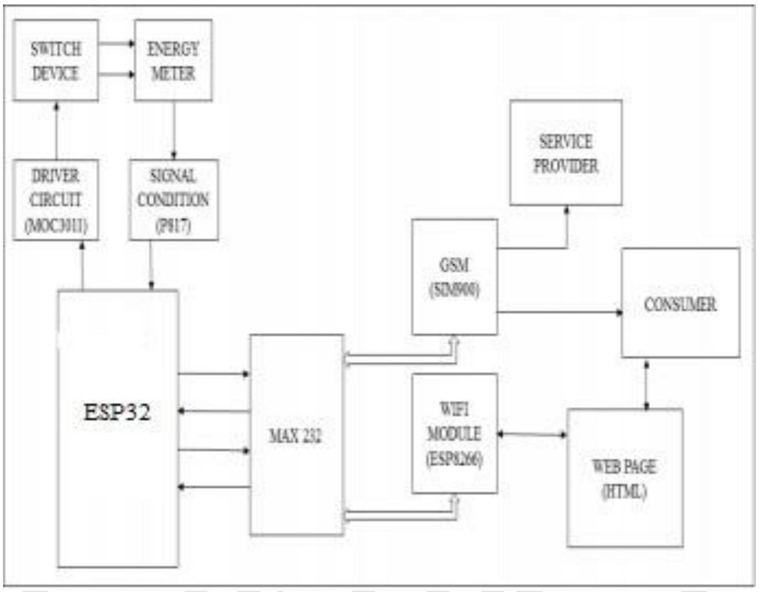


figure 5.1: block diagram representation

**5.1 SIGNAL CONDITIONER (P817):**

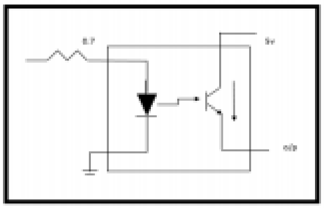

figure 5.1.1: signal conditioning circuit

Above figure shown is the simple internal working of optocoupler P817 which we are using as signal conditioning block. As we can see on a working meter that one LED continuously blinks, it is nothing but indicates the count of power. The LED whenever blinks it produces only 0.7v which is not suitable for ESP32 board to capture, so to remove this error we are using this block. When the LED blinks the diode will conduct, transistor will get active and it will give 5v at output which we are externally giving to transistor. Whenever LED will blink the 5v supply will be provided to ESP32 board and it will count them. We are using signal conditioning block to increase voltage.

**5.2 ESP32:**

ESP32 is a series of low cost, low power system on a chip microcontrollers with integrated Wi-Fi and dual-mode Bluetooth. ESP32 is created and developed by Espressif Systems, a Shanghai-based Chinese company, and is manufactured by TSMC using their 40 nm process. ESP32is the heart of our system. Entire functioning of system depends on this board. ESP32 reacts to the 5v supply given by opto-coupler and keeps on counting the supply and then calculates the power consumed and also the cost. This data, it continuously stores on webpage, so that users can visit any time and check their consumption. It even reacts accordingly as per programed, to the situations like message sending during threshold value etc.

**5.3 MAX 232:**

We are using MAX 232 for serial communication with the components that are GSM module and Wi-Fi module MAX232 is used to provide TTL to the components as per the requirement. GSM needs TTL so it is connected to ESP32 through MAX232. Some Wi-Fi module doesn't require TTL because it's already build in it and some may require based on its working.

**5.4 GSM MODULE (SIM900):**

GSM stands for Global System for Mobile communication. It is widely used mobile communication modem system in the world. GSM is an open and digital cellular technology used for transmitting mobile voice and data services operates at the 850MHZ, 900MHZ, 1800MHZ, 1900MHZ frequency bands. It has ability to carry 64kbps to 120Mbps of data rates. In our system GSM is used to send the notification of threshold reaching to consumer and for sending message of total consumption of unit with cost to the service provider and consumer.

**5.5 WI-FI MODULE (ESP8266):**

Wi-Fi stands for Wireless Fidelity. We are using Wi-Fi which acts as heart for IoT. Through Wi-Fi the consumer can set changes in threshold value, he can ON and OFF the energy meter. Time to time the readings of units and cost are displayed on webpage. Consumer can accesses the ESP32 board and meter with help of Wi-Fi.

**5.6 DRIVER CIRCUIT (MOC3071):**

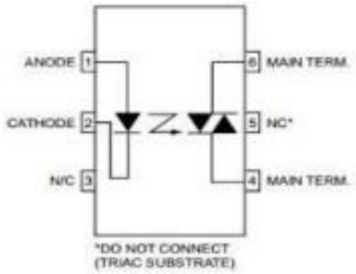


figure 5.6.1: driver circuit

It is a 6 pin device known as opto coupler or opto isolator. In our project we are using this opto coupler to cut off the AC load. It is connected to the SSR to cut off the AC load.

**5.7 SWITCHING DEVICE (RELAY):**

Relay acts like a switch and it is used to control the high power devices. As the operating voltage of ESP32 is 5v it can't control higher voltage devices directly, so a 5v relay can be used to switch the 230v current and then ESP32 is used to control the relay. The relay work by controlling one electrical circuit by switching contact in another circuit either electrically or mechanically. A relay is said to be in open contact when it is normally open (NO) i.e. NC pin connected to COM and connected when INT1 is set high and thereby relay is not energized. A relay contact is a closed contact when it is normally closed (NC) i.e. disconnected when INT1 is high, and hence there will be no supply to relay.

## 6. SYSTEM REQUIREMENT

Internet is an interconnection of computers all over the world. Internet links billion of devices worldwide, and is used to send, receive data all over the world. Internet has vast uses and applications in many fields and domain. One of the important applications of the internet is IoT[1]. IoT is interconnection of physical objects, vehicles etc. mixed with various other fields like embedded systems, sensors, software which helps to collect, transfer and exchange information. HP did a small survey in which they estimated the rise of connected devices over the years. In 1990 number of connected devices are 0.3 million, in 1999 number of connected devices are 90.0 million, in 2010 this number is 5.0 billion, in 2013 this number is 9.0 billion and in 2025 estimated number of connected devices is 1.0 trillion.

6.1 DESIGN AND IMPLEMENTATION

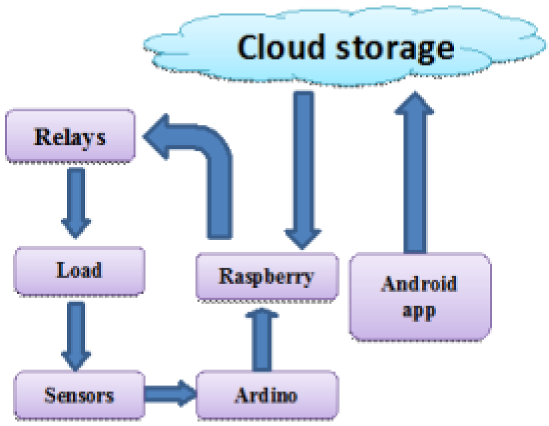


figure 6.1.1.functional description of system

### 6.2 HARDWARE

### 6.2.1. RASPBERRY PI

Raspberry Pi is a credit card sized small CPU or a complete computing platform[12] developed by Raspberry Pi foundation in UK and released in February, 2012. It supports different distributions of linux but recommended is Raspbain. Raspbian is a new operating system with the use of Debian by Raspberry Pi foundation i.e., Raspberry + Debian = Raspbian. The raspberry Pi foundation provides OS like Raspbian, Noobs, Snappy, Ubuntu Core, Openlec, osmc, pidora, RISC OS etc. on their official website www.raspberrypi.org. The most important feature of Raspberry Pi is its processor's speed and its small size. It is very much small according to its powerful features. Raspberry Pi supports various programming languages such as Python, C, Perl and Ruby. Python is the main programming Language.

Raspberry Pi model A+ was released followed by B, B+, Raspberry Pi 2 and recently released Pi 3. There are some basic changes in hardware with the changes in the board version. The Broadcom BCM2835 SOC utilized as a part of the original Raspberry Pi is to some degree comparable to the chip utilized as a part of original cell phones (its CPU is a more established ARMv6 design), which incorporates a 700 MHz ARM1176JZF-S processor, Video Core IV representation handling unit (GPU), and RAM.It has a level 1 (L1) store of 16 KB and a level 2 (L2) reserve of 128 KB. The level 2 cache is used primarily by the GPU.The SOC is stacked underneath the RAM chip, so simply its edge is self-evident. The Broadcom BCM2836 SOC is used by Raspberry Pi 2 with a 900 MHz 32-bit quad-focus ARM Cortex-A7 processor (as do various current phones), with 256 KB shared L2 store.The Broadcom BCM2837 SOC is used by Raspberry Pi 3 with a 1.2 GHz 64-bit quad-core ARM CortexA53 processor, with 512 KB shared L2 cache.

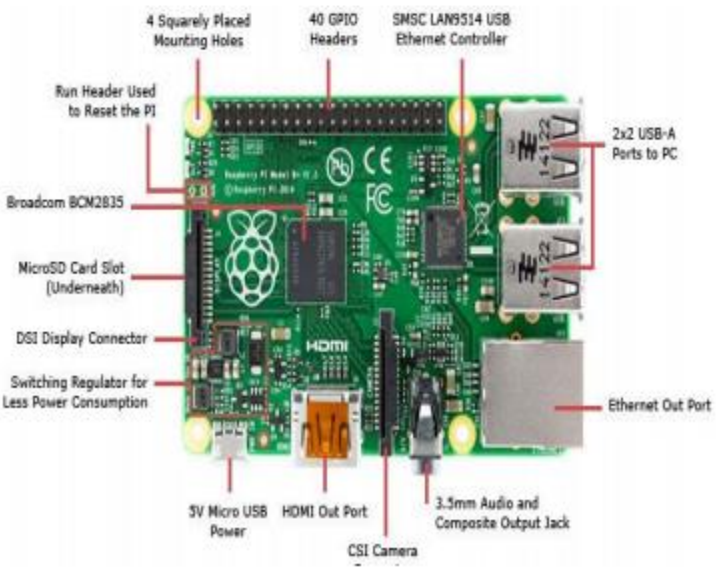


figure.6.2.1.1 .raspberry pi 3b+ microcontroller board

### 6.2.2. ARDUINO UNO

Arduino Uno is a microcontroller board based on the ATmega328[13]. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header, a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDIUSB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial convertor. "Uno" means one in Italian and was chosen to mark the release of Arduino Software 1.0. The Uno and version 1.0 will be the reference versions of Arduino, moving forward. The Uno is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform.

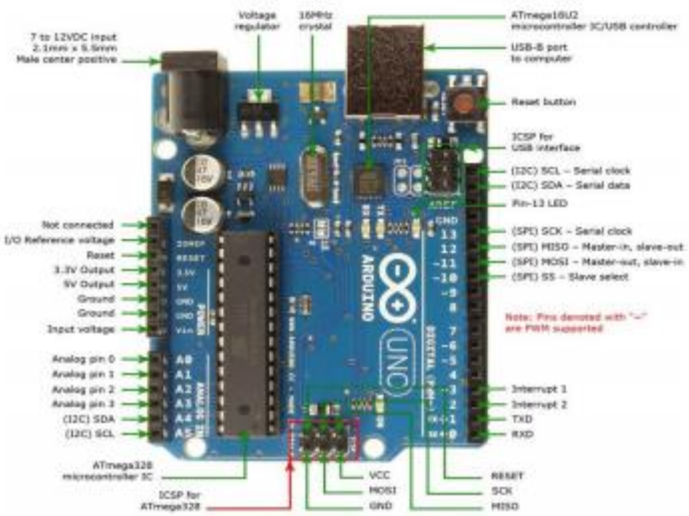

figure 6.2.2.1. .arduino uno board

### 6.2.3. CURRENT SENSOR

In this project current sensor ACS712[14] is used to measure the current, voltage. It gives accurate current measurement for both AC and DC signals. These are good sensors for metering and measuring overall power consumption of systems. This sensor produces an output voltage which is directly proportional to sensed current. It works on the principle of Hall Effect. 5V should be supplied to Vcc of ACS712 breakout board and the GND should be the negative of 0v of supply. Once it is powered, the Vout should produce output voltage which represent current going through the sensing pads. When the load is in OFF state then the sensor produces Vcc/2 voltage (no load voltage).ACS712 is able to measure current in two directions. Output voltage more than 2.5V (VCC/2) indicates current in one direction and voltage less than 2.5V indicates current in another direction.

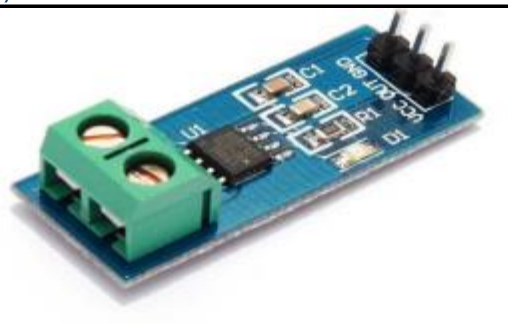

fig.6.2.3.1. 712 hall effect current sensor

### 6.2.4 VOLTAGE SENSING CIRCUIT

AC voltage measurement can be carried out by converting AC voltage into proportional DC Voltage using rectifier and filter circuits. For low AC voltage (mili volts) measurement precision rectifier is used as diode knee voltage is 0.7 Volt. Similar to DC voltage measurement Voltage divider is constructed using 47K Ohm variable resistor R1. 5v zener diode is used to protect Arduino from accidental excess voltages. Adjust the resistor R1 (47K) to calibrate the voltage. Here the AC voltage that we can give to transformer is from 50V to 230V depending on its ratings. Rectified DC is fed to the voltage divider circuit. Connect Arduino as per circuit shown in fig.6.2.4.1[15], make ground common for Arduino and circuit shown in figure. Adjust the resistor R1 to get proper reading. When AC Voltage is 250V we get 5V output.

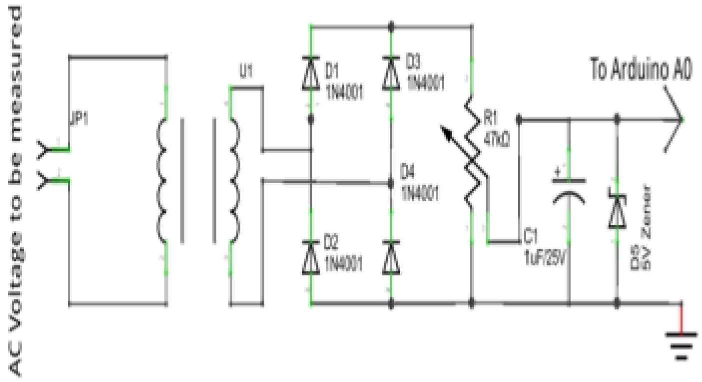


fig.6.2.4.1 voltage sensing circuit

## 6.3. SOFTWARE

### 6.3.1. ANDROID STUDIO

Android studio is the official IDE (Integrated Development Environment) or tool (layman terms) for developing application exclusively for Android platform. It has a strong editor tool for developing creative UI and emulators for different versions to test and simulate sensors without having actual Android devices. It also has a very useful Gradle plugin using which you can create application files (apks) with different configurations. Moreover it makes exporting and uploading apk on playstore easy with a single click. . In the recent updates Android studio has brought instant run which makes testing even faster and easier.

### 6.3.2. RASPBIAN OPERATING SYSTEM

Debian Wheezy is a form of Debian which was produced for gadgets with the ARM processor, for example, the Raspberry Pi. As Wheezy is a general ARM discharge it didn't exploit the Raspberry Pi's equipment where huge speed increments could be made. A little gathering of engineers kicked together and off improving the product that is accessible for Debian Wheezy particularly for the Raspberry Pi and discharged another conveyance as Raspbian. Raspbian has a straightforward desktop condition with the commonplace format of a menu bar at the base of the screen and a projects menu in the base left corner.

It is a decent decision for individuals who are not use to a Linux working frameworks, it additionally requires less specialized information to use than some other working frameworks. There is additionally a wide bolster group with heaps of aides and instructional exercises accessible on the web. As Raspbian is a Linux working framework it has great security highlights, has brilliant systems administration and abilities and access to 1000's of free projects and utilities called bundles that can be introduced basically from the terminal.

## 7. ALGORITHM IMPLEMENTATION

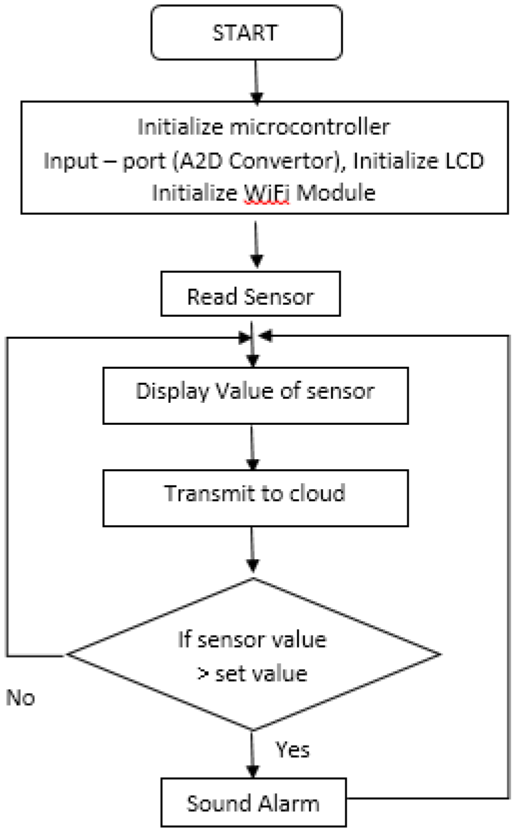


figure 7.1. algorithm

This system enables the electricity department to read the meter readings monthly without a person visiting each house. This can be achieved by the use of ESP32 unit that continuously monitor and records the energy meter reading in its permanent (non-volatile) memory location. This system continuously records the reading and the live meter reading can be displayed on webpage to the consumer on request. This system also can be used to disconnect the power supply of the house when needed.

When the various appliances of the household consume energy the energy meter reads the reading continuously and this consumed load can be seen on meter.

- We can see that the LED on meter continuously blinks which counts the meter reading. Based on
- The blinking, the units are counted. Normally, 3200 blinks is one unit.
- In our project we are trying to develop, a system in which esp32 act as main controller, which continuously monitor energy meter.
- As per the blinking of LED on energy meter the ESP32 will measure the unit consumption.
- The measured reading with the calculation of the cost will be continuously displayed on web page that we have designed.
- Threshold value can be set on webpage with the help of Wi-Fi, as per the consumer's requirement. When the consumers reading will be near about to the set threshold value it will send a notification value to the consumer.
- This threshold value notification will increase the awareness amongst the consumer about the energy.
- When the consumer gets the notification he can visit the webpage and change the threshold value.
- If the consumer is not aware with the threshold notification, then the meter will automatically get off. Then the consumer has to visit the webpage again and increment the threshold value. By the incrementation, the meter will automatically get ON.
- Finally the overall monthly bill with cost will be sent to customer as well as service provider in the form of text at first day of every month.

**8. RESULT:**

The system comprises of energy monitoring nodes that use low-cost energy meter using a noninvasive CT (current transformer) sensor, the SD3004 energy measurement chip and microcontroller for measuring the voltage, current, active power and accumulative power consumption. The measured data will then be submitted to server via MQTT in JSON (JavaScript Object Notation) format. The Raspberry Pi 3 model B was chosen to run as a local server. Thus, users can access to get information of their energy consumption via web application locally or via Internet. The system overview is shown in Fig.8.1.

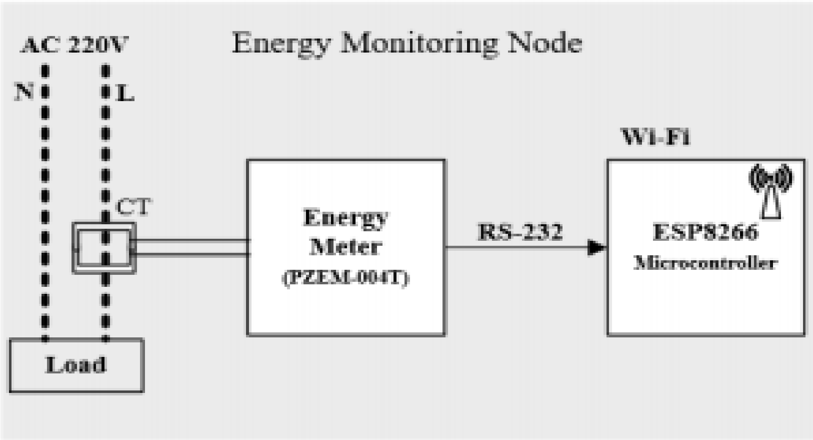


figure 8.1 diagram of an IOT based electric energy monitoring module

In order to send measured data from the PZEM-004T to the network or the internet, we employed the ESP8266 Wemos D1 mini to communicate with the PZEM-004T via RS-232. Fig 8.1 illustrates the prototype of energy monitoring node in which the PZEM-004T is connected with the Wemos D1 mini via RS232 port. The firmware for Wemos D1 mini was developed using the Arduino software environments. The main function of the Wemos D1 mini is used to collect energy data from the PZEM-004T and send recived data to the server wirelessly, through Wi-Fi. The data will be sent to the server approximatly every 20 seconds. The JSON format is a lightweight data-interchange format and easy to understand. Therefore, JSON format is used for transmitting structured data over network connection via MQTT. The JSON data used in this system is represented in Fig. 8.2

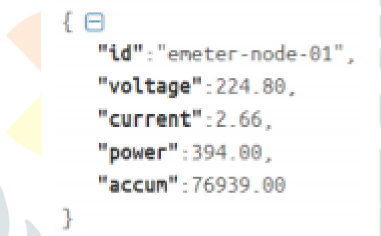


figure 8.2. JSON structured data format.

C. Energy Calcuation : Energy consumed per day can be determined in (1). The energy E in kilowatt-hours (kWh) per day is equal to the power P in watts (W) times number of usage hours per day t divided by 1000 watts per kilowatt: E = P ×t 1000 (kWh day) (W) (h day) (W kW) (1) For example, if we use desktop computer that requires power consumption of 300 watts and we use it for 8 hours per day. By following (1), thus this desktop computer will consume the electric energy per day at 2.4 kWh or 72 kWh per month. Hence, performing the calculation in (1), the energy consumptions are automatically stored and calculated in database on the server.

D. Local Server The Raspberry Pi 3 model B is responsible to run server software packages at local network, the software include MQTT broker, Python, database server using InfluxDB, and data visualization.

E. MQTT Communication Protocol MQTT is a publish/subscribe protocol, which is very simple and lightweight messaging, designed for constrained devices and low-bandwidth, unreliable networks. It is a good solution for our design since it provides an easy communication between the server and many IoT nodes [13-16]. The central server is so called a broker, and sensor nodes can subscribe to the topic and the topics are created automatically. It can also publish the data to topics of any kind of data. The broker then distributes the data to any node that has subscribed to that topic. The publishing can be done at 3 quality of service levels (QoS). In our setup, we use the Eclipse Mosquitto software that run as a broker on our local server, the Raspberry Pi 3.

**8.1. EQUATIONS AND MATHEMATICAL CALCULATION:**

Our system does not contain very vast and difficult Calculations. Usually different meters have different readings.
Some have,1500 blinks = 1 unit
Mostly, 3200 blinks = 1 unit depends on manufacturer.
In our case 3200 blinks of LED is 1 unit. But for practical purpose, Assumption we made in our system,
5 blinks = 1 unit of power consumption.
Let, X = number of blinks of LED ; Y = number of units of electricity.; Z = cost of consumption.
Basically,
No. of units (Y) = (X/3200), But in our case,
Y = (X/5)
Assume that 1 unit cost = 5rs.
Z = Y * 5rs

For Threshold, Assumed threshold set value will be = 5 units for practical. If units reach,
Threshold value – 1 unit = 5-1 = 4 units,
Notification will be send to consumer, if consumer doesn't react and increase the threshold value then meter will Automatically get OFF. Again to turn it ON consumer has to visit webpage again to increase threshold value.
For practical purpose increment and decrement of threshold can be done by +5units or -5units.

**8.2 UNIT:**

Normally, basic unit of electricity is Kilowatt hour (KWh).
1kWh = 1000 watt for 1 hour.
Example,
Ten 100watt bulbs used for 1 hour gives 1kWh.

**8.3 EXPERIMENTAL RESULTS**

In this section, we demonstrate the operation of the developed IoT energy monitoring system. It was experimentally implemented. Fig. 8.3.1 depicts the user-interface dashboard; the dashboard of the sensor node-1 was used as an example. The dashboards were created by using the Grafana.The dashboard consists of the gauges that indicate the active values of voltage, current and power. The graphs represent the measured energy data as a function of time. The energy were captured from the energy sensor node and then sent to the server. Each sensor has a unique ID and will send data every 20 seconds throughout the day, thus multiple sensor nodes can be deployed and data can be displayed simultaneously on the dashboard.

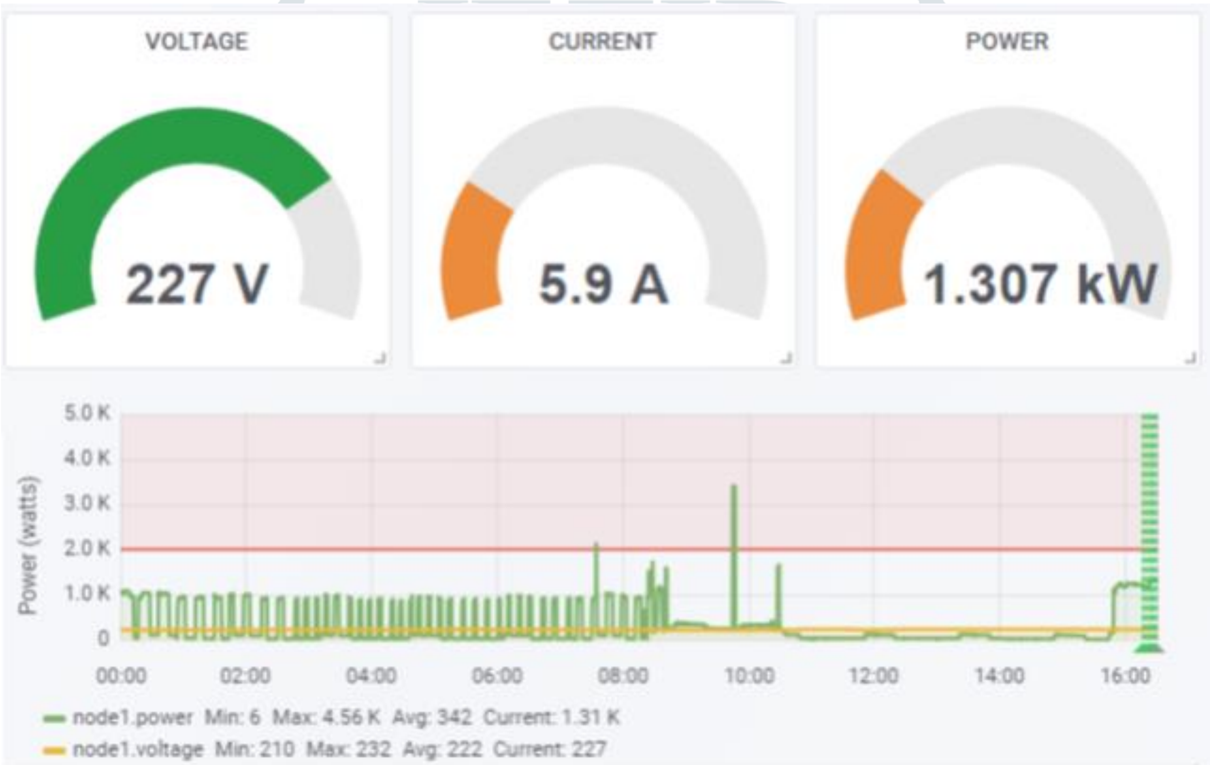


figure 8.3.1 the dashboard of the developed energy monitoring system.

Fig. 8.3.2 shows the accuracy test in which the known load currents were varied and the measured currents from the sensor node were recorded. It can be seen that the reading accuracy of the measuring node was acceptable with the error less than 5%.

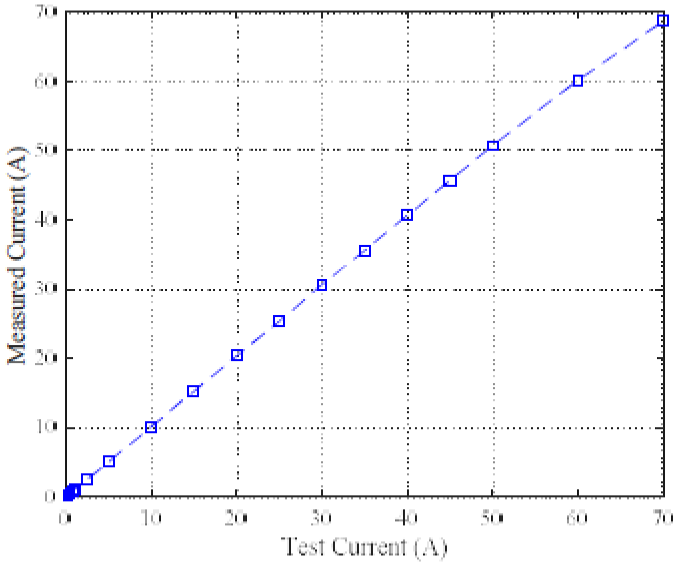


figure 8.3.2 result of the accuracy test.

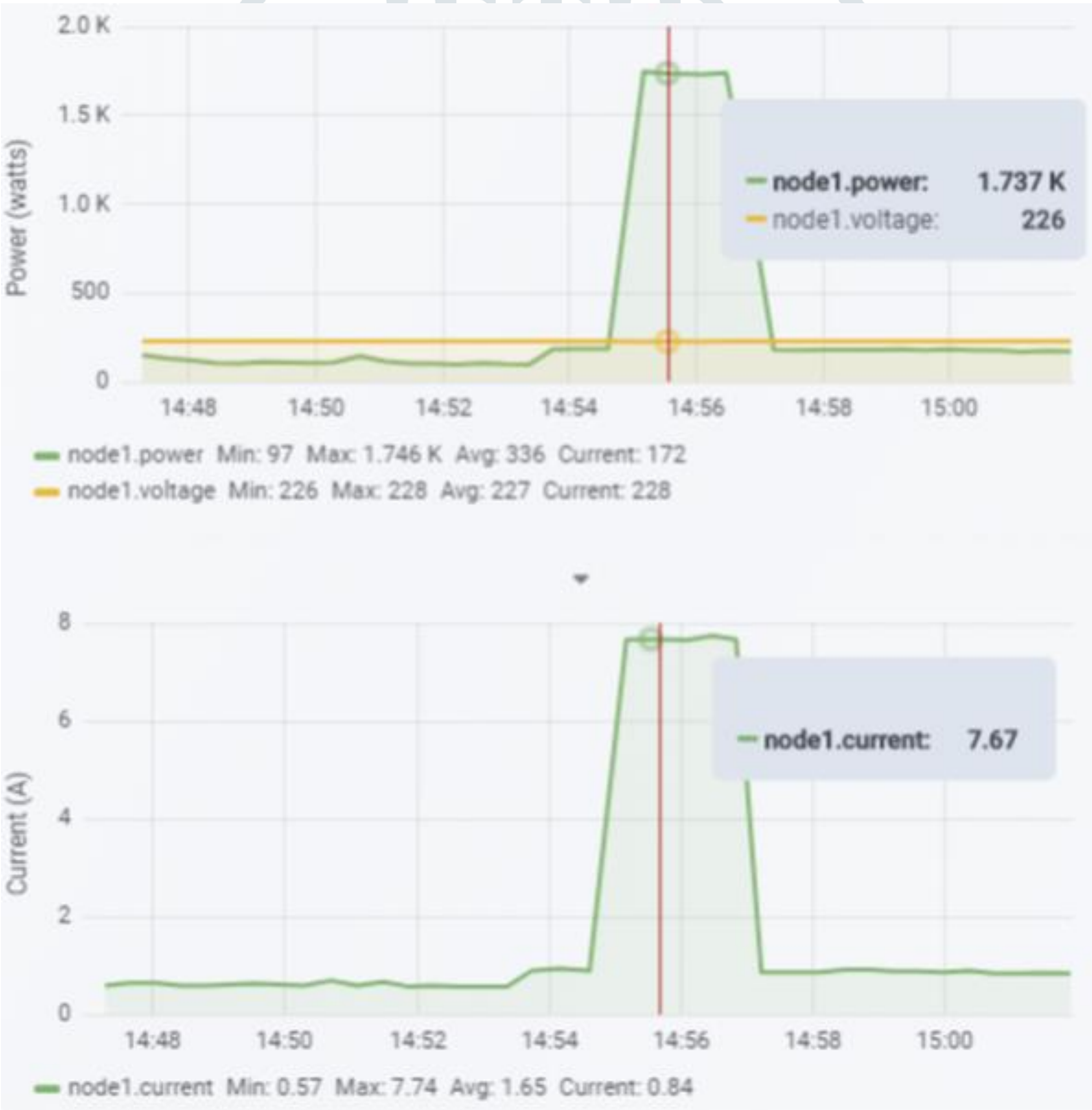


figure 8.3.3. energy consumption profile of the electric kettle.

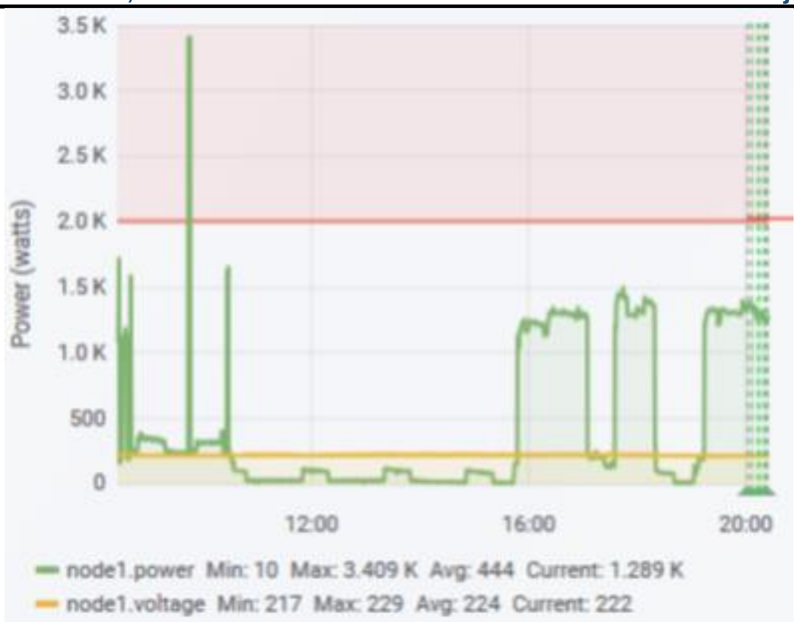


figure 8.3.4 energy monitoring and alert notification

Fig. 8.3.4 illustrates the application of the developed system that will monitor the power consumption and compare the power reading with alert threshold. The alert threshold can be configured on the software. If the power consumption is above the alert threshold, the software will send notification via email.

## 9. CONCLUSION

A smart power monitoring and control system has been designed and developed towards the implementation of an intelligent building. This system monitors and controls the power consumption of home appliances remotely by using wireless network. And also protect the load from High voltages. The entire system is designed on an embedded platform which is easy to design and consume less power, and provides at low cost with portable size. Thus, the continuous monitoring of the electrical appliances can be observed through a website as well as android app.

Further, this work can be extended for power consumption of whole building and electricity bill can be determined. This project can be installed at the transformer to determine the illegal connections for households and by verifying the power in each transmission line, the load at the end of line from transformer can be regulated.

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